

# The Structure of the FTAP Model

Research  
Memorandum

Cat No: MC 58

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February 2000

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# 1 Introduction

The FTAP model is a comparative static, computable general equilibrium model of the world economy that includes a treatment of foreign direct investment on a bilateral basis. The FTAP model was developed in stages from the GTAP model, with the addition of the structure necessary to support the analysis of services liberalisation. A major component of this liberalisation is the removal of barriers to FDI in the tertiary sector.

This research memorandum documents the equations of the FTAP model. The database is documented in Stone, Strzlecki and Welsh (1999) and Hanslow, Phamduc, Verikios and Welsh (1999). The current database is a 19 region, 3 commodity (primary, secondary and tertiary) representation of the world economy after the full implementation of the Uruguay Round (UR) of trade liberalisation. The concordances between GTAP and FTAP regions, and between FTAP and GTAP commodities, are shown in tables 1.1 and 1.2 at the end of this chapter.

The equations of the FTAP model are non-linear, but are specified in linearized form for solution by the GEMPACK software (Harrison and Pearson 1996). In the following chapters, all FTAP equations are also written in linearized form in the GEMPACK TABLO language. Within these equations, names in capital letters are GEMPACK coefficients (that is, values in or calculated from the FTAP database), while names in lower case letters are GEMPACK variables (that is, absolute or percent changes in the variables occurring in the non-linear FTAP equations).

This research memorandum is intended to provide self-contained documentation for the FTAP equation system. Thus all FTAP equations are described in this document, even the many equations unaltered from the original GTAP model.

It has been decided to document the process by which FTAP evolved step by step from GTAP, rather than just document the final FTAP equation system. There are two reasons for this.

First, although much of FTAP is similar in structure to GTAP, the FTAP equations appear very different and are less transparent, due to the use of various ‘tricks’ in the implementation to save on memory and increase computational speed. Thus a discussion of the antecedents of FTAP is helpful in introducing the reader to a

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model structure that is obscured somewhat in the final equation system, due to these complexities of implementation.

Second, this research memorandum can double as documentation for one of the intermediate products of the FTAP development process — GTAP with international capital mobility, or GTAPICM. This is important since not only has GTAPICM been used for analysis of the Uruguay Round (Verikios & Hanslow 1999), but the output of this analysis — a post-UR GTAP database — was used as the starting point for the FTAP database (Hanslow, Phamduc, Verikios & Welsh 1999).

Chapter 2 of this research memorandum provides a verbal and pictorial description of the distinctive features of FTAP. Such an overview of the final product serves two purposes. First, a non-algebraic description of FTAP may be sufficient for many model users. Second, it provides a sense of the ‘destination to which we are travelling’ for those wishing to work through the algebraic representation of FTAP.

Chapters 3 to 9 of this research memorandum correspond to the stages of FTAP development.

Chapter 3 documents the changes made to the GTAP model in order to incorporate international capital mobility (ICM) into its theoretical structure and database. This procedure closely follows that set out in McDougall (1993b), which describes the implementation of international capital mobility into GTAP’s predecessor, SALTER. Foreign income flows must be added to the GTAP income accounting equations, and contributions from these income flows must be added to the welfare decomposition. The international capital mobility version of GTAP is called GTAPICM.

Chapter 4 describes how the international capital mobility introduced in GTAPICM is modified so that the supply of equity capital by each (home) country is imperfectly transformable across destination industries and (host) regions. The treatment of capital supply is very similar to Petri (1997). It allows industry specific bilateral ownership of capital to be modelled, and requires capital rentals to be repatriated to the regions owning the capital. Extra terms arising from the foreign equity capital income flows are added to the welfare decomposition.

Chapter 5 describes the changes to the equation structure required to allow the separate specification of production by domestic and foreign-owned industries of the same commodity type (primary, secondary or tertiary). At this stage, GEMPACK set mappings are used in the model implementation to avoid the introduction of many industries with zero inputs and outputs, corresponding to home, host and industry combinations where no FDI occurs. An equation structure

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like that of a single region model is used to represent input demands of all industries spawned by the domestic/foreign ownership split, the IO data for which is stored in a single IO table with columns ranging across a set whose elements map onto (home, host, industry) triplets. Thus input demands are only modelled for non-null industries.

Chapter 6 describes how the outputs of the domestic and foreign-owned industries producing the same commodity type are distinguished as imperfectly substitutable varieties of that commodity. At this stage an extra dimension, corresponding to the region owning the industry producing a commodity, is added to the trade flows. Consequently, an extra level is added to the GTAP nested CES domestic/import/source choice. The pattern of the nesting reflects a judgement about relative similarities between the varieties of a commodity produced by industries with different (home, host) combinations. An extra level is also added to the CES nest to capture firm-level product differentiation, the implementation of which is via an endogenous technical change term (after the manner of Francois 1998).

Chapter 7 describes the changes to the welfare decomposition — an extra allocative efficiency term — required due to the changes in the production structure introduced in chapters 1 and 6. The derivation of this extra term, however, involves an interesting ‘piggybacking’ on the existing GTAP welfare decomposition. The magnitude of the extra term was determined by representing it as a type of technical efficiency change captured by the existing welfare decomposition term for technical efficiency. Then some algebra was performed to show how it could be written in terms of quantity changes multiplied by tax revenues, as with other allocative efficiency terms in GTAP’s welfare decomposition.

Chapter 8 describes the income accounting and welfare decomposition equations required to account for the repatriation of the rents arising from barriers to services trade. A combination of capital taxes, output taxes and export taxes are used to represent barriers to services trade. But as these impediments are not in reality taxes, it is important that the rents they generate be allocated to private agents (after income taxation of the rents). The assumptions about which private agents receive impediment rents, and the provisions in the model structure to vary these assumptions, are described.

Chapter 9 deals with a variety of small issues. Equations defining useful summary variables are described. Which of these equations are present in FTAP only, and which are present in both GTAPICM and FTAP, will be indicated.

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Chapter 10 discusses a future research item: altering the definition of welfare to account for the non-pecuniary benefits/costs of asset ownership implicit in the asset supply function with less than perfect transformation described in chapter 4. A proposal is formulated and the derivation of the asset supply function as the solution of an optimisation problem is presented.

**Table 1.1 Concordance between GTAP and FTAP regions**

<i>GTAP region</i>	<i>FTAP region</i>	<i>Abbreviation used in FTAP</i>
Australia	Australia	AUS
New Zealand	New Zealand	NZL
Japan	Japan	JPN
Republic of Korea	Republic of Korea	KOR
Indonesia	Indonesia	IDN
Malaysia	Malaysia	MYS
Philippines	Philippines	PHL
Singapore	Singapore	SGP
Thailand	Thailand	THA
Vietnam	Rest of world	RST
China	China	CHN
Hong Kong	Hong Kong	HKG
Taiwan	Taiwan	TWN
India	Rest of world	RST
Sri Lanka	Rest of world	RST
Rest of South Asia	Rest of world	RST
Canada	Canada	CAN
United States of America	United States of America	USA
Mexico	Mexico	MEX
Central America and Caribbean	Rest of world	RST
Venezuela	Rest of world	RST
Colombia	Rest of Cairns Group	ROC
Rest of Andean Pact	Rest of world	RST
Argentina	Rest of Cairns Group	ROC
Brazil	Rest of Cairns Group	ROC
Chile	Chile	CHL
Uruguay	Rest of Cairns Group	ROC
Rest of South America	Rest of world	RST
United Kingdom	European Union	EUN
Germany	European Union	EUN
Denmark	European Union	EUN
Sweden	European Union	EUN
Finland	European Union	EUN
Rest of European Union	European Union	EUN
European Free Trade Area	Rest of world	RST
Central European Associates	Rest of world	RST
Former Soviet Union	Rest of world	RST
Turkey	Rest of world	RST
Rest of Middle East	Rest of world	RST
Morocco	Rest of world	RST
Rest of North Africa	Rest of world	RST
South African Customs Union	Rest of world	RST
Rest of Southern Africa	Rest of world	RST
Rest of Sub Saharan Africa	Rest of world	RST
Rest of World	Rest of world	RST

**Table 1.2 Concordance between GTAP and FTAP commodities**

<i>GTAP commodity</i>	<i>FTAP commodity</i>	<i>Abbreviation used in FTAP</i>
Paddy rice	Primary	Pri
Wheat	Primary	Pri
Cereal grains nec	Primary	Pri
Vegetables, fruit, nuts	Primary	Pri
Oil seeds	Primary	Pri
Sugar cane, sugar beet	Primary	Pri
Plant-based fibers	Primary	Pri
Crops nec	Primary	Pri
Bovine cattle, sheep and goats, horses	Primary	Pri
Animal products nec	Primary	Pri
Raw milk	Primary	Pri
Wool silk-worm cocoons	Primary	Pri
Forestry	Primary	Pri
Fishing	Primary	Pri
Coal	Primary	Pri
Oil	Primary	Pri
Gas	Primary	Pri
Minerals nec	Primary	Pri
Bovine cattle, sheep and goat, horse meat prods	Primary	Pri
Meat products nec	Primary	Pri
Vegetable oils and fats	Primary	Pri
Dairy products	Primary	Pri
Processed rice	Primary	Pri
Sugar	Primary	Pri
Food products nec	Primary	Pri
Beverages and tobacco products	Primary	Pri
Textiles	Secondary	Sec
Wearing apparel	Secondary	Sec
Leather products	Secondary	Sec
Wood products	Secondary	Sec
Paper products, publishing	Secondary	Sec
Petroleum, coal products	Secondary	Sec
Chemical, rubber, plastic products	Secondary	Sec
Mineral products nec	Secondary	Sec
Ferrous metals	Secondary	Sec
Metals nec	Secondary	Sec
Metal products	Secondary	Sec
Motor vehicles and parts	Secondary	Sec
Transport equipment nec	Secondary	Sec
Electronic equipment	Secondary	Sec
Machinery and equipment nec	Secondary	Sec
Manufactures nec	Secondary	Sec

(Continued on next page)

**Table 1.2 (continued)**

<i>GTAP commodity</i>	<i>FTAP commodity</i>	<i>Abbreviation used in FTAP</i>
Electricity	Tertiary	Ter
Gas manufacture, distribution	Tertiary	Ter
Water	Tertiary	Ter
Construction	Tertiary	Ter
Trade, transport	Tertiary	Ter
Financial, business, recreational services	Tertiary	Ter
Public admin and defence, education, health	Tertiary	Ter
Dwellings	Tertiary	Ter

nec Not elsewhere classified

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## 2 Overview of the FTAP model

This chapter provides a verbal and diagrammatic description of the FTAP model. It is intended to be a self-contained description of FTAP for those desiring a non-algebraic presentation, and draws heavily on material in Dee and Hanslow (1999).

As some general familiarity with the GTAP model is a prerequisite for understanding FTAP, a brief verbal description of GTAP is presented in section 2.1. Section 2.2 describes the FTAP model structure. Section 2.3 describes how barriers to services trade were represented as tax equivalents in FTAP.

### 2.1 The structure of GTAP

GTAP is a comparative static, multi-commodity, multi-region CGE model of the world economy. A region may be either a single country or a composite region consisting of many countries, such as the European Union.

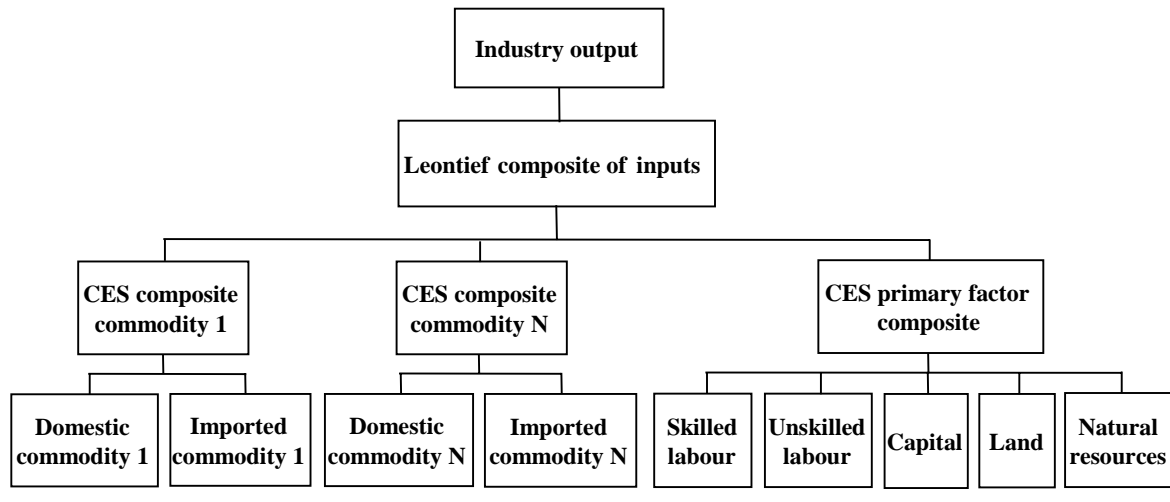
Each region produces its own distinctive variety of each commodity, which is imperfectly substitutable with the varieties produced by other regions. Within each region, each commodity is produced by a single-product industry from inputs of domestically-produced and imported commodities and the primary factors skilled and unskilled labour, capital, land and natural resources, as illustrated in figure 2.1.

Each industry input has an ad valorem tax associated with it. Further, industry inputs of each composite commodity and primary factor have technical efficiency terms associated with them. Thus the user can vary intermediate input taxes, primary factor input taxes and the efficiency with which inputs are used.

Each primary factor is supplied to industries from a fixed regional endowment of the factor. The supplies of skilled and unskilled labour and capital are perfectly transformable between industries, while land is supplied with a transformation elasticity of 1 and natural resources with a transformation elasticity so small that its supply to each industry is essentially fixed. Consequently, wages for each category of labour and the user price of capital are uniform across industries, but the rental prices of land and natural resources can vary from industry to industry.



Figure 2.1 **Industry demands in GTAP**



Regional primary factor endowments each have an income tax applied to them, though the tax rates are set to zero in the standard GTAP database.<sup>1</sup>

Commodities produced in each region are either used as intermediate inputs in production, consumed as inputs to final demand, or exported. There are three categories of final demand — investment, government consumption and private consumption. Each of these consumes composite commodities that are CES combinations of the domestic and the imported variety, similar to composite commodity inputs to industries (figure 2.1). Composite commodity inputs to investment are in fixed proportion to aggregate real investment. Composite commodity inputs to government consumption are determined by the maximisation of a Cobb-Douglas utility function of these inputs, while a constant-difference-elasticities (CDE)<sup>2</sup> utility function is used for private consumption.

Aggregate government and private consumption are determined by the allocation of net (of depreciation) national income between government consumption, private consumption and net (of depreciation) saving to maximise a Cobb-Douglas utility function. Therefore, nominal government consumption, private consumption and net (of depreciation) saving are each a fixed share of nominal national income. Foreign income flows in GTAP are zero, so that national income is equal to primary factor returns plus tax revenue minus subsidies.

Aggregate investment can be determined by one of two user configurable mechanisms. First, global net saving can be allocated between regions in fixed

<sup>1</sup> In the FTAP and GTAPICM databases, the tax rates are set to non-zero values, as described in appendix E.

<sup>2</sup> The CDE form is described in chapter 4 of Hertel (1997).

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shares. Second, elasticities of future expected rates of return with respect to future capital stocks can be postulated, and in each region determined so as to equalise the future expected rates of return. How these investment mechanisms are superseded in GTAPICM (and, consequently, FTAP) is described in chapter 3. Note that investment does not add to the capital stock available for productive use, but does add to the future capital stock, which may be relevant in determining the level of investment.

Exports fall into two categories — commodities that are sold to other regions, and sales to an international pool of freight and insurance services that is used to convey internationally traded commodities from source to destination regions. This international pool is a Cobb-Douglas aggregate of the contributions from all industries in all regions. Plainly, the contributions of most industries will be zero. Only services sectors, such as trade and transport and insurance, produce outputs that could contribute to such a pool. The quantity of freight and insurance services used to convey a particular commodity from a source to destination region is proportional to the quantity of commodity transported, subject to a change in the efficiency of conveyance for that commodity and trade route.

The total regional imports of each commodity is a CES composite of imports of the commodity from each exporting region. The prices determining the allocation of total imports among exporters is the domestic market price in the exporting region, plus (minus) export taxes (subsidies), plus the price of international freight and insurance costs per unit of the commodity, plus import tariffs. Thus the choice among sources of imports occurs at the economy-wide level, while the choice between the domestic and the imported (aggregated across sources) varieties of each commodity occurs at the level of agents within the economy, that is, industries and final demands. Figure 2.2 (ignoring the ‘owned by’ and ‘individual firms’ boxes, which are only relevant to FTAP) illustrates this.

All core standard GTAP equations are briefly<sup>3</sup> described in appendix A. For those GTAP equations that have been changed or deleted in the final FTAP equation system, appendix A gives cross-references to the sections in the text that discuss how they have been altered or why they have been deleted.

All equations of FTAP that are not standard GTAP equations are described in the text.

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<sup>3</sup> They are described more fully in Hertel (1997).

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## 2.2 The structure of FTAP

The FTAP model is a version of GTAP (Hertel 1997) with foreign direct investment. The treatment of FDI follows closely the pioneering work of Petri (1997). FTAP also incorporates large-group monopolistic competition in all sectors. This follows Francois, McDonald and Nordstrom (1996), among others, who adopted this treatment for manufacturing and resource sectors, and Brown et al. (1996) and Markusen, Rutherford and Tarr (1999), who used similar treatments for services. Finally, FTAP makes provision for capital accumulation and international borrowing and lending. This uses a treatment of international (portfolio) capital mobility developed by McDougall (1993b), and recently incorporated into GTAP by Verikios and Hanslow (1999).

### Structure of commodity preferences

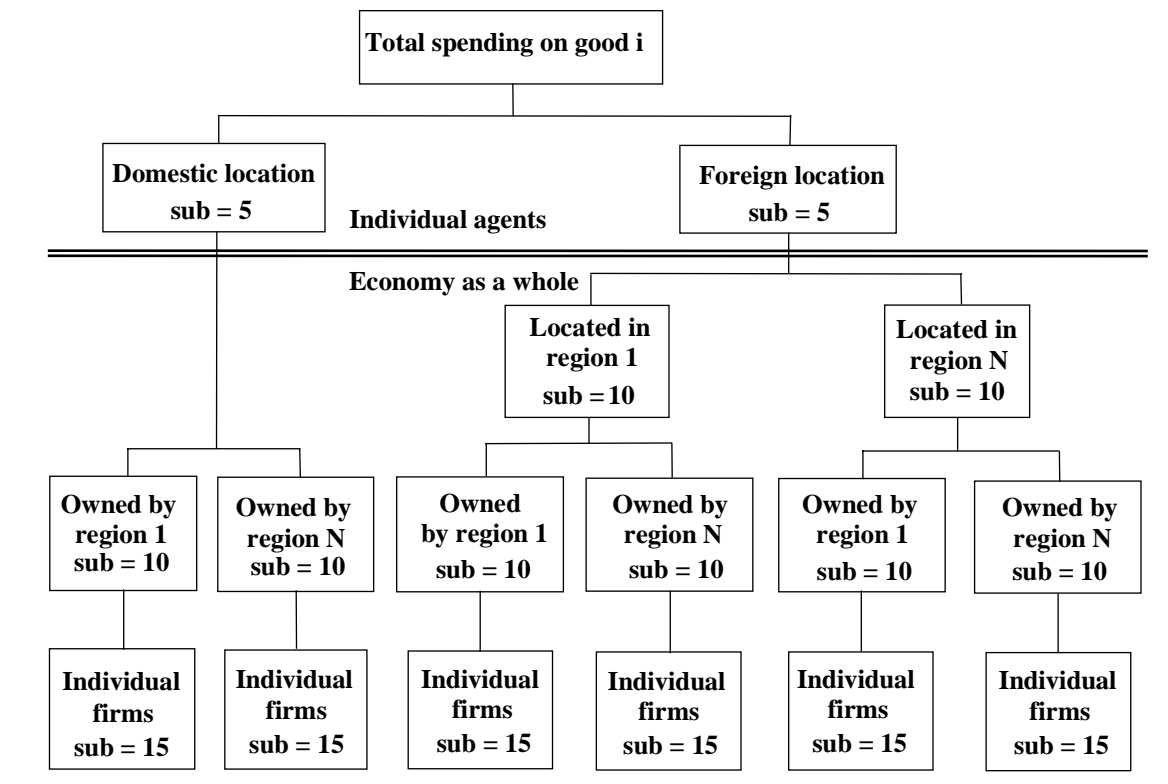
FTAP takes the standard GTAP framework as a description of the *location* of economic activity, and then disaggregates this by *ownership*. For example, each industry located in Australia comprises Australian owned firms, along with multinationals owned by each of the other regions in the model. Each of these firm *types* is modelled as making its own independent choice of inputs to production, according to standard GTAP theory, but with the more extensive choice of commodity varieties about to be described. Each firm type has its own sales structure.

On the purchasing side, agents in each economy make choices among the products or services of each firm type, distinguished by both ownership and location, and then among the individual (and symmetric) firms of a given type. Thus, the model recognises the firm-level product differentiation associated with monopolistic competition. Firms choose among intermediate inputs, investment goods and primary factors (skilled & unskilled labour, capital, land and natural resources), while households and governments choose among final goods and services.

The FTAP choice of commodity varieties in figure 2.2 builds on the standard GTAP scheme. *Individual agents* are assumed to choose first among products or services from domestic or foreign locations, with a CES elasticity of substitution of 5. The imports of each commodity *for the economy as a whole* are then chosen from among foreign locations with a CES elasticity of substitution of 10. Thus far this is the standard GTAP nesting of domestic/foreign choice.

In FTAP, a choice is then made for the economy as a whole among ownership categories for imports of each commodity from each location, and for domestically-produced commodities, also with a CES elasticity of substitution of 10.

Figure 2.2 FTAP structure of commodity preferences



Finally, a choice is made from among the individual firms of a particular ownership and location, with a CES elasticity of substitution of 15.

The choices common to FTAP and GTAP — among domestic and foreign locations — have been parameterised in FTAP using values, 5 and 10, that are roughly twice the standard GTAP Armington elasticities. Two reasons can be given for doubling the standard elasticities. The first is that they enable GTAP to successfully reproduce historical changes in trade patterns (Gehlhar 1997). The second is that higher elasticities accord better with notions of firm level product differentiation.

With firm-level product differentiation, agents benefit from having more firms to choose among, because it is more likely that they can find a product or service suited to their particular needs. Capitalising on this, Francois, McDonald and Nordstrom (1996) show that the choice among individual firms can be modelled in a conventional model of firm types (not firms) by allowing a productivity improvement whenever the output of a particular firm type (and hence the number of individual firms in it) expands. But because the substitutability among individual firms is assumed here to be very high, the incremental gain from greater variety is not very great and this productivity enhancing effect is not particularly strong.

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Section 6.7 reproduces the result, derived in Francois (1998), that the elasticity of productivity with respect to inputs is  $1/(15-1) = 0.0714$ .<sup>4</sup>

The order of the choices, among locations and then among ownership categories, is the opposite of the order adopted by Petri (1997). For example, the current treatment assumes that, from an Australian perspective, a US multinational located in Australia is a closer substitute for an Australian-owned firm than it is for a US firm located in the United States. Petri's treatment assumes that US-owned firms are closer substitutes for each other than for Australian firms, irrespective of location.

There are two reasons for preferring the current treatment.

The first is that Petri's treatment produces a model in which multilateral liberalisation of tariffs on manufactured goods produces large economic welfare losses, for most individual economies and for the world as a whole — an uncomfortable result at odds with conventional trade theory. The reason for the result can be seen by considering the choices that Australians would make at the top of Petri's decision tree in the face of a tariff cut. They would choose between an aggregate of the output of Australian firms (irrespective of location) and an aggregate of the output of US firms (irrespective of location). The Australian aggregate would be overwhelmingly dominated by the output of domestically located Australian firms, since 'boomerang' imports from Australian firms located offshore would be minimal. Thus, the Australian aggregate would have a very small proportion of goods attracting a tariff. The US aggregate would include both goods produced by US multinationals located in Australia, and imports from US firms located in the United States. Only the latter would initially attract a tariff. Depending on relative shares, there is no guarantee that the price of the US aggregate would be dominated by the removal of the tariff on imports, rather than by endogenous changes in the cost structure of US multinationals in Australia. Simulations with a model of this structure showed that the price of the US aggregate *rose* relative to the price of the Australian aggregate in the face of a tariff cut, encouraging resources in Australia to move *into* the domestic protected sector as its protection was removed. This led to a deterioration in allocative efficiency and an overall economic welfare loss. The story was repeated in many other regions.

The second reason for preferring the current treatment of FTAP is that, in many instances, it accords better with reality. Firms in a given location, irrespective of ownership, will tailor their services to meet local tastes and requirements, and thus appear to be closer substitutes, as in the present treatment. This is particularly so

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<sup>4</sup> Section 6.7 also shows that the elasticity of technical change with respect to output is  $1/15 = 0.0667$ . The elasticities with respect to output and inputs differ because of the underlying assumption of increasing returns to scale.

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when foreign direct investment is ‘horizontal’ rather than ‘vertical’, and particularly so for services delivered face to face, where commercial presence (through FDI) is often the only viable means of trade.<sup>5</sup>

## Structure of investor preferences

The supply of FDI is determined in FTAP by the same imperfect transformation among types of wealth as in Petri (1997). Investors in each economy first divide their wealth between ‘bonds’ (which can be thought of as any instrument of portfolio investment), real physical capital, and land and natural resources in their country of residence.

In FTAP, this choice is governed by a CET semi-elasticity of 1, meaning that a one percentage point increase in the rate of return on real physical capital, for example, would increase the ratio of real physical capital to bond holdings by one per cent. Investors next choose the industry sector in which they invest (with a CET semi-elasticity of 1.2). In GTAPICM (chapter 3), by contrast, there was perfect transformation among these assets, and capital was also restricted to being in the country of residence.

In FTAP, as in GTAPICM, a bond is a bond irrespective of who issues it, implying perfect international arbitrage of rates of return on bonds. However, investors in FTAP see capital in different locations as different things. They next choose whether to invest at home or overseas in their chosen sector (with a CET semi-elasticity of 1.3). Finally, they choose a particular overseas region in which to invest (with a CET semi-elasticity of 1.4).

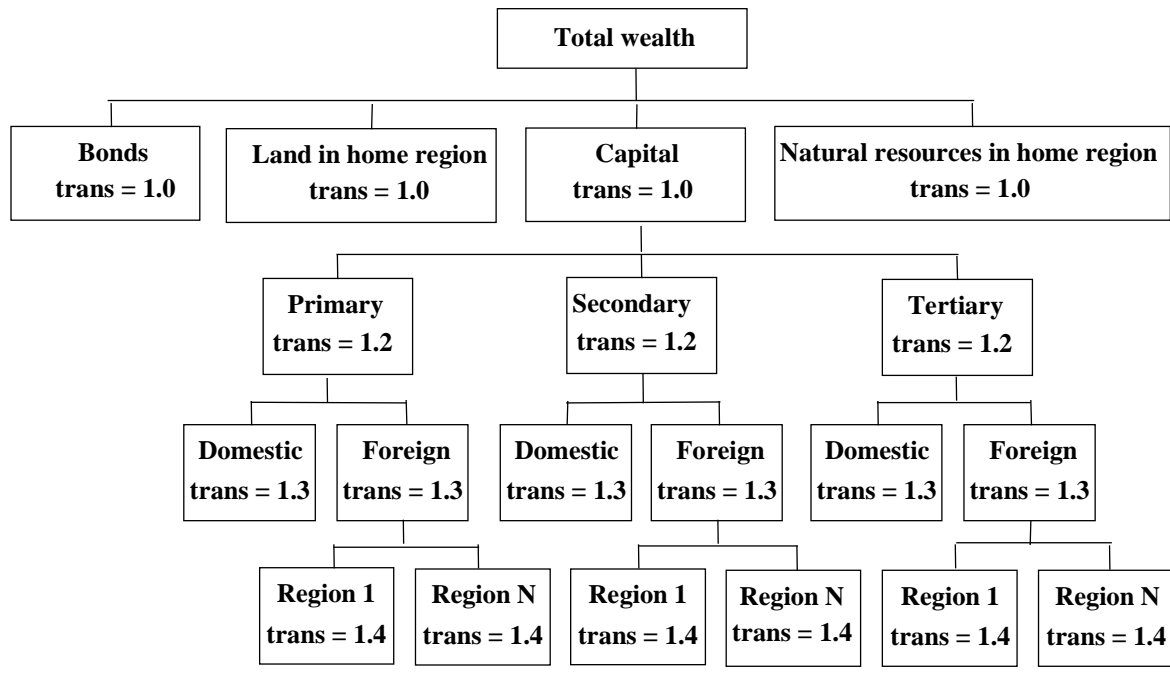
While the chosen CET parameters at each ‘node’ of the nesting structure may appear low, the number of nests means that choices at the final level (across destinations of FDI) are actually very flexible. For example, it can be shown that, holding total wealth fixed, but allowing all other adjustments across asset types and locations to take place, the implied semi-elasticity of transformation between foreign destinations can easily reach 20, and be as high as 60.<sup>6</sup> The variation across regions in these implied elasticities comes about because of the different initial shares of assets in various regional portfolios.

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<sup>5</sup> Some Australian examples are provided in Dee and Hanslow (1999).

<sup>6</sup> Some examples are provided in appendix F.5.

Figure 2.3 FTAP asset supply function



The choice of CET parameters at each ‘node’ was determined partly by this consideration of what they implied for the final elasticities, holding only total wealth constant. They were also chosen so that this version of FTAP gave results that were broadly comparable to GTAPICM with imperfect international (portfolio) capital mobility, for experiments involving the complete liberalisation of agricultural and manufacturing protection. Imperfect capital mobility was also a feature of the GTAP-based examination of APEC liberalisation by Dee, Geisler and Watts (1996) and Dee, Hardin and Schuele (1998). Thus, these parameters provide a familiar starting point, from which variations could be made in the future.

In one respect, however, the current version of FTAP differs from previous versions of GTAP with imperfect capital mobility. The GTAP variants assumed that capital was perfectly mobile across sectors, whereas FTAP has less than perfect sectoral mobility. Furthermore, the choice of sector is relatively early in the nesting structure, so that the implied elasticities guiding choice of sector, holding only total wealth constant, are relatively low (eg 1.2 in the United States). As a result, FTAP tends to exhibit behaviour where resources move less readily between sectors in a given region, but more readily across regions in a given sector, although the differences are not dramatic. The current treatment is consistent with the idea that the knowledge capital often required to succeed in foreign direct investment, despite the difficulties of language and distance, is likely to be sector-specific.

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This imperfect transformation among assets means that rates of return on equity capital can differ by sector, region of ownership and region of location.

Bonds are the difference between total wealth and equity in productive assets — capital, local land and local natural resources — for each region. Each region decides how much to borrow (lend) to finance (supplement) its investment in productive assets. In particular, bonds are a means of financing investment in equity in *aggregate*. The model does not track the financing of FDI in *particular* industries and host regions. This would require a further level at the bottom of the nest determining the debt to equity ratio for particular industries. While such a treatment would be possible, it would seem to add little for the current applications of FTAP.

In reality, less than perfect transformation among different forms of wealth can result from a range of factors such as risk aversion and less than perfect information. While such factors are not explicitly modelled in FTAP, they nevertheless provide some justification for adopting the present treatment of asset supply. It is important to note, however, that while the measure of economic welfare in FTAP currently recognises the positive income contribution that FDI can make, it does not account for any non-pecuniary costs associated with risk taking. This is an important qualification to the current results, and will be the subject of further research (chapter 10).

Petri's model assumed that total wealth in each region was fixed. In FTAP, while regional endowments of land and natural resources are fixed (and held solely by each region's residents), regional capital stocks can accumulate over time, and net bond holdings of each region can adjust to help finance the accumulation of domestic and foreign capital by each region's investors. The treatment of capital accumulation follows the original treatment of McDougall (1993b), and was also used by Verikios and Hanslow (1999), Dee, Geisler and Watts (1996) and Dee, Hardin and Schuele (1998).

With this treatment of capital accumulation, FTAP provides a long-run snapshot of the impact of trade liberalisation, ten years after it has occurred. To the extent that liberalisation leads to changes in regional incomes and savings, this will be reflected in changes to the capital stocks that investors in each region will have been able to accumulate. As noted, investors in each region are not restricted to their own savings pool in order to finance capital investment. They may also issue bonds to help with that investment, but only according to their own preferences about capital versus bond holding, and only according to the willingness of others to accept the additional bonds. These issues are discussed more fully within the detailed documentation of GTAPICM in chapter 3.



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## 2.3 Representing barriers to services trade in FTAP

Barriers to services trade are represented in FTAP as tax equivalents, with the rents from these impediments flowing to the appropriate private agents. Although there is the capacity in the model to include such non-tariff barriers in all sectors, they are only implemented in the tertiary sector, based on the work of Kaleeswaran et al. (2000) and Warren (2000) (to be documented in Findlay and Warren 2000) for banking and telecommunications.

The General Agreement on Trade in Services (GATS) framework distinguishes four modes of service delivery — via commercial presence, cross border supply, consumption abroad, and the presence of natural persons. The FTAP model distinguishes barriers to establishment from barriers to ongoing operation. This is similar to the distinction between commercial presence and other modes of delivery, since barriers to establishment are a component of the barriers to commercial presence.

Barriers to establishment have been modelled in FTAP as taxes on capital. Barriers to ongoing operation may affect either FDI firms or those supplying via the other modes, and have been modelled as taxes on the output of locally-based firms (either domestic or foreign owned), and taxes on the exports of firms supplying via the other modes, respectively.

The GATS framework also distinguishes restrictions on market access from restrictions on national treatment. The former are restrictions on entry, applying equally to locally-owned or foreign-owned firms. In this sense, they are non-discriminatory restrictions. Restrictions on national treatment mean that foreign owned firms are treated less favourably than domestic firms. These are discriminatory restrictions.

These various kinds of barriers to services trade in FTAP are summarised in table 2.1. The taxes on capital of foreign-owned firms are higher than those on domestically-owned firms, because they capture restrictions on national treatment as well as market access. The taxes on the output or exports of foreign-owned firms are higher than those on domestically-owned firms, for similar reasons. This is also reflected in the estimates in the last four columns of table 2.2, drawn from Dee and Hanslow (1999).

**Table 2.1      Categorisation of barriers to services trade**

	<i>Restrictions on market access</i>	<i>Restrictions on national treatment</i>
<i>Barriers to establishment</i>	'Taxes' on capital	'Taxes' on capital
<i>Barriers to ongoing operation</i>	'Taxes' on output and exports	'Taxes' on output and exports

**Table 2.2      Tax equivalents of Post-Uruguay barriers to trade in services (per cent)**

	<i>Exports</i>	<i>Domestic output</i>	<i>Foreign affiliates' output</i>	<i>Domestic capital</i>	<i>Foreign affiliates' capital</i>
Australia	4.81	0.00	0.69	0.62	14.79
NZ	3.78	0.00	0.67	0.41	4.18
Japan	4.41	3.59	4.75	0.33	3.01
Korea	4.57	5.11	6.78	1.91	22.01
Indonesia	4.68	13.23	28.11	22.69	68.06
Malaysia	4.50	3.58	10.20	15.35	37.58
Philippines	4.80	8.38	22.65	7.40	54.28
Singapore	4.70	3.40	8.32	2.42	24.50
Thailand	4.14	4.69	13.36	12.16	36.49
China	4.08	18.75	36.40	123.46	250.66
Hong Kong	9.91	1.39	2.36	1.35	5.41
Taiwan	4.35	2.88	4.90	1.90	19.19
Canada	3.54	0.25	1.67	0.53	6.11
USA	4.26	0.07	1.08	0.00	3.83
Mexico	5.23	2.17	5.59	0.68	12.99
Chile	4.36	2.97	4.11	14.15	20.36
Rest of Cairns Group	4.49	0.98	5.55	7.19	19.45
EU	4.72	0.10	1.31	1.33	6.49
Rest of World	4.95	4.89	13.92	39.07	86.97

*Source:* Dee and Hanslow (1999, table 4).

The estimates of export taxes on services in the second column of table 2.2 are trade weighted averages of the taxes on exports to particular destinations, where these are equal in turn to the taxes on foreign affiliates' output (shown in the fourth column) in the destination regions. The reason for modelling these as taxes in the exporting region, rather than as tariffs in the importing region, is that it allows the rents created by the barriers to be retained in the exporting region.

Because barriers to services trade appear to be significant, and because they are non-tariff barriers, they will generate significant rents. A key issue is whether those rents should be modelled as being retained by incumbent firms, appropriated by

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governments via taxation, or passed from one country to another by transfer pricing or other mechanisms. In FTAP, the rents on output have been modelled as accruing to the selling region, and those on capital have been modelled as accruing to the region of ownership, once the government in the region of location has taxed them at its general property income tax rate. Despite this, the asset choices of investors are modelled as being driven by pre-tax rates of return. This is because many economies, in the developed world at least, have primarily destination-based tax systems. For example, if tax credits are granted for taxes paid overseas, investors are ultimately taxed on *all* income at the owning region's tax rate. Although such tax credits have not been modelled explicitly, their effect has been captured by having investors respond to relative pre-tax rates of return. Nevertheless, investor choices are also assumed to be determined by rates of return excluding any abnormal rent component. Investors would like to supply an amount of capital consistent with rates of return including abnormal rents, but are prevented from doing so by barriers to investment. The amount of capital actually supplied is, therefore, that amount that investors would like to supply at rates of return excluding abnormal rents.

Thus a portion of the rent associated with barriers to services trade is assumed to remain in the region of location in the form of property income tax revenue, while the remainder accrues to the region of ownership. Thus liberalisation of services trade could have significant income effects in both home and host regions as these rents are gradually eliminated. Dee and Hanslow (1999) examine how significant these effects are, relative to the allocative efficiency effects and other effects normally associated with trade liberalisation.

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## 3 International capital mobility in GTAP

This chapter describes the changes made to the GTAP model in order to incorporate international capital mobility (ICM) into its theoretical structure and database. This procedure closely follows that set out in McDougall (1993b), which describes the implementation of international capital mobility into GTAP's predecessor, *SALTER*.

Where a GTAPICM equation is changed further in FTAP, a GEMPACK comment (!...!) in bold alongside the name of an equation indicates the status of the equation in FTAP. The possibilities are:

- negated — rendered inoperative in FTAP simulations by endogenising the associated slack variable;
- altered; or
- replaced by an FTAP equation.

Where a GTAPICM equation is negated or altered in FTAP, a cross-reference to the section describing why this is done is provided in the comment.

Where a GTAP equation is replaced by an FTAP equation, the name of the FTAP equation and a section cross-reference is provided.

### 3.1 GTAP background

GTAP is a multi-regional, comparative static model, expressed as a system of linear equations written in percentage change form. GTAP's comparative static nature means it does not track changes in the economy through time. Instead, it compares alternative states of the economy at a single point in time. Simulation results represent differences between these alternative states.

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The ICM modifications are made to the latest available (at the time of writing) version of GTAP. This is known as version 4.1, dating from November 1998.<sup>1</sup> The standard model is documented in detail in Hertel (1997).

In order to explain the motivation for incorporating ICM into GTAP, some explanation of the GTAP theory of investment, capital accumulation and capital allocation is necessary.

### **Investment, capital accumulation and capital allocation in GTAP**

GTAP allows divergences between regional investment and saving, but forces all existing capital within a region to move only across industries within that region. Such a treatment of capital movements is likely to ignore some of the important long-run effects of large scale structural policy shocks such as the Uruguay Round trade agreement. These long-run effects include capital moving to regions where returns are highest.

The user is given a choice of two mechanisms for the allocation of investment across regions. The first mechanism allocates global net (of depreciation) investment in fixed shares across regions. This is the so-called ‘fixed shares mechanism’. Importantly, the investment does not come on line in the simulation period. Thus, the behaviour of investment can only influence output through changes in the composition of final demand. Productive capacity is unaffected. This closure is appropriate for short-run analysis. The short run is usually regarded as a period of time long enough to allow for changes in the rates of return on factors within an economy, but too short to allow any investment that may occur to affect the stock of factors in that economy. The ‘fixed shares mechanism’ allows the return on all factors to be determined endogenously at the regional level, while fixing the stock of all factors at the regional level.

The second investment allocation mechanism in GTAP allocates investment so as to equilibrate expected rates of return on capital across regions. This is the so-called ‘rates of return’ mechanism. This fixes the differences in the rates of return on capital across regions. But as before, the stock of capital within each region remains fixed. Such a closure adopts the long-run assumption of fixing the (relative) rate of return on capital in an economy, but retains the short-run assumption of also keeping the stock of capital in an economy fixed. This investment closure does not allow GTAP to be used for true long-run policy analysis.

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<sup>1</sup> This version comes with the RunGTAP software available on the GTAP world wide web home page. See <http://www.agecon.purdue.edu/gtap/index.htm>.

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In order to conduct long-run analysis with GTAP, a mechanism which allows both capital accumulation and its allocation among regions is needed. The ICM extension serves this purpose. The next section provides a detailed overview of the ICM extension. It also explains the modifications required to GTAP's theoretical structure and database, in order to incorporate the ICM extension into GTAP. This section is largely based on sections 2 and 3 of McDougall (1993b).

## 3.2 Modifications to the GTAP theoretical structure

### Overview

The ICM extension allows GTAP to simulate the effects of policy changes on regional capital stocks. Hence, the extension contains modules covering the international allocation of capital, regional wealth accumulation, international stocks of assets and liabilities, and the international allocation of investment. It also adds household and government sector modules which capture international investment flows and international income payments.

GTAP is a comparative static model, and like most comparative static models, it includes no treatment of time. Household and government wealth in the ICM extension are modelled as the outcome of a wealth accumulation process. This process requires that some treatment of time be introduced to the model. This is done by assuming that all shocks applied to the model represent distinct changes at a certain initial point in time, ie the initial instant. The database and endogenous variables represent values observed at a certain final point in time, ie the terminal instant. The simulation period is the period of time between the initial and terminal instants. Certain reasonable assumptions are then made about (i) the shape of the adjustment paths of income and savings, and (ii) the length of the simulation period. These assumptions allow the accumulation equations to be derived. The accumulation equations use price movements over the simulation period to calculate the change in wealth.

At this stage, two sets of assets are added to the model: bonds and equity in productive assets (capital, land and natural resources) in each region. Capital is distinguished from land and natural resources at a later stage. Bonds can be owned or owed by private households and governments in each region. Equity in productive assets can only be owned by private households in each region.

The movement of bonds between regions requires that they are denominated in a common unit of measurement. It is assumed that lenders are protected against

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inflation by indexing the value of bonds to a world consumption price index. This assumption also preserves price homogeneity.

With regard to international flows and stocks, GTAPICM only incorporates net rather than gross values. For instance, only net foreign assets and net property income flows are modelled. As the model assumes perfect arbitrage on internationally mobile assets (capital and bonds), it can only determine the behaviour of net international flows and stocks. Thus, only net flow and stock values are required to calibrate the model. This also limits the modelling of income taxes on households, which are sometimes based on gross rather than net asset positions. In this model, no income taxes are levied on government receipts of foreign income. Further, income taxes on (private household) property income do not distinguish taxes on equity (in productive assets) and taxes on interest income.

The equations describing the ICM extension will be presented in TABLO code. The convention is that original variables in the underlying theory (termed coefficients) and set names are denoted by upper case letters, and absolute or percentage changes in the underlying variables are denoted by lower case letters. The new (non-GTAP) TABLO notation is almost identical to the original implementation of the ICM extension in SALTER (see Jomini et al. 1994).

### **International allocation of capital**

The allocation of capital between regions is determined by two parity conditions. The first is an international interest parity condition, which is necessary for equilibrium in international financial markets:

INTERNL\_INTT\_PARY (all,r,REG)

$$rbr(r) = rb;$$

where REG is the set of regions,  $rbr(r)$  denotes the real bond rate in region  $r$ , and  $rb$  the world real bond rate. These variables are specified as absolute changes, due to the possibility that these rates can become negative, and thus pass through zero. This condition reflects profit maximising behaviour in the international bond market. The parity condition applies to pre-tax interest rates.

The second parity condition is a capital-bond parity condition. This reflects maximisation of rates of return by households, ie parity between the interest rate and the rate of return on capital:

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**EQY\_BOND\_PARY (all,r,REG) ! Negated section 4.3!**

$$rkr(r) = rbr(r) + frer(r);$$

where  $rkr(r)$  denotes the (absolute change in) the average rate of return on capital in region  $r$ , and  $frer(r)$  is a shift term which allows for an equity premium in region  $r$  (this variable is usually exogenous). With no change in the equity premium, equation EQY\_BOND\_PARY reflects profit maximisation by domestic investors. The model applies a common tax rate on household equity (in productive assets) income and household interest income, so the capital-bond parity condition can be applied using either pre- or post-tax rates. In implementing this extension in GTAP, pre-tax rates are used.

In the short run, industry-specific capital stocks are able to earn abnormal returns. To allow for this possibility, the absolute change in the rate of return on capital in industry  $i$  in region  $r$  ( $rkri(i,r)$ ), is represented as the sum of  $rkr(r)$  and the absolute change in the abnormal rate of return on capital in industry  $i$  in region  $r$  ( $rari(i,r)$ ):

**ABNL\_RETN\_CAPL !Replaced by E\_rp section 4.6!**

(all,i,TRAD\_COMM)(all,r,REG)

$$rkri(i,r) = rkr(r) + rari(i,r);$$

where TRAD\_COMM is the set of traded commodities. In the long run,  $rari(i,r)$  is held fixed and industry-specific capital stocks in each region are free to vary. In the short run,  $rari(i,r)$  is free to vary and industry-specific capital stocks are held fixed.

Having described the behaviour of rates of return for bonds and capital, these can be defined in terms of prices and earnings of all productive assets (capital, land and natural resources). For capital,

RENTL\_PRICE\_CAPL (all,i,TRAD\_COMM)(all,r,REG)

$$rkri(i,r) = RTKPGRRI(i,r)*(rp(i,r) - pcgds(r));$$

where  $RTKPGRRI(i,r)$  is the (coefficient) gross rate of return on capital in industry  $i$  in region  $r$ ,  $rp(i,r)$  is the (percentage change in the) pre-tax rental price of capital in industry  $i$  in region  $r$  and  $pcgds(r)$  is the GTAP (percentage change in the) price of investment in region  $r$ .

With rates of return held fixed at the world real bond rate, equation RENTL\_PRICE\_CAPL determines the (pre-tax) rental price of capital in each industry in each region. In conjunction with the input demand equations for current



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production, this determines the inter-industry and inter-regional allocation of capital.

GTAP specifies the (pre-tax) rental prices of land and natural resources as a subset of the prices of all non-savings commodities. However, the ICM extension requires that the rental price of land and natural resources be defined as separate variables, to be used later in the definition of the purchase price of land and natural resources. This is done in the following two equations:

E\_rm (all,r,REG)

$$rm(r) = \text{sum}(n, \text{LAND}, pm(n,r));$$

E\_nrp (all,r,REG)

$$nrp(r) = \text{sum}(nr, \text{NATRES}, pm(nr,r));$$

where  $rm(r)$  is the (pre-tax) rental price of land in region  $r$ ,  $\text{LAND}$  is the set of the single land endowment,  $pm(i,r)$  is the GTAP variable for the market (or pre-tax) price of non-savings commodity  $i$  in region  $r$ ,  $nrp(r)$  is the (pre-tax) rental price of natural resources in region  $r$ , and  $\text{NATRES}$  is the set of the single natural resource endowment.

GTAP distinguishes unskilled and skilled labour in each region. For the purposes of the ICM extension a single region-wide (pre-tax) wage rate needs to be defined, to be used later in the definition of regional net factor income. This is done by equation E\_w:

E\_w (all,r,REG)

$$w(r) = \text{sum}(l, \text{LABOR}, \text{EVOA}(l,r) / \text{sum}(l, \text{LABOR}, \text{EVOA}(l,r)) * pm(l,r));$$

where  $w(r)$  is the (pre-tax) wage rate in region  $r$ ,  $\text{LABOR}$  is the set of labour endowments, and  $\text{EVOA}(i,r)$  is the GTAP coefficient for the post-tax (or agent's) price value of output of endowment commodity  $i$  in region  $r$ . Note that as GTAP distinguishes between unskilled and skilled labour, the region-wide wage rate is a share-weighted sum of the unskilled and skilled wage rates in each region.

The purchase price of land in each region,  $pnr(r)$ , is determined implicitly by

**PRICE\_LAND (all,r,REG) !Replaced by E\_pnr section 4.2!**

$$rkr(r) = \text{RTBD} * (rm(r) - pnr(r));$$

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where RTBD is the parameter form of the world real bond rate, and  $rm(r)$  is the rental price of land in region  $r$ .

The purchase price of natural resources in each region,  $pnrr(r)$ , is determined implicitly by

$E_{pnrr}$  (all,r,REG) **!Replaced by  $E_{pnrr}$  section 4.2!**

$$rkr(r) = RTBD*(nrp(r) - pnrr(r));$$

The purchase prices of land and natural resources are used later, along with the value of capital, to define the total value of the world stocks of all productive assets (ie capital, land and natural resources).

### The world capital stock

The total value of world stocks of productive assets (ie capital, land and natural resources) is equal to the total value of net wealth of households and governments in all regions. This is based on the assumptions that:

- private household and government net wealth is equal to equity in productive assets plus net ownership of bonds;
- the value of equity (in productive assets) is equal to the value of the underlying productive assets; and
- the world net ownership of bonds is zero.

World net ownership of bonds is equal to the sum of the net ownership of bonds in each region:

OWNP\_BONDS

$$YC*qyb + ASBD*yn = \text{sum}(r,REG, YCR(r)*qybr(r) + ASBDR(r)*y_r(r));$$

where  $YC$  is the coefficient form of world (nominal) income,  $qyb$  is the (absolute change in the) world bond-income ratio,  $ASBD$  is the coefficient form of the world net ownership of bonds,  $yn$  is world (nominal) income,  $YCR(r)$  is the coefficient form of income in region  $r$ ,  $qybr(r)$  is (the absolute change in) the bond-income ratio in region  $r$ ,  $ASBDR(r)$  is the coefficient form of net ownership of bonds in region  $r$ , and  $y_r(r)$  is (nominal) income in region  $r$ .

In the initial database the world net ownership of bonds is zero. To ensure that this condition continues to be met, the world bond-income ratio variable (ie  $qyb$ ) is

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exogenous. This is done by allowing the world real bond rate variable (ie  $rb$ ) to vary.

The sum of net ownership of bonds by households and government in each region gives net ownership of bonds in that region:

OWNP\_BONDS\_REG (all,r,REG)

$$\begin{aligned} & YCR(r)*qybr(r) + ASBDR(r)*y_r(r) = \\ & YCHHDPR(r)*qyhbr(r) + ASHHBDR(r)*yhdr(r) + \\ & RCGVR(r)*qrgbr(r) + ASGVR(r)*rgr(r); \end{aligned}$$

where  $YCHHDPR(r)$  is the coefficient form of private household disposable income in region  $r$ ,  $qyhbr(r)$  is the (absolute change in the) household bond-income ratio in region  $r$ ,  $ASHHBDR(r)$  is the coefficient form of net household ownership of bonds in region  $r$ ,  $yhdr(r)$  is (nominal) household disposable income in region  $r$ ,  $RCGVR(r)$  is the coefficient form of government receipts in region  $r$ ,  $qrgbr(r)$  is the (absolute change in the) government bond-income ratio in region  $r$ ,  $ASGVR(r)$  is the coefficient form of net government ownership of bonds in region  $r$ , and  $rgr(r)$  is government receipts in region  $r$ .

Private household wealth is the sum of net household ownership of bonds and (private household) equity in productive assets:

HHOLD\_OWNP\_BONDS\_REG (all,r,REG)

$$\begin{aligned} & ASHHR(r)*ahr(r) = \\ & ASEQR(r)*aer(r) + YCHHDPR(r)*qyhbr(r) + ASHHBDR(r)*yhdr(r); \end{aligned}$$

where  $ASHHR(r)$  and  $ahr(r)$  are the coefficient and variable forms, respectively, of private household wealth in region  $r$ , and  $ASEQR(r)$  and  $aer(r)$  are the coefficient and variable forms, respectively, of equity in productive assets in region  $r$ .

In order to determine the value of equity in productive assets in each region, it is necessary to first determine the value of the individual endowments, which make up all productive assets in that region. In levels, the value of a particular endowment in a region is equal to price multiplied quantity. The next four equations define variables for the quantity of those endowment commodities that make up total productive assets in each region, and also for total labour endowments in each region:

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**E\_kt (all,r,REG) ! Replaced by E\_kt section 4.2!**

$$kt(r) = ksvces(r);$$

**E\_mt (all,r,REG)**

$$mt(r) = \text{sum}(n, \text{LAND}, qo(n,r));$$

**E\_nru (all,r,REG)**

$$nru(r) = \text{sum}(nr, \text{NATRES}, qo(nr,r));$$

**E\_lt\_ (all,r,REG)**

$$lt_(r) = \text{sum}(l, \text{LABOR}, \text{EVOA}(l,r) / \text{sum}(l, \text{LABOR}, \text{EVOA}(l,r)) * qo(l,r));$$

where  $kt(r)$ ,  $mt(r)$ ,  $nru(r)$  and  $lt_(r)$  is the total use of capital, land, natural resources and labour, respectively, in region  $r$ ,  $ksvces(r)$  is the GTAP variable for the use of capital in region  $r$ , and  $qo(i,r)$  is the GTAP variable for the output of non-savings commodity  $i$  in region  $r$ .

Note that as GTAP distinguishes between unskilled and skilled labour, the use of all labour endowments in each region is a share-weighted sum of the use of unskilled and skilled labour in each region.

The value of capital, land and natural resources is determined by the following equations:

**VALUE\_CAPL (all,r,REG) ! Altered section 4.2 !**

$$akr(r) = pcgds(r) + kt(r);$$

**VALUE\_LAND (all,r,REG)**

$$anr(r) = pnr(r) + mt(r);$$

**E\_anrr (all,r,REG)**

$$anrr(r) = pnrr(r) + nru(r);$$

where  $akr(r)$ ,  $anr(r)$  and  $anrr(r)$  is the value of capital, land and natural resources, respectively, in region  $r$ .

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Note that assuming industry depreciation rates are constant, depreciation allowances in each region ( $\text{depr}(r)$ ) are proportional to the value of capital in each region, and are therefore defined accordingly:

**DEP\_CAPITAL (all,r,REG) ! Altered section 4.7 !**

$$\text{depr}(r) = \text{pcgds}(r) + \text{kt}(r);$$

Equity in productive assets in each region is equal to sum of the value of productive assets:

**EQY (all,r,REG) ! Altered section 4.2 !**

$$\begin{aligned} \text{ASEQR}(r)*\text{aer}(r) = \\ \text{VKB}(r)*\text{akr}(r) + \text{ASLNR}(r)*\text{anr}(r) + \text{ASLNRR}(r)*\text{anrr}(r); \end{aligned}$$

where  $\text{VKB}(r)$  is the GTAP coefficient denoting the value of beginning-of-period capital stock in region  $r$ , and  $\text{ASLNR}(r)$  and  $\text{ASLNRR}(r)$  are the coefficient forms of the value of land and the value of natural resources, respectively, in region  $r$ .

Equation  $\text{EQY\_PRICE\_INDX}$  defines an equity price index for productive assets in each region. This is used, later on, in determining wealth accumulation:

**EQY\_PRICE\_INDXX (all,r,REG) ! Replaced by E\_iper section 4.5 !**

$$\begin{aligned} \text{ASEQR}(r)*\text{iper}(r) = \\ \text{VKB}(r)*\text{pcgds}(r) + \text{ASLNR}(r)*\text{pnr}(r) + \text{ASLNRR}(r)*\text{pnrr}(r); \end{aligned}$$

where  $\text{iper}(r)$  is the equity price index in region  $r$ .

For a given set of prices and household and government net wealth in each region, the equations in this section are sufficient to determine the value of the total world stock of productive assets.

## **Wealth accumulation**

The wealth accumulation process reflects the intrinsic dynamics of saving and wealth accumulation. However, since GTAP is comparative static, the accumulation equations must be derived outside the model. This is done by making certain assumptions regarding the time paths of the explanatory variables in the equations, based on the initial assumption that households and governments save (or dissave)

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some predetermined fraction of their net disposable income. The key assumptions are:

- real income grows at a constant rate through the simulation period;
- any change in the saving ratio is concentrated at the beginning of the simulation period; and
- changes in relative prices are concentrated at the beginning of the simulation period.

Using these assumptions, McDougall (1993b, appendix A) derives accumulation equations that express wealth at the terminal instant as a function of the saving ratio, real income and price variables, also at the terminal instant.

The first of the wealth accumulation equations determines household wealth accumulation:

HHOLD\_WEALTH\_ACCN (all,r,REG)

$$\begin{aligned}
 & \text{ASHHR}(r) * \text{ahr}(r) = \\
 & (\text{ASHHR}(r) - \text{CEACWTHH01R}(r) * \text{SVT}(r) * \text{LGPRSM}) * \text{ipahr}(r) + \\
 & \text{CEACWTHH01R}(r) * \text{YCHHDPR}(r) * \text{LGPRSM} * \text{qyhsr}(r) + \\
 & \text{CEACWTHH01R}(r) * \text{SVT}(r) * \text{LGPRSM} * \text{ppriv}(r) + \\
 & \text{CEACWTHH02R}(r) * \text{SVT}(r) * \text{LGPRSM} * (\text{yhdr}(r) - \text{ppriv}(r));
 \end{aligned}$$

where  $\text{CEACWTHH01R}(r)$  and  $\text{CEACWTHH02R}(r)$  are household wealth accumulation coefficients defined below,  $\text{SVT}(r)$  is the coefficient form of private household savings in region  $r$ ,  $\text{LGPRSM}$  is a coefficient setting the length of the simulation interval,  $\text{ipahr}(r)$  is the price index for private household wealth in region  $r$ ,  $\text{qyhsr}(r)$  is the (absolute change in the) household saving-disposable income ratio in region  $r$ , and  $\text{ppriv}(r)$  is the price index for private household expenditures in region  $r$ .

The coefficients  $\text{CEACWTHH01R}(r)$  and  $\text{CEACWTHH02R}(r)$  are defined by the formulae

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(all,r,REG)

$$\begin{aligned} \text{CEACWTHH01R}(r) = & \\ & (1.0 - \text{EXP}(-\text{GTYCHHRLR}(r)*\text{LGPRSM}))/ \\ & (\text{GTYCHHRLR}(r)*\text{LGPRSM}); \text{ and} \end{aligned}$$

(all,r,REG)

$$\begin{aligned} \text{CEACWTHH02R}(r) = & \\ & (\text{GTYCHHRLR}(r)*\text{LGPRSM} - 1.0 + \text{EXP}(-\text{GTYCHHRLR}(r)*\text{LGPRSM}))/ \\ & (\text{GTYCHHRLR}(r)*\text{LGPRSM})^2; \end{aligned}$$

where  $\text{GTYCHHRLR}(r)$  is a parameter giving the (annual) rate of growth in real household income in region  $r$ .<sup>2</sup>

Equation `HHOLD_WEALTH_ACCN` defines the change in (nominal) private household wealth (the term on the left hand side) as being made up four effects. The first is the change in household wealth due to changes in the prices of assets held at the beginning of the simulation period (the first term on the right hand side). The second is the change in household wealth due to effect of changes in the household saving-disposable income ratio (the second term on the right hand side). The third is the change in household wealth due to the effects of changes in the price of private household expenditures (the third term on the right hand side). The fourth is the change in household wealth due to the effects of changes in real household income (the fourth term on the right hand side). The coefficients in the third and fourth terms on the right hand side are different. This is because in the derivation of the accumulation relation, changes in prices relative to the pre-simulation solution are assumed to be concentrated at the beginning of the simulation period, whereas, changes in real income are assumed to occur evenly over the simulation period.

For use in calculating a household asset price index, a regional and global consumption price index is defined by the equations `NATL_CONSN_PRINDX` and `WORLD_CONSN_PRINDX`, respectively:

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<sup>2</sup> McDougall (1993b, appendix A) shows how these coefficients are derived.

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NATL\_CONSN\_PRINDX (all,r,REG)

$$YCR(r)*ipcr(r) =$$

$$PRIVEXP(r)*ppriv(r) + GOVEXP(r)*pgov(r) + SVR(r)*pcgds(r); \text{ and}$$

WORLD\_CONSN\_PRINDX

$$EPCS*ipc = \text{sum}(r,REG, EPCSR(r)*ipcr(r));$$

where  $ipcr(r)$  is the national consumption price index in region  $r$ ,  $PRIVEXP(r)$  and  $GOVEXP$  are coefficients for private household and government consumption expenditure, respectively, in region  $r$ ,  $pgov(r)$  is the price index for government consumption in region  $r$ ,  $SVR(r)$  is the coefficient form of net (of depreciation) savings in region  $r$ ,  $EPCS$  is the coefficient form of world consumption expenditure,  $ipc$  is the world consumption price index, and  $EPCSR(r)$  is the coefficient form of consumption expenditure in region  $r$ .

Equation `NATL_CONSN_PRINDX` defines the consumption price index in each region as a share-weighted average of the prices of consumption and investment in each region. Equation `WORLD_CONSN_PRINDX` defines the world consumption price index as a share-weighted sum of the regional consumption price indices.

The first term on the right hand side of the household accumulation equation (`HHOLD_WEALTH_ACCN`) calculates the change in household wealth due to changes in the prices of assets held at the beginning of the simulation period. This requires that a household asset price index be defined. This household asset price index is a share weighted average of the equity price index in each region and the world consumption price index:

`HHOLD_ASST_PRINDX` (all,r,REG) ! **Altered in FTAP version 2, Appendix J !**

$$ASHHR(r)*ipahr(r) = ASEQR(r)*iper(r) + ASHHBDR(r)*ipc;$$

The calculation of  $ipahr(r)$  should be done using data at the beginning of the simulation period. Equation `HHOLD_ASST_PRINDX`, however, uses data applying to the end of the simulation period. Thus, it is not strictly correct. In practice, however, the second and fourth terms on the right hand side of equation `HHOLD_WEALTH_ACCN`, which relate to real saving, are likely to dominate the asset revaluation term (the first term on the right hand side of equation `HHOLD_WEALTH_ACCN`).

Further, the equation `NATL_CONSN_PRINDX` is also not strictly correct. It uses the price of investment in each region ( $pcgds(r)$ ), whereas the correct deflator would



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be the price of savings in each region. However, no such variable existed in the original SALTER implementation of the ICM extension. Thus, the price of investment was used to define a world consumption price index, as well as being used to define real national income (see equation REAL\_NATL\_INCOME in section 8). In GTAP, however, the price of savings is defined for each region and, therefore, real national income is (correctly) specified using the price of savings.

There is a similar wealth accumulation relation for government:

GOVT\_WEALTH\_ACCN (all,r,REG)

$$\begin{aligned}
 &RCGVR(r)*qrgbr(r) + ASGVR(r)*rgr(r) = \\
 &(ASGVR(r) - CEACWTGV01R(r)*SPGVR(r)*LGPRSM)*ipc + \\
 &CEACWTGV01R(r)*RCGVR(r)*LGPRSM*qrgsr(r) + \\
 &CEACWTGV01R(r)*SPGVR(r)*LGPRSM*pgov(r) + \\
 &CEACWTGV02R(r)*SPGVR(r)*LGPRSM*(rgr(r) - pgov(r));
 \end{aligned}$$

where SPGVR(r) is the coefficient form of the government surplus on current transactions in region r, and qrgsr(r) is the (absolute change in the) ratio of government surplus on current transactions to net government receipts (government saving ratio) in region r. CEACWTGV01R(r) and CEACWTGV02R(r) are government wealth accumulation coefficients defined in the same way as CEACWTHH01R(r) and CEACWTHH02R(r), with the rate of growth in real household income in region r (GTYCHHRLR(r)) replaced by the rate of growth in real government receipts in region r (GTYCGVRLR(r)).<sup>3</sup>

## National income and saving

Net factor income in each region (yfn(r)) is a share-weighted sum of all factor income less depreciation of capital in each region:

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<sup>3</sup> McDougall (1993b, appendix A) shows how these coefficients are derived.

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NET\_FACT\_INC (all,r,REG)

$$\begin{aligned} yfn(r) = & \\ & SLYF(r)*(w(r) + lt_(r)) + \\ & \text{sum}(j, \text{TRAD\_COMM}, (SKYF(j,r)*(rp(j,r) + kk(j,r)))) + \\ & SMYF(r)*(rm(r) + mt(r)) + SNYF(r)*(nrp(r) + nru(r)) - SDDDF(r)*depr(r); \end{aligned}$$

where SLYF(r), SMYF(r), SNYF(r) and SDDDF(r) are coefficients representing the market (or pre-tax) price share of labour income, land income, natural resource income and depreciation, respectively, in net (of depreciation) factor income in region r, and SKYF(j,r) is a coefficient representing the market (or pre-tax) price share of capital income in net (of depreciation) factor income of industry j in region r.

The introduction of foreign income flows causes the value of domestic product and national income to diverge. This necessitates the introduction of a national income variable, which is the sum of domestic factor income, net (of subsidies) indirect taxes, and net (foreign) interest income:

NATL\_INCOME (all,r,REG) ! **Altered section 8.6 !**

$$\begin{aligned} YCR(r)*y_r(r) = & \\ & YFNT(r)*yfn(r) + YCR(r)*qyir(r) + YCITR(r)*y_r(r) + GRCOMT(r)*rc(r); \end{aligned}$$

where YFNT(r) is the coefficient form of net (of depreciation) factor income in region r, respectively, qyir(r) is the (absolute change in the) ratio of net interest income (from bonds) to national (nominal) income in region r, YCITR(r) is the coefficient form of net interest income in region r, GRCOMT(r) is the coefficient form of net (of subsidies) indirect tax revenue in region r, and rc(r) is government revenue from commodity taxes in region r. Thus, national income is the sum of domestic factor income (the first term on the right hand side), net (interest) income from abroad (the second and third terms on the right hand side) and net indirect taxes (the fourth term on the right hand side). The equation NATL\_INCOME replaces the GTAP equation REGIONALINCOME and the variable  $y_r(r)$  replaces the GTAP variable  $y(r)$ .

The (absolute change in the) ratio of net interest income to national income in each region is determined by the equation:

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INTT\_INCOME\_REGN (all,r,REG)

$$YCR(r)*qyir(r) = ASBDR(r)*rbr(r) + RTBD*YCR(r)*qybr(r);$$

that is, in levels, the bond rate in each region multiplied by the ratio of the net ownership of bonds to national income in each region.

## Household income

Household disposable income is given by the equation:

HHOLD\_DISPBLE\_INCOME (all,r,REG)

$$YCHHDPR(r)*yhdr(r) = YCHHR(r)*yhr(r) - RVTXYCR(r)*rtyr(r);$$

where YCHHR(r) and yhr(r) are the coefficient and variable forms, respectively, of household income in region r, and RVTXYCR(r) and rtyr(r) are the coefficient and variable forms of income tax revenue in region r. Thus, the change in household disposable income (the left hand side of equation HHOLD\_DISPBLE\_INCOME) is equal to the change in household income (the first term on the right hand side) less the change in income tax (the second term on the right hand side).

Household income is given by the equation:

HHOLD\_INCOME (all,r,REG)

$$\begin{aligned} YCHHR(r)*yhr(r) = \\ LTT(r)*ylr(r) + YCHHPPR(r)*yhpr(r) + \\ URGVHHR(r)*ughr(r) + d\_ughr(r); \end{aligned}$$

where LTT(r) and ylr(r) are the coefficient and variable forms, respectively, of labour income in region r, YCHHPPR(r) and yhpr(r) are coefficient and variable forms of household property income in region r, URGVHHR(r) and ughr(r) are the coefficient and variable forms, respectively, of government transfer payments in region r, and d\_ughr(r) is a (usually) exogenous variable defined in absolute change form. This variable can be used to shock government transfer payments.

Equation HHOLD\_INCOME says that household income in each region is the sum (in levels) of labour income, household property income and government transfer payments in that region. It should be noted that a new form of household income

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(and government spending) has been added to the model, in the form of transfer payments from governments to households.

Labour income (in levels) in each region is the product of the wage rate and labour employed in that region:

LABR\_INCOME (all,r,REG)

$$ylr(r) = w(r) + lt_(r);$$

Household property income is defined by the equation:

PROPY\_INCOME (all,r,REG)

$$YCHHPPR(r)*yhpr(r) = \\ YCEQR(r)*yer(r) + YCHHDPR(r)*qyhir(r) + YCHHITR(r)*yhdr(r);$$

where YCEQR(r) and yer(r) are the coefficient and variable forms, respectively, of equity (in productive assets) income region r, qyhir(r) is the (absolute change in the) ratio of household net interest income to household disposable income, and YCHHITR(r) is the coefficient form of net interest income of households in region r. Thus, household property income in each region is the sum of equity income and household net interest income in that region. Household net interest income is a new source of household income introduced as part of the ICM extension.

Equity income in each region is equal to net (of depreciation) income from all productive assets (capital, land and natural resources) in each region:

EQY\_INCOME (all,r,REG)

$$YCEQR(r)*yer(r) = \\ KTT(r)*fke(r) + MTT(r)*(rm(r) + mt(r)) + NTT(r)*(nrp(r) + nru(r)) - \\ VDEP(r)*depr(r);$$

where KTT(r) and fke(r) are the coefficient and variable forms, respectively, of capital earnings in region r, MTT(r) is land earnings in region r, NTT(r) is natural resource earnings in region r, and VDEP(r) is the coefficient form of depreciation in region r.

Equation FIXD\_CAPL\_EARNINGS defines the market (or pre-tax) price value of capital earnings in each region:

FIXD\_CAPL\_EARNINGS (all,r,REG)

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$$KTT(r)*fke(r) = \text{sum}(j, \text{TRAD\_COMM}, \text{CAP}(j,r)*(rp(j,r) + kk(j,r)));$$

where  $\text{CAP}(j,r)$  is the coefficient form of the market (or pre-tax) price value of capital earnings from industry  $j$  in region  $r$ . Capital earnings (in levels) from each industry in each region is equal to the rental price multiplied by the quantity of capital. By extension, the market price value of capital earnings in each region is a share-weighted sum of the capital earnings from all industries in each region.

The ratio of household net interest income to household disposable income in each region is given (in levels) by the product of the bond rate and the ratio of household net ownership of bonds to household disposable income in that region:

HHOLD\_INTT\_INCOME (all,r,REG)

$$\begin{aligned} YCHHDPR(r)*qyhir(r) = \\ ASHHBDR(r)*rbr(r) + RTBD*YCHHDPR(r)*qyhbr(r); \end{aligned}$$

The equation `DISPN_HHOLD_INCOME` sets private household consumption proportional to private household disposable income, if the household savings ratio is held fixed:

DISPN\_HHOLD\_INCOME (all,r,REG)

$$\begin{aligned} YCHHDPR(r)*yhdr(r) = \\ PRIVEXP(r)*yp(r) + YCHHDPR(r)*qyhsr(r) + SVT(r)*yhdr(r); \end{aligned}$$

where  $yp(r)$  is private household consumption expenditure in region  $r$ . Equation `DISPN_HHOLD_INCOME` says that the change in private household consumption expenditure (the first term on the right hand side) is equal to the difference between the change in private household disposable income (the term on the left hand side) and the change in private household savings (the second and third terms on the right hand side).

An equation determining private household pre-transfer (disposable) income, used later in determining private household transfer payments, is also added:

HHOLD\_PRIVTE\_INCME (all,r,REG)

$$\begin{aligned} YCHHPVR(r)*yhvr(r) = \\ LTT(r)*ylr(r) + YCHHPPR(r)*yhpr(r) - RVTXYCR(r)*rtyr(r); \end{aligned}$$

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where  $YCHHPVR(r)$  and  $yhvr(r)$  are the coefficient and variable forms of private household pre-transfer (disposable) income in region  $r$ . That is, private household pre-transfer (disposable) income in each region is equal to labour income plus private household property income less income tax in each region.

### Government receipts and outlays

In order to determine government revenue from commodity taxes, four variables relating to the use, and taxes on the use, of intermediate inputs into the production of capital goods (investment) need to be defined.

The use of domestic and imported commodities in the production of capital goods is defined by the equations:

$E\_invd$  (all,i,TRAD\_COMM)(all,r,REG)

$$invd(i,r) = \text{sum}(c,CGDS\_COMM, qfd(i,c,r));$$

$E\_invi$  (all,i,TRAD\_COMM)(all,r,REG)

$$invi(i,r) = \text{sum}(c,CGDS\_COMM, qfm(i,c,r));$$

where  $invd(i,r)$  and  $invi(i,r)$  is the use of domestic and imported traded commodity  $i$ , respectively, in investment in region  $r$ ,  $CGDS\_COMM$  is the set of the single capital goods commodity (investment), and  $qfd(i,c,r)$  and  $qfm(i,c,r)$  is the GTAP variable for the use of domestic and imported traded commodity  $i$ , respectively, in produced commodity  $c$  in region  $r$ .

Taxes on the use of these commodities are also defined:

$E\_tinvd$  (all,i,TRAD\_COMM)(all,r,REG)

$$tinvd(i,r) = \text{sum}(c,CGDS\_COMM, tfd(i,c,r));$$

$E\_tinvi$  (all,i,TRAD\_COMM)(all,r,REG)

$$tinvi(i,r) = \text{sum}(c,CGDS\_COMM, tfm(i,c,r));$$

where  $tinvd(i,r)$  and  $tinvi(i,r)$  is the power of the tax on domestic and imported traded commodity  $i$ , respectively, used for investment in region  $r$ , and  $tfd(i,c,r)$  and  $tfm(i,c,r)$  is the GTAP variable for the power of the tax on domestic and imported commodity  $i$ , respectively, used by industry  $c$  in region  $r$ .

A group of eight equations together calculate commodity tax revenue in each region. The derivation of these equations is described in appendix A of Jomini, McDougall, Watts, and Dee (1994).

The contribution of a change in output taxes to the per cent change in commodity tax revenue in each region, is defined by equation REVINDT:

REVINDT (all,r,REG)

$$\begin{aligned} \text{grsub}(r) = & \\ & (\text{RECIP\_GRCOMT}(r)) * \text{sum}(i, \text{TRAD\_COMM}, \\ & (\text{COSTINP}(i,r) * \text{to}(i,r)) + \text{PTAX}(i,r) * (\text{qo}(i,r) + \text{pm}(i,r))); \end{aligned}$$

where  $\text{grsub}(r)$  is the (absolute change in the) contribution of a change in output taxes to the per cent change in commodity tax revenue in region  $r$ ,  $\text{RECIP\_GRCOMT}(r)$  is a coefficient defining the inverse of commodity tax revenue in region  $r$ ,  $\text{COSTINP}(i,r)$  is the coefficient form of the agent's (or post-tax) price value of the total cost of intermediate inputs used by industry  $i$  in region  $r$ ,  $\text{to}(i,r)$  is the GTAP variable for the power of the output (or income) tax on non-savings commodity  $i$  in region  $r$ , and  $\text{PTAX}(i,r)$  is the GTAP coefficient for the value of the output (or income) tax on non-savings commodity  $i$  in region  $r$ .

The contribution of a change in taxes on intermediate inputs into current production to the per cent change in commodity tax revenue in each region, is defined by the equation REVINT:

REVINT (all,r,REG)

$$\begin{aligned} \text{grint}(r) = & \\ & (\text{RECIP\_GRCOMT}(r)) * (\text{sum}(i, \text{TRAD\_COMM}, \\ & \text{sum}(j, \text{TRAD\_COMM}, (\text{VDFM}(i,j,r) + \text{DFTAX}(i,j,r)) * \text{tfd}(i,j,r) + \\ & \text{DFTAX}(i,j,r) * (\text{qfd}(i,j,r) + \text{pm}(i,r)))) + \\ & \text{sum}(i, \text{TRAD\_COMM}, \text{sum}(j, \text{TRAD\_COMM}, \\ & (\text{VIFM}(i,j,r) + \text{IFTAX}(i,j,r)) * \text{tfm}(i,j,r) + \text{IFTAX}(i,j,r) * (\text{qfm}(i,j,r) + \\ & \text{pim}(i,r))))); \end{aligned}$$

where  $\text{grint}(r)$  is the (absolute change in the) contribution of a change in taxes on intermediate inputs to the per cent change in commodity tax revenue in region  $r$ ,

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VDFM(i,j,r) is the GTAP coefficient for the market (or pre-tax) price value of purchases of domestic traded good i by industry j in region r, DFTAX(i,j,r) is the GTAP coefficient for the value of taxes on the use of domestic traded good i by industry j in region r, VIFM(i,j,r) is the GTAP coefficient for the market (or pre-tax) price value of purchases of imported traded good i by industry j in region r, and IFTAX(i,j,r) is the GTAP coefficient for the value of taxes on the use of imported traded good i by industry j in region r.

The contribution of a change in taxes on intermediate inputs into the production of capital goods (investment) to the per cent change in commodity tax revenue in each region, is given by equation REVINV:

REVINV (all,r,REG)

$$\begin{aligned} \text{grinv}(r) = & \\ & (\text{RECIP\_GRCOMT}(r)) * (\text{sum}(i, \text{TRAD\_COMM}, (\text{DINV}(i,r) + \\ & \text{TIRD}(i,r)) * \text{tinvd}(i,r) + \text{TIRD}(i,r) * (\text{invd}(i,r) + \text{pm}(i,r))) + \\ & \text{sum}(i, \text{TRAD\_COMM}, (\text{IINV}(i,r) + \text{TIRI}(i,r)) * \text{tinvi}(i,r) + \\ & \text{TIRI}(i,r) * (\text{invi}(i,r) + \text{pim}(i,r))))); \end{aligned}$$

where grinv(r) is the (absolute change in the) contribution of a change in taxes on intermediate inputs into investment to the per cent change in commodity tax revenue in region r, DINV(i,r) is the coefficient form of the market (or pre-tax) price value of domestic intermediate input good i used for investment in region r, TIRD(i,r) is the coefficient form of the value of taxes on domestic intermediate input good i used for investment in region r, IINV(i,r) is the coefficient form of the market (or pre-tax) price value of imported intermediate input good i used for investment in region r, and TIRI(i,r) is the coefficient form of the value of taxes on imported intermediate input good i used for investment in region r.

The contribution of a change in taxes on goods used for private household consumption to the per cent change in commodity tax revenue in each region, is given by the equation REVCON:



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REVCON (all,r,REG)

$$\begin{aligned} \text{grcon}(r) = & \\ & (\text{RECIP\_GRCOMT}(r)) * (\text{sum}(i, \text{TRAD\_COMM}, (\text{VDPM}(i,r) + \\ & \text{DPTAX}(i,r)) * \text{tpd}(i,r) + \text{DPTAX}(i,r) * (\text{qpd}(i,r) + \text{pm}(i,r))) + \\ & \text{sum}(i, \text{TRAD\_COMM}, (\text{VIPM}(i,r) + \text{IPTAX}(i,r)) * \text{tpm}(i,r) + \\ & \text{IPTAX}(i,r) * (\text{qpm}(i,r) + \text{pim}(i,r))))); \end{aligned}$$

where  $\text{grcon}(r)$  is the (absolute change in the) contribution of a change in taxes on goods used for private household consumption to the per cent change in commodity tax revenue in region  $r$ ,  $\text{VDPM}(i,r)$  is the GTAP coefficient for the market (or pre-tax) price value of private household expenditure on domestic traded good  $i$  in region  $r$ ,  $\text{DPTAX}(i,r)$  is the GTAP coefficient for taxes on private consumption of domestic traded good  $i$  in region  $r$ ,  $\text{tpd}(i,r)$  is the GTAP variable for the power of the tax on private household consumption of domestic traded good  $i$  in region  $r$ ,  $\text{qpd}(i,r)$  is the GTAP variable for the demand for private household consumption of domestic traded good  $i$  in region  $r$ ,  $\text{VIPM}(i,r)$  is the GTAP coefficient for the market (or pre-tax) price value of private household expenditure on imported traded good  $i$  in region  $r$ ,  $\text{IPTAX}(i,r)$  is the GTAP coefficient for taxes on private household consumption of imported traded good  $i$  in region  $r$ ,  $\text{tpm}(i,r)$  is the GTAP variable for the power of the tax on private household consumption of imported traded good  $i$  in region  $r$ , and  $\text{qpm}(i,r)$  is the GTAP variable for the demand for private household consumption of imported traded good  $i$  in region  $r$ .

The contribution of a change in taxes on goods consumed by government to the per cent change in commodity tax revenue in each region, is given by equation REVGGOV:

REVGGOV (all,r,REG)

$$\begin{aligned} \text{grgov}(r) = & \\ & (\text{RECIP\_GRCOMT}(r)) * (\text{sum}(i, \text{TRAD\_COMM}, (\text{VDGM}(i,r) + \\ & \text{DGTAX}(i,r)) * \text{tgd}(i,r) + \text{DGTAX}(i,r) * (\text{qgd}(i,r) + \text{pm}(i,r))) + \\ & \text{sum}(i, \text{TRAD\_COMM}, (\text{VIGM}(i,r) + \text{IGTAX}(i,r)) * \text{tgm}(i,r) + \\ & \text{IGTAX}(i,r) * (\text{qgm}(i,r) + \text{pim}(i,r))))); \end{aligned}$$

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where  $grgov(r)$  is the (absolute change in the) contribution of a change in taxes on goods consumed by government to the per cent change in commodity tax revenue in region  $r$ ,  $VDGM(i,r)$  is the GTAP coefficient for the market (or pre-tax) price value of domestic traded good  $i$  consumed by government in region  $r$ ,  $DGTAX(i,r)$  is the GTAP coefficient for the value of taxes on domestic traded good  $i$  consumed by government in region  $r$ ,  $tgD(i,r)$  is the GTAP variable representing the power of the tax on domestic traded good  $i$  consumed by government in region  $r$ ,  $qgd(i,r)$  is the GTAP variable representing the demand for domestic traded good  $i$  by government in region  $r$ ,  $VIGM(i,r)$  is the GTAP coefficient for the market (or pre-tax) price value of imported traded good  $i$  consumed by government in region  $r$ ,  $IGTAX(i,r)$  is the GTAP coefficient for the value of taxes on imported traded good  $i$  consumed by government in region  $r$ , and  $qgm(i,r)$  is the GTAP variable representing the demand for imported traded good  $i$  by government in region  $r$ .

The contribution of a change in export taxes to the per cent change in commodity tax revenue in each region, is defined by the equation REVEXP:

REVEXP (all,r,REG)

$$\begin{aligned}
 grexp(r) = & \\
 & (RECIP\_GRCOMT(r))*sum(i,TRAD\_COMM, sum(s,REG, \\
 & VXWD(i,r,s)*txs(i,r,s) + XTAXD(i,r,s)*(qxs(i,r,s) + pm(i,r))));
 \end{aligned}$$

where  $grexp(r)$  is the (absolute change in the) contribution of a change in export taxes to the per cent change in commodity tax revenue in region  $r$ ,  $VXWD(i,r,s)$  is the GTAP coefficient for the fob world price value of exports of traded good  $i$  from region  $r$  to region  $s$ ,  $txs(i,r,s)$  is the GTAP variable representing the power of the tax on exports of traded good  $i$  from region  $r$  to region  $s$ ,  $XTAXD(i,r,s)$  is the GTAP coefficient for the value of taxes on exports of traded good  $i$  from region  $r$  to region  $s$ , and  $qxs(i,r,s)$  is the GTAP variable for exports of traded good  $i$  from region  $r$  to region  $s$ .

The contribution of a change in import taxes to the per cent change in commodity tax revenue in each region, is given by equation REVIMP:

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REVIMP (all,s,REG)

$$\begin{aligned} \text{grdut}(s) = & \\ & (\text{RECIP\_GRCOMT}(s)) * \text{sum}(i, \text{TRAD\_COMM}, \text{sum}(r, \text{REG}, \\ & (\text{VIWS}(i,r,s) + \text{MTAX}(i,r,s)) * \text{tms}(i,r,s) + \\ & \text{MTAX}(i,r,s) * (\text{pcif}(i,r,s) + \text{qxs}(i,r,s))))); \end{aligned}$$

where  $\text{grdut}(s)$  is the (absolute change in the) contribution of a change in import taxes to the per cent change in commodity tax revenue in region  $r$ ,  $\text{VIWS}(i,r,s)$  is the GTAP coefficient for the cif world price value of imports of traded good  $i$  from region  $r$  to region  $s$ ,  $\text{MTAX}(i,r,s)$  is the GTAP coefficient representing the value of taxes on imports of traded good  $i$  from region  $r$  to region  $s$ ,  $\text{tms}(i,r,s)$  is the GTAP variable for the power of the tax on imports of traded good  $i$  from region  $r$  to region  $s$ , and  $\text{pcif}(i,r,s)$  is the GTAP variable representing the cif world price of imports of traded good  $i$  from region  $r$  to region  $s$ .

These seven equations together define total government revenue from commodity taxes in each region:

GOVREVCOMM (all,r,REG)

$$\begin{aligned} \text{rc}(r) = & \\ & \text{grsub}(r) + \text{grint}(r) + \text{grinv}(r) + \text{grcon}(r) + \text{grexp}(r) + \text{rgov}(r) + \text{grdut}(r); \end{aligned}$$

A new component of government receipts is introduced to the model, ie net interest receipts. Thus (net) government receipts is defined as:

GOVT\_RECTS (all,r,REG)

$$\begin{aligned} \text{RCGVR}(r) * \text{rgr}(r) = & \\ & \text{RVXYCR}(r) * \text{rtyr}(r) + \text{GRCOMT}(r) * \text{rc}(r) + \\ & \text{RCGVR}(r) * \text{qrgir}(r) + \text{RCGVITR}(r) * \text{rgr}(r); \end{aligned}$$

where  $\text{qrgir}(r)$  is the (absolute change in the) ratio of government net interest receipts to (net) government receipts in region  $r$ , and  $\text{RCGVITR}(r)$  is the coefficient form of government net interest receipts in region  $r$ . The change in government receipts in each region (the term on the left hand side) is the sum of the change in income taxes (the first term on the right hand side), the change in net (of subsidies) indirect taxes (the second term on the right hand side), and the change in

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government net interest receipts (the third and fourth terms on the right hand side) in each region.

Income tax in each region is the sum of taxes on labour income and property income in each region:

INCOME\_TAX (all,r,REG)

$$\begin{aligned} RVTXYCR(r)*rtyr(r) = \\ RVTXYCLBR(r)*rtylr(r) + RVTXYCPPR(r)*rtypr(r); \end{aligned}$$

where  $RVTXYCLBR(r)$  and  $rtylr(r)$  are the coefficient and variable forms, respectively, of tax revenue from labour income in region  $r$ , and  $RVTXYCPPR(r)$  and  $rtypr(r)$  are the coefficient and variable forms, respectively, of tax revenue from property income in region  $r$ . As household net interest income is now a component of household property income, it is also a component of the tax base for taxes on household property income. Thus, the income tax base has been altered to include household interest income. It does not, however, include the other new component of household income, namely, transfer payments from governments to households.

Tax revenue from labour income and property income in each region is the product of the respective tax rates and tax bases in each region:

TAX\_LABR\_INCOME (all,r,REG)

$$rtylr(r) = tylr(r) + ylr(r);$$

TAX\_PROPY\_INCOME (all,r,REG) ! **Altered section 4.7 !**

$$rtypr(r) = typr(r) + yhpr(r);$$

where  $tylr(r)$  and  $typr(r)$  are the tax rates on labour income and property income, respectively, in region  $r$ .

The rates of tax on labour income and property income in each region are a function of a general shift in income tax rates, and a tax base-specific shift in tax rates, in each region:

RATE\_TAX\_LABR\_INCOME (all,r,REG)

$$tylr(r) = ftyr(r) + ftylr(r);$$

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RATE\_TAX\_PRPY\_INCOME (all,r,REG)

$$\text{typr}(r) = \text{ftyr}(r) + \text{ftypr}(r);$$

where  $\text{ftyr}(r)$  represents a general shift in income tax rates in region  $r$ ,  $\text{ftypr}(r)$  represents a shift in the labour income tax rate in region  $r$ , and  $\text{ftypr}(r)$  represents a shift in the property income tax rate in region  $r$ . In the standard closure  $\text{ftypr}(r)$  and  $\text{ftypr}(r)$  are exogenous, along with  $\text{qrgsr}(r)$  (ie the ratio of government surplus on current transactions to net government receipts (government saving ratio) in region  $r$ ), while  $\text{ftyr}(r)$  is endogenous. This has the effect of constraining the budget deficit in each region. Thus, in simulations where indirect tax rates are shocked (eg tariffs), direct tax rates will adjust equally (via  $\text{ftyr}(r)$ ) so as to keep the government saving rate fixed. If it is seen as appropriate to have all this adjustment occur on either labour income tax rates or property income tax rates, then a closure swap is necessary. This requires swapping  $\text{ftyr}(r)$  with either  $\text{ftypr}(r)$  or  $\text{ftypr}(r)$ , on the exogenous list. The first swap would force all tax revenue adjustment to occur via labour income tax rates, and the second swap would force all adjustment to occur via property income tax rates.

The ratio of government net interest receipts to total government receipts in each region is (in levels) the product of the bond rate and the ratio of government net ownership of bonds to total government receipts in that region:

GOVT\_INTT\_RECTS (all,r,REG)

$$\begin{aligned} \text{RCGVR}(r) * \text{qrgir}(r) = \\ \text{ASGVR}(r) * \text{rbr}(r) + \text{RTBD} * \text{RCGVR}(r) * \text{qrgbr}(r); \end{aligned}$$

Nominal government consumption expenditure in each region ( $\text{zg}(r)$ ) is equal to the price multiplied by the quantity of government consumption in each region:

VALGOVDEMCOM (all,r,REG)

$$\text{zg}(r) = \text{pgov}(r) + \text{ug}(r);$$

where  $\text{ug}(r)$  is government demand for commodities in region  $r$ .

Government (current) expenditure in each region is determined by the equation:

GOVT\_CURRNT\_OUTLS (all,r,REG)

$$\text{OLGVR}(r) * \text{ogr}(r) =$$

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$$\text{GOVEXP}(r)*z_g(r) + \text{URGVHHR}(r)*u_{ghr}(r) + d_{ughr}(r);$$

where  $\text{OLGVR}(r)$  and  $\text{ogr}(r)$  are the coefficient and variable forms, respectively, of total government expenditure region  $r$ , and. The change in government expenditure in each region (the left side of equation  $\text{GOVT\_CURRNT\_OUTLS}$ ) is equal to the change in government consumption expenditure in that region (the first term on the right hand side) plus the change in transfer payments in that region (the second and third terms on the right hand side). Note that government interest payments are not included as a form of government expenditure. This is because government interest receipts are measured net of interest payments. Thus they are excluded as a separate form of government expenditure.

Equation  $\text{TRANSFRS\_GOVT\_HHOLD}$  determines transfer payments to private households in each region, allowing them to move in proportion to household pre-transfer disposable income:

$\text{TRANSFRS\_GOVT\_HHOLD}$  (all,r,REG)

$$u_{ghr}(r) = f_{ghr}(r) + y_{hvr}(r);$$

where  $f_{ghr}(r)$  is a shift in transfer payments in region  $r$ . That is, transfer payments (in levels) in each region are equal to the product of a shift in transfer payments and household pre-transfer (disposable) income in that region.

Equation  $\text{DISPN\_GOVT\_RECTS}$  equates net government receipts in each region with the sum of government expenditure and the government surplus on current transactions (government saving) in each region:

$\text{DISPN\_GOVT\_RECTS}$  (all,r,REG)

$$\begin{aligned} \text{RCGVR}(r)*r_{gr}(r) = \\ \text{OLGVR}(r)*\text{ogr}(r) + \text{RCGVR}(r)*q_{rgsr}(r) + \text{SPGVR}(r)*r_{gr}(r); \end{aligned}$$

With all indirect tax rates and the government saving ratio ( $q_{rgsr}(r)$ ) set exogenously, and all direct tax revenue endogenous, this equation determines the direct tax rate.

## International allocation of investment

As noted above, the allocation of capital among regions is governed by a set of parity conditions which ensure that rates of return are equal between regions. For this condition to hold over time, investment must be allocated so that *time* rates of

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change in rates of return are equal across regions and industries. This is the new parity condition required for the allocation of investment among regions.

As GTAP is a comparative static model, it is not possible to impose model-consistent expectations, that is, where rates of return expected to be earned in later periods are consistent with actual rates in those periods. The most that can be achieved is broad consistency between expected rates of return and actual rates of return. It is within these limits that the international allocation of investment equations are derived.

To determine the expected time rate of change in the rate of return on capital, several assumptions are made regarding investors' expectations. The expected rate of return on capital at any given point in time depends only on the size of the capital stock. Given growth in the world economy over time, investors expect that capital stocks can also grow at some rate without a fall in the rate of return. The elasticity of the expected (gross) rate of return with respect to the expected size of the capital stock is fixed. The growth rate of the capital stock consistent with an expectation of no change, over time, in the rate of return is also fixed. Given these assumptions, an equation determining the expected rate of change, over time, in the rate of return on capital can be derived (see McDougall 1993b, appendix B):

EXPD\_RATE\_RETN\_CAPL (all,r,REG)

$$\begin{aligned} \text{ercrkr}(r) = & \\ & \text{EL\_ERCRK\_K\_R}(r) * \text{RTKPGRR}(r) * \text{RTIVKPR}(r) * (\text{qcgds}(r) - \text{kt}(r)) + \\ & \text{EL\_ERCRK\_K\_R}(r) * (\text{RTIVKPR}(r) - \text{RTDPR}(r) - \text{GTSSKPR}(r)) * \text{rkr}(r); \end{aligned}$$

where  $\text{ercrkr}(r)$  is the (absolute change in the) expected rate of change in rate of return on capital in region  $r$ ,  $\text{EL\_ERCRK\_K\_R}(r)$  is a parameter representing the elasticity of the expected rate of return on capital with respect to the capital stock in region  $r$ ,  $\text{RTKPGRR}(r)$  is the coefficient form of the average (gross) rate of return on capital in region  $r$ ,  $\text{RTIVKPR}(r)$  is a parameter defining the ratio of (gross) investment to capital in region  $r$ ,  $\text{qcgds}(r)$  is the GTAP variable for gross real investment in region  $r$ ,  $\text{RTDPR}(r)$  is a parameter defining the depreciation rate in region  $r$ , and  $\text{GTSSKPR}(r)$  is a parameter representing the steady-state rate of growth in real capital stock in region  $r$  (ie a growth rate consistent with zero expected change, over time, in the rate of return). The parameters  $\text{EL\_ERCRK\_K\_R}(r)$  and  $\text{GTSSKPR}(r)$  are estimated outside the model. How this is done is outlined in the section detailing the modifications made to the GTAP database, as part of this extension (see appendix E).

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Remembering that  $EL\_ERCRK\_K\_R(r)$  is negative, then the first term on the right hand side of equation  $EXPD\_RATE\_RETN\_CAPL$  says that the higher the level of investment, the quicker will be the decline in the rate of return. The second term on the right hand side captures two important determinants of  $ercrkr(r)$ . If the ratio of *net* (of depreciation) investment to capital in a given region is equal to the steady-state rate of growth in the real capital stock in that region, then there will no expected decline in the rate of return in that region. Where the former ratio is greater than the latter, the expected rate of change in the rate of return in that region will be negative. Another important determinant of  $ercrkr(r)$  is the actual (gross) rate of return ( $rkr(r)$ ). In those circumstances, when net investment exceeds the steady state rate of growth of capital, the greater the increase in the actual rate of return in a region, the greater the decline in the expected rate of return in that region.

Equation  $EXPD\_RATE\_RETN\_CAPL$  requires the definition of the average rate of return on capital in each region. This is defined in terms of the equivalent GTAP variable:

$AVGE\_RATE\_RETN\_CAPL$  (all,r,REG)

$$rkr(r) =$$

$$RTKPGRR(r) * \{ \text{sum}[k, \text{ENDWC\_COMM}, pm(k,r)] - pcgds(r) \};$$

where  $\text{ENDWC\_COMM}$  is the set of the single capital endowment commodity, ie capital.

It is necessary also to specify how rates of return equilibrate over time. Starting from the premise that the expected average rate of return on capital is equal to the sum of the expected normal rate of return (identified here with the required rate of return on equity) and the average abnormal rate of return, and assuming that the average abnormal rate of return is expected to shrink to zero over time, the following equation can be derived:

$EQN\_RATE\_RETN\_CAPL$  (all,r,REG)

$$ercrkr(r) = \text{ercrer}(r) - \text{CEAJRTKPR}(r) * \text{rar}(r);$$

where  $\text{ercrer}(r)$  is the (absolute change in the) expected rate of change in the required rate of return on equity in region  $r$ ,  $\text{CEAJRTKPR}(r)$  is a parameter representing the rate of adjustment in the returns to capital (per annum) in region  $r$ , and  $\text{rar}(r)$  is the (absolute change in the) average abnormal rate of return on capital in region  $r$ .



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The average abnormal rate of return in each region is determined by the equation:

AVGE\_ABNL\_RETN\_CAPL (all,r,REG)

$$\begin{aligned} \text{rar}(r) = & \\ & \text{sum}(i, \text{TRAD\_COMM}, \text{SKT}(i,r) * \text{rari}(i,r)) + \\ & \text{sum}(i, \text{TRAD\_COMM}, \text{RTKPANRI}(i,r) * \text{SKT}(i,r) * \text{kk}(i,r)) - \\ & \text{RTKPANR}(r) * \text{kt}(r); \end{aligned}$$

where  $\text{SKT}(i,r)$  is share of industry  $i$  in the capital stock of region  $r$ , and  $\text{RTKPANRI}(i,r)$  is the coefficient form of abnormal rate of return on capital in industry  $i$  in region  $r$ . The variable  $\text{kk}(i,r)$  is the usage of capital by industry  $i$  in region  $r$  defined by the equation  $E\_kk$ :

$E\_kk$  (all,i,TRAD\_COMM)(all,r,REG)

$$\text{kk}(i,r) = \text{sum}(k, \text{ENDWC\_COMM}, \text{qfe}(k,i,r));$$

where  $\text{qfe}(i,j,r)$  is the GTAP variable for the demand for endowment  $i$  by industry  $j$  in region  $r$ .

Equation AVGE\_ABNL\_RETN\_CAPL says that the average abnormal rate of return in each region is the share-weighted sum of the abnormal returns to capital in each industry in that region.

The expected rate of change in the required rate of return on equity in each region is determined by an equation derived from the capital-bond parity condition (equation EQY\_BOND\_PARY):

EXPD\_RATE\_RETN\_EQY (all,r,REG)

$$\text{ercrer}(r) = \text{ercrbr}(r) + \text{ercfrer}(r);$$

where  $\text{ercrbr}(r)$  is the (absolute change in the) expected rate of change in the bond rate in region  $r$ , and  $\text{ercfrer}(r)$  is the (absolute change in the) expected rate of change in the equity premium in region  $r$ .

The expected rate of change in the bond rate in each region is determined by an equation derived from the international interest parity condition (equation INTERNL\_INTT\_PARY):

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EXPD\_BOND\_RATE (all,r,REG)

$$\text{ercrbr}(r) = \text{ercrb};$$

where  $\text{ercrb}$  is the (absolute change in the) expected rate of change in the world bond rate.

Collectively, equations EXPD\_RATE\_RETN\_CAPL, EQN\_RATE\_RETN\_CAPL, EXPD\_RATE\_RETN\_EQY and EXPD\_BOND\_RATE define a global investment demand function. Global investment demand is an inverse function of the expected rate of change in the world bond rate. That is, the higher the expected future bond rate, the lower the level of investment demand. The global supply of investment is determined by global saving. Together, the global investment demand and supply functions determine the expected rate of change in the world bond rate, which in turn determines investment in each region.

Plainly, the GTAP investment equation RORGLOBAL is inconsistent with the new investment theory introduced for GTAPICM. Therefore, the GTAP equation is turned off by a closure change and parameter choice. Coefficient RORDELTA is set equal to 1. All but one component of the RORGLOBAL slack variable  $\text{cgdslack}$  are made endogenous,<sup>4</sup> while all components of the EXPD\_RATE\_RETN\_EQY slack variable  $\text{ercfrer}$  are made exogenous. The variable  $\text{ercrb}$  is made endogenous, and plays a parallel role to that played by the variable  $\text{rorg}$  in the GTAP investment theory. It adjusts to ensure that the sum of investment across regions equals the global pool of savings.

## Various miscellaneous alterations to GTAP equations

In GTAP, the rental price of capital is uniform across industries, since capital is a mobile endowment. In the ICM extension, an industry specific price (variable  $\text{rp}$ ) is introduced. This is tied to the regional price via an alteration to the capital component of the GTAP market clearing condition for mobile endowments, thus:

MKTCLENDWM (all,i,ENDWM\_COMM)(all,r,REG)

$$\text{VOM}(i,r) * \text{qo}(i,r) = \text{sum}(j,\text{PROD\_COMM}, \text{VFM}(i,j,r) * \text{qfe}(i,j,r)) + \\ \text{sum}[k,\text{ENDWC\_COMM}:k \text{ eq } i,$$

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<sup>4</sup> One component remains exogenous so that the corresponding component of equation RORGLOBAL determines the variable  $\text{rorg}$ . Even though the variable  $\text{rorg}$  does not influence the behaviour of GTAPICM, it still needs to be determined or the model will not solve.

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$$\begin{aligned}
& -\text{VOM}(i,r) * \text{pm}(i,r) + \text{sum}(j,\text{TRAD\_COMM}, \text{VFM}(i,j,r) * \text{rp}(j,r))] \\
& + \text{VOM}(i,r) * \text{endwslack}(i,r) ;
\end{aligned}$$

So the market clearing condition determines the pre-tax regional rental of capital  $\text{pm}(\text{"capital"},r)$  for region  $r$  by equating the pre-tax regional rental value of capital with the sum of rentals across industries.

The ICM extension has an industry-specific rental price of capital (variable  $\text{rp}$ ) to allow rates of return to vary across industries if desired by the model user. GTAP has only a region-specific rental price of capital, but allows industry specific taxes on capital, leading to an industry-specific tax-inclusive price  $\text{pfe}(\text{"capital"},j,r)$ . The associated tax revenues are not, however, included in government revenue in GTAPICM, so that they are in effect abnormal rentals to capital. Consequently,  $\text{pfe}(\text{"capital"},j,r)$  performs the same function in GTAP as  $\text{rp}(j,r)$  performs in the ICM extension. Therefore, to fully integrate GTAP and the ICM extension, it is necessary to equate the variables  $\text{rp}$  and  $\text{pfe}(\text{"capital"},j,r)$  by alteration of the capital component of the GTAP equation  $\text{MPFACTPRICE}$ , thus:

$\text{MPFACTPRICE}(\text{all},i,\text{ENDWC\_COMM})(\text{all},j,\text{PROD\_COMM})(\text{all},r,\text{REG})$

$$\begin{aligned}
\text{pfe}(i,j,r) &= \text{tf}(i,j,r) + \text{pm}(i,r) + \\
& \text{sum}\{k,\text{ENDWC\_COMM}:k \text{ eq } i, \text{sum}[j_-, \text{TRAD\_COMM}:j \text{ eq } j_-, \\
& \quad \text{rp}(j_-,r) - \text{pm}(i,r)]\};
\end{aligned}$$

The sum on the right hand side calculates the difference between the industry-specific ICM-extension rental price of capital and the GTAP regional rental price of capital, when  $i$  is in set  $\text{ENDWC\_COMM}=\{\text{capital}\}$ . Consequently, the equation becomes

$$\text{pfe}(i,j,r) = \text{tf}(i,j,r) + \text{rp}(j,r);$$

when  $i=\text{"capital"}$ . Plainly, the capital components of  $\text{tf}$  should not be shocked in the current implementation of GTAPICM.

These modifications are currently redundant, since for current applications of GTAPICM both data and closure ensure that  $\text{rp}(j,r)$  are equal for all  $j$  (no abnormal returns), and consequently equal to the capital component of  $\text{pm}$ . They are included for the sake of completeness.

The GTAP variables for income taxes — the primary factor components of the power of output taxes (variable  $\text{to}$ ) — must be linked to the GTAPICM income tax variables, thus:

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LAB\_TAX (all,i,LABOR)(all,r,REG)

$$to(i,r)=[VOM(i,r)-VOA(i,r)]/VOA(i,r)*tylr(r);$$

NON\_LAB\_TAX (all,i,NONLAB\_ENDW)(all,r,REG)

$$to(i,r)=[VOM(i,r)-VOA(i,r)]/VOA(i,r)*typr(r);$$

Note that as variables  $tylr$  and  $typr$  are percentage changes in the *rates* of income taxes, and variable  $to$  is a percentage change in the *power* of incomes taxes, the coefficient expression on the right hand side of each equation ( $[VOM(i,r)-VOA(i,r)]/VOA(i,r)$ ) is required.

Some inconsequential alterations were made to some GTAP equations, almost as an accidental by-product of the vacillations involved in model development. In standard GTAP, equation SAVINGS specified nominal savings as a fixed share of nominal income, while equation PRIVATEXP defined nominal private consumption as a residual after subtracting nominal savings and government consumption from income. In GTAPICM the form of these equations is reversed thus:

SAVINGS (all,r,REG)

$$\begin{aligned} PRIVEXP(r)*yp(r) &= INCOME(r)*y_r(r) \\ &\quad -SAVE(r)*[psave(r)+qsave(r)] \\ &\quad -sum(i,TRAD_COMM,VGA(i,r)*[pg(i,r)+qg(i,r)]) \\ &\quad +saveslack1(r); \end{aligned}$$

PRIVATEXP (all,r,REG)

$$yp(r)=y_r(r)+privslack(r);$$

Some slack variables have been added. A closure with  $saveslack1$  endogenous would plainly be a non-GE closure, since the identity between national income and its components — private and government consumption and savings — would be broken. The variable  $privslack$  could be endogenised if it was required to hold the ratio of private savings to private income (variable  $qyhsr$ ) fixed. While this may be a sensible choice in some circumstances, it should be noted that this would invalidate the GTAP utility measure (variable  $u$ ), which is based on the assumption that utility is a Cobb-Douglas function of private and government consumption and savings. In current applications, private saving adjusts to ensure that total nominal savings is a fixed share of nominal income, consistent with a Cobb-Douglas functional form, and thereby preserving the validity of the welfare measure.

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### 3.3 Extension of the welfare decomposition

Foreign income from bond holdings contributes to national income and hence welfare. The contribution of net foreign interest income to welfare is decomposed into an interest rate (rate of return on bonds) effect, an asset price effect, and an endowment (real quantity of bonds) effect according to the scheme described in appendix B.

EQUATION CONT\_EV\_pricer (all,r,REG) ! **Altered section 4.5 !**

$$\text{CNTpricer}(r) = \text{CNTcgdsr}(r) + \text{CNTtotr}(r) + \\ [.01/\text{INCRATIO}(r)] * [\text{YCITR}(r) * \text{ipc}];$$

The third term on the right hand side is the contribution of the asset price of bonds (equals the world consumption price index) to welfare. It is amalgamated with the GTAP contributions CNTtotr and CNTcgdsr into one overall contribution of prices to welfare.

CONT\_EV\_intrater (all,r,REG)

$$\text{CNTintrater}(r) = [.01/\text{INCRATIO}(r)] * \text{ASBDR}(r) * \text{rbr}(r);$$

The contribution of the rate of return on bonds to welfare involves the asset value of bonds (coefficient ASBDR) times the percentage point change in the rate of return on bonds (variable rbr), in line with the derivation in appendix B.

CONT\_EV\_bondr (all,r,REG) ! **Altered section 4.5 !**

$$\text{CNTbondr}(r) = [.01/\text{INCRATIO}(r)] * \\ \{ \text{YCR}(r) * \text{qyir}(r) + \text{YCITR}(r) * [\text{y}_r(r) - \text{ipc}] \} - \text{CNTintrater}(r);$$

The endowment effect contribution to welfare from bonds is determined as the difference between net foreign interest income

$$\text{YCR}(r) * \text{qyir}(r) + \text{YCITR}(r) * \text{y}_r(r)$$

scaled by  $0.01/\text{INCRATIO}(r)$  and the sum of the other two contributions.

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## 4 FTAP asset supply

The international capital mobility extension of GTAP (GTAPICM) enables private and government wealth to be endogenised, with private wealth being perfectly transformable between local equity (capital, land and natural resources) and bonds (foreign lending and borrowing). Consequently, rates of return equate between all assets (except where lending and borrowing is restricted in the so-called ‘imperfect capital mobility’ closure, which holds regional bond to income ratios fixed), and bilateral ownership of assets is indeterminate. Thus, only a country’s total net income from abroad can be uniquely defined, not the disposition of that income between creditors and debtors or between alternative assets.

However, the modelling of FDI requires that bilateral ownership of capital be represented in the model. There are at least two reasons for this.

First, at least domestic and foreign-owned capital in each industry must be distinguished to support the differing levels of impediments to services trade by foreigners versus residents of a region.

Second, bilateral ownership of capital allows the FDI linkages between countries of similar income levels to be captured. Inward (outward) FDI is not spread uniformly across all possible home (host) regions, but tends to be associated with regions at a similar stage of economic development to the host (home). When policy shocks affect the returns to foreign-owned capital in a region, plainly it is critical that the impacts fall upon the particular owners of that capital, and not just on foreigners in general.

To model FDI, the imperfect transformation of private wealth across bonds, local land and natural resources, and capital in all regions and industries, replaces the perfect transformation between bonds and local equity of GTAPICM. The treatment used is very close to that of Petri (1997), who uses a nested CET supply function for capital, with rates of return acting as supply prices. A full description of the approach and parameter settings is provided in section 4.1.

Sections 4.2 to 4.6 describe the equations determining asset supply in FTAP. Section 4.2 covers the equations determining how the quantities of assets supplied depend on rates of return. Section 4.3 details the equations defining rates of return and deals with provisions for choosing between pre- or post-tax rates of return.

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Section 4.4 contains the definitions of pre- and post-tax and pre- and post-impediment rental prices of capital. Section 4.5 contains the definitions of asset prices. Section 4.6 gives the new market clearing conditions for capital.

Section 4.7 describes the equations for foreign income flows arising from FDI.

Section 4.8 describes the new welfare decomposition terms spawned by the foreign income flows according to the approach outlined in appendix B.

## **4.1 Asset supply function — structure and parameterization**

In the model of Petri (1997), the fixed amount of capital owned by each region is allocated between host regions and industries according to a three level nested CET scheme. At the first level, capital is allocated among industries. Second, the capital allocated among industries is partitioned between the domestic industry and foreign industries in general. Third, the capital allocated to foreign industries in general is partitioned across host regions.

This nested CET specification is extended two levels higher in FTAP, since the (endogenous) private wealth introduced in GTAPICM includes assets other than capital, that is, land, natural resources and bonds. At the highest level, private wealth is allocated between bonds<sup>1</sup> and equity. At the second level, equity is allocated between local land and natural resources and capital. Capital is then allocated via the three level nest of Petri (1997). The same transformation parameter is used at the top two levels, so they can effectively be regarded as one level (as in figure 2.3).<sup>2</sup>

FTAP uses the exponential of the rate of return as the supply price driving asset allocation, rather than just the rate of return as in Petri (1997). This change to the theory permits rates of return to be negative, both in the original database and

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<sup>1</sup> The distinction in the interpretation of private bonds after the introduction of FDI and private bonds in GTAPICM should be noted. Private bonds in GTAPICM represent the excess (deficit) of private wealth above (below) productive assets residing in a region. The counterpart to private bonds under the FDI extension would be private bonds plus domestic capital plus foreign capital owned by the region plus local land and natural resources minus local capital owned by foreigners.

<sup>2</sup> It should be noted that the asset supply nest equations presented in section 4.2 are actually of CRETH (a generalisation of CET) form, except for the upper two levels where wealth is split between bonds and equity, and equity is split among capital, land and natural resources. The selected parameter settings, however, reduce all levels to CET.

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during the course of a simulation. There is one reason, specific to FTAP, why this is necessary, and a second reason why it is highly desirable.

First, the (asset or rental) value of private bonds held by a region can be either positive or negative. This was not an issue for Petri (1997), where the capital owned by a region was fixed and bonds were not required to cover the financing of capital supply. The difficulty it raises in the present context is that the prices and quantities of a CET aggregator function must be positive. The resolution of the difficulty relies on being able to accommodate negative rates of return within the theory of asset supply. The quantity of private bonds held by a region is always considered to be positive, but their rate of return is of the same sign as the rental value of the bonds, and can be positive or negative. But since the exponential of the rate of return is used as the bond supply price in the CET aggregator, both the quantity and supply ‘price’ of bonds are positive for all regions.

Second, it is possible that in the FTAP database, negative rates of return could occur, especially when it is disaggregated to a higher level of commodity coverage, as will be necessary for modelling services liberalisation in particular sectors. While the Petri (1997) treatment could possibly deal with rates of return that approach zero during the course of a policy simulation,<sup>3</sup> it could not accommodate initial negative rates of return for the reasons discussed in the previous paragraph.

An implication of using the exponential of the rate of return as the asset supply price is that the transformation parameters are semi-elasticities, that is, they are the percentage changes in relative quantities induced by *percentage point* changes in rates of return. For example, at the top level in figure 2.3, a change of one percentage point in the bond rate, with the rates of return on capital, land and natural resources constant, would induce a one per cent change in the ratio of the quantity of bonds to equity.

The imperfect transformation treatment of asset supply means that rates of return can differ among assets and among regions. The exception to the latter is that bonds are considered to be globally uniform, so that their rate of return is the same regardless of who issues them. By way of contrast, the rate of return on capital can differ not just between regions, but between industries and across different owners of capital in a particular industry.

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<sup>3</sup> As the rate of return in an industry approached zero, the capital supplied would approach zero. If the demand for capital is a CES choice among primary factors — as in most GE models — the demand price of capital would approach infinity as the quantity of capital approached zero. That is, necessarily positive demand quantities for capital would cause rates of return to remain positive.



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Bonds are a means of financing the aggregate FDI and domestic investment undertaken by a region (borrowing) or funding the aggregate FDI and domestic investment of foreign regions (lending). Bonds are not instruments for financing FDI in particular industries and host regions. This would require a further level at the bottom of the nest determining the debt to equity ratio for particular industries. While such a treatment would be possible, it would seem to add little for the current applications of FTAP.

The pattern of nesting reflects the relative difficulty of reallocating wealth between different assets. At the top level, bonds, land, natural resources and capital are very different assets. Assigning the sectoral allocation of capital to a higher level in the nest than the regional allocation implies that it is easier to reallocate FDI among regions than among sectors. One possible interpretation of this structure is that the acquisition of the sector-specific knowledge associated with FDI is more difficult than the acquisition of any region-specific knowledge required for shifting between regions.

The transformation semi-elasticities for the asset supply nest (figure 2.3) were chosen so that the behaviour of FTAP for a simulation of the complete removal of primary and secondary protection was similar to GTAPICM with the ‘imperfect capital mobility’ closure. This represents a conservative model development strategy: introduce an innovation, but parameterize so that it remains close to what is familiar. By proceeding in this manner it is possible to discover new insights, but not be completely overwhelmed by a multitude of unfamiliar phenomena.

Though the semi-elasticities at each level appear small, the overall transformation semi-elasticities (that is, with wealth fixed) between items at the lowest levels can be quite high — often of magnitude 20 and possibly as high as 60 (differences being due to shares of assets in regional portfolios). For example, for two assets with a semi-elasticity of 20, a one percentage point increase in the rate of return on the first asset will increase the ratio of the quantity of the first asset to the second by 20 per cent.<sup>4</sup>

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<sup>4</sup> Formulae for calculating elasticities for a general CES nesting are provided on page 83 of Keller (1980).

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## 4.2 Quantity of assets supplied

### Preliminaries

The names of variables introduced for the asset supply extension follow certain conventions. An initial ‘k’ means ‘quantity of capital supplied’. Supply quantities of other assets begin with ‘q’. An initial ‘c\_rr’ means ‘percentage point change in rate of return’. Where the last three letters of a variable name are some combination of ‘h’, ‘\_’ and ‘i’, this indicates that the variable ranges over a home region, a host region and an industry, or is an aggregate over one of these dimensions. For example, a suffix of ‘h\_i’ means that the variable ranges over home region and industry, and is an aggregate across all host regions.

An initial ‘r\_’ means ‘percentage change in the reciprocal of the exponential of the rate of return’. These might seem like strange variables, but they are required in the updating of the shares of assets in the asset supply function (these shares are used in the rates of return equations of section 4.3, and discussed in appendix C). The ‘r\_’ variables have thus been defined for the terminal nodes on branches of the supply nest, where the GEMPACK updating formulae for shares are applied. Each of the ‘r\_’ variables is related to the change in the corresponding rate of return as follows. Letting  $R$  be a rate of return, the percentage change in the reciprocal of the exponential of the rate of return is:

$$\begin{aligned} 100.\Delta\{\exp(-R)\}/\exp(-R) &= -100.\exp(-R).\Delta R/\exp(-R) \\ &= -100.\Delta R \end{aligned}$$

That is, the percentage change in the reciprocal of the exponential of a rate of return equals minus the percentage point change in the rate of return.

Names of variables in the model prior to the addition of the asset supply extension remain unchanged, and will not conform to the above conventions. Nevertheless, rates of return generally begin with ‘r’ and asset values with ‘a’.

### The equations

In GTAPICM each region owns all capital residing in it. This is not the case in FTAP. Therefore, equity must be redefined in terms of capital owned by a region. This requires alterations to the GTAPICM equations VALUE\_CAPL and EQY, thus:

VALUE\_CAPL # value of physical capital, by region # (all,r,REG)

$$akr(r)=pk\_h\_\_(r)+kt(r);$$

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EQY # equity in productive assets, by region # (all,r,REG)

$$ASEQR(r)*aer(r)=VKT(r)*akr(r)+ASLNR(r)*anr(r)+ASLNR(r)*anrr(r);$$

Variable  $pk\_h\_ (r)$  is the asset price of capital owned by region  $r$  (defined in section 4.5), while  $kt(r)$  is the real quantity of capital owned by region  $r$ . Thus the variable  $akr(r)$  has been redefined to be the asset value of capital owned by region  $r$ , rather than residing in region  $r$ . The value of equity in productive assets for region  $r$  — variable  $aer(r)$  — is likewise redefined. Note that since  $akr$  has been redefined in equation VALUE\_CAPL, the only alteration required (from GTAPICM) to equation EQY is to replace the coefficient  $VKB(r)$  (the asset value of capital residing in region  $r$ ) with the coefficient  $VKT(r)$  (the asset value of capital owned by region  $r$ ). A parallel alteration to the formula calculating the coefficient  $ASEQR$  is also made.

E\_qhr #Private real wealth# (all,s,home)

$$ipahr(s)=ahr(s)-qhr(s);$$

This equation defines real private wealth  $qhr(s)$  as nominal private wealth  $ahr(s)$  deflated by the private wealth price index  $ipahr(s)$ . The latter two variables are defined by the GTAPICM equations HHOLD\_OWNP\_BONDS\_REG and HHOLD\_ASST\_PRINDX, respectively. Real private wealth is not required in any of the GTAPICM equations (and so is not defined there), but is needed in FTAP as the quantity that is partitioned between alternative assets in the nest CET asset supply function.

E\_qbr #Private ownership of bonds# (all,s,home)

$$qhr(s)-qbr(s)=KTRA\_H\_ (s)*[rhr(s)+CRED\_DEBT(s)*r\_rbr(s)];$$

E\_qer #Private ownership of equity# (all,s,home)

$$qhr(s)-qer(s)=KTRA\_H\_ (s)*[rhr(s)-rer(s)];$$

These two equations correspond to the top level of the supply nest, and determine the allocation of private wealth between bonds and equity, respectively. Variables  $qhr(s)$ ,  $qbr(s)$  and  $qer(s)$  are the percentage changes in the quantities of private wealth, bonds and equity held by region  $s$ , while  $rhr(s)$ ,  $rbr(s)$  and  $rer(s)$  are the corresponding percentage point changes in rates of return. As discussed in the preliminaries,  $r\_rbr(s)=-rbr(s)$ . The coefficient  $KTRA\_H\_ (s)$  is the transformation semi-elasticity and is set equal to 1 (figure 2.3).

The coefficient  $CRED\_DEBT(s)$  is an indicator of whether region  $s$  has positive or negative rentals from private bond holdings: 1 for positive, -1 for negative. Thus the

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quantity of bonds is positively (negatively) correlated with the rate of return on bonds if a region has positive (negative) bond rentals. Expressed more conventionally, a creditor (debtor) will lend (borrow) more (less) if the interest rate increases.

E\_pnr #Purchase price of land# (all,r,REG)

$$mt(r)-qer(r)=KTRA\_H\_(r)*[-r\_rr\_land(r)-rer(r)];$$

E\_pnrr #Purchase price of natural resources# (all,r,REG)

$$nru(r)-qer(r)=KTRA\_H\_(r)*[-r\_rr\_natres(r)-rer(r)];$$

E\_k\_h\_\_ #Aggregate supply of capital by home region# (all,s,home)

$$k\_h\_(s)-qer(s)=KTRA\_H\_(s)*[c\_rr\_h\_(s)-rer(s)];$$

These equations determine the second level partitioning of equity between local land and natural resources and capital, respectively. The supply quantities of land, natural resources and capital for region r are  $mt(r)$ ,  $nru(r)$  and  $k\_h\_(r)$ , the first two variables being present in GTAPICM and the last —  $k\_h\_(r)$ , the capital owned by region r — being introduced for FTAP. The percentage point changes in the rates of return for land, natural resources and the capital owned by region r are  $c\_rr\_land(r)$ ,  $c\_rr\_natres(r)$  and  $c\_rr\_h\_(r)$ , with the first two having corresponding ‘r\_’ variables. The same transformation semi-elasticity  $KTRA\_H\_\_$  as occurs at the top level of the nest occurs here also.

The first two equations are named after the purchase or asset prices of land and natural resources, pnr and pnrr, respectively. This reflects the function of these equations in determining these prices via the fixity of land and natural resources in each region. Thus equations E\_pnr and E\_pnrr replace GTAPICM equations PRICE\_LAND and E\_pnrr, which define the asset prices of land and natural resources by perfect arbitrage between rates of return.

In GTAPICM there is no distinction between the capital owned by a region and the capital residing in a region. In FTAP there is, and it is critical that the equality from GTAPICM between the (GTAPICM) variable  $kt$  and the (GTAP) variable  $kb$  be broken. Both variables are redefined thus:

E\_kt #SALTER quantity of capital kt is capital owned by home#

$$(all,r,REG) k\_h\_(r)=kt(r);$$

E\_kb #GTAP quantity of capital kb is capital residing in the host, asset weights# (all,d,host)

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$$\begin{aligned} & \text{sum}(i, \text{TRAD\_COMM}, \text{sum}(s, \text{home}, \text{VFDI\_HHI}(i, s, d)) + \text{VKD}(i, d)) * \text{kb}(d) = \\ & \text{sum}(i, \text{TRAD\_COMM}, \\ & \quad \text{sum}(s, \text{home}, \text{VFDI\_HHI}(i, s, d)) * \text{k\_hhi}(i, s, d)) + \\ & \quad \text{VKD}(i, d) * \text{kd\_h\_i}(i, d)) + \text{f\_kb}(d); \end{aligned}$$

That is,  $kt(r)$  is equated with the quantity of capital owned by region  $r$ , while  $kb(d)$  is an asset value weighted index of the quantity of capital residing in region  $d$ . Defined thus, both  $kt$  and  $kb$  operate correctly in the GTAPICM equations in which they already occur. Equation  $E\_kt$  replaces GTAPICM equation  $E\_kt$ , which equated  $kt$  and  $kb$ . The determination of  $kb$  via equation  $E\_kb$  means that variable  $frer$  must be endogenised, permitting regional rates of return of capital (variable  $rkr$ ) to vary among regions. That is, GTAPICM equation  $EQY\_BOND\_PARY$  is essentially removed from FTAP.

$$E\_k\_h\_i(\text{all}, i, \text{TRAD\_COMM})(\text{all}, s, \text{home})$$

$$\text{k\_h\_i}(i, s) - \text{k\_h\_}(s) = \text{KTRA\_H\_I}(i, s) * [\text{c\_rr\_h\_i}(i, s) - \text{c\_rr\_h\_}(s)];$$

This equation, which allocates total capital owned by a region among industries, is the first level of the nest at which it is possible to specify a CRETH rather than CET form. This is due to the industry dimension  $i$  on the transformation parameter  $\text{KTRA\_H\_I}$ . In practice, all components of  $\text{KTRA\_H\_I}$  have been set to 1.2 (figure 2.3).

$$E\_kd\_h\_i(\text{all}, i, \text{TRAD\_COMM})(\text{all}, s, \text{home})$$

$$\text{kd\_h\_i}(i, s) - \text{k\_h\_i}(i, s) = \text{KTRAD\_H\_I}(i, s) * [-\text{r\_rrd\_h\_i}(i, s) - \text{c\_rr\_h\_i}(i, s)];$$

$$E\_kf\_h\_i(\text{all}, i, \text{TRAD\_COMM})(\text{all}, s, \text{home})$$

$$\text{kf\_h\_i}(i, s) - \text{k\_h\_i}(i, s) = \text{KTRAF\_H\_I}(i, s) * [\text{c\_rrf\_h\_i}(i, s) - \text{c\_rr\_h\_i}(i, s)];$$

The equations for partitioning capital allocated to a particular industry between the domestic and foreign industries are also written in the CRETH form, but in practice collapsed to the CET form by setting all components of  $\text{KTRAD\_H\_I}$  and  $\text{KTRAF\_H\_I}$  to 1.3 (figure 2.3). Note that as ‘capital in the domestic industry’ is the terminal node of a branch, the equation  $E\_kd\_h\_i$  is written with the ‘ $r\_$ ’ variable for capital in the domestic industry. The equation for capital allocation to the foreign industries is written entirely in terms of rates of return.

$$E\_k\_hhi(\text{all}, i, \text{TRAD\_COMM})(\text{all}, s, \text{home})(\text{all}, d, \text{host})$$

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$$k_{\text{hhi}}(i,s,d) - k_{\text{f}_i}(i,s) = K\text{TRA\_HHI}(i,s,d) * [-r_{\text{rr\_hhi}}(i,s,d) - c_{\text{rrf}_i}(i,s)];$$

This is the equation representing the lowest level of the asset supply nest, the division of capital, allocated to foreign industries of a particular type (primary, secondary or tertiary), between host regions. Again, it is of CRETH form but collapsed to CET with all components of KTRA\_HHI set equal to 1.4 (figure 2.3).

## 4.3 Rates of return

### Preliminaries

An initial ‘c\_trr’ means ‘percentage point change in post-tax rate of return’, while the prefix ‘c\_rr’ is used for pre-tax rates of return.

The equations defining the ‘r\_’ variables (‘percentage change in the reciprocal of the exponential of the rate of return’ variables) are presented in this section. As shown in the previous section, the percentage change in the reciprocal of the exponential of a rate of return equals minus the percentage point change in the rate of return.

Throughout this group of equations, the rate of return of an asset that is an aggregate of other assets is defined implicitly by an equation that equates the aggregate quantity to a share-weighted sum of constituent quantities. For example, the real quantity of equity is equated with a share-weighted sum of the quantities of land, natural resources and capital. There are two advantages with this implicit mode of definition.

First, in linearised form, the equation for the rate of return of the aggregate will remain the same if the CET aggregator function is replaced by the more general CRETH function.<sup>5</sup> For all such constant returns to scale aggregator functions, under optimising behaviour the percentage change in the aggregate quantity equals the value share-weighted sum of the percentage changes in constituent quantities.

Second, the form of the equation is the same regardless of whether pre- or post-tax rates of return are used, since the constituent rates of return do not enter the definition of the aggregate rate of return.

The rates of return defined by the following equations are net of depreciation. The linearised relationship between a net rate of return and its constituent rental price,

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<sup>5</sup> The transformation parameters KTRA\_\* are already dimensioned to accommodate this extension.

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asset price and depreciation rate is derived as follows: letting  $R$  be the net rate of return,  $P$  the rental price,  $A$  the asset price,  $D$  the depreciation rate and lower case letters denote percentage changes,

$$R = P/A - D$$

Therefore

$$\begin{aligned} 100.\Delta R &= 100.(\Delta P/A - P/A^2.\Delta A - \Delta D) \\ &= P/A.(p - a) - 100.\Delta D \end{aligned}$$

Thus, for a constant depreciation rate, the percentage point change in the net rate of return is equal to the *gross* rate of return times the difference of the percentage changes in rental and asset prices.

### The equations

$E\_c\_rr\_hhi$  (all,i,TRAD\_COMM)(all,s,home)(all,d,host)

$$c\_rr\_hhi(i,s,d)=[RR\_HHI(i,s,d)+DEPRIND(i,d)]*[rps(i,s,d)-pcgds(d)];$$

$E\_c\_trr\_hhi$  (all,i,TRAD\_COMM)(all,s,home)(all,d,host)

$$c\_trr\_hhi(i,s,d)=$$

$$[1-TYPR\_L(d)]*[RR\_HHI(i,s,d)+DEPRIND(i,d)]*[psks(i,s,d)-pcgds(d)];$$

$E\_r\_rr\_hhi$  (all,i,TRAD\_COMM)(all,s,home)(all,d,host)

$$r\_rr\_hhi(i,s,d)=$$

$$-[POST\_TAX\_RR*c\_trr\_hhi(i,s,d)+PRE\_TAX\_RR*c\_rr\_hhi(i,s,d)];$$

The first two equations define the pre- and post-tax rates of return,  $c\_rr\_hhi(i,s,d)$  and  $c\_trr\_hhi(i,s,d)$ , respectively, for capital owned by region  $s$  in industry  $i$  located in region  $d$ . They both follow the pattern derived in the preliminaries. The coefficient  $RR\_HHI$  is the net rate of return, while  $DEPRIND$  is the depreciation rate, which is specific to an industry in a particular location. Pre- and post-tax rental prices  $rps$  and  $psks$  are used for defining pre- and post-tax rates of return, but the asset price of capital  $pcgds$  is the same in both cases and is specific to the host region. Multiplication by one minus the property income tax rate —  $[1-TYPR\_L(d)]$  — ensures that the gross rate of return used in equation  $E\_c\_trr\_hhi$  is post-tax.

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The third equation defines the ‘r\_’ variable that is used in the asset supply decision. It is in this equation that the choice between pre- and post-tax rates of return is made. In current applications, setting the coefficient PRE\_TAX\_RR to 1 and POST\_TAX\_RR to 0 uses pre-tax rates of return. This setting is preferred because many economies, in the developed world at least, have primarily destination-based tax systems. For example, if tax credits are granted for taxes paid overseas, investors are ultimately taxed on all income at the owning region’s tax rate. Modelling investors as responding to pre-tax rates of return captures the effect of such tax credits, even though these have not been represented explicitly in FTAP.

$E\_c\_rrd\_h\_i$  (all,i,TRAD\_COMM)(all,s,home)

$$c\_rrd\_h\_i(i,s)=[RRD\_H\_I(i,s)+DEPRIND(i,s)]*[rpd(i,s)-pcgds(s)];$$

$E\_c\_trrd\_h\_i$  (all,i,TRAD\_COMM)(all,s,home)

$$c\_trrd\_h\_i(i,s)=$$

$$[1-TYPR\_L(s)]*[RRD\_H\_I(i,s)+DEPRIND(i,s)]*[pskd(i,s)-pcgds(s)];$$

$E\_r\_rrd\_h\_i$  (all,i,TRAD\_COMM)(all,s,home)

$$r\_rrd\_h\_i(i,s)=$$

$$-[POST\_TAX\_RR*c\_trrd\_h\_i(i,s)+PRE\_TAX\_RR*c\_rrd\_h\_i(i,s)];$$

These three equations are similar to the previous three, but deal with rates of return on domestically-owned capital.

$E\_c\_rr\_land$  (all,s,home)

$$c\_rr\_land(s)=RR\_LAND(s)*[rm(s)-pnr(s)];$$

$E\_c\_trr\_land$  (all,s,home)

$$c\_trr\_land(s)=[1-TYPR\_L(s)]*RR\_LAND(s)*[psland(s)-pnr(s)];$$

$E\_r\_rr\_land$  (all,s,home)

$$r\_rr\_land(s)=$$

$$-[POST\_TAX\_RR*c\_trr\_land(s)+PRE\_TAX\_RR*c\_rr\_land(s)];$$

These three equations are similar to the previous three, but deal with rates of return on land. The post-tax rental price of land is defined by picking out the land



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component of the (GTAP) supply price variable  $ps$  in equation  $E_{psland}$  (chapter 9).

$E_{c\_rr\_natres}$  (all,s,home)

$$c\_rr\_natres(s) = RR\_NATRES(s) * [nrp(s) - pnrr(s)];$$

$E_{c\_trr\_natres}$  (all,s,home)

$$c\_trr\_natres(s) = [1 - TYPR\_L(s)] * RR\_NATRES(s) * [psnatres(s) - pnrr(s)];$$

$E_{r\_rr\_natres}$  (all,s,home)

$$r\_rr\_natres(s) = -[POST\_TAX\_RR * c\_trr\_natres(s) + PRE\_TAX\_RR * c\_rr\_natres(s)];$$

These three equations are similar to the previous three, but deal with rates of return on natural resources. The post-tax rental price of natural resources is defined by picking out the natural resources component of the (GTAP) supply price variable  $ps$  in equation  $E_{psnatres}$  (chapter 9).

$E_{rbrpt}$  (all,r,REG)

$$rbrpt(r) = [1 - TYPR\_L(r)] * rbr(r) - RTBDR(r) * TYPR\_L(r) * typr(r);$$

$E_{r\_rbr}$  (all,s,home)

$$r\_rbr(s) = -[POST\_TAX\_RR * rbrpt(s) + PRE\_TAX\_RR * rbr(s)];$$

These equations define the post-tax rate of return on bonds, variable  $rbrpt$ , and the 'r' variable associated with bonds, variable  $r\_rbr$ . The post-tax rate of return is defined in terms of the pre-tax rate of return (coefficient  $RTBDR$ , variable  $rbr$ ) and the property income tax rate (coefficient  $TYPR\_L$ , variable  $typr$ ), rather than in terms of rental and asset prices. The derivation of the form of equation  $E_{rbrpt}$  is as follows. Letting  $S$  be the post-tax rate of return,  $R$  the pre-tax rate of return,  $T$  the tax rate and lower case letters percentage changes:

$$\begin{aligned} 100.\Delta S &= 100.\Delta[(1 - T).R] \\ &= (1 - T).100.\Delta R - R.100.\Delta T \\ &= (1 - T).100.\Delta R - R.T.t \end{aligned}$$

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E\_rhr (all,s,home)

$$\begin{aligned} & [\text{VK\_H\_}(s)+\text{VLAND}(s)+\text{VNATRES}(s)+\text{VBR}(s)]*\text{qhr}(s)= \\ & [\text{VK\_H\_}(s)+\text{VLAND}(s)+\text{VNATRES}(s)]*\text{qer}(s)+\text{VBR}(s)*\text{qbr}(s); \end{aligned}$$

E\_rer (all,s,home)

$$\begin{aligned} & \text{VK\_H\_}(s)*\text{k\_h\_}(s)+\text{VLAND}(s)*\text{mt}(s)+\text{VNATRES}(s)*\text{nru}(s)= \\ & [\text{VK\_H\_}(s)+\text{VLAND}(s)+\text{VNATRES}(s)]*\text{qer}(s); \end{aligned}$$

E\_c\_rr\_h\_\_ (all,s,home)

$$\begin{aligned} & \text{IF}\{\text{VK\_H\_}(s) \text{ ne } 0, \\ & \text{sum}(i,\text{TRAD\_COMM},\text{VK\_H\_I}(i,s)*[\text{k\_h\_i}(i,s)-\text{k\_h\_}(s)])\}= \\ & \text{IF}\{\text{VK\_H\_}(s)=0,\text{c\_rr\_h\_}(s)\}; \end{aligned}$$

E\_c\_rr\_h\_i (all,i,TRAD\_COMM)(all,s,home)

$$\begin{aligned} & \text{IF}\{\text{VK\_H\_I}(i,s) \text{ ne } 0, \\ & \text{VKD\_H\_I}(i,s)*\text{kd\_h\_i}(i,s)+\text{VKF\_H\_I}(i,s)*\text{kf\_h\_i}(i,s) \\ & -\text{VK\_H\_I}(i,s)*\text{k\_h\_i}(i,s)\}= \\ & \text{IF}\{\text{VK\_H\_I}(i,s)=0,\text{c\_rr\_h\_i}(i,s)\}; \end{aligned}$$

E\_c\_rrf\_h\_i (all,i,TRAD\_COMM)(all,s,home)

$$\begin{aligned} & \text{IF}\{\text{VKF\_H\_I}(i,s) \text{ ne } 0, \\ & \text{sum}(d,\text{host},\text{VK\_HHI}(i,s,d)*[\text{k\_hhi}(i,s,d)-\text{kf\_h\_i}(i,s)])\}= \\ & \text{IF}\{\text{VKF\_H\_I}(i,s)=0,\text{c\_rrf\_h\_i}(i,s)\}; \end{aligned}$$

These equations define percentage point changes in rates of return associated with nodes of the CET asset supply nest that are aggregates of assets at lower levels. The names of the rate of return variables are embedded in the equation names. For example, equation E\_rhr defines variable rhr. Equation E\_rhr is associated with private wealth, E\_rer with equity, E\_c\_rr\_h\_\_ with capital owned by a region, E\_c\_rr\_h\_i with capital owned by a region in a particular industry, and E\_c\_rrf\_h\_i with capital owned by a region in a particular industry located overseas. The method of implicit definition via aggregation of quantities, discussed in the

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preliminaries, is used in each equation. The coefficients defining the shares of each asset in the aggregates (all the coefficients beginning with ‘V’) are neither capital rentals nor asset values, but are defined and updated according to the distinctive features of the asset supply specification. These coefficients shall be called ‘Petri asset values’, and are discussed at length in appendix C.

Note the use of conditionals to set rates of return to zero for null nodes.

## 4.4 Rental prices of capital

### Preliminaries

There are three types of rental prices of capital in FTAP.

First is the pre-tax, impediment-inclusive rental price. This is the price that an incumbent firm must pay to use an unit of capital. In the definition of this rental price, impediments are represented as taxes on capital, though the revenue is diverted from government to private agents (chapter 8). Tax terms of various dimensions are included, to provide flexibility to the model user wishing to alter impediments through a simulation.

Second is the pre-tax, impediment-exclusive rental price. In the current applications of the model, this is the rental price that enters the capital supply decision via pre-tax rates of return. Impediments do not enter the decision to allocate capital to an industry, since investors are constrained, by barriers to investment, to supply according to pre-tax, impediment-exclusive rates of return.

Third is the post-tax, impediment-exclusive rental price. This is the return per unit of capital received by new entrants to the industry. It is equal to the pre-tax, impediment-exclusive rental price taxed at the property income tax rate (coefficient TYPR\_L, variable typr) of the host region.

### The equations

$E\_pskd$  (all,i,TRAD\_COMM)(all,r,REG)

$$rpd(i,r)=pskd(i,r)+sum(k,ENDWC\_COMM,to(k,r));$$

$E\_psks$  (all,i,TRAD\_COMM)(all,s,home)(all,d,host)

$$rps(i,s,d)=psks(i,s,d)+sum(k,ENDWC\_COMM,to(k,d));$$

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These equations link pre-tax, impediment-exclusive rental prices  $rpd$  and  $rps$  of domestic and foreign capital, respectively, to post-tax, impediment-exclusive prices  $pskd$  and  $psks$ . The sums on the right hand sides pick out the capital component (since the one element set  $ENDWC\_COMM=\{capital\}$ ) of the (GTAP) variable  $to$ , which is the percentage change in the power of the output tax on primary factors, commodities or investment.

$E\_pfeda$  (all,i,TRAD\_COMM)(all,r,REG)

$$pfeda(i,r)=tfda(i,r)+toad(r)+toa(r)+rpd(i,r)+$$

$$\text{sum}(k,ENDWC\_COMM,tf(k,i,r));$$

$E\_pfesa$  (all,i,TRAD\_COMM)(all,s,home)(all,d,host)

$$pfesa(i,s,d)=tfsa(i,s,d)+toas(s,d)+tfia(i,d)+toai(d)+toa(d)+rps(i,s,d)+$$

$$\text{sum}(k,ENDWC\_COMM,tf(k,i,d));$$

These equations link pre-tax, impediment-inclusive rental prices  $pfeda$  and  $pfesa$  of domestic and foreign capital, respectively, to pre-tax, impediment-exclusive prices  $rpd$  and  $rps$ . The sums on the right hand sides pick out the capital component of the (GTAP) variable  $tf$ , which is the percentage change in the power of the tax on primary factor inputs to industries. All other variables beginning with ‘t’ represent the powers of the ad-valorem tax equivalents of impediments on capital. They are intended to cover the full range of dimension combinations so as to provide flexibility to the model user.

$E\_pfeia$  (all,i,TRAD\_COMM)(all,d,host)

$$\text{sum}(s,home,$$

$$EVIFAS(i,s,d)*[(pfesa(i,s,d)+qfes(i,s,d))-(pfeia(i,d)+qfei(i,d))]=$$

$$\text{IF}[EVIFA(i,d)=0,pfeia(i,d)-pfactwld];$$

This equation is merely definitional, providing an index of the pre-tax, impediment-inclusive rental price of foreign capital by industry and host region. The coefficient  $EVIFAS(i,s,d)$  is the value of pre-tax, impediment-inclusive rentals to capital in industry  $i$ , owned by home region  $s$  and operating in host region  $d$ . The coefficient  $EVIFA(i,d)$  is the total of  $EVIFAS(i,s,d)$  across all home regions  $s$ . The variable  $qfes(i,s,d)$  is the percentage change in the quantity of capital from region  $s$  demanded by industry  $i$  operating in host region  $d$ . The variable  $qfei(i,d)$  is the total quantity of foreign capital demanded by industry  $i$  in host region  $d$ . It is a share-weighted index of  $qfes$ , the shares being calculated from  $EVIFAS$ .  $qfei$  is defined in

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the section on the demand for capital. By using these coefficients and variables,  $pfeia$  can be defined by equating the total pre-tax, impediment-inclusive foreign capital rentals by industry with the sum of these rentals across different foreign owners. Where there is no foreign ownership in an industry ( $EVIFA(i,d)=0$ ),  $pfeia$  is set equal to the numeraire.

$E\_f\_pfek$  (all,i,TRAD\_COMM)(all,r,REG)

$$EVDFFA(i,r)*(pfeda(i,r)+qfed(i,r))+EVIFA(i,r)*(pfeia(i,r)+qfei(i,r))-$$

$$\text{sum}[k,ENDWC\_COMM,EVFA(k,i,r)*(pfe(k,i,r)+qfe(k,i,r))]=$$

$$IF\{\text{sum}[k,ENDWC\_COMM,EVFA(k,i,r)]=0,f\_pfek(i,r)\};$$

Due to the introduction of imperfectly transformable capital, the component of the (GTAP) equation  $MPFACTPRICE$  defining the user price (pre-tax, impediment-inclusive in FTAP-speak) of capital  $pfe$  (“capital”,  $j,r$ ) in industry  $j$  in region  $r$  must be nullified by adding a slack variable  $f\_pfek(j,r)$  to it. This is because in GTAP, all primary factors covered by equation  $MPFACTPRICE$  are assumed to be perfectly mobile among industries. The variable  $pfe$  for capital is then defined as an index of the pre-tax, impediment-inclusive rental price of foreign and domestic capital by industry and host region.

## 4.5 Asset prices

### Preliminaries

The introduction of imperfect transformation in asset supply spawns new quantity variables for assets, for example, the quantity of capital owned by a region (as distinct from that residing in a region), the quantity of private bonds, and the quantity of equity (section 4.2). These new quantity variables can be used with the corresponding values of the assets to define, or redefine, the corresponding asset prices.

### The equations

$E\_pk\_h$  (all,s,home)

$$\{\text{sum}(d,dest,\text{sum}(i,TRAD\_COMM,VFDI\_HHI(i,s,d)))+$$

$$\text{sum}(i,TRAD\_COMM,VKD(i,s))\}*$$

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$$\begin{aligned}
& [pk\_h\_(s)+k\_h\_(s)]= \\
& \text{sum}(d,\text{dest},\text{sum}(i,\text{TRAD\_COMM}, \\
& \quad \text{VFDI\_HHI}(i,s,d)*[\text{pcgds}(d)+k\_hhi(i,s,d)]))+ \\
& \text{sum}(i,\text{TRAD\_COMM},\text{VKD}(i,s)*[\text{pcgds}(s)+kd\_h\_i(i,s)]);
\end{aligned}$$

This equation defines the asset price of capital owned by region  $s$ ,  $pk\_h\_(s)$ . The definition equates the asset value of capital owned by region  $s$  with the sum of the asset values of capital across all industries, domestic and foreign, owned by region  $s$ . The coefficients  $\text{VKD}$  and  $\text{VFDI\_HHI}$  are the asset values of capital in domestic and foreign industries, respectively. The variables with names beginning with 'k' are supply quantities of capital determined by the asset supply equations in section 4.2. The asset price of capital is uniform across industries in a region  $d$  and is equal to the (GTAP) price of capital creation  $\text{pcgds}(d)$ .

$E\_pbr$  #Bond price# (all,s,REG)

$$pbr(s)=pb;$$

$E\_pb$  #World bond price#      **! Deleted in FTAP version 2, Appendix J !**

$$\begin{aligned}
0 & = \text{sum}\{s,\text{REG},\text{ASHHBDR}(s)*[pbr(s)+qbr(s)]- \\
& \quad [\text{YCHHDPR}(s)*qyhbr(s)+\text{ASHHBDR}(s)*yhdr(s)]\};
\end{aligned}$$

The first equation ensures that the asset price of bonds for region  $s$ ,  $pbr(s)$ , is the same for all regions  $s$ , since bonds are globally uniform (section 4.1). The second equation determines the global price of bonds by equating the world asset value of private bonds expressed in terms of FTAP variable  $pbr$  and  $qbr$  with the world asset value of private bonds expressed in terms of GTAPICM variables  $qyhbr$  and  $yhdr$ . The variable  $pbr$  replaces the variable  $ipc$  (which is used as the asset price of bonds in GTAPICM) in equations  $\text{HHOLD\_ASST\_PRINDX}$ ,  $\text{GOVT\_WEALTH\_ACCN}$ ,  $\text{CONT\_EV\_PRICER}$  and  $\text{CONT\_EV\_BONDR}$ .

$\text{SAVEPRICE}$  (all,r,REG)

$$\begin{aligned}
\text{SAVE}(r)*\text{psave}(r) & = \text{NETINV}(r)*\text{pcgds}(r)+[\text{SAVE}(r)-\text{NETINV}(r)]*pbr(r)+ \\
& \text{SAVE}(r)*\text{psaveslack}(r) ;
\end{aligned}$$

The GTAP equation  $\text{SAVEPRICE}$ , which defines the price of savings (variable  $\text{psave}$ ), is altered. The price of savings is redefined to be a share-weighted combination of the price of capital creation (variable  $\text{pcgds}$ ) and the price of bonds. The price of

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bonds enters with a positive (negative) sign if net saving (coefficient SAVE) is greater (less) than net investment (coefficient NETINV). Note that under the new definition of psave, the prices of savings and investment cancel out in the welfare decomposition term CNTpricer (chapter 3), which becomes equal to the terms of trade effect, CNTtotr, plus asset price effects.<sup>6</sup> This is due to the identity  $S-I=X-M+FY$ .

E\_iper (all,r,REG)

$$\text{iper}(r)=\text{aer}(r)-\text{qer}(r);$$

The asset price of equity owned by region  $r$ ,  $\text{iper}(r)$ , is defined as the ratio of the value of equity,  $\text{aer}(r)$ , to the quantity of equity,  $\text{qer}(r)$ , determined by the asset supply equation E\_qer. Equation E\_iper replaces the GTAPICM equation EQY\_PRICE\_INDX that defines the price index for equity as a share-weighted sum of the constituent price variables — the asset prices of capital, land and natural resources.

## 4.6 Market clearing for capital

### Preliminaries

The pre-tax, impediment-exclusive rental prices of capital,  $\text{rpd}$  and  $\text{rps}$ , are determined by market clearing conditions in the markets for each type of capital (that is, the markets for capital for each domestically-owned industry, and the markets for capital for each foreign-owned industry). As capital is no longer uniform within an industry, the industry and region specific price of capital,  $\text{rp}$ , is determined not by perfect arbitrage between industry rates of return, but as a share-weighted index of constituent rental prices  $\text{rpd}$  and  $\text{rps}$ .

### The equations

E\_rps #Supply equals demand for capital by host, home and industry#

$$(\text{all},i,\text{TRAD\_COMM})(\text{all},s,\text{home})(\text{all},d,\text{host}) \text{k\_hhi}(i,s,d)=\text{qfes}(i,s,d);$$

E\_rpd #Supply equals demand for domestic capital by industry#

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<sup>6</sup> In the definition of CNTpricer in the TABLO code, the asset price effect from FDI, variable CNTpcapr from section 4.8, is also added to CNTpricer.

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$$(all,i,TRAD\_COMM)(all,s,home) kd\_h\_i(i,s)=qfed(i,s);$$

Variables  $k\_hhi$  and  $kd\_h\_i$  ( $qfes$  and  $qfed$ ) are the quantities of capital supplied to (demanded by) foreign-owned and domestic industries, respectively.

$$E\_rp (all,i,TRAD\_COMM)(all,r,REG)$$

$$\begin{aligned} & IF\{CAP(i,r) \neq 0, \\ & CAP(i,r)*(rp(i,r)+qfek(i,r))- \\ & [EVDFM(i,r)*(rpd(i,r)+qfed(i,r))+ \\ & sum(s,home,EVIFMS(i,s,r)*(rps(i,s,r)+qfes(i,s,r)))]\} = \\ & IF\{CAP(i,r)=0,rp(i,r)-pfactwld\}; \end{aligned}$$

The capital rental price  $rp$  is defined by equating, in linearised form,  $CAP$  with the sum of  $EVDFM$  and  $EVIFMS$  summed across owners for each industry and host region, where the coefficients  $EVIFMS$ ,  $EVDFM$  and  $CAP$  are the pre-tax, impediment-exclusive rentals to capital in, respectively, foreign-owned industries, domestically-owned industries and industries regardless of ownership. Equation  $E\_rp$  replaces the  $GTAPICM$  equation  $ABNL\_RETN\_CAPL$ , which defines  $rp$  via perfect arbitrage in industry rates of return (in the long run).

## 4.7 FDI income accounting

### Preliminaries

The net foreign income from FDI is the difference of the sum of all income inflows resulting from investment abroad and the sum of all income outflows resulting from repatriation of income by foreign investors. Each individual income flow is expressed as the product of the asset price, quantity and rate of return of the capital producing the income (as described in appendix B). Post-tax, impediment-exclusive, net rates of return are used, since it is assumed that FDI income is taxed in the host region. Impediment rents are excluded from the rates of return used here, and dealt with separately (chapter 8). This allows the impacts of the different sources of foreign income to be separately identified (see table B.1 in appendix B).

Net foreign income must be added to some of the income accounting equations introduced in  $GTAPICM$ . As these equations will undergo further modification later (chapter 8), their intermediate form is not listed here. They are just noted below.



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## The equations

$E_{yfdi\_hhi}(all,i,TRAD\_COMM)(all,s,REG)(all,d,REG)$

$$100*yfdi\_hhi(i,s,d)=$$
$$VFDI\_HHI(i,s,d)*c\_trr\_hhi(i,s,d) +$$
$$VINC\_HHI(i,s,d)*[pcgds(d)+k\_hhi(i,s,d)];$$

The variable  $yfdi\_hhi(i,s,d)$  is the change in income from capital in industry  $i$  in region  $d$  owned by region  $s$ . The first two terms on the right hand side are (100 times) the contribution to income of changes in the post-tax rate of return. The third term is (100 times) the sum of the asset price contribution (equals the income  $VINC\_HHI(i,s,d)$  times the percentage change in the asset price  $pcgds(d)/100$ ) and the contribution of changes in the size of the capital stock (equals the income  $VINC\_HHI(i,s,d)$  times the percentage change in the size of the capital stock  $k\_hhi(i,s,d)/100$ ).

$E_{yfdi\_h\_}(all,r,REG)$

$$yfdi\_h\_ (r)=$$
$$\text{sum}(i,TRAD\_COMM,\text{sum}(d,\text{dest},yfdi\_hhi(i,r,d)))-$$
$$\text{sum}(i,TRAD\_COMM,\text{sum}(s,\text{home},yfdi\_hhi(i,s,r)));$$

The change in net foreign income from FDI for region  $r$ ,  $yfdi\_h\_ (r)$ , is the sum of changes in inflows (components of  $yfdi\_hhi$  where region  $r$  is the home region), minus the sum of changes in outflows (components of  $yfdi\_hhi$  where region  $r$  is the host region).

Net foreign income from FDI must be added to GTAPICM equations  $NATL\_INCOME$  and  $PROPY\_INCOME$  for correct international income accounting. Since taxation of FDI income occurs in the host region, to avoid double taxation and correctly account for home region property income tax revenue, a variable  $yhpntax$ , percentage change in property income to be taxed, is defined. The equation defining this is  $E_{yhpntax}$ . The final form of equations  $NATL\_INCOME$ ,  $PROPY\_INCOME$  and  $E_{yhpntax}$  will be listed in section 8.6, after all international income flows are implemented. Variable  $yhpntax$  replaces variable  $yhpr$  in the (GTAPICM) equation  $TAX\_PROPY\_INCOME$  defining property income tax revenue.

The definition of the value of depreciation is changed from GTAPICM to FTAP to accommodate industry-specific depreciation rates. The GTAPICM equation

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DEP\_CAPITAL that defines the percentage change in the value of depreciation — variable *depr* — is changed to link the percentage change with the corresponding absolute change, thus:

DEP\_CAPITAL # depreciation of capital stock, by region #(all,r,REG)

$$VDEP(r)*depr(r)=100*c\_VDEP(r);$$

The change in the value of depreciation is then defined as the sum of changes in the values of depreciation on domestic and foreign-owned capital, thus:

E\_c\_VDEP (all,d,REG)

$$c\_VDEP(d)=\text{sum}(i,\text{TRAD\_COMM},\text{DEPRIND}(i,d)* \\ [c\_VKD(i,d)+\text{sum}(s,\text{home},c\_VFDI\_HHI(i,s,d))]);$$

The change in the value of depreciation in each industry is the industry depreciation rate times the change in the asset values of capital — variables *c\_VKD* and *c\_VFDI\_HHI* for domestic and foreign-owned industries, respectively. Note that there are no terms corresponding to changes in depreciation rates (coefficient *DEPRIND*), which are assumed constant for each industry. However, the depreciation rate for a region may vary due to compositional changes in the share of each industry in the capital stock residing in the region. The percentage change in the regional depreciation rate — variable *deprate* — is defined thus:

E\_deprate (all,r,REG)

$$depr(r)=deprate(r)+pcgds(r)+kb(r);$$

## 4.8 Contributions of FDI income flows to welfare

### Preliminaries

The separation of FDI income flows into rate of return, asset price and capital stock change effects is paralleled in this section in the equations defining the corresponding welfare decomposition terms, again in line with the approach outlined in appendix B.

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## The equations

CONT\_EV\_ror\_hhi (all,i,TRAD\_COMM)(all,s,HOME)(all,d,host)

$$\text{CNTror\_hhi}(i,s,d)=[.01/\text{INCRATIO}(s)]*\text{VFDI\_HHI}(i,s,d)*\text{c\_trr\_hhi}(i,s,d);$$

CONT\_EV\_cap\_hhi (all,i,TRAD\_COMM)(all,s,HOME)(all,d,host)

$$\text{CNTcap\_hhi}(i,s,d)=[.01/\text{INCRATIO}(s)]*\text{VINC\_HHI}(i,s,d)*\text{k\_hhi}(i,s,d);$$

CONT\_EV\_pcap\_hhi (all,i,TRAD\_COMM)(all,s,HOME)(all,d,host)

$$\text{CNTpcap\_hhi}(i,s,d)=[.01/\text{INCRATIO}(s)]*\text{VINC\_HHI}(i,s,d)*\text{pcgds}(d);$$

These equations define, respectively, the contribution to welfare in region  $s$  from rate of return changes, capital stock changes and asset price changes in that part of industry  $i$  in region  $d$  owned by region  $s$ . The right hand sides of the equation are the corresponding contributions to the FDI income flow  $y\text{fdi\_hhi}(i,s,d)$  multiplied by the GTAP coefficient  $[.01/\text{INCRATIO}(s)]$  to convert them to welfare contributions for region  $s$ .

CONT\_EV\_ror\_hh\_ (all,s,HOME)(all,d,host)

$$\text{CNTror\_hh\_}(s,d)=\text{sum}\{i,\text{TRAD\_COMM},\text{CNTror\_hhi}(i,s,d)\};$$

CONT\_EV\_ror\_\_h\_ (all,d,host)

$$\text{CNTror\___h\_}(d)=$$

$$-\text{sum}\{s,\text{HOME},\text{INCRATIO}(s)/\text{INCRATIO}(d)*\text{CNTror\_hh\_}(s,d)\};$$

CONT\_EV\_ror\_h\_\_ (all,s,HOME)

$$\text{CNTror\_h__}(s)=\text{sum}\{d,\text{dest},\text{CNTror\_hh\_}(s,d)\};$$

CONT\_EV\_ror (all,s,REG)

$$\text{CNTror}(s)=\text{CNTror\_h__}(s)+\text{CNTror\___h\_}(s);$$

This sequence of equations generates a total contribution to welfare from rates of return for region  $s$ . First, host specific contributions  $\text{CNTror\_hh\_}(s,d)$  are generated by summing  $\text{CNTror\_hhi}(i,s,d)$  over industries. Second, a total contribution to host region  $d$ ,  $\text{CNTror\___h\_}(d)$ , is generated by summing  $\text{CNTror\_hh\_}(s,d)$  over all home regions  $s$ , after scaling by  $\text{INCRATIO}(s)/\text{INCRATIO}(d)$  to ensure the contribution is relative to region  $d$ . Third, a total contribution to home region  $s$ ,  $\text{CNTror\_h__}(s)$ , is generated by summing  $\text{CNTror\_hh\_}(s,d)$  over all host regions  $d$ . Finally, a total

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contribution to region  $s$ ,  $CNTror(s)$ , is generated by summing contributions to region  $s$  as home and as host.

$CONT\_EV\_capr$  (all,s,REG)

$$CNTcapr(s)=CNTcap\_h\_(s)+CNTcap\_h\_(s);$$

$CONT\_EV\_pcapr$  (all,s,REG)

$$CNTpcapr(s)=CNTpcap\_h\_(s)+CNTpcap\_h\_(s);$$

Total contributions to welfare from capital stock changes and asset prices for region  $s$  are built up in the same way as the rate of return contributions. The parallel equation sequences are identical, but with ‘ror’ replaced by ‘cap’ and ‘pcap’ in all the names.

$E\_check\_EV\_FDI$  (all,s,HOME)

$$\begin{aligned} check\_EV\_FDI(s)= & yfdi\_h\_(s)-INCRATIO(s)* \\ & \{CNTror\_h\_(s)+CNTror\_h\_(s)+ \\ & CNTcap\_h\_(s)+CNTcap\_h\_(s)+ \\ & CNTpcap\_h\_(s)+CNTpcap\_h\_(s)\}; \end{aligned}$$

This equation checks that the welfare contributions from FDI, scaled by  $INCRATIO$ , sum to net FDI income  $yfdi\_h\_$ . The units of the checking variable  $check\_EV\_FDI$  are millions of US dollars.

Contribution terms for all three types of effects — rate of return, capital stock and asset price — ranging over (home, industry) and (host, industry) are also defined by summation (with scaling for host-oriented measures), for example:

$CONT\_EV\_ror\_hi$  (all,i,TRAD\_COMM)(all,d,host)

$$\begin{aligned} CNTror\_hi(i,d)= \\ -sum\{s,HOME,INCRATIO(s)/INCRATIO(d)*CNTror\_hhi(i,s,d)\}; \end{aligned}$$

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## 5 Supply side of FDI differentiated products

This chapter discusses the replacement of single (standard GTAP) industries with many industries based on ownership of capital — domestically-owned, or foreign-owned by home region. The input demand functions for the new industries are identical to the standard GTAP specification,<sup>1</sup> and the initial cost structures are identical to the associated GTAP industry (as described in Hanslow, Phamduc, Verikios and Welsh 1999). In a sense, the model extensions described here amount to just adding an extra dimension — home (owner) region — to all items in the standard GTAP industry demand equations.

Although the model features described in this chapter are very simple, their TABLO implementation — driven by concerns for computational efficiency — is among the most difficult parts of the FTAP model implementation. Consequently, this chapter, more than any other chapter, is largely about the computer implementation of FTAP, rather than primarily being a description of the conceptual model being implemented.

It is hoped that the description of the standard GTAP industry demand equations, presented in chapter 2 and appendix A, and the verbal discussion in this chapter, will provide a good picture of the model attributes for those who do not wish to pursue the implementation details.

The potential increase in computational burden caused by distinguishing domestic and foreign-owned industries can be seen from the following: if all such industries are represented in the model, the number of industries increases (relative to standard GTAP) by a factor equal to the number of regions plus 1 (20 in the case of FTAP).

But representing all possible domestic and foreign-owned industries in the model is wasteful. In the FTAP database there is no FDI for many industry, home and host combinations, and no FDI at all for some industries in particular regions. Hence, the

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<sup>1</sup> Intermediate inputs and the primary factor bundle are used in fixed proportions. There is CES substitution between the domestic and imported varieties of each intermediate input. There is CES substitution within the primary factor bundle.

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representation of all industries amounts to specifying many sets of input demand equations for which it is known that demands are zero!<sup>2</sup>

The incorporation of only those industries for which FDI is non-zero is accomplished through the use of GEMPACK set mappings. These allow each element of one set to be associated with one element of another set. Set mappings are used to associate the elements of the set of all domestic and foreign-owned industries in the world — a set called ‘IND’ in the FTAP TABLO code — with industry, host region and home region combinations.

This is best illustrated with an example.

Consider the case of two commodities (TRAD\_COMM={C1,C2}) and two regions (REG={R1,R2}). Table 5.1 illustrates the set mappings used in FTAP.

In the first column of the table all possible domestic and foreign-owned industries are listed (12 in total; home region is listed first, D means domestically-owned).

The entries in the second column are ‘yes’ or ‘no’ indicating whether the industry has a non-zero output.

The elements of the set IND associated with the industries in column one are listed in column three. Note that as commodity C1 in region R1 is produced entirely by domestically-owned firms (zero output for C1.R1.R1 and C1.R2.R1), industry C1.R1.D is not allocated an element in the set IND even though it has non-zero output.

The next three columns are the set mappings used in FTAP. The first mapping maps IND to TRAD\_COMM (the commodity being produced, what would be called *the* industry prior to the domestic/foreign split), the second maps IND to the associated home region in REG, and the third maps IND to the associated host region in REG.<sup>3</sup>

The final column is an array of zeroes and ones that identifies whether an industry is domestically-owned or foreign-owned (1 for foreign, 0 for domestic). This array is necessary since for composite regions (like the European Union, the Rest of Cairns Group and the Rest of World) intra-regional FDI is possible. For example, a French-owned firm operating in Germany is a foreign-owned industry with the European Union as both the host and home region. In the small example in table 5.1, region

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<sup>2</sup> Industries cannot come into existence, due to the functional form used in the asset supply functions (chapter 4 ).

<sup>3</sup> In the FTAP database a vector of integers defines a set mapping. The integers are the position in the target set of the element corresponding to the specified element of the input set. So the set mapping IND2COMM would be stored as the vector (2,1,2,2,1,2,1,2).

R2 is a composite region. Consequently the three set mappings produce identical results for I2 (corresponding to C1.R2.D) and I7 (corresponding to C1.R2.R2), but these two industries are distinguished by NOT\_DOM being equal to 0 and 1, respectively.

As the input demand equations for all industries spawned by the domestic/foreign split are indexed over set IND (rather than over sets TRAD\_COMM, HOME and HOST), they appear more like the equations from a single region model. Consequently, a portion of the code from the TABLO implementation of a single region model has been used as the basis for implementing these equations.

**Table 5.1 GEMPACK set mappings for domestic and foreign-owned industries**

<i>Industry</i>	<i>Non-zero output</i>	<i>IND</i>	<i>IND2COMM</i> <i>IND → TRAD_COMM</i>	<i>HOME_REG</i> <i>IND → REG</i>	<i>DEST_REG</i> <i>IND → REG</i>	<i>NOT_DOM</i>
C1.R1.D	Yes					
C2.R1.D	Yes	I1	C2	R1	R1	0
C1.R2.D	Yes	I2	C1	R2	R2	0
C2.R2.D	Yes	I3	C2	R2	R2	0
C1.R1.R1	No					
C2.R1.R1	No					
C1.R2.R1	No					
C2.R2.R1	Yes	I4	C2	R2	R1	1
C1.R1.R2	Yes	I5	C1	R1	R2	1
C2.R1.R2	Yes	I6	C2	R1	R2	1
C1.R2.R2	Yes	I7	C1	R2	R2	1
C2.R2.R2	Yes	I8	C2	R2	R2	1

---

The single region model used (adapted where necessary) was CRUSOE,<sup>4</sup> an ORANI-style model<sup>5</sup> that can operate with the data for a single region available from the GTAP database. The input data for all domestic and foreign-owned industries — domestic and imported intermediate inputs, commodity taxes, primary factor inputs and output taxes — are stored in the single-region IO-table format required by CRUSOE, as described in Hanslow, Phamduc, Verikios and Welsh (1999). The industry input equations from CRUSOE, as adapted for FTAP, are discussed in section 5.1.

The GEMPACK set mappings are crucial for integrating the CRUSOE-based and GTAP (or GTAP-style<sup>6</sup>) portions of FTAP. The integration occurs in three ways — two of which are critical to model operation, the third of which is not essential but convenient.

The first requirement is a one-to-one correspondence between the components of a CRUSOE variable and GTAP-style variables as a mechanism for passing CRUSOE variables into behavioural equations written in GTAP-style, or vice versa. An example of the former is equating CRUSOE industry output  $x1_{tot}$  with GTAP-style variables  $qod$  and  $qoh$  defining the quantities of FDI differentiated commodities from which demand is satisfied (chapter 6). An example of the latter is the equating of basic prices in CRUSOE (variable  $p0$ ) with GTAP market prices of domestic and imported goods (variables  $pds$  and  $pid$ , respectively). Equations performing this critical one-to-one correspondence function are described in section 5.2.

The second requirement is the equating of a GTAP variable (for example, domestically produced intermediate inputs  $qfd$ ) with an aggregate over components of CRUSOE variables (the domestic components of  $x1$  in this case). Even when they are just aggregates of CRUSOE variables, the standard GTAP industry variables have an importance in FTAP beyond their direct value as useful summary information. They play a role in the welfare decomposition for FTAP, which is largely expressed in terms of GTAP variables (being based on the GTAP welfare decomposition). Also, they can serve useful checking functions. For example, the GTAP output tax (variable  $to$ ) is determined by aggregation across CRUSOE variables (equation  $E_{to\_FDI}$ , section 5.3) and is used, via variable  $grsub1$ , as a check on the calculation of output tax revenue (in variable  $check\_grsub$  — see chapter 9). The value of such checking processes during model development cannot

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<sup>4</sup> The CRUSOE model is available with documentation at

<http://www.monash.edu.au/policy/crusoe.htm>.

<sup>5</sup> The ORANI model is described in Dixon et al. (1982).

<sup>6</sup> This means conventional multi-region variables and equations, dimensioned over sets such as  $TRAD\_COMM$  and  $REG$ .



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be over-emphasised. Equations performing this aggregation function are described in section 5.3.

The third way in which integration occurs is identical to the first except that the only role of the GTAP-style variables is for convenient reporting of results. As can be imagined, it is very difficult interpreting model output for variables indexed across the set IND. Such variables need to be reshaped to commodity and region dimensions to facilitate easy viewing. Equations defining such ‘convenience’ variables are described in section 5.4.

## **5.1 CRUSOE input demand equations for all domestic and foreign-owned industries**

### **Preliminaries**

Three adjustments must be made to the industry demand equations from CRUSOE to accommodate the FTAP set of industry inputs.

First, FTAP distinguishes skilled and unskilled labour, whereas CRUSOE does not. Therefore, demand equations for labour by skill level must be added, and the industry specific price of labour defined.

Second, FTAP has a primary factor called natural resources which is absent from CRUSOE. Therefore, a demand equation for natural resources (equation E\_p1nr) is added.

Third, the CRUSOE specification of each industry’s ‘other costs’ — a typical feature of ORANI-type models — has been replaced by the FTAP treatment of other costs as an output tax (or impediment). Precisely, variables  $p_{loct}$  and  $x_{loct}$  — the price and quantity of other costs, respectively — have been dropped, and a new variable  $p_{rloct}$  — the percentage change in the ratio of total industry costs to industry costs less other costs — has been introduced. Plainly,  $p_{rloct}$  is the percentage change in the power of the output tax. CRUSOE equations and updates have been rewritten in terms of  $p_{rloct}$ . The evolution of other costs throughout the policy simulation is re-expressed as a function of  $p_{rloct}$  in the FTAP update statement:

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(Change)(all,i,IND)

$$V1OCT(i) = \{ V1OCT(i) * [p1tot(i) + x1tot(i)] + \\ [V1TOT(i) - V1OCT(i)] * p_r1oct(i) \} / 100;$$

where V1OCT(i) is the output tax revenue or output impediment rent associated with industry i.

As the industry input demand functions of CRUSOE are identical to standard GTAP, it may be helpful to list corresponding variables and equations from each equation set. Corresponding variables are shown in table 5.2, and equations are shown in table 5.3.

Note that table 5.2 is *not* saying that the associated variables are equal in FTAP. It is saying that they perform identical *functions* in the CRUSOE (used in FTAP) and standard GTAP (overridden in FTAP as required — see section 5.3) industry input demand equations.

It is clear that sometimes one CRUSOE variable plays the role of more than one GTAP variable (for example, x1 for qfd and qfm) and vice versa. Therefore, sometimes one CRUSOE equation will correspond to more than one GTAP equation and vice versa. This will be clear from table 5.3.

The values of the substitution elasticities used in the CRUSOE demand equations are equal to the values used in the corresponding GTAP equations, thus:

$$(all,i,IND) \text{ SIGMA1PRIM}(i) = \text{ESUBVA}(\text{IND2COMM}(i))$$

for primary factor substitution and

$$(all,c,COM) \text{ SIGMA1}(c) = \text{ESUBD}(c)$$

for domestic/import substitution.

CRUSOE does not include as many technical efficiency variables as GTAP — only total primary factor augmenting (variable a1prim, corresponding to GTAP variable ava) and output augmenting (variable a1tot, corresponding to GTAP variable ao). There are no input specific technical efficiency variables, but these could be easily added if required.

**Table 5.2 Variables with identical functions in CRUSOE and standard GTAP industry demand equations**

<i>Description</i>	<i>CRUSOE variable</i>	<i>GTAP variable</i>
Industry output	x1tot	qo
Market (output tax inclusive) price of output	p1tot	pm
Agents' (output tax exclusive) price of output	p1tot_eo	ps
Demand for intermediate inputs	x1_s	qf
Purchasers' price of intermediate inputs	p1_s	pf
Demand for domestically produced intermediate inputs	x1(•,"dom",•)	qfd
Purchasers' price of domestically produced intermediate inputs	p1(•,"dom",•)	pdf
Demand for imported intermediate inputs	x1(•,"imp",•)	qfm
Purchasers' price of imported intermediate inputs	p1(•,"imp",•)	pfm
Demand for primary factor bundle	x1prim	qva
Price of primary factor bundle	p1prim	pva
Demand for skilled labour	x1lab_s(•,"SkLab")	qfe("SkLab",•,•)
Demand for unskilled labour	x1lab_s(•,"UnSkLab")	qfe("UnSkLab",•,•)
Demand for capital	x1cap	qfe("capital",•,•)
Demand for land	x1lnd	qfe("land",•,•)
Demand for natural resources	x1nr	qfe("NatRes",•,•)
Price to industry of skilled labour	p1lab_s(•,"SkLab")	pfe("SkLab",•,•)
Price to industry of unskilled labour	p1lab_s(•,"UnSkLab")	pfe("UnSkLab",•,•)
Price to industry of capital	p1cap	pfe("capital",•,•)
Price to industry of land	p1lnd	pfe("land",•,•)
Price to industry of natural resources	p1nr	pfe("NatRes",•,•)

**Table 5.3 Equations with identical functions in CRUSOE and standard GTAP industry demand equations**

<i>Description</i>	<i>CRUSOE equation(s)</i>	<i>GTAP equation(s)</i>
Demand for intermediate inputs	E_x1_s	INTDEMAND
Demand for intermediate inputs by source	E_x1	INDDOM, INDIMP
Price of intermediate inputs	E_p1_s	ICOMPRICE
Price of intermediate inputs by source	E_p1	DMNDDPRICE, DMNDIPRICES
Demand for primary factor bundle	E_x1prim	VADEMAND
Demand for individual primary factors	E_x1lab_s + E_x1lab, E_p1cap, E_p1lnd, E_p1nr	ENDWDEMAND
Price of primary factor bundle	E_p1prim	VAPRICE

---

## The equations

Equation E\_p1tot #Zero pure profits in production # (all,i,IND)

$$\begin{aligned} & (TINY+V1TOT(i))*\{p1tot(i)+x1tot(i)-f\_p1tot(i)\}= \\ & \text{Sum}(c,COM,V1PUR\_S(c,i)*\{p1\_s(c,i)+x1\_s(c,i)\}) \\ & +V1PRIM(i)*\{p1prim(i)+x1prim(i)\}+ \\ & \{V1OCT(i)*[p1tot(i)+x1tot(i)]+[V1TOT(i)-V1OCT(i)]*p\_r1oct(i)\}; \end{aligned}$$

Equation E\_p1tot\_eo #Other costs exclusive price of output# (all,i,IND)

$$\begin{aligned} & (TINY+V1TOT\_EO(i))*\{p1tot\_eo(i)+x1tot(i)\}= \\ & V1TOT(i)*\{p1tot(i)+x1tot(i)\}- \\ & \{V1OCT(i)*[p1tot(i)+x1tot(i)]+[V1TOT(i)-V1OCT(i)]*p\_r1oct(i)\}; \end{aligned}$$

These equations define what would, in GTAP terminology, be called market and agents' prices of output, respectively. The first equation is the zero pure profit condition for each domestic and foreign-owned industry. It is the linearisation of the relationship that equates the market (output tax inclusive) value of industry output with the total of industry costs — the cost of intermediate inputs (coefficient V1PUR\_S), the cost of primary factors (coefficient V1PRIM) and output taxes (CRUSOE 'other costs', coefficient V1OCT). It includes a slack variable f\_p1tot (similar to the slack variable profitslack in the standard GTAP zero pure profit condition) that allows the equation to be turned off by a closure change if required. The second equation defines the agents' (producers') value of output as the difference of the market value and other costs, that is, output tax revenue.

Equation E\_x1\_s #Demands for Commodity Composites # (all,c,COM)(all,i,IND)

$$x1\_s(c,i)-a1tot(i)=x1tot(i);$$

Equation E\_x1prim #Demands for primary factor composite # (all,i,IND)

$$x1prim(i)-a1prim(i)-a1tot(i)=x1tot(i);$$

Equation E\_p1\_s #Effective Price of Commodity Composite #

(all,c,COM)(all,i,IND)

$$p1\_s(c,i)=\text{Sum}(s,Src,S1(c,s,i)*\{p1(c,s,i)\});$$

---

Equation E\_p1prim #Effective price term for factor demand equations #(all,i,IND)

$$(TINY+V1PRIM(i))*p1prim(i)=$$

$$V1LAB(i)*\{p1lab(i)\}+V1CAP(i)*\{p1cap(i)\}+V1LND(i)*\{p1lnd(i)\}+$$

$$V1NR(i)*\{p1nr(i)\};$$

The first two equations specify a Leontief demand function for intermediate inputs (variable x1\_s) and total primary factors (variable x1prim), respectively. The technical efficiency variables a1prim and a1tot govern per unit input requirements. Note the (ORANI) convention that positive shocks to the technical efficiency variables correspond to declines in efficiency.

The third and fourth equations calculate the prices associated with the quantities determined in the first two equations — the prices of intermediate inputs (variable p1\_s) and the price of the primary factor bundle (variable p1prim), respectively. The prices are share-weighted sums of the prices of constituents — the prices of the domestic and imported varieties of a commodity (variable p1) and individual primary factor prices, respectively.

Equation E\_x1 #Source - Specific Commodity Demands #

(all,c,COM)(all,s,SRC)(all,i,IND)

$$x1(c,s,i)=x1\_s(c,i)-SIGMA1(c)*\{p1(c,s,i)-p1\_s(c,i)\};$$

Equation E\_p1 #purchasers prices - producers # (all,c,COM)(all,s,SRC)(all,i,IND)

$$p1(c,s,i)=p0(c,s,i)+t1(c,s,i);$$

The first equation is the CES demand function for the domestic and imported varieties of each commodity. The second equation defines the purchasers' price of a commodity as the basic price plus the commodity tax.

Equation E\_x1lab #Industry demands for effective labour #

(all,i,IND) x1lab(i) =

$$x1prim(i)-SIGMA1PRIM(i)*\{p1lab(i)-p1prim(i)\};$$

Equation E\_p1cap #Industry demands for capital # (all,i,IND)

$$x1cap(i)=x1prim(i)-SIGMA1PRIM(i)*\{p1cap(i)-p1prim(i)\};$$

Equation E\_p1lnd #Industry demands for land # (all,i,IND)

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$$x1lnd(i)=x1prim(i)-SIGMA1PRIM(i)*\{p1lnd(i)-p1prim(i)\};$$

Equation E\_p1nr #Industry demands for natural resources# (all,i,IND)

$$x1nr(i)=x1prim(i)-SIGMA1PRIM(i)*\{p1nr(i)-p1prim(i)\};$$

These equations are the CES demand equations for labour, capital, land and natural resources, respectively. The first three equations are in the original CRUSOE model, the last equation is an addition for FTAP. The last three equations are named after prices rather than quantities. This is done because in the standard closure for the CRUSOE model, capital and land (and presumably natural resources if they were present) are fixed in each industry, so the demand equations serve to determine the corresponding prices.

Equation E\_x1lab\_s #Industry demands for skilled and unskilled labour#

(all,i,IND)(all,l,LABOR)

$$x1lab\_s(i,l)=x1lab(i)-SIGMA1PRIM(i)*\{p1lab\_s(i,l)-p1lab(i)\};$$

Equation E\_p1lab #Industry specific wage# (all,i,IND)

$$\{TINY+V1LAB(i)\}*p1lab(i)=sum[l,LABOR,V1LAB\_S(i,l)*p1lab\_s(i,l)];$$

These two equations are added in FTAP to the standard CRUSOE equations to accommodate the demand for labour by skill level. The first equation determines the demand for labour by skill level (variable  $x1lab\_s$ ), while the second equation defines the industry specific price of labour (variable  $p1lab$ ) as a composite of skill level specific prices (variable  $p1lab\_s$ ). Total labour (variable  $x1lab$ ) is defined as a CES composite of the two skill levels. However, since the substitution elasticity between skill levels is the same as between all other primary factors, the choice between all primary factors is CES — as in standard GTAP.

## 5.2 Integration of CRUSOE and GTAP code — one-to-one correspondence equations

### Preliminaries

The equations in this section equate components of CRUSOE variables with components of GTAP-style variables using the GEMPACK set mappings IND2COMM, HOME\_REG and DEST\_REG.

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While this is an accurate description of the function of the equations, their appearance will differ depending on how they have been expressed. The equations take one of two forms, which can be stylised as

(all,i,IND)

crusoe\_var(i)=

$$\begin{aligned} & \text{IF}[(\text{NOT\_DOM}(i)=1) \text{ or } (\text{HOME\_REG}(i) \text{ ne } \text{DEST\_REG}(i)), \\ & \quad \text{foreign\_gtap\_var}(\text{IND2COMM}(i), \text{HOME\_REG}(i), \text{DEST\_REG}(i))] + \\ & \text{IF}[(\text{NOT\_DOM}(i)=0) \text{ and } (\text{HOME\_REG}(i) \text{ eq } \text{DEST\_REG}(i)), \\ & \quad \text{domestic\_gtap\_var}(\text{IND2COMM}(i), \text{HOME\_REG}(i), \text{DEST\_REG}(i))]; \end{aligned}$$

for equations that range over the CRUSOE set IND, and

(all,i,TRAD\_COMM)(all,h,HOME)(all,d,HOST)

foreign\_gtap\_var(i,o,l)=

$$\begin{aligned} & \text{sum}[j, \text{IND}: \quad (\text{IND2COMM}(j) \text{ eq } i) \text{ and } (\text{HOME\_REG}(j) \text{ eq } h) \text{ and} \\ & \quad (\text{DEST\_REG}(j) \text{ eq } d) \text{ and } (\text{NOT\_DOM}(j)=1), \\ & \quad \text{crusoe\_var}(j)]; \end{aligned}$$

for equations that range over GTAP sets such as TRAD\_COMM and (the various aliases of) REG. Only the foreign-owned version of the second form of equation is shown, but the domestic version likewise employs a conditional sum over a CRUSOE variable.

In the first form of equation, there are two GTAP-style variables, one related to domestically-owned industries and the other to foreign-owned industries. The IF conditions identify whether industry i is domestic or foreign-owned.

In the second form of equation, the sum on the right hand side has at most one term. The conditions in the sum use the set mappings to pick out the element of set IND (if any) corresponding to each component of the GTAP-style variable.

**Table 5.4 CRUSOE and GTAP-style variables the components of which are equated**

<i>Description</i>	<i>CRUSOE variable(s)</i>	<i>GTAP-style variable(s)</i>
Industry output	x1tot	qod, qoh
Market (output tax inclusive) price of output	p1tot	pod, poh
Agents' (output tax exclusive) price of output	p1tot_eo	psd, psh
Purchasers' price of intermediate inputs by source	p1	pdf, pfm
Basic price of intermediate inputs by source	p0	pds, pid
Demand by industries for capital	x1cap	qfed, qfes
Rental price paid by industries for capital	p1cap	pfeda, pfesa
Prices of primary factors other than capital	p1lab_s, p1lnd, p1nr	pfe
Power of the output tax	p_r1oct	tod, tof, remotaxd, remotaxf
Output augmenting technical efficiency (section 5.4)	a1tot	a1tot_d, a1tot_f

In the equations listed below, up to two enhancements are made to the second form of equation. First, price variables for null industries are set equal to the numeraire (variable pfactwld) to ensure a clean price homogeneity test. Second, domestic GTAP-style variables (such as variable pod) are set equal to their standard GTAP counterpart (variable pm in this case) for industries which are entirely domestically-owned, that is, which have not been split into domestic and foreign-owned. This is indicated by a value of zero for the corresponding component of coefficient FDI\_FLAG1.

Table 5.4 lists all one-to-one correspondences between CRUSOE and GTAP-style variables.

### The equations

$E_{psd}(all,i,TRAD\_COMM)(all,r,REG)$

$psd(i,r)-pfactwld=$

$sum[j,IND: (IND2COMM(j) eq i) and (HOME\_REG(j) eq r) and$

$(DEST\_REG(j) eq r) and (NOT\_DOM(j)=0),$

$p1tot\_eo(j)-pfactwld]+$

$IF[FDI\_FLAG1(i,r)=0,ps(i,r)-pfactwld];$



---

E\_pod (all,i,TRAD\_COMM)(all,r,REG)

pod(i,r)-pfactwld=

sum[j,IND: (IND2COMM(j) eq i) and (HOME\_REG(j) eq r) and  
(DEST\_REG(j) eq r) and (NOT\_DOM(j)=0),

p1tot(j)-pfactwld]+

IF[FDI\_FLAG1(i,r)=0,pm(i,r)-pfactwld];

E\_psh (all,i,TRAD\_COMM)(all,h,HOME)(all,d,host)

psh(i,h,d)-pfactwld=

sum[j,IND: (IND2COMM(j) eq i) and (HOME\_REG(j) eq h) and  
(DEST\_REG(j) eq d) and (NOT\_DOM(j)=1),

p1tot\_eo(j)-pfactwld];

E\_poh (all,i,TRAD\_COMM)(all,h,HOME)(all,d,host)

poh(i,h,d)-pfactwld=

sum[j,IND: (IND2COMM(j) eq i) and (HOME\_REG(j) eq h) and  
(DEST\_REG(j) eq d) and (NOT\_DOM(j)=1),

p1tot(j)-pfactwld];

The equations define GTAP-style variables for, respectively, agents' and market prices of output for domestically-owned industries, and agents' and market prices of output for foreign-owned industries.

E\_x1tot (all,i,IND)

x1tot(i) = IF{NOT\_DOM(i)=0,qod(IND2COMM(i),DEST\_REG(i))}+  
IF{NOT\_DOM(i)=1,  
qoh(IND2COMM(i),HOME\_REG(i),DEST\_REG(i))};

The equation ties together CRUSOE and GTAP-style industry output variables.

E\_p0 #Define basic prices p0 in terms of pds and pid#

---

(all,c,COM)(all,s,SRC)(all,i,IND)

$$p0(c,s,i) = \text{IF}\{\text{IS\_DOM}(s)=1,\text{pds}(c,\text{DEST\_REG}(i))\}+ \\ \text{IF}\{\text{IS\_DOM}(s)=0,\text{pid}(c,\text{DEST\_REG}(i))\};$$

E\_t1 #Define purchasers prices p1 in terms of pfd and pfm#

(all,c,COM)(all,s,SRC)(all,i,IND)

$$p1(c,s,i) = \text{IF}\{\text{IS\_DOM}(s)=1,\text{pfd}(c,\text{IND2COMM}(i),\text{DEST\_REG}(i))\}+ \\ \text{IF}\{\text{IS\_DOM}(s)=0,\text{pfm}(c,\text{IND2COMM}(i),\text{DEST\_REG}(i))\};$$

These equations tie together CRUSOE and GTAP-style variables for basic and purchasers' prices of intermediate inputs, respectively. Two features are noteworthy. First, the CRUSOE basic price variable  $p0$  has a dimension over IND, in contrast to standard CRUSOE. This is because the set IND ranges over industries located in different regions, and basic prices vary between regions. Second, the second equation is named E\_t1 as it determines the CRUSOE variable t1 (taxes on intermediate inputs), which is exogenous in standard CRUSOE. There is already a CRUSOE equation E\_p1 that defines  $p1$  to be the sum of  $p0$  and t1 (section 5.1). Equating CRUSOE purchasers' prices with GTAP purchasers' prices implies that taxes on intermediate inputs are uniform within a region across all industries producing the same commodity. Thus variable t1 is forced to be equal to GTAP variables tfd and tfm.

E\_p\_r1oct (all,i,IND)

$$\text{R1OCT}(i)*\text{p\_r1oct}(i)= \\ \text{IF}\{(\text{NOT\_DOM}(i)=1) \text{ or } (\text{HOME\_REG}(i) \text{ ne } \text{DEST\_REG}(i)), \\ \text{R1OCT}(i)*\text{tof}(\text{IND2COMM}(i),\text{HOME\_REG}(i),\text{DEST\_REG}(i))+ \\ [1-\text{R1OCT0}(i)]* \\ \text{remotaxf}(\text{IND2COMM}(i),\text{HOME\_REG}(i),\text{DEST\_REG}(i))\}+ \\ \text{IF}\{(\text{NOT\_DOM}(i)=0) \text{ and } (\text{HOME\_REG}(i) \text{ eq } \text{DEST\_REG}(i)), \\ \text{R1OCT}(i)*\text{tod}(\text{IND2COMM}(i),\text{HOME\_REG}(i))+ \\ [1-\text{R1OCT0}(i)]*\text{remotaxd}(\text{IND2COMM}(i),\text{HOME\_REG}(i))\};$$

---

This equation equates CRUSOE and GTAP-style output tax variables. It is easier to understand if the equation is written without the remotax\* terms. The coefficients R1OCT(i) then cancel from both sides of the equation and it becomes

$$\begin{aligned}
 p\_r1oct(i) = & \\
 & IF\{(NOT\_DOM(i)=1) \text{ or } (HOME\_REG(i) \neq DEST\_REG(i)), \\
 & \quad \text{tof}(IND2COMM(i),HOME\_REG(i),DEST\_REG(i))\} + \\
 & IF\{(NOT\_DOM(i)=0) \text{ and } (HOME\_REG(i) \text{ eq } DEST\_REG(i)), \\
 & \quad \text{tod}(IND2COMM(i),HOME\_REG(i))\};
 \end{aligned}$$

It is now easy to see that the CRUSOE power of the output tax variable p\_r1oct is linked to its GTAP-style counterparts tod and tof. The remotax\* variables in the original equation are introduced to allow easier application of policy shocks. The name remotaxd (remotaxf) stands for **remove** output tax for **domestic** (foreign-owned) industries. A shock of 100 completely removes an output tax. A shock of 50 reduces the output tax rate to half of its initial level. The two coefficients R1OCT and R1OCT0 are required for incorporating the remotax\* terms into equation E\_p\_r1oct. The coefficient R1OCT is the ratio of total industry costs to total industry costs less output tax revenue. It is the level counterpart of the percentage change variable p\_r1oct. The coefficient R1OCT0 is the initial value of R1OCT and remains constant throughout a policy simulation.

E\_x1cap (all,i,IND)

$$\begin{aligned}
 x1cap(i) = & \\
 & IF[NOT\_DOM(i)=1, \\
 & \quad \text{qfes}(IND2COMM(i),HOME\_REG(i),DEST\_REG(i))] + \\
 & IF[NOT\_DOM(i)=0, \text{qfed}(IND2COMM(i),HOME\_REG(i))];
 \end{aligned}$$

This equation equates the CRUSOE and GTAP-style demand for capital variables.

E\_qfes (all,c,TRAD\_COMM)(all,s,home)(all,d,host)

$$\begin{aligned}
 p\_fesa(c,s,d) - p\_factwld = & \\
 & \text{sum}[i,IND:(IND2COMM(i) \text{ eq } c) \text{ and } (HOME\_REG(i) \text{ eq } s) \text{ and} \\
 & (DEST\_REG(i) \text{ eq } d) \text{ and } (NOT\_DOM(i)=1),
 \end{aligned}$$

---


$$p1cap(i)-pfactwld];$$

$$E\_qfed (all,c,TRAD\_COMM)(all,r,REG)$$

$$IF\{FDI\_FLAG1(c,r)>0,$$

$$pfeda(c,r)-pfactwld-$$

$$\text{sum}[i,IND: (IND2COMM(i) eq c) \text{ and } (HOME\_REG(i) eq r) \text{ and}$$

$$(DEST\_REG(i) eq r) \text{ and } (NOT\_DOM(i)=0),$$

$$p1cap(i)-pfactwld] \} =$$

$$IF\{FDI\_FLAG1(c,r)=0,qfed(c,r)-\text{sum}[k,ENDWC\_COMM,qfe(k,c,r)]\};$$

These equations tie together the CRUSOE and GTAP-style rental prices paid by domestic and foreign-owned industries, respectively, for capital. Note that as the function of these equations is to determine the demand for capital (hence the equation names  $E\_qfes$  and  $E\_qfed$ ), in equation  $E\_qfed$  the demand for capital has been equated with its standard GTAP counterpart when no FDI is present.

$$E\_p1lab\_s (all,i,IND)(all,l,LABOR)$$

$$p1lab\_s(i,l)=pfe(l,IND2COMM(i),DEST\_REG(i));$$

$$E\_x1lnd (all,i,IND)$$

$$p1lnd(i)=\text{sum}[l,LAND,pfe(l,IND2COMM(i),DEST\_REG(i))];$$

$$E\_x1nr (all,i,IND)$$

$$p1nr(i)=\text{sum}[l,NATRES,pfe(l,IND2COMM(i),DEST\_REG(i))];$$

These equations tie together the CRUSOE and GTAP-style prices paid by industries for labour, land and natural resources, respectively. These primary factors are considered to be mobile, within a region, between all industries producing the same commodity. Consequently, the price of any one of these primary factors is uniform across those industries. Further, there are no counterparts to equation  $E\_x1cap$  for these primary factors, as only capital is specific to each industry represented in the set IND.

## 5.3 Integration of CRUSOE and GTAP code — redefinition of GTAP variables as aggregates of CRUSOE variables

### Preliminaries

The equations discussed in this section fall into two categories.

The first category is those equations in which standard GTAP industry input variables are *redefined* as aggregates, as necessitated by the domestic/foreign split.

The second category is extra equations that do not replace existing GTAP equations. These lead to some previously exogenous GTAP variables becoming endogenous. Their function is to ensure that the original GTAP industry — a sum of domestic and foreign-owned industries — behaves consistently with its parts. For example, the GTAP output tax (variable *to*) associated with the production of each commodity becomes endogenous as its value is determined by output taxes across all domestic and foreign-owned industries producing that commodity.

The equations in this section must accommodate two possibilities, depending on whether or not both domestic and foreign-owned firms produce a commodity. As illustrated in table 5.1, not all industries are represented in the set IND, only those arising from the domestic/foreign split. The standard GTAP equations continue to determine the components of GTAP industry variables (such as *qf*, *qfd* and *qfm*) associated with industries that are totally domestically-owned (such as industry C1.R1.D in table 5.1). Therefore, the FTAP equations for these variables must cover two cases — where the standard GTAP equation continues to operate, and where aggregation across CRUSOE variables occurs.

These FTAP equations can be stylised as

$$\begin{aligned} X(i,r) &= f(G(i,r)) && \text{if } Y_F(i,r) = 0 \\ &= \sum_{\{j: j \in \text{IND}, I(j)=i, D(j)=r\}} C_X(j) && \text{if } Y_F(i,r) \neq 0 \end{aligned}$$

where  $X$  is a GTAP industry variable associated with the production of commodity  $i$  in region  $r$ ,  $Y_F$  is the output of the foreign-owned part of the industry producing commodity  $i$  in region  $r$ ,  $G$  is a collection of GTAP variables upon which  $X$  depends via the (standard GTAP) function  $f$  and  $C_X$  is the CRUSOE variable the components of which sum to  $X$  when the domestic/foreign split applies.  $I(\cdot)$  and  $D(\cdot)$  are the set mappings IND2COMM and DEST\_REG, respectively.

**Table 5.5 Standard GTAP variables that are equated with aggregates across CRUSOE variables**

<i>Description</i>	<i>GTAP variable(s)</i>	<i>CRUSOE variable(s)</i>
Industry output	qo	x1tot <sup>a</sup>
Market (output tax inclusive) price of output	pm	p1tot
Demand for primary factor bundle	qva	x1prim
Demand for primary factors	qfe	x1lab_s, x1cap, x1lnd, x1nr
Demand for intermediate inputs	qf	x1_s
Purchasers' price of intermediate inputs	pf	p1_s
Demand for intermediate inputs by source	qfd, qfm	x1

<sup>a</sup> In the TABLO equation defining qo, the summation involves qod and qoh, but it could be written in terms of x1tot given the equivalence between x1tot and qod and qoh (table 5.4).

In the FTAP TABLO code the two parts of the above equation are welded together using conditionals. The coefficient FDI\_FLAG1 plays the role of  $Y_F$ . When the equation is a redefinition of a GTAP variable, new variables are defined to be equal to the CRUSOE-based expression on the second line. The names of these variables have 'f\_' prefixed to the name of the GTAP variable to which they are related — for example, 'f\_qfd' for 'qfd'. The FTAP equation sets, for example, qfd equal to the GTAP expression for qfd if FDI\_FLAG1=0, and equal to f\_qfd otherwise.

Table 5.5 lists all redefined GTAP variables.

### The equations

E\_f\_qf (all,c,TRAD\_COMM)(all,i,FDI\_COMM)(all,r,FDI\_DEST)

$$\begin{aligned} & \text{VFA}(c,i,r)*f\_qf(c,i,r)= \\ & \text{sum}\{j,\text{IND}:(\text{DEST\_REG}(j) \text{ eq } r) \text{ and } (\text{IND2COMM}(j) \text{ eq } i), \\ & \quad \text{VIPUR\_S}(c,j)*x1\_s(c,j)\}; \end{aligned}$$

E\_f\_pf (all,c,TRAD\_COMM)(all,i,FDI\_COMM)(all,r,FDI\_DEST)

$$\begin{aligned} & [\text{VFA}(c,i,r)+\text{IF}(\text{VFA}(c,i,r)=0,1)]*[f\_pf(c,i,r)-\text{pfactwld}]= \\ & \text{sum}\{j,\text{IND}:(\text{DEST\_REG}(j) \text{ eq } r) \text{ and } (\text{IND2COMM}(j) \text{ eq } i), \\ & \quad \text{VIPUR\_S}(c,j)*[p1\_s(c,j)-\text{pfactwld}]\}; \end{aligned}$$

E\_f\_qfd (all,c,TRAD\_COMM)(all,i,FDI\_COMM)(all,r,FDI\_DEST)

---

$$\text{VDFM}(c,i,r)*f\_qfd(c,i,r)=$$

$$\text{sum}[j,\text{IND}:(\text{DEST\_REG}(j) \text{ eq } r) \text{ and } (\text{IND2COMM}(j) \text{ eq } i),$$

$$\text{V1BAS}(c,"dom",j)*x1(c,"dom",j)];$$

$$\text{E\_f\_qfm}(\text{all},c,\text{TRAD\_COMM})(\text{all},i,\text{FDI\_COMM})(\text{all},r,\text{FDI\_DEST})$$

$$\text{VIFM}(c,i,r)*f\_qfm(c,i,r)=$$

$$\text{sum}[j,\text{IND}:(\text{DEST\_REG}(j) \text{ eq } r) \text{ and } (\text{IND2COMM}(j) \text{ eq } i),$$

$$\text{V1BAS}(c,"imp",j)*x1(c,"imp",j)];$$

$$\text{E\_f\_qva}(\text{all},i,\text{FDI\_COMM})(\text{all},r,\text{FDI\_DEST})$$

$$\text{VVA}(i,r)*f\_qva(i,r)=$$

$$\text{sum}\{j,\text{IND}:(\text{DEST\_REG}(j) \text{ eq } r) \text{ and } (\text{IND2COMM}(j) \text{ eq } i),$$

$$\text{V1PRIM}(j)*x1\text{prim}(j)\};$$

$$\text{E\_f\_qfel}(\text{all},c,\text{LABOR})(\text{all},i,\text{FDI\_COMM})(\text{all},r,\text{FDI\_DEST})$$

$$\text{EVFA}(c,i,r)*[\text{pfe}(c,i,r)+f\_qfel(c,i,r)-\text{pfactwld}]=$$

$$\text{sum}\{j,\text{IND}:(\text{DEST\_REG}(j) \text{ eq } r) \text{ and } (\text{IND2COMM}(j) \text{ eq } i),$$

$$\text{V1LAB\_S}(j,c)*[\text{p1lab\_s}(j,c)+x1\text{lab\_s}(j,c)-\text{pfactwld}]\};$$

$$\text{E\_f\_qfek}(\text{all},c,\text{ENDWC\_COMM})(\text{all},i,\text{FDI\_COMM})(\text{all},r,\text{FDI\_DEST})$$

$$\text{EVFA}(c,i,r)*f\_qfek(c,i,r)=$$

$$\text{sum}\{j,\text{IND}:(\text{DEST\_REG}(j) \text{ eq } r) \text{ and } (\text{IND2COMM}(j) \text{ eq } i),$$

$$\text{V1CAP}(j)*x1\text{cap}(j)\};$$

$$\text{E\_f\_qfen}(\text{all},c,\text{LAND})(\text{all},i,\text{FDI\_COMM})(\text{all},r,\text{FDI\_DEST})$$

$$\text{IF}[\text{EVFA}(c,i,r)=0,f\_qfen(c,i,r)]=$$

$$\text{IF}[\text{EVFA}(c,i,r) \text{ ne } 0,$$

$$\text{EVFA}(c,i,r)*[\text{pfe}(c,i,r)+f\_qfen(c,i,r)-\text{pfactwld}]-$$

$$\text{sum}\{j,\text{IND}:(\text{DEST\_REG}(j) \text{ eq } r) \text{ and } (\text{IND2COMM}(j) \text{ eq } i),$$

---


$$V1LND(j)*[p1lnd(j)+x1lnd(j)-pfactwld] ]];$$

E\_f\_qfenr (all,c,NATRES)(all,i,FDI\_COMM)(all,r,FDI\_DEST)

$$IF[EVFA(c,i,r)=0,f_qfenr(c,i,r)=$$

$$IF[EVFA(c,i,r) \neq 0,$$

$$EVFA(c,i,r)*[pfe(c,i,r)+f_qfenr(c,i,r)-pfactwld]-$$

$$\text{sum}\{j,IND:(DEST\_REG(j) \text{ eq } r) \text{ and } (IND2COMM(j) \text{ eq } i),$$

$$V1NR(j)*[p1nr(j)+x1nr(j)-pfactwld] ]];$$

The equations all define ‘f\_’ variables — aggregations across CRUSOE variables — described in the preliminaries. The equations define the ‘f\_’ variables for:

- the demand for intermediate inputs of each commodity;
- the price of intermediate inputs of each commodity;
- the demand for intermediate inputs of each domestically produced commodity;
- the demand for intermediate inputs of each imported commodity;
- the demand for aggregate primary factors; and
- the demands for labour, capital, land and natural resources.

Note how the equations defining prices have been constructed to equate the price with the numeraire (variable pfactwld) in the presence of zero data. The variable f\_qva is not actually used to redefine qva. The only uses of qva in FTAP involve components of qva that are determined by the standard GTAP equation VADEMAND.

INTDEMAND (all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

$$qf(i,j,r)=$$

$$IF\{FDI\_FLAG1(j,r)=0,$$

$$-af(i,j,r)+qo(j,r)-ao(j,r)-ESUBT(j)*[pf(i,j,r)-af(i,j,r)-ps(j,r)]\}+$$

$$IF\{FDI\_FLAG1(j,r) \neq 0,f\_qf(i,PROD2FDI(j),REG2FDI(r))\} ;$$

ICOMPRICE (all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

$$pf(i,j,r)=$$

$$IF\{FDI\_FLAG1(j,r)=0,$$



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$$\begin{aligned}
& \text{FMSHR}(i,j,r)*\text{pfm}(i,j,r)+[1-\text{FMSHR}(i,j,r)]*\text{pfd}(i,j,r)+ \\
& \text{IF}\{\text{FDI\_FLAG1}(j,r) \text{ ne } 0, \text{f\_pf}(i,\text{PROD2FDI}(j),\text{REG2FDI}(r))\}; \\
\text{INDDOM} & (\text{all},i,\text{TRAD\_COMM})(\text{all},j,\text{PROD\_COMM})(\text{all},s,\text{REG}) \\
\text{qfd}(i,j,s) & = \\
& \text{IF}\{\text{FDI\_FLAG1}(j,s)=0, \\
& \quad \text{qf}(i,j,s)-\text{ESUBD}(i)*[\text{pfd}(i,j,s)-\text{pf}(i,j,s)]\}+ \\
& \text{IF}\{\text{FDI\_FLAG1}(j,s) \text{ ne } 0, \text{f\_qfd}(i,\text{PROD2FDI}(j),\text{REG2FDI}(s))\}; \\
\text{INDIMP} & (\text{all},i,\text{TRAD\_COMM})(\text{all},j,\text{PROD\_COMM})(\text{all},s,\text{REG}) \\
\text{qfm}(i,j,s) & = \\
& \text{IF}\{\text{FDI\_FLAG1}(j,s)=0, \\
& \quad \text{qf}(i,j,s)-\text{ESUBD}(i)*[\text{pfm}(i,j,s)-\text{pf}(i,j,s)]\}+ \\
& \text{IF}\{\text{FDI\_FLAG1}(j,s) \text{ ne } 0, \text{f\_qfm}(i,\text{PROD2FDI}(j),\text{REG2FDI}(s))\}; \\
\text{ENDWDEMAND} & (\text{all},i,\text{ENDW\_COMM})(\text{all},j,\text{PROD\_COMM})(\text{all},r,\text{REG}) \\
\text{qfe}(i,j,r) & = \\
& \text{IF}\{\text{FDI\_FLAG1}(j,r)=0, \\
& \quad -\text{afe}(i,j,r)+\text{qva}(j,r)-\text{ESUBVA}(j)*[\text{pfe}(i,j,r)-\text{afe}(i,j,r)-\text{pva}(j,r)]\}+ \\
& \text{IF}\{\text{FDI\_FLAG1}(j,r) \text{ ne } 0, \\
& \quad \text{sum}[k,\text{LABOR}:k \text{ eq } i, \text{f\_qfel}(k,\text{PROD2FDI}(j),\text{REG2FDI}(r))] + \\
& \quad \text{sum}[k,\text{ENDWC\_COMM}:k \text{ eq } i, \text{f\_qfek}(k,\text{PROD2FDI}(j),\text{REG2FDI}(r))] + \\
& \quad \text{sum}[k,\text{LAND}:k \text{ eq } i, \text{f\_qfen}(k,\text{PROD2FDI}(j),\text{REG2FDI}(r))] + \\
& \quad \text{sum}[k,\text{NATRES}:k \text{ eq } i, \text{f\_qfenr}(k,\text{PROD2FDI}(j),\text{REG2FDI}(r))]\};
\end{aligned}$$

These equations are alterations to the GTAP equations of the same names. They redefine standard GTAP variables as aggregations across CRUSOE variables, using the 'f\_' variables. The equations redefine:

- the demand for intermediate inputs of each commodity (INTDEMAND);

- the price of intermediate inputs of each commodity (ICOMPRICE);
- the demand for intermediate inputs of each domestically produced commodity (INDDOM);
- the demand for intermediate inputs of each imported commodity (INDIMP); and
- the demands for each primary factor (ENDWDEMAND).

Conditional sums have been used within the second IF in equation ENDWDEMAND to ensure that the correct  $f\_qfe^*$  variable is selected.

$E\_qo$  (all,i,TRAD\_COMM)(all,r,REG)

$$[VOM(i,r)+IF(VOM(i,r)=0,1)]*qo(i,r)=$$

$$IF\{VOM(i,r) \neq 0,$$

$$VODM(i,r)*qod(i,r)+sum[o,HOME,VOHM(i,o,r)*qoh(i,o,r)]\};$$

This equation defines the total quantity of commodity  $i$  produced in region  $r$  as an aggregation across the quantities produced by domestic and foreign-owned industries. Although this equation involves only GTAP-style variables, its function can be seen to be that of aggregating CRUSOE variables to determine a GTAP variable, as variables  $qod$  and  $qoh$  are equated with components of  $x1tot$  in equation  $E\_x1tot$  (section 5.2). This equation overrides the standard GTAP domestic market clearing equation  $MKTCLTRD$ , which is negated by endogenising the slack variable  $tradslack$ .

$E\_to\_FDI$  (all,i,TRAD\_COMM)(all,r,REG)

$$IF\{FDI\_FLAG1(i,r)>0,$$

$$VOM(i,r)*\{pm(i,r)+qo(i,r)\}-$$

$$sum[j,IND:(DEST\_REG(j) \text{ eq } r) \text{ and } (IND2COMM(j) \text{ eq } i),$$

$$V1TOT(j)*\{p1tot(j)+x1tot(j)\}\}\}=$$

$$IF\{FDI\_FLAG1(i,r)=0,to(i,r)-to\_shk(i,r)\};$$

This equation implicitly determines, for commodities produced by both domestic and foreign-owned industries, the value of the GTAP output tax (variable  $to$ ) that is consistent with the output taxes applying across the producing industries. It accomplishes this by equating the GTAP expression for the market value of production with the corresponding CRUSOE expression (that involves a sum across all producing industries). For commodities that are produced entirely by

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domestically-owned firms, that is, for industries not represented in the CRUSOE set IND, the variable  $to\_shk$  remains effectively exogenous. It is equated with the exogenous variable  $to\_shk$ .

## 5.4 Integration of CRUSOE and GTAP code — convenience variables

### The equations

$E\_a1tot\_f$  (all,i,TRAD\_COMM)(all,o,HOME)(all,l,HOST)

$a1tot\_f(i,o,l)=$

sum[j,IND: (IND2COMM(j) eq i) and (HOME\_REG(j) eq o) and  
(DEST\_REG(j) eq l) and (NOT\_DOM(j)=1),a1tot(j)];

$E\_a1tot\_d$  (all,i,TRAD\_COMM)(all,r,REG)

$a1tot\_d(i,r)=$

sum[j,IND: (IND2COMM(j) eq i) and (HOME\_REG(j) eq r) and  
(DEST\_REG(j) eq r) and (NOT\_DOM(j)=0),a1tot(j)];

These equations are useful reporting equations that map the components of the technical efficiency variable  $a1tot$  (which ranges over the set IND) to the corresponding commodities, host and home regions. The first equation covers those components of  $a1tot$  associated with foreign-owned industries. The second equation covers the domestic industries.

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## 6 Demand side of FDI differentiated products

In standard GTAP, agents in the economy satisfy their demand for a particular commodity by choosing between an imperfectly substitutable domestic and imported variety of the commodity. The total demand by the economy as a whole for the imported variety of a commodity is satisfied by choosing between imperfectly substitutable varieties of the commodity from each region from which the commodity is imported. This specification of demand was illustrated in figure 2.2.

Since FTAP distinguishes domestic and foreign-owned industries, a further level of commodity differentiation arises, based on the region owning the industry producing a commodity. This applies to both the domestic variety of the commodity and the imports of a commodity from each source.

So in FTAP, the total demand by the economy as a whole for the domestic variety of a commodity is satisfied by choosing between imperfectly substitutable varieties produced by the domestic and foreign-owned industries producing that commodity locally. The choice occurs at the level of the economy as a whole, rather than for each agent, to reduce the computational burden of solving the model.

Similarly, the total demand by the economy as a whole for the imported variety of a commodity from a particular region is satisfied by choosing between imperfectly substitutable varieties produced by the domestic and foreign-owned industries in the exporting region.

Thus an extra level based on ownership is added to the nested demand structure of GTAP.

The chosen pattern of nesting reflects the assumption that the region in which goods are produced is the primary determinant of their degree of similarity. That is, the ownership of an industry confers a lower degree of product differentiation than the location in which the industry operates. This assumption is supported by the observation that foreign firms often adjust the nature of their goods to satisfy the local market, especially in cases of horizontal FDI.

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At each node of the nest, goods are combined by a CES function. The substitution elasticity between domestic and imported varieties is 5. All other industry-level substitution elasticities are 10 (recall that there is also substitution among individual firms within a particular firm type). So substitution between the domestic and imported variety is more restricted than substitution among varieties produced by different domestic agents or substitution among varieties produced by different exporters.

With respect to this parameter choice, two points of comparison between GTAP and FTAP are noteworthy.

First, the new structure is parameterised so that the pattern of substitution is as close as possible to standard GTAP, that is, substitution among all sources of imports is double the domestic/import substitution.

Second, the magnitude of substitution in FTAP is about double that in GTAP, since the values of FTAP substitution elasticities — 5 and 10 — are about double the values used in GTAP. The doubling of the GTAP values can be justified on two grounds. One is that Gehlhar (1997) found that only by doubling the GTAP elasticities could the GTAP model successfully reproduce historical changes in trade patterns. The other is that the higher elasticities accord better with the degree of substitution expected in the presence of firm-level product differentiation.

One further level of commodity choice exists beneath the ownership level, based on firm-level product differentiation.<sup>1</sup> Each industry is modelled as a variable number of firms of identical fixed size<sup>2</sup> and identical production technology. Each firm's output is assumed to be imperfectly substitutable with the output of other firms within the industry, while the output of all firms is combined into industry output with a CES aggregator function with elasticity of substitution equal to 15. Under these assumptions, industry output can only increase by increasing the number of firms, but because this increases variety, effective industry output increases more than proportionally with the number of firms. Francois (1998) has shown that this specification of firm-level product differentiation can be fully represented by an endogenous change in technical efficiency related positively to industry output. The elasticity of technical efficiency with respect to inputs is inversely related to the

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<sup>1</sup> The specification to be described is consistent with large-group monopolistic competition within each region (Francois 1998, pp. 12–13.)

<sup>2</sup> The identical fixed firm size arises from the assumptions of a large number of identical firms with some fixed costs (Francois et al. 1995, pp. A-6–A-8.) If the firms had CRTS technologies, there would be an infinite number of infinitely small firms, and consequently always an infinite number of varieties. Hence, the variety effect when industry output increases would be indeterminate.

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elasticity of substitution between different firms' outputs, and for the present choice of substitution elasticity is  $1/(15-1) = 0.0714$ . The FTAP demand structure for FDI-differentiated commodities with firm-level product differentiation was shown in figure 2.2.

In the implementation of this demand nest, defining a complete set of consistently named new variables enhanced transparency. Sometimes new variables were identical to GTAP variables,<sup>3</sup> for example, the quantity of exports by commodity, source and destination *qxs* (GTAP) and *qisd* (FTAP). In most cases the GTAP variables were redefined (either explicitly or implicitly) by summations over more highly disaggregated FTAP variables (for example, equation *E\_qxs* section 6.5), and then used for checking purposes (for example, equation *E\_check\_qisd* section 6.6).<sup>4</sup>

The variable naming conventions are as follows. An initial 'q', 'p', 't' and 'a' means quantity, price, power of tax and technical efficiency, respectively. Characters 'o', 'x' and 'i' in the second position designate output, exports and imports. The character 'h' indicates that the variable has a dimension ranging over home region (that is, region of ownership), while the characters 'l' (designating 'location') and 's' (designating 'source') are used to indicate a dimension for the location of an activity. The character 'd' has multiple meanings that are hopefully clear from the context. It can mean domestic use, domestically-owned or destination region. Some examples are: *qdd* — quantity of domestic use of the output of the domestically-owned industry; *qxd* — quantity of exports of the domestically-owned industry; and *qxdd* — quantity of exports of the domestically-owned industry by destination region. A 'w' on the end of the name of import prices is used to indicate world (that is, CIF) as distinct from tariff inclusive prices. A 't' in other than the initial position indicates an association with international freight activities (for example, *atsd* — technical efficiency of international transport on a particular trade route, that is, from source to destination).

As always, some exceptions to the conventions exist due to variables being already in the model. The standard GTAP variable *qds* — quantity of the domestically produced commodity used domestically — was already defined, and it was thought prudent to name its associated price variable *pds*.

Modifications to the international freight module are also required due to the domestic/foreign split of industries. New equations are patterned on the standard

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<sup>3</sup> This is the case for a wide range of policy shocks, and certainly any implemented to date or likely in the foreseeable future. See section 6.5 for a full discussion.

<sup>4</sup> Checking variables have not been defined in every case, but checking can still be performed manually.

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GTAP specification — with a Cobb-Douglas combination of regional freight supplies forming the international freight pool and freight requirements per unit of commodity being constant (subject to no efficiency improvements) for each (commodity, source, destination) triplet.

## 6.1 Demands for FDI differentiated products

### Preliminaries

All equations related to demands at the same node of the nest are grouped together.

### The equations

E\_qdd (all,i,TRAD\_COMM)(all,r,REG)

$$qdd(i,r)=qds(i,r)-ESUBM(i)*[pdd(i,r)-pds(i,r)];$$

E\_qdh (all,i,TRAD\_COMM)(all,o,HOME)(all,l,HOST)

$$qdh(i,o,l)=IF\{VDHM(i,o,l) \neq 0,$$

$$qds(i,l)-ESUBM(i)*[pdh(i,o,l)-pds(i,l)]\};$$

These equations represent demands for locally produced commodities (entering the domestic node at the second level of the nest). The (GTAP) variable  $qds(i,r)$  is the economy wide demand for the domestically produced commodity  $i$  in region  $r$ . Variables  $qdd(i,r)$  and  $qdh(i,o,r)$  are the economy wide demands by region  $r$  for the commodity  $i$  produced by the locally owned industry and the industry in region  $r$  owned by region  $o$ . Variables  $pds$ ,  $pdd$  and  $pdh$  are the corresponding prices. The coefficient  $ESUBM$  is used in standard GTAP and FTAP as the substitution elasticity between imports from different sources. In FTAP it is also used as the substitution elasticity between different domestically produced varieties. It is set to 10 in current applications of FTAP.

E\_qid (all,i,TRAD\_COMM)(all,d,DEST)

$$qid(i,d)=qim(i,d);$$

Variable  $qid(i,d)$  is identical to GTAP variable  $qim(i,d)$  and is the quantity of imports of commodity  $i$  used by region  $d$ . Variable  $qid$  is introduced merely for consistency of variable naming for these equations.

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E\_qisd (all,i,TRAD\_COMM)(all,s,SOURCE)(all,d,DEST)

qisd(i,s,d)=

IF{VIMS(i,s,d) ne 0, qid(i,d)-ESUBM(i)\*[pisd(i,s,d)-pid(i,d)]};

This equation represents demands for imported commodities from different sources (entering the import node at the second level of the nest). It is written in terms of FTAP variables but is identical to GTAP equation IMPORTDEMAND. Thus pisd and pid are the same as (GTAP) variables pms and pim, and this is tested in the checking equations (section 6.6)

E\_qxdd (all,i,TRAD\_COMM)(all,s,SOURCE)(all,d,DEST)

qxdd(i,s,d)=IF{VIMS\_DD(i,s,d) ne 0,

qisd(i,s,d)-ESUBM(i)\*[pild(i,s,d)-pisd(i,s,d)]};

E\_qxhd (all,i,TRAD\_COMM)(all,o,HOME)(all,l,HOST)(all,d,DEST)

qxhd(i,o,l,d)=IF[VIMS\_D(i,o,l,d) ne 0,

qisd(i,l,d)-ESUBM(i)\*[pihld(i,o,l,d)-pisd(i,l,d)]};

These equations represent demands for imported commodities from different industry owners within a particular exporting region (entering the import by source nodes at the third level of the nest). Variables qxdd(i,s,d) and qxhd(i,o,s,d) are the exports to region d of commodity i from region s by the domestic industry and the industry in region s owned by region o. Variables pild and pihld are the tariff inclusive prices of imports associated with qxdd and qxhd, respectively.

## 6.2 International freight

### Preliminaries

In standard GTAP each industry can sell part of its output to a pool of international freight services. The international freight pool is a Cobb-Douglas composite of the contributions from each industry. It is applied to the transportation of commodities from exporting to importing regions.

The treatment in FTAP is identical except that both domestic and foreign-owned industries sell to the freight pool. Therefore more variables and equations must be defined.



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To preserve the existing GTAP freight variables in FTAP (which is convenient for implementation and simulation interpretation) both domestic and foreign-owned industries of each industry group (primary, secondary and tertiary) sell their freight services to an industry group, region-specific pool.<sup>5</sup> This pool corresponds to the GTAP supply of freight services by each industry. Then this is sold to the international freight pool. Cobb-Douglas combination is used throughout.

In standard GTAP the supply price of freight services by each industry is equal to the market (output tax inclusive) price of industry output. In FTAP this is not the case for each industry group, since the supply of freight services is a composite of many industry contributions. The composition of freight service supply for an industry group may differ from the composition of total industry group output. Hence the freight supply price for an industry group may differ from the output price for the industry group. Consequently, a new variable for the freight supply price by industry group must be defined.

Section 6.3 deals with the freight requirements for each trade route and commodity in the discussion of FOB and CIF prices. The market clearing condition for international freight is still GTAP equation QTRANS.

## The equations

E\_qdst (all,i,TRAD\_COMM)(all,r,REG)

$$qdst(i,r)=IF\{VDST(i,r) \neq 0, qst(i,r)-[pod(i,r)-pst(i,r)]\};$$

E\_qhst (all,i,TRAD\_COMM)(all,o,HOME)(all,l,HOST)

$$qhst(i,o,l)=IF\{VHST(i,o,l) \neq 0, qst(i,l)-[poh(i,o,l)-pst(i,l)]\};$$

Variables qdst and qhst are the contributions of domestic and foreign-owned industries, respectively, to the total industry group supply of freight services, (GTAP) variable qst. The relative output prices, variables pod and poh, respectively, determine the relative contributions.

E\_pst (all,i,TRAD\_COMM)(all,r,REG)

$$IF\{VST(i,r) \neq 0, VST(i,r)*pst(i,r)-$$

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<sup>5</sup> As international freight services (which include insurance) are only produced by the tertiary sector, the primary and secondary pools are empty. All sectors are modelled as contributing to an international freight pool to accommodate future disaggregations of the database with more detail in the tertiary sector.

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$$(VDST(i,r)*pod(i,r) + \text{sum}[o,HOME, VHST(i,o,r)*poh(i,o,r)]) =$$

$$IF\{VST(i,r)=0, pst(i,r)-pfactwld\};$$

The price of freight services by industry group, variable  $pst$ , is a share-weighted combination of the output prices of contributing industries. The shares are calculated from the value of freight services supplied by domestic and foreign-owned industries, coefficients  $VDST$  and  $VHST$ , respectively. The variable  $pst$  replaces the variable  $pm$  in the GTAP equations  $PTRANS$  and  $TRANSVCES$  defining the world price of international freight services (variable  $pt$ ) and the demand for international freight services from each region (variable  $qst$ ), respectively.

### 6.3 Price definition and transmission equations

#### Preliminaries

Throughout this group of equations, the price of a commodity that is a CES aggregate of other commodities<sup>6</sup> is defined implicitly by an equation relating the aggregate quantity to the constituent quantities, as was done previously (section 4.3). These equations are identified with their associated node in figure 2.2.

The FTAP equations defining the relationships between the domestic market, FOB, CIF and tariff inclusive prices of goods — the price relationships affecting international trade — are of exactly the same structure as the standard GTAP equations. The difference is that prices for both domestic and foreign-owned industries must be defined in FTAP. Table 6.1 shows the correspondence between the GTAP and FTAP variables.

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<sup>6</sup> For example, the domestic variety of a commodity is an aggregate of that commodity produced by the domestic and foreign-owned industries operating locally.

**Table 6.1 Correspondence between standard GTAP and FTAP prices**

<i>Variable description</i>	<i>Standard GTAP variable</i>	<i>FTAP variables (domestic first, foreign second)</i>
Domestic market price (output tax inclusive)	pm	pod, poh
FOB price (export tax inclusive)	pfob	pxdd, pxhd
CIF price (export tax and freight inclusive)	pcif	pildw, pihldw
Export tax-freight-import tariff inclusive price	pms	pild, pihld

### The equations

E\_pdd (all,i,TRAD\_COMM)(all,r,REG)

$$pdd(i,r)=pod(i,r)!+tdd(i,r)!$$

E\_pxd (all,i,TRAD\_COMM)(all,r,REG)

$$pxd(i,r)=pod(i,r)!+txd(i,r)!$$

E\_pdh (all,i,TRAD\_COMM)(all,o,HOME)(all,l,HOST)

$$pdh(i,o,l)=poh(i,o,l)!+tdh(i,o,l)!$$

E\_pXH (all,i,TRAD\_COMM)(all,o,HOME)(all,l,HOST)

$$pxh(i,o,l)=poh(i,o,l)!+txh(i,o,l)!$$

These equations only serve the function of setting variables pdd and pxd (pdh and pxh), the domestic market prices of domestic use and exports of the domestically (foreign) owned industry (industries), equal to the domestic market price of output, variable pod (poh). The commented out variables are tax terms that are suggestive of a possible future development in which domestic taxes may discriminate on the basis of ownership.

E\_pds (all,i,TRAD\_COMM)(all,r,REG)

**! Corresponds to the ‘Domestic Location Sub=5’ node in figure 2.2 !**

$$IF\{VDM(i,r) \neq 0,$$

$$VDM(i,r)*qds(i,r)-$$

$$\{ \text{sum}[o,HOME,VDHM(i,o,r)*qdh(i,o,r)]+\}$$

---


$$VDDM(i,r)*qdd(i,r)\} =$$

$$IF\{VDM(i,r)=0,pds(i,r)-pfactwld\};$$

The price of domestically produced commodity  $i$  in region  $r$ , variable  $pds(i,r)$  (associated with the domestic node at the second level of the nest), is defined implicitly by the aggregation of the quantities contributing to the associated (GTAP) quantity of domestic supply variable  $qds(i,r)$ . These quantities are the domestic use of commodity  $i$  produced by both domestic (variable  $qdd(i,r)$ ) and foreign (variable  $qdh(i,o,r)$ ) industries. The weights used in the aggregation are the market values of the domestic use of commodity  $i$  from the domestic (coefficient  $VDDM(i,r)$ ) and foreign-owned (coefficient  $VDHM(i,o,r)$ ) industries.

In the GTAP equations defining the purchasers' prices of domestic goods —  $PHHDPRI$ C,  $GHHDPRI$ C and  $DMNDDPRI$ C — the variable  $pm$  — the market price of domestically *produced* goods — must be replaced with variable  $pds$  — the market price of domestically *consumed* goods.

$$E\_pid (all,i,TRAD\_COMM)(all,d,DEST)$$

**! Corresponds to the 'Foreign Location Sub=5' node in figure 2.2 !**

$$IF\{VIM(i,d)=0,pid(i,d)-pfactwld\} =$$

$$IF\{VIM(i,d) \neq 0,$$

$$VIM(i,d)*qid(i,d)-sum[s,SOURCE,VIMS(i,s,d)*qisd(i,s,d)]\};$$

The price of imported commodity  $i$  in region  $d$ , variable  $pid(i,d)$  (associated with the imported node at the second level of the nest), is defined implicitly by the aggregation of the quantities contributing to the associated import quantity variable  $qid(i,d)$ . These quantities are the imports of commodity  $i$  from each source region  $s$  (variable  $qisd(i,s,d)$ ). The weights used in the aggregation are the import tariff inclusive (market in GTAP terminology) values of imports (coefficient  $VIMS$ ). Variable  $pid$  should always be identical to GTAP variable  $pim$  (see equation  $E\_check\_pid$  section 6.6).

$$E\_pisd (all,i,TRAD\_COMM)(all,s,SOURCE)(all,d,DEST)$$

**! Corresponds to the 'Located in region 1...N Sub=10' nodes in figure 2.2 !**

$$IF\{VIMS(i,s,d)=0,pisd(i,s,d)-pfactwld\} =$$

$$IF\{VIMS(i,s,d) \neq 0,VIMS(i,s,d)*qisd(i,s,d)$$

---


$$-[VIMS\_DD(i,s,d)*qxdd(i,s,d)+$$

$$\text{sum}[o,HOME,VIMS\_D(i,o,s,d)*qxhd(i,o,s,d)]]];$$

The price of commodity  $i$  from region  $s$  imported by region  $d$ , variable  $pisd(i,s,d)$  (associated with the import nodes by source at the third level of the nest), is defined implicitly by the aggregation of the quantities contributing to the associated import quantity variable  $qisd(i,s,d)$ . These quantities are the imports of commodity  $i$  from both domestic and foreign-owned industries operating in region  $s$  (variables  $qxdd(i,s,d)$  and  $qxhd(i,o,s,d)$ , respectively). The weights used in the aggregation are the import tariff inclusive (market in GTAP terminology) values of imports (coefficient  $VIMS\_D(i,s,d)$  for imports from the domestically-owned industry in region  $s$  and coefficient  $VIMS\_D(i,o,s,d)$  for imports from the industry in region  $s$  owned by region  $o$ ).

$E\_pxdd$  (all,i,TRAD\_COMM)(all,s,SOURCE)(all,d,DEST)

$$pxdd(i,s,d)=pxd(i,s)+tx(i,s)+txsd(i,s,d);$$

$E\_pxhd$  (all,i,TRAD\_COMM)(all,o,HOME)(all,l,HOST)(all,d,DEST)

$$pxhd(i,o,l,d)=pxh(i,o,l)+tx(i,l)+txsd(i,l,d)+txhd(i,o,l,d);$$

The function and structure of these equations is identical to GTAP equation  $EXPRICES$ . The new power of tax variable —  $txsd$  and  $txhd$  — have been chosen to allow discrimination not just among destinations but among owners of the exporting industry. The GTAP variable  $txs$  has been retained in the model and its function is discussed in section 6.5.

$E\_pildw$  (all,i,TRAD\_COMM)(all,s,SOURCE)(all,d,DEST)

$$pildw(i,s,d)=FOBSHR2(i,s,d)*pxdd(i,s,d)+TRNSHR2(i,s,d)*$$

$$[pt-atsd(i,s,d)]+IF[FOBSHR2(i,s,d)+TRNSHR2(i,s,d)=0,pfactwld];$$

$E\_pihldw$  (all,i,TRAD\_COMM)(all,o,HOME)(all,l,HOST)(all,d,DEST)

$$pihldw(i,o,l,d)=FOBSHRL2(i,o,l,d)*pxhd(i,o,l,d)+TRNSHRL2(i,o,l,d)*$$

$$[pt-atsd(i,l,d)-athsd(i,o,l,d)]+$$

$$IF[FOBSHRL2(i,o,l,d)+TRNSHRL2(i,o,l,d)=0,pfactwld];$$

The function and structure of these equations is identical to GTAP equation  $FOBCIF$ . The new technical efficiency variables —  $atsd$  and  $athsd$  — have been chosen to

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allow discrimination not just between destinations but between owners of the exporting industry. The GTAP variable *atr* has been retained in the model and its function is discussed in section 6.5. In the absence of technical efficiency changes, these equations imply that the requirements for international freight services are proportional to the amount of commodity being traded.

$E\_pild$  (*all,i,TRAD\_COMM*)(*all,s,SOURCE*)(*all,d,DEST*)

$$pild(i,s,d)=pildw(i,s,d)+tm(i,d)+tmsd(i,s,d);$$

$E\_pihld$  (*all,i,TRAD\_COMM*)(*all,o,HOME*)(*all,l,HOST*)(*all,d,DEST*)

$$pihld(i,o,l,d)=pihldw(i,o,l,d)+tm(i,d)+tmsd(i,l,d)+tmhs(i,o,l,d);$$

The function and structure of these equations is identical to GTAP equation *MKTPRICES*. The new power of tax variables — *tmsd* and *tmhs* — have been chosen to allow discrimination not just among destinations but among owners of the exporting industry. The GTAP variable *tms* has been retained in the model and its function is discussed in section 6.5.

## 6.4 Market clearing and accounting equations

### Preliminaries

The equations in this group are similar in structure and identical in function to the standard GTAP equations for market clearing in domestically produced commodities. They have arisen due to the domestic/foreign split of industries and their outputs.

### The equations

$E\_qod$  (*all,i,TRAD\_COMM*)(*all,r,REG*)

$$[VODM(i,r)+IF(VODM(i,r)=0,1)]*qod(i,r)=$$

$$IF[VODM(i,r) \neq 0,$$

$$VXDM(i,r)*qxd(i,r)+VDDM(i,r)*qdd(i,r)+VDST(i,r)*qdst(i,r)];$$

---

E\_qoh (all,i,TRAD\_COMM)(all,o,HOME)(all,l,HOST)

$$[\text{VOHM}(i,o,l)+\text{IF}(\text{VOHM}(i,o,l)=0,1)]*qoh(i,o,l)=\text{IF}[\text{VOHM}(i,o,l) \neq 0,$$

$$\text{VXHM}(i,o,l)*qxh(i,o,l)+\text{VDHM}(i,o,l)*qdh(i,o,l)+\text{VHST}(i,o,l)*qhst(i,o,l)];$$

These equations serve the same function as standard GTAP equation MKTCLTRD. They specify that output from domestic and foreign-owned industries (variables qod and qoh) is divided between domestic use (variables qdd and qdh), exports (variables qxd and qxh) and sales to international freight (variables qdst and qhst). The major difference in structure from the GTAP equation MKTCLTRD is that exports by source have been aggregated into total exports for equations E\_qod and E\_qoh. If the next two equations were used to expand out qxd and qxh, then equations E\_qod and E\_qoh would be identical in structure to GTAP equation MKTCLTRD.

E\_qxd (all,i,TRAD\_COMM)(all,s,SOURCE)

$$[\text{VXDM}(i,s)+\text{IF}(\text{VXDM}(i,s)=0,1)]*qxd(i,s)=\text{IF}\{\text{VXDM}(i,s) \neq 0,$$

$$\text{sum}[d,\text{DEST},\text{VXMD\_DD}(i,s,d)*qxdd(i,s,d)]\};$$

E\_qxh (all,i,TRAD\_COMM)(all,o,HOME)(all,l,HOST)

$$[\text{VXHM}(i,o,l)+\text{IF}(\text{VXHM}(i,o,l)=0,1)]*qxh(i,o,l)=\text{IF}\{\text{VXHM}(i,o,l) \neq 0,$$

$$\text{sum}[d,\text{DEST},\text{VXMD\_D}(i,o,l,d)*qxhd(i,o,l,d)]\};$$

These equations define the exports of commodity  $i$  from region  $r$  by domestic (variable  $qxd(i,r)$ ) and foreign-owned (variable  $qxh(i,o,r)$ ) industries. These variables are the totals across destinations of destination-specific export variables  $qxdd$  and  $qxhd$ . In the linearised form of this totalling, the value weights used are market values, which are proportional to quantities since they are all evaluated at the same (market) price.

## 6.5 Links to GTAP variables

### Preliminaries

Duplicates of some GTAP variables were introduced among the variables created for the equations described in this chapter. All these variables except the price of imports (variable  $pid$ , discussed in section 6.3) are related to bilateral trade flows. They are shown in table 6.2.

**Table 6.2 Correspondence between standard GTAP and FTAP duplicate variables**

<i>Variable description</i>	<i>Standard GTAP variable</i>	<i>FTAP duplicate variable</i>
Quantity of exports by commodity, source and destination	qxs	qisd
Power of export tax by commodity, source and destination	txs	txsd
Technical efficiency of international transport by commodity, source and destination	atr	atsd
Power of import tariff by commodity, source and destination	tms	tmsd

The simulation values of the two sets of variables are identical under the following assumptions about bilateral trades:

- the export tax, freight ratios and import tariffs in the database are independent of the ownership of the producing sector, that is, they are determined by the commodity and trade route alone; and
- ownership-specific export tax, technical efficiency in international freight and import tariff shocks are not applied in the policy simulation, that is, txhd, athsd and tmhs are not shocked.

Both these conditions are satisfied in current applications. Although the model allows the flexibility to use a database, and/or run a simulation, that invalidates these assumptions, these seem unlikely applications.<sup>7</sup> Therefore, for current applications at least, the equality of the two sets of variables in table 6.2 is a good check on the integrity of the model and database.

The equations of this section also ensure that the original GTAP trade matrices — coefficients VXMD, VXWD, VIWS and VIMS — are updated correctly. This point merits further discussion.

Plainly the GTAP trade matrices could be derived by summing the FTAP trade matrices that parallel the GTAP ones but are disaggregated by the ownership of the producing industry. For example,

$$VXMD(i,s,d)=VXMD\_DD(i,s,d)+\text{sum}[o,HOME,VXMD\_D(i,o,s,d)];$$

<sup>7</sup> But if it is decided in the future that a different value of the export tax is required for boomerang imports of services, as opposed to imports from foreign-owned firms, then the equality between txs and txsd will no longer hold.



This is not done, however, and the GTAP matrices are read as an independent piece of data and updated over the course of a policy simulation as in standard GTAP.

The equations of this section ensure that the variables used for the updating are calculated so that the GTAP trade matrices remain consistent with their FTAP counterparts. This data redundancy provides another check on the integrity of the database and model.

### The equations

$E_{qxs}(all,i,TRAD\_COMM)(all,s,SOURCE)(all,d,DEST)$

$$\begin{aligned} & \text{IF}\{VXMD(i,s,d) \text{ gt } 0, \\ & VXMD(i,s,d)*qxs(i,s,d)- \\ & \{\text{sum}[o,HOME,VXMD\_D(i,o,s,d)*qxhd(i,o,s,d)]+ \\ & VXMD\_DD(i,s,d)*qxdd(i,s,d)\} \} = \\ & \text{IF}\{VXMD(i,s,d) \text{ le } 0,qxs(i,s,d)\}; \end{aligned}$$

This equation replaces GTAP equation IMPORTDEMAND and defines variable  $qxs$  as a market value of exports weighted sum over bilateral exports distinguished by ownership of producing industry (variables  $qxdd$  and  $qxhd$  for domestic and foreign-owned producers, respectively). Note that under the assumptions of the preliminaries for this section,

$$\begin{aligned} VXMD(i,s,d)/VIMS(i,s,d) &= VXMD\_DD(i,s,d)/VIMS\_DD(i,s,d) \\ &= VXMD\_D(i,o,s,d)/VIMS\_D(i,o,s,d) \end{aligned}$$

for all  $o$ . Then equation  $E_{qxs}$  could be rewritten with VIMS coefficients replacing VXMD coefficients throughout, implying  $qxs$  equals  $qisd$ .

$E_{pxs}(all,i,TRAD\_COMM)(all,s,SOURCE)(all,d,DEST)$

$$\begin{aligned} & \text{IF}\{VXMD(i,s,d) \text{ gt } 0, \\ & VXMD(i,s,d)*[pxs(i,s,d)+qxs(i,s,d)]- \\ & \{\text{sum}[o,HOME,VXMD\_D(i,o,s,d)*[pxh(i,o,s)+qxhd(i,o,s,d)]]+ \\ & VXMD\_DD(i,s,d)*[pxd(i,s)+qxdd(i,s,d)] \} \} = \end{aligned}$$

---

IF{VXMD(i,s,d) le 0,pxs(i,s,d)-pfactwld};

This equation defines the new variable pxs, the domestic market (output tax inclusive, export tax exclusive) price of exports by commodity, source and destination. This is required for correct updating of VXMD. In standard GTAP, VXMD is updated with pm (market price of output) and qxs. With the domestic/foreign split of industries, pxs is not necessarily the same as pm due to compositional effects — the ownership composition of exports may differ from the output composition. Consequently, the variable pm must be replaced by pxs in the GTAP equation EXPRICES.

E\_txs (all,i,TRAD\_COMM)(all,s,SOURCE)(all,d,DEST)

IF{VXWD(i,s,d) gt 0,  
 VXWD(i,s,d)\*[pfob(i,s,d)+qxs(i,s,d)]-  
 {sum[o,HOME,VXWD\_D(i,o,s,d)\*[pxhd(i,o,s,d)+qxhd(i,o,s,d)]]+  
 VXWD\_DD(i,s,d)\*[pxdd(i,s,d)+qxdd(i,s,d)]}}=  
 IF{VXWD(i,s,d) le 0,txs(i,s,d)};

This essentially defines the GTAP variable txs as a weighted combination of the FTAP export tax variables txsd and txhd. However, provided txhd is not shocked (see preliminaries) txs equals txsd. The equation also ensures that txs is calculated so that the GTAP FOB price of exports variable pfob (still defined by GTAP equation EXPRICES) will be correct for updating VXWD.

E\_atr (all,i,TRAD\_COMM)(all,s,SOURCE)(all,d,DEST)

IF{VTWR(i,s,d) gt 0,  
 VIWS(i,s,d)\*[pcif(i,s,d)+qxs(i,s,d)]-  
 {sum[o,HOME,VIWS\_D(i,o,s,d)\*[pihldw(i,o,s,d)+qxhd(i,o,s,d)]]+  
 VIWS\_DD(i,s,d)\*[pildw(i,s,d)+qxdd(i,s,d)]}}=  
 IF{VTWR(i,s,d) le 0,atr(i,s,d)};

This essentially defines the GTAP variable atr as a weighted combination of the FTAP technical efficiency of international freight variables atsd and athd. However, provided athd is not shocked (see preliminaries), atr equals atsd. The equation also

ensures that atr is calculated so that the GTAP CIF price of imports variable pcif (still defined by GTAP equation FOBCIF) will be correct for updating VIWS.

E\_tms (all,i,TRAD\_COMM)(all,s,SOURCE)(all,d,DEST)

IF{ VIMS(i,s,d) gt 0,

VIMS(i,s,d)\*[pms(i,s,d)+qxs(i,s,d)]-

{sum[o,HOME,VIMS\_D(i,o,s,d)\*[pihld(i,o,s,d)+qxhd(i,o,s,d)]]+

VIMS\_DD(i,s,d)\*[pild(i,s,d)+qxdd(i,s,d)]} }=

IF{ VIMS(i,s,d) le 0,tms(i,s,d)};

This essentially defines the GTAP variable tms as a weighted combination of the FTAP import tariff variables tmsd and tmhs. However, provided tmhs is not shocked (see preliminaries), tms equals tmsd. The equation also ensures that tms is calculated so that the GTAP tariff inclusive price of imports variable pms (still defined by GTAP equation MKTPRICES) will be correct for updating VIMS.

## 6.6 Checking equations

### Preliminaries

All variables in this section with names starting with ‘check’ should be zero whenever the (very broad) assumptions of section 6.5 are true. Variable check\_pid should always be zero.

The equations are fairly self-explanatory.

### The equations

E\_check\_qisd (all,i,TRAD\_COMM)(all,s,SOURCE)(all,d,DEST)

check\_qisd(i,s,d)=qxs(i,s,d)-qisd(i,s,d);

E\_check\_pisd (all,i,TRAD\_COMM)(all,s,SOURCE)(all,d,DEST)

check\_pisd(i,s,d)=pms(i,s,d)-pisd(i,s,d);

E\_frt (all,i,TRAD\_COMM)(all,s,SOURCE)(all,d,DEST)

---


$$\text{frt}(i,s,d)=\text{pcif}(i,s,d)-\text{pfob}(i,s,d);$$

This defines CIF/FOB ratio (variable frt) based on standard GTAP prices.

$$\text{E\_check\_frt}(\text{all},i,\text{TRAD\_COMM})(\text{all},o,\text{HOME})(\text{all},l,\text{HOST})(\text{all},d,\text{DEST})$$

$$\text{check\_frt}(i,o,l,d) = \text{pihldw}(i,o,l,d)-\text{pxhd}(i,o,l,d)-\text{frt}(i,l,d);$$

This compares GTAP CIF/FOB ratios with FTAP ones.

$$\text{E\_check\_pid}(\text{all},i,\text{TRAD\_COMM})(\text{all},d,\text{DEST})$$

$$\text{check\_pid}(i,d)=\text{pid}(i,d)-\text{pim}(i,d);$$

## 6.7 Firm-level product differentiation

### Preliminaries

Industry output is related to firm outputs thus:

$$Y = \left( \sum_{f=1}^N Y_f^\rho \right)^{1/\rho}$$

where  $Y$  is industry output,  $N$  is the number of firms,  $Y_f$  is the output of firm  $f$  and the elasticity of substitution between firms is

$$\sigma = 1/(1 - \rho)$$

Since all firms are of identical size

$$Y = Y_1 \cdot N^{\sigma/(\sigma-1)}$$

Since all firms are assumed to have identical increasing returns to scale production technology, industry inputs are equal to  $X=N \cdot X_1$ . So industry output and industry inputs are related thus:

$$Y = Y_1 \cdot X_1^{-\sigma/(\sigma-1)} \cdot X^{\sigma/(\sigma-1)}$$

which in linearised form is

$$y = y_1 - \sigma/(\sigma - 1) \cdot x_1 + \sigma/(\sigma - 1) \cdot x$$

Since firms are of fixed size,  $x_1=y_1=0$ .

---

The non-CRTS relationship between industry output and industry inputs is represented in FTAP as endogenous technical efficiency at the industry level. Industry output efficiency is

$$y - x = 1/(\sigma - 1).x$$

$$= 1/\sigma.y$$

So the elasticity of industry output efficiency, with respect to either industry output or input, is inversely related to the substitution elasticity between the outputs of different firms. The interpretation of this is that the more differentiated firm outputs are, the more benefit there is (to users of the industry's output) from having a larger number of varieties from which to choose. So although the implementation of firm-level product differentiation may look like a change to the FTAP supply-side (endogenous technical efficiency), it is really a representation of a demand-side feature. There is, as noted in footnote 2, an implicit supply-side assumption about economies of scale in production for *firms*, underlying the specification of fixed firm size. *Industry* input demand functions, however, are still CRTS, precisely because of fixed firm size!

## The equations

E\_a1tot #Endog tech change from firm choice for FDI industries# (all,i,IND)

$$a1tot(i) = -ETECH * x1tot(i) + f_a1tot(i);$$

E\_ao #Endog tech change from firm choice for purely local industries#

(all,i,TRAD\_COMM)(all,r,REG)

$$ao(i,r) = IF\{FDI\_FLAG1(i,r) = 0, ETECH * qo(i,r)\} + f_ao(i,r);$$

These equations implement the endogenous technical efficiency used to represent firm-level product differentiation. The first equation covers those industries spawned by the domestic/foreign split and represented by the set IND. The second equation covers those industries for which no FDI is represented in the FTAP database. The variables in the former equation are the industry output efficiency (variable a1tot) and industry output (variable x1tot) variables from the CRUSOE model used to represent the supply-side of FDI industries (chapter 5). The variables in the latter equation are GTAP variables for industry output efficiency (variable ao) and industry output (variable qo). Both equations have slack variables (f\_a1tot and f\_ao) to allow the endogenous technical efficiency to be turned-off by a closure

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change. Coefficient ETECH is the elasticity of technical efficiency with respect to output.<sup>8</sup>

The negative sign before ETECH in equation E\_a1tot is not a mistake. It has been a convention in ORANI-type models (and CRUSOE follows this convention) of setting-up the technical efficiency variables so that a negative shock corresponds to a productivity improvement.<sup>9</sup> GTAP, however, follows the sensible convention of having a positive shock corresponding to a productivity improvement. Hence there is no negative sign in the second equation.

---

<sup>8</sup> In the implementation of firm-level product differentiation given in Francois (1998), the elasticity with respect to inputs is used. The two approaches yield identical results.

<sup>9</sup> This was an inhumane decision that has been a source of considerable suffering over the years.

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## 7 An amendment to allocative efficiency measures

Much of the structure of the FTAP model is very similar to GTAP. In particular, industry demand functions are identical — intermediates and the primary factor bundle are in fixed proportion to output, and there is substitution among primary factors, as well as domestic/import substitution.

While input demands for industries are of an identical form to those in GTAP, the industry coverage in FTAP is broader due to the domestic/foreign ownership split of the GTAP industries. In FTAP, what was the demand for an input by a single industry is now a total across the demands by many industries. The demand is not the product of behaviour by a single cost minimising agent, but is the consequence of the actions of many agents.

Consequently the welfare decomposition implemented as part of the GTAP model may not be valid in FTAP under the redefinition of GTAP industry demand variables. In particular, allocative efficiency effects may not be correctly measured. Plainly, allocative efficiency effects can arise from distortions in any of the FTAP domestic and foreign-owned industries. These distortions differ between domestic and foreign industries. However, the GTAP based welfare decomposition measures allocative efficiency as a function of distortions and quantity changes for the more aggregate (summation across domestic and foreign-owned) GTAP industries.

The GTAP welfare decomposition can be used to correctly quantify allocative efficiency changes in FTAP by introducing extra equations that express the redefined GTAP industry demand variables in terms of the superseded GTAP industry demand functions, subject to changes in technical efficiency. These changes in technical efficiency, when substituted into the GTAP variable for the welfare contribution of technical efficiency (variable CNTtechr), provide a measure of the FTAP allocative efficiency effects not explicitly represented in the GTAP-based welfare decomposition. A formal description and the implementation of this approach are presented in section 7.1.

This approach produces a welfare decomposition that works, but the new allocative efficiency effects are not written in a form in which they are associated with the distortion producing them, that is, they are not expressed in terms of taxes and

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quantity changes. Further, the welfare effects of any actual changes to technical efficiency (such as are required for firm level product differentiation) are confounded with allocative efficiency in the variable CNTtechr.

Consequently, having obtained a welfare decomposition for FTAP that works, it is highly desirable to algebraically manipulate the decomposition to make it more transparent. It can be shown that the new allocative efficiency effects subsumed in CNTtechr are functions of differential output distortions between the domestic and foreign-owned constituents in each industry group. The derivation of this, and its implementation in FTAP, are discussed in section 7.2.

## 7.1 Adapting the GTAP welfare decomposition

### Preliminaries

The formal specification of the adaptation of the GTAP welfare decomposition proceeds as follows. Let  $X$ ,  $Y$ ,  $\mathbf{P}$  and  $\mathbf{A}$  represent, respectively, the quantity of a particular industry input, the quantity of industry output, the vector of all input prices and the vector of technical efficiencies associated with all inputs. The GTAP equation for  $X$  can be written as

$$X = f(Y, \mathbf{P}, \mathbf{A})$$

If the industry is disaggregated into domestic and foreign-owned, then the GTAP equation is replaced by<sup>1</sup>

$$X = \sum_r X_r$$
$$X_r = f(Y_r, \mathbf{P}_r, \mathbf{A}_r)$$

The subscript  $r$  represents the owner of the disaggregated FTAP industries.<sup>2</sup>

The next step is to reintroduce

$$X = f(Y, \mathbf{P}, \mathbf{A})$$

---

<sup>1</sup> The implementation of the next equation in percentage change form in FTAP is, in fact, not identical to summation in the levels (see equation E\_f\_qf in section 5.3). But this complication is merely a distraction for the exposition in this section.

<sup>2</sup> The choice of the same input demand function  $f()$  is deliberate.



$Y$  and  $\mathbf{P}$  are appropriately defined aggregates of their disaggregate counterparts. In linearised form, using lower case letters for percentage changes and  $S$  for shares, they are expressed as

$$y = \sum_r S_r^Y \cdot y_r$$

$$\mathbf{p} = \sum_r S_r^P \cdot \mathbf{p}_r$$

The corresponding equations in the FTAP implementation (see chapter 5) are  $E\_qo$  (output) and the  $E\_f\_pf^*$  series of equations (input prices).

As there are now two equations for  $X$ ,  $\mathbf{A}$  is made endogenous. That is, the level of ‘technical efficiency’ is determined such that the original GTAP input demand equations are satisfied by the redefined (by summation over domestic and foreign-owned industries) GTAP input demand variables. Therefore the GTAP welfare decomposition, built on the GTAP input demand equations, remains valid.

Consequently, the contribution of percentage changes in the  $\mathbf{A}$ s to the GTAP variable  $CNTtechr$  — contribution of technical efficiency to welfare — is actually the contribution to welfare of allocative efficiency not captured in the GTAP allocative efficiency variable  $CNTalleffr$ .

## The equations

$E\_af$  (all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

$$0 = \text{IF}\{\text{FDI\_FLAG1}(j,r) \neq 0, -qf(i,j,r) - af(i,j,r) + qo(j,r) - ao(j,r) -$$

$$\text{ESUBT}(j) * [pf(i,j,r) - af(i,j,r) - ps(j,r)]\} +$$

$$\text{IF}\{\text{FDI\_FLAG1}(j,r) = 0, af(i,j,r)\};$$

This equation covers intermediate inputs to industries. For those industries that undergo the domestic/foreign ownership split (the  $j$  in  $r$  for which  $\text{FDI\_FLAG1}(j,r)$  is not zero) the GTAP demand equation (that is, the expression inside the first  $\text{IF} = 0$ ) is reintroduced to the model. For other industries the GTAP technical efficiency variable  $af$  is just set to zero.

$E\_o\_qfe$  (all,i,ENDW\_COMM)(all,j,PROD\_COMM)(all,r,REG)

$$o\_qfe(i,j,r) =$$

$$-afe(i,j,r) + qva(j,r) - \text{ESUBVA}(j) * [pfe(i,j,r) - afe(i,j,r) - pva(j,r)];$$

$E\_afe$  (all,i,ENDW\_COMM)(all,j,PROD\_COMM)(all,r,REG)

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$$\text{IF}[(\text{EVFA}(i,j,r)=0) \text{ or } (\text{FDI\_FLAG1}(j,r)=0), \text{afe}(i,j,r)] = f_{\text{afe}}(i,j,r) +$$

$$\text{IF}[(\text{EVFA}(i,j,r) \neq 0) \text{ and } (\text{FDI\_FLAG1}(j,r) \neq 0), \text{o\_qfe}(i,j,r) - \text{qfe}(i,j,r)];$$

These equations cover primary factor inputs to industries. A trivial extra step has been introduced this time, with the introduction of the variable  $\text{o\_qfe}$ , but substituting this into equation  $E_{\text{afe}}$  produces the same form as for intermediate inputs. The value of primary factor use — coefficient  $\text{EVFA}$  — is also checked in the conditions inside the IFs, so that variable  $\text{afe}$  is also set to zero if there is no primary factor use. This is a trivial difference from the intermediate input case.

## 7.2 Respecifying the GTAP welfare decomposition

### Preliminaries

The technical efficiency variables that are endogenously determined under the approach of section 7.1 can be expressed in terms of the inputs and outputs of domestic and foreign-owned industries. Consequently their contributions to welfare can be expressed in a more conventional form for allocative efficiency effects.

To avoid notational clutter that provides no additional insights, it is assumed throughout this derivation that no technical efficiency changes occur within the domestic and foreign-owned industries. The only ‘technical efficiency’ changes are the de facto allocative efficiency changes being analysed.

The following notation is employed.  $V$  is the purchasers’ value of industry inputs.  $W$  is the output tax inclusive (GTAP market) value of industry outputs.  $E$  is own or cross price demand elasticities.  $x$  is the percentage change in industry inputs.  $y$  is the percentage change in industry outputs.  $a$  is the percentage change in technical efficiency associated with industry inputs. A subscript of  $i$  or  $k$  runs across all industry inputs. A subscript of  $j$  runs across domestic and foreign-owned industries within one industry group. A dot in a subscript indicates totalling over that dimension.

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The following linearised relationships are critical to the current derivation.

$$\begin{aligned}
 W \cdot y &= \sum_j W_j \cdot y_j \\
 V_{i \cdot} \cdot x_{i \cdot} &= \sum_j V_{ij} \cdot x_{ij} \\
 V_{\cdot j} \cdot y_j &= \sum_i V_{ij} \cdot x_{ij} \\
 0 &= \sum_i V_{i \cdot} \cdot E_{ik}
 \end{aligned}$$

The first equation corresponds to FTAP equation E\_qo that aggregates the outputs of domestic and foreign-owned industries into a total industry output based on market value weights. The second equation is the totalling of inputs across domestic and foreign-owned industries (for example, equation E\_f\_qf). The third equation states that industry output is a share-weighted combination of industry inputs, and is a consequence of the use of constant returns to scale production functions. The fourth equation is from the properties of own and cross price elasticities.

A GTAP industry input demand equation in linearised form is

$$x_{i \cdot} + a_i = y + \sum_k E_{ik} \cdot (p_{k \cdot} - a_k)$$

Totalling is over all constituent domestic and foreign-owned industries.

By manipulating the four relationships and the GTAP demand equation, it is possible to derive the following relationship.

$$\begin{aligned}
 \sum_i V_{i \cdot} \cdot a_i &= V_{\cdot \cdot} \cdot y - \sum_i V_{i \cdot} \cdot x_{i \cdot} + \sum_k (p_{k \cdot} - a_k) \cdot \sum_i V_{i \cdot} \cdot E_{ik} \\
 &= \sum_j [(V_{\cdot \cdot} / W_{\cdot}) \cdot (W_j / V_{\cdot j}) - 1] V_{\cdot j} \cdot y_j
 \end{aligned}$$

The right hand side is identical in form to the terms in variable CNTtechr involving the GTAP technical efficiency variables af and afe. The contribution of ‘technical’ (de facto allocative) efficiency to welfare is proportional to this expression. The term in square brackets is greater than (equal to/less than) zero if the power of the output tax on industry j is greater than (equal to/less than) the average power of the output tax for the industry group. That is, this expression captures the allocative efficiency gains (losses) from an expansion in the output of the relatively heavily (lightly) taxed industries within the domestic and foreign-owned industries producing a particular commodity.

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## The equations

E\_CNTallefffdi (All,r,REG)

$$\begin{aligned} \text{CNTallefffdi}(r) &= [0.01/\text{INCRATIO}(r)] * \\ &\text{sum}\{i, \text{TRAD\_COMM}, \\ &[\text{VOA}(i,r)/\text{VOM}(i,r) * \text{VODM}(i,r) - \text{VODA}(i,r)] * \text{qod}(i,r) + \\ &\text{sum}[o, \text{HOME}, \\ &[\text{VOA}(i,r)/\text{VOM}(i,r) * \text{VOHM}(i,o,r) - \text{VOHA}(i,o,r)] * \text{qoh}(i,o,r)\} \}; \end{aligned}$$

The coefficients VODA and VOHA are pre-output tax (GTAP agents') values of output for the domestic and foreign-owned industries, respectively, while the coefficients VODM and VOHM are the values inclusive of output taxes (GTAP market values). Coefficients VOA and VOM are totals across domestic and foreign-owned industries. The agents' values correspond to the  $V$ s in the final expression in the preliminaries, while the market values correspond to the  $W$ s. The percentage changes in the output of domestic and foreign-owned industries — variables  $qod$  and  $qoh$ , respectively — correspond to the  $y$ s. The contributions for each industry group, that is, element of  $\text{TRAD\_COMM}$ , are summed before scaling by (as always)  $0.01/\text{INCRATIO}$ .

This new allocative efficiency contribution (variable  $\text{CNTallefffdi}$ ) is added to and subtracted from, respectively, the expressions defining total allocative (variable  $\text{CNTalleffr}$ ) and total technical (variable  $\text{CNTtechr}$ ) efficiency contributions in GTAP equations  $\text{CONT\_EV\_alleffr}$  and  $\text{CNT\_EV\_techr}$ . This corrects for the fact that in FTAP part of the standard GTAP expression for  $\text{CNTtechr}$  is de facto allocative efficiency.

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## 8 Rents from barriers to services trade — accounting and welfare decomposition

Two types of barriers to trade in services are represented in FTAP — barriers to establishment and barriers to ongoing operation. The direct effects of these barriers on resource allocation can be represented as taxes. In FTAP, barriers to establishment are represented as taxes on capital, while barriers to ongoing operations are represented as taxes on output (that is, on the operation of the foreign firm domestically) and exports (that is, on the operation of the foreign firm overseas selling into the domestic market). This is illustrated in table 2.1.

While the incorporation of these taxes adequately represents the allocative effects of barriers to services trade, two issues need to be dealt with regarding the tax revenue raised.

First, as the barriers to services trade are not true taxes but impediments such as rules and regulations, the revenue generated by the taxes used to represent barriers should not be accounted as part of government revenue, but as rents accruing to private agents.<sup>1</sup> This accounting matters in models such as GTAPICM and FTAP (but not GTAP) where government income is calculated separately from private income, and income tax rates are endogenised to ensure budget neutrality.

Second, a decision needs to be made as to which private agents obtain the impediment rents — those in the domestic economy or foreigners. It is possible to think of non-tax barriers that distribute the rents either way. An auction of the right to operate in the domestic economy would give the rents to domestic agents. However, the nature of the barriers actually operating, in banking and telecommunications, for example, suggests that rents should be allocated to foreigners based on the following: the barriers restrict supply, thereby raising the price of the commodity being produced and generating abnormally high returns for those producers fortunate enough to gain access to the market.

The FTAP equations have been constructed to allow for taxation of impediment rents in either the home or host region. In current applications of the model, taxation

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<sup>1</sup> Of course, the government may still recover some of these rents through income taxes.

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occurs in the host region, with the home region receiving only the post-tax impediment rent.<sup>2</sup>

For each new foreign income flow spawned by impediment rents, there are three welfare contribution terms — rate of return, asset price and endowment effect — after the manner of appendix B.

The parallelism between foreign income flows and welfare decomposition has influenced the structure of this chapter. Section 8.1 deals with foreign income flows related to output impediment rents, while section 8.2 describes the corresponding welfare decomposition. Section 8.3 deals with foreign income flows related to capital impediment rents, while section 8.4 describes the corresponding welfare decomposition. Section 8.5 deals with export impediment rents, but these do not generate any new welfare decomposition terms.

Section 8.6 lists the final form — accounting for all FDI income and impediment rents — of the national income accounting equations introduced in GTAPICM (chapter 3).

## 8.1 Income from output impediments

### Preliminaries

Output taxes in the FTAP database represent both genuine taxes and barriers to services trade. Therefore, it is necessary to distinguish what proportion of output tax revenue for each industry is actually genuine revenue, and what proportion is impediment rents. The latter portion must then be distributed to the correct recipients, and subtracted from the tax revenue equations in the host country.

### The equations

E\_yanpr (all,r,REG)

$$\text{yanpr}(r)=\text{sum}[j,\text{TRAD\_COMM},\text{yanpri}(j,r)];$$

E\_yanpri (all,i,TRAD\_COMM)(all,r,REG)

$$100*\text{yanpri}(i,r)=$$

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<sup>2</sup> An exception is noted in section 8.5.

$$(1-SHPTAX(i,r))*$$

$$\{ \text{VOM}(i,r)*[pm(i,r)+qo(i,r)]-$$

$$\text{VOA}(i,r)*[ps(i,r)+qo(i,r)]\}-$$

$$100*PTAX(i,r)*c\_SHPTAX(i,r);$$

These equations calculate, for each region, the change in total (variable yanpr) and industry specific (variable yanpri) output impediment rents. The expression inside the braces on the right hand side of equation E\_yanpri is (100 times the change in) the output tax revenue from industry i in region r — calculated as the difference between the market and agents' value of output. The coefficient (actually a GEMPACK levels variable — see the next equation) SHPTAX(i,r) is the proportion of that revenue that is genuine tax revenue. In the current implementation of the model it is hard-wired at 1 for the primary and secondary industries, and 0 for the tertiary industry via the equation:

FORMULA (Initial) & EQUATION (Levels)

E\_c\_SHPTAX (all,i,PROD\_COMM)(all,r,REG)

$$SHPTAX(i,r)=1-IF[\$POS(i,PROD\_COMM)=3,1];$$

This is all that is required for current applications. Note that equation E\_yanpri allows for the future possibility that SHPTAX may vary during the course of a simulation.

E\_yanp\_hhi (all,i,TRAD\_COMM)(all,s,HOME)(all,d,host)

$$100*yanp\_hhi(i,s,d)=$$

$$IF[PHTAX(i,s,d) \neq 0,$$

$$(1-SHPTAX(i,d))*$$

$$\{ \text{VOHM}(i,s,d)*[poh(i,s,d)+qoh(i,s,d)]-$$

$$\text{VOHA}(i,s,d)*[psh(i,s,d)+qoh(i,s,d)]\}-$$

$$100*PHTAX(i,s,d)*c\_SHPTAX(i,d)];$$

This equation defines the change in the output impediment rents for all foreign industries (variable yanp\_hhi) by industry, home region (owner) and host region (location). The expression in braces is (100 times the change in) the output tax revenue from industry i owned by region s but operating in region d — calculated as

the difference between market (coefficient VOHM(i,s,d), variable expression poh(i,s,d)+qoh(i,s,d)) and agents' (coefficient VOHA(i,s,d), variable expression psh(i,s,d)+qoh(i,s,d)) values of output. Again, coefficient SHPTAX is used to determine what proportion of this revenue is impediment rents.

E\_yanp\_h\_\_ (all,r,REG)

$$\begin{aligned}
 \text{yanp\_h\_}(r) = & \\
 & \text{IF}\{\text{HOME\_TAX\_ANP} \neq 0, \\
 & \quad \text{HOME\_TAX\_ANP}\{ \\
 & \quad \quad \text{sum}[i,\text{TRAD\_COMM},\text{sum}[d,\text{DEST},\text{yanp\_hhi}(i,r,d)]] - \\
 & \quad \quad \text{sum}[i,\text{TRAD\_COMM},\text{sum}[s,\text{HOME},\text{yanp\_hhi}(i,s,r)]]\} + \\
 & \text{IF}\{\text{HOST\_TAX\_ANP} \neq 0, \\
 & \quad \text{HOST\_TAX\_ANP}\{ \\
 & \quad \quad \text{sum}[i,\text{TRAD\_COMM},\text{sum}[d,\text{DEST}, \\
 & \quad \quad \quad [1-\text{TYPR\_L}(d)]*\text{yanp\_hhi}(i,r,d) - \\
 & \quad \quad \quad 0.01*\text{ANPTAX\_HHI}(i,r,d)*\text{TYPR\_L}(d)*\text{typr}(d)]] - \\
 & \quad \quad \text{sum}[i,\text{TRAD\_COMM},\text{sum}[s,\text{HOME}, \\
 & \quad \quad \quad [1-\text{TYPR\_L}(r)]*\text{yanp\_hhi}(i,s,r) - \\
 & \quad \quad \quad 0.01*\text{ANPTAX\_HHI}(i,s,r)*\text{TYPR\_L}(r)*\text{typr}(r)]]\} \};
 \end{aligned}$$

This equation defines the net change in income for region r (variable yanp\_h\_\_(r)) from output impediment rents of industries owned by region r but operating abroad and industries located in region r but owned by foreigners. It is in this equation that the taxation of rents in the home versus host country is determined. The first IF covers taxation in the home country, while the second IF covers taxation in the host country. In current applications, setting coefficient HOST\_TAX\_ANP equal to 1 and coefficient HOME\_TAX\_ANP equal to 0 activates host-based taxation. This is consistent with the treatment of FDI income arising from normal returns to capital (section 4.7).

In the first IF statement, income flows in yanp\_hhi are just summed. In the second IF, the property income tax rate is deducted prior to summing (hence the 1-TYPR\_L terms). There are two terms contributing to each income flow under host-based



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taxation. The terms involving  $yanp\_hhi$  are the effects of changes in pre-tax rents on income received by the home country. The terms involving  $typr$  are the effects of changes in host country property income tax rates on income received by the home country. The coefficient  $ANPTAX\_HHI$  ('AN' — abnormal returns; 'PTAX' — the coefficient for output tax revenue in GTAP) is the pre-tax output impediment rents. It equals the output tax revenue — calculated as the difference of market (coefficient  $VOHM$ ) and agents' (coefficient  $VOHA$ ) values of output — multiplied by the factor  $1-SHPTAX$  for the host region.

Note that within each IF there are two sums. The first has region  $r$  as home region. It captures the income coming to region  $r$  from industries owned by region  $r$  but operating abroad. The second sum has region  $r$  as host region and captures the income outflow from region  $r$  due to the repatriation of rents by foreigners.

REVINDT (all,r,REG)

$$\begin{aligned} gsub(r) = & (RECIP\_GRCOMT(r))*sum(i,TRAD\_COMM, \\ & SHPTAX(i,r)*[(COSTINP(i,r)*to(i,r))+PTAX(i,r)*(qo(i,r)+pm(i,r))]+ \\ & 100*PTAX(i,r)*c\_SHPTAX(i,r)); \end{aligned}$$

The GTAPICM equation REVINDT is modified (italicised portion) to account for the fact that not all output tax revenue is genuine — only the proportion indicated by coefficient  $SHPTAX$ .

## 8.2 Welfare effects of income from output impediments

### Preliminaries

As described in appendix B, each foreign income flow gives rise to three welfare contribution terms — rate of return, asset price and endowment effects. The equations in this section are the implementation of these effects for output impediment rents.

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## The equations

E\_anrro\_hhi (all,i,TRAD\_COMM)(all,s,HOME)(all,d,host)

$$\begin{aligned} & \text{IF}[\text{VFDI\_HHI}(i,s,d)=0,\text{anrro\_hhi}(i,s,d)]= \\ & \text{IF}[\text{VFDI\_HHI}(i,s,d)>0, \\ & 100*[ \\ & \quad \text{IF}\{\text{HOME\_TAX\_ANP} \text{ ne } 0,\text{HOME\_TAX\_ANP}*\text{yanp\_hhi}(i,s,d)\}+ \\ & \quad \text{IF}\{\text{HOST\_TAX\_ANP} \text{ ne } 0,\text{HOST\_TAX\_ANP}*[ \\ & \quad \quad [1-\text{TYPR\_L}(d)]*\text{yanp\_hhi}(i,s,d)- \\ & \quad \quad 0.01*\text{ANPTAX\_HHI}(i,s,d)*\text{TYPR\_L}(d)*\text{typr}(d)]\}- \\ & \quad \{\{1-\text{HOST\_TAX\_ANP}*\text{TYPR\_L}(d)\}* \\ & \quad \quad \text{ANPTAX\_HHI}(i,s,d)*[\text{pcgds}(d)+\text{qfes}(i,s,d)]+ \\ & \quad \quad \text{VFDI\_HHI}(i,s,d)*\text{anrro\_hhi}(i,s,d)\}]; \end{aligned}$$

For each foreign-owned industry, this equation defines the percentage point change in the abnormal component of the rate of return to capital (variable `anrro_hhi`), which is calculated from output impediment rents considered as a return on the asset value of the capital stock associated with the industry (coefficient `VFDI_HHI(i,s,d)`, variable expression `[pcgds(d)+qfes(i,s,d)]`). It defines the rate of return implicitly by equating (in linearised form) the rents (the terms on the right hand side inside the square brackets that are pre-multiplied by 100) with the rate of return times the asset value, after the manner of appendix B. Note the use of the coefficients `HOME_TAX_ANP` and `HOST_TAX_ANP` to correctly apply property income tax rates (coefficient `TYPR_L`, variable `typr`) to pre-tax rents (coefficient `ANPTAX_HHI`, variable `yanp_hhi`) for host-based taxation. This is the current default, so `anrro_hhi` is a post-tax rate of return.

E\_CNTanto\_hhi (all,i,TRAD\_COMM)(all,s,HOME)(all,d,host)

$$\begin{aligned} & \text{CNTanto\_hhi}(i,s,d)= \\ & \quad [.01/\text{INCRATIO}(s)]*\text{VFDI\_HHI}(i,s,d)*\text{anrro\_hhi}(i,s,d); \end{aligned}$$

E\_CNTanpo\_hhi (all,i,TRAD\_COMM)(all,s,HOME)(all,d,host)

---


$$\begin{aligned} \text{CNTanpo\_hhi}(i,s,d) = & \\ & [.01/\text{INCRATIO}(s)] * [1 - \text{HOST\_TAX\_ANP} * \text{TYPR\_L}(d)] * \\ & \text{ANPTAX\_HHI}(i,s,d) * \text{pcgds}(d); \end{aligned}$$

E\_CNTanqo\_hhi (all,i,TRAD\_COMM)(all,s,HOME)(all,d,host)

$$\begin{aligned} \text{CNTanqo\_hhi}(i,s,d) = & \\ & [.01/\text{INCRATIO}(s)] * [1 - \text{HOST\_TAX\_ANP} * \text{TYPR\_L}(d)] * \\ & \text{ANPTAX\_HHI}(i,s,d) * \text{qfes}(i,s,d); \end{aligned}$$

These three equations define, for each foreign-owned industry, the rate of return, asset price and endowment effect welfare contributions to the home region from output impediment rents. The equations basically take the terms whose sum is equated with impediment rents in equation E\_rrr\_hhi:

$$\begin{aligned} & \text{VFDI\_HHI}(i,s,d) * \text{anrrr\_hhi}(i,s,d) \\ & [1 - \text{HOST\_TAX\_ANP} * \text{TYPR\_L}(d)] * \text{ANPTAX\_HHI}(i,s,d) * \text{pcgds}(d) \\ & [1 - \text{HOST\_TAX\_ANP} * \text{TYPR\_L}(d)] * \text{ANPTAX\_HHI}(i,s,d) * \text{qfes}(i,s,d) \end{aligned}$$

and pre-multiplies them by the factor [.01/INCRATIO(s)] to convert them to welfare contributions.

E\_CNTanto\_h\_\_ (all,r,REG)

$$\begin{aligned} \text{CNTanto\_h__}(r) = & \\ & \text{sum}[i, \text{TRAD\_COMM}, \text{sum}[d, \text{DEST}, \text{CNTanto\_hhi}(i,r,d)]] - \\ & [1/\text{INCRATIO}(r)] * \\ & \text{sum}[i, \text{TRAD\_COMM}, \text{sum}[s, \text{HOME}, \\ & \quad \text{INCRATIO}(s) * \text{CNTanto\_hhi}(i,s,r)]]; \end{aligned}$$

E\_CNTanpo\_h\_\_ (all,r,REG)

$$\begin{aligned} \text{CNTanpo\_h__}(r) = & \\ & \text{sum}[i, \text{TRAD\_COMM}, \text{sum}[d, \text{DEST}, \text{CNTanpo\_hhi}(i,r,d)]] - \\ & [1/\text{INCRATIO}(r)] * \end{aligned}$$

---


$$\begin{aligned} & \text{sum}[i, \text{TRAD\_COMM}, \text{sum}[s, \text{HOME}, \\ & \quad \text{INCRATIO}(s) * \text{CNTanqo\_hhi}(i, s, r)]]; \\ E\_ \text{CNTanqo\_h\_} & (\text{all}, r, \text{REG}) \\ \text{CNTanqo\_h\_}(r) = & \\ & \text{sum}[i, \text{TRAD\_COMM}, \text{sum}[d, \text{DEST}, \text{CNTanqo\_hhi}(i, r, d)]] - \\ & [1 / \text{INCRATIO}(r)] * \\ & \text{sum}[i, \text{TRAD\_COMM}, \text{sum}[s, \text{HOME}, \\ & \quad \text{INCRATIO}(s) * \text{CNTanqo\_hhi}(i, s, r)]]; \end{aligned}$$

These equations define, respectively, the total rate of return, asset price and endowment effect welfare contributions from output impediment rents. Each equation involves two sums. The first is over the contributions from those rents where region  $r$  is the home region, that is, the recipient of the rents. It is a straight sum of the previous  $\text{CNT}^*_{\text{hhi}}$  variables. The second sum is over the contributions from those rents where region  $r$  is the host region, that is, where an outflow of rents occurs. Since the previous  $\text{CNT}^*_{\text{hhi}}$  variables are defined as contributions to welfare with respect to the home region, they need to be scaled in the second sum by  $\text{INCRATIO}(s) / \text{INCRATIO}(r)$  to convert them to host region contributions.

## 8.3 Income from capital impediments

### Preliminaries

Since all industry specific taxes on capital in the GTAP database are zero, capital taxes in the FTAP database represent only barriers to establishment. These must be distributed to the correct recipients, but adjustments to the tax revenue equations in the host country are not necessary because of a happy accident in the implementation sequence.

The government revenue accounting equations were taken from McDougall (1993b) during the construction of GTAPICM. These equations did not allow for industry specific capital taxes, so the revenue from such taxes was not represented in the government revenue accounting equations. When capital impediments were added, they were represented through the GTAP structure, which allowed for industry specific capital taxes but did not distinguish government and private income. It was

thus only necessary to add the industry specific capital taxes (de facto impediment rents) to national and private income (section 8.6) without adjustment to government revenue accounting.

## The equations

$E\_yankr$  (all,r,REG)

$$yankr(r)=\text{sum}[j,\text{TRAD\_COMM},yankri(j,r)];$$

$E\_yankri$  (all,j,TRAD\_COMM)(all,r,REG)

$$100*yankri(j,r)=$$

$$\text{sum}\{i,\text{ENDWC\_COMM},\text{EVFA}(i,j,r)*[\text{pfe}(i,j,r)+\text{qfe}(i,j,r)]-$$

$$\text{VFM}(i,j,r)*[\text{rp}(j,r)+\text{qfe}(i,j,r)]\};$$

These equations calculate, for each region, the change in total (variable  $yankr$ ) and industry specific (variable  $yankri$ ) capital impediment rents. The sum on the right hand side of equation  $E\_yankri$  is (100 times the change in) the industry specific capital tax revenue for industry  $j$  in region  $r$ . This is calculated as the difference between the agents' and market value of capital, the function of the sum being just to pick out the capital input ( $i$  in the single element set  $\text{ENDWC\_COMM}=\{\text{capital}\}$ ) to industry  $j$ .

Since all industry specific taxes on capital in the GTAP database are zero, the only industry specific taxes on capital in the FTAP database are those representing capital impediments. So for the present implementation of FTAP, no coefficient has been introduced to specify what portion of the capital tax revenues are impediment rents (since it is always 100 per cent). This contrasts with the case of output impediments (section 8.1).

$E\_yank\_hhi$  (all,i,TRAD\_COMM)(all,s,HOME)(all,d,host)

$$100*yank\_hhi(i,s,d)=\text{EVIFAS}(i,s,d)*[\text{pfesa}(i,s,d)+\text{qfes}(i,s,d)]-$$

$$\text{EVIFMS}(i,s,d)*[\text{rps}(i,s,d)+\text{qfes}(i,s,d)];$$

This equation defines the change in the capital impediment rents for all foreign industries (variable  $yank\_hhi$ ) by industry, home region (owner) and host region (location). The expression in braces is (100 times the change in) the capital tax revenue from industry  $i$  owned by region  $s$  but operating in region  $d$  — calculated as the difference between agents' (coefficient  $\text{EVIFAS}(i,s,d)$ , variable expression

pfesa(i,s,d)+qfes(i,s,d)) and market (coefficient EVIFMS(i,s,d), variable expression rps(i,s,d)+qfes(i,s,d)) values of capital.

E\_yank\_h\_\_ (all,r,REG)

$$\begin{aligned}
 & \text{yank\_h\_}(r)= \\
 & \text{IF}\{\text{HOME\_TAX\_ANK ne 0,} \\
 & \quad \text{HOME\_TAX\_ANK}\{ \\
 & \quad \quad \text{sum}[i,\text{TRAD\_COMM},\text{sum}[d,\text{DEST},\text{yank\_hhi}(i,r,d)]]- \\
 & \quad \quad \text{sum}[i,\text{TRAD\_COMM},\text{sum}[s,\text{HOME},\text{yank\_hhi}(i,s,r)]]\}\}+ \\
 & \text{IF}\{\text{HOST\_TAX\_ANK ne 0,} \\
 & \quad \text{HOST\_TAX\_ANK}\{ \\
 & \quad \quad \text{sum}[i,\text{TRAD\_COMM},\text{sum}[d,\text{DEST}, \\
 & \quad \quad \quad [1-\text{TYPR\_L}(d)]*\text{yank\_hhi}(i,r,d)- \\
 & \quad \quad \quad 0.01*\text{ANKTAX\_HHI}(i,r,d)*\text{TYPR\_L}(d)*\text{typr}(d)]]- \\
 & \quad \quad \text{sum}[i,\text{TRAD\_COMM},\text{sum}[s,\text{HOME}, \\
 & \quad \quad \quad [1-\text{TYPR\_L}(r)]*\text{yank\_hhi}(i,s,r)- \\
 & \quad \quad \quad 0.01*\text{ANKTAX\_HHI}(i,s,r)*\text{TYPR\_L}(r)*\text{typr}(r)]]\}\};
 \end{aligned}$$

This equation defines the net change in income for region r (variable yank\_h\_\_(r)) from capital impediment rents of industries owned by region r but operating abroad and industries located in region r but owned by foreigners. It is in this equation that the taxation of rents in the home versus host country is determined. The first IF covers taxation in the home country, while the second IF covers taxation in the host country. In current applications, setting coefficient HOST\_TAX\_ANK equal to 1 and coefficient HOME\_TAX\_ANK equal to 0 activates host-based taxation. This is consistent with the treatment of FDI income arising from normal returns to capital (section 4.7).

In the first IF statement, income flows in yank\_hhi are just summed, while in the second IF statement the property income tax rate is deducted prior to summing (hence the 1-TYPR\_L terms). There are two terms contributing to each income flow under host-based taxation. The terms involving yank\_hhi are the effects of changes in pre-tax rents on income received by the home country. The terms involving typr

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are the effects of changes in host country property income tax rates on income received by the home country. The coefficient ANKTAX\_HHI ('AN' — abnormal returns; 'KTAX' — represented as capital tax revenue) is the pre-tax capital impediment rents. It equals the capital tax revenue — calculated as the difference of agents' (coefficient EVIFAS) and market (coefficient EVIFMS) values of capital.

Note that within each IF statement, there are two sums. The first has region r as home region. It captures the income coming to region r from industries owned by region r but operating abroad. The second sum has region r as host region and captures the income outflow from region r due to the repatriation of rents by foreigners.

## 8.4 Welfare effects of income from capital impediments

### Preliminaries

As described in appendix B, each foreign income flow gives rise to three welfare contribution terms — rate of return, asset price and endowment effects. The equations in this section are the implementation of these effects for capital impediment rents.

### The equations

E\_anrrk\_hhi (all,i,TRAD\_COMM)(all,s,HOME)(all,d,host)

IF[VFDI\_HHI(i,s,d)=0,anrrk\_hhi(i,s,d)]=

IF[VFDI\_HHI(i,s,d)>0,

100\*[

IF{HOME\_TAX\_ANK ne 0,HOME\_TAX\_ANK\*yank\_hhi(i,s,d)}+

IF{HOST\_TAX\_ANK ne 0,

HOST\_TAX\_ANK\*{

[1-TYPR\_L(d)]\*yank\_hhi(i,s,d)-

0.01\*ANKTAX\_HHI(i,s,d)\*TYPR\_L(d)\*typr(d)}]-

{[1-HOST\_TAX\_ANK\*TYPR\_L(d)]\*

---


$$\text{ANKTAX\_HHI}(i,s,d)*[\text{pcgds}(d)+\text{qfes}(i,s,d)]+ \\ \text{VFDI\_HHI}(i,s,d)*\text{anrrk\_hhi}(i,s,d)\}}];$$

For each foreign-owned industry, this equation defines the percentage point change in the abnormal component of the rate of return to capital (variable `anrrk_hhi`), which is calculated from capital impediment rents considered as a return on the asset value of the capital stock associated with the industry (coefficient `VFDI_HHI(i,s,d)`, variable expression `[pcgds(d)+qfes(i,s,d)]`). It defines the rate of return implicitly by equating (in linearised form) the rents (the terms on the right hand side inside the square brackets that are pre-multiplied by 100) with the rate of return times the asset value, after the manner of appendix B. Note the use of the coefficients `HOME_TAX_ANK` and `HOST_TAX_ANK` to correctly apply property income tax rates (coefficient `TYPR_L`, variable `typr`) to pre-tax rents (coefficient `ANKTAX_HHI`, variable `yank_hhi`) for host-based taxation. This is the current default, so `anrrk_hhi` is a post-tax rate of return.

$$\text{E\_CNTanrr\_hhi}(\text{all},i,\text{TRAD\_COMM})(\text{all},s,\text{HOME})(\text{all},d,\text{host})$$

$$\text{CNTanrr\_hhi}(i,s,d)= \\ [.01/\text{INCRATIO}(s)]*\text{VFDI\_HHI}(i,s,d)*\text{anrrk\_hhi}(i,s,d);$$

$$\text{E\_CNTanpk\_hhi}(\text{all},i,\text{TRAD\_COMM})(\text{all},s,\text{HOME})(\text{all},d,\text{host})$$

$$\text{CNTanpk\_hhi}(i,s,d)= \\ [.01/\text{INCRATIO}(s)]*[1-\text{HOST\_TAX\_ANK}*\text{TYPR\_L}(d)]* \\ \text{ANKTAX\_HHI}(i,s,d)*\text{pcgds}(d);$$

$$\text{E\_CNTanend\_hhi}(\text{all},i,\text{TRAD\_COMM})(\text{all},s,\text{HOME})(\text{all},d,\text{host})$$

$$\text{CNTanend\_hhi}(i,s,d)= \\ [.01/\text{INCRATIO}(s)]*[1-\text{HOST\_TAX\_ANK}*\text{TYPR\_L}(d)]* \\ \text{ANKTAX\_HHI}(i,s,d)*\text{qfes}(i,s,d);$$

These three equations define, for each foreign-owned industry, the rate of return, asset price and endowment effect welfare contributions to the home region from capital impediment rents. The equations basically take the terms whose sum is equated with impediment rents in equation `E_rrk_hhi`:

$$\text{VFDI\_HHI}(i,s,d)*\text{anrrk\_hhi}(i,s,d)$$



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$$[1-\text{HOST\_TAX\_ANK}*\text{TYPR\_L}(d)]*\text{ANKTAX\_HHI}(i,s,d)*\text{pcgds}(d)$$

$$[1-\text{HOST\_TAX\_ANK}*\text{TYPR\_L}(d)]*\text{ANKTAX\_HHI}(i,s,d)*\text{qfes}(i,s,d)$$

and pre-multiplies them by the factor  $[\text{.01}/\text{INCRATIO}(s)]$  to convert them to welfare contributions.

$E\_CNTanrr\_h\_ (all,r,REG)$

$$\text{CNTanrr\_h\_}(r)=$$

$$\text{sum}[i,\text{TRAD\_COMM},\text{sum}[d,\text{DEST},\text{CNTanrr\_hhi}(i,r,d)]]-$$

$$[1/\text{INCRATIO}(r)]*$$

$$\text{sum}[i,\text{TRAD\_COMM},\text{sum}[s,\text{HOME},$$

$$\text{INCRATIO}(s)*\text{CNTanrr\_hhi}(i,s,r)];$$

$E\_CNTanpk\_h\_ (all,r,REG)$

$$\text{CNTanpk\_h\_}(r)=$$

$$\text{sum}[i,\text{TRAD\_COMM},\text{sum}[d,\text{DEST},\text{CNTanpk\_hhi}(i,r,d)]]-$$

$$[1/\text{INCRATIO}(r)]*$$

$$\text{sum}[i,\text{TRAD\_COMM},\text{sum}[s,\text{HOME},$$

$$\text{INCRATIO}(s)*\text{CNTanpk\_hhi}(i,s,r)];$$

$E\_CNTanend\_h\_ (all,r,REG)$

$$\text{CNTanend\_h\_}(r)=$$

$$\text{sum}[i,\text{TRAD\_COMM},\text{sum}[d,\text{DEST},\text{CNTanend\_hhi}(i,r,d)]]-$$

$$[1/\text{INCRATIO}(r)]*$$

$$\text{sum}[i,\text{TRAD\_COMM},\text{sum}[s,\text{HOME},$$

$$\text{INCRATIO}(s)*\text{CNTanend\_hhi}(i,s,r)];$$

These equations define, respectively, the total rate of return, asset price and endowment effect welfare contributions from capital impediment rents. Each equation involves two sums. The first is over the contributions from those rents where region  $r$  is the home region, that is, the recipient of the rents. It is a straight

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sum of the previous CNT\*\_hhi variables. The second sum is over the contributions from those rents where region r is the host region, that is, where an outflow of rents occurs. Since the previous CNT\*\_hhi variables are defined as contributions to welfare with respect to the home region, they need to be scaled in the second sum by INCRATIO(s)/ INCRATIO(r) to convert them to host region contributions.

## 8.5 Income from export impediments

### Preliminaries

Barriers to ongoing operations are represented as export taxes as well as output taxes, as they may inhibit both the operation of foreign firms in the domestic market and the operation of foreign firms exporting into the domestic market.

The magnitude of the export tax is determined by the size of the barriers to ongoing operation in the destination region.

The representation as an export tax in the source region rather than an import tariff in the destination region (that imposes the barrier) automatically directs the impediment rents (captured in the export tax revenue) to the home region.<sup>3</sup>

The portion of export tax revenue that is impediment rents is taxed at the property income tax rate. The post-tax value is transferred from government revenue to private income through a government transfer variable already in the model from the GTAPICM extension. Thus no adjustment to government revenue accounting equations is necessary to account for export taxes that are de facto private income.

### The equations

E\_d\_ughr\_ (all,r,REG)

$$d\_ughr\_ (r)=d\_ughr(r)+$$

$$\text{sum}[i,\text{TRAD\_COMM},\text{sum}[d,\text{DEST},$$

$$(1-\text{SHXTAXD}(i,r,d))*$$

$$\{ \text{VXWD}(i,r,d)*[\text{pfob}(i,r,d)+\text{qxs}(i,r,d)]-$$

---

<sup>3</sup> This is identical to the representation of the Multifibre Arrangement in the GTAP database.

$$VXMD(i,r,d)*[pxs(i,r,d)+qxs(i,r,d)]- \\ 100*XTAXD(i,r,d)*c\_SHXTAXD(i,r,d)];$$

This equation determines the government to private transfers necessitated by the impediment rents contained within export tax revenues.

The GTAPICM equations HHOLD\_INCOME and GOVT\_CURRNT\_OUTLS have two variables associated with them — ughr and d\_ughr — which permit transfers from government revenue to private income to occur. The first variable is a percentage change variable (linked to the nominal household pre-transfer income variable yhr and an exogenous shift variable fghr), the second a change variable. To permit the transfer of endogenously determined amounts of revenue, d\_ughr is replaced throughout the model code with d\_ughr\_. Equation E\_d\_ughr\_ sets d\_ughr\_ equal to d\_ughr plus the endogenous component of transfers, which is the proportion of export tax revenue representing post-tax impediment rents. Thus d\_ughr continues to fulfil its role as an exogenous transfer variable.

Tax revenues on exports of commodity i from region r to region d (coefficient XTAXD(i,r,d)) are calculated in linearised form in equation E\_d\_ughr\_ as world (coefficient VXWD(i,r,d), variable expression pfob(i,r,d)+qxs(i,r,d)) minus market (coefficient VXMD(i,r,d), variable expression pxs(i,r,d)+qxs(i,r,d)) values of exports. The proportion of export tax revenue that is genuine is specified by the coefficient SHXTAXD. In the current FTAP database, all export taxes on the primary and secondary commodities are genuine, while all export taxes on the tertiary commodity are impediment rents. Therefore, SHXTAXD is constant at 1 for the primary and secondary commodities, and is equal to the property income tax rate for the tertiary commodity, thus:

FORMULA (Initial) (all,i,TRAD\_COMM)(all,s,SOURCE)(all,d,DEST)

$$SHXTAXD(i,s,d)=1-IF[$POS(i,TRAD_COMM)=3,1-TYPR_L(s)];$$

EQUATION E\_c\_SHXTAXD

(all,i,TRAD\_COMM)(all,s,SOURCE)(all,d,DEST)

$$c\_SHXTAXD(i,s,d)=0.01*TYPR_L(s)*typr(s);$$

In contrast to output and capital impediment rents (sections 8.1 and 8.3, respectively), the export impediment rents are taxed in the home (source) rather than host (destination) region (note the s region specifier on the right hand side of equation E\_c\_SHXTAXD). However, if it is reasonable to represent impediments as export taxes, this assumption about taxes on the impediment rents seems the only

reasonable one. The export impediment rents are generated within the home region rather than within the host region, so how would the host region taxation system access them?

## 8.6 National income equations

### Preliminaries

In section 4.7 it was indicated that certain GTAPICM income accounting equations need to be modified each time new foreign income terms are added, and that the final form of these equations would be presented in this section after the addition of all international income flows.

### The equations

NATL\_INCOME # national income, by region # (all,r,REG)

$$\begin{aligned}
 & YCR(r)*[y_r(r)-incomelack(r)] \\
 & = YFNT(r)*yfn(r) + YCR(r)*qyir(r)+ \\
 & \quad 100*yankr(r)+100*yank\_h\_\_(r)+ \\
 & \quad 100*yanpr(r)+100*yanp\_h\_\_(r)+ \\
 & \quad + YCITR(r)*y_r(r) + GRCOMT(r)*rc(r) + 100*yfdi\_h\_\_(r);
 \end{aligned}$$

PROPY\_INCOME # property income, by region # (all,r,REG)

$$\begin{aligned}
 & YCHHPPR(r)*yhpr(r) = 100*yankr(r)+100*yank\_h\_\_(r)+ \\
 & \quad 100*yanpr(r)+100*yanp\_h\_\_(r)+ \\
 & \quad YCEQR(r)*yer(r) + YCHHDPR(r)*qyhir(r) + YCHHITR(r)*yhdr(r) + \\
 & \quad 100*yfdi\_h\_\_(r);
 \end{aligned}$$

These equations, without the italicised terms, were introduced in the GTAPICM extension (chapter 3). FDI income, and output and capital impediment rents, must be added to both equations. FDI income is easy — just add the *yfdi\_h\_\_* term (defined by equation E\_yfdi\_h\_\_ in section 4.7) to each equation. The impediment rents are subtler, but the construction of the equations is best conceived as follows.

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All impediment rents generated in a region (variable yanpr for output, variable yankr for capital) are added to income. Then the impediment rents that are gained (lost) from investment abroad (to foreign investors) are added to (subtracted from) income. The variables yanp\_h\_\_ and yank\_h\_\_ represent the net value of these gains and losses for output and capital impediment rents, respectively.

The slack variable incomeslack, familiar from original GTAP, is added to allow partial equilibrium closures to be used with FTAP if desired.

E\_yoit (all,r,REG) yoit(r)=

```

IF{HOST_TAX_ANP ne 0,
  HOST_TAX_ANP*{
    -sum[i,TRAD_COMM,sum[d,DEST,
      [1-TYPR_L(d)]*yanp_hhi(i,r,d)-
      0.01*ANPTAX_HHI(i,r,d)*TYPR_L(d)*typr(d)]]
    +sum[i,TRAD_COMM,sum[s,HOME,
      [2-TYPR_L(r)]*yanp_hhi(i,s,r)-
      0.01*ANPTAX_HHI(i,s,r)*TYPR_L(r)*typr(r)]]} };

```

E\_ykit (all,r,REG) ykit(r)=

```

IF{HOST_TAX_ANK ne 0,
  HOST_TAX_ANK*{
    -sum[i,TRAD_COMM,sum[d,DEST,
      [1-TYPR_L(d)]*yank_hhi(i,r,d)-
      0.01*ANKTAX_HHI(i,r,d)*TYPR_L(d)*typr(d)]]
    +sum[i,TRAD_COMM,sum[s,HOME,
      [2-TYPR_L(r)]*yank_hhi(i,s,r)-
      0.01*ANKTAX_HHI(i,s,r)*TYPR_L(r)*typr(r)]]} };

```

E\_yhprtax # property income which is taxed # (all,r,REG)

---

$$YCHHPPRTAX(r)*yhprtax(r)=$$

$$YCHHPPR(r)*yhpr(r)+100*[yoit(r)+ykit(r)-yfdi\_h\_\_(r)];$$

The first two equations determine adjustments (variables yoit and ykit) that must be made to property income before it is taxed in order to eliminate double taxation of output and capital impediment rents, respectively. Note that both yoit and ykit are zero under home-based taxation of impediments. But when impediment rents are taxed in the host region, yoit and ykit must be added to property income to determine the correct property income tax base (coefficient YCHHPPRTAX, variable yhprtax). The third equation calculates this property income tax base by subtracting FDI income (which is taxed in the host region — see section 4.7) from total property income (coefficient YCHHPPR, variable yhpr) and then adding the adjustments for output and capital impediment rents.

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## 9 Miscellaneous equations

This section captures all the leftovers — equations such as definitions, equations that perform checking functions on income accounting, or equations that merely make some results easy to view.

Section 9.1 covers the equations for GTAPICM.

Some of the variable definitions introduced in GTAPICM required modification if they were to be valid for FTAP. Sometimes these modifications were done, sometimes not, depending on which variable definitions were found useful when analysing FTAP policy simulations. Where relevant, the required or actual change to a GTAPICM equation is indicated by a bold GEMPACK comment alongside the equation name. Section 9.2 lists the adaptations for FTAP of GTAPICM definitions.

Section 9.3 lists other miscellaneous FTAP equations, grouped according to their functions.

### 9.1 Miscellaneous equations for GTAPICM

There are a number of miscellaneous equations that form part of the ICM extension. These specify definitional variables that are not used in the behavioural equations of the model, but which are useful when interpreting simulation results.

This group of equations begins with four equations that define firms' demand for endowment commodities in each region:

E\_qfel (all,l,LABOR)(all,j,PROD\_COMM)(all,r,REG)

$$qfel(l,j,r) = qfe(l,j,r);$$

E\_qfek (all,j,PROD\_COMM)(all,r,REG)

$$qfek(j,r) = \text{sum}(k, \text{ENDWC\_COMM}, qfe(k,j,r));$$

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E\_qfen (all,j,PROD\_COMM)(all,r,REG)

$$qfen(j,r) = \text{sum}(n, \text{LAND}, qfe(n,j,r));$$

E\_qfenr (all,j,PROD\_COMM)(all,r,REG)

$$qfenr(j,r) = \text{sum}(nr, \text{NATRES}, qfe(nr,j,r));$$

where  $qfel(l,j,r)$ ,  $qfek(j,r)$ ,  $qfen(j,r)$  and  $qfenr(j,r)$  is the demand for labour, capital, land and natural resources, respectively, by industry  $j$  in region  $r$ , and  $\text{PROD\_COMM}$  is the set of produced commodities.

Equation E\_wr defines the real post-tax wage rate in each region  $wr(r)$  as the nominal post-tax wage rate deflated by the price index for private household consumption in each region:

E\_wr (all,r,REG)

$$wr(r) = w(r) - ppriv(r);$$

Value added in each region  $qvar(r)$  is a share-weighted sum of value added in all industries in each region, as defined by equation E\_qvar:

E\_qvar ! **Altered in section 9.2 !**

(all,r,REG)

$$\begin{aligned} \text{sum}(j, \text{PROD\_COMM}, VVA(j,r)) * qvar(r) = \\ \text{sum}(i, \text{PROD\_COMM}, VVA(i,r) * qva(i,r)); \end{aligned}$$

where  $VVA(j,r)$  is the coefficient form of the agent's (or post-tax) price value of value added in industry  $j$  in region  $r$ , and  $qva(i,r)$  is the quantity of value added in industry  $i$  in region  $r$ .

Equation GDPFACTCOST defines gross domestic product at factor cost in each region  $gdpfc(r)$ , as the share-weighted sum of all factor income in each region:



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GDPFACTCOST (all,r,REG)

$$\begin{aligned} \text{gdpfc}(r) = & \\ & \text{SLGDP}(r) * (\text{w}(r) + \text{lt}(r)) + \\ & \text{sum}(i, \text{TRAD\_COMM}, \text{SKGDP}(i,r) * (\text{rp}(i,r) + \text{kk}(i,r))) + \\ & \text{SMGDP}(r) * (\text{rm}(r) + \text{mt}(r)) + \text{SNGDP}(r) * (\text{nrp}(r) + \text{nru}(r)); \end{aligned}$$

where  $\text{SLGDP}(r)$ ,  $\text{SMGDP}(r)$  and  $\text{SNGDP}(r)$  are coefficients representing the market (or pre-tax) price share of labour income, land income and natural resource income, respectively, in gross domestic product at factor cost in region  $r$ , and  $\text{SKGDP}(i,r)$  is a coefficient representing the market (or pre-tax) price share of capital income from industry  $i$  in region  $r$ , in gross domestic product at factor cost in region  $r$ .

National consumption expenditure in each region  $\text{ecr}(r)$  is the sum of private household consumption expenditure and government consumption expenditure in each region, as defined by equation  $\text{NATL\_CONSN\_EXPRES}$ :

$\text{NATL\_CONSN\_EXPRES}$  (all,r,REG)

$$\begin{aligned} \text{EPCSR}(r) * \text{ecr}(r) = & \\ & \text{PRIVEXP}(r) * \text{yp}(r) + \text{GOVEXP}(r) * \text{zg}(r); \end{aligned}$$

The national savings ratio in each region is defined by the equation  $\text{NAT\_SAVINGS}$ :

$\text{NAT\_SAVINGS}$  (all,r,REG)

$$\begin{aligned} \text{YCR}(r) * \text{qysr}(r) + \text{SVR}(r) * \text{y}_r(r) = & \\ & \text{YCHHDPR}(r) * \text{qyhsr}(r) + \text{SVT}(r) * \text{yhdr}(r) + \\ & \text{RCGVR}(r) * \text{qrgrs}(r) + \text{SPGVR}(r) * \text{rgr}(r); \end{aligned}$$

where  $\text{qysr}(r)$  is the (absolute change in the) ratio of savings to income in region  $r$ . Thus, the change in national savings in each region (the left side of equation  $\text{NAT\_SAVINGS}$ ) is made up of the change in household savings in each region (the first and second terms on the right hand side) plus the change in government savings in each region (the third and fourth terms on the right hand side).

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Real private household consumption in each region  $ctr(r)$  is equal to nominal private household consumption deflated by the private household consumption index in each region:

REALCONS (all,r,REG)

$$ctr(r) = yp(r) - ppriv(r);$$

Nominal investment in each region  $invt(r)$  is equal (in levels) to the price multiplied by the quantity of investment in each region:

AGGINV (all,r,REG)

$$invt(r) = pcgds(r) + qcgds(r);$$

Real household disposable income in each region  $ydr(r)$  is nominal household disposable income deflated by the private household consumption index in each region:

REALDISPY (all,r,REG)

$$ydr(r) = yhdr(r) - ppriv(r);$$

The size of the budget deficit relative to gross domestic product in each region is captured by the ratio of the government current account surplus to gross domestic product in each region:

RATIO\_GCUAS\_GDP (all,r,REG)

$$\begin{aligned} GDP(r)*gcass(r) + SPGVR(r)*gdpr(r) = \\ RCGVR(r)*qrgr(r) + SPGVR(r)*rgr(r); \end{aligned}$$

where  $GDP(r)$  is the GTAP coefficient for the value of gross domestic product in region  $r$ ,  $gcass(r)$  is the (absolute change in the) ratio of the government current account surplus to nominal gross domestic product in region  $r$ , and  $gdpr(r)$  is nominal gross domestic product in region  $r$ . Equation RATIO\_GCUAS\_GDP says that the change in the government current account surplus in each region (the left hand side) is equal to the change in government savings in each region (the right hand side).

Standard GTAP has no inter-regional capital mobility and thus all income from capital accrues to the region in which the capital is located. In this case, the balance of payments, which must always equal zero, is the sum of net capital inflow (net (of depreciation) savings less investment) and the balance of trade or net exports

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(exports less imports). Allowing capital mobility gives each region a new source of (foreign) income from capital that is located outside its borders, but in which it has an indirect share. In this case, income from abroad must be added to net capital inflow and net exports in order to correctly specify the balance of payments.

The first component of the balance of payments in each region is the balance of trade (or net exports) in that region:

RATIO\_BAL\_TRADE\_GDP (all,r,REG)

$$\begin{aligned} \text{GDP}(r)*\text{bts}(r) + \text{BTL}(r)*\text{gdpn}(r) = \\ \text{VXWREGION}(r)*\text{vxwreg}(r) - \text{VIWREGION}(r)*\text{viwreg}(r); \end{aligned}$$

where  $\text{bts}(r)$  is the (absolute change in the) ratio of the balance of trade to nominal gross domestic product in region  $r$ ,  $\text{BTL}(r)$  is the coefficient form of the balance of trade in region  $r$ ,  $\text{VXWREGION}(r)$  and  $\text{vxwreg}(r)$  are the GTAP coefficient and variable form, respectively, of the fob world price value of exports in region  $r$ , and  $\text{VIWREGION}(r)$  and  $\text{viwreg}(r)$  are the GTAP coefficient and variable form, respectively, of the cif world price value of imports in region  $r$ .

The second component of the regional balance of payments is regional net capital inflow:

RATIO\_NET\_CAPL\_INFLW (all,r,REG)

$$\begin{aligned} \text{VDEP}(r)*\text{depr}(r) + \text{YCR}(r)*\text{qysr}(r) + \text{SVR}(r)*\text{y}_r(r) + \\ \text{GDP}(r)*\text{nkis}(r) + \text{NCIL}(r)*\text{gdpn}(r) = \\ \text{REGINV}(r)*\text{inv}(r); \end{aligned}$$

where  $\text{nkis}(r)$  is the (absolute change in the) ratio of net capital inflow to nominal gross domestic product in region  $r$ , and  $\text{NCIL}(r)$  is the coefficient form of net capital inflow in region  $r$ . Equation RATIO\_NET\_CAPL\_INFLW says that net capital inflow in each region is equal to net (of depreciation) investment less savings, in each region.

The ‘new’ and final component of the regional balance of payments is net (interest) income from abroad:

RATIO\_YCAB\_GDP (all,r,REG)

$$\text{GDP}(r)*\text{nyas}(r) + \text{YCITR}(r)*\text{gdpn}(r) = \text{YCR}(r)*\text{qyir}(r) + \text{YCITR}(r)*\text{y}_r(r);$$

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where  $nyas(r)$  is the (absolute change in the) ratio of net income from abroad to nominal gross domestic product in region  $r$ .

Together these three components specify the (absolute change in the) balance of payments in each region ( $bop(r)$ ):

**E\_bop ! Altered in section 9.2 !** (all,r,REG)

$$bop(r) = bts(r) + nyas(r) + nkis(r);$$

Nominal gross national expenditure in each region  $gne(r)$  is a share-weighted sum of (nominal) private household expenditure, (nominal) government expenditure and (nominal) investment in each region:

GROSS\_NATL\_EXPRES (all,r,REG)

$$GNEL(r)*gne(r) = \\ PRIVEXP(r)*yp(r) + GOVEXP(r)*zg(r) + REGINV(r)*invr(r);$$

where  $GNEL(r)$  is the coefficient form of the value of gross national expenditure in region  $r$ .

The price index for gross national expenditure in each region  $gnepi(r)$  is a share-weighted sum of the prices of each of the components of gross national expenditure in each region:

PRICE\_INDX\_GNE (all,r,REG)

$$GNEL(r)*gnepi(r) = \\ PRIVEXP(r)*ppriv(r) + GOVEXP(r)*pgov(r) + REGINV(r)*pcgds(r);$$

Real gross national expenditure in each region  $gner(r)$  is a share-weighted sum of the components of real gross national expenditure in each region:

REAL\_GNE (all, r, REG)

$$GNEL(r)*gner(r) = \\ PRIVEXP(r)*ctr(r) + GOVEXP(r)*ug(r) + REGINV(r)*qcgds(r);$$

Expenditure on gross domestic product in each region  $gdpe(r)$  is a share-weighted sum of nominal private household consumption, nominal government consumption, nominal investment, and nominal net exports in each region:

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EXPRES\_GDP (all,r,REG)

$$\begin{aligned} \text{GDP}(r)*\text{gdpe}(r) = \\ \text{PRIVEXP}(r)*\text{yp}(r) + \text{GOVEXP}(r)*\text{zg}(r) + \text{REGINV}(r)*\text{inv}(r) + \\ \text{VXWREGION}(r)*\text{vxwreg}(r) - \text{VIWREGION}(r)*\text{viwreg}(r); \end{aligned}$$

Note that  $\text{gdpe}(r)$  is identical to the GTAP variable for the value of gross domestic product  $\text{vgdp}(r)$ .

Similarly, the price index for gross domestic product in each region ( $\text{gdppi}(r)$ ) is a share-weighted sum of the prices for private household consumption, government consumption, investment and net exports:

PRICE\_INDEX\_GDP (all,r,REG)

$$\begin{aligned} \text{GDP}(r)*\text{gdppi}(r) = \\ \text{PRIVEXP}(r)*\text{ppriv}(r) + \text{GOVEXP}(r)*\text{pgov}(r) + \text{REGINV}(r)*\text{pcgds}(r) + \\ \text{VXWREGION}(r)*\text{pxwreg}(r) - \text{VIWREGION}(r)*\text{piwreg}(r); \end{aligned}$$

where  $\text{pxwreg}(r)$  and  $\text{piwreg}(r)$  are the GTAP variables for the price index for exports and imports, respectively, in region  $r$ . Note that  $\text{gdppi}(r)$  is identical to the GTAP variable for the price index for gross domestic product  $\text{pgdp}(r)$ .

Real gross domestic product in each region  $\text{gdpr}(r)$  is the share-weighted sum of the real components of gross domestic product in each region:

REAL\_GDP (all,r,REG)

$$\begin{aligned} \text{GDP}(r)*\text{gdpr}(r) = \\ \text{PRIVEXP}(r)*\text{ctr}(r) + \text{GOVEXP}(r)*\text{ug}(r) + \text{REGINV}(r)*\text{qcgds}(r) + \\ \text{VXWREGION}(r)*\text{qxwreg}(r) - \text{VIWREGION}(r)*\text{qiwreg}(r); \end{aligned}$$

where  $\text{qxwreg}(r)$  and  $\text{qiwreg}(r)$  are the GTAP variables for real exports and real imports, respectively, in region  $r$ . Note that  $\text{gdpr}(r)$  is identical to the GTAP variable for the quantity index for gross domestic product  $\text{qgdp}(r)$ .

Nominal gross domestic product in each region  $\text{gdpn}(r)$  is set equal to the GTAP variable for nominal gross domestic product in each region  $\text{vgdp}(r)$ :

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GROSS\_DOMC\_PRODT (all,r,REG)

$$\text{gdpn}(r) = \text{vgdp}(r);$$

Gross national product in each region now diverges from gross domestic product due to income earned from abroad:

**GROSS\_NATL\_PRODT ! Add FDI income flows for FTAP - NOT DONE !**

(all,r,REG)

$$\text{GNPL}(r) * \text{gnp}(r) =$$

$$\text{GDP}(r) * \text{gdpn}(r) + \text{GDP}(r) * \text{nyas}(r) + \text{YCITR}(r) * \text{gdpn}(r);$$

where  $\text{GNPL}(r)$  and  $\text{gnp}(r)$  is the coefficient and variable form, respectively, of gross national product in region  $r$ . Thus, the change in gross national product in each region (the left hand side of equation GROSS\_NATL\_PRODT) is equal to the change in nominal gross domestic product in each region (the first term on the right hand side of equation GROSS\_NATL\_PRODT) plus the change in net income from abroad in each region (the second and third terms on the right hand side of equation GROSS\_NATL\_PRODT).

One of the unique features of GTAP is the comprehensive welfare decomposition. This welfare indicator is written in terms of \$US million. It is converted from the GTAP measure of utility  $u(r)$ . A similar indicator of welfare, ie real income in each region  $\text{yr}_r(r)$ , is included in the ICM extension. This is defined as (nominal) income in each region, deflated by the consumption price index in each region:

REAL\_NATL\_INCOME (all,r,REG)

$$\text{y}_r(r) = \text{ipcr}(r) + \text{yr}_r(r);$$

This indicator of welfare is very similar to the GTAP measure of real income. The only difference is the deflator used for savings in defining a national consumption price index. GTAP uses the price of savings to deflate savings in defining a national consumption price index. GTAPICM, however, (incorrectly) uses the price of investment. Apart from this difference, the two measures of real income (and hence welfare) are identical.

A number of useful global variables are also defined. World nominal income is a share-weighted average of income in each region:

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## WORLD\_INCOME

$$YC*yn = \text{SUM}(r, \text{REG}, YCR(r)*y_r(r));$$

where YC and yn are the coefficient and variable forms, respectively, of world income.

World real income (yr) is equal to world nominal income deflated by the world consumption price index:

## WORLD\_REAL\_INCOME

$$yn = ipc + yr;$$

World gross product is the share-weighted sum of gross domestic product in all regions:

## WORLD\_GROSS\_PRODUCT

$$WGPL*wgp = \text{sum}(r, \text{REG}, \text{GDP}(r)*\text{gdpn}(r));$$

where WGPL and wgp is the coefficient and variable form, respectively, of world gross product.

Similarly, world net income from abroad is the share-weighted sum of net income from abroad in all regions:

## WORLD\_NET\_Y\_ABROAD

$$\begin{aligned} &WGPL*wnyas + YCIT*wgp = \\ &\text{sum}(r, \text{REG}, \text{GDP}(r)*nyas(r)) + \text{sum}(r, \text{REG}, YCITR(r)*\text{gdpn}(r)); \end{aligned}$$

where wnyas is the (absolute change in the) ratio of world net income from abroad to world gross product, and YCIT is the coefficient form of world net interest income. To maintain the starting database condition that world net interest income equals zero, the post-simulation value of the variable wnyas should also always equal zero.

World net capital inflow is the share-weighted sum of net capital inflow in all regions:

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## WORLD\_NET\_CAPL\_INFLW

$$\text{WGPL} * \text{wnkis} + \text{WNCIL} * \text{wgp} = \\ \text{sum}(r, \text{REG}, \text{GDP}(r) * \text{nkis}(r)) + \text{sum}(r, \text{REG}, \text{NCIL}(r) * \text{gdpn}(r));$$

where *wnkis* is the (absolute change in the) ratio of world net capital inflow to world gross product, and *WNCIL* is the coefficient form of world net capital inflow. World net capital inflow is also zero in initial database, and must remain so post-simulation.

The world real capital stock is the share-weighted sum of the real capital stock in all regions:

## WORLD\_CAPL\_STOCK

$$\text{ASKP} * \text{wkt} = \text{sum}(r, \text{REG}, \text{VKB}(r) * \text{kt}(r));$$

where *ASKP* and *wkt* is the coefficient and variable form, respectively, of the world real capital stock.

World real investment is simply a share-weighted sum of real investment in all regions:

## WORLD\_REAL\_INVT

$$\text{WINVTT} * \text{winvtr} = \text{sum}(r, \text{REG}, \text{REGINV}(r) * \text{qcgds}(r));$$

where *WINVTT* and *winvtr* is the coefficient and variable form, respectively, of world real investment.

## 9.2 Adaptation of miscellaneous GTAPICM equations for FTAP

Three new components of net foreign income are introduced in the transition from GTAPICM to FTAP — net normal returns to foreign capital, net output impediment rents and net capital impediment rents. These three new components of foreign income must be included in the balance of payments equation. As the components in the BOP equation are expressed as ratios to GDP, variables for the ratios of the three new components of foreign income to GDP must be defined. The first three equations in this section define the ratios, while the fourth equation is the revised BOP equation.



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E\_nyfdirat # ratio of net FDI income to gdp # (all,r,REG)

$$\text{GDP}(r)*\text{nyfdirat}(r)+\text{VINC\_H\_}(r)*\text{gdpn}(r)=100*\text{yfdi\_h\_}(r);$$

E\_nyanp\_h\_\_ #ratio of net output impediment rents to gdp# (all,r,REG)

$$\text{GDP}(r)*\text{nyanp\_h\_}(r)+\text{ANPTAX\_H\_}(r)*\text{gdpn}(r)=100*\text{yanp\_h\_}(r);$$

E\_nyank\_h\_\_ #ratio of net capital impediment rents to gdp# (all,r,REG)

$$\text{GDP}(r)*\text{nyank\_h\_}(r)+\text{ANKTAX\_H\_}(r)*\text{gdpn}(r)=100*\text{yank\_h\_}(r);$$

E\_bop (all,r,REG)

$$\text{bop}(r)=\text{bts}(r)+\text{nyas}(r)+\text{nkis}(r)+\text{nyfdirat}(r)+\text{nyank\_h\_}(r)+\text{nyanp\_h\_}(r);$$

Total value added for a GTAP industry is a sum across value-added for the corresponding domestic and foreign-owned industries in FTAP. This sum is defined as variable f\_qva in section 5.3. For any industries in which FDI occurs, variable f\_qva should replace the GTAP variable qva in the definition of regional (real) value-added (variable qvar) from section 9.1.

E\_qvar (all,r,REG)

$$\begin{aligned} &\text{sum}(j,\text{PROD\_COMM}, \text{VVA}(j,r))*\text{qvar}(r) = \\ &\text{sum}(i,\text{PROD\_COMM}, \\ &\quad \text{IF}[\text{FDI\_FLAG1}(i,r)=0, \text{VVA}(i,r)*\text{qva}(i,r)]+ \\ &\quad \text{sum}(i,\text{FDI\_COMM}:i \text{ eq } i_, \text{sum}(r_,\text{FDI\_DEST}:r \text{ eq } r_, \\ &\quad \quad \text{IF}[\text{FDI\_FLAG1}(i_,r_) \text{ ne } 0, \text{VVA}(i_,r_)*\text{f\_qva}(i_,r_) ])); \end{aligned}$$

The final two awkward looking conditional sums are required because variable f\_qva is dimensioned over subsets of PROD\_COMM and REG.

## 9.3 New miscellaneous equations for FTAP

### CRUSOE-GTAP link variables

In chapter 5 a compact way of representing domestic and foreign-owned industries was introduced by lifting some code from the CRUSOE single-region model. This approach may lead to computational gains, but the variables of the CRUSOE

module are inconvenient for viewing or shocking. They need to be linked to more conventionally defined variables with dimensions over home and host regions and over commodities produced. The four equations of this section perform this function for the percentage change in the powers of output taxes (or impediments in the case of the tertiary sector) for domestic and foreign-owned industries.

$E\_see\_doct(All,i,FDI\_COMM)(All,r,FDI\_DEST)$

$$\begin{aligned}
 &see\_doct(i,r)= \\
 &sum[j,IND: (NOT\_DOM(j)=0) \text{ and } (IND2COMM(j) \text{ eq } i) \text{ and} \\
 &\quad (HOME\_REG(j) \text{ eq } r) \text{ and } (DEST\_REG(j) \text{ eq } r), \\
 &\quad p\_r1oct(j)];
 \end{aligned}$$

$E\_see\_foct(All,i,FDI\_COMM)(All,s,HOME)(All,d,FDI\_DEST)$

$$\begin{aligned}
 &see\_foct(i,s,d)= \\
 &sum[j,IND: (NOT\_DOM(j)=1) \text{ and } (IND2COMM(j) \text{ eq } i) \text{ and} \\
 &\quad (HOME\_REG(j) \text{ eq } s) \text{ and } (DEST\_REG(j) \text{ eq } d), \\
 &\quad p\_r1oct(j)];
 \end{aligned}$$

These two equations allow the user to see the percentage change in the powers of the output taxes on domestic and foreign-owned industries, respectively. Each component of the CRUSOE variable  $p\_r1oct$  — which is the percentage change in the ratio of other costs to total industry costs within the CRUSOE module — is associated with the appropriate home region, host region and commodity using GEMPACK set mappings. Note that each sum will contain only one item.

$E\_tod(All,i,TRAD\_COMM)(All,r,REG)$

$$tod(i,r)=to\_shk(i,r);$$

$E\_tof(All,i,TRAD\_COMM)(All,o,HOME)(All,l,HOST)$

$$tof(i,o,l)=to\_shk(i,l)+f\_tof(i,o,l);$$

These two equations allow the user to shock the percentage change in the powers of the output taxes on domestic and foreign-owned industries, respectively. Section 5.2 described how output taxes could be altered by shocks to the variables  $tod$  and  $tof$  or to the special removal-of-output-tax variables  $remotaxd$  and  $remotaxf$ . The latter two variables cannot be used when there is a zero level of output tax, and are really

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only convenient for specifying the *reduction* of output taxes to some *proportion* of their initial level. For other types of output tax changes, percentage changes in the powers of taxes are a more natural way of representing the policy shock. The variable `to_shk` allows uniform shocks to be applied to the domestic and foreign-owned industries producing the one commodity.<sup>1</sup> It is also linked, through equation `E_to_FDI` of section 5.3, to the GTAP output tax variable `to`, for commodities that are produced entirely by domestically-owned industries.<sup>2</sup> The variable `f_tof` allows tax shocks to foreign-owned industries to vary from those to domestically-owned industries.

### Rates of return and capital stock definitions

`E_kf__hi` (All,i,TRAD\_COMM)(All,d,REG)

IF{VKF\_\_HI(i,d) ne 0,  
 sum(s,home,VK\_HHI(i,s,d)\*[k\_hhi(i,s,d)-kf\_\_hi(i,d)])=  
 IF{VKF\_\_HI(i,d)=0,kf\_\_hi(i,d)};

`E_kd__h_` (All,d,REG)

IF{VKD\_\_H\_(d) ne 0,  
 sum(i,TRAD\_COMM,VKD\_H\_I(i,d)\*[kd\_h\_i(i,d)-kd\_\_h\_(d)])=  
 IF{VKD\_\_H\_(d)=0,kd\_\_h\_(d)};

`E_kf__h_` (All,d,REG)

IF{VKF\_\_H\_(d) ne 0,  
 sum(i,TRAD\_COMM,VKF\_\_HI(i,d)\*[kf\_\_hi(i,d)-kf\_\_h\_(d)])=  
 IF{VKF\_\_H\_(d)=0,kf\_\_h\_(d)};

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<sup>1</sup> This can be useful since for the primary and secondary sectors, output taxes in the FTAP database are uniform across domestic and foreign-owned industries.

<sup>2</sup> The variable `to_shk` has been used in simulations of agricultural trade liberalisation where output subsidies were removed. As the primary sector in FTAP contains mining and food, beverages and tobacco, as well as agriculture, calculations using the more disaggregated GTAPICM database were performed to calculate the shocks that corresponded to the removal of agricultural subsidies. Shocking `to_shk` covers all industries represented in the CRUSOE module, and also those industries that are entirely domestically-owned and live in the GTAP-style part of the TABLO code.

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$E\_c\_rrf\_hi(All,i,TRAD\_COMM)(All,d,host)$

IF{VKF\_\_HI(i,d) ne 0,  
sum(s,home,VK\_HHI(i,s,d)\*[-r\_rr\_hhi(i,s,d)-c\_rrf\_\_hi(i,d)])=  
IF{VKF\_\_HI(i,d)=0,c\_rrf\_\_hi(i,d)};

$E\_c\_rrd\_h\_ (All,d,host)$

IF{VKD\_\_H\_(d) ne 0,  
sum(i,TRAD\\_COMM,VKD\_H\_I(i,d)\*[-r\_rrd\_h\_i(i,d)-c\_rrd\_\_h\_(d)])=  
IF{VKD\_\_H\_(d)=0,c\_rrd\_\_h\_(d)};

$E\_c\_rrf\_h\_ (All,d,host)$

IF{VKF\_\_H\_(d) ne 0,  
sum(i,TRAD\\_COMM,VKF\_\_HI(i,d)\*[c\_rrf\_\_hi(i,d)-c\_rrf\_\_h\_(d)])=  
IF{VKF\_\_H\_(d)=0,c\_rrf\_\_h\_(d)};

This series of equations defines various capital stock aggregates and rates of return associated with those aggregates. The variable naming conventions are fairly straightforward:

- ‘rr’ means ‘rate of return’, ‘k’ means ‘capital stock’,
- ‘d’ means ‘domestic’, ‘f’ means ‘foreign’,
- a suffix of ‘hi’ means ‘by host region and industry’, and
- a suffix of ‘h\_’ means ‘by host region’.

Petri-asset values are used as weights. This seems the most reasonable choice so that the variables are defined here in a way that is consistent with the variables that arise out of the asset supply function of section 4.

$E\_anrrd\_h\_i(All,i,TRAD\_COMM)(All,r,REG)$

IF[VKD(i,r)=0,anrrd\_h\_i(i,r)]=  
IF[VKD(i,r)>0,  
100\*{yankri(i,r)-sum[s,HOME,yank\_hhi(i,s,r)]}-  
{[EVDFM(i,r)-EVDFD(i,r)]\*[pcgds(r)+qfed(i,r)]}+

---


$$\begin{aligned}
& \text{VKD}(i,r)*\text{anrrd\_h\_i}(i,r)\}}]; \\
\text{E\_anrr\_hhi} & (\text{All},i,\text{TRAD\_COMM})(\text{All},s,\text{HOME})(\text{All},d,\text{host}) \\
& \text{IF}[\text{VFDI\_HHI}(i,s,d)=0,\text{anrr\_hhi}(i,s,d)]= \\
& \text{IF}[\text{VFDI\_HHI}(i,s,d)>0, \\
& \quad 100*\text{yank\_hhi}(i,s,d)- \\
& \quad \{ [\text{EVIFAS}(i,s,d)-\text{EVIFMS}(i,s,d)]*[\text{pcgds}(d)+\text{qfes}(i,s,d)]+ \\
& \quad \quad \text{VFDI\_HHI}(i,s,d)*\text{anrr\_hhi}(i,s,d)\}}];
\end{aligned}$$

For each domestic and foreign-owned industry, respectively, these equations define the pre-tax abnormal component of the rates of return to capital due to FDI capital impediments. They define the rates of return implicitly using the decomposition of foreign income approach of appendix B.

### Checking equations for CRUSOE module

A standard GTAP variable for industry inputs covers the combined domestic and foreign-owned industry usage of the inputs. Industry input variables from the CRUSOE module, however, differentiate the inputs used by domestic and foreign-owned industries. Plainly, the value of an input to a GTAP industry must equal the sum of the values of that input used by all CRUSOE industries that are part of the GTAP industry. Therefore, several useful variables for checking the consistency of the GTAP-style and CRUSOE sections of FTAP can be formulated, as follows:

$$\begin{aligned}
\text{E\_check\_evfa} & (\text{All},c,\text{ENDW\_COMM})(\text{All},j,\text{FDI\_COMM})(\text{All},r,\text{FDI\_DEST}) \\
& \text{check\_evfa}(c,j,r)= \\
& \text{IF}\{(\text{FDI\_FLAG1}(j,r) \neq 0) \text{ and } (\text{EVFA}(c,j,r)>0), \\
& \quad \text{pfe}(c,j,r)+\text{qfe}(c,j,r)- \\
& \quad \text{sum}[i,\text{IND}:(\text{IND2COMM}(i) \text{ eq } j) \text{ and } (\text{DEST\_REG}(i) \text{ eq } r), \\
& \quad \quad \text{sum}[k,\text{ENDWC\_COMM}:k \text{ eq } c, \\
& \quad \quad \quad \text{VICAP}(i)/\text{EVFA}(c,j,r)*(\text{p1cap}(i)+\text{x1cap}(i))]+ \\
& \quad \quad \text{sum}[k,\text{LABOR}:k \text{ eq } c,
\end{aligned}$$

$$\begin{aligned}
& V1LAB\_S(i,k)/EVFA(c,j,r)*(p1lab\_s(i,k)+x1lab\_s(i,k))] + \\
& \text{sum}[k, \text{LAND}:k \text{ eq } c, \\
& \quad V1LND(i)/EVFA(c,j,r)*(p1lnd(i)+x1lnd(i))] + \\
& \text{sum}[k, \text{NATRES}:k \text{ eq } c, \\
& \quad V1NR(i)/EVFA(c,j,r)*(p1nr(i)+x1nr(i))]];
\end{aligned}$$

E\_check\_vdfm (All,c,TRAD\_COMM)(All,j,FDI\_COMM)(All,r,FDI\_DEST)

check\_vdfm(c,j,r)=

IF{(FDI\_FLAG1(j,r) ne 0) and (VDFM(c,j,r)>0),

pds(c,r)+qfd(c,j,r)-

sum[i,IND:(IND2COMM(i) eq j) and (DEST\_REG(i) eq r),

V1BAS(c,"dom",i)/VDFM(c,j,r)\*(p0(c,"dom",i)+x1(c,"dom",i))]};

E\_check\_vdfa (All,c,TRAD\_COMM)(All,j,FDI\_COMM)(All,r,FDI\_DEST)

check\_vdfa(c,j,r)=

IF{(FDI\_FLAG1(j,r) ne 0) and (VDFA(c,j,r)>0),

pdf(c,j,r)+qfd(c,j,r)-

sum[i,IND:(IND2COMM(i) eq j) and (DEST\_REG(i) eq r),

V1PUR(c,"dom",i)/VDFA(c,j,r)\*(p1(c,"dom",i)+x1(c,"dom",i))]};

E\_check\_vifm (All,c,TRAD\_COMM)(All,j,FDI\_COMM)(All,r,FDI\_DEST)

check\_vifm(c,j,r)=

IF{(FDI\_FLAG1(j,r) ne 0) and (VIFM(c,j,r)>0),

pid(c,r)+qfm(c,j,r)-

sum[i,IND:(IND2COMM(i) eq j) and (DEST\_REG(i) eq r),

V1BAS(c,"imp",i)/VIFM(c,j,r)\*(p0(c,"imp",i)+x1(c,"imp",i))]};

E\_check\_vifa (All,c,TRAD\_COMM)(All,j,FDI\_COMM)(All,r,FDI\_DEST)

---

$check\_vifa(c,j,r)=$   
 $IF\{(FDI\_FLAG1(j,r) \neq 0) \text{ and } (VIFA(c,j,r)>0),$   
 $pfm(c,j,r)+qfm(c,j,r)-$   
 $sum[i,IND:(IND2COMM(i) \text{ eq } j) \text{ and } (DEST\_REG(i) \text{ eq } r),$   
 $V1PUR(c,"imp",i)/VIFA(c,j,r)*(p1(c,"imp",i)+x1(c,"imp",i))]\};$   
 $E\_check\_vfa(All,c,TRAD\_COMM)(All,j,FDI\_COMM)(All,r,FDI\_DEST)$

$check\_vfa(c,j,r)=$   
 $IF\{(FDI\_FLAG1(j,r) \neq 0) \text{ and } (VFA(c,j,r)>0),$   
 $pf(c,j,r)+qf(c,j,r)-$   
 $sum[i,IND:(IND2COMM(i) \text{ eq } j) \text{ and } (DEST\_REG(i) \text{ eq } r),$   
 $V1PUR\_S(c,i)/VFA(c,j,r)*(p1\_s(c,i)+x1\_s(c,i))]\};$

$E\_check\_oct(All,i,FDI\_COMM)(All,r,FDI\_DEST)$   
 $100*check\_oct(i,r)=$   
 $IF\{(FDI\_FLAG1(i,r) \neq 0) \text{ and } (PTAX(i,r) \neq 0),$   
 $[ VOM(i,r)/PTAX(i,r)*[pm(i,r)+qo(i,r)]-$   
 $VOA(i,r)/PTAX(i,r)*[ps(i,r)+qo(i,r)] ]-$   
 $sum[j,IND:(IND2COMM(j) \text{ eq } i) \text{ and } (DEST\_REG(j) \text{ eq } r),$   
 $V1OCT(j)/PTAX(i,r)*(p1tot(j)+x1tot(j))+$   
 $(V1TOT(j)-V1OCT(j))/PTAX(i,r)*p\_r1oct(j)]\};$

$E\_check\_voa(All,i,FDI\_COMM)(All,r,FDI\_DEST)$   
 $check\_voa(i,r)=$   
 $IF\{(FDI\_FLAG1(i,r) \neq 0) \text{ and } (VOA(i,r)>0),$   
 $\{ps(i,r)+qo(i,r)\}-$   
 $sum[j,IND:(DEST\_REG(j) \text{ eq } r) \text{ and } (IND2COMM(j) \text{ eq } i),$

---


$$\text{Sum}(c, \text{COM}, \text{VIPUR\_S}(c, j) / \text{VOA}(i, r) * \{p1\_s(c, j) + x1\_s(c, j)\}) \\ + \text{VIPRIM}(j) / \text{VOA}(i, r) * \{p1\text{prim}(j) + x1\text{prim}(j)\} \}];$$

These equations allow the model user to check the consistency between the GTAP and CRUSOE expressions for:

- purchasers' values of primary factor inputs (equation E\_check\_evfa);
- market values of domestic intermediate inputs (equation E\_check\_vdfm);
- purchasers' values of domestic intermediate inputs (equation E\_check\_vdfa);
- market values of imported intermediate inputs (equation E\_check\_vifm);
- purchasers' values of imported intermediate inputs (equation E\_check\_vifa);
- purchasers' values of domestic plus intermediate intermediate inputs (equation E\_check\_vfa);
- values of output taxes plus output subsidies plus impediment rents (equation E\_check\_oct); and
- producers' values of output (equation E\_check\_voa).

All components of all check\_\* variables should be zero (allowing for the accuracy of the computer in performing calculations) for any simulation. They are all percentage change variables, so this should be taken into account in deciding whether they are 'close enough' to zero.

## Tax-revenue checking equations

These equations arise from a happy accident in the sequence of model development.

In standard GTAP, separate accounts of government and private income are not kept. Tax revenue merely enters the pool of national income, and government consumption is merely one of the expenditure items for national income.

In GTAPICM, following the original SALTER treatment, a richer specification of government expenditure and revenue is introduced, and separate account is kept of government and private income and expenditure. The default closure is the revenue neutral one in which income taxes adjust to ensure that the ratio of government savings to revenue is fixed. This treatment carries through to FTAP.

When implementing ICM, basically all the relevant equations of the original implementation in SALTER were imported into the standard GTAP model, and the nightmare of equating and linking corresponding variables was then undertaken. A useful by-product of this process was that many variables for checking tax revenue



accounting could be created. Tax revenues could be defined both in terms of SALTER variables and GTAP variables. The difference in two expressions defining the same revenue item should be zero at the conclusion of any policy simulation. Values that are not zero (allowing for the accuracy of the computer in performing calculations) indicate an error.

*Income tax*

E\_check\_inctax (All,r,REG)

$$\begin{aligned}
 &RVXYCR(r)*check\_inctax(r)=RVXYCR(r)*rtyr(r) - \{ \\
 &sum(i,NONCAP\_COMM, \{VOM(i,r) * [pm(i,r) + qo(i,r)]\} \\
 &\quad - \{VOA(i,r) * [ps(i,r) + qo(i,r)]\})+ \\
 &sum(i,ENDWC\_COMM, \{VOM(i,r) * [pm(i,r) + kr(r)]\} \\
 &\quad - \{VOA(i,r) * [ps(i,r) + kr(r)]\})+ \\
 &TYPR\_L(r)*\{YCHHDPR(r)*qyhir(r) + YCHHITR(r)*yhdr(r)\}+ \\
 &TCHHITR(r)*typr(r)- \\
 &TDEP(r)*\{typr(r)+depr(r)\}+ \\
 &TYPR\_L(r)*100*[yankr(r)+yank\_h__(r)+ykit(r)]+ \\
 &[ANKTAX(r)+ANKTAX\_H__(r)+ \\
 &\quad YKAPIMPTAX(r)]*TYPR\_L(r)*typr(r)+ \\
 &TYPR\_L(r)*100*[yanpr(r)+yanp\_h__(r)+yoit(r)]+ \\
 &[ANPTAX(r)+ANPTAX\_H__(r)+ \\
 &\quad YOUTIMPTAX(r)]*TYPR\_L(r)*typr(r)\};
 \end{aligned}$$

E\_check\_capinc (All,r,REG)

$$\begin{aligned}
 &KTT(r)*check\_capinc(r)=KTT(r)*fke(r)- \\
 &sum(i,ENDWC\_COMM, \{VOM(i,r) * [pm(i,r) + kr(r)]\});
 \end{aligned}$$

E\_rtykr # tax on capital income, by region # (All,r,REG)

---


$$\text{rtykr}(r) = \text{typr}(r) + \text{fke}(r);$$

E\_check\_captax (All,r,REG)

$$\begin{aligned} \text{RVXYCKR}(r) * \text{check\_captax}(r) = & \text{RVXYCKR}(r) * \text{rtykr}(r) - \\ & \text{sum}(i, \text{ENDWC\_COMM}, \{ \text{VOM}(i,r) * [\text{pm}(i,r) + \text{kr}(r)] \} \\ & - \{ \text{VOA}(i,r) * [\text{ps}(i,r) + \text{kr}(r)] \}); \end{aligned}$$

E\_check\_labtax (All,r,REG)

$$\begin{aligned} \text{RVXYCLBR}(r) * \text{check\_labtax}(r) = & \text{RVXYCLBR}(r) * \text{rtylr}(r) - \\ & \text{sum}(i, \text{LABOR}, \{ \text{VOM}(i,r) * [\text{pm}(i,r) + \text{qo}(i,r)] \} \\ & - \{ \text{VOA}(i,r) * [\text{ps}(i,r) + \text{qo}(i,r)] \}); \end{aligned}$$

The first equation is for checking the calculation of total income tax. RVXYCR and rtyr are the original SALTER coefficient and variable, respectively, for total income tax revenue. The first sum on the right hand side calculates non-capital income tax revenue as the difference between regional pre-tax (coefficient VOM) and post-tax (coefficient VOA) rentals to capital. A separate sum is needed for capital income, since the rental-weighted capital stock (variable kr) must be used instead of the asset-weighted capital stock (the capital component of variable qo). After the second sum is two terms accounting for taxes on bond income. Two terms arise because the linearisation of a tax rate times an income leads to a term involving the change in income and a term involving the change in the tax rate. Next is a term for the loss in income tax revenue due to depreciation. There are, in fact, the two typical terms here also, with the percentage changes in the property income tax rate and the value of regional depreciation — variables typr and depr, respectively — occurring in {...}. The next two terms are the tax revenue from property income tax applied to capital impediment rents — the first term arising from the change in the income being taxed, the second from the change in the property income tax rate. The variable ykit, and its associated coefficient YKAPIMPTAX, are the rather strange correction terms necessary to account for whether taxation of capital impediment rents occurs in the home or host regions (see section 8.6). The last two terms of equation E\_check\_inctax are the tax revenue from property income tax applied to capital impediment rents, and have a similar form to the terms associated with capital impediments.

The remaining equations are much simpler than E\_check\_inctax and will be dealt with briefly. Equation E\_check\_capinc compares the SALTER variable for regional pre-tax rentals to capital (variable fke) with the GTAP calculation using coefficient

VOM and variables pm and kr . Equation E\_rtykr defines the revenue from capital income taxes using SALTER-variables typr and fke, while equation E\_check\_captax compares this with the expression based on GTAP variables. Equation E\_check\_labtax checks the SALTER and GTAP calculations of labour income taxes.

All components of all check\_\* variables should be zero (allowing for the accuracy of the computer in performing calculations) for any simulation. They are all percentage change variables, so this should be taken into account in deciding whether they are 'close enough' to zero.

### *Commodity taxes*

Total commodity tax revenue (variable rc) and the contributions to this from various types of commodity tax (variables gr\*) are defined in terms of SALTER variables. Definitions using GTAP variables are also included in FTAP, and a sequence of commodity tax checking variables defined.

E\_rc1 # revenue from commodity taxes, by region # (all,r,REG)

$$\begin{aligned}
 & \text{GRCOMT1}(r) * \text{rc1}(r) = \\
 & \text{sum}(i, \text{PROD\_COMM}, \text{SHPTAX}(i,r) * \\
 & \quad \{ \text{VOM}(i,r) * [\text{pm}(i,r) + \text{qo}(i,r)] - \\
 & \quad \quad \text{VOA}(i,r) * [\text{ps}(i,r) + \text{qo}(i,r)] \} + \\
 & 100 * \text{PTAX}(i,r) * \text{c\_SHPTAX}(i,r)) \\
 & + \text{sum}(j, \text{PROD\_COMM}, \text{sum}(i, \text{TRAD\_COMM}, \\
 & \quad \{ \text{VIFA}(i,j,r) * [\text{pfm}(i,j,r) + \text{qfm}(i,j,r)] \} \\
 & \quad - \{ \text{VIFM}(i,j,r) * [\text{pid}(i,r) + \text{qfm}(i,j,r)] \} \} ) \\
 & + \text{sum}(j, \text{PROD\_COMM}, \text{sum}(i, \text{TRAD\_COMM}, \\
 & \quad \{ \text{VDFA}(i,j,r) * [\text{pfd}(i,j,r) + \text{qfd}(i,j,r)] \} \\
 & \quad - \{ \text{VDFM}(i,j,r) * [\text{pds}(i,r) + \text{qfd}(i,j,r)] \} \} ) \\
 & + \text{sum}(i, \text{TRAD\_COMM}, \\
 & \quad \{ \text{VIPA}(i,r) * [\text{ppm}(i,r) + \text{qpm}(i,r)] \}
 \end{aligned}$$

$$\begin{aligned}
& - \{VIPM(i,r) * [pid(i,r) + qpm(i,r)]\}) \\
& + \text{sum}(i, \text{TRAD\_COMM}, \\
& \quad \{VDPA(i,r) * [ppd(i,r) + qpd(i,r)]\} \\
& \quad - \{VDPM(i,r) * [pds(i,r) + qpd(i,r)]\}) \\
& + \text{sum}(i, \text{TRAD\_COMM}, \\
& \quad \{VIGA(i,r) * [pgm(i,r) + qgm(i,r)]\} \\
& \quad - \{VIGM(i,r) * [pid(i,r) + qgm(i,r)]\}) \\
& + \text{sum}(i, \text{TRAD\_COMM}, \\
& \quad \{VDGA(i,r) * [pgd(i,r) + qgd(i,r)]\} \\
& \quad - \{VDGM(i,r) * [pds(i,r) + qgd(i,r)]\}) \\
& + \text{sum}(i, \text{TRAD\_COMM}, \text{sum}(s, \text{REG}, \\
& \quad \{VXWD(i,r,s) * [pfob(i,r,s) + qxs(i,r,s)]\} \\
& \quad - \{VXMD(i,r,s) * [pxs(i,r,s) + qxs(i,r,s)]\})) \\
& + \text{sum}(i, \text{TRAD\_COMM}, \text{sum}(s, \text{REG}, \\
& \quad \{VIMS(i,s,r) * [pms(i,s,r) + qxs(i,s,r)]\} \\
& \quad - \{VIWS(i,s,r) * [pcif(i,s,r) + qxs(i,s,r)]\}));
\end{aligned}$$

E\_check\_rc (All,r,REG)

$$\text{check\_rc}(r) = \text{rc}(r) - \text{rc1}(r);$$

The first equation is total commodity tax revenue written in terms of GTAP variables. It is a sum across all types of commodity taxes and all users, that is, in order of occurrence in the equation:

- production taxes and subsidies (VOM minus VOA times the share of this which is tax SHPTAX);
- taxes on imported intermediates (VIFA minus VIFM);
- taxes on domestic intermediates (VDFA minus VDFM);
- taxes on imported private consumption (VIPA minus VIPM);

- 
- taxes on domestic private consumption (VDPA minus VDPM);
  - taxes on imported government consumption (VIGA minus VIGM);
  - taxes on domestic government consumption (VDGA minus VDGM);
  - export taxes and subsidies (VXWD minus VXMD); and
  - import tariffs (VIMS minus VIWS).

The second equation compares SALTER variable  $rc$  with GTAP variable  $rc1$ .

Several variables for comparing contributions to commodity taxes calculated from SALTER and GTAP variables are also defined. One example — for export tax revenue — will be shown, and the remainder just listed.

$E\_grexp1$  (All,r,REG)

$$\begin{aligned} &GRCOMT1(r)*grexp1(r)= \\ &sum(i,TRAD\_COMM, sum(s,REG, \\ &\quad \{VXWD(i,r,s) * [pfob(i,r,s)+qxs(i,r,s)]\} \\ &\quad - \{VXMD(i,r,s) * [pxs(i,r,s)+qxs(i,r,s)]\})); \end{aligned}$$

$E\_check\_grexp$  (All,r,REG)

$$check\_grexp(r)=grexp(r)-grexp1(r);$$

Equation  $E\_grexp1$  defines variable  $grexp1$  and is similar in structure to the equation defining variable  $grexp$  (section 3.2). Coefficient  $GRCOMT1$  is *total* commodity tax revenue, and  $grexp1$  is a change variable. It is thus a contribution variable, that is, one of a set of variables which, when added together, equal some variable to be explained (variable  $rc1$  in this case), *regardless of the solution algorithm used*. Variable  $grexp1$  is the contribution of exports taxes to total commodity tax revenue. Although contribution variables may be path dependent, the variable  $grexp1$  should always equal  $grexp$ , since at each step of the solution procedure the definitions of export tax revenue in the equations defining  $grsub1$  and  $grsub$  should be identical. Equation  $E\_check\_grexp1$  obviously compares variables  $grexp$  and  $grexp1$ .

Checking equations exist for the following contributions to total commodity tax revenue:

- import tariffs (variable  $grdut$ );
- output taxes and subsidies (variable  $grsub$ );

- taxes on private consumption (variable grcon);
- taxes on government consumption (variable grcon);
- taxes on intermediate inputs (variable grint); and
- taxes on inputs to investment (variable griniv).

## Trade flows

A host of real trade flow and real output variables — some covering firms generally, some covering the activities of foreign-owned firms — are defined in the following equations. Equation labels describe what is being defined. The equations take the familiar ‘definition of an aggregate by share-weighting’ form. Conditionals are used to trap cases where a flow is zero, in which case the aggregate quantity being defined is set equal to zero.

E\_qgxmd #Total Real exports from s, domestic price wgts#

(all,i,TRAD\_COMM)(all,s,SOURCE)

IF[GXMD(i,s)=0,qgxmd(i,s)]+

GXMD(i,s)\*qgxmd(i,s) =

SUM(d,DEST, (SUM(h,HOME, VXMD\_D(i,h,s,d)\*qxhd(i,h,s,d)) +

VXMD\_DD(i,s,d)\*qxdd(i,s,d)) ) ;

E\_qgxwd #Total Real exports from s, FOB price wgts#

(all,i,TRAD\_COMM)(all,s,SOURCE)

IF[GXWD(i,s)=0,qgxwd(i,s)]+

GXWD(i,s)\*qgxwd(i,s) =

SUM(d,DEST, (SUM(h,HOME, VXWD\_D(i,h,s,d)\*qxhd(i,h,s,d)) +

VXWD\_DD(i,s,d)\*qxdd(i,s,d)) ) ;

E\_qgviw #Total Real imports to d, CIF price wgts#

(all,i,TRAD\_COMM)(all,d,DEST)

IF[GVIW(i,d)=0,qgviw(i,d)]+

---


$$\begin{aligned} & \text{GVIW}(i,d) * \text{qgviw}(i,d) = \\ & \text{SUM}(s, \text{SOURCE}, (\text{SUM}(h, \text{HOME}, \text{VIWS\_D}(i,h,s,d) * \text{qxhd}(i,h,s,d)) + \\ & \quad \text{VIWS\_DD}(i,s,d) * \text{qxdd}(i,s,d))) ; \end{aligned}$$

E\_qgvim #Total Real imports to d, tariff inclusive price#

(all,i,TRAD\_COMM)(all,d,DEST)

$$\begin{aligned} & \text{IF}[\text{GVIM}(i,d)=0, \text{qgvim}(i,d)] + \\ & \text{GVIM}(i,d) * \text{qgvim}(i,d) = \\ & \text{SUM}(s, \text{SOURCE}, (\text{SUM}(h, \text{HOME}, \text{VIMS\_D}(i,h,s,d) * \text{qxhd}(i,h,s,d)) + \\ & \quad \text{VIMS\_DD}(i,s,d) * \text{qxdd}(i,s,d))) ; \end{aligned}$$

E\_qx\_fdi\_wd #Real exports of fdi ind to third countries, FOB price wgts#

(all,i,TRAD\_COMM)(all,h,HOME)(all,s,SOURCE)

$$\begin{aligned} & \text{IF}[\text{X\_FDI\_WD}(i,h,s)=0, \text{qx\_fdi\_wd}(i,h,s)] + \\ & \text{X\_FDI\_WD}(i,h,s) * \text{qx\_fdi\_wd}(i,h,s) = \\ & \text{SUM}(d, \text{DEST}: (d \text{ ne } h) \text{ and } (h \text{ ne } s), \text{VXWD\_D}(i,h,s,d) * \text{qxhd}(i,h,s,d)) ; \end{aligned}$$

E\_qx\_fdi\_md #Real exports of fdi ind to third countries, domestic price wgts#

(all,i,TRAD\_COMM)(all,h,HOME)(all,s,SOURCE)

$$\begin{aligned} & \text{IF}[\text{X\_FDI\_MD}(i,h,s)=0, \text{qx\_fdi\_md}(i,h,s)] + \\ & \text{X\_FDI\_MD}(i,h,s) * \text{qx\_fdi\_md}(i,h,s) = \\ & \text{SUM}(d, \text{DEST}: d \text{ ne } h, \text{VXMD\_D}(i,h,s,d) * \text{qxhd}(i,h,s,d)) ; \end{aligned}$$

E\_qm\_fdi\_ws #Real imports from third country fdi ind, CIF price wgts#

(all,i,TRAD\_COMM)(all,h,HOME)(all,d,DEST)

$$\begin{aligned} & \text{IF}[\text{M\_FDI\_WS}(i,h,d)=0, \text{qm\_fdi\_ws}(i,h,d)] + \\ & \text{M\_FDI\_WS}(i,h,d) * \text{qm\_fdi\_ws}(i,h,d) = \\ & \text{SUM}(s, \text{SOURCE}: s \text{ ne } h, \text{VIWS\_D}(i,h,s,d) * \text{qxhd}(i,h,s,d)) ; \end{aligned}$$

---

E\_qm\_fdi\_ms #Real imports from third country fdi ind, tariff incl price wgts#

(all,i,TRAD\_COMM)(all,h,HOME)(all,d,DEST)

IF[M\_FDI\_MS(i,h,d)=0,qm\_fdi\_ms(i,h,d)]+

M\_FDI\_MS(i,h,d)\*qm\_fdi\_ms(i,h,d) =

SUM(s,SOURCE: s ne h, VIMS\_D(i,h,s,d)\*qxhd(i,h,s,d)) ;

E\_qx\_wd #Real exports of fdi ind to third countries, FOB price wgts#

(all,i,TRAD\_COMM)(all,h,HOME)

IF[X\_WD(i,h)=0,qx\_wd(i,h)]+

X\_WD(i,h)\*qx\_wd(i,h) =

SUM(s,SOURCE, X\_FDI\_WD(i,h,s)\*qx\_fdi\_wd(i,h,s)) ;

E\_qx\_md #Real exports of fdi ind to third countries, domestic price wgts#

(all,i,TRAD\_COMM)(all,h,HOME)

IF[X\_MD(i,h)=0,qx\_md(i,h)]+

X\_MD(i,h)\*qx\_md(i,h) =

SUM(s,SOURCE, X\_FDI\_MD(i,h,s)\*qx\_fdi\_md(i,h,s)) ;

E\_qm\_ws #Real imports from third country fdi ind, CIF price wgts#

(all,i,TRAD\_COMM)(all,d,DEST)

IF[M\_WS(i,d)=0,qm\_ws(i,d)]+

M\_WS(i,d)\*qm\_ws(i,d)=

SUM(h,HOME, M\_FDI\_WS(i,h,d)\*qm\_fdi\_ws(i,h,d)) ;

E\_qm\_ms #Real imports from third country fdi ind, tariff incl price wgts#

(all,i,TRAD\_COMM)(all,d,DEST)

IF[M\_MS(i,d)=0,qm\_ms(i,d)]+

M\_MS(i,d)\*qm\_ms(i,d)=



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$$\text{SUM}(h, \text{HOME}, M\_FDI\_MS(i, h, d) * qm\_fdi\_ms(i, h, d)) ;$$

E\_qvxhm #Real exports of foreign-owned industry, domestic price wgts#

$$(All, i, \text{TRAD\_COMM})(All, o, \text{HOME})(All, l, \text{HOST})$$

$$\text{IF}[\text{VXHM}(i, o, l) = 0, qvxhm(i, o, l)] +$$

$$\text{VXHM}(i, o, l) * qvxhm(i, o, l) = \text{sum}[d, \text{DEST}, \text{VXMD\_D}(i, o, l, d) * qxhd(i, o, l, d)];$$

E\_qvtotdhm #Real domestic use of foreign industry output#

$$(All, i, \text{TRAD\_COMM})(All, r, \text{REG})$$

$$\text{IF}[\text{VTOTDHM}(i, r) = 0, qvtotdhm(i, r)] +$$

$$\text{VTOTDHM}(i, r) * qvtotdhm(i, r) =$$

$$\text{SUM}(o, \text{HOME}, \text{VDHM}(i, o, r) * qdh(i, o, r)) ;$$

E\_qvtotohm #Real output of foreign firms in host country#

$$(all, i, \text{TRAD\_COMM})(all, r, \text{HOST})$$

$$\text{IF}[\text{VTOTOHM}(i, r) = 0, qvtotohm(i, r)] +$$

$$\text{VTOTOHM}(i, r) * qvtotohm(i, r) =$$

$$\text{SUM}(o, \text{HOME}, \text{VOHM}(i, o, r) * qoh(i, o, r)) ;$$

E\_qvtotown\_os #Real output of firms located abroad#

$$(all, i, \text{TRAD\_COMM})(all, o, \text{HOME})$$

$$\text{IF}[\text{VTOTOWN\_OS}(i, o) = 0, qvtotown\_os(i, o)] +$$

$$\text{VTOTOWN\_OS}(i, o) * qvtotown\_os(i, o) =$$

$$\text{SUM}(r, \text{DEST}, \text{VOHM}(i, o, r) * qoh(i, o, r));$$

### Other equations

Definitions of some useful ratios follow.

E\_qaer #Equity to income ratio# (all, r, REG)

---


$$qaer(r)=ASEQR(r)/YCR(r)*[aer(r)-y_r(r)];$$

E\_qyanp\_h\_\_#ratio of net output impediment rents to national income# (all,r,REG)

$$INCOME(r)*qyanp_h__(r)+ANPTAX_H__(r)*y_r(r)=100*yanp_h__(r);$$

E\_qyank\_h\_\_#ratio of net capital impediment rents to national income# (all,r,REG)

$$INCOME(r)*qyank_h__(r)+ANKTAX_H__(r)*y_r(r)=100*yank_h__(r);$$

E\_qyfdirat # ratio of net FDI income to national income# (all,r,REG)

$$INCOME(r)*qyfdirat(r)+VINC_H__(r)*y_r(r)=100*yfdi_h__(r);$$

E\_nyanpr # ratio of locally generated output impediment rents to gdp # (all,r,REG)

$$GDP(r)*nyanpr(r)+ANPTAX(r)*gdpr(r)=100*yanpr(r);$$

E\_nyankr # ratio of locally generated capital impediment rents to gdp # (all,r,REG)

$$GDP(r)*nyankr(r)+ANKTAX(r)*gdpr(r)=100*yankr(r);$$

Finally, for convenience in defining post-tax rates of return (section 4.3), variables for the post-tax rental prices of land (psland) and natural resources (psnatres) are defined by the technique of picking out components of the (GTAP) variable ps, thus:

E\_psland (All,s,home)

$$psland(s)=sum[k,LAND,ps(k,s)];$$

E\_psnatres (All,s,home)

$$psnatres(s)=sum[k,NATRES,ps(k,s)];$$

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## 10 Further research — an extended definition of welfare

In FTAP (as in GTAP and GTAPICM) welfare is derived from maximising a Cobb-Douglas utility function across the uses of national income — private and government consumption and savings. Utility is therefore equal to nominal national income divided by an utility price index that is an aggregation of various prices. Plainly, utility depends only on the level of income, and not on the sources from which income is derived. In particular, utility does not depend on the composition of the asset portfolio (bonds, capital in various industries and regions, land and natural resources) from which a significant portion of income is derived.

The allocation of wealth between assets, however, is driven by more than just the income generated by the assets. The allocation of wealth just to maximise returns would lead to the allocation of all wealth to the asset(s) with the highest rate of return (the so-called flip-flop or bang-bang characteristic of linear programming models). The consequent asset supply function would embody perfect transformation, and perfect arbitrage would prevail between rates of return (as in GTAPICM). Plainly, this is not the case with the FTAP asset supply function (chapter 4).

So in FTAP investors implicitly derive benefits — non-pecuniary benefits — from the composition of their portfolios, and not just from the income generated from their assets.<sup>1</sup> FTAP does not identify what these benefits are, but implicitly there must be some. The chief purpose of this appendix is to determine how these benefits, implicit in the current model structure, might be quantified and incorporated in a revised measure of utility.

All benefits from asset income, but none of the non-pecuniary benefits, are fully accounted for in the current welfare measure. This could lead to a distorted assessment of welfare impacts. For example, a policy that caused wealth to be reallocated towards assets with high rates of return could increase the current measure of utility by increasing income. But any loss in non-pecuniary benefits would not be measured.

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<sup>1</sup> Another interpretation is that they are acting sub-optimally, perhaps due to incomplete information. This possibility is not dealt with in this research memorandum.

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It is proposed that, as a future enhancement to FTAP, a new utility function be defined as the current utility function plus a new term that accounts for the non-pecuniary aspects of wealth allocation. This new term must be chosen so that the current FTAP asset supply function arises from maximisation of the new utility function. That is, both the income and wealth allocation decisions will be outcomes of maximising the new utility function. A new equivalent variation could be defined based on the new utility, and the welfare decomposition extended to cover non-pecuniary benefits of asset ownership.

The new utility maximisation problem — for the allocation of given amounts of nominal non-asset income and nominal wealth at given prices — can be expressed formally as:

Choose

$$C, G, S, \{A_i : i = 1 \dots n\}$$

to maximise

$$V(C, G, S, A_1, \dots, A_n) = U(C, G, S) + \sum_{i=1}^n (\alpha_i \cdot \phi(A_i) + \beta_i \cdot A_i)$$

subject to

$$W = \sum_{i=1}^n P_i \cdot A_i$$

$$Y = Y_0 + \sum_{i=1}^n (R_i - D_i \cdot P_i) \cdot A_i = P_C \cdot C + P_G \cdot G + P_S \cdot S$$

where

- C, G and S are the expenditure items real private and government consumption and savings, respectively,
  - with corresponding prices  $P_C$ ,  $P_G$  and  $P_S$ , respectively;
- $A_i$  is the quantity of asset i,
  - with corresponding rental price, asset price and depreciation rate  $R_i$ ,  $P_i$  and  $D_i$ , respectively;
- $V(\cdot)$  is the new utility function, which is a function of both expenditure items and asset holdings;
- $U(\cdot)$  is the current (Cobb-Douglas) utility function;
- $\phi(\cdot)$  is a function that will be determined below;
- the  $\alpha$ s and  $\beta$ s are weights, taken as given by the agent, the values of which will be determined below;

- 
- W is nominal wealth;
  - Y is nominal income; and
  - $Y_0$  is nominal non-asset income.

Note that the  $\alpha$ s and  $\beta$ s may not be constant. What is important to the validity of the following derivation is that they are only functions of items that are fixed for the optimisation problem. It will be shown that this is the case and that they are, in fact, functions of nominal wealth and prices.

The solution to this problem produces the same income allocation decision rule as currently (that is, allocate nominal income in constant shares between expenditure items). Maximisation with respect to expenditure items (C, G and S) can be performed to yield a reduced problem:

Choose

$$\{A_i : i = 1 \dots n\}$$

to maximise

$$\hat{V}(A_1, \dots, A_n) = Y/P_U + \sum_{i=1}^n (\alpha_i \cdot \phi(A_i) + \beta_i \cdot A_i)$$

subject to

$$W = \sum_{i=1}^n P_i \cdot A_i$$

where  $P_U$  is the price of utility (a Cobb-Douglas function of  $P_C$ ,  $P_G$  and  $P_S$ ) and ‘^’ indicates that maximisation with respect to C, G and S has been done. The first order conditions for this reduced problem are

$$\begin{aligned} \partial \hat{V} / \partial A_i &= (R_i - D_i \cdot P_i) / P_U + \alpha_i \cdot \phi'(A_i) + \beta_i - \lambda \cdot P_i \\ &= 0 \end{aligned}$$

Therefore

$$A_i = \phi'^{-1} [(- (R_i - D_i \cdot P_i) / P_U - \beta_i + \lambda \cdot P_i) / \alpha_i]$$

The trick now is to choose  $\phi(\cdot)$ , the  $\alpha$ s and the  $\beta$ s so that this asset supply function is the same as in FTAP. To this end choose:

$$\begin{aligned} \alpha_i &= -P_i / (\sigma_i \cdot P_U) \\ \phi(A_i) &= A_i \cdot (\ln(A_i) - 1) \end{aligned}$$

where  $\sigma_i$  is the transformation elasticity associated with asset  $i$ . Then, defining

$$\begin{aligned}\gamma_i &= \exp(\beta_i/\alpha_i - \lambda.P_i/\alpha_i) \\ &= \exp(\beta_i/\alpha_i + \lambda.P_U.\sigma_i)\end{aligned}$$

the asset supply function becomes

$$\begin{aligned}A_i &= \frac{\exp(\sigma_i.\tilde{R}_i)}{\gamma_i} \\ &= \frac{\exp(\tilde{R}_i)^{\sigma_i}}{\gamma_i} \\ &= \frac{\gamma_i^{-1}}{\exp(-\tilde{R}_i)^{\sigma_i}}\end{aligned}$$

where  $\tilde{R}_i$  is the net rate of return on asset  $i$ .

Note that with the choice of  $\phi(\cdot)$ ,

$$\begin{aligned}\partial^2 \hat{V} / \partial A_i^2 &= \alpha_i \cdot \phi''(A_i) \\ &= \alpha_i / A_i \\ &< 0\end{aligned}$$

$$\partial^2 \hat{V} / \partial A_i \partial A_j = 0 \quad \forall i \neq j$$

since  $\alpha_i < 0$ . Therefore the second order conditions for a maximum are satisfied.

The values of  $\gamma_i$  will be the same within each group of assets that are part of the same composite asset in the FTAP nested asset supply function. Let  $J(i)$  denote the set of all assets that are part of the same composite asset as asset  $i$ . Let  $A_{J(i)}$  denote the quantity of the composite asset of which asset  $i$  is a part. If

$$\begin{aligned}\gamma_i^{-1} &= A_{J(i)} \cdot \left[ \sum_{j \in J(i)} \exp(-\tilde{R}_j)^{1-\sigma_i} \right]^{\frac{\sigma_i}{1-\sigma_i}} \\ &= A_{J(i)} \cdot \exp(-\tilde{R}_{J(i)})^{\sigma_i}\end{aligned}$$

then asset supply is a nested CES demand function with the reciprocals of the exponentials of the rates of return acting as prices, as in FTAP.<sup>2</sup> The expression in

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<sup>2</sup> The discussion of Petri asset values in appendix C explains why the asset *supply* function is, in fact, a nested CES *demand* function with reciprocal prices. The terminology of ‘nested CET supply function’ has been used wherever possible throughout this research memorandum as a simplification to avoid confusion.

square brackets arises because the price of a CES aggregate is itself a CES aggregate of prices.

$A_{J(i)}$  is not one of the decision variables of the optimisation problem. Of course, it is chosen to conform to the FTAP nested asset supply function, that is, with an obvious generalisation of the  $J()$  notation,

$$\begin{aligned} A_{J(i)} &= A_{J^2(i)} \cdot \frac{\left[ \sum_{j \in J^2(i)} \exp(-\tilde{R}_j)^{-\sigma_{J(i)}} \right]^{\frac{\sigma_{J(i)}}{1-\sigma_{J(i)}}}}{\exp(-\tilde{R}_{J(i)})^{\sigma_{J(i)}}} \\ &= A_{J^2(i)} \cdot \frac{\exp(-\tilde{R}_{J^2(i)})^{\sigma_{J(i)}}}{\exp(-\tilde{R}_{J(i)})^{\sigma_{J(i)}}} \end{aligned}$$

Thus, by continuing to work up the nest,  $A_{J(i)}$  can eventually be expressed as a function of rates of return and *real* wealth:

$$A_{J(i)} = f_{J(i)}(\tilde{R}_1, \dots, \tilde{R}_n) W / P_W$$

where  $P_W$  is the asset price of wealth.

All the rates of return are functions of rental and asset prices and depreciation rates  $\{R_i, P_i, D_i; i=1, \dots, n\}$ , all of which are given for the optimisation problem. Nominal wealth is also given. If it can be shown that  $P_W$  is also function of only  $\{R_i, P_i, D_i; i=1, \dots, n\}$ , and not of decision variables, then  $\gamma_i$  is likewise expressible entirely in terms of values that are given for the optimisation problem.

Plainly, a parallel expression to the one for  $A_{J(i)}$  exists for  $A_i$ , thus:

$$A_i = f_i(\tilde{R}_1, \dots, \tilde{R}_n) W / P_W$$

so, using the wealth constraint,

$$\begin{aligned} W &= \sum_{i=1}^n P_i \cdot A_i \\ &= \sum_{i=1}^n P_i \cdot f_i(\tilde{R}_1, \dots, \tilde{R}_n) W / P_W \end{aligned}$$

therefore

$$P_W = \sum_{i=1}^n P_i \cdot f_i(\tilde{R}_1, \dots, \tilde{R}_n) \quad \text{QED}$$

One step remains to complete the formulation of the new utility measure — the determination of the Lagrange multiplier  $\lambda$ , the marginal utility of nominal wealth. This is derived from the first order conditions as follows:

$$\begin{aligned}
0 &= \sum_{i=1}^n A_i \cdot \partial \hat{V} / \partial A_i \\
&= (Y - Y_0) / P_U + \sum_{i=1}^n (\alpha_i \cdot A_i \cdot \ln(A_i) + \beta_i \cdot A_i) - \lambda \cdot W \\
&= (Y - Y_0) / P_U + \sum_{i=1}^n (\alpha_i \cdot \phi(A_i) + \beta_i \cdot A_i + \alpha_i \cdot A_i) - \lambda \cdot W \\
&= V - Y_0 / P_U - \sum_{i=1}^n P_i / (\sigma_i \cdot P_U) \cdot A_i - \lambda \cdot W
\end{aligned}$$

Therefore, the marginal utility of real wealth is:

$$\lambda \cdot P_U = V / (W / P_U) - (Y_0 / W + \sum_{i=1}^n S_i^W / \sigma_i)$$

where  $S_i^W$  is the share of the asset value of asset  $i$  in total wealth.

The interpretation of the expression for  $\lambda \cdot P_U$  is interesting. The sum is a decrease in the marginal utility of wealth from imperfect transformation between assets. The higher the transformation elasticities, the greater is  $\lambda \cdot P_U$ . Also,  $\lambda \cdot P_U$  will tend to be larger if assets with a high share in total wealth are highly substitutable with other assets that are part of the same composite asset. The expression

$$\frac{(V - Y_0 / P_U)}{W / P_U}$$

is the rate of return to wealth in utils per unit of real wealth. Thus, in the presence of perfect transformation (all  $\sigma_i \rightarrow \infty$ ), the marginal utility of real wealth is just this overall rate of return to wealth. With imperfect transformation, however, a small increase in real wealth will contribute less to utility because of the difficulty of shifting out of one asset into another. This is especially so when a large share of wealth is tied up in an asset from which it is particularly hard to shift.

Plainly,  $\lambda$  could be written in terms of values that are given for the optimisation problem.<sup>3</sup> It has already been shown that  $\gamma_i$  can be. Therefore, so can  $\beta_i$ .

The following equations would need to be added to FTAP to determine the new measure of utility  $V$ :

$$V = Y / P_U + \sum_{i=1}^n (\alpha_i \cdot \phi(A_i) + \beta_i \cdot A_i)$$

$$\alpha_i = -P_i / (\sigma_i \cdot P_U)$$

$$\gamma_i = \exp(\beta_i / \alpha_i + \lambda \cdot P_U \cdot \sigma_i)$$

<sup>3</sup> Just replace occurrences of  $A_i$  in the expression for  $\lambda$  with the expression for  $A_i$  in terms of rates of return and nominal wealth.



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$$\gamma_i^{-1} = A_{J(i)} \cdot \left[ \sum_{j \in J(i)} \exp(-\tilde{R}_j) \right]^{1-\sigma_i} \frac{\sigma_i}{1-\sigma_i}$$

$$\lambda = V/W - \left( Y_0/W + \sum_{i=1}^n S_i^W / \sigma_i \right) / P_U$$

These equations jointly determine  $V$ ,  $\alpha$ s,  $\beta$ s,  $\gamma$ s and  $\lambda$ .

Note that although the optimising agent takes the  $\alpha$ s and  $\beta$ s as given, that is, fixed during the solution of the optimisation problem, they are not constant. The welfare decomposition for the new utility measure would contain terms where the  $\alpha$ s and  $\beta$ s occur as coefficients associated with linearised variables, and also terms containing changes in the  $\alpha$ s and  $\beta$ s. A necessary stage in ensuring the usefulness of the welfare decomposition would involve finding an economic interpretation for these new terms.

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# A The core equations of GTAP

## Preliminaries

The core equations of GTAP are defined to be those equations that:

- determine the behaviour of the model; and
- define the regional welfare decomposition variables.

Only core GTAP equations are described in this appendix. Consequently, GTAP definitional equations (like the definition of GDP), and equations that decompose welfare contributions to the sectoral level, are not included. The former are described in Hertel (1997). The derivation of the welfare decomposition is presented in Huff and Hertel (1996). The GTAP terms of trade decomposition is described in McDougall (1993a).

Alongside each GTAP equation name is a GEMPACK comment (!...!) indicating the status of the equation in FTAP. The possibilities are:

- negated — rendered inoperative in FTAP simulations by endogenising the associated slack variable;
- altered — usually means that the GTAP equation continues to operate across some subset of its range;
- replaced by an FTAP equation; or
- redundant — the equation remains unchanged in FTAP but plays no role in determining model behaviour.

Where a GTAP equation is negated or altered, a cross-reference to the section describing why this is done is provided in the comment. If the change to the equation is minor and could not be easily categorised under any of the section topics, a description of the change is provided in bold in the description following the equation.

Where a GTAP equation is replaced by an FTAP equation, the name of the FTAP equation and a section cross-reference is provided.

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Trivial changes to GTAP equations are not documented. An example of a trivial change is where a term such as

$$\text{IF}(\text{VIM}(i,s)=0,\text{pfactwld})$$

is added to a price equation so that the price is set equal to the numeraire when the associated data are zero. Another example is where the GTAP price of imports (variable pim) is replaced by the FTAP price of imports (variable pid). The two are always equal (section 6.6), so this is a trivial change. A final example is the renaming of the GTAP nominal national income variable from y to y\_r.

The description of each equation in this appendix is largely a tidying-up of the comments in the TABLO code implementation of GTAP.<sup>1</sup>

Where indicated, more extensive documentation of each equation can be found in chapter 2 of Hertel (1997).

## The equations

### MKTCLTRD ! Negated section 5.3 !

(all,i,TRAD\_COMM)(all,r,REG)

$$\begin{aligned} \text{VOM}(i,r)*\text{qo}(i,r) = & \text{VDM}(i,r)*\text{qds}(i,r) \\ & +\text{VST}(i,r)*\text{qst}(i,r) \\ & +\text{sum}(s,\text{REG},\text{VXMD}(i,r,s)*\text{qxs}(i,r,s)) \\ & +\text{VOM}(i,r)*\text{tradslack}(i,r); \end{aligned}$$

This equation ensures market clearing in domestically produced commodities. This is equation (1) in chapter 2 of Hertel (1997).

MKTCLIMP (all,i,TRAD\_COMM)(all,r,REG)

$$\begin{aligned} \text{qim}(i,r) = & \text{sum}(j,\text{PROD\_COMM},\text{SHRIFM}(i,j,r)*\text{qfm}(i,j,r)) \\ & +\text{SHRIPM}(i,r)*\text{qpm}(i,r)+\text{SHRIGM}(i,r)*\text{qgm}(i,r); \end{aligned}$$

This equation ensures market clearing for imports of each commodity. This is equation (2) in chapter 2 of Hertel (1997).

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<sup>1</sup> The latest version of which is version 4.1 (November 1998), available at <http://www.agecon.purdue.edu/gtap/model/>.

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MKTCLDOM (all,i,TRAD\_COMM)(all,r,REG)

$$\begin{aligned} qds(i,r) = & \text{sum}(j, \text{PROD\_COMM}, \text{SHRDFM}(i,j,r) * qfd(i,j,r)) \\ & + \text{SHRDPM}(i,r) * qpd(i,r) + \text{SHRDGM}(i,r) * qgd(i,r); \end{aligned}$$

This equation ensures market clearing for domestic use of domestically produced commodities. This is equation (3) in chapter 2 of Hertel (1997).

**MKTCLENDWM ! Altered section 3.2 !**

(all,i,ENDWM\_COMM)(all,r,REG)

$$\begin{aligned} \text{VOM}(i,r) * qo(i,r) = & \text{sum}(j, \text{PROD\_COMM}, \text{VFM}(i,j,r) * qfe(i,j,r)) \\ & + \text{VOM}(i,r) * \text{endwslack}(i,r); \end{aligned}$$

In each of the regions, this equation ensures the clearing of markets for endowment goods that are perfectly mobile among uses. This is equation (4) in chapter 2 of Hertel (1997).

MKTCLENDWS (all,i,ENDWS\_COMM)(all,j,PROD\_COMM)(all,r,REG)

$$qoes(i,j,r) = qfe(i,j,r);$$

In each of the regions, this equation ensures the clearing of markets for endowment goods that are imperfectly mobile among uses. This is equation (5) in chapter 2 of Hertel (1997).

**PRIVATEXP ! Altered section 3.2 !**

(all,r,REG)

$$\begin{aligned} \text{PRIVEXP}(r) * yp(r) = & \text{INCOME}(r) * y(r) \\ & - \text{SAVE}(r) * [\text{psave}(r) + \text{qsave}(r)] \\ & - \text{sum}(i, \text{TRAD\_COMM}, \text{VGA}(i,r) * [\text{pg}(i,r) + \text{qg}(i,r)]); \end{aligned}$$

This equation computes private household expenditure as household income less savings less government expenditures. This is equation (8) in chapter 2 of Hertel (1997).

**REGIONALINCOME ! Replaced by NATL\_INCOME section 3.2 !**

(all,r,REG)

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$$\begin{aligned}
& \text{INCOME}(r)*y(r)= \\
& \text{sum}(i,\text{ENDW\_COMM},\text{VOA}(i,r)*[\text{ps}(i,r)+\text{qo}(i,r)]) \\
& -\text{VDEP}(r)*[\text{pcgds}(r)+\text{kb}(r)] \\
& +\text{sum}(i,\text{NSAV\_COMM}, \\
& \quad \{ \text{VOM}(i,r)*[\text{pm}(i,r)+\text{qo}(i,r)] \} \\
& \quad -\{ \text{VOA}(i,r)*[\text{ps}(i,r)+\text{qo}(i,r)] \}) \\
& +\text{sum}(i,\text{ENDWM\_COMM},\text{sum}(j,\text{PROD\_COMM}, \\
& \quad \{ \text{VFA}(i,j,r)*[\text{pfe}(i,j,r)+\text{qfe}(i,j,r)] \} \\
& \quad -\{ \text{VFM}(i,j,r)*[\text{pm}(i,r)+\text{qfe}(i,j,r)] \}) \\
& +\text{sum}(i,\text{ENDWS\_COMM},\text{sum}(j,\text{PROD\_COMM}, \\
& \quad \{ \text{VFA}(i,j,r)*[\text{pfe}(i,j,r)+\text{qfe}(i,j,r)] \} \\
& \quad -\{ \text{VFM}(i,j,r)*[\text{pmes}(i,j,r)+\text{qfe}(i,j,r)] \}) \\
& +\text{sum}(j,\text{PROD\_COMM},\text{sum}(i,\text{TRAD\_COMM}, \\
& \quad \{ \text{VIFA}(i,j,r)*[\text{pfm}(i,j,r)+\text{qfm}(i,j,r)] \} \\
& \quad -\{ \text{VIFM}(i,j,r)*[\text{pim}(i,r)+\text{qfm}(i,j,r)] \}) \\
& +\text{sum}(j,\text{PROD\_COMM},\text{sum}(i,\text{TRAD\_COMM}, \\
& \quad \{ \text{VDFA}(i,j,r)*[\text{pfd}(i,j,r)+\text{qfd}(i,j,r)] \} \\
& \quad -\{ \text{VDFM}(i,j,r)*[\text{pm}(i,r)+\text{qfd}(i,j,r)] \}) \\
& +\text{sum}(i,\text{TRAD\_COMM}, \\
& \quad \{ \text{VIPA}(i,r)*[\text{ppm}(i,r)+\text{qpm}(i,r)] \} \\
& \quad -\{ \text{VIPM}(i,r)*[\text{pim}(i,r)+\text{qpm}(i,r)] \}) \\
& +\text{sum}(i,\text{TRAD\_COMM}, \\
& \quad \{ \text{VDPA}(i,r)*[\text{ppd}(i,r)+\text{qpd}(i,r)] \} \\
& \quad -\{ \text{VDPM}(i,r)*[\text{pm}(i,r)+\text{qpd}(i,r)] \})
\end{aligned}$$

---


$$\begin{aligned}
& +\text{sum}(i, \text{TRAD\_COMM}, \\
& \quad \{ \text{VIGA}(i,r) * [\text{pgm}(i,r) + \text{qgm}(i,r)] \} \\
& \quad - \{ \text{VIGM}(i,r) * [\text{pim}(i,r) + \text{qgm}(i,r)] \}) \\
& +\text{sum}(i, \text{TRAD\_COMM}, \\
& \quad \{ \text{VDGA}(i,r) * [\text{pgd}(i,r) + \text{qgd}(i,r)] \} \\
& \quad - \{ \text{VDGM}(i,r) * [\text{pm}(i,r) + \text{qgd}(i,r)] \}) \\
& +\text{sum}(i, \text{TRAD\_COMM}, \text{sum}(s, \text{REG}, \\
& \quad \{ \text{VXWD}(i,r,s) * [\text{pfob}(i,r,s) + \text{qxs}(i,r,s)] \} \\
& \quad - \{ \text{VXMD}(i,r,s) * [\text{pm}(i,r) + \text{qxs}(i,r,s)] \}) \\
& +\text{sum}(i, \text{TRAD\_COMM}, \text{sum}(s, \text{REG}, \\
& \quad \{ \text{VIMS}(i,s,r) * [\text{pms}(i,s,r) + \text{qxs}(i,s,r)] \} \\
& \quad - \{ \text{VIWS}(i,s,r) * [\text{pcif}(i,s,r) + \text{qxs}(i,s,r)] \}) \\
& +\text{INCOME}(r) * \text{incomeslack}(r);
\end{aligned}$$

This equation computes regional income as the sum of primary factor payments and tax receipts. This is equation (9) in chapter 2 of Hertel (1997). The first term computes the change in endowment income, net of depreciation. The subsequent terms compute the change in tax receipts for various transaction taxes. Note that in each of these terms the quantity change is common. This defines the common transaction that is being taxed. It is the prices which potentially diverge.

**KEND ! Redundant !**

(all, r, REG)

$$ke(r) = \text{INVKERATIO}(r) * \text{qcgds}(r) + [1.0 - \text{INVKERATIO}(r)] * kb(r);$$

Ending capital stock equals beginning stock plus net investment. This is equation (10) in chapter 2 of Hertel (1997).

PRICGDS

$$\text{pcgds} = \text{sum}(r, \text{REG}, [\text{NETINV}(r) / \text{GLOBINV}] * \text{pcgds}(r));$$

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This equation defines the world investment price index. This is equation (60) in chapter 2 of Hertel (1997).

#### WALRAS\_S

$$\text{walras\_sup}=\text{pcgds}\text{wld}+\text{globalc}\text{gds};$$

This is an extra equation that simply computes change in supply in the omitted market, and is modified from equation (12) in chapter 2 of Hertel (1997) to reflect the value, as opposed to quantity, change.

#### WALRAS\_D

$$\text{GLOBINV}*\text{walras\_dem}=\text{sum}(\text{r},\text{REG},\text{SAVE}(\text{r})*[\text{psave}(\text{r})+\text{qsave}(\text{r})]);$$

This is an extra equation that simply computes change in demand in the omitted market, and is modified from equation (13) in chapter 2 of Hertel (1997) to reflect the value, as opposed to quantity change.

#### WALRAS

$$\text{walras\_sup}=\text{walras\_dem}+\text{walras}\text{slack};$$

This equation checks Walras Law. The value of the endogenous slack variable should be zero. This is equation (14) in chapter 2 of Hertel (1997).

#### SUPPLYPRICES ! Altered — see below !

(all,i,NSAV\_COMM)(all,r,REG)

$$\text{ps}(\text{i},\text{r})=\text{to}(\text{i},\text{r})+\text{pm}(\text{i},\text{r});$$

This equation links pre- and post-tax supply prices for all industries. This captures the effect of output subsidies. A positive shock to variable to is an increase in subsidies. This is equation (15) in chapter 2 of Hertel (1997). **It has been altered in GTAPICM and FTAP by moving the variable to to the other side of the equation. The variable to therefore becomes an output tax rather than output subsidy.**

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**MPFACTPRICE ! Altered sections 3.2 and 4.4 !**

(all,i,ENDWM\_COMM)(all,j,PROD\_COMM)(all,r,REG)

$$pfe(i,j,r)=tf(i,j,r)+pm(i,r);$$

This equation links domestic and firm demand prices. It holds for mobile endowment goods and captures the effect of taxation of firms' usage of primary factors. This is equation (16) in chapter 2 of Hertel (1997).

SPFACTPRICE (all,i,ENDWS\_COMM)(all,j,PROD\_COMM)(all,r,REG)

$$pfe(i,j,r)=tf(i,j,r)+pmes(i,j,r);$$

This equation links domestic and firm demand prices. It holds for sluggish endowment goods and captures the effect of taxation of firms' usage of primary factors. This is equation (17) in chapter 2 of Hertel (1997).

**PHHDPRICE ! Altered section 6.3 !**

(all,i,TRAD\_COMM)(all,r,REG)

$$ppd(i,r)=tpd(i,r)+pm(i,r);$$

This equation links domestic market and private household prices. It holds only for domestic goods and it captures the effect of commodity taxation of private households. This is equation (18) in chapter 2 of Hertel (1997).

**GHHDPRICE ! Altered section 6.3 !**

(all,i,TRAD\_COMM)(all,r,REG)

$$pgd(i,r)=tgd(i,r)+pm(i,r);$$

This equation links domestic market and government household prices. It holds only for domestic goods and it captures the effect of commodity taxation of government households. This is equation (19) in chapter 2 of Hertel (1997).

**DMNDDPRICE ! Altered section 6.3 !**

(all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

$$pfd(i,j,r)=tfd(i,j,r)+pm(i,r);$$



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This equation links domestic market and firm prices. It holds only for domestic goods and it captures the effect of commodity taxation of firms. This is equation (20) in chapter 2 of Hertel (1997).

PHHIPRICES (all,i,TRAD\_COMM)(all,r,REG)

$$ppm(i,r)=tpm(i,r)+pim(i,r);$$

This equation links domestic market and private household prices. It holds only for imports and it captures the effect of commodity taxation of private households. This is equation (21) in chapter 2 of Hertel (1997).

GHHIPRICES (all,i,TRAD\_COMM)(all,r,REG)

$$pgm(i,r)=tgm(i,r)+pim(i,r);$$

This equation links domestic market and government household prices. It holds only for imports and it captures the effect of commodity taxation of government households. This is equation (22) in chapter 2 of Hertel (1997).

DMNDIPRICES (all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

$$pfm(i,j,r)=tfm(i,j,r)+pim(i,r);$$

This equation links domestic market and firm prices. It holds only for imported goods and it captures the effect of commodity taxation of firms. This is equation (23) in chapter 2 of Hertel (1997).

MKTPRICES (all,i,TRAD\_COMM)(all,r,REG)(all,s,REG)

$$pms(i,r,s)=tm(i,s)+tms(i,r,s)+pcif(i,r,s);$$

This equation links domestic and world prices. It includes a source-generic import levy. This is equation (24) in chapter 2 of Hertel (1997).

**EXPRICES ! Altered section 6.5 and see below !**

(all,i,TRAD\_COMM)(all,r,REG)(all,s,REG)

$$pfob(i,r,s)=pm(i,r)-tx(i,r)-txs(i,r,s);$$

This equation links the prices of exports before (domestic market prices) and after (FOB prices) the imposition of export subsidies. A positive shock to variables tx or txs is an increase in subsidies. This is equation (27) in chapter 2 of Hertel (1997). **It has been altered in GTAPICM by changing the sign on txs to ‘+’. The variable**

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**txs therefore becomes an export tax rather than export subsidy. In FTAP variable tx is a tax also.**

DPRICEIMP

(all,i,TRAD\_COMM)(all,s,REG)

$$pim(i,s)=\text{sum}(k,REG,MSHRS(i,k,s)*pms(i,k,s));$$

This equation specifies the domestic market price for aggregate imports of a commodity from all sources. This is equation (28) in chapter 2 of Hertel (1997).

**IMPORTDEMAND ! Replaced by E\_qxs section 6.5 !**

(all,i,TRAD\_COMM)(all,r,REG)(all,s,REG)

$$qxs(i,r,s)=qim(i,s)-ESUBM(i)*[pms(i,r,s)-pim(i,s)];$$

This equation specifies regional demand for disaggregated imported commodities by source. This is equation (29) in chapter 2 of Hertel (1997).

**ICOMPRICE ! Altered section 5.3 !**

(all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

$$pf(i,j,r)=FMSHR(i,j,r)*pfm(i,j,r)+[1-FMSHR(i,j,r)]*pfd(i,j,r);$$

This equation specifies the industry price for composite commodities. This is equation (30) in chapter 2 of Hertel (1997).

**INDIMP ! Altered section 5.3 !**

(all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,s,REG)

$$qfm(i,j,s)=qf(i,j,s) \\ -ESUBD(i)*[pfm(i,j,s)-pf(i,j,s)];$$

This equation specifies industry j demands for composite import i. This is equation (31) in chapter 2 of Hertel (1997).

**INDDOM ! Altered section 5.3 !**

(all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,s,REG)

$$qfd(i,j,s)=qf(i,j,s)-ESUBD(i)*[pfd(i,j,s)-pf(i,j,s)];$$

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This equation specifies industry  $j$  demands for domestic good  $i$ . This is equation (32) in chapter 2 of Hertel (1997).

VAPRICE (all,j,PROD\_COMM)(all,r,REG)

$$pva(j,r)=\text{sum}(k,\text{ENDW\_COMM},\text{SVA}(k,j,r)*[\text{pfe}(k,j,r)-\text{afe}(k,j,r)]);$$

This equation specifies the effective price of the primary factor composite in each sector/region. This is equation (33) in chapter 2 of Hertel (1997).

**ENDWDEMAND ! Altered section 5.3 !**

(all,i,ENDW\_COMM)(all,j,PROD\_COMM)(all,r,REG)

$$\begin{aligned} qfe(i,j,r) &= -afe(i,j,r) + qva(j,r) \\ & - \text{ESUBVA}(j) * [\text{pfe}(i,j,r) - \text{afe}(i,j,r) - pva(j,r)]; \end{aligned}$$

This equation determines the demands for endowment commodities. This is equation (34) in chapter 2 of Hertel (1997).

VADEMAND (all,j,PROD\_COMM)(all,r,REG)

$$\begin{aligned} qva(j,r) &= -ava(j,r) + qo(j,r) - ao(j,r) \\ & - \text{ESUBT}(j) * [pva(j,r) - ava(j,r) - ps(j,r)]; \end{aligned}$$

This equation specifies sector demands for the primary factor composite. This equation differs from equation (35) in chapter 2 of Hertel (1997), due to the presence of intermediate input substitution.

**INTDEMAND ! Altered section 5.3 !**

(all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

$$\begin{aligned} qf(i,j,r) &= -af(i,j,r) + qo(j,r) - ao(j,r) \\ & - \text{ESUBT}(j) * [pf(i,j,r) - af(i,j,r) - ps(j,r)]; \end{aligned}$$

This equation specifies industry and investment (industry “cgds”) demands for intermediate inputs. This equation differs from equation (36) in chapter 2 of Hertel (1997), due to the presence of intermediate input substitution.

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## ZEROPROFITS ! Altered — see below !

(all,j,PROD\_COMM)(all,r,REG)

$$\begin{aligned} & \text{VOA}(j,r)*[\text{ps}(j,r)+\text{ao}(j,r)]= \\ & \text{sum}(i,\text{ENDW\_COMM},\text{VFA}(i,j,r)*[\text{pfe}(i,j,r)-\text{afe}(i,j,r)-\text{ava}(j,r)]) \\ & +\text{sum}(i,\text{TRAD\_COMM},\text{VFA}(i,j,r)*[\text{pf}(i,j,r)-\text{af}(i,j,r)]) \\ & +\text{VOA}(j,r)*\text{profitslack}(j,r); \end{aligned}$$

Each industry, and the investment (capital goods) activity, makes zero pure profits. This is equation (6) in chapter 2 of Hertel (1997). **In FTAP, this zero pure profits condition for GTAP-style industries (that is, combined domestic and foreign-owned) is written in terms of prices and quantities, rather than prices and technical efficiency terms. In FTAP, it defines the GTAP-industry variable ps, the output tax/impediment-exclusive price of industry output.**

UTILITY (all,r,REG)

$$\begin{aligned} & \text{INCOME}(r)*u(r)=\text{PRIVEXP}(r)*\text{up}(r) \\ & +\text{GOVEXP}(r)*[\text{ug}(r)-\text{pop}(r)] \\ & +\text{SAVE}(r)*[\text{qsave}(r)-\text{pop}(r)]; \end{aligned}$$

This equation defines per capita regional utility. This is equation (37) in chapter 2 of Hertel (1997). Note that private utility has already been defined on a per capita basis.

## SAVEPRICE ! Altered section 4.5 !

(all,r,REG)

$$\begin{aligned} & \text{psave}(r)= \\ & \text{pcgds}(r)+\{\text{sum}(s,\text{REG},\{[\text{NETINV}(s)-\text{SAVE}(s)]/\text{GLOBINV}\}*\text{pcgds}(s))\} \\ & +\text{psaveslack}(r); \end{aligned}$$

This equation defines a region specific price of savings, which is now region-specific and is equal to the price of regional investment, plus an adjustment factor that accounts for the fact that regional savings and investment are not equal. This is an amendment to GTAP since the version of the model that was documented in Hertel (1997).

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## SAVINGS ! Altered section 3.2 !

(all,r,REG)

$$qsave(r)=y(r)-psave(r)+saveslack(r);$$

Regional real net saving (variable  $qsave$ ) is generated from the maximisation of a Cobb-Douglas utility function of savings, private consumption and government consumption. Hence nominal saving is a constant share of nominal net national product (variable  $y$ ). This is equation (38) in chapter 2 of Hertel (1997).

GOVERTU (all,r,REG)

$$ug(r)=y(r)-pgov(r)+govslack(r);$$

This equation defines regional government consumption. Unlike the variable  $up$ , it is not per capita. In some closures this index of government activity may be fixed, in which case  $govslack$  is endogenized. In this case the mix of regional expenditures changes and the aggregate utility index no longer applies. This is equation (39) in chapter 2 of Hertel (1997).

GPRICEINDEX (all,r,REG)

$$pgov(r)=\text{sum}(i,\text{TRAD\_COMM},[\text{VGA}(i,r)/\text{GOVEXP}(r)]*\text{pg}(i,r));$$

This is the government consumption price index. This is equation (40) in chapter 2 of Hertel (1997).

GOVDMNDS (all,i,TRAD\_COMM)(all,r,REG)

$$qg(i,r)=ug(r)-[\text{pg}(i,r)-\text{pgov}(r)];$$

This equation determines government demands for each commodity. Total government consumption is a Cobb-Douglas composite of all commodities. Note that the population (variable  $pop$ ) does not occur in this equation due to homotheticity. This is equation (41) in chapter 2 of Hertel (1997).

GCOMPRICE (all,i,TRAD\_COMM)(all,s,REG)

$$\text{pg}(i,s)=\text{GMSHR}(i,s)*\text{pgm}(i,s)+[1-\text{GMSHR}(i,s)]*\text{pgd}(i,s);$$

This equation defines the prices paid by the government for each commodity. This is equation (42) in chapter 2 of Hertel (1997).

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GHHLDAGRIMP (all,i,TRAD\_COMM)(all,s,REG)

$$qgm(i,s)=qg(i,s)+ESUBD(i)*[pg(i,s)-pgm(i,s)];$$

This equation determines government demands for the imported variety of each commodity. Government consumption of each commodity is a CES composite of the domestic and imported varieties. This is equation (43) in chapter 2 of Hertel (1997).

GHHLDDOM (all,i,TRAD\_COMM)(all,s,REG)

$$qgd(i,s)=qg(i,s)+ESUBD(i)*(pg(i,s)-pgd(i,s));$$

This equation determines government demands for the domestic variety of each commodity. Government consumption of each commodity is a CES composite of the domestic and imported varieties. This is equation (44) in chapter 2 of Hertel (1997).

PRIVATEU (all,r,REG)

$$\begin{aligned} yp(r) &= \text{sum}(i, \text{TRAD\_COMM}, (\text{CONSHR}(i,r) * pp(i,r))) \\ &+ \text{sum}(i, \text{TRAD\_COMM}, (\text{CONSHR}(i,r) * \text{INCPAR}(i,r))) * up(r) \\ &+ pop(r); \end{aligned}$$

This equation determines private consumption utility for a representative household in region r, based on the per capita private expenditure function. This is equation (45) in chapter 2 of Hertel (1997).

PRIVDMNDS (all,i,TRAD\_COMM)(all,r,REG)

$$\begin{aligned} qp(i,r) &= \text{sum}(k, \text{TRAD\_COMM}, EP(i,k,r) * pp(k,r)) \\ &+ EY(i,r) * [yp(r) - pop(r)] \\ &+ pop(r); \end{aligned}$$

The first two right hand side terms of this equation determine the demands by an individual private household for each commodity. Consequently, the demand system is on a per capita basis. Here,  $yp(r) - pop(r)$  is the percentage change in per capita income. The demand is scaled by the size of the population — the third right hand side term — to determine aggregate private consumption of each commodity. This is equation (46) in chapter 2 of Hertel (1997).

PCOMPRICE (all,i,TRAD\_COMM)(all,s,REG)

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$$pp(i,s)=PMSHR(i,s)*ppm(i,s)+[1-PMSHR(i,s)]*ppd(i,s);$$

This equation defines the prices paid by private households for each commodity. This is equation (47) in chapter 2 of Hertel (1997).

PHHLDDOM (all,i,TRAD\_COMM)(all,s,REG)

$$qpd(i,s)=qp(i,s)+ESUBD(i)*[pp(i,s)-ppd(i,s)];$$

This equation determines aggregate private demands for the domestic variety of each commodity. Private consumption of each commodity is a CES composite of the domestic and imported varieties. This is equation (48) in chapter 2 of Hertel (1997).

PHHLDAGRIMP (all,i,TRAD\_COMM)(all,s,REG)

$$qpm(i,s)=qp(i,s)+ESUBD(i)*[pp(i,s)-ppm(i,s)];$$

This equation determines aggregate private demands for the imported variety of each commodity. Private consumption of each commodity is a CES composite of the domestic and imported varieties. This is equation (49) in chapter 2 of Hertel (1997).

ENDW\_PRICE (all,i,ENDWS\_COMM)(all,r,REG)

$$pm(i,r)=\text{sum}(k,PROD\_COMM,REVSHR(i,k,r)*pmes(i,k,r));$$

This equation generates the composite price for sluggish endowments. This is equation (50) in chapter 2 of Hertel (1997).

ENDW\_SUPPLY (all,i,ENDWS\_COMM)(all,j,PROD\_COMM)(all,r,REG)

$$qoes(i,j,r)=qo(i,r)-\text{endwslack}(i,r)+ETRAE(i)*[pm(i,r)-pmes(i,j,r)];$$

This equation distributes the sluggish endowments across sectors according to a CET transformation function. This is equation (51) in chapter 2 of Hertel (1997).

KAPSVCES (all,r,REG)

$$ksvc(r)=$$

$$\text{sum}(h,ENDWC\_COMM,[VOA(h,r)/\text{sum}(k,ENDWC\_COMM,VOA(k,r))] * qo(h,r));$$

---

This equation defines a variable for capital services for convenience. There is currently only one capital service (that is, element of ENDWC\_COMM), so this equation is fairly trivial. This is equation (52) in chapter 2 of Hertel (1997).

KAPRENTAL (all,r,REG)

$$\text{rental}(r)=\text{sum}(h,\text{ENDWC\_COMM},[\text{VOA}(h,r)/\text{sum}(k,\text{ENDWC\_COMM},\text{VOA}(k,r))]*\text{ps}(h,r));$$

This equation defines a variable for the regional, post-tax rental-price of capital for convenience. It is just the capital component of the variable  $ps$ . This is equation (53) in chapter 2 of Hertel (1997).

CAPGOODS (all,r,REG)

$$\text{qcgds}(r)=\text{sum}(h,\text{CGDS\_COMM},[\text{VOA}(h,r)/\text{REGINV}(r)]*\text{qo}(h,r));$$

This equation defines a variable for real regional gross investment for convenience. There is really only one capital goods item. This is equation (54) in chapter 2 of Hertel (1997).

PRCGOODS (all,r,REG)

$$\text{pcgds}(r)=\text{sum}(h,\text{CGDS\_COMM},[\text{VOA}(h,r)/\text{REGINV}(r)]*\text{ps}(h,r));$$

This equation defines the investment price index (that is, the price of capital creation) for convenience. This is equation (55) in chapter 2 of Hertel (1997).

KBEGINNING (all,r,REG)

$$\text{kb}(r)=\text{ksvces}(r);$$

This equation associates any change in capital services during the period with a change in capital stock. Full capacity utilization is assumed. This is equation (56) in chapter 2 of Hertel (1997).

RORCURRENT (all, r, REG)

$$\text{rorc}(r)=\text{GRNETRATIO}(r)*[\text{rental}(r)-\text{pcgds}(r)];$$

This defines the percentage change in the post-tax current rate of return on capital in region  $r$ . This is equation (57) in chapter 2 of Hertel (1997).



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## ROREXPECTED ! Redundant !

(all, r, REG)

$$\text{rore}(r) = \text{rorc}(r) - \text{RORFLEX}(r) * [\text{ke}(r) - \text{kb}(r)];$$

This defines the percentage change in the post-tax expected future rate of return on capital. It is derived from the assumption of a constant elasticity between capital growth and expected rate of return growth. of This is equation (58) in chapter 2 of Hertel (1997).

## RORGLOBAL ! Negated section 3.2 !

(all,r,REG)

$$\begin{aligned} & \text{RORDELTA} * \text{rore}(r) + \\ & [1 - \text{RORDELTA}] * \{ [\text{REGINV}(r) / \text{NETINV}(r)] * \text{qcgds}(r) \\ & - [\text{VDEP}(r) / \text{NETINV}(r)] * \text{kb}(r) \} \\ & = \text{RORDELTA} * \text{rorg} + [1 - \text{RORDELTA}] * \text{globalcgds} + \text{cgdslack}(r); \end{aligned}$$

This equation determines the partitioning of global net savings into regional investment either by equating percentage changes in expected future rates of return ( $\text{RORDELTA}=1$ ), or by equating percentage changes in regional real net investment ( $\text{RORDELTA}=0$ ). This is equation (59) in chapter 2 of Hertel (1997).

## GLOBALINV

$$\begin{aligned} & \text{RORDELTA} * \text{globalcgds} + [1 - \text{RORDELTA}] * \text{rorg} = \\ & \text{RORDELTA} * [\text{sum}(r, \text{REG}, \{ \text{REGINV}(r) / \text{GLOBINV} \} * \text{qcgds}(r) \\ & - \{ \text{VDEP}(r) / \text{GLOBINV} \} * \text{kb}(r))] \\ & + [1 - \text{RORDELTA}] * [\text{sum}(r, \text{REG}, \{ \text{NETINV}(r) / \text{GLOBINV} \} * \text{rore}(r))]; \end{aligned}$$

This equation calculates either the change in global real net investment (when  $\text{RORDELTA}=1$ ), or the change in the expected global rate of return on capital (when  $\text{RORDELTA}=0$ ). This is equation (11) in chapter 2 of Hertel (1997).

## PTRANS ! Altered section 6.2 !

$$\text{VT} * \text{pt} = \text{sum}(i, \text{TRAD\_COMM}, \text{sum}(r, \text{REG}, \text{VST}(i, r) * \text{pm}(i, r)));$$

---

This equation generates a world price index for international transportation services based on zero profits. Sales to international transportation are not subject to export tax. Consequently, the costs to the transport sector depend on the domestic market prices (variable  $pm$ ) of the goods sold to international transportation. This is equation (7) in chapter 2 of Hertel (1997).

**TRANSVCES ! Altered section 6.2 !**

(all,i,TRAD\_COMM)(all,r,REG)

$$qst(i,r)=qt+[pt-pm(i,r)];$$

This equation generates the demand for international freight services from each region. It reflects a unitary elasticity of substitution between transportation services inputs from different regions. This is equation (61) in chapter 2 of Hertel (1997).

**QTRANS**

$$VT*qt=\text{sum}(i,TRAD\_COMM,\text{sum}(r,REG, \\ \text{sum}(s,REG,VTWR(i,r,s)*[qxs(i,r,s)-atr(i,r,s)]))));$$

This equation computes the global demand for international transportation services (that is, variable  $qt$ ). It reflects the fact that the demand for services along any particular route is proportional to the quantity of merchandise shipped (that is, variable  $qxs$ ) subject to the technical efficiency of transport services (variable  $atr$ ). This is equation (62) in chapter 2 of Hertel (1997).

FOBCIF (all,i,TRAD\_COMM)(all,r,REG)(all,s,REG)

$$pcif(i,r,s)=FOBSHR(i,r,s)*pfob(i,r,s)+TRNSHR(i,r,s)*[pt-atr(i,r,s)];$$

This equation links fob and cif prices for good  $i$  shipped from region  $r$  to  $s$ . This is equation (26) in chapter 2 of Hertel (1997).

PRIMFACTPR (all,r,REG)

$$VENDWREG(r)*pfactor(r)=\text{sum}(i,ENDW\_COMM,VOM(i,r)*pm(i,r));$$

This equation defines a primary factor price index for each region (variable  $pfactor$ ). This is an addition to GTAP since the version of the model which was documented in Hertel (1997). It is required for the definition of the world primary-factor price index (variable  $pfactwld$ ), which is the current numeraire.

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## PRIMFACTPRWLD

$$\text{VENDWWLD} * \text{pfactwld} = \text{sum}(r, \text{REG}, \text{VENDWREG}(r) * \text{pfactor}(r));$$

This equation defines the world primary-factor price index (variable `pfactwld`). This is an addition to GTAP since the version of the model which was documented in Hertel (1997). Variable `pfactwld` is the current numeraire.

## EVREG (all,r,REG)

$$\text{EV}(r) = [\text{INC}(r)/100] * [\text{URATIO}(r) * \text{POPRTATIO}(r)] * [\text{u}(r) + \text{pop}(r)];$$

This equation defines the regional EV, which is the money metric welfare change. This is equation (67) in chapter 2 of Hertel (1997).

## EVWLD

$$\text{WEV} - \text{sum}(r, \text{REG}, \text{EV}(r)) = 0;$$

This equation defines the EV for the world. This is equation (68) in chapter 2 of Hertel (1997).

## EV\_DECOMPOSITION ! Altered appendix D !

### (all,r,REG)

$$\begin{aligned} \text{EV\_ALT}(r) = & \\ & [.01/\text{INCRATIO}(r)] * \\ & [\text{sum}(i, \text{NSAV\_COMM}, \text{PTAX}(i,r) * \text{qo}(i,r)) \\ & + \text{sum}(i, \text{ENDW\_COMM}, \text{sum}(j, \text{PROD\_COMM}, \text{ETAX}(i,j,r) * \text{qfe}(i,j,r))) \\ & + \text{sum}(j, \text{PROD\_COMM}, \text{sum}(i, \text{TRAD\_COMM}, \text{IFTAX}(i,j,r) * \text{qfm}(i,j,r))) \\ & + \text{sum}(j, \text{PROD\_COMM}, \text{sum}(i, \text{TRAD\_COMM}, \text{DFTAX}(i,j,r) * \text{qfd}(i,j,r))) \\ & + \text{sum}(i, \text{TRAD\_COMM}, \text{IPTAX}(i,r) * \text{qpm}(i,r)) \\ & + \text{sum}(i, \text{TRAD\_COMM}, \text{DPTAX}(i,r) * \text{qpd}(i,r)) \\ & + \text{sum}(i, \text{TRAD\_COMM}, \text{IGTAX}(i,r) * \text{qgm}(i,r)) \\ & + \text{sum}(i, \text{TRAD\_COMM}, \text{DGTAX}(i,r) * \text{qgd}(i,r)) \\ & + \text{sum}(i, \text{TRAD\_COMM}, \text{sum}(s, \text{REG}, \text{XTAXD}(i,r,s) * \text{qxs}(i,r,s))) \end{aligned}$$

---


$$\begin{aligned}
& +\text{sum}(i, \text{TRAD\_COMM}, \text{sum}(s, \text{REG}, \text{MTAX}(i, s, r) * \text{qxs}(i, s, r))) \\
& +\text{sum}(i, \text{ENDW\_COMM}, \text{VOA}(i, r) * \text{qo}(i, r)) \\
& -\text{VDEP}(r) * \text{kb}(r) \\
& +\text{sum}(i, \text{PROD\_COMM}, \text{VOA}(i, r) * \text{ao}(i, r)) \\
& +\text{sum}(i, \text{ENDW\_COMM}, \text{sum}(j, \text{PROD\_COMM}, \\
& \quad \text{VFA}(i, j, r) * [\text{afe}(i, j, r) + \text{ava}(j, r)])) \\
& +\text{sum}(j, \text{PROD\_COMM}, \text{sum}(i, \text{TRAD\_COMM}, \\
& \quad [\text{VIFA}(i, j, r) + \text{VDFA}(i, j, r)] * \text{af}(i, j, r))) \\
& +\text{sum}(i, \text{TRAD\_COMM}, \text{sum}(s, \text{REG}, \text{VTWR}(i, s, r) * \text{atr}(i, s, r))) \\
& +\text{sum}(i, \text{TRAD\_COMM}, \text{sum}(s, \text{REG}, \text{VXWD}(i, r, s) * \text{pfob}(i, r, s))) \\
& +\text{sum}(i, \text{TRAD\_COMM}, \text{VST}(i, r) * \text{pm}(i, r)) \\
& +\text{NETINV}(r) * \text{pcgds}(r) \\
& -\text{sum}(i, \text{TRAD\_COMM}, \text{sum}(s, \text{REG}, \text{VXWD}(i, s, r) * \text{pfob}(i, s, r)) \\
& +\text{VTWR}(i, s, r) * \text{pt})) \\
& -\text{SAVE}(r) * \text{psave}(r) \\
& +\text{sum}(i, \text{TRAD\_COMM}, \text{VPA}(i, r) - \text{VPA}(i, r) * \text{INCPAR}(i, r) * \text{up}(r)];
\end{aligned}$$

This equation calculates regional equivalent variations as the sum of various contributions to welfare. All the terms on the right hand side occur in exactly one of the main GTAP welfare decomposition variables (variables CNT\*), the definitions of which are listed below.

#### WORLDDEV

$$\text{WEV\_ALT} = \text{sum}(r, \text{REG}, \text{EV\_ALT}(r));$$

This is an expression for WEV calculated in an alternative way, that is, as a sum of contributions to welfare.

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**CONT\_EV\_alleffr ! Altered section 7.2 and appendix D !**

(all,r,REG)

$$\begin{aligned} \text{CNTalleffr}(r) &= [.01/\text{INCRATIO}(r)] * \\ & [\text{sum}(i, \text{NSAV\_COMM}, \text{PTAX}(i,r) * \text{qo}(i,r)) \\ & + \text{sum}(i, \text{ENDW\_COMM}, \text{sum}(j, \text{PROD\_COMM}, \text{ETAX}(i,j,r) * \text{qfe}(i,j,r))) \\ & + \text{sum}(j, \text{PROD\_COMM}, \text{sum}(i, \text{TRAD\_COMM}, \text{IFTAX}(i,j,r) * \text{qfm}(i,j,r))) \\ & + \text{sum}(j, \text{PROD\_COMM}, \text{sum}(i, \text{TRAD\_COMM}, \text{DFTAX}(i,j,r) * \text{qfd}(i,j,r))) \\ & + \text{sum}(i, \text{TRAD\_COMM}, \text{IPTAX}(i,r) * \text{qpm}(i,r)) \\ & + \text{sum}(i, \text{TRAD\_COMM}, \text{DPTAX}(i,r) * \text{qpd}(i,r)) \\ & + \text{sum}(i, \text{TRAD\_COMM}, \text{IGTAX}(i,r) * \text{qgm}(i,r)) \\ & + \text{sum}(i, \text{TRAD\_COMM}, \text{DGTAX}(i,r) * \text{qgd}(i,r)) \\ & + \text{sum}(i, \text{TRAD\_COMM}, \text{sum}(s, \text{REG}, \text{XTAXD}(i,r,s) * \text{qxs}(i,r,s))) \\ & + \text{sum}(i, \text{TRAD\_COMM}, \text{sum}(s, \text{REG}, \text{MTAX}(i,s,r) * \text{qxs}(i,s,r)))]]; \end{aligned}$$

This defines the total contribution to each region's EV of changes in allocative efficiency.

**CONT\_EV\_techr ! Altered section 7.2 and appendix D !**

(all,r,REG)

$$\begin{aligned} \text{CNTtechr}(r) &= [.01/\text{INCRATIO}(r)] * \\ & [\text{sum}(i, \text{PROD\_COMM}, \text{VOA}(i,r) * \text{ao}(i,r)) \\ & + \text{sum}(i, \text{ENDW\_COMM}, \text{sum}(j, \text{PROD\_COMM}, \\ & \quad \text{VFA}(i,j,r) * [\text{afe}(i,j,r) + \text{ava}(j,r)])) \\ & + \text{sum}(j, \text{PROD\_COMM}, \text{sum}(i, \text{TRAD\_COMM}, \\ & \quad \{ \text{VIFA}(i,j,r) + \text{VDFA}(i,j,r) \} * \text{af}(i,j,r))) \\ & + \text{sum}(i, \text{TRAD\_COMM}, \text{sum}(s, \text{REG}, \{ \text{VTWR}(i,s,r) * \text{atr}(i,s,r) \}))]; \end{aligned}$$

---

This defines the total contribution to each region's EV of changes in technical efficiency.

**CONT\_EV\_totr ! Altered appendix D !**

(all,r,REG)

$$\begin{aligned} \text{CNTtotr}(r) = & [.01/\text{INCRATIO}(r)] * \\ & [\text{sum}(i, \text{TRAD\_COMM}, \text{sum}(s, \text{REG}, \{ \text{VXWD}(i,r,s) * \text{pfob}(i,r,s) \})) \\ & + \text{sum}(i, \text{TRAD\_COMM}, \text{VST}(i,r) * \text{pm}(i,r)) \\ & - \text{sum}(i, \text{TRAD\_COMM}, \text{sum}(s, \text{REG}, \{ \text{VIWS}(i,s,r) * \\ & [\text{FOBSHR}(i,s,r) * \text{pfob}(i,s,r) + \text{TRNSHR}(i,s,r) * \text{pt} \} \})); \end{aligned}$$

This defines the total contribution to each region's EV of changes in its terms of trade.

**CONT\_EV\_endwr ! Altered appendix D !**

(all,r,REG)

$$\begin{aligned} \text{CNTendwr}(r) = & \\ & [.01/\text{INCRATIO}(r)] * [\text{sum}(i, \text{ENDW\_COMM}, \text{VOA}(i,r) * \text{qo}(i,r)); \end{aligned}$$

This defines the total contribution to each region's EV of gross changes in its endowments.

**CONT\_EV\_kbr ! Altered appendix D !**

(all,r,REG)

$$\text{CNTkbr}(r) = -[.01/\text{INCRATIO}(r)] * \text{VDEP}(r) * \text{kb}(r);$$

This defines the total contribution to each region's EV of changes to regional capital stock due to depreciation.

---

CONT\_EV\_MUr (all,r,REG)

$$\text{CNT\_MUr}(r)=[.01/\text{INCRATIO}(r)]^*$$

$$[\text{sum}(i,\text{TRAD\_COMM},\text{VPA}(i,r)-\text{VPA}(i,r)*\text{INCPAR}(i,r))*\text{up}(r)];$$

This defines the total contribution to each region's EV due to the marginal utility of income.

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## B Decomposing foreign income flows

The FTAP model incorporates various types of foreign income flows into national income. All of these flows can, however, be interpreted as being returns to some asset.

Therefore, foreign income flows can be expressed as follows: letting  $R$  be a rate of return,  $P$  the asset price,  $Q$  the quantity of asset and  $Y$  the foreign income flow:

$$Y = R.P.Q$$

This can be expressed in linearised form (using lower case letters for percentage changes) as:

$$\begin{aligned} 100.\Delta Y &= 100.(\Delta R.P.Q + R.\Delta P.Q + R.P.\Delta Q) \\ &= 100.P.Q.\Delta R + R.Q.P.p + R.P.Q.q \\ &= P.Q.(100.\Delta R) + Y.(p + q) \end{aligned}$$

That is, the change in foreign income is a sum of contributions due to changes in the rate of return, the asset price and the quantity of the asset (the last being an endowment effect in GTAP terminology).

The approach to welfare decomposition used in FTAP is to preserve as much as possible of the GTAP welfare decomposition, which is basically a decomposition of GDP (since  $S-I=X-M$  in GTAP), and introduce separate decomposition terms for the contributions arising from foreign income.

The rate of return, asset price and endowment contributions in the linearised foreign income equation give rise to three new welfare decomposition variables for each foreign income flow in FTAP. The foreign income flows in FTAP are income from bonds (chapter 3) and FDI (chapter 4), and rents arising from barriers to services trade (chapter 8). The last set of flows divides into two groups due to the two types of barriers — barriers to establishment and barriers to ongoing operations — which are represented as ad valorem tax equivalents on capital and output,<sup>1</sup> respectively.

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<sup>1</sup> Export taxes in supplying regions are also used to represent barriers to ongoing operations, but these do not give rise to foreign income flows.



The names of these new welfare decomposition variables conform to the following conventions. The names begin with ‘CNT’. The next part of the name indicates the nature of the contribution and the income flow with which it is associated (table B.1). The last part of the name may be just ‘r’ indicating a regional dimension or a more detailed specification of the dimensions where applicable. In the latter case, following a ‘\_’, the last three characters of the variable name indicate the dimensions of the variable. The characters are some combination of ‘h’, ‘\_’ and ‘i’, and indicate whether the variable ranges over a home region, a host region and an industry, or is an aggregate over one of these dimensions. For example,

VARIABLE (Change)(all,i,TRAD\_COMM)(all,d,host) CNTror\_\_hi(i,d)

is the contribution to the change in welfare (equivalent variation) in each host region due to changes in the rate of return on foreign-owned capital in each sector.

**Table B.1 Names of welfare contribution types by income flow**  
 subtitle

	<i>Bond income</i>	<i>FDI income</i>	<i>Impediment income</i>	
			<i>Barriers to establishment (capital taxes)</i>	<i>Barriers to ongoing operations (output taxes)</i>
<i>Rate of return</i>	intrate	ror	anrr	anto
<i>Asset price</i>	pb	pcap	anpk	anpo
<i>Endowment</i>	bond	cap	anend	anqo

---

## C Petri asset values - defining shares for the asset supply equations

The Petri asset values are the weights used in the (linearised) equations that define (the percentage change in) the quantity of an asset as a share weighted sum of (the percentage changes in) the quantities of component assets. For example, an alternative rendering of equation  $E\_c\_rrf\_h\_i$  from section 4.3 (ignoring possible division by zero cases) is

$E\_c\_rrf\_h\_i$  (all,i,TRAD\_COMM)(all,s,home)

$$kf\_h\_i(i,s)= \text{sum}\{d,\text{host},[VK\_HHI(i,s,d)/VKF\_H\_I(i,s)]*k\_hhi(i,s,d)\};$$

Plainly, the Petri asset values will evolve during the course of a policy simulation according to quantities determined by, and prices (exponentials of rates of return) entering into, the asset supply function described in chapter 4. Such evolution is specified in the GEMPACK TABLO update statements in the implementation of FTAP.

Regretably, the way Petri asset values are updated is not obvious. This is due to a decision, taken early in the course of model development, to parallel the existing treatment used by Petri as closely as possible.

Petri (1997) specified the allocation of wealth between assets as a nested *CES demand* function, rather than as a supply function. The reciprocal of the rate of return was used as the demand price, so that wealth was allocated in a sensible way, that is, toward assets with high rates of return.

The attraction of this approach is that the initial Petri asset values are identical to the conventional asset values if the initial quantities of capital are set equal to net (of depreciation) rentals to capital — as they were in Petri (1997) (page 14).

FTAP development has paralleled this as closely as possible, subject to two alterations. First, the reciprocal of the *exponential* of the rate of return was used to accommodate the possibility of negative rates of return. Second, gross rather than

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net rentals were used as the initial quantities of capital, again to avoid the possibility of negative net returns.<sup>1</sup>

Consequently, each initial Petri asset value is the reciprocal of the exponential of the asset's rate of return times the asset's gross rental value. Each Petri asset value is updated with the sum of the percentage change in this reciprocal (the 'r\_' variables of chapter 4) and the percentage change in the quantity of the asset, using GEMPACK TABLO implicit updates. For example, the update statement for the Petri asset value of foreign capital by industry, home region (owner) and host region (location) is:

(all,s,home)(all,d,host)(all,i,TRAD\_COMM)

$$VK\_HHI(i,s,d)=r\_rr\_hhi(i,s,d)*k\_hhi(i,s,d);$$

So asset supply in FTAP is determined by a nested CES demand function with the reciprocal of the exponential of the rate of return being used as the price of an asset. The (linearised) equations are identical to a nested CET structure with the exponentials of rates of return used as prices, but the update statements for Petri asset values (hence the values of shares entering the equations) are different.

Therefore the asset supply function is not strictly as described — nested CET — in the main sections of this paper. However, as the linearised equations of FTAP are identical to the nested CET form, and as it would have been confusing to describe asset *supply* as being determined by a nested *CES demand* function, the simplification of using the expression 'nested CET supply function' seems acceptable.

Importantly, both the FTAP and Petri (1997) asset supply specification can be represented as the outcome of the decisions of optimising agents. This is shown for the FTAP specification in chapter 10.

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<sup>1</sup> Both these possibilities become more probable under further sectoral disaggregation of the FTAP database.

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## D Miscellaneous changes to the welfare decomposition

Extensions to the GTAP welfare decomposition to accommodate foreign income flows have been described in chapters 3, 4 and 8.

This appendix describes other changes, some subtle and some simple, which did not readily fall under any of the main chapters of this research memorandum.

Fortunately, the entire welfare decomposition is summarised in the equation EV\_DECOMPOSITION, which expresses the equivalent variation as a sum of contributions from various effects (allocative efficiency, technical efficiency, terms of trade and so on).

For this appendix, both the GTAP and FTAP versions of this equation have been collapsed into one equation. The terms common to both are shown in normal type. The FTAP specific terms are shown in bold and, where applicable, the GTAP terms that they replace are on a grey background and are commented out in GEMPACK style (between two exclamation marks). Alterations are allocated numbers with a GEMPACK comment. A description of the changes from GTAP to FTAP follows the equation.

EV\_DECOMPOSITION (all,r,REG)

$$\begin{aligned} &EV\_ALT(r)= \\ &[.01/INCRATIO(r)]* \\ &[\mathbf{sum(i, PROD\_COMM, PTAX(i,r)*qo(i,r))} \quad \mathbf{! Alteration 1!}] \\ &+\mathbf{sum(i, NONCAP\_COMM, PTAX(i,r)*qo(i,r))} \quad \mathbf{! Alteration 1!} \\ &+\mathbf{sum(i, ENDWC\_COMM, PTAX(i,r)*kr(r))} \quad \mathbf{! Alteration 1!} \\ &!\mathbf{sum(i, NSAV\_COMM, PTAX(i,r)*qo(i,r))!} \quad \mathbf{! Alteration 1!} \\ &+\mathbf{sum(i, ENDW\_COMM, sum(j, PROD\_COMM, ETAX(i,j,r)*qfe(i,j,r)))} \\ &+\mathbf{sum(j, PROD\_COMM, sum(i, TRAD\_COMM, IFTAX(i,j,r)*qfm(i,j,r)))} \end{aligned}$$

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$+ \sum(j, \text{PROD\_COMM}, \sum(i, \text{TRAD\_COMM}, \text{DFTAX}(i,j,r) * \text{qfd}(i,j,r)))$   
 $+ \sum(i, \text{TRAD\_COMM}, \text{IPTAX}(i,r) * \text{qpm}(i,r))$   
 $+ \sum(i, \text{TRAD\_COMM}, \text{DPTAX}(i,r) * \text{qpd}(i,r))$   
 $+ \sum(i, \text{TRAD\_COMM}, \text{IGTAX}(i,r) * \text{qgm}(i,r))$   
 $+ \sum(i, \text{TRAD\_COMM}, \text{DGTAX}(i,r) * \text{qgd}(i,r))$   
 $+ \sum(i, \text{TRAD\_COMM}, \sum(s, \text{REG}, \text{XTAXD}(i,r,s) * \text{qxs}(i,r,s)))$   
 $+ \sum(i, \text{TRAD\_COMM}, \sum(s, \text{REG}, \text{MTAX}(i,s,r) * \text{qxs}(i,s,r)))$   
 $+ \sum(i, \text{ENDW\_COMM}, \text{VOA}(i,r))$  **! Alteration 2!**  
 **$[\text{qo}(i,r) - \sum\{k, \text{ENDWC\_COMM}: k \text{ eq } i, \text{qo}(i,r) - \text{kr}(r)\}]$**  **! Alteration 2!**  
 $! + \sum(i, \text{ENDW\_COMM}, \text{VOA}(i,r) * \text{qo}(i,r))!$  **! Alteration 2!**  
 **$-\text{VDEP}(r) * [\text{deprate}(r) + \text{kb}(r)]$**  **! Alteration 3!**  
 $! - \text{VDEP}(r) * \text{kb}(r)!$  **! Alteration 3!**  
 $+ \sum(i, \text{PROD\_COMM}, \text{VOA}(i,r) * \text{ao}(i,r))$   
 $+ \sum(i, \text{ENDW\_COMM}, \sum(j, \text{PROD\_COMM},$   
 $\quad \text{VFA}(i,j,r) * [\text{afe}(i,j,r) + \text{ava}(j,r)])$   
 $+ \sum(j, \text{PROD\_COMM}, \sum(i, \text{TRAD\_COMM},$   
 $\quad [\text{VIFA}(i,j,r) + \text{VDFA}(i,j,r)] * \text{af}(i,j,r)))$   
 $+ \sum(i, \text{TRAD\_COMM}, \sum(s, \text{REG}, \text{VTWR}(i,s,r) * \text{atr}(i,s,r)))$   
 $+ \sum(i, \text{TRAD\_COMM}, \sum(s, \text{REG}, \text{VXWD}(i,r,s) * \text{pfob}(i,r,s)))$   
 $+ \sum(i, \text{TRAD\_COMM}, \text{VST}(i,r) * \text{pst}(i,r))$  **! Alteration 4!**  
 $! + \sum(i, \text{TRAD\_COMM}, \text{VST}(i,r) * \text{pm}(i,r))!$  **! Alteration 4!**  
 $+ \text{NETINV}(r) * \text{pcgds}(r)$   
 $- \sum(i, \text{TRAD\_COMM}, \sum(s, \text{REG}, \text{VXWD}(i,s,r) * \text{pfob}(i,s,r)$   
 $+ \text{VTWR}(i,s,r) * \text{pt}))$

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$-SAVE(r)*psave(r)$   
 $+sum(i, TRAD\_COMM, VPA(i,r)-VPA(i,r)*INCPAR(i,r))*up(r)$   
 $+YCR(r)*qyir(r)+YCITR(r)*y_r(r)$                     **! Alteration 5!**  
 $+100*yfdi_h__(r)$     **! Alteration 5!**  
 $+100*yank_h__(r)+100*yanp_h__(r)];$                     **! Alteration 5!**

The first alteration is required because of the introduction of industry specific capital in FTAP. A consequence of this is that there is no unique measure of the regional capital stock. In linearised form, the regional capital stock is a share-weighted sum of industry specific capital, but different values will be obtained through using asset-value weights versus rental weights.<sup>1</sup> In FTAP the capital component of the GTAP variable  $qo$  is equated with the asset weighted measure. The rental weighted measure is a new variable  $kr$ . Which is the correct measure to use in the welfare decomposition depends on the context. In the derivation of the welfare decomposition (Huff and Hertel 1996), the GTAP expression

$$sum(i, NSAV\_COMM, PTAX(i,r)*qo(i,r))$$

arises from the (linearised) terms for income tax revenue. For capital, the tax base is the rentals to capital. Consequently,  $qo$  in this expression must be replaced by  $kr$ .

The second alteration is for the same reason as the first.

The third alteration is required because of the introduction of constant industry-specific depreciation rates in FTAP. If depreciation rates vary among industries (as they do in the FTAP database), then the regional depreciation rate can vary during the course of a simulation due to compositional change. The percentage change in the regional depreciation rate is FTAP variable  $deprate$ .

The fourth alteration is because, in contrast to GTAP, the FTAP price of international freight services (variable  $pst$ ) is not equal to the market price of output (variable  $pm$ ). The reason for this is discussed in chapter 6.

The three lines of the fifth alteration are the foreign income flows described in chapters 3, 4 and 8, respectively.

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<sup>1</sup> This is not so in GTAP, where capital is perfectly mobile between industries within a region.

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# E Data requirements for GTAPICM

As indicated in Section 3, besides the modifications to the theoretical structure of GTAP, a number of modifications were also necessary to the GTAP 4 database (McDougall, Elbehri and Truong 1998) in order to complete the implementation of the ICM extension in GTAP. These modifications include, in the main, the addition of new data to GTAP 4. They also include a small number of important modifications to GTAP 4. This appendix discusses these modifications.

The changes to GTAP 4 will be discussed in terms of the header arrays that were added or modified. In summary, 14 new header arrays were added to the model, and three existing header arrays were modified.

In modifying GTAP 4, the data sources and data calculations in the original implementation of the ICM extension in *SALTER* were followed as closely as possible.

GTAP 4 is specified in \$US million for 1995. For consistency, all data added to GTAP 4 must also be in \$US million for 1995.

## **E.E.1 Regional aggregation**

For the implementation of the ICM extension in GTAP, a 19 region aggregation was chosen from GTAP 4. The regions were Australia, New Zealand, Japan, the Republic of South Korea, Indonesia, Malaysia, the Philippines, Singapore, Thailand, China, Hong Kong, Taiwan, Canada, the United States, Mexico, Chile, the rest of the Cairns Group (ROC), the European Union (EUN) and the rest of the world (RST). Except for the last three regions, all are stand alone regions in GTAP 4. ROC, EUN and RST are aggregations of existing GTAP 4 regions. ROC includes Colombia, Argentina, Brazil and Uruguay. EUN includes the 15 European Union members at the time of writing. All remaining regions are aggregated into RST.

In most cases, the data collected were in the form of ratios (usually as a proportion of gross domestic product), which were subsequently applied to the GDP values in the GTAP 4 database to calculate \$US dollar values for 1995. In these cases, for the aggregated regions ROC, EUN and RST, individual country ratios were aggregated using gross domestic product (in \$US) shares taken from World Bank (1997), Table

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12 titled ‘Structure of the economy: production’. Where the raw data were collected in the form of dollar values, they were aggregated where necessary using simple sums.

For RST, data were only collected for four countries. These were India, South Africa, Switzerland and Turkey. These countries were chosen either for their large size (eg Switzerland and South Africa) relative to other nations represented in this group, for being typical of other nations in their geographic area, or for both of these reasons (eg India is large and is also representative of other South Asian nations). All in all, this required that data be collected for a total of 39 countries.

## **E.E.2 Taxes on labour and property income, by region**

The header arrays CM05 and CM06 contain data on taxes on labour income and property income, respectively, for each region. They are used to calibrate the coefficients RVTXYCLBR(r) and RVTXYCPPR(r), respectively. Both of these coefficients are defined over the set REG.

The calibration of these ‘coefficients’ can be represented algebraically by the following equations:

$$\text{RVTXYCLBR}(r) =$$

$$\{\text{GDP}(r) * [\text{TOTINCTAX}(r) / \text{GDP\_DC}(r)]\} *$$

$$\{\text{LABINCTAX}(r) / \text{TOTINCTAX}(r)\};$$

$$\text{RVTXYCPPR}(r) =$$

$$\{\text{GDP}(r) * [\text{TOTINCTAX}(r) / \text{GDP\_DC}(r)]\} *$$

$$\{\text{PROPINCTAX}(r) / \text{TOTINCTAX}(r)\};$$

where GDP(r) is the GTAP coefficient for the value of gross domestic product in region r, TOTINCTAX(r) is total income tax in region r, GDP\_DC(r) is current price gross domestic product in region r, LABINCTAX(r) is labour income tax in region r and PROPINCTAX(r) is property income tax in region r. All these non-GTAP ‘coefficients’ are for 1995 and are specified in domestic currency. The first term in curly brackets on the right hand side of each of the above equations is total income tax in \$US million for 1995 in region r. The second term in curly brackets is the ratio of either labour or property income tax, to total income tax in region r, respectively. Together these two terms calculate labour or property income tax in each region, in \$US million for 1995.



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The primary data source for the coefficients TOTINCTAX(r), LABINCTAX(r) and PROPINCTAX(r) is IMF (1997a), ‘Country tables’, line 1.1 (assumed to be labour taxes), line 1.2 (assumed to be property taxes), line 1.3 (assumed to be property taxes), and line 2 (assumed to be labour taxes).

The data source for Japan was Statistics Bureau (1996), Table 14-7, titled ‘National Taxes by Item’, and Table 14-14 titled ‘Local Tax Revenue by Tax Item’. The data source for Taiwan was Directorate-General of Budget (1997), Table 139 titled ‘Total tax revenues’. The data source for Singapore was Singapore Department of Statistics (1997), Table 16.8 titled ‘Taxpayers, Assessed Income & Gross Tax Assessed, 1995, Gross tax assessed, Companies’. The data source for Hong Kong was Census and Statistics Department of the Government of the Hong Kong Special Administrative Region (1997), Table 8.2 titled ‘Actual Revenue (General Revenue Account and Funds), 1994/95’.

Where data were not available for 1995 for certain countries, the latest year for which data were available was used in its place. The countries (and the years for which data were collected) were Belgium (1994), Brazil (1993), Canada (1994), Colombia (1985), Germany (1993), Indonesia (1994), Ireland (1994), Italy (1994), Japan (1993), Portugal (1990) and Spain (1994).

The primary data source for GDP\_DC(r) was IMF (1997b) ‘Country Tables’, Line 99b, or 99b.c or 99b.r. Data for Hong Kong were sourced from <http://www.info.gov.hk/censtatd/>. Data for Luxembourg were sourced from Statistics Directorate, OECD (1997).

Table E.1 reports total income taxes (as a percentage of gross domestic product (GDP)), and taxes on labour income and taxes on property income (as a percentage of total income taxes), for all GTAPICM regions.

### **E.E.3 Transfers from government to private households, by region**

The name of this header array is CM01, and it contains data required to calibrate the coefficient URGVHHR(r). This coefficient is defined over the set REG.

Table E.E.1 Taxes on labour and property income by GTAPICM region

	<i>Total income taxes</i>	<i>Taxes on labour income</i>	<i>Taxes on property income</i>
	% of GDP	% of total income taxes	% of total income taxes
Australia	15.61	73.94	26.06
New Zealand	21.31	74.62	25.38
Japan	8.59	58.48	41.52
Korea	7.90	68.67	31.33
Indonesia	8.97	20.53	79.47
Malaysia	9.74	33.04	66.96
Philippines	5.83	34.77	65.23
Singapore	6.73	42.97	57.03
Thailand	6.14	36.94	63.06
China	1.56	14.40	85.60
Hong Kong	6.90	42.97	57.03
Taiwan	4.63	54.04	45.96
Canada	22.15	88.74	11.26
United States	19.41	86.56	13.44
Mexico	7.59	31.22	68.78
Chile	5.05	62.96	37.04
ROC	10.42	72.04	27.96
EUN	25.70	87.73	12.27
RST	12.19	71.00	29.00

Source: See text.

The calibration of  $URGVHHR(r)$  can be represented algebraically by the following equation:

$$URGVHHR(r) =$$

$$[(RVXYCR(r) + GRCOMT(r)) - CGGS(r) - \text{sum}(i, \text{TRAD\_COMM}, \text{VGA}(i,r))];$$

where  $RVXYCR(r)$  is the GTAPICM coefficient for income tax revenue in region  $r$ ,  $GRCOMT(r)$  is the GTAPICM coefficient for net (of subsidies) indirect tax revenue in region  $r$ , and  $VGA(i,r)$  is the GTAP coefficient for the agent's (or post-tax) price value of government household expenditure on commodity  $i$  in region  $r$ .

$CGGS(r)$  is the consolidated general government surplus in region  $r$  (in \$US million for 1995). This includes all levels of government and is net of capital expenditure. IMF (1997b) contains data for  $CGGS(r)$ , which is defined as total revenue plus total grants, less total recurrent expenditure, plus lending minus repayments. The data were taken from the 'Country tables', 'Summary Table, Consolidated Central

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Government’, Lines 11 and 9, ‘Table St. State, Region or Province Governments’, Line S.11 and line IV (table C), and ‘Table L. Local Governments’, Line S.11 and line IV (table C).

IMF (1997b) did not contain data on CGGS(r) for Chile, Hong Kong and Taiwan. Data for Hong Kong were taken from Data Census & Statistics Division (1997), Tables 8.2 and 8.3. Data for Taiwan were taken from Council for Economic Planning & Development (1998). Data for Chile were taken from WTO (1997), Table I.2 Economic performance, 1990-96.

CGGS(r) data for 1995 were not available for all countries. In these cases, the latest available data were used instead. The countries (and years for which data were collected) were Brazil (1993), Canada (1991), Colombia (1986), India (1994), Indonesia (1993), Ireland (1994), Japan (1989), Mexico (1994), Spain (1994) and the Philippines (1992). Where non-1995 data were used, it was scaled to 1995 by the difference in GDP\_DC(r) in 1995 and the year for which the data were collected.

Once data had been collected for 1995, or scaled to 1995, they were converted from domestic currency to \$US, using the exchange rate in the year for which the data were collected. Exchange rates were sourced from IMF (1997b), using the ‘rf’ series data, or ‘rh’ series data where the ‘rf’ was not available.

Table E.2 reports CGGS(r) in 1995 \$US million for all GTAPICM regions.

#### **E.E.4 Abnormal earnings of capital, by region and industry**

The name of this header array is CM02, and it contains data required to calibrate the coefficient ENANKPRI(j,r). This coefficient is defined over the sets TRAD\_COMM and REG.

In long-run equilibrium, no abnormal returns can be earned. To reflect this, all entries in this header array are set equal to zero.

#### **E.E.5 Net interest receipts of government, by region**

The name of this header array is CMO4, and it contains data required to calibrate the coefficient RCGVITR(r). This coefficient is defined over the set REG.

Table E.E.2 Consolidated general government surplus (CGGS) by GTAPICM region

	1995 \$US million
Australia	6 794
New Zealand	749
Japan	364 523
Korea	17 492
Indonesia	18 218
Malaysia	8 767
Philippines	2 180
Singapore	15 319
Thailand	15 000
China	21 330
Hong Kong	2 221
Taiwan	28 399
Canada	-29 130
United States	70 590
Mexico	8 518
Chile	3 567
ROC	1 197
EUN	-74 578
RST	-9 317

Source: See text.

The calibration of RCGVITR(r) can be represented algebraically by the following equation:

RCGVITR(r) =

$$\text{GDP}(r) * \{ [\text{NGIP}(r) / \text{GDP\_DC}(r)] * -1 \};$$

where NIP(r) is net government interest payments in region r, specified in domestic currency for 1995.

The primary data sources for NGIP(r) were IMF (1996) and IMF (1997a). The data were taken from Table B titled 'Expenditure by Function, Consolidated Central Government', Line 14 titled 'Other Expenditures of which: Interest Payments'. For Japan the data source was Statistics Bureau (1996), Table 14-3 titled 'General Disbursements, Interest Paid'.

IMF (1996, 1997a) did not contain data for Hong Kong, Taiwan, South Africa and China. In its place, data were used from Singapore (for Hong Kong), South Korea (for Taiwan), Mexico (for South Africa) and Indonesia (for China).

**Table E.E.3 Net government interest payments by GTAPICM region**

	% of GDP
Australia	1.72
New Zealand	4.24
Japan	2.41
Korea	0.61
Indonesia	1.58
Malaysia	3.08
Philippines	3.81
Singapore	1.01
Thailand	0.34
China	1.58
Hong Kong	1.01
Taiwan	0.61
Canada	4.39
United States	3.19
Mexico	2.83
Chile	0.72
ROC	13.02
EUN	7.50
RST	2.76

Source: See text.

Most data were available for 1995, except for Brazil (1993), Colombia (1993), Canada (1994), Ireland (1994) and Spain (1994). In these cases, where data for NGIP(r) were collected for a year other than 1995, then equivalent year data were collected for GDP\_DC(r). For example, the latest available data on NGIP(r) for Brazil was for 1993. Thus, GDP\_DC(r) for Brazil was also collected for 1993.

Table E.3 reports net government interest payments (NGIP(r)) as a percentage of GDP for all GTAPICM regions.

### **E.E.6 Net interest income of households, by region**

The name of this header array is CMO3, and it contains data required to calibrate the coefficient YCHHITR(r). This coefficient is defined over the set REG.

The calibration of YCHHITR(r) can be represented algebraically by the following equation:

YCHHITR(r) =

$$\{[(FIRA(r) - FIPA(r))/GDP\_DC(r)]*GDP(r)\}*$$

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$$\{[CIRA(r) - CIPA(r)]/[FIRA(r) - FIPA(r)]\} - RCGVITR(r);$$

where FIRA(r) is total factor income received from abroad by region r, FIPA(r) is total factor income paid abroad by region r, CIRA(r) is capital income received from abroad by region r, and CIPA(r) is capital income paid abroad by region r. All these 'coefficients' are specified in domestic currency for 1993, as data for 1995 were not available for any countries at the time. When summed across all regions, YCHHITR(r) must equal zero. To ensure this condition is met, the value used for RST is calculated as the sum of YCHHITR(r) for all other regions, multiplied by -1.

The primary data source for FIRA(r), FIPA(r), CIRA(r) and CIPA(r) is UN (1996). Data for FIRA(r) were taken from Table 1.7 titled 'External transactions on current account summary', section titled 'Receipts from the rest of the world', line 2. Data for FIPA(r) were also taken from the Table 1.7, section titled 'Payments to the rest of the world', line 2. Data for CIRA(r) and CIPA(r) were taken from the same table and sections as FIRA(r) and FIPA(r), but line 2B.

For Australia, the data source was ABS (1998), Table 41 titled 'External Account, current prices'. For Taiwan, the data source was Council for Economic Planning & Development (1998), Table 100 titled 'External transactions'. For Singapore, the data source was Singapore Department of Statistics (1997), Table 5.2 titled 'Output, saving and investment (at current market prices)'. For Hong Kong, the data source was Census & Statistics Division (1997), Table 17.9 titled 'Estimates of Gross National Product and External Factor Income Flows by Income Component by Type of Transactor (at current market prices)'.

Data for FIRA(r) and FIPA(r) were unavailable for Argentina. In its place, data were used from Brazil. Data for CIRA(r) and CIPA(r) were unavailable for Argentina, Chile, China, Indonesia, Singapore, Thailand, Turkey, and Uruguay. In its place, data were used from Brazil (for Argentina, Chile, and China), from India (for Indonesia), from Hong Kong (for Singapore), from Malaysia (for Thailand) and from Greece (for Turkey).

For certain countries data was not available for 1993. In these cases, the latest available data were used. The countries (and the years for which data were collected) were Australia (1994/95), Brazil (1989), Chile (1990), Colombia (1992), Greece (1992), Hong Kong (1995), Luxembourg (1991), Malaysia (1992), Portugal (1989), Singapore (1995), South Africa (1992), Taiwan (1995) and Uruguay (1991).

Table E.4 reports the data collected on net factor income from abroad (as a percentage of GDP) and net capital income from abroad (as a percentage of net factor income from abroad) for all GTAPICM regions.

**Table E.E.4 Net factor income from abroad and net capital income from abroad by GTAPICM region**

	<i>Net factor income from abroad</i>	<i>Net capital income from abroad</i>
	% of GDP	% of net factor income from abroad
Australia	-3.87	100.88
New Zealand	-3.98	100.00
Japan	0.94	95.43
Korea	-0.64	128.33
Indonesia	-4.68	97.36
Malaysia	-5.09	98.86
Philippines	3.04	-57.07
Singapore	0.98	100.00
Thailand	-1.86	98.86
China	-11.13	97.36
Hong Kong	1.34	100.00
Taiwan	0.90	144.08
Canada	-3.42	0.00
United States	0.26	100.63
Mexico	-2.72	106.66
Chile	-5.83	99.12
ROC	-3.08	98.96
EUN	0.73	49.38
RST	0.48	135.57

Source: See text.

### **E.E.7 Rate of growth in real household income and real government receipts, by region (per year)**

The header arrays CMO9 and CM11 contain data on the rate of growth in real household income and government receipts, respectively, for each region. They are used to calibrate the coefficients  $GTCHHRLR(r)$  and  $GTTCGVRLR(r)$ , respectively. Both of these coefficients are defined over the set REG.

These coefficients are both set equal to the average annual growth rate of real gross domestic product in each region, for the period 1985 to 1995, expressed as a fraction.

The primary data source was Statistics Directorate (1998). Data were taken from Table 'Volume Indices, Gross Domestic Product'.

For Argentina, Brazil, Chile, Colombia, Denmark, Germany, India, Indonesia, Ireland, Korea, Portugal, RST, South Africa and Uruguay, data were taken from

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IMF (1997b), 'Country tables', lines 99b.p, 99b.r, 99a.p or 99a.r. All refer to constant price GDP. Data for RST were taken from the 'World tables', GDP at constant prices, line 001.

Data for Malaysia, the Philippines, Singapore, Thailand and Turkey were taken from Economic & Social Commission for Asia & the Pacific (1997), 'Country tables', line 'National Accounts, Gross national product at constant prices'.

Data for Belgium, Greece and Luxembourg were taken from Statistics Directorate (1997), Table 3.1, line 'Real gross domestic product'.

Data for Taiwan were taken from Council for Economic Planning & Development Council for Economic Planning & Development (1998).

Data for China were taken from State Statistical Bureau (1996), Table 3-4 titled 'Indices of Gross Domestic Product'.

Data for Hong Kong were taken from Census & Statistics Division (1997), Table 17.2 titled 'Gross Domestic Product Estimates by Main Expenditure Component', line 'Expenditure-based GDP at constant (1990) market prices'.

Table E.5 reports the average annual growth of real GDP over the period 1985-1995, by GTAPICM region.



Table E.E.5 Average annual growth of real GDP, 1985-1995, by GTAPICM region

	per cent
Australia	3.06
New Zealand	1.61
Japan	3.03
Korea	8.77
Indonesia	6.69
Malaysia	7.77
Philippines	3.48
Singapore	8.51
Thailand	9.40
China	9.97
Hong Kong	6.53
Taiwan	7.68
Canada	2.21
United States	2.42
Mexico	1.72
Chile	7.00
ROC	2.74
EUN	2.67
RST	3.39

Source: See text.

## E.E.8 Capital depreciation and net saving, by region

The data for net (of capital depreciation) saving in each region is contained in the GTAP 4 header SAVE. The 19 region aggregation of GTAP 4, chosen for the initial implementation of the ICM extension in GTAP, gives negative net saving for two regions. These are the Philippines and Hong Kong. With negative net saving, the allocation of income between consumption and saving can no longer be regarded as the result of a utility maximising decision. For instance, consider total consumption (government and private household spending) as one item. Then, when net saving is negative, nominal consumption is equal to a constant proportion of nominal income in the GTAP specification. The income elasticity of consumption is 1, and the uncompensated price elasticity is -1. The compensated price elasticity is thus, by the Slutsky relationship,

$$-1 + [SC(r)]*1 > 0$$

where  $SC(r)$  is the share of consumption in income in region  $r$ , since the share of consumption in income is greater than 1. Thus the allocation of income cannot be the outcome of a utility maximisation decision. Consequently, to avoid spurious

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welfare results from policy simulations, negative net saving values must be removed from the database.

GTAP 4 contains headers for net saving in each region ( $SAVE(r)$ ) and capital depreciation in each region ( $VDEP(r)$ ), where net saving is equal to

$SAVE(r) =$

$$GROSSAVE(r) - VDEP(r);$$

where  $GROSSAVE(r)$  is gross saving in region  $r$ .  $GROSSAVE(r)$  is not directly observable in the GTAP database. Thus in order to increase  $SAVE(r)$  to a positive value for the Philippines and Hong Kong,  $VDEP(r)$  must be decreased and  $SAVE(r)$  increased by the same absolute amount. This maintains the initial value of gross domestic product and a balanced database, for each region.

For the Philippines, negative net saving was removed by setting the depreciation rate equal to the lowest depreciation rate observed in all other regions. This was 7.08 per cent for Taiwan. For Hong Kong, the above procedure still left negative savings. Therefore, the depreciation rate was set (arbitrarily) equal to half the depreciation rate for Taiwan.

## **E.E.9 Capital stock, by region**

The capital stock data are contained in the GTAP 4 header  $VKB(r)$ . In long run equilibrium, the net (of depreciation) rate of return on capital is equal in each region. The GTAPICM theoretical structure assumes this parity condition. However, the GTAP 4 capital stock data are not calibrated for long run equilibrium. To prevent these differences from distorting capital stock results,  $VKB(r)$  for each region is adjusted, up or down as the case may be, to ensure that the net (of depreciation) rate of return on capital in each region is equal that for the world as a whole, ie 8.1 per cent.

## **E.E.10 Steady-state rate of growth in real capital stock, by region**

The name of this header array is  $CM14$ , and it contains the data required to calibrate the coefficient  $GTSSKPR(r)$ . This coefficient is defined over the set  $REG$ .

The calibration of  $GTSSKPR(r)$  can be represented algebraically by the following equation:

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GTSSKPR(r) =

$$\{\text{REGINV}(r) - \text{VDEP}(r)\}/$$

$$\{[\text{sum}(c, \text{ENDWC\_COMM}, \text{EVOA}(c,r)) - \text{VDEP}(r)]/\text{RTEQR}(r)\};$$

where REGINV(r) is the GTAP coefficient for gross investment in region r, ENDWC\_COMM is the set of the single capital endowment commodity, EVOA(c,r) is the agent's (or post-tax) price value of output of commodity c in region r, and RTEQR(r) is the GTAPICM coefficient defining the pre-tax net (of depreciation) rate of return on capital in region r. The values used for VDEP(r) are those after the net saving was adjusted to remove negative values for the Philippines and Hong Kong.

The first term in curly brackets on the right hand side of the above equation is the net addition to the capital stock in each region. The second term in curly brackets is a capital stock figure. Together these two terms calculate the steady-state capital stock growth rate, which is used in the GTAPICM theoretical structure to represent the rate of growth in each region which is consistent with zero change, over time, in the rate of return on capital. If GTAP 4 were calibrated to represent long-run equilibrium, the actual rates of growth implicit in the database would be close to the steady-state growth rates. But GTAP 4 is not calibrated for long-run equilibrium. Thus, to prevent deviations from long-run equilibrium from distorting investment results, the entries for GTSSKPR(r) are calculated to be equal to the actual capital stock growth rates implicit in the database.

## **E.E.11 World real bond rate**

The name of this header array is CMO7, and it contains the datum required to calibrate the coefficient RTBD.

This coefficient is set equal to the world net (of depreciation) rate of return on capital implied in the GTAP 4 database, after the capital stock has been calibrated for long run equilibrium (see Capital Stock).

The calibration of GTSSKPR(r) can be represented algebraically by the following equation:

RTBD =

$$\text{sum}(c, \text{ENDC\_COMM}, \text{sum}(r, \text{REG}, \text{EVOA}(c,r)) - \text{VDEP}(r)/\text{VKB}(r));$$

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## **E.E.12 Coefficient for FORMULA (INITIAL) statements**

The name of this header is 1. It contains the datum required for the GTAPICM coefficient FIRST.

FIRST is set equal to 1 for initial implementation, and updated to a value of zero in the updated database.

This coefficient is used to explicitly adjust, in the TABLO code, two GTAP coefficients in the database. This is done only for the initial implementation of the ICM extension. For post-initial simulations of GTAPICM, this coefficient has no effect.

FIRST is used to make the following adjustments to GTAP coefficients:

- to add net interest receipts to net saving in each region;
- to subtract taxes on labour income from post-tax labour income; and
- to subtract taxes on property income from post-tax property income.

## **E.E.13 Length of simulation period**

The name of this header array is CM10, and it contains the datum required to calibrate the coefficient LGPRSM.

This is a single parameter which is set equal to 10.

## **E.E.14 Coefficient of adjustment in returns to capital**

The name of this header array is CM12, and it contains the datum required to calibrate the coefficient CEJRTKPR.

This coefficient is set equal to 0.2.

## **E.E.15 Elasticity of the expected rate of return on capital with respect to the size of the capital stock, by region**

The name of this header array is CM13, and it contains the data required to calibrate the coefficient EL\_ERCRK\_K\_R(r). This coefficient is defined over the set REG.

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These elasticities are set so that they agree with those implicit in the initial database. The implicit elasticities are obtained via simulation once all other data modifications have been completed. Shocks of 1 are applied to the equity premium shift variables  $frer(r)$ , on a country by country basis. The elasticities are the calculated by the following equation:

$$EL\_ERCRK\_K\_R(r) = \frac{1}{\{[RTEQR(r) + RTDPR(r)]*kt(r)\}};$$

where  $RTDPR(r)$  is the GTAPICM coefficient for the depreciation rate in region  $r$  and  $kt(r)$  is the GTAPICM variable for the capital stock in region  $r$ . These elasticities are then incorporated in the database, and the simulation repeated with the revised database. This procedure is repeated until the changes in  $EL\_ERCRK\_K\_R(r)$  are not discernible to six decimal places.

## **E.E.16 Pre-tax rate of return on equity, by region**

In the SALTER model, the values for this coefficient,  $RTEQR(r)$ , were calculated from the database and stored in the header MK07 in the data files. In GTAPICM, this coefficient is now calculated via a FORMULA statement in TABLO input file.

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## F Asset supply transformation elasticities - some numerical examples

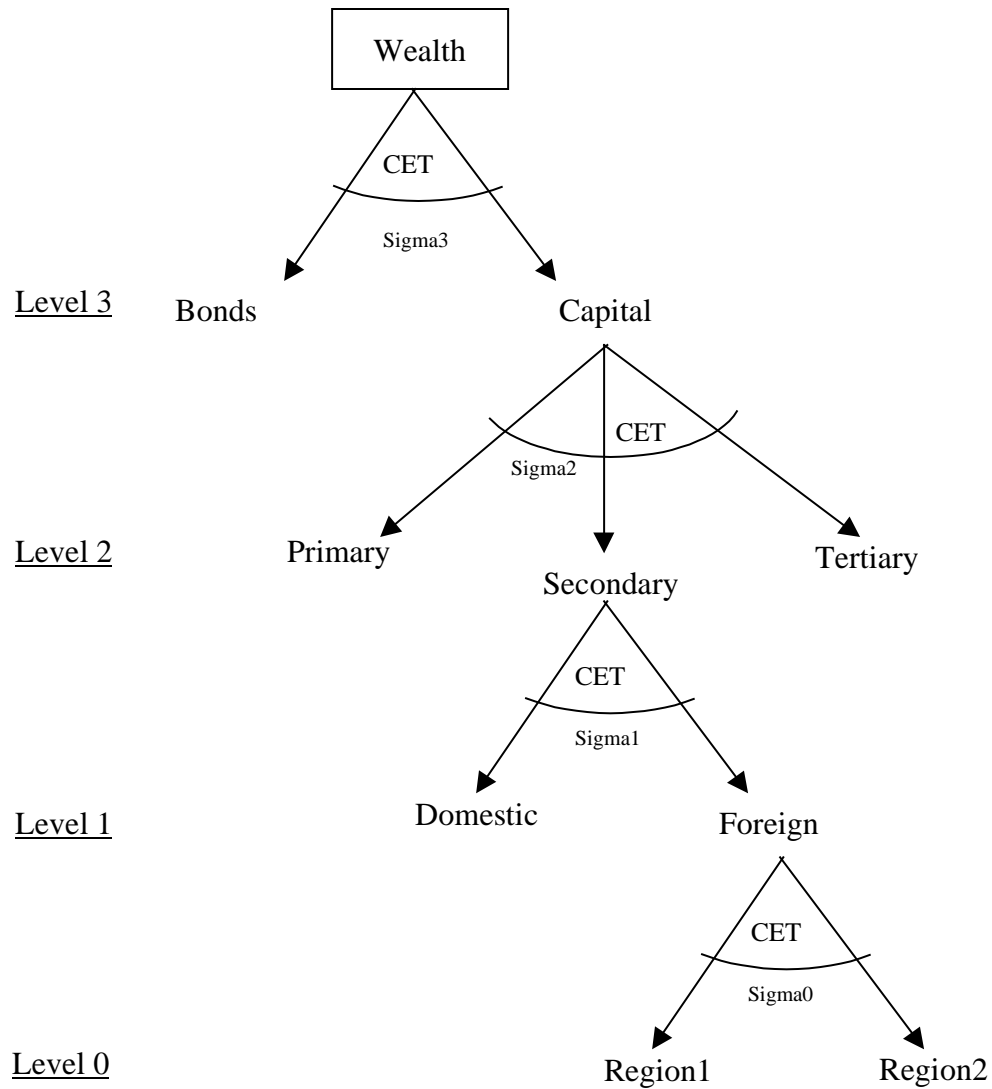
This appendix examines the responsiveness of capital supply for different users at different levels of a CET nest, when total wealth in the supplying region is held constant. Several numerical examples, based on a slight simplification of the asset supply function in chapter 4, but using actual data from the FTAP database, are provided.

The structure of the CET nest is portrayed by figure F.1, where the lowest level in the nest is the choice to invest in foreign regions.

When total wealth at the highest level of a CET nest is fixed, the transformation elasticity of capital supply at lower levels can be magnified to be much larger than the CET parameter specified at that level of the nest. The magnification depends largely on the shares at that 'node' in the structure in relation to the total wealth at the top level.

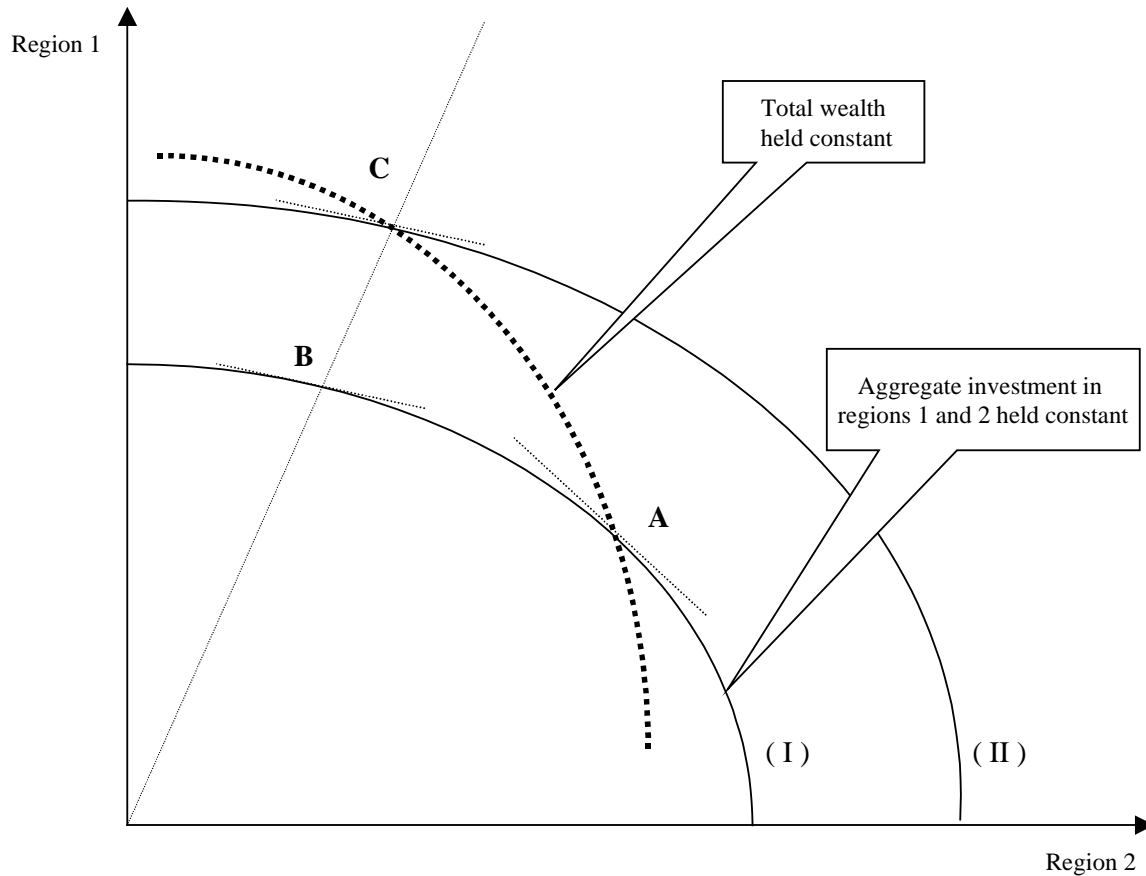
The following explanation for this phenomenon is taken from Truong (1999). The specified parameters at each level of the structure only represent the transformation of capital, between possible activities or destinations, for a fixed amount of capital at that level, while the total wealth can vary. Thus changes in the choice of destinations of capital, with total foreign capital ownership fixed, are only movements along the foreign-capital-fixed transformation curve, from A to B in figure F.2. In contrast, when total wealth is held constant, changes in relative prices are likely to change other decisions of capital suppliers, for example, as regards domestic versus foreign investment. The aggregate investment at different levels in the CET nest is therefore no longer constant. It can be higher or lower, depending on relative profitabilities. Graphically, it is represented as a shift in the transformation curve, from I to II, for example. Thus the magnitude of transformation of investment among destinations is magnified, from A to C instead. Changes to a low base are usually large in percentage changes. Consequently, countries that have low outward foreign investments usually have high transformation elasticities of investment among foreign destinations.

Figure F.1 **Nested CET structure of investor choice**



Examples of this phenomenon, and other interesting interactions, will be examined for the nested CET structure in figure F.1. This is a simplification of the FTAP asset supply function illustrated in figure 2.3. Also, for simplicity of the exercise, bonds, land and natural resources are grouped together in *bonds*. Only two foreign regions, high-income and low-income, are presented in these examples. The calculations are in the companion spreadsheet CAP\_SUB\_NEST.XLS using data on bonds and capital extracted from the FTAP database. In this spreadsheet, specified parameters (or CET nested parameters) for levels from 0 to 3 are named as sigma0, sigma1, sigma2, and sigma3, respectively.

Figure F.2 Magnification of lower level substitution elasticities



Data source: Adapted from Truong (1999).

Formulas to calculate transformation elasticities with an assumption of a *fixed* amount of total wealth for a region are taken from Keller (1980), page 83:

Level 3 (The highest level): *Bonds* vs Capital

$$\eta_{\text{level 3}} = \sigma_3 / B_{\text{Cap\_shr}}$$

Level 2: Among three sectors

$$\eta_{\text{level 2}} = \sigma_2 / \text{Cap\_shr} - \sigma_3 * (1 / \text{Cap\_shr} - 1 / B_{\text{Cap\_shr}})$$

Level 1: Between Domestic and Foreign for each sector



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$$\eta_{\text{level 1 P}} = (\sigma_{1P}/\text{Pri\_Total\_K\_shr})$$

- $\sigma_{2^*}(1/\text{Pri\_Total\_K\_shr} - 1/\text{Cap\_shr})$
- $\sigma_{3^*}(1/\text{Cap\_shr} - 1/\text{B\_Cap\_shr})$

$$\eta_{\text{level 1 S}} = (\sigma_{1S}/\text{Sec\_Total\_K\_shr})$$

- $\sigma_{2^*}(1/\text{Sec\_Total\_K\_shr} - 1/\text{Cap\_shr})$
- $\sigma_{3^*}(1/\text{Cap\_shr} - 1/\text{B\_Cap\_shr})$

$$\eta_{\text{level 1 T}} = (\sigma_{1T}/\text{Ter\_Total\_K\_shr})$$

- $\sigma_{2^*}(1/\text{Ter\_Total\_K\_shr} - 1/\text{Cap\_shr})$
- $\sigma_{3^*}(1/\text{Cap\_shr} - 1/\text{B\_Cap\_shr})$

Level 0 (the bottom level): Two destinations abroad for each sector

$$\eta_{\text{level 0 P}} = \sigma_{0P}/\text{Forgn\_Tot\_PriK\_shr}$$

- $\sigma_{1^*}(1/\text{Forgn\_Tot\_PriK\_shr} - 1/\text{Pri\_Total\_k\_shr})$
- $\sigma_{2^*}(1/\text{Pri\_Total\_k\_shr} - 1/\text{Cap\_shr})$
- $\sigma_{3^*}(1/\text{Cap\_shr} - 1/\text{B\_Cap\_shr})$

$$\eta_{\text{level 0 S}} = \sigma_{0S}/\text{Forgn\_Tot\_SecK\_shr}$$

- $\sigma_{1^*}(1/\text{Forgn\_Tot\_SecK\_shr} - 1/\text{Sec\_Total\_K\_shr})$
- $\sigma_{2^*}(1/\text{Sec\_Total\_K\_shr} - 1/\text{Cap\_shr})$
- $\sigma_{3^*}(1/\text{Cap\_shr} - 1/\text{B\_Cap\_shr})$

$$\eta_{\text{level 0 T}} = \sigma_{0T}/\text{Forgn\_Tot\_TerK\_shr}$$

- $\sigma_{1^*}(1/\text{Forgn\_Tot\_TerK\_shr} - 1/\text{Ter\_Total\_K\_shr})$
- $\sigma_{2^*}(1/\text{Ter\_Total\_K\_shr} - 1/\text{Cap\_shr})$

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$$- \sigma_3 \cdot (1/\text{Cap\_shr} - 1/\text{B\_Cap\_shr})$$

where:

$\text{B\_Cap\_shr}$  = share of *bonds* plus capital in total wealth (at this highest level of the nest, level 3, total wealth equals the sum of *bonds* and capital, so the share is 1 in this case)

$\text{Cap\_shr}$  = share of capital in total wealth (Level 2)

$\text{Pri\_Total\_K\_shr}$ ,  $\text{Sec\_Total\_K\_shr}$ , and  $\text{Ter\_Total\_K\_shr}$  = sectoral capital shares in total wealth (Level 1)

$\text{Forgn\_Tot\_PriK\_shr}$ ,  $\text{Forgn\_Tot\_SecK\_shr}$ , and  $\text{Forgn\_Tot\_TerK\_shr}$  = shares in total wealth of capital invested abroad by sector (Level 0)

In figure F.1, all investing regions face the same CET parameter for the same level in the nest, although different levels in the nest have different parameters. However, the observed elasticities of transformation at the same level in the nest are not the same for all investing regions, and not even the same among sectors for an individual investing region. The main reason for this is differences in capital shares in total wealth in each investing region.

Interesting patterns are highlighted in the following dot points, based on the observed elasticities provided in the following four boxes, which are based on data for Australia, a country typical of those with relatively large investment abroad. Note that short arrows in the box indicate experimental changes in the CET specified parameters in the upper and lower parts of each box, while long arrows represent changes to the implied transformation elasticities.

- The elasticity of transformation ( $\eta$ ) at levels 0 and 1 is not sensitive to values of  $\sigma_3$  (box F.1) since the share of bonds plus capital in total wealth is 1.
- The elasticity of transformation ( $\eta$ ) at level  $n$  is inversely related to  $\sigma$  level  $(n+1)$  (box F.2) when holding  $\sigma$  at level  $n$  constant.
- The elasticity of transformation ( $\eta$ ) at level 0 is *extremely* sensitive to specified parameters at levels 0 and 1, but in opposite directions:
  - it is positively related to  $\sigma_0$  (box F.3), but
  - it is inversely related to  $\sigma_1$  (box F.4).

**Box F.1      Insensitivity to sigma3**

AUS	Elasticities	CET Specified Parameters	
Bonds vs Capital	1.0	Level 3	1 ←
Three Sectors	1.22	Level 2	1.2
Dom vs Foreign		Level 1	1.3
Pri	2.03		
Sec	2.43		
Ter	1.36		
Group1 vs Group2		Level 0	1.4
Pri	8.0 ←		
Sec	11.9		
Ter	9.8		

The set of CET parameters above is the standard setting in the FTAP model

AUS	Elasticities	CET Specified Parameters	
Bonds vs Capital	0.5	Level 3	0.5 ←
Three Sectors	1.26	Level 2	1.2
Dom vs Foreign		Level 1	1.3
Pri	2.07		
Sec	2.47		
Ter	1.40		
Group1 vs Group2		Level 0	1.4
Pri	8.0 ←		
Sec	11.9		
Ter	9.9		

**Box F.2 Inverse relationship to sigma at higher levels**

AUS	Elasticities	CET Specified Parameters	
Bonds vs Capital	0.5	Level 3	0.5
Three Sectors	0.83	Level 2	0.8 ←
Dom vs Foreign		Level 1	1.3
Pri	4.87 ←		
Sec	6.88		
Ter	1.53		
Group1 vs Group2		Level 0	1.4
Pri	10.8		
Sec	16.3		
Ter	10.0		

AUS	Elasticities	CET Specified Parameters	
Bonds vs Capital	0.5	Level 3	0.5
Three Sectors	1.26	Level 2	1.2 ←
Dom vs Foreign		Level 1	1.3
Pri	2.07 ←		
Sec	2.47		
Ter	1.40		
Group1 vs Group2		Level 0	1.4
Pri	8.0		
Sec	11.9		
Ter	9.9		

**Box F.3 Extreme sensitivity to sigma0: positive relationship**

AUS	Elasticities	CET Specified Parameters	
Bonds vs Capital	1.0	Level 3	1
Three Sectors	1.22	Level 2	1.2
Dom vs Foreign		Level 1	1.3
Pri	2.03		
Sec	2.43		
Ter	1.36		
Group1 vs Group2		Level 0	1.4 ←
Pri	8.0	←	
Sec	11.9		
Ter	9.8		

AUS	Elasticities	CET Specified Parameters	
Bonds vs Capital	1.0	Level 3	1
Three Sectors	1.22	Level 2	1.2
Dom vs Foreign		Level 1	1.3
Pri	2.03		
Sec	2.43		
Ter	1.36		
Group1 vs Group2		Level 0	1.6 ←
Pri	19.9	←	
Sec	30.7		
Ter	26.8		

**Box F.4 Extreme sensitivity to sigma1: inverse relationship**

AUS	Elasticities	CET Specified Parameters	
Bonds vs Capital	1.0	Level 3	1
Three Sectors	1.22	Level 2	1.2
Dom vs Foreign		Level 1	1.25 ←
Pri	1.62		
Sec	1.82		
Ter	1.29		
Group1 vs Group2		Level 0	1.4
Pri	10.6	←	
Sec	16.0		
Ter	14.0		

AUS	Elasticities	CET Specified Parameters	
Bonds vs Capital	1.0	Level 3	1
Three Sectors	1.22	Level 2	1.2
Dom vs Foreign		Level 1	1.35 ←
Pri	2.43		
Sec	3.03		
Ter	1.43		
Group1 vs Group2		Level 0	1.4
Pri	5.4	←	
Sec	7.8		
Ter	5.7		

Finally, box F.5 provides some examples of very high elasticities of transformation for countries that have relatively small investments abroad, such as China, Indonesia and Mexico.

**Box F.5 High transformation elasticities for countries with small investments abroad**

CHINA

CHN	Elasticities	CET Specified Parameters	
Bonds vs Capital	1.0	Level 3	1
Three Sectors	1.33	Level 2	1.2
Dom vs Foreign		Level 1	1.3
Pri	2.11		
Sec	1.65		
Ter	1.95		
Group1 vs Group2		Level 0	1.4
Pri	248.1		
Sec	1222.4		
Ter	537.6		

INDONESIA

IDN	Elasticities	CET Specified Parameters	
Bonds vs Capital	1.0	Level 3	1
Three Sectors	1.31	Level 2	1.2
Dom vs Foreign		Level 1	1.3
Pri	2.74		
Sec	1.88		
Ter	1.56		
Group1 vs Group2		Level 0	1.4
Pri	271.1		
Sec	58.5		
Ter	46.4		

MEXICO

MEX	Elasticities	CET Specified Parameters	
Bonds vs Capital	1.0	Level 3	1
Three Sectors	1.22	Level 2	1.2
Dom vs Foreign		Level 1	1.3
Pri	1.79		
Sec	1.78		
Ter	1.41		
Group1 vs Group2		Level 0	1.4
Pri	412.5		
Sec	164.5		
Ter	205.8		

---

# G Computational issues

A number of computational issues arose in developing GTAPICM and FTAP. These concerned the condensation and the GEMPACK settings used when running simulations. Both of these issues are important because of their effect on the time taken to run simulations. This appendix details the condensation and GEMPACK settings that were found to minimise simulation time for GTAPICM and FTAP.

## G.1 Condensation

In order to solve the linearised equations in GTAPICM and FTAP, especially when using data aggregations involving many regions and commodities, the size of the model needs to be reduced. This is the purpose of the condensation. This is done via two main methods — by substituting out endogenous variables, and by omitting exogenous variables that are not shocked in a group of simulations (Harrison and Pearson 1998).

The condensations for GTAPICM and FTAP were performed using a stored input or sti file. The sti files used for condensing GTAPICM (GTAPICM.sti) and FTAP (FTAP.sti) are reproduced below. It is recommended that variable omissions are performed first, and variable substitutions subsequently (Harrison and Pearson 1998). This recommendation was followed in performing the GTAPICM and FTAP condensations.

### GTAPICM

The first group of variables in GTAPICM.sti are those that were chosen for omission from the model. Choosing which variables to omit was fairly straightforward. It involved taking the list of exogenous variables, and choosing those variables that were not shocked in the group of simulations performed. In the initial implementation of GTAPICM, the remainder of the Uruguay Round was implemented using GTAP 4 as the pre-simulation database. This involved shocking import taxes, export taxes and subsidies, and output subsidies. Thus, this group of exogenous variables could not be omitted. All other exogenous variables were possible candidates for omission.



---

It is not necessary to omit all exogenous variables that are not shocked in a group of simulations, only those that have many components. Removing the variables with the most components will considerably reduce the size of the model and, therefore, simulation time. Another reason why it is not wise to omit all exogenous variables not shocked, is that it allows for closure changes to be made quickly and easily in the GEMPACK command file. Otherwise, the condensation sti file must be altered and the condensation re-run, before a new simulation can be performed. For these reasons, the smallest variables (that is, those with the least number of components) omitted were those that ranged over TRAD\_COMM and REG.

More flexibility exists in choosing the list of variables to be substituted out of the model. When substituting endogenous variables out of a model, their post-simulation values are not reported. If the value of the variable needs to be reported, then a backsolve should be performed instead of a substitution. This allows the post-simulation value to be reported. It is recommended that only those variables whose values need to be reported are backsolved. This is because backsolving requires slightly more (computer) memory than a straight substitution, and thus it increases simulation time (Harrison and Pearson 1998).

The list of substituted variables in GTAPICM.sti was arrived at by trial and error. The procedure followed was that the endogenous variables with the most components were substituted out first, that is, those that ranged over TRAD\_COMM, PROD\_COMM and REG. Then the next biggest variables (in terms of the number of components) were substituted out and so on. Simulation time was recorded and compared between different condensations. Substituting out an endogenous variable has two effects. First, it increases the complexity of the FORTRAN code produced when a condensation is run, and this also increases simulation time. Second, it decreases the size of the model, which decreases simulation time. When the increased complexity of the FORTRAN code outweighs the benefit of reducing the size of the model, further condensation increases total simulation time. At this point the “optimum” condensation has been achieved. This is the condensation in GTAPICM.sti. It must be remembered that the optimum condensation will depend on the size of the aggregation with which the simulations are being run. In this case, a 19 region and 50 commodity aggregation was used. It will also depend on the speed and memory of the computer on which the simulations are performed. All simulations were performed on a PC with a dual 450 MHZ Pentium II processor and 512 megabytes of RAM.

---

```

!_____start of GTAPICM.sti_____
! choose condensation
o ! begin with omitting exogenous variables which are not shocked
af
tfm
tfd
atr
afe
tf
ao
ava
profitslack
tpm
tpd
tgm
tgd
tm
tx
tradslack
rari

s ! now indicate which variables are substituted (or backsolved) out
qf
INTDEMAND
s
qfm
INDIMP
b
qfd
INDDOM
s
pf
ICOMPRICE
s
pfm
DMNDIPRICES
s
pfd
DMNDDPRICE
s
CNTqfmijr

```

---

CONT\_WEV\_qfmi jr  
s  
CNTqfdi jr  
CONT\_WEV\_qfdi jr  
s  
qxs  
IMPORTDEMAND  
s  
pms  
MKTPRICES  
b  
pfob  
EXPRICES  
b  
pcif  
FOBCIF  
s  
CNTqxsirs  
CONT\_WEV\_qxsirs  
s  
CNTqimirs  
CONT\_WEV\_qimirs  
s  
qoes  
MKTCLENDWS  
b  
qfe  
ENDWDEMAND  
s  
pms  
SPFACTPRICE  
s  
CNTqfeijr  
CONT\_WEV\_qfeijr  
b  
qfel  
E\_qfel  
s  
ps  
SUPPLYPRICES  
s  
CNTqoir

---

CONT\_WEV\_qoir  
s  
qva  
VADEMAND  
s  
pva  
VAPRICE  
s  
compvalad  
compvaladeq  
s  
CNTqfejr  
CONT\_WEV\_qfejr  
s  
CNTqfmjr  
CONT\_WEV\_qfmjr  
s  
CNTqfdjr  
CONT\_WEV\_qfdjr  
b  
qfek  
E\_qfek  
b  
qfen  
E\_qfen  
b  
qfenr  
E\_qfenr  
s  
qst  
MKTCLTRD  
s  
qds  
MKTCLDOM  
s  
qp  
PRIVDMNDS  
s  
qg  
GOVDMNDS  
s  
qpm

---

PHHLDAGRIMP  
s  
qpd  
PHHLDDOM  
s  
qgm  
GHHLDAGRIMP  
s  
qgd  
GHHLDDOM  
s  
qim  
MKTCLIMP  
b  
qiw  
QREGIM\_is  
b  
qxw  
QREGEX\_ir  
s  
pp  
PCOMPRICE  
s  
ppm  
PHHIPRICES  
s  
ppd  
PHHDPRICE  
s  
pg  
GCOMPRICE  
s  
pgm  
GHHIPRICES  
s  
pgd  
GHHDPRICE  
s  
rp  
RENTL\_PRICE\_CAPL  
s  
pim

---

DPRICEIMP  
b  
piw  
PREGIM\_is  
s  
pxw  
PREGEX\_ir  
s  
pr  
PRICETGT  
s  
viwCIF  
VREGIM\_is  
s  
vxwFOB  
VREGEX\_ir  
s  
DTBALi  
TRADEBAL\_i  
s  
CNTqfmir  
CONT\_WEV\_qfmir  
s  
CNTqfdir  
CONT\_WEV\_qfdir  
s  
CNTqpmir  
CONT\_WEV\_qpmir  
s  
CNTqmdir  
CONT\_WEV\_qmdir  
s  
CNTqgmir  
CONT\_WEV\_qgmir  
s  
CNTqgdir  
CONT\_WEV\_qgdir  
s  
CNTqxsir  
CONT\_WEV\_qxsir  
s  
CNTqimir

---

CONT\_WEV\_qimir  
b  
CNTalleffir  
CONT\_EV\_alleffir  
s  
CNT\_MUir  
CONT\_EV\_MUir  
b  
px\_ir  
EXPPRICE1  
b  
pm\_ir  
IMPPRICE1  
b  
c1\_ir  
C1\_irEQ  
b  
c2\_ir  
C2\_irEQ  
b  
c3\_ir  
C3\_irEQ  
s  
rkri  
ABNL\_RETN\_CAPL  
s  
invd  
E\_invd  
s  
invi  
E\_invi  
s  
kk  
E\_kk  
s  
CNTqxsrs  
CONT\_WEV\_qxsrs  
s  
CNTqimsr  
CONT\_WEV\_qimsr  
s  
pfactreal

---

REALRETURN  
s  
CNTqfeir  
CONT\_WEV\_qfeir  
s  
CNTendwir  
CONT\_EV\_endwir  
b  
qxwcom  
QWLDEX\_i  
b  
qiwcom  
QWLDIM\_i  
b  
qow  
QWLDOUT  
s  
qowu  
QWLDOUTU  
b  
pxwcom  
PWLDEX\_i  
b  
piwcom  
PWLDIM\_i  
s  
pw  
PWLDOUT  
s  
pwu  
PWLDUSE  
s  
vxwcom  
VWLDEX\_i  
s  
viwcom  
VWLDIM\_i  
s  
valuew  
VWLDOUT  
s  
valuewu



---

VWLDOUTUSE  
b  
px\_i  
WRLDPRICEi  
s  
ksvces  
KAPSVCES  
b  
qcgds  
CAPGOODS  
s  
qsave  
E\_saveslack  
b  
qxwreg  
QREGEX\_r  
b  
qiwreg  
QREGIM\_s  
s  
kb  
KBEGINNING  
b  
ke  
KEND  
b  
qgdp  
QGDP\_r  
s  
pbr  
E\_pbr  
s  
prentb  
E\_prentb  
b  
pgov  
GPRICEINDEX  
b  
ppriv  
PHHLDINDEX  
b  
pxwreg

---

PREGEX\_r  
b  
piwreg  
PREGIM\_s  
b  
pfactor  
PRIMFACTPR  
s  
rental  
KAPRENTAL  
b  
rorc  
RORCURRENT  
b  
rore  
ROREXPECTED  
s  
psave  
SAVEPRICE  
s  
psw  
REGSUPPRICE  
b  
pdw  
REGDEMPRICE  
b  
tot  
TOTeq  
b  
pgdp  
PGDP\_r  
s  
vxwreg  
VREGEX\_r  
b  
viwreg  
VREGIM\_s  
b  
vgdp  
VGDP\_r  
b  
y\_r

---

NATL\_INCOME

b

ug

GOVERTU

b

u

UTILITY

b

EV

EVREG

b

DTBAL

TRADEBALANCE

b

EV\_ALT

EV\_DECOMPOSITION

b

CNTbondr

CONT\_EV\_bondr

s

CNTqor

CONT\_WEV\_qor

s

CNTqfer

CONT\_WEV\_qfer

s

CNTqfmr

CONT\_WEV\_qfmr

s

CNTqfdr

CONT\_WEV\_qfdr

s

CNTqpnr

CONT\_WEV\_qpnr

s

CNTqpdr

CONT\_WEV\_qpdr

s

CNTqgmr

CONT\_WEV\_qgmr

s

CNTqgdr

---

CONT\_WEV\_qgdr  
s  
CNTqxsr  
CONT\_WEV\_qxsr  
b  
CNTqimr  
CONT\_WEV\_qimr  
b  
CNTalleffr  
CONT\_EV\_alleffr  
b  
CNTtotr  
CONT\_EV\_totr  
b  
CNTcgdsr  
CONT\_EV\_cgdsr  
s  
CNTpricer  
CONT\_EV\_pricer  
b  
CNTendwr  
CONT\_EV\_endwr  
b  
CNTkbr  
CONT\_EV\_kbr  
b  
CNT\_MUr  
CONT\_EV\_MUr  
b  
c1\_r  
c1\_rEQ  
b  
c2\_r  
c2\_rEQ  
b  
c3\_r  
c3\_rEQ  
b  
tot2  
TOT2eq  
b  
rbr

---

INTERNL\_INTT\_PARY

b

pnr

PRICE\_LAND

b

ughr

TRANSFRS\_GOVH\_HOLD

b

qyhbr

HHOLD\_OWNP\_BONDS\_REG

b

yhdr

HHOLD\_DISPBLE\_INCOME

b

rgr

GOVT\_RECTS

s

ahr

HHOLD\_WEALTH\_ACCN

s

aer

EQY

s

akr

VALUE\_CAPL

s

anr

VALUE\_LAND

s

anrr

E\_anrr

s

pnrr

E\_pnrr

s

iper

EQY\_PRICE\_INDX

b

ipahr

HHOLD\_ASST\_PRINDX

b

depr

---

DEP\_CAPITAL  
b  
ecr  
NATL\_CONSN\_EXPRES  
b  
zg  
VALGOVDEMCOM  
b  
ipcr  
NATL\_CONSN\_PRINDX  
b  
yhr  
HHOLD\_INCOME  
b  
rtyr  
INCOME\_TAX  
s  
qrgir  
GOVT\_INTT\_RECTS  
s  
tylr  
TAX\_LABR\_INCOME  
s  
typr  
TAX\_PROPY\_INCOME  
b  
ogr  
GOVT\_CURRNT\_OUTLS  
b  
ercrer  
EXPD\_RATE\_RETN\_EQY  
b  
rar  
AVGE\_ABNL\_RETN\_CAPL  
b  
ercrkr  
EQN\_RATE\_RETN\_CAPL  
b  
yr\_r  
REAL\_NATL\_INCOME  
b  
rkr

---

EQY\_BOND\_PARY  
s  
yhvr  
HHOLD\_PRIVTE\_INCME  
s  
grsub  
REVINDT  
s  
grint  
REVINT  
s  
grinv  
REVINV  
s  
grcon  
REVCON  
s  
grexp  
REVEXP  
s  
grgov  
REVGGOV  
s  
grdut  
REVIMP  
b  
fke  
FIXD\_CAPL\_EARNINGS  
b  
rm  
E\_rm  
s  
nrp  
E\_nrp  
s  
mt  
E\_mt  
s  
nru  
E\_nru  
b  
w

---

E\_w  
s  
lt\_  
E\_lt\_  
b  
gne  
GROSS\_NATL\_EXPRES  
b  
invt  
AGGINV  
s  
gnepi  
PRICE\_INDX\_GNE  
s  
gner  
REAL\_GNE  
b  
ctr  
REALCONS  
s  
rcl  
E\_rcl  
b  
check\_rc  
E\_check\_rc  
s  
grsubl  
E\_grsubl  
s  
grintl  
E\_grintl  
s  
grinvl  
E\_grinvl  
s  
grconl  
E\_grconl  
s  
grexpl  
E\_grexpl  
s  
grgovl



---

E\_grgov1  
s  
grdut1  
E\_grdut1  
s  
grend1  
E\_grend1  
b  
check\_grdut  
E\_check\_grdut  
b  
check\_grexp  
E\_check\_grexp  
b  
check\_grsub  
E\_check\_grsub  
b  
check\_grcon  
E\_check\_grcon  
b  
check\_grgov  
E\_check\_grgov  
b  
check\_grint  
E\_check\_grint  
b  
check\_grinv  
E\_check\_grinv  
b  
bop  
E\_bop  
b  
wr  
E\_wr  
b  
qvar  
E\_qvar  
b  
gdpfc  
GDPFACTCOST  
b  
ydr

---

REALDISPY

! \_\_\_\_\_end of file\_\_\_\_\_

## FTAP

In developing FTAP from GTAPICM, considerable extra theory, and variables, were added. This included many variables that range over as many as 5 sets. Thus their maximum size in the model is enormous, even when using a relatively small aggregation. Consequently, in choosing a condensation for FTAP, it was necessary to start from a completely uncondensed model, and follow the procedure described above in arriving at the optimum condensation.

! \_\_\_\_\_start of FTAP.sti\_\_\_\_\_

! choose condensation

o ! begin with omitting exogenous variables which are not shocked

txhd

tmhs

athsd

tfm

tfd

atsd

qihd

pihd

tf

f\_afe

ava

profitslack

tpm

tpd

tgm

tgd

tm

tx

rari

tfia ! Don't omit if doing partial tertiary liberalisation

toas ! Don't omit if doing partial tertiary liberalisation

s ! now indicate which variables are substituted (or backsolved) out

grsub

REVINDT

---

s  
grint  
REVINT  
s  
grinv  
REVINV  
s  
grcon  
REVCON  
s  
gexp  
REVEXP  
s  
grgov  
REVGGOV  
s  
grdut  
REVIMP  
b  
yfdi\_hhi  
E\_yfdi\_hhi  
b  
c\_VFDI\_HHI  
E\_c\_VFDI\_HHI  
b  
CNTror\_hhi  
CONT\_EV\_ror\_hhi  
b  
CNTcap\_hhi  
CONT\_EV\_cap\_hhi  
b  
CNTpcap\_hhi  
CONT\_EV\_pcap\_hhi  
b  
check\_qisd  
E\_check\_qisd  
b  
check\_pisd  
E\_check\_pisd  
b  
see\_foct  
E\_see\_foct

---

b  
check\_vdfa  
E\_check\_vdfa  
b  
check\_vdfm  
E\_check\_vdfm  
b  
check\_vifa  
E\_check\_vifa  
b  
check\_vifm  
E\_check\_vifm  
b  
check\_evfa  
E\_check\_evfa  
b  
check\_vfa  
E\_check\_vfa  
b  
falleffi\_ci  
E\_falleffi\_ci  
b  
falleff\_ei  
E\_falleff\_ei  
b  
yank\_hhi  
E\_yank\_hhi  
b  
yanp\_hhi  
E\_yanp\_hhi  
b  
CNTanrr\_hhi  
E\_CNTanrr\_hhi  
b  
CNTanend\_hhi  
E\_CNTanend\_hhi  
b  
CNTanpk\_hhi  
E\_CNTanpk\_hhi  
b  
CNTqfes\_hhi  
E\_CNTqfes\_hhi

---

b  
psh  
E\_psh  
b  
frt  
E\_frt  
b  
check\_frt  
E\_check\_frt  
s  
qid  
E\_qid  
b  
anrr\_hhi  
E\_anrr\_hhi  
b  
anto\_hhi  
E\_anto\_hhi  
b  
altot\_f  
E\_altot\_f  
b  
c\_SHXTAXD  
E\_c\_SHXTAXD  
b  
anrro\_hhi  
E\_anrro\_hhi  
b  
CNTanto\_hhi  
E\_CNTanto\_hhi  
b  
CNTanqo\_hhi  
E\_CNTanqo\_hhi  
b  
CNTanpo\_hhi  
E\_CNTanpo\_hhi  
b  
qx\_fdi\_wd  
E\_qx\_fdi\_wd  
b  
qx\_fdi\_md  
E\_qx\_fdi\_md

---

b  
qm\_fdi\_ws  
E\_qm\_fdi\_ws  
b  
qm\_fdi\_ms  
E\_qm\_fdi\_ms  
b  
qvxhm  
E\_qvxhm  
b  
tof  
E\_tof  
b  
anrrk\_hhi  
E\_anrrk\_hhi  
b  
pxhd  
E\_pxhd  
b  
pihldw  
E\_pihldw  
b  
pihld  
E\_pihld  
b  
qxhd  
E\_qxhd  
b  
k\_hhi  
E\_k\_hhi  
b  
c\_rr\_hhi  
E\_c\_rr\_hhi  
b  
r\_rr\_hhi  
E\_r\_rr\_hhi  
b  
pfesa  
E\_pfesa  
b  
psks  
E\_psk

---

b  
pild  
E\_pild  
b  
pildw  
E\_pildw  
b  
pxdd  
E\_pxdd  
b  
pxh  
E\_pxh  
b  
qf  
INTDEMAND  
b  
qfm  
INDIMP  
b  
qfd  
INDDOM  
b  
pf  
ICOMPRICE  
b  
pfm  
DMNDIPRICES  
b  
pfd  
DMNDDPRICE  
b  
CNTqfmijr  
CONT\_WEV\_qfmijr  
b  
CNTqfdijr  
CONT\_WEV\_qfdijr  
b  
CNTtech\_afijr  
CONT\_EV\_tech\_afijr  
b  
falleffd\_ci  
E\_falleffd\_ci

---

```
b
qxs
E_qxs
b
pxs
E_pxs
b
CNTqxsirs
CONT_WEV_qxsirs
b
CNTqimirs
CONT_WEV_qimirs
!_____end of file_____
```

## G.2 GEMPACK settings

In conducting simulations with GTAPICM and FTAP, a small number of advanced GEMPACK settings are available that minimise simulation time. These are discussed below.

### Memory allocation

All GTAPICM and FTAP simulations were carried out using the GEMPACK Release 6.0 software suite (Harrison and Pearson 1998). This version of GEMPACK dynamically allocates the necessary memory required to run a simulation. This procedure sees GEMPACK starting with small allocations and successively increasing them till an adequate amount of memory has been allocated. When using models requiring large amounts of memory, this process may take a considerable amount of time. Thus, instructing GEMPACK how much memory it will require when beginning a simulation can reduce simulation time. In this way, the first allocation of memory is sufficient. This is done via a statement in the command file such as “MMNZ = 20000000”. GTAPICM simulations using a 19 region and 50 commodity aggregation, require a statement such as this one to ensure that enough memory is allocated from the beginning of a simulation.

FTAP is a much larger model in terms of equations and variables than GTAPICM. However, the FTAP simulations were run with a much smaller aggregation, that is, 19 regions and 3 commodities. Overall, a much smaller amount of memory was required to run FTAP. Despite this, employing command file statements telling GEMPACK how much memory to allocate to the simulation also reduced the



---

simulation time. The value of MMNZ used in the FTAP simulations was six million.

### **Zero coefficients**

All GTAPICM and FTAP multi-step simulations were solved using Gragg's method (Harrison and Pearson 1998). Hertel (1997) recommends choosing the GEMPACK option of 'keeping zero coefficients' in the first step of a multi-step GTAP simulation. This allows the 'reuse of pivots' which decreases simulation time with most models, including GTAP. This option is chosen using a statement of the form "IZ1 = no" in the command file. Keeping zero coefficients in the first step of a multi-step simulation also speeded up multi-step simulations with GTAPICM. Therefore, this option was also chosen for all GTAPICM simulations.

Choosing to keep zero coefficients on the first step of a multi-step simulation with FTAP, however, required more memory than was available on the computer used for these simulations. This meant that pivots could not be reused. In order to prevent GEMPACK wasting time by trying to reuse pivots at each step, the GEMPACK option of 'no reuse of pivots' was chosen. This is done using a statement of the form "NRP = yes" in the command file.

## **G.3 Simulation times**

The following table reports simulation times for GTAPICM and FTAP, and the condensation and GEMPACK settings used.

**Table G.1 Indicative simulation times with GTAPICM and FTAP**

<i>Model and simulation</i>	<i>Condensation</i>	<i>Aggregation</i>	<i>GEMPACK settings</i>	<i>Solution procedure</i>	<i>Simulation time (approximate)</i>
	file	regions by commodities			
GTAPICM - Remainder of Uruguay Round	GTAPICM.sti	19 by 50	MMNZ = 20000000	Johansen's method (1-step)	16 minutes
GTAPICM - Remainder of Uruguay Round	GTAPICM.sti	19 by 50	IZ1= no, MMNZ = 20000000	Gragg's method (13 subintervals)	21 hours
FTAP - Complete services liberalisation	FTAP.sti	19 by 3	MMNZ = 6000000	Johansen's method (1-step)	1 minute and 20 seconds
FTAP - Complete services liberalisation	FTAP.sti	19 by 3	NRP = yes, MMNZ = 6000000	Gragg's method (12 subintervals)	2 hours and 40 minutes

<sup>a</sup> All Gragg simulations were performed using user-specified accuracy. The accuracy specified was that 99 per cent of the updated (post-simulation) data was accurate to 4 *figures* (not decimal places). When using user-specified accuracy, the number of subintervals performed is determined by GEMPACK.

---

# H Closing GTAPICM and FTAP

When constructing a model in linearised form, such as FTAP, there are necessarily more variables than equations. In order for such a system of equations to have a unique solution, a number of these variables must be set exogenously. More precisely, the number of exogenous variables must be such that the remaining number of (endogenous) variables, exactly equals the number of equations in the model. This is referred to as ‘closing the model’. This appendix addresses the issue of closing GTAPICM and FTAP.

## H.1 GTAPICM

As the number of exogenous variables is usually much less than the endogenous variables, closures are usually specified in terms of the exogenous variables. The standard closure for GTAP version 4.1 holds fixed the world price index of primary factors (`pfactwld`) which is the numeraire, population in each region (`pop(r)`), and all slack variables (`psaveslack(r)`, `incomeslack(r)`, `endwslack(i,r)`, `cgdslack(r)`, `saveslack(r)`, `govslack(r)`, `trdslack(i,r)` and `profitslack(j,r)`), some of which are omitted when the model is condensed (see appendix G). All technical change variables are set exogenous (`ao(j,r)`, `af(i,j,r)`, `afe(i,j,r)`, `ava(i,r)` and `atr(i,r,s)`), as are all tax variables (`tx(i,r)`, `tm(i,s)`, `tf(i,j,r)`, `tpm(i,r)`, `tpd(i,r)`, `tgm(i,r)`, `tgd(i,r)`, `tfm(i,j,r)`, `tfd(i,j,r)`, `to(i,r)`, `txs(i,r,s)` and `tms(i,r,s)`). Finally, all endowment commodities are held fixed in each region (`qo(ENDW_COMM,REG)`). All other variables are endogenous.

The purpose of developing GTAPICM was to model international capital mobility within GTAP. Thus, the essential difference between GTAP and GTAPICM is how regional capital stocks are determined. In GTAP, regional capital stocks are exogenously fixed. In GTAPICM, they are determined endogenously within the model. GTAPICM also has its own (dynamic) investment theory, which requires that the GTAP investment theory be ‘turned off’. These are the two essential differences which guided the development of the GTAPICM closure.

In GTAPICM, regional private wealth is determined by equation `HHOLD_WEALTH_ACCN`. How much of this is regional capital stocks, `qo(ENDWC_COMM, REG)`, depends on the closure used. With perfect capital

---

mobility, the equity-bond parity condition (equation EQY\_BOND\_PARY, section 3.2) determines the regional capital stock. In the preferred closure to be described in this appendix, the fixed bond to income ratio determines the regional capital stock. Either way,  $qo(\text{ENDWC\_COMM}, \text{REG})$  is endogenous.

Chapter 3 explains how the GTAP investment theory is turned off through a closure change and parameter choice. The closure change involves making all but one component of the regional investment slack variable,  $cgdslack(r)$ , endogenous, while all components of the expected change in the equity premium slack variable,  $ercfrer(r)$ , are made exogenous. The expected rate of change in the world bond rate,  $ercrb$ , is made endogenous.

The GTAP regional savings shifter,  $saveslack(r)$ , is made endogenous and a new regional savings slack variable,  $saveslack1(r)$ , is made exogenous. Thus the Cobb-Douglas relationship between national income and its components — private and government consumption and savings — is maintained (see chapter 3).

In order to ensure budget neutrality in government accounts, the government saving ratio in each region,  $qrgsr(r)$ , is made exogenous. All income tax rates,  $typr(r)$  and  $tylr(r)$ , are made endogenous by endogenising the general income tax shifter,  $ftypr(r)$ , to which they are linked by equations `RATE_TAX_PRPY_INCOME` and `RATE_TAX_LABR_INCOME`, respectively. The specific income tax shift terms,  $ftypr(r)$  and  $ftylyr(r)$ , are set exogenous. The shift term for government transfer payments,  $fughr(r)$ , is also made exogenous. Further, the GTAP income tax variables,  $to(\text{ENDW\_COMM}, \text{REG})$ , must be linked to the GTAPICM income tax variables, and are therefore made endogenous.

In the pre-simulation database the world net ownership of bonds,  $qyb$ , is zero. To maintain this condition during any simulation,  $qyb$  is made exogenous.

In the original SALTER implementation of ICM there was a variable for the rate of return on equity in each region,  $rer(r)$ . This variable is not used in GTAPICM, though it is still declared in the TABLO code. Therefore, it is made exogenous, as is  $d\_ughr(r)$  and the shift term for the equity premium in each region,  $frer(r)$ .

The net bond to income ratio in each region,  $qybr(r)$ , can be determined endogenously. This allows capital (and debt though regional bond holdings) to move between regions, to completely eliminate differences between returns on capital and returns on bonds in each region. With no restrictions on the accumulation or decumulation of debt, regions can source overseas saving to finance growth in their capital stock. Under this closure capital is perfectly mobile internationally. For the initial implementation of GTAPICM, it was felt that it would be more appropriate to limit the movement of capital, in a way that forces

regions to source only their own saving to finance growth in their capital stock. This can be done by making all except one component of  $qybr(r)$  exogenous (with the last component being endogenously fixed at zero because net world bond holding is zero), and making all but one component of  $frer(r)$  endogenous. All other variables are endogenous.

When using GEMPACK for model simulations, closures are specified in 'command' or cmf files. The GTAPICM closure is specified in the file GTAPICM.cmf, which is reproduced below.

```

!_____start of GTAPICM.cmf_____
! This GEMPACK command file specifies the shocks required to generate
! a Uruguay Round database using GTAP4 as the initial database. The
! closure forces all capital stock growth to be funded from domestic
! saving only.
!
!_____
!
Auxiliary files = GTAPICM;
File GTAPSETS = 19x50set.har;
File GTAPPARM = 19x50par.dat;
File GTAPDATA = 19X50ICM.har;
!
Identifier = GTAPICM.tab condensed using GTAPICM.sti;
!
!Closure
!
Exogenous    pfactwld pop psaveslack incomeslack endwslack govslack
               privslack to txs tms qo(ENDW_COMM,REG)

!The following GTAP variables have been omitted to reduce the
!size of the model:
               !profitslack tradslack ao af afe ava atr tx tm tf tpm
               !tpd tgm tgd tfm tfd
!
!Turn off GTAP investment theory and link national income and its
!components
               cgdslack 14 ercfrer saveslack1
!
!Fix the government saving ratio
               qrgsr ftypr ftylr fughr
!

```

---

```

!Fix world net ownership of bonds and remaining exogenous variables
      qyb rer d_ughr frer;

!

!The following GTAPICM variable has been omitted to reduce the
!size of the model:
      !rari

!

!Endogenise regional capital stocks and GTAP income tax variables
Endogenous  qo(ENDWC_COMM,REG) to(ENDW_COMM,REG);

!

Rest endogenous;

!

!Swap required to force capital accumulation to be funded from
!domestic savings
Endogenous  frer 1-18;
Exogenous  qybr 1-18;

!

!Shock

!

Shock tms = file tms.txt;
Shock txs = file 41a_txs.txt;
Shock to(TRAD_COMM,REG) = file 41a_to.txt;

!

! Solution method

!

Automatic accuracy = yes;
Accuracy percent = 99;
Subintervals = 13; !Minimum number of subintervals required to
!achieve specified accuracy

!

Verbal Description =
      ++++++
+                               Model: GTAPICM                               +
+                               Solution Method: Automatic accuracy         +
+ Simulation: Generating UR database sourcing dom savings only           +
      ++++++;

!

! Output File Specification (they are experiment dependent)

!

Solution File = <cmf>;

!

! Updated (i.e. post-simulation) data files

```

---

```

!
Updated file GTAPDATA = GTAPICM.upd;
!
! Options
!
CPU = yes ; !Report simulation time
NDS = yes ; !Do no displays
Start with MMNZ = 20000000;
Check-on-read all = no ; !Don't check coefficient information
IZ1 = no; !Keep zero coefficients on first step
Log file = yes; !Generate log file
!
!_____end of file_____

```

## H.2 FTAP

The closure used for FTAP appears in the file FTAP.cmf, which is reproduced below. The FTAP closure is developed from the GTAPICM closure. First, the restriction on sourcing overseas saving is turned off. This restriction is no longer required, as imperfect substitution of capital and bonds between regions is now part of the underlying theory that has been added to FTAP.

A variety of new variables is introduced, and the closure status of some of the existing variables is changed.

The GTAP equation MKTCLTRD is turned off by endogenising the slack variable for this equation, tradslack(i,r). In FTAP, the variable qo is merely defined by the new equation E\_qo (section 5.3).

For various reasons (other than for modelling firm-level product differentiation — see below), some GTAP technical efficiency variables must be made endogenous. These include af(i,j,r), afe(i,j,r) (section 7.1) and atr(i,r,s) (section 6.5).

Nine new endogenous FTAP price and quantity variables, f\_qva(j,r), f\_pf(i,j,r), f\_qf(i,j,r), f\_qfd(i,j,s), f\_qfm(i,j,s), f\_qfel(i,j,r), f\_qfek(i,j,r), f\_qfen(i,j,r) and f\_qfenr(i,j,r), are then introduced to the model along with the relevant equations.

The GTAPICM variable rer(r) is activated (it was previously exogenous because it was declared but served no function) by making it endogenous and adding an equation determining it.

---

New FDI output impediment shock variables,  $remotaxd(i,r)$  and  $remotaxf(i,s,d)$ , and new technical change variables,  $a1prim(i)$  and  $a1tot(i)$ , are also introduced. More shock variables for output and capital taxes,  $toad(r)$   $toai(r)$   $tfda(i,r)$  and  $tfsa(i,s,d)$  are introduced. All these variables are exogenous.

Four new slack variables,  $f\_pfek(CGDS\_COMM,REG)$ ,  $f\_tof(i,s,d)$ ,  $f\_p1tot(i)$  and  $f\_afe(i,j,r)$ , are introduced and set exogenous. The remaining components of  $f\_pfek$  are endogenous as they cancel out the GTAP equation determining  $pfe(ENDWC\_COMM,TRAD\_COMM,REG)$ .

Finally, two new foreign capital tax variables,  $tfia(i,r)$  and  $toas(s,d)$ , are introduced. These variables are effectively made exogenous by omitting them when the model is condensed (see appendix G).

Subsequent to introducing these new variables, a number of closure swaps are performed in order to turn on certain features of the new theory.

First, imperfect arbitrage between regional rates of return on capital and bonds is introduced by turning off the capital-bond parity condition, equation  $EQY\_BOND\_PARY$ , and turning on equation  $E\_kb$ . This is done by making  $frer(r)$  endogenous and  $f\_kb(r)$  exogenous.

The GTAP tax variables  $to(i,r)$ ,  $txs(i,r,s)$  and  $tms(i,r,s)$  are made endogenous, and are replaced with the new exogenous tax variables  $to\_shk(i,r)$ ,  $txsd(i,s,d)$  and  $tmsd(i,s,d)$ , respectively.

Lastly, endogenous technical change for the output of local industries is turned on by making  $ao(TRAD\_COMM,REG)$  endogenous, and  $f\_ao(i,r)$  exogenous. Endogenous technical change for the output of FDI industries is turned on by making  $a1tot(i)$  endogenous, and  $f\_a1tot(i)$  exogenous.

All remaining variables are made endogenous.

```
! _____start of FTAP.cmf_____
! This GEMPACK command file specifies the shocks required for
! complete liberalisation of services, using a post-UR, post-ALTERTAX
! database.
!
! Using Petri parameters of 1, 1.2, 1.3, 1.4, Armingtons of 5, 10 &
! ETECH=0.0714
! _____
!
```

**Auxiliary files** = FTAP;  
**File** GTAPSETS = sets.har;



---

```

File GTAPPARM = para.dat;
File GTAPDATA = fdata.har;
File fdi_file = fdi.har;
FILE KDATA = kdata.har;
FILE fdi_ind_dat = fdi_ind.har;
!
Identifier = FTAP.tab condensed using FTAP.sti;
!
!Closure
!
!Begin with GTAPICM closure
Exogenous    pfactwld pop psaveslack incomeslack endwslack govslack
                privslack to(PROD_COMM,REG) txs tms qo(ENDW_COMM, REG)
                cgdslack 14 ercfrer saveslack1 qrgsr ftypr ftylr fughr qyb
                rer d_ughr frer qybr 1-18;
!
Endogenous    qo(ENDWC_COMM,REG) frer 1-18;
!
!The following GTAPICM variables have been omitted to reduce the size
!of the model:
                !profitslack ava tx tm tf tpm tpd tgm tgd tfm tfd rari
!
!The following GTAPICM variables were previously omitted & are now
!exogenous
Exogenous    tradslack ao af afe atr;
!
!End of GTAPICM closure
!
!FTAP closure changes
!
!Restriction on sourcing overseas saving no longer required
Endogenous    qybr 1-18;
Exogenous    frer 1-18;
!
!Turn off GTAP equation MKTCLTRD
Endogenous    tradslack
!
!Endogenise input, endowments & intl. freight tech change
                af afe atr
!

```

---

```

!Endogenise all new FDI variables
    f_qva(FDI_COMM,FDI_DEST)
    f_pf( TRAD_COMM,FDI_COMM,FDI_DEST)
    f_qf( TRAD_COMM,FDI_COMM,FDI_DEST)
    f_qfd( TRAD_COMM,FDI_COMM,FDI_DEST)
    f_qfm( TRAD_COMM,FDI_COMM,FDI_DEST)
    f_qfel( LABOR,FDI_COMM,FDI_DEST)
    f_qfek( ENDWC_COMM,FDI_COMM,FDI_DEST)
    f_qfen( LAND,FDI_COMM,FDI_DEST)
    f_qfenr( NATRES,FDI_COMM,FDI_DEST)

!
!Endogenise rer as now measures average regional rate of return
! on productive assets
    rer;

!
!Introduce new FDI output impediment shock variables
Exogenous    remotaxd remotaxf

!
!Introduce new tech change variables
    alprim altot

!
!Introduce new capital tax and output tax shock variables
    toad toai to_shk tfda tfsa

!
!Introduce new slack variables
    f_pfek(CGDS_COMM,REG) f_tof f_pltot;

!
!FTAP variables omitted to reduce size of the model,
! but tfia and toas needed for some partial tertiary liberalisations:
    !f_afe tfia toas

!
!Introduce imperfect arbitrage between regional rates of return
Endogenous    frer;
Exogenous    f_kb;

!
!to, txs & tms replaced with new tax variables
Endogenous    to(FDI_COMM,FDI_DEST) txs tms;
Exogenous    toa txsd tmsd;

!
!Turn on endogenous tech change for output of local industries
Endogenous    ao( TRAD_COMM,REG);
Exogenous    f_ao;

```

---

```

!
!Turn on endogenous tech change for output of FDI industries
Endogenous   altot;
Exogenous   f_altot;
!
Rest endogenous;
!
!Shock
Shock txsd = file txsd_Ter.txt;
Shock tfda = file tfda_Ter.txt;
Shock tfsa = file tfsa_Ter.txt;
XSET Ter (Ter);!Create single services commodity set
XSUBSET Ter IS SUBSET OF TRAD_COMM;
Shock remotaxf(Ter,HOME,DEST) = uniform 100;
Shock remotaxd(Ter,REG) = uniform 100;
!
!Solution method
Automatic accuracy = yes;
Accuracy percent = 99;
Subintervals = 12;!Minimum number of subintervals required to
!achieve specified accuracy
!
Verbal Description =
      ++++++
+                               Model: FTAP                               +
+           Solution Method: Automatic accuracy           +
+           Simulation: complete tertiary liberalisation           +
      ++++++;
!
!Output File Specification (they are experiment dependent)
!
Solution File = <cmf>;
!
!Updated (i.e. post-simulation) data files
!
Updated file GTAPDATA = fdata.upd;
Updated file fdi_file = fdi.upd;
Updated file KDATA = kdata.upd;
!
!Options
!
CPU = yes;!Report simulation time

```

---

NDS = **yes**; ! Do no displays.

Start with MMNZ = 6000000;

**Check-on-read all** = **no**; !Don't check coefficient information

NRP = **yes**; !Don't reuse pivots

**Log file** = **yes**; !Generate log file

!

!\_\_\_\_\_end of file\_\_\_\_\_

---

# I The FTAP TABLO code

```
!-----!  
!  
!           FDI & Trade Analysis Project           !  
!  
!           The FTAP Modeling Framework           !  
!  
!           FTAP Version 1 - Merging fdi_8 and gtpicm11 !  
!  
!           Notes on adjustments required in notes7 !  
!  
!-----!  
!  
!-----!  
!  
!           For documentation see:           !  
!  
!           Hertel, T.W. and M.E. Tsigas "Structure of the Standard GTAP  
!  
!           Model", Chapter 2 in T.W. Hertel (editor) Global Trade Analysis:  
!  
!           Modeling and Applications, Cambridge University Press, 1997.           !  
!  
!-----!  
!  
!-----!  
!  
!           HISTORY of this file           !  
!  
!-----!  
!  
! Version 1    July 1993    (Used in GTAP Short Course, July 1993)  
  
Version 2.1    July 1994    (GTAP94 version 1: used in GTAP Short  
  
Course, July-August 1994. This places the  
  
sourcing of imports at the border,  
  
resulting in considerable computational
```

---

savings. However, composite imports are  
still tracked to individual agents in the  
economy.) !

! Version 2.2 April 1995 (GTAP94 version 2: used in GTAP short  
course, July-August 1995. This adds DTBAL  
equation, corrects some errors in summary  
equations and adds some new reporting  
equations. But, the theory of the model  
is identical to that in GTAP Version 2.1.)

Version 2.2a August 1995 (GTAP94 version 2a: This corrects the EV  
equation to eliminate prior approximation  
errors. It also straightens out the sign on  
endwslack for the sluggish endowments so  
that it matches its partner in the mobile  
market clearing condition.)!

! Version 3.0 November 1997 (GTAP version 3.0: Addition of  
decomposition tools (add-on at bottom). For documentation,  
see GTAP technical paper no. 5 by Karen Huff and Thomas  
Hertel (welfare decomposition: term for  $ao(cgds,r)$  has now  
been added), and SALTER working paper No.12 by Robert  
McDougall (terms of trade decomposition). Also augmented  
primary factor sets to accommodate the version 4 data  
base.) Finally dummy vars have been removed from the  
behavioral equns. !

---

! Version 4.0 July 1998 Includes features for version 6.0 of GEMPACK:

- Region-specific  $psave(r)$  is introduced. It is equal to the price of investment goods in region  $r$ , plus a region-generic adjustment factor which accounts for the fact that regions also invest abroad.
- GE 0 restrictions on all data flows
- Volume initialization on flows at market prices
- Market price and price index initialization at 1.0
- Set definitions are simplified using unions and complements
- Value of world output at user prices introduced
- Real rate of return to factors introduced to facilitate fixed real wage closure
- Regional primary factor price indices introduced
- Global primary factor price index,  $pfactwld$ , is new numeraire. Therefore  $pfactor(r)$  now shows directly which regions experienced real appreciation/depreciation in the wake of the simulation.

Version 4.1 September 1998: Includes:

- switch for changing sluggish endowments via parameter file
- intermediate input substitution

Version 4.1a October 1998: Includes: SALTER international capital

mobility (ICM) extension added by George Verikios, Productivity Commission, Canberra. Original international allocation of investment structure commented out ie,

---

equations RORGLOBAL and GLOBALINV. The ICM extension is  
located at the end of the original file. !

! FTAP (FDI and Trade Analysis Project) Version 1

October 1999 - Kevin Hanslow.

In addition to the capital mobility that Version 4.1a added to  
GTAP, FTAP now has a major development to incorporate bilateral  
capital ownership, and to allow capital rentals to accrue to  
the corresponding owners (Petri's approach).

A single-country model (CRUSOE) is imbedded in FTAP, a multi-country  
model, in order to model FDI industries. An FDI industry is jointly  
defined by three elements inclusively: HOME, HOST, and TRAD\_COMM.  
The implementation of CRUSOE is to represent non-null FDI industries,  
and to eliminate equations that account for zero inputs-ouputs FDI  
industries in the database. This helps to save on memory and  
increase computational speed.

In the CRUSOE section, mapping technique is intensively applied to  
relate FDI industries to the capital ownership (HOME), the location  
of the production (HOST), and the type of GTAP commodity being  
produced (TRAD\_COMM).

Welfare decomposition is further developed for the new production



---

```

    structure to take care of the repatriation of FDI impediment rents.

!

!-----!

!                               FTAP   FILES                               !

!-----!

FILE  GTAPSETS # File with set specification #;

FILE  fdi_ind_dat #Set mappings and parameters for FDI industry extension#;

File  KDATA #CRUSOE format flows Data File and set definitions#;

FILE  GTAPDATA # The file containing all base data. # ;

FILE  fdi_file #Data for FDI extension#;

FILE (TEXT) GTAPPARM # The file containing behavioral parameters. # ;

    ! Moved from fdi module as required in initialisation of SAVE !

FILE (text) rr_flag "rr_flag.txt";

FILE (new) chk_file #File for checking database#  "check.har";

FILE (new) Trade_dat #Comparing trade flow: Petri vs Original # "trade.har" ;

!-----!

!                               SETS                               !

!-----!

! Sets define relevant groupings of entities over which we will be

```

---

performing operations in the model. SUBSETS are defined in order to facilitate summation over only a portion of a given group, e.g. tradeable commodities.

Of special note is the use of an international transport industry which absorbs services from each of the regions and supplies the margins which convert fob to cif values. This requires the use of an additional "destination" for exports of services.

Consumption is disaggregated between private and public households, but savings is strictly a regional variable. The expenditure share on public goods is fixed except when the level of government activity is exogenously specified. A global banking system purchases capital goods in each of the regions on the behalf of the savers of the world, who buy shares in this portfolio at an average price: pcgswld.

Users with access to GEMPACK can increase the maximum set sizes to permit larger aggregations, provided you have sufficient RAM for implementing them. The standard model (10x10 aggregation with decomposition code) is designed to run with 16 Mb of RAM.

!

!-----!

---

```
SET REG # Regions in the model #

    MAXIMUM SIZE 19 READ ELEMENTS FROM FILE gtapsets HEADER "H1";

SET HOME # Regions in the model #

    MAXIMUM SIZE 19 READ ELEMENTS FROM FILE gtapsets HEADER "H1";

SET DEST # Regions in the model #

    MAXIMUM SIZE 19 READ ELEMENTS FROM FILE gtapsets HEADER "H1";

SET HOST # Regions in the model #

    MAXIMUM SIZE 19 READ ELEMENTS FROM FILE gtapsets HEADER "H1";

SET SOURCE # Regions in the model #

    MAXIMUM SIZE 19 READ ELEMENTS FROM FILE gtapsets HEADER "H1";

SUBSET HOST IS SUBSET OF REG;

SUBSET SOURCE IS SUBSET OF REG;

SUBSET REG IS SUBSET OF HOST;

SUBSET REG IS SUBSET OF SOURCE;

SUBSET HOME IS SUBSET OF REG;

SUBSET DEST IS SUBSET OF REG;

SUBSET REG IS SUBSET OF HOME;

SUBSET REG IS SUBSET OF DEST;

SET TRAD_COMM # TRADED COMMODITIES #

    MAXIMUM SIZE 50 READ ELEMENTS FROM FILE gtapsets HEADER "H2";

SET COM # TRADED COMMODITIES #
```

---

```

MAXIMUM SIZE 50 READ ELEMENTS FROM FILE KDATA HEADER "COM";

SUBSET COM IS SUBSET OF TRAD_COMM;

SUBSET TRAD_COMM IS SUBSET OF COM;

SET IND # FDI industries #

    MAXIMUM SIZE 50 READ ELEMENTS FROM FILE KDATA HEADER "IND";

SET CGDS_COMM # CAPITAL GOODS Commodities #

    MAXIMUM SIZE 1 READ ELEMENTS FROM FILE gtapsets HEADER "H9";

SET ENDW_COMM # ENDOWMENT COMMODITIES #

    MAXIMUM SIZE 5 READ ELEMENTS FROM FILE gtapsets HEADER "H6";

SET ENDWC_COMM # Capital Endowment Commodity # (capital) ;

SET PROD_COMM # PRODUCED COMMODITIES # = TRAD_COMM UNION CGDS_COMM ;

SET DEMD_COMM # DEMANDED COMMODITIES # = ENDW_COMM UNION TRAD_COMM ;

SET NSAV_COMM # NON-SAVINGS COMMODITIES # = DEMD_COMM UNION CGDS_COMM ;

SUBSET PROD_COMM IS SUBSET OF NSAV_COMM ;

SET LABOR (UnSkLab, SkLab);

SET UnSkLab (UnSkLab);

SET SkLab (SkLab);

SET LAND (LAND);

SUBSET LABOR IS SUBSET OF ENDW_COMM;

```



---

COEFFICIENT FIRST;

READ FIRST FROM FILE GTAPDATA HEADER "1";

UPDATE (Change) FIRST=IF[FIRST>0.5,-FIRST];

COEFFICIENT FIRST1;

READ FIRST1 FROM FILE GTAPDATA HEADER "F1";

UPDATE (Change) FIRST1=IF[FIRST1>0.5,-FIRST1];

COEFFICIENT post\_tax\_rr #Is 1 if post-tax RoRs used in asset supply function#;

COEFFICIENT home\_tax\_ank #Is 1 if home country taxes capital impediment rents#;

COEFFICIENT home\_tax\_anp #Is 1 if home country taxes output impediment rents#;

READ post\_tax\_rr FROM FILE rr\_flag;

READ home\_tax\_ank FROM FILE rr\_flag;

READ home\_tax\_anp FROM FILE rr\_flag;

!-----!

! FDI industry extension set definitions !

!-----!

!'''''''''''''''''''' Define set mappings read from file ''''''''''''''''''''!

Coefficient



---

! Define subsets based on the industries and regions in which FDI is present.!

SET FDI\_DEST #Regions in which some FDI is undertaken#

= (All,r,REG:0<sum[i,IND:DEST\_REG(i) eq r,1]);

SET FDI\_COMM #Commodities which are somewhere produced by FDI industries#

= (All,c,TRAD\_COMM:0<sum[i,IND:IND2COMM(i) eq c,1]);

!.....!

! Define mappings from FTAP sets PROD\_COMM and REG to subsets FDI\_COMM and !

! FDI\_DEST respectively. !

!.....!

Mapping PROD2FDI from PROD\_COMM to FDI\_COMM;

Mapping REG2FDI from REG to FDI\_DEST;

Formula

(All,j,PROD\_COMM) PROD2FDI(j)=1;

(All,j,FDI\_COMM) PROD2FDI(j)=\$POS(j,FDI\_COMM);

(All,j,REG) REG2FDI(j)=1;

(All,j,FDI\_DEST) REG2FDI(j)=\$POS(j,FDI\_DEST);





---

```

!.....!
!   Note that the sluggish endowments are now defined dynamically,   !
!   based on the variable. This requires us to define and read in   !
!   this variable before proceeding further.                           !
!.....!

```

```

COEFFICIENT (all,i,ENDW_COMM)                                SLUG(i);

```

```

! SLUG is a variable used to dynamically define the set of
!
! sluggish primary factor endowments. It is zero for mobile
!
! endowments and one for sluggish endowments. !

```

```

READ SLUG      FROM FILE GTAPPARM ;

```

```

Set ENDWS_COMM # Sluggish ENDOWMENT COMMODITIES # =

```

```

(all,i,ENDW_COMM: SLUG(i)>0);

```

```

SET ENDWM_COMM # Mobile ENDOWMENT COMMODITIES # = ENDW_COMM - ENDWS_COMM;

```

```

SUBSET ENDWC_COMM IS SUBSET OF ENDWM_COMM;

```

```

SET NONCAP_COMM #Endowments other than capital# = ENDW_COMM - ENDWC_COMM;

```

```

SET NSAVNC_COMM #All non-savings commodities other than capital#

```

```

= NSAV_COMM - ENDWC_COMM;

```

```

SET NATRES (NATRES);

```

---

SUBSET NATRES IS SUBSET OF ENDWS\_COMM;

COEFFICIENT (integer)(all,i,ENDWM\_COMM) IS\_CAP(i)

#Is 1 for capital, 0 for all other mobile endowments#;

FORMULA

(all,i,ENDWM\_COMM) IS\_CAP(i)=0;

(all,i,ENDWC\_COMM) IS\_CAP(i)=1;

SET NONLAB\_ENDW # non labour endowments # = ENDW\_COMM - LABOR;

!-----!

! VARIABLES !

!-----!

!.....!

! Variables are divided into four groups -- proportional changes in quantities, prices, technical change, policies (i.e. tax/subsidiy "wedges"), income and utility, and finally slack variables. In GEMPACK, variables refer to those items which will be changing endogenously with each Johansen solution. They are assigned lower case labels to denote the fact that they are proportional changes. This is purely for convenience, since GEMPACK is not case sensitive.

---

Variables of FTAP are listed in the same structure set out by GTAP  
as mentioned above. In each group, variables are arranged into  
sub-sections of GTAP, ICM and FTAP

```
!
!.....!
!-----!
!
!               Quantity Variables               !
!-----!
```

! GTAP Section !

```
VARIABLE (Orig_Level=VOM)(all,i,NSAV_COMM)(all,r,REG)          qo(i,r)
# industry output of commodity i in region r # ;
```

```
VARIABLE (all,i,TRAD_COMM)(all,r,REG)                          qoa(i,r)
# industry output of commodity i in region r, producer value weighted # ;
```

```
VARIABLE (all,i,ENDWS_COMM)(all,j,PROD_COMM)(all,r,REG)      goes(i,j,r)
# supply of sluggish endowment i used in j, in r # ;
```

```
VARIABLE (Orig_Level=VXMD)
(all,i,TRAD_COMM)(all,r,SOURCE)(all,s,DEST)                  qxs(i,r,s)
# export sales of commodity i from r to region s # ;
```

---

VARIABLE (Orig\_Level=VST)(all,i,TRAD\_COMM)(all,r,REG) qst(i,r)

# sales of i from r to international transport # ;

VARIABLE (Orig\_Level=VDM)(all,i,TRAD\_COMM)(all,r,REG) qds(i,r)

# domestic sales of commodity i in r # ;

VARIABLE (Orig\_Level=VFM)

(all,i,ENDW\_COMM)(all,j,PROD\_COMM)(all,r,REG) qfe(i,j,r)

# demand for endowment i for use in j in region r # ;

VARIABLE (Orig\_Level=VKBI)(all,j,TRAD\_COMM)(all,r,REG) kk(j,r)

# usage of capital, by industry and region #;

VARIABLE (all,j,PROD\_COMM)(all,r,REG) qva(j,r)

# value-added in industry j of region r # ;

VARIABLE (all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG) qf(i,j,r)

# demand for commodity i for use in j in region r # ;

VARIABLE (Orig\_Level=VIFM)

(all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,s,REG) qfm(i,j,s)

# Industry demands for aggregate imports # ;

---

```

VARIABLE (Orig_Level=VDFM)

(all,i,TRAD_COMM)(all,j,PROD_COMM)(all,s,REG)                                qfd(i,j,s)

# Industry demands for domestic goods # ;

VARIABLE (all,i,TRAD_COMM)(all,r,REG)                                        qp(i,r)

# private household demand for commodity i in region r # ;

VARIABLE (all,i,TRAD_COMM)(all,r,REG)                                        qg(i,r)

# government household demand for commodity i in region r # ;

VARIABLE (Orig_Level=VIPM)(all,i,TRAD_COMM)(all,s,REG)                    qpm(i,s)

# private hhld demand for imports of i in region s # ;

VARIABLE (Orig_Level=VDPM)(all,i,TRAD_COMM)(all,s,REG)                    qpd(i,s)

# private hhld demand for domestic i in region s # ;

VARIABLE (Orig_Level=VIGM)(all,i,TRAD_COMM)(all,s,REG)                    qgm(i,s)

# government hhld demand for imports of i in region s # ;

VARIABLE (Orig_Level=VDGM)(all,i,TRAD_COMM)(all,s,REG)                    qgd(i,s)

# government hhld demand for domestic i in region s # ;

VARIABLE (all, r, REG)                                                        ksvces(r)

# capital services = qo("capital",r) # ;

```

---

```

VARIABLE (all, r, REG)                                qcgds(r)

# Output of capital goods sector = qo("cgds",r) # ;

VARIABLE (all,r,REG)                                qsave(r)

# regional demand for NET savings # ;

VARIABLE (Orig_Level=VIM)(all,i,TRAD_COMM)(all,s,REG)  qim(i,s)

# aggregate imports of i in region s, market price weights # ;

VARIABLE (all,i,TRAD_COMM)(all,s,REG)                qiwi(i,s)

# aggregate imports of i in region s, cif weights # ;

VARIABLE (Orig_Level=VXW)(all,i,TRAD_COMM)(all,r,REG)  qxw(i,r)

# aggregate exports of i from region r, fob weights # ;

VARIABLE (Orig_Level=VXWREGION)(all,r,REG)            qxwreg(r)

# volume of merchandise exports, by region # ;

VARIABLE (Orig_Level=VIWREGION)(all,r,REG)            qiwreg(r)

# volume of merchandise imports, by region # ;

VARIABLE (Orig_Level=VXWCOMMOD)(all,i,TRAD_COMM)      qxwcom(i)

# volume of global merchandise exports by commodity # ;

```

---

VARIABLE (Orig\_Level=VIWCOMMOD)(all,i,TRAD\_COMM) qiwcom(i)

# volume of global merchandise imports by commodity # ;

VARIABLE (Orig\_Level=VXWLD) qxwwld

# volume of world trade # ;

VARIABLE (all,i,TRAD\_COMM) qow(i)

# Quantity Index for world supply of good i # ;

VARIABLE (Orig\_Level=VWOU)(all,i,TRAD\_COMM) qowu(i)

# Quantity Index for world supply of good i at user prices # ;

VARIABLE (all, r, REG) kb(r)

# Regional capital stock, asset weights#;

VARIABLE (all, r, REG) kr(r)

# Regional capital stock, rental weights#;

VARIABLE (all, r, REG) ke(r)

# End-of-period capital stock, in r # ;

VARIABLE globalcgds

# Global supply of capital goods for NET investment # ;



---

VARIABLE qt  
# quantity of global shipping services provided # ;

VARIABLE (all,r,REG) pop(r)  
# regional population # ;

VARIABLE walras\_dem  
# demand in the omitted market--global demand for savings # ;

VARIABLE walras\_sup  
# supply in omitted market--global supply of cgds composite #;

VARIABLE (ORIG\_LEVEL = GDP)(all,r,REG) qgdp(r)  
# GDP quantity index # ;

VARIABLE (All,s,home) k\_h\_\_(s)  
#Quantity of capital owned by region s#;

VARIABLE (All,s,home)(All,i,TRAD\_COMM) k\_h\_i(i,s)  
#Quantity of capital in industry i globally owned by region s#;

VARIABLE (All,s,home)(All,i,TRAD\_COMM) kd\_h\_i(i,s)  
#Quantity of domestic capital#;

---

VARIABLE (All,s,home)(All,i,TRAD\_COMM) kf\_h\_i(i,s)

#Quantity of foreign capital#;

VARIABLE (All,s,home)(All,d,host)(All,i,TRAD\_COMM) k\_hhi(i,s,d)

#Quantity of capital in industry i in region d owned by region s#;

VARIABLE (Orig\_Level=VDEP)(all,r,REG) depr(r)

# depreciation of capital stock, by region #;

VARIABLE (all,i,TRAD\_COMM)(all,r,REG) invd(i,r)

# investment sales of the ith domestic commodity #;

VARIABLE (all,i,TRAD\_COMM)(all,r,REG) invi(i,r)

# investment sales of the ith composite imported commodity #;

VARIABLE (all,r,REG) kt(r)

# real aggregate capital owned by region #;

VARIABLE (all,r,REG) mt(r)

# real aggregate demand for land, by region #;

VARIABLE (all,r,REG) nru(r)

#real aggregate demand for natural resources, by region#;

---

VARIABLE (all,r,REG) lt\_(r)

# aggregate usage of labour, by region #;

VARIABLE (all,l,LABOR)(all,j,PROD\_COMM)(all,r,REG) qfel(l,j,r)

# demand for labour for use in j in region r # ;

VARIABLE (all,j,PROD\_COMM)(all,r,REG) qfek(j,r)

# demand for capital for use in j in region r # ;

VARIABLE (all,j,PROD\_COMM)(all,r,REG) qfen(j,r)

# demand for land for use in j in region r # ;

VARIABLE (all,j,PROD\_COMM)(all,r,REG) qfenr(j,r)

# demand for nat resrcs for use in j in region r # ;

VARIABLE (All,i,TRAD\_COMM)(All,r,REG) qfed(i,r)

#Quantity of domestic capital demanded by industry i#;

VARIABLE (All,i,TRAD\_COMM)(All,r,REG) qfei(i,r)

#Quantity of foreign capital demanded by industry i#;

VARIABLE (All,i,TRAD\_COMM)(All,s,home)(All,d,host) qfes(i,s,d)

#Quantity of capital from region s demanded by industry i in region d#;

---

VARIABLE (all,j,FDI\_COMM)(all,r,FDI\_DEST) f\_qva(j,r)

# value-added in industry j in region r # ;

VARIABLE (all,i,TRAD\_COMM)(all,j,FDI\_COMM)(all,r,FDI\_DEST) f\_pf(i,j,r)

# purchase price of commodity i for use in j in region r # ;

VARIABLE (all,i,TRAD\_COMM)(all,j,FDI\_COMM)(all,r,FDI\_DEST) f\_qf(i,j,r)

# demand for commodity i for use in j in region r # ;

VARIABLE (all,i,TRAD\_COMM)(all,j,FDI\_COMM)(all,s,FDI\_DEST) f\_qfm(i,j,s)

# Industry demands for aggregate imports # ;

VARIABLE (all,i,TRAD\_COMM)(all,j,FDI\_COMM)(all,s,FDI\_DEST) f\_qfd(i,j,s)

# Industry demands for domestic goods # ;

VARIABLE (all,i,LABOR)(all,j,FDI\_COMM)(all,r,FDI\_DEST) f\_qfel(i,j,r);

VARIABLE (all,i,ENDWC\_COMM)(all,j,FDI\_COMM)(all,r,FDI\_DEST) f\_qfek(i,j,r);

VARIABLE (all,i,LAND)(all,j,FDI\_COMM)(all,r,FDI\_DEST) f\_qfen(i,j,r);

VARIABLE (all,i,NATRES)(all,j,FDI\_COMM)(all,r,FDI\_DEST) f\_qfenr(i,j,r);

---

VARIABLE (All,i,TRAD\_COMM)(All,r,REG) qod(i,r)  
#Output from domestic industry#;

VARIABLE (All,i,TRAD\_COMM)(All,r,REG) qdd(i,r)  
#Domestic use of output from domestic industry#;

VARIABLE (All,i,TRAD\_COMM)(All,r,REG) qxd(i,r)  
#Exports of output from domestic industry#;

VARIABLE (All,i,TRAD\_COMM)(All,r,REG) qdst(i,r)  
#International freight services from domestic industry#;

VARIABLE (All,i,TRAD\_COMM)(All,o,HOME)(All,l,HOST) qoh(i,o,l)  
#Output from foreign industry located in region l owned by region o#;

VARIABLE (All,i,TRAD\_COMM)(All,o,HOME)(All,l,HOST) qdh(i,o,l)  
#Domestic use of output from foreign industry loc in reg l owned by reg o#;

VARIABLE (All,i,TRAD\_COMM)(All,o,HOME)(All,l,HOST) qxh(i,o,l)  
#Exports of output from foreign industry loc in reg l owned by reg o#;

VARIABLE (All,i,TRAD\_COMM)(All,o,HOME)(All,l,HOST) qhst(i,o,l)  
#Intl. freight services from foreign industry loc in reg l owned by reg o#;

---

```

VARIABLE (All,i,TRAD_COMM)(All,s,SOURCE)(All,d,DEST)          qxdd(i,s,d)

#Exports to region d from domestic industry in region s#;

VARIABLE (All,i,TRAD_COMM)(All,o,HOME)(All,l,HOST)(All,d,DEST) qxhd(i,o,l,d)

#Exports to region d from foreign industry loc in reg l and owned by reg o#;

VARIABLE (All,i,TRAD_COMM)(All,s,SOURCE)(All,d,DEST)          qisd(i,s,d)

#Quantity of exports by commodity, source and destination (same as qxs)#;

VARIABLE (All,i,TRAD_COMM)(All,o,HOME)(All,d,DEST)          qihd(i,o,d)

#Use by region d of commodity i from foreign industries owned by reg o#;

VARIABLE (All,i,TRAD_COMM)(All,d,DEST)                      qid(i,d)

#Use by region d of commodity i from foreign industries#;

VARIABLE (Orig_Level=VFM)

(all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)                o_qfe(i,j,r)

# demand for endowment i for use in j in region r # ;

VARIABLE

(all,i,TRAD_COMM)(all,s,SOURCE)                              qgxmd(i,s)

#Total Real exports from s, domestic price wgts# ;

(all,i,TRAD_COMM)(all,s,SOURCE)                              qgxwd(i,s)

#Total Real exports from s, FOB price wgts# ;

```

---

```

      (all,i,TRAD_COMM)(all,d,DEST)                qgviv(i,d)
#Total Real imports to d, CIF price wgts# ;

      (all,i,TRAD_COMM)(all,d,DEST)                qgvim(i,d)
#Total Real imports to d, tariff inclusive price # ;

      (all,i,TRAD_COMM)(all,h,HOME)(all,s,SOURCE) qx_fdi_wd(i,h,s)
#Real exports of fdi ind to third countries, FOB price wgts# ;

      (all,i,TRAD_COMM)(all,h,HOME)(all,s,SOURCE) qx_fdi_md(i,h,s)
#Real exports of fdi ind to third countries, domestic price wgts# ;

      (all,i,TRAD_COMM)(all,h,HOME)(all,d,DEST)    qm_fdi_ws(i,h,d)
#Real imports from third country fdi ind, CIF price wgts# ;

      (all,i,TRAD_COMM)(all,h,HOME)(all,d,DEST)    qm_fdi_ms(i,h,d)
#Real imports from third country fdi ind, tariff incl price wgts# ;

      (all,i,TRAD_COMM)(all,h,HOME)                qx_wd(i,h)
#Real exports of fdi ind to third countries, FOB price wgts# ;

      (all,i,TRAD_COMM)(all,h,HOME)                qx_md(i,h)
#Real exports of fdi ind to third countries, domestic price wgts# ;

      (all,i,TRAD_COMM)(all,d,DEST)                qm_ws(i,d)
#Real imports from third country fdi ind, CIF price wgts# ;

      (all,i,TRAD_COMM)(all,d,DEST)                qm_ms(i,d)
#Real imports from third country fdi ind, tariff incl price wgts# ;

      (All,i,TRAD_COMM)(All,o,HOME)(All,l,HOST)    qvxhm(i,o,l)
#Real exports of foreign-owned industry, domestic price wgts#;

      (All,i,TRAD_COMM)(All,r,REG)                qvtotdhm(i,r)
#Real domestic use of foreign industry output#;

```

---

```

    (all,i,TRAD_COMM)(all,r,HOST)                qvtotohm(i,r)

#Real output of foreign firms in host country # ;

    (all,i,TRAD_COMM)(all,o,HOME)                qvtotown_os(i,o)

#Real output of firms located abroad # ;

VARIABLE (all,i,PROD_COMM)(all,r,REG)            compvalad(i,r)

    # composition of value added for good i and region r # ;

!-----!
!
!                price variables                !
!-----!

VARIABLE (all,i,NSAV_COMM)(all,r,REG)            ps(i,r)

# supply price of commodity i in region r # ;

VARIABLE (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,r,REG)    pf(i,j,r)

# firms' price for commodity i for use in j, in r # ;

VARIABLE (all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)    pfe(i,j,r)

# firms' price for endowment commodity i in j of r # ;

VARIABLE (all,j,PROD_COMM)(all,r,REG)            pva(j,r)

# firms' price of value-added in industry j of region r # ;

```



---

VARIABLE (all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,s,REG) pfm(i,j,s)

# price index for imports of i by j in region s # ;

VARIABLE (all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,s,REG) pfd(i,j,s)

# price index for domestic purchases of i by j in region s # ;

VARIABLE (all,i,TRAD\_COMM)(all,r,REG) pp(i,r)

# private household price for commodity i in region r # ;

VARIABLE (all,i,TRAD\_COMM)(all,s,REG) ppm(i,s)

# price of imports of i by private households in s # ;

VARIABLE (all,i,TRAD\_COMM)(all,s,REG) ppd(i,s)

# price of domestic i to private households in s # ;

VARIABLE (all,r,REG) pgov(r)

# price index for govt hhld expenditures in region r # ;

VARIABLE (all,r,REG) ppriv(r)

# price index for private household expenditures in region r # ;

VARIABLE (all,i,TRAD\_COMM)(all,r,REG) pg(i,r)

# government household price for commodity i in region r # ;

---

VARIABLE (all,i,TRAD\_COMM)(all,s,REG) pgm(i,s)

# price of imports of i by government households in s # ;

VARIABLE (all,i,TRAD\_COMM)(all,s,REG) pgd(i,s)

# price of domestic i to government households in s # ;

VARIABLE (ORIG\_LEVEL = 1.0)(all,i,NSAV\_COMM)(all,r,REG) pm(i,r)

# market price of domestic commodity i in region r # ;

VARIABLE (ORIG\_LEVEL=1.0)(All,i,TRAD\_COMM)(All,r,REG) pst(i,r)

#Market price of domestically produced international freight services#;

VARIABLE (all,j,TRAD\_COMM)(all,r,REG) rp(j,r)

# rental price of a unit of capital, by industry and region #;

VARIABLE (ORIG\_LEVEL = 1.0)(all,i,TRAD\_COMM)(all,r,REG) pim(i,r)

# market price of composite import i in region r # ;

VARIABLE (all,i,TRAD\_COMM)(all,r,REG) piw(i,r)

# world price of composite import i in region r # ;

VARIABLE (ORIG\_LEVEL = 1.0)(all,i,TRAD\_COMM)(all,r,REG) pxw(i,r)

# aggregate exports price index of i from region r # ;

---

VARIABLE (ORIG\_LEVEL = 1.0)(all,r,REG) pxwreg(r)  
# price index of merchandise exports, by region # ;

VARIABLE (ORIG\_LEVEL = 1.0)(all,r,REG) piwreg(r)  
# price index of merchandise imports, by region # ;

VARIABLE (ORIG\_LEVEL = 1.0)(all,r,REG) pfactor(r)  
# market price index of primary factors, by region # ;

VARIABLE (ORIG\_LEVEL = 1.0)(all,i,TRAD\_COMM) pxwcom(i)  
# price index of global merchandise exports by commodity # ;

VARIABLE (ORIG\_LEVEL = 1.0)(all,i,TRAD\_COMM) piwcom(i)  
# price index of global merchandise imports by commodity # ;

VARIABLE (ORIG\_LEVEL = 1.0) pxwld  
# price index of world trade # ;

VARIABLE (ORIG\_LEVEL = 1.0) pfactwld  
# world price index of primary factors # ;

VARIABLE (all,i,TRAD\_COMM) pw(i)  
# World price index for total good i supplies #;

---

```

VARIABLE (ORIG_LEVEL = 1.0)(all,i,TRAD_COMM)                pwu(i)

# World price index for total good i supplies at user prices #;

VARIABLE (all,i,ENDWS_COMM)(all,j,PROD_COMM)(all,r,REG)    pmes(i,j,r)

# market price of sluggish endowment used by j, in r # ;

VARIABLE (all,i,TRAD_COMM)(all,r,SOURCE)(all,s,DEST)      pms(i,r,s)

# domestic price for good i supplied from r to region s # ;

VARIABLE (All,i,TRAD_COMM)(All,s,SOURCE)(All,d,DEST)      pxs(i,s,d)

#Domestic market price of commodity i supplied from r to s # ;

VARIABLE (all,i,TRAD_COMM)(all,r,SOURCE)(all,s,DEST)      pfob(i,r,s)

# FOB world price of commodity i supplied from r to s # ;

! i.e., prior to incorporation of transportation margin !

VARIABLE (all,i,TRAD_COMM)(all,r,SOURCE)(all,s,DEST)      pcif(i,r,s)

# CIF world price of commodity i supplied from r to s #;

! i.e., subsequent to incorporation of transportation margin !

VARIABLE                                                    pt

# price of global shipping services provided # ;

```

---

VARIABLE (all, r, REG) rental(r)

# rental rate on capital = ps("capital",r) # ;

VARIABLE (all, r, REG) rorc(r)

# Current net rate of return on capital stock, in r # ;

VARIABLE (all, r, REG) rore(r)

# Expected net rate of return on capital stock, in r # ;

VARIABLE rorg

# Global net rate of return on capital stock # ;

VARIABLE (all, r, REG) psave(r)

# price of savings in region r # ;

VARIABLE pcgdsfld

# world average price of capital goods (net investment weights) # ;

VARIABLE (all, r, REG) pcgds(r)

# price of investment goods = ps("cgds",r) # ;

VARIABLE (Orig\_Level=DEPRREG)(All,r,REG) deprete(r)

#Regional depreciation rate#;

---

VARIABLE (ORIG\_LEVEL = 1.0)(all,r,REG) psw(r)

# Index of prices received for tradeables produced in r # ;

! Note: this no longer includes sales of net investment in r !

VARIABLE (ORIG\_LEVEL = 1.0)(all,r,REG) pdw(r)

# Index of prices paid for tradeables used in region r # ;

!Note: this no longer includes purchases of net savings in region r!

VARIABLE (ORIG\_LEVEL = 1.0)(all,r,REG) tot(r)

# terms of trade for region r:  $tot(r) = psw(r) - pdw(r)$  # ;

VARIABLE (ORIG\_LEVEL = 1.0)(all,r,REG) pgdp(r)

# GDP price index # ;

VARIABLE (Orig\_Level=1)(all,r,REG) pnr(r)

# purchase price of land, by region #;

VARIABLE (Orig\_Level=1)(all,r,REG) pcap(r)

#purchase price of capital owned by region#;

VARIABLE (Orig\_Level=1)(all,r,REG) pnrr(r)

#purchase price of natural resources, by region#;

VARIABLE (Orig\_Level=1) ipc

---

```

# world consumption price index #;

VARIABLE (Orig_Level=1)(all,r,REG)                                ipcr(r)

# national consumption price index #;

VARIABLE (CHANGE) (all,r,REG)                                    rkr(r)

#change in average rate of return on capital, by region #;

VARIABLE (Orig_Level=1)(all,r,REG)                                rm(r)

# rental price of a unit of land, by region #;

VARIABLE (Orig_Level=1)(all,r,REG)                                nrp(r)

#rental price of a unit of natural resource, by region#;

VARIABLE (Orig_Level=1)(all,r,REG)                                w(r)

# nominal wage rate, by region #;

VARIABLE (All,i,TRAD_COMM)(All,r,REG)                            pfeda(i,r)

#Purchase price of domestic capital in industry i in region r#;

VARIABLE (All,i,TRAD_COMM)(All,r,REG)                            pfeia(i,r)

#Purchase price of foreign capital in industry i in region r#;

VARIABLE (All,i,TRAD_COMM)(All,s,home)(All,d,host)              pfesa(i,s,d)

```

---

#Purchase price of capital from region s for industry i in region d#;

VARIABLE (All,i,TRAD\_COMM)(All,r,REG) pskd(i,r)

#Supply price of domestic capital to industry in in region r#;

VARIABLE (All,i,TRAD\_COMM)(All,s,home)(All,d,host) psks(i,s,d)

#Supply price of capital from region s to industry i in region d#;

VARIABLE (All,i,TRAD\_COMM)(All,r,REG) rpd(i,r)

#Market price of domestic capital to industry in in region r#;

VARIABLE (All,i,TRAD\_COMM)(All,s,home)(All,d,host) rps(i,s,d)

#Market price of capital from region s to industry i in region d#;

VARIABLE

(All,s,home) psland(s) #Post-tax rental price of land#;

(All,s,home) psnatres(s) #Post-tax rental price of natural resources#;

VARIABLE (All,i,TRAD\_COMM)(All,h,HOME)(All,d,host) psh(i,h,d)

#Producers price of output from foreign-owned industries#;

VARIABLE (All,i,TRAD\_COMM)(All,r,REG) psd(i,r)

#Producers price of output from domestically-owned industries#;



---

VARIABLE (All,i,TRAD\_COMM)(All,r,REG) pod(i,r)  
 #Market price of output from domestic industry#;

VARIABLE (All,i,TRAD\_COMM)(All,r,REG) pdd(i,r)  
 #Market price of domestic use of output from domestic industry#;

VARIABLE (All,i,TRAD\_COMM)(All,r,REG) pxd(i,r)  
 #Domestic market price of exports from domestic industry#;

VARIABLE (All,i,TRAD\_COMM)(All,o,HOME)(All,l,HOST) poh(i,o,l)  
 #Market price of output from foreign-owned industry#;

VARIABLE (All,i,TRAD\_COMM)(All,o,HOME)(All,l,HOST) pdh(i,o,l)  
 #Market price of domestic use of output from foreign-owned industries#;

VARIABLE (All,i,TRAD\_COMM)(All,o,HOME)(All,l,HOST) pxh(i,o,l)  
 #Domestic market price of exports from foreign-owned industries#;

VARIABLE (All,i,TRAD\_COMM)(All,s,SOURCE)(All,d,DEST) pxdd(i,s,d)  
 #FOB price of exports from domestically-owned industries#;

VARIABLE (All,i,TRAD\_COMM)(All,o,HOME)(All,l,HOST)(All,d,DEST) pxhd(i,o,l,d)  
 #FOB price of exports from foreign-owned industries#;

---

VARIABLE (All,i,TRAD\_COMM)(All,s,SOURCE)(All,d,DEST) pisd(i,s,d)

#Tariff incl. price of imports by comm, source and dest (same as pms)#;

VARIABLE (All,i,TRAD\_COMM)(All,o,HOME)(All,d,DEST) pihd(i,o,d)

#Price of Use by region d of commodity i from foreign ind. owned by reg o#;

VARIABLE (All,i,TRAD\_COMM)(All,o,HOME)(All,l,HOST)(All,d,DEST) pihldw(i,o,l,d)

#CIF price of imports from foreign-owned industries#;

VARIABLE (All,i,TRAD\_COMM)(All,o,HOME)(All,l,HOST)(All,d,DEST) pihld(i,o,l,d)

#Tariff incl. price of imports from foreign-owned industries#;

VARIABLE (All,i,TRAD\_COMM)(All,s,SOURCE)(All,d,DEST) pildw(i,s,d)

#CIF price of imports from domestically-owned industries#;

VARIABLE (All,i,TRAD\_COMM)(All,s,SOURCE)(All,d,DEST) pild(i,s,d)

#Tariff incl. price of imports from domestically-owned industries#;

VARIABLE (all,i,ENDW\_COMM)(all,j,PROD\_COMM)(all,r,REG) f\_afe(i,j,r);

VARIABLE (All,i,TRAD\_COMM)(All,s,SOURCE)(All,d,DEST) frt(i,s,d)

#Freight rate by commodity source and destination#;

VARIABLE (All,i,TRAD\_COMM)(All,d,DEST) pid(i,d)

---

#Same as GTAP variable pim#;

VARIABLE (All,i,TRAD\_COMM)(All,r,REG) pds(i,r)

#Market price of commodities used domestically#;

!.....!  
!  
! Ratios !  
!.....!

VARIABLE (CHANGE) qyb

# change in world bond-income ratio #;

VARIABLE (CHANGE) (all,r,REG) qybr(r)

# change in bond-income ratio, by region #;

VARIABLE (CHANGE) (all,r,REG) qyhbr(r)

# change in household bond-income ratio, by region #;

VARIABLE (CHANGE) (all,r,REG) qrgbr(r)

#change in government bond-income ratio, by region #;

VARIABLE (Change)(all,r,REG) qaer(r)

# Equity to income ratio # ;

---

VARIABLE (CHANGE) (all,r,REG) qyir(r)

#change in ratio of net interest income to nominal income, by reg# ;

VARIABLE (ORIG\_LEVEL = 1.0)(all,i,TRAD\_COMM)(all,r,REG) pr(i,r)

# ratio of domestic to imported prices in r # ;

VARIABLE (ORIG\_LEVEL = 1.0)(all,i,ENDW\_COMM)(all,r,REG) pfactreal(i,r)

# ratio of return to primary factor i to cpi in r # ;

VARIABLE (CHANGE) (all,r,REG) qyhsr(r)

# change in household saving ratio #;

VARIABLE (CHANGE) (all,r,REG) qrgrs(r)

#change in government saving ratio, by region #;

VARIABLE (CHANGE) (all,r,REG) qyhir(r)

#change in ratio of hhold net interest income to hhold disp income #;

VARIABLE (CHANGE) (all,r,REG) qrgir(r)

#change in ratio of govt net int recpts to tot govt recpts, by reg#;

VARIABLE (Change)(all,r,REG) qyanp\_h\_\_(r)

#Ratio of output impediment rents to national income#;

---

VARIABLE (Change)(all,r,REG) qyank\_h\_\_(r)

#Ratio of capital impediment rents to national income#;

VARIABLE (Change)(all,r,REG) qyfdirat(r)

#Ratio of FDI income to national income#;

VARIABLE (CHANGE)(all,r,REG) nyank\_h\_\_(r)

#change in ratio of FDI abnormal capital income to nominal gdp#;

VARIABLE (CHANGE)(all,r,REG) nyankr(r)

#change in ratio of abnormal capital income to nominal gdp#;

VARIABLE (CHANGE)(all,r,REG) nyanp\_h\_\_(r)

#change in ratio of FDI output impediment income to nominal gdp#;

VARIABLE (CHANGE)(all,r,REG) nyanpr(r)

#change in ratio of output impediment income to nominal gdp#;

VARIABLE (CHANGE)(all,r,REG) nyfdirat(r)

#change in ratio of net FDI income to nominal gdp#;

VARIABLE (CHANGE)(all,r,REG) nyas(r)

#change in ratio of net income from abroad to nominal gdp#;

---

VARIABLE (CHANGE) (all,r,REG) qysr(r)  
#change in national saving-income ratio #;

VARIABLE (CHANGE)(all,r,REG) gcass(r)  
#change in ratio of gvt crrt acct surpl to nominal gdp #;

VARIABLE (CHANGE)(all,r,REG) nkis(r)  
#change in ratio of net capital inflow to nominal gdp #;

VARIABLE (CHANGE)(all,r,REG) bts(r)  
#change in ratio of balance of trade to nominal gdp #;

VARIABLE (CHANGE) wnyas  
#change in ratio of world net interest income to world gdp #;

VARIABLE (CHANGE) wnkis  
#change in ratio of world net capital inflow to world gdp #;

VARIABLE (all,i,TRAD\_COMM)(all,r,REG) px\_ir(i,r)  
# export price index for good i and region r # ;

VARIABLE (all,i,TRAD\_COMM) px\_i(i)  
# world export price index for commodity i # ;

---

```

VARIABLE                                                                                               px_

# world export price index for all commodities # ;

VARIABLE (all,i,TRAD_COMM)(all,r,REG)                       pm_ir(i,r)

# imports price index for good i and region r # ;

VARIABLE (all,i,TRAD_COMM)(all,r,REG)                       c1_ir(i,r)

# contribution of world price, px_i, to ToT # ;

VARIABLE (all,i,TRAD_COMM)(all,r,REG)                       c2_ir(i,r)

# contribution of regional export price, px_ir, to ToT # ;

VARIABLE (all,i,TRAD_COMM)(all,r,REG)                       c3_ir(i,r)

# contribution of regional import price, pm_ir, to ToT # ;

VARIABLE (all,r,REG)                                         c1_r(r)

# contribution world prices for all goods to ToT # ;

VARIABLE (all,r,REG)                                         c2_r(r)

# contribution of regional export prices to ToT # ;

VARIABLE (all,r,REG)                                         c3_r(r)

# contribution of regional import prices to ToT # ;

```

---

```

VARIABLE (all,r,REG)                                tot2(r)

# Trade terms for region r, computed from components # ;

!-----!
!
!           Technical change variables.                !
!
!   Specification: If, for example, technical progress is      !
!   Hicks-neutral across!! all inputs at the rate of 1 percent, then      !
!   ao(j,r) = 1.                                             !
!-----!

VARIABLE (all,j,PROD_COMM)(all,r,REG)                ao(j,r)

# output augmenting technical change in sector j of r # ;

VARIABLE (all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)    afe(i,j,r)

# primary factor i augmenting tech change in j of r # ;

VARIABLE (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,r,REG)    af(i,j,r)

# composite interm. input i augmenting tech change in j of r # ;

VARIABLE (all,i,PROD_COMM)(all,r,REG)                ava(i,r)

# Value added augmenting tech change in sector i of r # ;

```



---

```

VARIABLE (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)          atr(i,r,s)

# tech change parameter in shipping of i from region r to s # ;

VARIABLE (All,i,TRAD_COMM)(All,s,SOURCE)(All,d,DEST)      atsd(i,s,d)

#Tech efficiency of shipping of output of domestically-owned industries# ;

VARIABLE (All,i,TRAD_COMM)(All,o,HOME)(All,l,HOST)(All,d,DEST) athsd(i,o,l,d)

#Tech efficiency of shipping of output of foreign-owned industries# ;

!-----!
!                               Policy variables                               !
!-----!

! All tax variables below are "powers" !

VARIABLE (all,i,TRAD_COMM)(all,r,REG)          to_shk(i,r)

# output (or income) tax shock in region r # ;

VARIABLE (all,i,NSAV_COMM)(all,r,REG)          to(i,r)

# output (or income) tax in region r # ;

VARIABLE (all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)  tf(i,j,r)

# tax on primary factor i used by j in region r # ;

```

---

VARIABLE (all,i,TRAD\_COMM)(all,r,REG) tpm(i,r)

# tax on imported i purchased by private hhlds in r # ;

VARIABLE (all,i,TRAD\_COMM)(all,r,REG) tpd(i,r)

# tax on domestic i purchased by private hhld in r # ;

VARIABLE (all,i,TRAD\_COMM)(all,r,REG) tgm(i,r)

# tax on imported i purchased by gov't hhld in r # ;

VARIABLE (all,i,TRAD\_COMM)(all,r,REG) tgd(i,r)

# tax on domestic i purchased by government hhlds in r # ;

VARIABLE (all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG) tfm(i,j,r)

# tax on imported i purchased by j in r # ;

VARIABLE (all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG) tfd(i,j,r)

# tax on domestic i purchased by j in r # ;

VARIABLE (all,i,TRAD\_COMM)(all,r,REG)(all,s,REG) txs(i,r,s)

# combined tax in r on good i bound for region s # ;

VARIABLE (all,i,TRAD\_COMM)(all,r,REG)(all,s,REG) tms(i,r,s)

# import tax in s on good i imported from region r # ;

---

```

VARIABLE (all,i,TRAD_COMM)(all,s,REG)                                tm(i,s)

# variable import levy -- source generic # ;

VARIABLE (all,i,TRAD_COMM)(all,r,REG)                                tx(i,r)

# variable export tax (subsidy) -- destination generic # ;

VARIABLE (Orig_Level=RVTXYCR)(all,r,REG)                            rtyr(r)

# income tax, by region #;

VARIABLE (all,r,REG)                                                ftypr(r)

# property income tax rate shift, by region #;

VARIABLE (Orig_Level=RVTXYCLBR)(all,r,REG)                          rtylr(r)

# tax on labour income, by region #;

VARIABLE (Orig_Level=RVTXYCPPR) (all,r,REG)                          rtypr(r)

# tax on property income, by region #;

VARIABLE (Orig_Level=RVTXYCKR) (all,r,REG)                          rtykr(r)

# tax on capital income, by region #;

VARIABLE (all,r,REG) tylr(r) # rate of tax on labour income, by region #;

VARIABLE (all,r,REG) typr(r) # rate of tax on property income, by region #;

```

---

```

VARIABLE (All,o,HOME)(All,l,HOST)                                typr_ank(o,l)

#Property tax rate to be applied to capital impediment income flow#;

VARIABLE (All,o,HOME)(All,l,HOST)                                typr_anp(o,l)

#Property tax rate to be applied to output impediment income flow#;

VARIABLE (all,r,REG) ftyr(r) # income tax rate shift, by region #;

VARIABLE (all,r,REG) ftylr(r) # labour income tax rate shift, by region #;

VARIABLE (all,i,TRAD_COMM)(all,r,REG)                            tinvd(i,r)

# power of the comm tax on the ith dom comm sold as invst #;

VARIABLE (all,i,TRAD_COMM)(all,r,REG)                            tinvi(i,r)

# power of the comm tax on the ith comp imp comm sold as invst #;

VARIABLE (all, r, REG)                                            f_kb(r)

#Swap in closure with frer to introduce perfect arbitrage between regions#;

VARIABLE (All,i,TRAD_COMM)(All,r,REG)                            tfda(i,r)

#Power of tax on domestic capital by industry#;

VARIABLE (All,i,TRAD_COMM)(All,r,REG)                            tfia(i,r)

#Power of tax on foreign capital by industry#;

```

---

VARIABLE (All,i,TRAD\_COMM)(All,s,home)(All,d,host) tfsa(i,s,d)  
#Power of tax on foreign capital by home region and industry#;

VARIABLE (All,r,REG) toa(r)  
#Power of uniform tax across industries on all capital#;

VARIABLE (All,r,REG) toad(r)  
#Power of uniform tax across industries on domestic capital#;

VARIABLE (All,r,REG) toai(r)  
#Power of uniform tax across industries on foreign capital#;

VARIABLE (All,s,home)(All,d,host) toas(s,d)  
#Power of uniform tax across industries on foreign capital by home region#;

VARIABLE (All,i,TRAD\_COMM)(All,s,HOME)(All,d,HOST) tof(i,s,d)  
#%change in the power of the output impediment in foreign FDI industries#;

VARIABLE (All,i,TRAD\_COMM)(All,r,REG) tod(i,r)  
#%change in the power of the output impediment in domestic FDI industries#;

VARIABLE (Change)(All,i,TRAD\_COMM)(All,s,HOME)(All,d,HOST) remotaxf(i,s,d)  
#Shock by x to remove x% of the output impediment in foreign FDI industries#;

---

```

VARIABLE (Change)(All,i,TRAD_COMM)(All,r,REG)          remotaxd(i,r)

#Shock by x to remove x% of the output impediment in domestic FDI industries#;

VARIABLE

(All,i,TRAD_COMM)(All,s,SOURCE)(All,d,DEST)          txsd(i,s,d)

#Power of route-specific export tax#;

(All,i,TRAD_COMM)(All,s,SOURCE)(All,d,DEST)          tmsd(i,s,d)

#Power of route-specific import tax#;

(All,i,TRAD_COMM)(All,o,HOME)(All,l,HOST)(All,d,DEST) txhd(i,o,l,d)

#Power of ownership-route-specific export tax on foreign-owned industries#;

(All,i,TRAD_COMM)(All,o,HOME)(All,l,HOST)(All,d,DEST) tmhs(i,o,l,d)

#Power of ownership-route-specific import tax on foreign-owned industries#;

VARIABLE      (All,i,IND)          f_altot(i)

#Slack variable to turn on/off monopolistic competition#;

VARIABLE      (All,i,TRAD_COMM)(All,r,REG)          f_ao(i,r)

#Slack variable to turn on/off monopolistic competition#;

VARIABLE      (All,i,TRAD_COMM)(All,o,HOME)(All,l,HOST) altot_f(i,o,l)

#Output efficiency of foreign-owned industries#;

VARIABLE      (All,i,TRAD_COMM)(All,r,REG)          altot_d(i,r)

#Output efficiency of domestically-owned industries#;

```

---

```

!-----!
!           Value, Income and Utility variables           !
!-----!

```

```

VARIABLE (all,r,REG)                                vxwreg(r)
# value of merchandise exports, by region # ;

```

```

VARIABLE (all,r,REG)                                viwreg(r)
# value of merchandise imports, by region, at world prices # ;

```

```

VARIABLE (all,i,TRAD_COMM)(all,s,REG)              viwcif(i,s)
# value of merchandise regional imports, by commodity, cif # ;

```

```

VARIABLE (all,i,TRAD_COMM)(all,s,REG)              vxwfob(i,s)
# value of merchandise regional exports, by commodity, fob # ;

```

```

VARIABLE (all,i,TRAD_COMM)                          vxwcom(i)
# value of global merchandise exports by commodity # ;

```

```

VARIABLE (all,i,TRAD_COMM)                          viwcom(i)
#value of global merchandise imports by commodity, at world prices #;

```

```

VARIABLE                                             vxwwld
# value of world trade # ;

```

---

```

VARIABLE (all,i,TRAD_COMM)                                valuew(i)

    # value of world supply of good i # ;

VARIABLE (all,i,TRAD_COMM)                                valuewu(i)

    # value of world supply of good i at user prices # ;

VARIABLE (all,r,REG)                                      vgdpr(r)

    # change in value of GDP # ;

VARIABLE !(all,r,REG)                                     yr(r)

    # regional household income, in region r # ;!

    ! Replace GTAP income variable with IC95 income variable !

(all,r,REG) yr(r) # nominal income, by region #;

VARIABLE (Change)(All,r,REG)                              yankr(r)

#(nom) income from abnormal returns to capital by region#;

VARIABLE (Change)(All,j,TRAD_COMM)(All,r,REG)            yankri(j,r)

#(nom) income from abnormal returns to capital by industry and region#;

VARIABLE (Change)(All,r,REG)                              yank_h__(r)

#(nom) net income from FDI abnormal returns by region#;

```



---

VARIABLE (Change)(All,i,TRAD\_COMM)(All,s,HOME)(All,d,host) yank\_hhi(i,s,d)

#(nom) income from abnormal returns to FDI capital by home, host and industry#;

VARIABLE (Change)(All,r,REG) yanpr(r)

#(nom) income from output impediments by region#;

VARIABLE (Change)(All,j,TRAD\_COMM)(All,r,REG) yanpri(j,r)

#(nom) income from output impediments by industry and region#;

VARIABLE (Change)(All,r,REG) yanp\_h\_\_(r)

#(nom) net income from FDI output impediments by region#;

VARIABLE (Change)(All,i,TRAD\_COMM)(All,s,HOME)(All,d,host) yanp\_hhi(i,s,d)

#(nom) income from output impediments to FDI capital by home, host and ind.#;

VARIABLE (Change)(All,i,TRAD\_COMM)(All,s,HOME)(All,d,host) anrro\_hhi(i,s,d)

#Output impediment RoR for foreign industries for welf decomp terms#;

VARIABLE (Change)(All,i,TRAD\_COMM)(All,s,HOME)(All,d,host) anto\_hhi(i,s,d)

#Output impediment rate of return for foreign industries#;

VARIABLE (Change)(All,i,TRAD\_COMM)(All,r,REG) anto\_h\_i(i,r)

#Output impediment rate of return for domestic industries#;

---

```

VARIABLE (change)(All,r,REG)          yfdi_h__(r) #Net FDI income#;

VARIABLE (change)(All,s,REG)(All,d,REG)(All,i,TRAD_COMM)    yfdi_hhi(i,s,d)

#Home region income from FDI in each industry and host region#;

VARIABLE (all,r,REG)                  yp(r)

      # regional private household expenditure, in region r # ;

VARIABLE (all,r,REG)                  up(r)

      # per capita utility from private expend., in region r #;

VARIABLE (all,r,REG)                  ug(r)

      # per capita utility from gov't expend., in region r #;

VARIABLE (all,r,REG)                  u(r)

      # per capita utility from aggregate hhld expend., in region r # ;

VARIABLE (CHANGE)(all,r,REG)          EV(r)

      # Equivalent Variation, $ US million # ;

      ! Hicksian equivalent variation. Positive figure

      indicates welfare improvement !

VARIABLE (CHANGE)                     WEV

      # Equivalent variation for the world # ;

```

---

VARIABLE (CHANGE)(all,r,REG) DTBAL(r)

# Change in trade balance X - M, \$ US million # ;

! Positive figure indicates increase in exports exceeds imports. !

VARIABLE (CHANGE)(all,i,TRAD\_COMM)(all,r,REG) DTBALi(i,r)

# Change in trade balance by commodity and by region, \$ US million #;

! Positive figure indicates increase in exports exceeds imports. !

VARIABLE (Orig\_Level=YC) yn

# world nominal income #;

VARIABLE (Orig\_Level=URGVHHR)(all,r,REG) ughr(r)

# government transfer payments #;

VARIABLE (CHANGE) (all,r,REG) d\_ughr\_(r)

# 100\*government transfer payments #;

VARIABLE (CHANGE) (all,r,REG) d\_ughr(r)

#100\*government transfer payments excluding export restriction rents#;

VARIABLE (Orig\_Level=YCHHDPR)(all,r,REG) yhdr(r)

# (nom) household disposable income, by region #;

---

VARIABLE (Orig\_Level=RCGVR)(all,r,REG) rgr(r)

# (nom) government receipts, by region #;

VARIABLE (Orig\_Level=ASEQR)(all,r,REG) aer(r)

#(value of) equity in productive assets in reg r#;

VARIABLE (Orig\_Level=VKB)(all,r,REG) akr(r)

# value of physical capital owned by region #;

VARIABLE (Orig\_Level=ASLNR)(all,r,REG) anr(r)

# value of land, by region #;

VARIABLE (Orig\_Level=ASLNRR)(all,r,REG) anrr(r)

#value of natural resources, by region#;

VARIABLE (Change)(All,r,REG) c\_VDEP(r)

#Change in value of aggregate depreciation in each region#;

VARIABLE (Orig\_Level=YFNT)(all,r,REG) yfn(r)

# net factor income, by region #;

VARIABLE (Orig\_Level=GRCOMT)(all,r,REG) rc(r)

# (nom) revenue from commodity taxes, by region #;

---

VARIABLE (Orig\_Level=EPCSR)(all,r,REG) ecr(r)

# aggregate consumption expenditure, by region #;

VARIABLE (Orig\_Level=GOVEXP)(all,r,REG) zg(r)

# government consumption expenditure, by region #;

VARIABLE (Orig\_Level=YC) yr

# world real income #;

VARIABLE (Orig\_Level=YCHHR)(all,r,REG) yhr(r)

# (nom) private household income, by region #;

VARIABLE (Orig\_Level=LTT)(all,r,REG) ylr(r)

# (nom) labour income, by region #;

VARIABLE (Orig\_Level=YCHHPPR)(all,r,REG) yhpr(r)

# household property income, by region #;

VARIABLE (Orig\_Level=YCHHPPRTAX)(all,r,REG) yhpntax(r)

# property income which is taxed #;

VARIABLE (Change)(All,r,REG) yoit(r);

VARIABLE (Change)(All,r,REG) ykit(r);



---

VARIABLE (Orig\_Level=KTT)(all,r,REG) fke(r)

# (nom) fixed capital earnings, by reg#;

VARIABLE (Orig\_Level=REGINV)(all,r,REG) invt(r)

# agg invst at curr prices # ;

VARIABLE(Orig\_Level=GRCOMT)(all,r,REG) rcl(r)

# (nom) revenue from commodity taxes, by region #;

VARIABLE (All,i,TRAD\_COMM)(all,d,REG) kf\_\_hi(i,d)

# FDI by industry and destination region #;

VARIABLE (all,d,REG) kf\_\_h\_(d) # FDI by destination region #;

VARIABLE (all,d,REG) kd\_\_h\_(d) # Domestic capital by region #;

!-----!

! Slack variables !

!-----!

VARIABLE (all,j,PROD\_COMM)(all,r,REG) profitslack(j,r)

# slack variable in the zero profit equation #

! This is exogenous, unless the user wishes to specify

---

output in a given region exogenously. ! ;

VARIABLE (all,r,REG) incomeslack(r)

# slack variable in the expression for regional income #

! This is exogenous, unless the user wishes to fix

regional income ! ;

VARIABLE (all,i,ENDW\_COMM)(all,r,REG) endwslack(i,r)

# slack variable in the endowment market clearing condition #

! This is exogenous, unless the user wishes to fix

the wage rate for one of the primary factors ! ;

VARIABLE (all, r, REG) cgdslack(r)

# slack variable for qcgds(r) #

! this is exogenous, unless the user wishes to specify

the level of new capital goods in a region !;

VARIABLE (all,r,REG) saveslack(r)

# slack variable in regional demand for savings #

! This is exogenous unless the user wishes to fix the

level of savings in a region. ! ;

VARIABLE (all,r,REG) privslack(r)

# slack variable to permit fixing of real private purchases #



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```

! This is exogenous unless the user wishes to fix the
    level of private purchases. ! ;

VARIABLE (all,r,REG)                                govslack(r)

# slack variable to permit fixing of real govt purchases #

! This is exogenous unless the user wishes to fix the
    level of government purchases. ! ;

VARIABLE (all,i,TRAD_COMM)(all,r,REG)              tradslack(i,r)

# slack variable in the tradeables market clearing condition #

! This is exogenous unless the user wishes to specify
    the price of tradeables exogenously ! ;

VARIABLE (all,r,REG)                                psaveslack(r)

# slack variable for the savings price equation #

! This is exogenous under the normal closure. However, in
    order to replicate simulations from the earlier model, where
    there was a single savings price, psaveslack may be swapped with
    psave in order to fix the latter. In this case, pcgdsfld must be
    the numeraire. ! ;

VARIABLE                                            walraslack

# slack variable in the omitted market #

! This is endogenous under normal, GE closure.

```

---

If the GE links are broken, then this must be swapped with the numeraire, thereby forcing global savings to explicitly equal global investment. ! ;

VARIABLE (All,i,PROD\_COMM)(All,r,REG) f\_pfek(i,r)

#Slack variable to nullify the capital component of the GTAP pfe equation#;

VARIABLE (All,i,TRAD\_COMM)(All,s,HOME)(All,d,HOST) f\_tof(i,s,d)

#Slack variable to allow tof to differ from tod#;

VARIABLE (all,r,REG) saveslack1(r);

!-----!  
! Variables for Bond and Wealth !  
!-----!

! The variable ipc is used as the bond price in the SALTER code. This should be replaced by the variable pbr for private bonds. Haven't thought about government bonds yet. !

VARIABLE pb #World private bond price#;

VARIABLE (All,r,REG) pbr(r) #Private bond price#;

VARIABLE (All,r,REG) prentb(r) #Rental price of bonds#;

VARIABLE (All,s,home) pk\_h\_\_(s) #Asset price of capital owned by region s#;

---

VARIABLE (CHANGE) (all,r,REG) rbr(r)  
# change in real bond rate, by region #;

VARIABLE (Orig\_Level=ASHHR)(all,r,REG) ahr(r)  
# household wealth, by region #;

VARIABLE (Orig\_Level=1)(all,r,REG) ipahr(r)  
# price index for private household wealth, by region #;

VARIABLE (change)(all,r,REG) rhr(r)  
#Rate of return on private wealth#;

VARIABLE (CHANGE) (all,r,REG) rbrpt(r)  
# change in post-tax real bond rate, by region #;

VARIABLE (CHANGE) rb  
# change in world real bond rate #;

VARIABLE (CHANGE) (all,r,REG) rer(r)  
# change in required rate of return on equity, by region #;

VARIABLE (CHANGE) (all,r,REG) frer(r)  
# change in shift in equity premium, by region #;

---

VARIABLE (CHANGE) (all,r,REG) ercrbr(r)

#change in expected rate of change in world bond rate, by region #;

VARIABLE (CHANGE) ercrb

#change in expected rate of change in world bond rate#;

VARIABLE (CHANGE) (all,r,REG) ercrer(r)

#change in expctd rate of change in reqrd rate of return on equity #;

VARIABLE (CHANGE) (all,r,REG) ercfrer(r)

#change in expected rate of change in equity premium #;

! Rate of return variables are percentage point changes, as in SALTER !

VARIABLE (change)(All,s,home) c\_rr\_h\_\_(s)

#Rate of return on capital owned by region s#;

VARIABLE (change)(All,s,home)(All,i,TRAD\_COMM) c\_rr\_h\_i(i,s)

#Rate of return on capital owned by region s in industry i globally#;

VARIABLE (change)(All,s,home)(All,i,TRAD\_COMM) c\_rrd\_h\_i(i,s)

#Rate of return on domestic capital#;

---

VARIABLE (change)(All,i,TRAD\_COMM)(All,s,home) c\_trrd\_h\_i(i,s)

#Post-tax c\_rrd\_h\_i#;

VARIABLE (change)(All,s,home)(All,i,TRAD\_COMM) c\_rrf\_h\_i(i,s)

#Rate of return on foreign capital owned by home region#;

VARIABLE (change)(All,s,home)(All,d,host)(All,i,TRAD\_COMM) c\_rr\_hhi(i,s,d)

#Rate of return on capital in industry i in region d owned by region s#;

VARIABLE (CHANGE) (all,r,REG) rar(r)

#change in average rate of abnormal return on capital, by region #;

VARIABLE (CHANGE) (all,r,REG) ercrkr(r)

#change in expected rate of change in rate of rtn on captl, by reg#;

VARIABLE (CHANGE) (all,i,TRAD\_COMM)(all,r,REG) rkri(i,r)

# change in rate of return on capital, by reg and industry#;

VARIABLE (CHANGE) (all,i,TRAD\_COMM)(all,r,REG) rari(i,r)

# change in rate of abnormal return on capital, by region and ind#;

VARIABLE (Orig\_Level=1)(all,r,REG) iper(r)

# equity price index, by region #;

---

VARIABLE (change)(All,s,home) c\_rr\_land(s)

#Rate of return on land#;

VARIABLE (change)(All,s,home) c\_rr\_natres(s)

#Rate of return on natural resources#;

VARIABLE (change)(All,d,host)(All,i,TRAD\_COMM) c\_rrf\_\_hi(i,d)

#Rate of return on foreign capital in destination region by industry#;

VARIABLE (change)(All,d,host) c\_rrf\_\_h\_(d)

#Rate of return on foreign capital in destination region#;

VARIABLE (change)(All,d,host) c\_rrd\_\_h\_(d)

#Rate of return on domestic capital by region#;

VARIABLE (change)(All,s,home)(All,d,host)(All,i,TRAD\_COMM) c\_trr\_hhi(i,s,d)

#Post tax c\_rr\_hhi#;

VARIABLE (change)(All,s,home) c\_trr\_land(s)

#Post tax c\_rr\_land#;

VARIABLE (change)(All,s,home) c\_trr\_natres(s)

#Post tax c\_rr\_natres#;

---

VARIABLE (Change)(All,i,TRAD\_COMM)(All,s,home) c\_VKD(i,s)

#Change in asset value of domestic capital stock in each industry#;

VARIABLE (Change)(All,i,TRAD\_COMM)(All,s,home)(All,d,host) c\_VFDI\_HHI(i,s,d)

#Change in asset value of FDI stock in each industry and host region#;

! Reciprocals of rates of return are defined as percentage change variables

so they can be used as prices in implicit updates !

VARIABLE (All,s,home)(All,i,TRAD\_COMM) r\_rrd\_h\_i(i,s)

#Reciprocal of c\_rrd\_h\_i#;

VARIABLE (All,s,home)(All,d,host)(All,i,TRAD\_COMM) r\_rr\_hhi(i,s,d)

#Reciprocal of c\_rr\_hhi#;

VARIABLE (All,s,home) r\_rr\_land(s) #Reciprocal of c\_rr\_land#;

VARIABLE (All,s,home) r\_rr\_natres(s) #Reciprocal of c\_rr\_natres#;

VARIABLE (All,s,home) r\_rbr(s) #Reciprocal of rbr# ;

VARIABLE (All,s,home) qhr(s) #Real private wealth#;

VARIABLE (All,s,home) qer(s) #Real equity#;

VARIABLE (All,s,home) qbr(s) #Real private bonds#;

---

!-----!  
! Macro variables !  
!-----!

VARIABLE (Orig\_Level=1)(all,r,REG) gnepi(r)

# price index for gross national expenditure #;

VARIABLE (Orig\_Level=GNEL)(all,r,REG) gner(r)

# gross national expenditure, real #;

VARIABLE (Orig\_Level=GNEL) (all,r,REG) gne(r)

# gross national expenditure #;

VARIABLE (Orig\_Level=PRIVEXP)(all,r,REG) ctr(r)

# real aggregate consumption # ;

VARIABLE (Orig\_Level=GDP)(all,r,REG) gdpe(r)

#expenditure on gross domestic product#;

VARIABLE(Orig\_Level=1) (all,r,REG) gdppi(r)

#price index for expend on GDP #;

VARIABLE (Orig\_Level=GDP)(all,r,REG) gdpr(r)



---

# real gdp #;

VARIABLE (Orig\_Level=GDP)(all,r,REG) gdpn(r)

# nominal GDP #;

VARIABLE (Orig\_Level=GNPL)(all,r,REG) gnp(r)

# gross national product #;

VARIABLE (Orig\_Level=WGPL) wgp

# world gross product (nominal) #;

VARIABLE (Orig\_Level=ASKP) wkt # world capital stock (real) #;

VARIABLE (Orig\_Level=WINVTT) winvtr # world investment (real) #;

VARIABLE (All,r,REG) bop(r);

VARIABLE (all,r,REG) wr(r) #real wage rate#;

VARIABLE (all,r,REG) qvar(r) #value-added of all inds in region r # ;

VARIABLE (all,r,REG) gdpfc(r) #GDP at factor cost#;

VARIABLE (Orig\_Level=YCHHDPR)(all,r,REG) ydr(r)

# real household disposable income #;

---

!-----!  
!                   Welfare Decomposition Variables                   !  
!-----!

VARIABLE (LINEAR,CHANGE) (all,r,REG)                   EV\_ALT(r)  
  
# expression for regional EV computed in alternative way # ;

VARIABLE (LINEAR,CHANGE)                   WEV\_ALT  
  
# expression for WEV computed in alternative way # ;

VARIABLE (CHANGE)(all,r,REG) grsub(r)  
  
# contrib of D in indirect tax/subs to % D in GRCOMT, by region #;  
  
!D = change!

VARIABLE (CHANGE)(all,r,REG) grint(r)  
  
# contrib of D in taxes on interm goods to %D in GRCOMT, by region #;

VARIABLE (CHANGE)(all,r,REG) grinv(r)  
  
# contrib of D in taxes on sales as invst to %D in GRCOMT, by reg#;

VARIABLE (CHANGE)(all,r,REG) grcon(r)  
  
#cont of D in tax on gds for pri hhold cons to %D in GRCOMT, by reg#;

VARIABLE (CHANGE)(all,r,REG) grexp(r)

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# contrib of D in export taxes to %D in GRCOMT, by region #;

VARIABLE (CHANGE)(all,r,REG) grgov(r)

#cont of D in tax on gds for govt cons to %D in GRCOMT, by region #;

VARIABLE (CHANGE)(all,r,REG) grdut(r)

# contrib of D in tariffs to %D in GRCOMT, by region #;

VARIABLE (CHANGE)(all,r,REG)                                grsub1(r)

# contrib of D in indirect tax/subs to % D in GRCOMT, by region #;

!D = change!

VARIABLE (CHANGE)(all,r,REG)                                grint1(r)

# contrib of D in taxes on interm goods to %D in GRCOMT, by region #;

VARIABLE (CHANGE)(all,r,REG)                                grinv1(r)

# contrib of D in taxes on sales as invst to %D in GRCOMT, by reg#;

VARIABLE (CHANGE)(all,r,REG)                                grcon1(r)

#cont of D in tax on gds for pri hhold cons to %D in GRCOMT, by reg#;

VARIABLE (CHANGE)(all,r,REG)                                grexpl(r)

# contrib of D in export taxes to %D in GRCOMT, by region #;

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VARIABLE (CHANGE)(all,r,REG)                                grgovl(r)

#cont of D in tax on gds for govt cons to %D in GRCOMT, by region #;

VARIABLE (CHANGE)(all,r,REG)                                grdutl(r)

# contrib of D in tariffs to %D in GRCOMT, by region #;

VARIABLE (Linear,Change) (All,r,REG) CNTbondr0(r)

# Contribution to regional EV of real bond holdings #;

VARIABLE (Linear,Change) (All,r,REG) CNTintrater(r)

#Contribution to regional EV of interest rates #;

!CNTintrate defined later after relevant SALTER data and variables are defined!

VARIABLE (Linear,Change) (All,r,REG) CNTbondr(r)

# Contr to reg EV of real bond holdings when using interest rate effect#;

VARIABLE (Linear,Change) (All,r,REG) CNTfyr(r)

# Contribution to regional EV of nominal foreign income#;

VARIABLE (LINEAR,CHANGE) (all,r,REG) CNTqor(r)

# Contrib to WEV of changes in outp of all NSAV_COMM from REG r # ;

VARIABLE (LINEAR,CHANGE) (all,i,NSAV_COMM)(all,r,REG) CNTqoir(i,r)

# Contrib to WEV of changes in output of NSAV_COMM i in REG r # ;

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VARIABLE (LINEAR,CHANGE) (all,r,REG) CNTqfer(r)

#Contrib to WEV of Ds in use of all ENDW\_COMM in all IND in REG r # ;

VARIABLE (LINEAR,CHANGE) (all,i,ENDW\_COMM)(all,r,REG) CNTqfeir(i,r)

#Contrib to WEV of Ds in use of ENDW\_COMM i in all IND in REG r # ;

VARIABLE (LINEAR,CHANGE) (all,j,PROD\_COMM)(all,r,REG) CNTqfejrr(j,r)

#Contrib to WEV of Ds in use of all ENDW\_COMM in IND j of REG r # ;

VARIABLE (LINEAR,CHANGE)

(all,i,ENDW\_COMM)(all,j,PROD\_COMM)(all,r,REG) CNTqfeijr(i,j,r)

#Contrib to WEV of Ds in use of ENDW\_COMM i in IND j of REG r # ;

VARIABLE (LINEAR,CHANGE) (all,r,REG) CNTqfmr(r)

#Contrib to WEV of Ds in use of imported int. in all IND in REG r # ;

VARIABLE (LINEAR,CHANGE) (all,i,TRAD\_COMM)(all,r,REG) CNTqfmir(i,r)

#Contrib to WEV of Ds in use of imported int. i in all IND in REG r#;

VARIABLE (LINEAR,CHANGE) (all,j,PROD\_COMM)(all,r,REG) CNTqfmjrr(j,r)

#Contrib to WEV of Ds in use of imported int. in IND j of REG r # ;

VARIABLE (LINEAR,CHANGE)

---

(all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG) CNTqfmijr(i,j,r)

#CONTRIB TO WEV OF Ds IN USE OF IMPORTED INT. I IN IND J OF REG R # ;

VARIABLE (LINEAR,CHANGE) (all,r,REG) CNTqfdr(r)

#Contrib to WEV of Ds in use of domestic int. in all IND in REG r # ;

VARIABLE (LINEAR,CHANGE) (all,i,TRAD\_COMM)(all,r,REG) CNTqfdir(i,r)

#Contrib to WEV of Ds in use of domestic int. i in all IND in REG r # ;

VARIABLE (LINEAR,CHANGE) (all,j,PROD\_COMM)(all,r,REG) CNTqfdjr(j,r)

#Contrib to WEV of Ds in use of domestic int. in IND j of REG r # ;

VARIABLE (LINEAR,CHANGE)

(all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG) CNTqfdijr(i,j,r)

#Contrib to WEV of Ds in use of domestic int i in IND j of REG r # ;

VARIABLE (LINEAR,CHANGE) (all,r,REG) CNTqpmr(r)

#Contrib to WEV of Ds in consumption of imported goods in REG r # ;

VARIABLE (LINEAR,CHANGE) (all,i,TRAD\_COMM)(all,r,REG) CNTqpmir(i,r)

#Contrib to WEV of changes in cons of imported good i in REG r # ;

VARIABLE (LINEAR,CHANGE) (all,r,REG) CNTqpdr(r)

#Contrib to WEV of changes in cons of domestic goods in REG r # ;

---

VARIABLE (LINEAR,CHANGE) (all,i,TRAD\_COMM)(all,r,REG) CNTqpdir(i,r)

#Contrib to WEV of changes in cons of domestic good i in REG r # ;

VARIABLE (LINEAR,CHANGE) (all,r,REG) CNTqgmr(r)

#Contrib to WEV of changes in gov't cons of imports in REG r # ;

VARIABLE (LINEAR,CHANGE) (all,i,TRAD\_COMM)(all,r,REG) CNTqgmir(i,r)

#Contrib to WEV of changes in gov't cons of import i in REG r # ;

VARIABLE (LINEAR,CHANGE) (all,r,REG) CNTqgdr(r)

#Contrib to WEV of changes in gov't cons of domestics in REG r # ;

VARIABLE (LINEAR,CHANGE) (all,i,TRAD\_COMM)(all,r,REG) CNTqgdir(i,r)

#Contrib to WEV of changes in gov't cons of domestic i in REG r # ;

VARIABLE (LINEAR,CHANGE) (all,r,REG) CNTqxsr(r)

#Cont to WEV of changes in exps of all gds from SRCE r to all DEST #;

VARIABLE (LINEAR,CHANGE) (all,i,TRAD\_COMM)(all,r,REG) CNTqxsir(i,r)

#Contrib to WEV of changes in exps of i from SRCE r to all DEST # ;

VARIABLE (LINEAR,CHANGE) (all,r,REG)(all,s,REG) CNTqxsrs(r,s)

#Cont to WEV of changes in exps of all goods from SRCE r to DEST s #;

---

VARIABLE (LINEAR,CHANGE)

(all,i,TRAD\_COMM)(all,r,REG)(all,s,REG) CNTqxsirs(i,r,s)

# Contrib. to WEV of changes in exports of i from SRCE r to DEST s#;

VARIABLE (LINEAR,CHANGE) (all,r,REG) CNTqimr(r)

#Cont to WEV of changes in imps of all gds from all SRCE to DEST r #;

VARIABLE (LINEAR,CHANGE) (all,i,TRAD\_COMM)(all,r,REG) CNTqimir(i,r)

#Contrib to WEV of changes in imps of i from all SRCE to DEST r # ;

VARIABLE (LINEAR,CHANGE) (all,s,REG)(all,r,REG) CNTqimsr(s,r)

#Cont to WEV of changes in imps of all goods from SRCE s to DEST r #;

VARIABLE (LINEAR,CHANGE)

(all,i,TRAD\_COMM)(all,s,REG)(all,r,REG) CNTqimisr(i,s,r)

#Contrib to WEV of changes in imps of i from SRCE s to DEST r#;

VARIABLE (Linear,Change) (All,r,REG) CNTalleffdi(r)

#Contrib to regional EV from alloc. eff. between for. & dom. industries#;

VARIABLE (LINEAR,CHANGE) (all,r,REG) CNTalleffr(r)

# Total contribution to regional EV of allocative effects # ;



---

VARIABLE (LINEAR,CHANGE) (all,i,TRAD\_COMM) (all,r,REG) CNTalleffir(i,r)

# Total contribution to regional EV of allocative effects # ;

VARIABLE (LINEAR,CHANGE) (all,r,REG) CNTtotr(r)

# Contribution to regional EV of changes in its terms of trade # ;

! Note that the capital account component of this change has now been  
removed and placed in a new term. !

VARIABLE (LINEAR,CHANGE) (all,r,REG) CNTcgdsr(r)

# Contribution to regional EV of changes in the price of cgds # ;

VARIABLE (Linear,Change) (All,r,REG) CNTror(r)

# Contribution to regional EV of rate of return changes for FDI assets#;

VARIABLE (Linear,Change) (All,r,REG) CNTcapr(r)

# Contribution to regional EV of stock changes for FDI assets#;

VARIABLE (Linear,Change) (All,r,REG) CNTpcapr(r)

# Contribution to regional EV of asset price changes for FDI assets#;

VARIABLE (Linear,Change) (All,r,REG) CNTpricer0(r)

# Contribution to regional EV of all price changes #;

VARIABLE (Linear,Change) (All,r,REG) CNTpricer1(r)

---

# Contr to reg EV of all price changes when using interest rate effect#;

VARIABLE (Linear,Change) (All,r,REG) CNTpbr(r)

# Contribution to regional EV of asset price of bonds#;

VARIABLE (Linear,Change) (All,r,REG) CNTpricer(r)

# Contr to reg EV of all price changes under FDI extension#;

VARIABLE (LINEAR,CHANGE) (all,r,REG) CNTendwr(r)

# Contribution to regional EV of changes in all ENDW\_COMM # ;

VARIABLE (LINEAR,CHANGE) (all,i,ENDW\_COMM)(all,r,REG) CNTendwir(i,r)

# Contribution to regional EV of changes in ENDW\_COMM i # ;

VARIABLE (LINEAR,CHANGE) (all,r,REG) CNTtechr(r)

# Contribution to regional EV of all technical change # ;

VARIABLE (LINEAR,CHANGE) (all,r,REG) CNTtech\_aor(r)

#Contrib to regional EV of output augmenting technical change# ;

VARIABLE (LINEAR,CHANGE) (all,i,PROD\_COMM)(all,r,REG)

CNTtech\_aoir(i,r)

#Cont to reg EV of output augmenting tech change in TRAD\_COMM i # ;

---

VARIABLE (LINEAR,CHANGE) (all,r,REG) CNTtech\_afer(r)

#Contrib to reg EV of primary factor augmenting tech change # ;

VARIABLE (LINEAR,CHANGE) (all,i,ENDW\_COMM)(all,r,REG) CNTtech\_afeir(i,r)

# Cont. to regional EV of primary factor i augmenting tech change# ;

VARIABLE (LINEAR,CHANGE) (all,j,PROD\_COMM)(all,r,REG) CNTtech\_afejr(j,r)

#Cont to EV of prim factor augmenting tech change in sector j # ;

VARIABLE (LINEAR,CHANGE)

(all,i,ENDW\_COMM)(all,j,PROD\_COMM)(all,r,REG) CNTtech\_afeijr(i,j,r)

#Cont to EV of primary factor i augmenting tech change in sector j #;

VARIABLE (LINEAR,CHANGE) (all,r,REG) CNTtech\_avar(r)

#Contrib to reg EV of value added augmenting tech change # ;

VARIABLE (LINEAR,CHANGE) (all,i,ENDW\_COMM)(all,r,REG) CNTtech\_avair(i,r)

#Cont to EV of value added augmenting tech change for ENDW\_COMM i # ;

VARIABLE (LINEAR,CHANGE) (all,j,PROD\_COMM)(all,r,REG) CNTtech\_avajr(j,r)

# Cont. to EV of value added augmenting tech change in sector j # ;

VARIABLE (LINEAR,CHANGE)

(all,i,ENDW\_COMM)(all,j,PROD\_COMM)(all,r,REG) CNTtech\_avaijr(i,j,r)

---

#Cont. to EV of VA augmenting tech D for ENDW\_COMM i in sect j # ;

!D is used to represent change from this point onwards!

VARIABLE (LINEAR,CHANGE) (all,r,REG) CNTtech\_afr(r)

# Cont. to regional EV of comp. int. input augmenting tech change# ;

VARIABLE (LINEAR,CHANGE) (all,j,PROD\_COMM)(all,r,REG) CNTtech\_afjr(j,r)

#Cont to EV of comp. int. input augmenting tech change in sector j #;

VARIABLE (LINEAR,CHANGE) (all,i,TRAD\_COMM)(all,r,REG) CNTtech\_afir(i,r)

# Cont. to EV of composite int. i input augmenting tech change # ;

VARIABLE (LINEAR,CHANGE)

(all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG) CNTtech\_afijr(i,j,r)

#Cont to EV of composite int. i input augmenting tech D in sect j # ;

VARIABLE (LINEAR,CHANGE) (all,r,REG) CNTtech\_attr(r)

#Contrib to regional EV of technical change in transportation # ;

VARIABLE (LINEAR,CHANGE) (all,i,TRAD\_COMM)(all,r,REG) CNTtech\_atrir(i,r)

# Cont. to EV of technical change in transportation of TRAD\_COMM i#;

VARIABLE (LINEAR,CHANGE) (all,s,REG)(all,r,REG) CNTtech\_atrsr(s,r)

# Cont. to EV of technical change in transportation to DEST s # ;

---

VARIABLE (LINEAR,CHANGE)

(all,i,TRAD\_COMM)(all,s,REG)(all,r,REG) CNTtech\_atrisr(i,s,r)

#Cont. to EV of tech change in transpN of TRAD\_COMM i to DEST s # ;

VARIABLE (LINEAR,CHANGE) (all,r,REG) CNTkbr(r)

#Cont to EV of changes to beg. period cap stock and depreciation # ;

VARIABLE (LINEAR,CHANGE) (all,r,REG) CNT\_MUr(r)

# Contribution to EV of marginal utility of income # ;

VARIABLE (LINEAR,CHANGE) (all,i,TRAD\_COMM) (all,r,REG) CNT\_MUir(i,r)

# Contribution to EV of marginal utility of income from good i # ;

VARIABLE (Change)(All,i,TRAD\_COMM)(All,s,HOME)(All,d,host) CNTror\_hhi(i,s,d)

#Contr. of ror on foreign capital, by sector and host, to EV #;

VARIABLE (Change)(All,i,TRAD\_COMM)(All,s,HOME) CNTror\_h\_i(i,s)

#Contr. of ror on foreign capital, by sector, to EV #;

VARIABLE (Change)(All,i,TRAD\_COMM)(All,d,host) CNTror\_\_hi(i,d)

#Contr. of ror on foreign owned capital, by sector, to EV #;

VARIABLE (Change)(All,s,HOME)(All,d,host) CNTror\_hh\_(s,d)

---

#Contr. of ror on foreign capital, by host, to EV #;

VARIABLE (Change)(All,d,host) CNTror\_\_h\_(d)

#Contr. of ror on foreign owned capital to EV #;

VARIABLE (Change)(All,s,HOME) CNTror\_h\_\_(s)

#Contr. of ror on foreign capital to EV #;

VARIABLE (Change)(All,i,TRAD\_COMM)(All,s,HOME)(All,d,host) CNTcap\_hhi(i,s,d)

#Contr. of foreign capital change, by sector and host, to EV #;

VARIABLE (Change)(All,i,TRAD\_COMM)(All,d,host) CNTcap\_\_hi(i,d)

#Contr. of foreign owned capital change, by sector, to EV #;

VARIABLE (Change)(All,i,TRAD\_COMM)(All,s,HOME) CNTcap\_h\_i(i,s)

#Contr. of foreign capital change, by sector, to EV #;

VARIABLE (Change)(All,s,HOME)(All,d,host) CNTcap\_hh\_(s,d)

#Contr. of foreign capital change, by host, to EV #;

VARIABLE (Change)(All,d,host) CNTcap\_\_h\_(d)

#Contr. of foreign owned capital change to EV #;

VARIABLE (Change)(All,s,HOME) CNTcap\_h\_\_(s)

---

#Contr. of foreign capital change to EV #;

VARIABLE (Change)(All,i,TRAD\_COMM)(All,s,HOME)(All,d,host) CNTpcap\_hhi(i,s,d)

#Contr. of foreign asset price, by sector and host, to EV #;

VARIABLE (Change)(All,i,TRAD\_COMM)(All,d,host) CNTpcap\_\_hi(i,d)

#Contr. of domestic asset price, by sector, to EV #;

VARIABLE (Change)(All,i,TRAD\_COMM)(All,s,HOME) CNTpcap\_h\_i(i,s)

#Contr. of foreign asset price, by sector, to EV #;

VARIABLE (Change)(All,s,HOME)(All,d,host) CNTpcap\_hh\_(s,d)

#Contr. of foreign asset price, by host, to EV #;

VARIABLE (Change)(All,d,host) CNTpcap\_\_h\_(d)

#Contr. of domestic asset price to EV #;

VARIABLE (Change)(All,s,HOME) CNTpcap\_h\_\_(s)

#Contr. of foreign asset price to EV #;

VARIABLE (Change)(All,s,HOME) check\_EV\_FDI(s);

VARIABLE (Change)(All,r,REG) CNTanto\_h\_\_(r)

#Contr to EV from abnormal RoR arising from output impediments#;

---

VARIABLE (Change)(All,r,REG) CNTango\_h\_\_(r)

#Contr of growth of capital to EV via output impediments#;

VARIABLE (Change)(All,r,REG) CNTanpo\_h\_\_(r)

#Contr of asset price of capital to EV via output impediments#;

VARIABLE (Change)(All,i,TRAD\_COMM)(All,s,HOME)(All,d,host) CNTanrr\_hhi(i,s,d)

#Contribution to EV of abnormal component of RoR by home, host and region#;

VARIABLE (Change)(All,i,TRAD\_COMM)(All,s,HOME)(All,d,host) CNTanend\_hhi(i,s,d)

#Abnormal contribution to EV of endowment growth by home, host and region#;

VARIABLE (Change)(All,i,TRAD\_COMM)(All,s,HOME)(All,d,host) CNTanpk\_hhi(i,s,d)

#Abnormal contribution to EV of asset price of CAP by home, host and region# ;

VARIABLE (Change)(All,i,TRAD\_COMM)(All,r,REG) CNTqfed\_i(i,r)

#Contr to EV of alloc eff from domestic cap allocation by industry#;

VARIABLE (Change)(All,r,REG) CNTqfed(r)

#Contr to EV of alloc eff from domestic cap allocation#;

VARIABLE (Change)(All,i,TRAD\_COMM)(All,s,HOME)(All,d,host) CNTqfes\_hhi(i,s,d)

#Contr to EV of all eff from foreign cap allocation by industry, home & host#;



---

VARIABLE (Change)(All,i,TRAD\_COMM)(All,d,host) CNTqfes\_\_hi(i,d)

#Contr to EV of all eff from foreign cap allocation by industry & host#;

VARIABLE (Change)(All,d,host) CNTqfes\_\_h\_(d)

#Contr to EV of all eff from foreign cap allocation by host#;

VARIABLE (Change)(All,r,REG) CNTanrr\_h\_\_(r)

#Contribution to EV of abnormal component of RoR by home#;

VARIABLE (Change)(All,r,REG) CNTanend\_h\_\_(r)

#Abnormal contribution to EV of endowment growth by home#;

VARIABLE (Change)(All,r,REG) CNTanpk\_h\_\_(r)

#Abnormal contribution to EV of asset price of capital by home#;

VARIABLE (LINEAR,CHANGE) (all,r,REG) check\_EV(r)

# Difference of EV and the sum of contributions: should be zero#;

VARIABLE (Change)(All,i,TRAD\_COMM)(All,s,HOME)(All,d,host) anrrk\_hhi(i,s,d)

#abnormal component of RoR on FDI capital for welf decomp terms#;

VARIABLE (Change)(All,i,TRAD\_COMM)(All,s,HOME)(All,d,host) anrr\_hhi(i,s,d)

#abnormal component of rate of return on FDI capital by home, host and ind #;

---

VARIABLE (Change)(All,i,TRAD\_COMM)(All,r,REG) anrrd\_h\_i(i,r)

#abnormal component of rate of return on domestic capital by reg. and ind # ;

VARIABLE (Change)(All,i,COM)(All,s,SRC)(All,j,IND) alleff\_csi(i,s,j);

VARIABLE (Change)(All,i,ENDW\_COMM)(All,j,IND) alleff\_ei(i,j);

VARIABLE (Change)(All,j,IND) alleff\_o(j);

VARIABLE (Change)

(All,c,TRAD\_COMM)(All,i,FDI\_COMM)(All,r,FDI\_DEST) falleffd\_ci(c,i,r);

VARIABLE (Change)

(All,c,TRAD\_COMM)(All,i,FDI\_COMM)(All,r,FDI\_DEST) falleffi\_ci(c,i,r);

VARIABLE (Change)

(All,c,ENDW\_COMM)(All,i,FDI\_COMM)(All,r,FDI\_DEST) falleff\_ei(c,i,r);

VARIABLE (Change)(All,i,FDI\_COMM)(All,r,FDI\_DEST) falleff\_o(i,r);

VARIABLE (Change)(All,r,FDI\_DEST) falleff(r);

VARIABLE (Change)(All,r,FDI\_DEST) falleffd\_t(r);

VARIABLE (Change)(All,r,FDI\_DEST) falleffi\_t(r);

VARIABLE (Change)(All,r,FDI\_DEST) falleff\_ot(r);

VARIABLE (Change)(All,r,FDI\_DEST) falleff\_et(r);

VARIABLE (LINEAR,CHANGE) (all,r,REG) galleffr(r);

! Welfare decomposition for rentals from output impediments. !

VARIABLE

---

(Change)(All,i,TRAD\_COMM)(All,s,HOME)(All,d,host) CNTanto\_hhi(i,s,d)

#Contr to EV from contr of output impediment rents to abnormal RoR#;

(Change)(All,i,TRAD\_COMM)(All,s,HOME)(All,d,host) CNTanqo\_hhi(i,s,d)

#Contr to EV of endowment effect from output impediment rents#;

(Change)(All,i,TRAD\_COMM)(All,s,HOME)(All,d,host) CNTanpo\_hhi(i,s,d)

#Contr to EV of asset price effect from output impediment rents#;

!-----!  
!  
! Variables for checking !  
!-----!

VARIABLE (All,r,REG) check\_grdut(r);

VARIABLE (All,r,REG) check\_grexp(r);

VARIABLE (All,r,REG) check\_grsub(r);

VARIABLE (All,r,REG) check\_grcon(r);

VARIABLE (All,r,REG) check\_grgov(r);

VARIABLE (All,r,REG) check\_grint(r);

VARIABLE (All,r,REG) check\_grinv(r);

VARIABLE (All,r,REG) check\_inctax(r);

VARIABLE (All,r,REG) check\_captax(r);

VARIABLE (All,r,REG) check\_capinc(r);

VARIABLE (All,r,REG) check\_labtax(r);

VARIABLE (All,r,REG) check\_qgdp(r);

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```

VARIABLE      (All,r,REG) check_vgdp(r);

VARIABLE      (All,r,REG) check_pgdp(r);

VARIABLE      (Change)(All,i,FDI_COMM)(All,r,FDI_DEST)      check_oct(i,r);

VARIABLE      (All,i,FDI_COMM)(All,s,HOME)(All,d,FDI_DEST)      see_foct(i,s,d)

#Ratio of foreign-owned ind total costs/(total costs-other costs) (CRUSOE)#;

VARIABLE      (All,i,FDI_COMM)(All,r,FDI_DEST)      see_doct(i,r)

#Ratio of domestic ind total costs/(total costs-other costs) (CRUSOE)#;

VARIABLE      (All,i,TRAD_COMM)(All,j,FDI_COMM)(All,r,FDI_DEST) check_vdfa(i,j,r);

VARIABLE      (All,i,TRAD_COMM)(All,j,FDI_COMM)(All,r,FDI_DEST) check_vdfm(i,j,r);

VARIABLE      (All,i,TRAD_COMM)(All,j,FDI_COMM)(All,r,FDI_DEST) check_vifa(i,j,r);

VARIABLE      (All,i,TRAD_COMM)(All,j,FDI_COMM)(All,r,FDI_DEST) check_vifm(i,j,r);

VARIABLE      (All,c,ENDW_COMM)(All,j,FDI_COMM)(All,r,FDI_DEST) check_evfa(c,j,r);

VARIABLE      (All,i,FDI_COMM)(All,r,FDI_DEST)      check_voa(i,r);

VARIABLE      (All,c,TRAD_COMM)(All,j,FDI_COMM)(All,r,FDI_DEST) check_vfa(c,j,r);

VARIABLE      (All,r,REG)      check_rc(r);

VARIABLE      (All,i,TRAD_COMM)(All,s,SOURCE)(All,d,DEST)      check_qisd(i,s,d);

VARIABLE      (All,i,TRAD_COMM)(All,s,SOURCE)(All,d,DEST)      check_pisd(i,s,d);

VARIABLE      (All,i,TRAD_COMM)(All,o,HOME)(All,l,HOST)(All,d,DEST)

                                                    check_frt(i,o,l,d)

#Checking calculation of freight margin for expanded trade matrices#;

VARIABLE      (All,i,TRAD_COMM)(All,d,DEST) check_pid(i,d) #Check pid=pim#;

```

---

!-----!  
! Variables of the CRUSOE model !  
!-----!

! CRUSOE: a simplified General Equilibrium Model adapted to GTAP data !

! Variables relating to commodity flows !

Variable

! Basic Demands for commodities !

(All,c,COM)(All,s,SRC)(All,i,IND) x1(c,s,i) #Demands: Intermediate#;

! FTAP CHANGE: CRUSOE variable p0 will need an industry dimension as

CRUSOE set IND = FTAP set of FDI industries. The latter  
set may include activities in more than one region.

Therefore both the domestic and imported basic price of  
a particular commodity may vary across

CRUSOE industries = FTAP FDI industries.

!

(All,c,COM)(All,s,SRC)(All,i,IND)

p0(c,s,i) #basic price of commodity c, source s#;

! Powers of Commodity Taxes on Basic Flows !

(All,c,COM)(All,s,SRC)(All,i,IND)

---

```

t1(c,s,i) #Power of Commodity Tax:Intermediate#;

! Purchaser's Prices !

(All,c,COM)(All,s,SRC)(All,i,IND) p1(c,s,i) #Purchasers Prices: Intermediate#;

! .....!

! Variables for primary-factor flows, commodity supplies and import duties !

! .....!

! Variables relating to usage of labour in industry i !

(All,i,IND)          xllab(i)      #Employment#;

(All,i,IND)(All,l,LABOR) xllab_s(i,l) #Employment by skill#;

(All,i,IND)          pllabor(i)    #Wage#;

(All,i,IND)(All,l,LABOR) pllabor_s(i,l) #Wage by skill#;

! Variables relating to usage of fixed capital in industry i !

(All,i,IND) x1cap(i) #Current Capital Stock#;

(All,i,IND) p1cap(i) #Rental Price of Capital#;

! Variables relating to usage of land !

(All,i,IND) x1lnd(i) #Use of Land#;

(All,i,IND) p1lnd(i) #Rental Price of Land#;

! Variables relating to usage of natural resources !

(All,i,IND) x1nr(i) #Use of natural resources#;

(All,i,IND) p1nr(i) #Rental Price of natural resources#;

```

---

```

!.....!
!           Variables relating to "Other Costs"           !
! Represent other costs as a change in the ratio of total costs      !
! including other costs to total costs excluding other costs      !
!.....!

```

```
(All,i,IND) p_rloct(i)
```

```
#Ratio of other costs incl. to other cost excl. total costs#;
```

```

!.....!
!           Variables describing composite commodities           !
!.....!

```

```
! Demands for import/domestic commodity composites !
```

```
(All,c,COM)(All,i,IND) x1_s(c,i) #Quantity imp/dom composite: Intermediate#;
```

```
! Effective Prices of import/domestic commodity composites !
```

```
(All,c,COM)(All,i,IND) p1_s(c,i) #Price imp/dom composite: Intermediate#;
```

```

!.....!
!           Miscellaneous vector variables           !

```

!.....!

Variable

- (All,i,IND) alprim(i) #All Factor Augmenting Technical Change#;
- (All,i,IND) altot(i) #All Input Augmenting Technical Change#;
- (All,i,IND) plprim(i) #Effective Price of Primary Factor Composite#;
- (All,i,IND) pltot(i) #Average Input/Output Price#;
- (All,i,IND) f\_pltot(i) #Slack variable on zero pure profits condition#;
- (All,i,IND) pltot\_eo(i) #Average Input/Output Price excluding other costs#;
- (All,i,IND) xlprim(i) #Primary Factor Composite#;
- (All,i,IND) xltot(i) #Activity Level or Value-Added#;

!-----!

! DATA BASE !

!-----!

!.....!

! The BASE DATA are divided into four sections: base revenues / expenditures at agent's prices, base revenues / expenditures at market prices, and base revenues /expenditures at world prices for all tradeable commodities, followed by the technology and preference parameters. Since these are invariant for each solution of the model, they are termed coefficients. Coefficients are assigned upper case to



---

distinguish them from variables. (Again, this is purely cosmetic, as GEMPACK is not case sensitive.)

The updating command indicates how the new level of the coefficient will be computed based on the previous Johansen solution. Note that the notation used in the update commands is a shorthand for total differentials of these coefficient values. Thus,  $w * v$  indicates that we want to take the total differential of  $W * V$ , plug in the calculated values of  $w$  and  $v$ , and add this to the base level in order to obtain a revised value for this product. Finally, the technology & preference parameters do not change at all and so require no update statement. !

```
!.....!  
  
!.....!  
  
!           Base revenues and expenditures at agent's prices           !  
  
!.....!
```

```
COEFFICIENT (GE 0)(all,i,ENDW_COMM)(all,r,REG)           EVOA(i,r)
```

```
! value of commodity i output in region r. ! ;
```

```
UPDATE (all,i,NONCAP_COMM)(all,r,REG)
```

```
EVOA(i,r) = ps(i,r) * qo(i,r) ;
```

```
UPDATE (all,i,ENDWC_COMM)(all,r,REG)
```

```
EVOA(i,r) = ps(i,r) * kr(r) ;
```

---

COEFFICIENT (GE 0)(all,i,ENDW\_COMM)(all,j,PROD\_COMM)(all,r,REG)

EVFA(i,j,r)

! producer expenditure on i by industry j,  
in region r, valued at agent's prices ! ;

UPDATE (all,i,ENDW\_COMM)(all,j,PROD\_COMM)(all,r,REG)

EVFA(i,j,r) = pfe(i,j,r) \* qfe(i,j,r) ;

COEFFICIENT (GE 0)(all,r,REG) SAVE(r)

!original GTAP savings data!;

UPDATE (all,r,REG) SAVE(r) = psave(r) \* qsave(r) ;

COEFFICIENT (GE 0)(all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

VDFA(i,j,r)

! purchases of domestic i for use in j  
in region r ! ;

UPDATE (all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

VDFA(i,j,r) = pfd(i,j,r) \* qfd(i,j,r) ;

COEFFICIENT (GE 0)(all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

VIFA(i,j,r)

! purchases of imported i r for use in j  
in region r ! ;

UPDATE (all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

VIFA(i,j,r) = pfm(i,j,r) \* qfm(i,j,r) ;

---

COEFFICIENT (GE 0)(all,i,TRAD\_COMM)(all,r,REG) VDPA(i,r)

! private household expenditure on domestic i in r ! ;

UPDATE (all,i,TRAD\_COMM)(all,r,REG)

VDPA(i,r) = ppd(i,r) \* qpd(i,r) ;

COEFFICIENT (GE 0)(all,i,TRAD\_COMM)(all,r,REG) VIPA(i,r)

! private household expenditure on imported i ! ;

UPDATE (all,i,TRAD\_COMM)(all,r,REG)

VIPA(i,r) = ppm(i,r) \* qpm(i,r) ;

COEFFICIENT (GE 0)(all,i,TRAD\_COMM)(all,r,REG) VDGA(i,r)

! government household expenditure on domestic i in r ! ;

UPDATE (all,i,TRAD\_COMM)(all,r,REG)

VDGA(i,r) = pgd(i,r) \* qgd(i,r) ;

COEFFICIENT (GE 0)(all,i,TRAD\_COMM)(all,r,REG) VIGA(i,r)

! government household expenditure on imported i ! ;

UPDATE (all,i,TRAD\_COMM)(all,r,REG)

VIGA(i,r) = pgm(i,r) \* qgm(i,r) ;

! .....

! Base revenues and expenditures at market prices !

---

!.....!

COEFFICIENT (GE 0)(all,i,TRAD\_COMM)(all,r,SOURCE)(all,s,DEST) VXMD(i,r,s)

! exports of commodity i from region r to  
destination s valued at market prices  
(tradeables only) ! ;

UPDATE (all,i,TRAD\_COMM)(all,r,REG)(all,s,REG)

VXMD(i,r,s) = pxs(i,r,s) \* qxs(i,r,s) ;

COEFFICIENT (GE 0)(all,i,TRAD\_COMM)(all,r,REG) VST(i,r)

! exports of commodity i from region r for  
international transportation valued at market prices  
(tradeables only) ! ;

UPDATE (all,i,TRAD\_COMM)(all,r,REG) VST(i,r) = pst(i,r) \* qst(i,r) ;

COEFFICIENT (GE 0)(all,i,ENDW\_COMM)(all,j,PROD\_COMM)(all,r,REG) VFM(i,j,r)

! producer expenditure on i by industry j,  
in region r, valued at market prices ! ;

UPDATE (all,i,ENDWM\_COMM)(all,j,PROD\_COMM)(all,r,REG)

VFM(i,j,r) = pm(i,r) \* qfe(i,j,r) ;

UPDATE (all,i,ENDWC\_COMM)(all,j,TRAD\_COMM)(all,r,REG)

VFM(i,j,r) = rp(j,r) \* qfe(i,j,r) ;

UPDATE (all,i,ENDWS\_COMM)(all,j,PROD\_COMM)(all,r,REG)

VFM(i,j,r) = pmes(i,j,r) \* qfe(i,j,r) ;

---

COEFFICIENT (GE 0)(all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

VIFM(i,j,r)

! purchases of imports i for use in j in region r ! ;

UPDATE (all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

VIFM(i,j,r) = pid(i,r) \* qfm(i,j,r) ;

COEFFICIENT (GE 0)(all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

VDFM(i,j,r)

! purchases of domestic i for use in j in region r ! ;

UPDATE (all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

VDFM(i,j,r) = pds(i,r) \* qfd(i,j,r) ;

COEFFICIENT (GE 0)(all,i,TRAD\_COMM)(all,r,REG)

VIPM(i,r)

! private household expenditure on i in r ! ;

UPDATE (all,i,TRAD\_COMM)(all,r,REG)

VIPM(i,r) = pid(i,r) \* qpm(i,r) ;

COEFFICIENT (GE 0)(all,i,TRAD\_COMM)(all,r,REG)

VDPM(i,r)

! private household expenditure on domestic i in r ! ;

UPDATE (all,i,TRAD\_COMM)(all,r,REG)

VDPM(i,r) = pds(i,r) \* qpd(i,r) ;

COEFFICIENT (GE 0)(all,i,TRAD\_COMM)(all,r,REG)

VIGM(i,r)

---

```

! gov't household expenditure on i in r ! ;

UPDATE (all,i,TRAD_COMM)(all,r,REG)

VIGM(i,r) = pid(i,r) * qgm(i,r) ;

COEFFICIENT (GE 0)(all,i,TRAD_COMM)(all,r,REG)          VDGM(i,r)

! government household expenditure on domestic i in r ! ;

UPDATE (all,i,TRAD_COMM)(all,r,REG)

VDGM(i,r) = pds(i,r) * qgd(i,r) ;

COEFFICIENT (GE 0)(all,i,TRAD_COMM)(all,r,REG)(all,s,REG) VIMS(i,r,s)

! imports of commodity i from region r to s, valued

at domestic market prices ! ;

UPDATE (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)

VIMS(i,r,s) = pms(i,r,s) * qxs(i,r,s) ;

! .....!

!      FDI module:      COEFFICIENT for reading Data in      !

! .....!

COEFFICIENT (all,r,REG) ASBDR(r) # net ownership of bonds, by reg #;

COEFFICIENT (All,i,TRAD_COMM)(All,s,REG)(All,d,REG)          EVIFMS(i,s,d)

#Market value of foreign capital by home region and industry#;

```

---

```

UPDATE (All,i,TRAD_COMM)(All,s,home)(All,d,host)

EVIFMS(i,s,d)=rps(i,s,d)*qfes(i,s,d);

COEFFICIENT (All,i,TRAD_COMM)(All,s,home)(All,d,host) EVIFAS(i,s,d)

#agents' value of foreign capital by home region and industry#;

UPDATE (All,i,TRAD_COMM)(All,s,home)(All,d,host)

EVIFAS(i,s,d)=pfesa(i,s,d)*qfes(i,s,d);

COEFFICIENT (All,i,TRAD_COMM)(All,s,home)(All,d,host) VFDD_HHI(i,s,d)

#Asset value of FDI stock in each industry and host region#;

UPDATE (All,s,home)(All,d,host)(All,i,TRAD_COMM)

VFDD_HHI(i,s,d)=pcgds(d)*k_hhi(i,s,d);

COEFFICIENT (All,i,TRAD_COMM)(All,s,home) VKD(i,s)

#Asset value of domestic capital stock by industry#;

UPDATE (All,s,home)(All,i,TRAD_COMM) VKD(i,s)=pcgds(s)*kd_h_i(i,s);

COEFFICIENT (All,i,TRAD_COMM)(All,r,REG) DEPRIND(i,r)

#Industry specific depreciation rate#;

COEFFICIENT (All,s,home)(All,i,TRAD_COMM) VKD_H_I(i,s)

#Petri asset value of domestic capital by industry and home region#;

UPDATE (All,s,home)(All,i,TRAD_COMM) VKD_H_I(i,s)=r_rrd_h_i(i,s)*kd_h_i(i,s);

```

---

COEFFICIENT (All,s,home)(All,d,host)(All,i,TRAD\_COMM) VK\_HHI(i,s,d)

#Petri asset value of capital by industry and home region#;

UPDATE (All,s,home)(All,d,host)(All,i,TRAD\_COMM)

VK\_HHI(i,s,d)=r\_rr\_hhi(i,s,d)\*k\_hhi(i,s,d);

COEFFICIENT (All,s,home) VBR(s)

#Petri asset value of private bonds#;

UPDATE (All,s,home) VBR(s)=r\_rbr(s)\*qbr(s);

COEFFICIENT (All,s,home) VLAND(s)

#Petri asset value of land#;

UPDATE (All,s,home) VLAND(s)=r\_rr\_land(s)\*mt(s);

COEFFICIENT (All,s,home) VNATRES(s)

#Petri asset value of natural resources#;

UPDATE (All,s,home) VNATRES(s)=r\_rr\_natres(s)\*nru(s);

COEFFICIENT (All,s,home) KTRA\_H\_\_(s)

#Transformation elasticity between bonds, capital and land#;

COEFFICIENT (All,s,home)(All,i,TRAD\_COMM) KTRA\_H\_I(i,s)

#CRETH transformation parameter for capital allocation by industry#;

COEFFICIENT (All,s,home)(All,i,TRAD\_COMM) KTRAD\_H\_I(i,s)



---

```

#CRETH transformation parameter for domestic capital in each industry#;

COEFFICIENT (All,s,home)(All,i,TRAD_COMM) KTRAF_H_I(i,s)

#CRETH transformation parameter for foreign capital in each industry#;

COEFFICIENT (All,s,home)(All,d,host)(All,i,TRAD_COMM) KTRA_HHI(i,s,d)

#CRETH trans. par. for host region allocation of cap. by ind. and home# ;

COEFFICIENT (All,s,home) RR_LAND(s)

#Rate of return on land#;

UPDATE (change)(All,s,home) RR_LAND(s)=c_rr_land(s)/100;

COEFFICIENT (All,s,home) RR_NATRES(s)

#Rate of return on natural resources#;

UPDATE (change)(All,s,home) RR_NATRES(s)=c_rr_natres(s)/100;

COEFFICIENT SKSUB1

#Ratio of domestic/foreign cap. subst. elas. to primary factor subst. elas.#;

COEFFICIENT SKSUB2

#Ratio of foreign cap. by source subst. elas. to dom./for. cap. subst. elas.# ;

COEFFICIENT RTBD

# world real bond rate #;

UPDATE (CHANGE) RTBD = rb/100;

```

---

COEFFICIENT RCLGPRSM

# change in rate of growth in real household income, by region #;

COEFFICIENT LGPRSM

# length of simulation period #;

COEFFICIENT (all,r,REG) URGVHHR(r)

# transfers from government to private hholds, by region #;

UPDATE (CHANGE)(all,r,REG) URGVHHR(r) = [URGVHHR(r)\*ughr(r) + d\_ughr\_(r)]/100;

COEFFICIENT (all,r,REG) GTYCHHRLR(r)

# rate of growth in real household income, by region (per year) #;

UPDATE (CHANGE) (all,r,REG) GTYCHHRLR(r)=RCLGPRSM\*(yhdr(r) - ppriv(r))/100.0;

COEFFICIENT (all,r,REG) GTYCGVRLR(r)

# rate of growth in real government receipts, by region (per year) #;

UPDATE (CHANGE) (all,r,REG) GTYCGVRLR(r) = RCLGPRSM\*(rgr(r) - pgov(r))/100.0;

COEFFICIENT (all,r,REG) CEAJRTKPR(r)

# coefficient of adjustment in returns to capital #;

COEFFICIENT (PARAMETER) (all,r,REG) EL\_ERCRK\_K\_R(r)

---

# elas of expec ROR on capital wrt capital stock, by region #;

!\*\*\*THIS ELASTICITY WILL HAVE TO BE RE-ESTIMATED IN GTAP\*\*\*!

COEFFICIENT (all,r,REG) GTSSKPR(r)

# steady-state rate of growth in real capital stock #;

COEFFICIENT (GE 0)(all,r,REG) RVTXYCLBR(r)

# tax on labour income, by region #;

UPDATE (all,r,REG) RVTXYCLBR(r) = rtylr(r);

COEFFICIENT (all,r,REG) RVTXYCPPR(r)

# tax on property income, by region #;

UPDATE (all,r,REG) RVTXYCPPR(r) = rtypr(r);

COEFFICIENT (all,r,REG) RCGVR(r)

# government receipts, by region #;

COEFFICIENT (all,r,REG) YCHHDPR(r)

# private household disposable income, by region #;

COEFFICIENT (all,r,REG) RCGVITR(r)

# net interest receipts of governments, by region #;

UPDATE (CHANGE) (all,r,REG) RCGVITR(r)

= (RCGVITR(r)\*rgr(r) + RCGVR(r)\*qrgir(r))/100.0;

---

```

COEFFICIENT (all,r,REG)                                YCHHITR(r)

# net interest income of households, by region #;

UPDATE (CHANGE) (all,r,REG) YCHHITR(r)

    = (YCHHITR(r)*yhdr(r) + YCHHDPR(r)*qyhir(r))/100.0;

!.....!

!           Base revenues and expenditures at world prices           !

!.....!

COEFFICIENT (GE 0)(all,i,TRAD_COMM)(all,r,REG)(all,s,REG) VXWD(i,r,s)

    ! exports of commodity i from region r to

        destination s valued fob (tradeables only) ! ;

UPDATE (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)

    VXWD(i,r,s) = pfob(i,r,s) * qxs(i,r,s) ;

COEFFICIENT (GE 0)(all,i,TRAD_COMM)(all,r,REG)(all,s,REG) VIWS(i,r,s)

    ! imports of commodity i from region r to s, valued

        cif (tradeables only) ! ;

UPDATE (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)

    VIWS(i,r,s) = pcif(i,r,s) * qxs(i,r,s) ;

!.....!

!           FTAP: Decomposition of Trade Flows           !

```



---

UPDATE (All,i,TRAD\_COMM)(All,o,HOME)(All,s,SOURCE)(All,d,DEST)

VIWS\_D(i,o,s,d)=pihldw(i,o,s,d)\*qxhd(i,o,s,d);

COEFFICIENT

(all,i,TRAD\_COMM)(all,h,HOME)(all,s,REG)(all,d,REG) VIMS\_D(i,h,s,d)

! Duty-inclusive import values of commodity i, produced from capital  
owned by HOME region h, and the capital is located in HOST country s,  
imports by destination region d ! ;

UPDATE (All,i,TRAD\_COMM)(All,o,HOME)(All,s,SOURCE)(All,d,DEST)

VIMS\_D(i,o,s,d)=pihld(i,o,s,d)\*qxhd(i,o,s,d);

COEFFICIENT

(GE 0)(all,i,TRAD\_COMM)(all,s,REG)(all,d,REG) VXMD\_DD(i,s,d)

! Tax-exclusive export values of commodity i, produced from capital owned  
by HOME country s, and the capital is located in host region s, exporting to  
destination region d !;

UPDATE (All,i,TRAD\_COMM)(All,s,SOURCE)(All,d,DEST)

VXMD\_DD(i,s,d)=pxd(i,s)\*qxdd(i,s,d);

COEFFICIENT

(GE 0)(all,i,TRAD\_COMM)(all,s,REG)(all,d,REG) VXWD\_DD(i,s,d)

! FOB export values of commodity i, produced from capital owned by HOME  
country s, and the capital is located in host region s, exporting to  
destination region d. This is valued at world price but not

---

including transport costs ! ;

UPDATE (All,i,TRAD\_COMM)(All,s,SOURCE)(All,d,DEST)

VXWD\_DD(i,s,d)=pxdd(i,s,d)\*qxdd(i,s,d);

COEFFICIENT

(GE 0)(all,i,TRAD\_COMM)(all,s,REG)(all,d,REG) VIWS\_DD(i,s,d)

! CIF import values of commodity i, produced from capital owned by HOME  
region s, and the capital is located in HOST country s, imports by  
destination region d ! ;

UPDATE (All,i,TRAD\_COMM)(All,s,SOURCE)(All,d,DEST)

VIWS\_DD(i,s,d)=pildw(i,s,d)\*qxdd(i,s,d);

COEFFICIENT

(GE 0)(all,i,TRAD\_COMM)(all,s,REG)(all,d,REG) VIMS\_DD(i,s,d)

! Duty-inclusive import values of commodity i, produced from capital  
owned by HOME region s, and the capital is located in HOST country s,  
imports by destination region d !;

UPDATE (All,i,TRAD\_COMM)(All,s,SOURCE)(All,d,DEST)

VIMS\_DD(i,s,d)=pild(i,s,d)\*qxdd(i,s,d);

COEFFICIENT

(all,i,TRAD\_COMM)(all,o,HOME)(all,r,REG) VHST(i,o,r)

! commodity i owned by region o, exported from region r for international  
transportation valued at market prices (tradeables only) !;

---

UPDATE (All,i,TRAD\_COMM)(All,o,HOME)(All,r,REG)

VHST(i,o,r)=poh(i,o,r)\*qhst(i,o,r);

COEFFICIENT

(all,i,TRAD\_COMM)(all,r,REG) VDST(i,r)

! commodity i owned by region r, exported from region r for international  
transportation valued at market prices (tradeables only) !;

UPDATE (All,i,TRAD\_COMM)(All,r,REG)

VDST(i,r)=pod(i,r)\*qdst(i,r);

!.....!  
! Regional income, utility and pop for calculating EV !  
!.....!

COEFFICIENT (PARAMETER) (all,r,REG) INC(r)

! initial equilibrium regional expenditure data  
INC is set equal to INCOME and does not change  
during a simulation ! ;

COEFFICIENT (all,r,REG) URATIO(r)

! Ratio of U(r), the per capita utility, to its  
presimulation value ! ;

FORMULA (Initial)(all,r,REG) URATIO(r) = 1;

UPDATE (all,r,REG) URATIO(r) = u(r);



---

```

COEFFICIENT (all,r,REG)                                POPRATIO(r)

! Ratio of POP(r), population in region r, to its presimulation value ! ;

FORMULA (Initial)(all,r,REG)    POPRATIO(r) = 1;

UPDATE      (all,r,REG)    POPRATIO(r) = pop(r);

```

```

! .....!

!           technology and preference parameters           !

! .....!

```

```

COEFFICIENT (all,i,TRAD_COMM)(all,r,REG)                SUBPAR(i,r)

! the substitution parameter in the CDE

! minimum expenditure function ! ;

```

```

COEFFICIENT (all,i,TRAD_COMM)(all,r,REG)                INCPAR(i,r)

! expansion parameter in the CDE minimum expenditure

! function ! ;

```

```

COEFFICIENT (all,i,TRAD_COMM)                            ESUBD(i)

! the elasticity of substitution between domestic and

! imported goods in the Armington aggregation structure

! for all agents in all regions. ! ;

```

```

COEFFICIENT (all,i,TRAD_COMM)                            ESUBM(i)

```





---

! .....

READ SUBPAR FROM FILE GTAPPARM ;  
READ INCPAR FROM FILE GTAPPARM ;  
READ ESUBD FROM FILE GTAPPARM ;  
READ ESUBM FROM FILE GTAPPARM ;  
READ ESUBVA FROM FILE GTAPPARM ;  
READ ETRAE FROM FILE GTAPPARM ;  
READ RORFLEX FROM FILE GTAPPARM ;  
READ RORDELTA FROM FILE GTAPPARM ;  
READ ESUBT FROM FILE GTAPPARM ;  
READ ETECH FROM FILE GTAPPARM ;

! .....

READ  
URGVHHR FROM FILE GTAPDATA HEADER "CM01" ;  
YCHHITR FROM FILE GTAPDATA HEADER "CM03" ;  
RCGVITR FROM FILE GTAPDATA HEADER "CM04" ;  
RVTXYCLBR FROM FILE GTAPDATA HEADER "CM05" ;  
RVTXYCPPR FROM FILE GTAPDATA HEADER "CM06" ;  
READ RTBD FROM FILE GTAPDATA HEADER "CM07" ;  
GTYCHHRLR FROM FILE GTAPDATA HEADER "CM09" ;  
LGPRSM FROM FILE GTAPDATA HEADER "CM10" ;

---

GTYCGVRLR FROM FILE GTAPDATA HEADER "CM11" ;

CEAJRTKPR FROM FILE GTAPDATA HEADER "CM12" ;

EL\_ERCRK\_K\_R FROM FILE GTAPDATA HEADER "CM13" ;

GTSSKPR FROM FILE GTAPDATA HEADER "CM14" ;

EVOA FROM FILE GTAPDATA HEADER "EVOA" ;

EVFA FROM FILE GTAPDATA HEADER "EVFA" ;

VIFA FROM FILE GTAPDATA HEADER "VIFA" ;

VDFa FROM FILE GTAPDATA HEADER "VDFa" ;

VIPA FROM FILE GTAPDATA HEADER "VIPA" ;

VDPA FROM FILE GTAPDATA HEADER "VDPA" ;

VIGA FROM FILE GTAPDATA HEADER "VIGA" ;

VDGA FROM FILE GTAPDATA HEADER "VDGA" ;

SAVE FROM FILE GTAPDATA HEADER "SAVE" ;

VXMD FROM FILE GTAPDATA HEADER "VXMD" ;

VST FROM FILE GTAPDATA HEADER "VST" ;

VFM FROM FILE GTAPDATA HEADER "VFM" ;

VIFM FROM FILE GTAPDATA HEADER "VIFM" ;

VDFM FROM FILE GTAPDATA HEADER "VDFM" ;

VIPM FROM FILE GTAPDATA HEADER "VIPM" ;

VDPM FROM FILE GTAPDATA HEADER "VDPM" ;

VIGM FROM FILE GTAPDATA HEADER "VIGM" ;

VDGM FROM FILE GTAPDATA HEADER "VDGM" ;

VIMS FROM FILE GTAPDATA HEADER "VIMS" ;

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```
VXWD FROM FILE GTAPDATA HEADER "VXWD" ;

VIWS FROM FILE GTAPDATA HEADER "VIWS" ;

! FTAP - Extra data. !

READ VXMD_D FROM FILE gtapdata HEADER "XMD" ;

READ VXMD_DD FROM FILE gtapdata HEADER "XMDD" ;

READ VXWD_D FROM FILE gtapdata HEADER "XWD" ;

READ VXWD_DD FROM FILE gtapdata HEADER "XWDD" ;

READ VIWS_D FROM FILE gtapdata HEADER "IWD" ;

READ VIWS_DD FROM FILE gtapdata HEADER "IWDD" ;

READ VIMS_D FROM FILE gtapdata HEADER "IMD" ;

READ VIMS_DD FROM FILE gtapdata HEADER "IMDD" ;

READ VDST FROM FILE GTAPDATA HEADER "VDST" ;

READ VHST FROM FILE GTAPDATA HEADER "VHST" ;

READ EVIFMS FROM FILE fdi_file HEADER "EVMS" ;

READ EVIFAS FROM FILE fdi_file HEADER "EVAS" ;

READ VFDI_HHI FROM FILE fdi_file HEADER "VFDI" ;

READ VKD FROM FILE fdi_file HEADER "VKD" ;

READ DEPRIND FROM FILE fdi_file HEADER "DEPR" ;

READ VK_HHI FROM FILE fdi_file HEADER "KHHI" ;

READ VKD_H_I FROM FILE fdi_file HEADER "KD" ;

READ VBR FROM FILE fdi_file HEADER "VBR" ;
```

---

```

READ VLAND      FROM FILE fdi_file HEADER "VLND" ;
READ VNATRES    FROM FILE fdi_file HEADER "VNR"  ;
READ SKSUB1     FROM FILE fdi_file HEADER "SKS1" ;
READ SKSUB2     FROM FILE fdi_file HEADER "SKS2" ;
READ KTRA_H__   FROM FILE fdi_file HEADER "TH__" ;
READ KTRA_H_I   FROM FILE fdi_file HEADER "TH_I" ;
READ KTRAD_H_I  FROM FILE fdi_file HEADER "TD"   ;
READ KTRAF_H_I  FROM FILE fdi_file HEADER "TF"   ;
READ KTRA_HHI   FROM FILE fdi_file HEADER "THHI" ;
READ RR_LAND    FROM FILE fdi_file HEADER "RRLN" ;
READ RR_NATRES  FROM FILE fdi_file HEADER "RRNR" ;

```

```

!-----!
!
!              DERIVATIVES OF THE BASE DATA              !
!-----!

```

```

!.....!
!
! DERIVATIVES OF THE BASE DATA include computations of household income,      !
! budget shares, and elasticities.  Since these are constant for each          !
! Johansen solution, they are termed coefficients.                             !
!.....!

```

---

COEFFICIENT (all,r,REG) YCR(r) # nominal income, by region #;

COEFFICIENT (All,r,REG) CHECK\_YCR(r) # Checking that income = expenditure#;

COEFFICIENT (all,r,REG) YCITR(r) # net interest income, by region #;

COEFFICIENT (all,r,REG) TCHHITR(r)

# revenue from income taxes on net interest income of households#;

COEFFICIENT (GE 0)(all, r, REG) TDEP(r)

#Revenue from income taxes on depreciation#;

! Move definition and formula for VOM for endowments from below !

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) VDM(i,r)

! domestic sales of commodity i in region r valued at market prices

(tradeables only) ! ;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

VDM(i,r) = VDPM(i,r) + VDGM(i,r) + sum(j,PROD\_COMM, VDFM(i,j,r)) ;

COEFFICIENT (all,i,DEMD\_COMM)(all,j,PROD\_COMM)(all,r,REG) VFA(i,j,r)

! producer expenditure on i by industry j, in region r,

valued at agent's prices ! ;

FORMULA (all,i,ENDW\_COMM)(all,j,PROD\_COMM)(all,r,REG)

VFA(i,j,r) = EVFA(i,j,r) ;



---

FORMULA (all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,s,REG)

VFA(i,j,s) = VDFA(i,j,s) + VIFA(i,j,s) ;

COEFFICIENT (all,i,NSAV\_COMM)(all,r,REG)

VOA(i,r)

! value of commodity i output in region r. ! ;

FORMULA (all,i,ENDW\_COMM)(all,r,REG) VOA(i,r) = EVOA(i,r);

FORMULA (all,i,PROD\_COMM)(all,r,REG)

VOA(i,r) = sum(j,DEMD\_COMM, VFA(j,i,r));

COEFFICIENT (all,i,NSAV\_COMM)(all,r,REG)

VOM(i,r)

! value of commodity i output in region r. ! ;

FORMULA (all,i,ENDW\_COMM)(all,r,REG)

VOM(i,r) = sum(j,PROD\_COMM, VFM(i,j,r)) ;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

VOM(i,r) = VDM(i,r) + sum(s,REG, VXMD(i,r,s))

+ VST(i,r) ;

FORMULA (all,h,CGDS\_COMM)(all,r,REG)

VOM(h,r) = VOA(h,r) ;

COEFFICIENT (all,r,REG)

TOTLAB(r)

#total labour earnings in reg r#;

FORMULA (all,r,REG) TOTLAB(r) = sum(l,LABOR, VOM(l,r));

COEFFICIENT (all,l,LABOR)(all,r,REG)

LABSHR(l,r)

---

```

#share of labour l in total lab earnings in region r#;

FORMULA (all,l,LABOR)(all,r,REG)

LABSHR(l,r) = VOM(l,r) / TOTLAB(r);

FORMULA (INITIAL) (all,l,LABOR)(all,r,REG)

EVOA(l,r) = EVOA(l,r) - IF{FIRST>0.5,(RVTXYCLBR(r) * LABSHR(l,r))};

(Initial)(all,r,REG)

RVTXYCLBR(r)=IF{FIRST1>0.5,sum[l,LABOR,VOM(l,r)-EVOA(l,r)]+
                IF{FIRST1 le 0.5,RVTXYCLBR(r)};

COEFFICIENT (GE 0)(all,i,TRAD_COMM)(all,r,REG)                VKBI(i,r)

# value of capital, by region and industry #;

FORMULA ! Calculate industry capital stock !

(All,j,TRAD_COMM)(All,r,REG)

VKBI(j,r)=VKD(j,r)+sum[s,home,VFDI_HHI(j,s,r)];

COEFFICIENT (GE 0)(all, r, REG)                VKB(r)

! value of beginning-of-period capital stock, in region r ! ;

FORMULA ! Calculate regional capital stock !

(all, r, REG) VKB(r) = sum[j,TRAD_COMM,VKBI(j,r)];

COEFFICIENT (GE 0)(all, r, REG)                VKT(r)

#Asset value of capital owned by region r#;

```

---

```

FORMULA (all,r,REG) VKT(r) = VKB(r)+

sum[i,TRAD_COMM,

sum[l,HOST,VFDI_HHI(i,r,l)]-sum[s,HOME,VFDI_HHI(i,s,r)]];

COEFFICIENT (GE 0)(all, r, REG)                                VDEP(r)

! value of capital depreciation, in r (depreciation
rate is exogenous and therefore does not appear in update) ! ;

FORMULA ! Calculate value of depreciation for the region !

(All,r,REG) VDEP(r)=sum[j,TRAD_COMM,DEPRIND(j,r)*VKBI(j,r)];

COEFFICIENT (All,r,REG)                                DEPRREG(r)

#Regional depreciation rate#;

FORMULA ! Calculate regional depreciation rate !

(all, r, REG) DEPRREG(r) = VDEP(r)/VKB(r);

COEFFICIENT (all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)    ETAX(i,j,r)

# Tax on use of endowment good i in industry j in region r # ;

FORMULA ! Calculate abnormal returns to capital !

(all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)

ETAX(i,j,r) = EVFA(i,j,r) - VFM(i,j,r) ;

! Calculate market values of domestic and imported capital !

```

---

COEFFICIENT (All,i,TRAD\_COMM)(All,r,REG) EVIFM(i,r)

#Market value of foreign capital by industry#;

FORMULA (All,i,TRAD\_COMM)(All,d,home) EVIFM(i,d)=sum(s,home,EVIFMS(i,s,d));

COEFFICIENT (All,i,TRAD\_COMM)(All,r,REG) EVDFM(i,r)

#Market value of domestic capital by industry#;

FORMULA (All,i,TRAD\_COMM)(All,r,REG)

EVDFM(i,r)=sum[k,ENDWC\_COMM,VFM(k,i,r)]-EVIFM(i,r);

! Calculate agents' values of domestic and imported capital !

COEFFICIENT (All,i,TRAD\_COMM)(All,r,REG) EVIFA(i,r)

#agents' value of foreign capital by industry#;

FORMULA (All,i,TRAD\_COMM)(All,d,home)

EVIFA(i,d)=sum(s,home,EVIFAS(i,s,d));

COEFFICIENT (All,i,TRAD\_COMM)(All,r,REG) EVDFA(i,r)

#agents' value of domestic capital by industry#;

FORMULA (All,i,TRAD\_COMM)(All,r,REG)

EVDFA(i,r)=sum[k,ENDWC\_COMM,EVFA(k,i,r)]-EVIFA(i,r);

! Calculate rates of return !

COEFFICIENT (All,s,home)(All,d,host)(All,i,TRAD\_COMM) RR\_HHI(i,s,d)

---

```

#Rate of return on capital by host region and industry#;

FORMULA (All,i,TRAD_COMM)(All,s,home)(All,d,dest:VFDD_HHI(i,s,d)=0)

RR_HHI(i,s,d)=RTBD;

FORMULA (All,i,TRAD_COMM)(All,s,home)(All,d,dest:VFDD_HHI(i,s,d) ne 0)

RR_HHI(i,s,d)=EVIFMS(i,s,d)/VFDD_HHI(i,s,d)-DEPRIND(i,d);

COEFFICIENT (All,s,home)(All,i,TRAD_COMM) RRD_H_I(i,s)

#Rate of return on domestic capital by industry#;

FORMULA (All,s,home)(All,i,TRAD_COMM:VKD(i,s)=0)

RRD_H_I(i,s)=RTBD;

FORMULA (All,s,home)(All,i,TRAD_COMM:VKD(i,s) ne 0)

RRD_H_I(i,s)=EVDFM(i,s)/VKD(i,s)-DEPRIND(i,s);

COEFFICIENT (all,r,REG) RVTXYCKR(r)

# tax on capital income, by region #;

DISPLAY EVDFM;

DISPLAY EVDFM;

ASSERTION #Domestic capital at agents values is non-negative#

(All,i,TRAD_COMM)(All,r,REG) EVDFM(i,r) ge 0;

ASSERTION #Domestic capital at market values is non-negative#

```

---

```

(All,i,TRAD_COMM)(All,r,REG) EVDFM(i,r) ge 0;

ASSERTION #check SAVE(r) greater than zero# (all,r,REG) SAVE(r)>0;

ZERODIVIDE (ZERO_BY_ZERO) DEFAULT 0 ;

COEFFICIENT (all,i,TRAD_COMM)(all,r,REG)                                VIM(i,r)

    ! value of imports of commodity i in r

    at domestic market prices ! ;

FORMULA (all,i,TRAD_COMM)(all,r,REG)

    VIM(i,r) = sum(j,PROD_COMM, VIFM(i,j,r))

    + VIPM(i,r) + VIGM(i,r) ;

COEFFICIENT (all,i,TRAD_COMM)(all,r,REG)                                VPA(i,r)

    ! private household expenditure on commodity i

    in region r valued at agent's prices ! ;

FORMULA (all,i,TRAD_COMM)(all,s,REG)

    VPA(i,s) = VDPA(i,s) + VIPA(i,s) ;

COEFFICIENT (all,r,REG)                                                PRIVEXP(r)

    ! private consumption expenditure in region r ! ;

FORMULA (all,r,REG) PRIVEXP(r) = sum(i,TRAD_COMM, VPA(i,r)) ;

COEFFICIENT (all,i,TRAD_COMM)(all,r,REG)                                VGA(i,r)

```

---

```

! government household expenditure on commodity
!
! i in region r valued at agent's prices ! ;

FORMULA (all,i,TRAD_COMM)(all,s,REG)

VGA(i,s) = VDGA(i,s) + VIGA(i,s) ;

COEFFICIENT (all,r,REG) GOVEXP(r)

! government expenditure in region r ! ;

FORMULA (all,r,REG) GOVEXP(r) = sum(i,TRAD_COMM, VGA(i,r)) ;

COEFFICIENT (all,r,REG) INCOME(r)

! level of expenditure, which equals NET income in region r
!
! (i.e., net of capital depreciation) ! ;

FORMULA (all,r,REG)

INCOME(r) = sum(i,TRAD_COMM, VPA(i,r) + VGA(i,r))
+ SAVE(r) ;

FORMULA (INITIAL) (all,r,REG)

INC(r) = INCOME(r) ;

COEFFICIENT (all,i,TRAD_COMM)(all,r,REG)(all,s,REG) VTWR(i,r,s)

! value of transportation services associated with
!
! the shipment of commodity i from r to s ! ;

FORMULA (all,i,TRAD_COMM)(all,r,REG)(all,s,REG)

VTWR(i,r,s) = VIWS(i,r,s) - VXWD(i,r,s) ;

```

---

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG)(all,s,REG) FOBSHR(i,r,s)

! The fob share in VIW. ! ;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)(all,s,REG)

FOBSHR(i,r,s) = VXWD(i,r,s)/VIWS(i,r,s) ;

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG)(all,s,REG) TRNSHR(i,r,s)

! The transport share in VIW. ! ;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)(all,s,REG)

TRNSHR(i,r,s) = VTWR(i,r,s)/VIWS(i,r,s) ;

COEFFICIENT VT

! The value of total international transportation  
services. !;

FORMULA VT = sum(i,TRAD\_COMM, sum(r,REG, sum(s,REG, VTWR(i,r,s)))) ;

COEFFICIENT (all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

SHRDFM(i,j,r)

! the share, at market prices, of domestic prod  
used by sector j ! ;

FORMULA (all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

SHRDFM(i,j,r) = VDFM(i,j,r)/VDM(i,r) ;

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) SHRDPM(i,r)



---

! share of domestic production used by private hhlds ! ;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

$$\text{SHRDPM}(i,r) = \text{VDPM}(i,r)/\text{VDM}(i,r) ;$$

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) SHRDGM(i,r)

! share of imports from r in s used by gov't hhlds ! ;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

$$\text{SHRDGM}(i,r) = \text{VDGM}(i,r)/\text{VDM}(i,r) ;$$

COEFFICIENT (all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

SHRIFM(i,j,r)

! share of imports in r used by sector j ! ;

FORMULA (all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

$$\text{SHRIFM}(i,j,r) = \text{VIFM}(i,j,r)/\text{VIM}(i,r) ;$$

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) SHRIPM(i,r)

! the share of imports in r used by private hhlds ! ;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

$$\text{SHRIPM}(i,r) = \text{VIPM}(i,r)/\text{VIM}(i,r) ;$$

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) SHRIGM(i,r)

! the share of imports from r used by gov't hhlds ! ;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

$$\text{SHRIGM}(i,r) = \text{VIGM}(i,r)/\text{VIM}(i,r) ;$$

---

COEFFICIENT (all, r, REG) REGINV(r)

! regional GROSS investment in region r, i.e.,

value of output of sector "cgds" ! ;

FORMULA (all, r, REG)

REGINV(r) = sum(k,CGDS\_COMM, VOA(k,r)) ;

COEFFICIENT (all, r, REG) NETINV(r)

! regional NET investment in region r ! ;

FORMULA (all, r, REG)

NETINV(r) = sum(k,CGDS\_COMM, VOA(k,r)) - VDEP(r) ;

COEFFICIENT GLOBINV

! global expenditures on net investment ! ;

! here, GLOBINV is computed as sum of NETINV(r) !

! alternatively, GLOBINV may be computed sum of

SAVE(r) !

FORMULA GLOBINV = sum(r,REG, NETINV(r));

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) VXW(i,r)

! The value of exports, at fob prices, by commodity and region! ;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

VXW(i,r) = sum(s,REG, VXWD(i,r,s)) + VST(i,r);

---

COEFFICIENT (all,r,REG)

VXWREGION(r)

! The value of exports, fob, by region ! ;

FORMULA (all,r,REG)

VXWREGION(r) = sum(i,TRAD\_COMM, VXW(i,r)) ;

COEFFICIENT (all,i,TRAD\_COMM)

VXWCOMMOD(i)

! The value of world exports, fob, by commodity ! ;

FORMULA (all,i,TRAD\_COMM)

VXWCOMMOD(i) = sum(r,REG, VXW(i,r)) ;

COEFFICIENT (all,i,TRAD\_COMM)(all,s,REG)

VIW(i,s)

! The value of commodity imports, at cif price, by commodity and region ! ;

FORMULA (all,i,TRAD\_COMM)(all,s,REG)

VIW(i,s) = sum(r,REG, VIWS(i,r,s)) ;

COEFFICIENT (all,r,REG)

VIWREGION(r)

! The value of commodity imports, cif, by region ! ;

FORMULA (all,r,REG)

VIWREGION(r) = sum(i,TRAD\_COMM, VIW(i,r)) ;

COEFFICIENT (all,r,REG) BTL(r) # balance of trade #;

FORMULA (all,r,REG) BTL(r) = VXWREGION(r) - VIWREGION(r);

COEFFICIENT (all,r,REG)

VENDWREG(r)

---

! The value of primary factors, at mkt prices, by region (new)! ;

FORMULA (all,r,REG)

VENDWREG(r) = sum(i,ENDW\_COMM, VOM(i,r)) ;

COEFFICIENT

VENDWWLD

! The value of primary factors, at mkt prices, worldwide (new)! ;

FORMULA VENDWWLD = sum(r,REG, VENDWREG(r)) ;

COEFFICIENT (all,i,TRAD\_COMM)

VIWCOMMODO(i)

! The global value of commodity imports, cif, by commodity ! ;

FORMULA (all,i,TRAD\_COMM) VIWCOMMODO(i) = sum(r,REG, VIW(i,r)) ;

COEFFICIENT

VXWLD

! The value of commodity exports, fob, globally ! ;

FORMULA VXWLD = sum(r,REG, VXWREGION(r)) ;

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG)

PW\_PM(i,r) ;

! Ratio of world to domestic prices !

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

PW\_PM(i,r) = sum(s,REG, VXWD(i,r,s)) / sum(s,REG, VXMD(i,r,s));

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG)

VOW(i,r);

! Value of region's r output at fob prices!

! INCLUDING transportation services !

---

FORMULA (all,i,TRAD\_COMM)(All,r,REG)

VOW(i,r) = VDM(i,r) \* PW\_PM(i,r) + sum(s,REG, VXWD(i,r,s))  
+ VST(i,r) ;

COEFFICIENT (all,i,TRAD\_COMM) VWOW(i)

! Value of world supply at world prices for i. ! ;

FORMULA (all,i,TRAD\_COMM)

VWOW(i) = sum(r,REG, VOW(i,r)) ;

COEFFICIENT (all,i,TRAD\_COMM) VWOU(i)

! Value of world output of i at user prices. ! ;

FORMULA (all,i,TRAD\_COMM)

VWOU(i) = sum{s,REG, [VPA(i,s) + VGA(i,s)] +  
sum[j,PROD\_COMM, VFA(i,j,s)]} ;

COEFFICIENT (all,i,ENDW\_COMM)(all,j,PROD\_COMM)(all,r,REG) SVA(i,j,r)

! The share of i in total value-added in j in r. ! ;

FORMULA (all,i,ENDW\_COMM)(all,j,PROD\_COMM)(all,r,REG)

SVA(i,j,r) = VFA(i,j,r)/sum(k,ENDW\_COMM, VFA(k,j,r)) ;

COEFFICIENT (all,i,TRAD\_COMM)(all,s,REG) PMSHR(i,s)

! The share of aggregate imports in the domestic  
composite for private households, evaluated at

---

agent's prices. ! ;

FORMULA (all,i,TRAD\_COMM)(all,s,REG)

$$PMSHR(i,s) = VIPA(i,s) / VPA(i,s) ;$$

COEFFICIENT (all,i,TRAD\_COMM)(all,s,REG) GMSHR(i,s)

! The share of aggregate imports in the domestic  
composite for gov't households, evaluated at  
agent's prices. ! ;

FORMULA (all,i,TRAD\_COMM)(all,s,REG)

$$GMSHR(i,s) = VIGA(i,s) / VGA(i,s) ;$$

COEFFICIENT (all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,s,REG)

FMSHR(i,j,s)

! The share of aggregate imports in the domestic  
composite for firms, evaluated at agents' prices. ! ;

FORMULA (all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,s,REG)

$$FMSHR(i,j,s) = VIFA(i,j,s) / VFA(i,j,s) ;$$

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG)(all,s,REG) MSHRS(i,r,s)

! The share of imports by source, r, in the aggregate  
import bill of region s evaluated at market prices. ! ;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)(all,s,REG)

$$MSHRS(i,r,s) = VIMS(i,r,s) / \text{sum}(k,REG, VIMS(i,k,s)) ;$$

---

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) CONSHR(i,r)

! The share of private household consumption

devoted to good i in region r. ! ;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

CONSHR(i,r) = VPA(i,r) / sum(m, TRAD\_COMM, VPA(m,r)) ;

COEFFICIENT (all,i,ENDW\_COMM)(all,j,PROD\_COMM)(all,r,REG)

REVSHR(i,j,r);

FORMULA (all,i,ENDW\_COMM)(all,j,PROD\_COMM)(all,r,REG)

REVSHR(i,j,r) = VFM(i,j,r)/sum(k,PROD\_COMM, VFM(i,k,r));

COEFFICIENT (all, r, REG)

INVKERATIO(r)

! ratio of gross investment to end-of-period

capital stock, in region r ! ;

FORMULA (all, r, REG)

INVKERATIO(r) = REGINV(r) / [VKB(r) + NETINV(r)] ;

COEFFICIENT (all, r, REG)

GRNETRATIO(r)

! ratio of GROSS/NET rates of return on capital,

in region r ! ;

! NOTE: VOA("capital",r) is GROSS returns to capital !

FORMULA (all, r, REG)

GRNETRATIO(r) = sum(h, ENDWC\_COMM, VOA(h,r)) /

[ sum(h, ENDWC\_COMM, VOA(h,r)) - VDEP(r) ] ;

---

COEFFICIENT (all,r,REG) GDP(r) ;

! Gross Domestic Product in region r. Trade is valued  
at fob and cif prices. !

FORMULA (all,s,REG)

GDP(s) = sum(i,TRAD\_COMM, VPA(i,s) )  
+ sum(i,TRAD\_COMM, VGA(i,s) )  
+ sum(k,CGDS\_COMM, VOA(k,s) )  
+ sum(i,TRAD\_COMM, sum(r,REG, VXWD(i,s,r)) + VST(i,s))  
- sum(i,TRAD\_COMM, sum(r,REG, VIWS(i,r,s))) ;

COEFFICIENT (All,r,REG) TYPR\_L(r)

#Property income tax rate#;

FORMULA

(All,r,REG) TYPR\_L(r)=sum[k,ENDWC\_COMM,1-EVOA(k,r)/VOM(k,r)];

COEFFICIENT (All,i,TRAD\_COMM)(All,s,home)(All,d,host) VINC\_HHI(i,s,d)

#FDI income by industry and host for each home region#;

!-----!

! Next, compute the Allen partials, price and income elasticities, !

! for the aggregated consumption commodities. !

!-----!



---

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) ALPHA(i,r)

! one minus the substitution parameter in the CDE

minimum expenditure function ! ;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

! (HT#F1) !

ALPHA(i,r) = (1 - SUBPAR(i,r)) ;

COEFFICIENT (all,i,TRAD\_COMM)(all,k,TRAD\_COMM)(all,r,REG) APE(i,k,r)

! the Allen partial elasticity of substitution

between composite goods i and k in region r ! ;

FORMULA (all,i,TRAD\_COMM)(all,k,TRAD\_COMM)(all,r,REG)

! (HT#F2) !

APE(i,k,r) = ALPHA(i,r) + ALPHA(k,r)

- sum(m,TRAD\_COMM, CONSHR(m,r) \* ALPHA(m,r)) ;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

! (HT#F3) !

APE(i,i,r) = 2.0 \* ALPHA(i,r)

- sum(m,TRAD\_COMM, CONSHR(m,r) \* ALPHA(m,r))

- ALPHA(i,r) / CONSHR(i,r) ;

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) COMPDEM(i,r)

! the own-price compensated elasticity of

household demand for composite commodity i ! ;

---

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

COMPDEM(i,r) = APE(i,i,r) \* CONSHR(i,r) ;

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG)

EY(i,r)

! the income elasticity of household demand for

composite good i in region r ! ;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

! (HT#F4) !

EY(i,r) = {1.0/[sum(m,TRAD\_COMM, CONSHR(m,r) \* INCPAR(m,r))]}

\* (INCPAR(i,r) \* (1.0 - ALPHA(i,r)))

+ sum(m,TRAD\_COMM, CONSHR(m,r) \* INCPAR(m,r) \* ALPHA(m,r))

+ (ALPHA(i,r) - sum(m,TRAD\_COMM, CONSHR(m,r) \* ALPHA(m,r))) ;

COEFFICIENT (all,i,TRAD\_COMM)(all,k,TRAD\_COMM)(all,r,REG)

EP(i,k,r)

! the uncompensated cross-price elasticity of hhld

demand for good i with respect to the kth price in

region r ! ;

FORMULA (all,i,TRAD\_COMM)(all,k,TRAD\_COMM)(all,r,REG)

! (HT#F5) !

EP(i,k,r) = 0 ;

FORMULA (all,i,TRAD\_COMM)(all,k,TRAD\_COMM)(all,r,REG)

EP(i,k,r) = (APE(i,k,r) - EY(i,r)) \* CONSHR(k,r) ;

DISPLAY COMPDEM ; DISPLAY EY ;



---

```

+ sum(i,TRAD_COMM, VIGA(i,r) - VIGM(i,r))

+ sum(i,TRAD_COMM, VDGA(i,r) - VDGM(i,r))

+ sum(j,PROD_COMM, sum(i,TRAD_COMM, VIFA(i,j,r) - VIFM(i,j,r)))

+ sum(j,PROD_COMM, sum(i,TRAD_COMM, VDFA(i,j,r) - VDFM(i,j,r)))

+ sum(i,TRAD_COMM, sum(s,REG, VXWD(i,r,s) - VXMD(i,r,s)))

+ sum(i,TRAD_COMM, sum(s,REG, VIMS(i,s,r) - VIWS(i,s,r)))

- sum(i,TRAD_COMM, VPA(i,r) + VGA(i,r))

- SAVE(r) ;

```

```

DISPLAY PROFITS ; DISPLAY SURPLUS ;

```

```

! .....!

!                                     The EQUATIONS                                     !

! .....!

! See GTAP model documentation by Hertel and Tsigas for derivations and          !

! discussion of these equations.  Specific references to tables and equations      !

! refer to that document.                                                         !

! .....!

! The EQUATIONS in this model are organized in the same manner as the tables    !

! in the documentation by Hertel and Tsigas.  Therefore we begin with the       !

! accounting relationships, and the price linkage equations.  Due to Walras'     !

! Law we exclude the equilibrium condition that the supply of global capital    !

```

---

! goods equal the global demand for savings. This offers a consistency check !  
! on the model under the usual, general equilibrium closure. Next come the !  
! equations describing producer behavior. Note that each sector combines !  
! imports with domestic goods and therefore faces a unique composite !  
! commodity price. The next set of behavioral equations refer to the !  
! regional households. In the normal closure, income in each region is !  
! distributed between private and government consumption and savings in !  
! constant proportions, as would be dictated by a Cobb Douglas aggregate !  
! utility function. Tables 7 and 8 describe behavior of the sluggish primary !  
! factors of production and regional investment, respectively. Finally we !  
! have the tables with equations for the global transport sector (table 8)and !  
! for the regional terms of trade. In order to determine the change in a !  
! region's terms of trade, one simply deducts the change in the price index !  
! for goods purchased, at world prices, from the change in the price indexes !  
! for goods sold. This includes all savings/investment transactions which are !  
! mediated on a global basis. !

!.....!

!.....!

! The accounting relationships in the model follow. These correspond to !  
! the equations from Table 1 of the documentation. !

!.....!

!.....!

---

! Market clearing conditions follow !

!.....!

!-----!

! The following equation enforces market clearing for all but one of the !

! tradeable commodities, while checking for equilibrium in the final market !

! (savings=investment). Note that walraslack must be endogenous in the usual !

! general equilibrium closure. However, in any of the partial equilibrium !

! closures it will be exogenous. !

!-----!

EQUATION MKTCLTRD

! This equation assures market clearing in the traded goods markets.

(HT#1)!

(all,i,TRAD\_COMM)(all,r,REG)

VOM(i,r) \* qo(i,r) = VDM(i,r) \* qds(i,r)

+ VST(i,r) \* qst(i,r)

+ sum(s,REG, VXMD(i,r,s) \* qxs(i,r,s))

+ VOM(i,r) \* tradslack(i,r) ;

EQUATION MKTCLIMP

! this equation assures market clearing for the tradeable commodities entering

each region (HT#2)!

(all,i,TRAD\_COMM)(all,r,REG)

---

```

qim(i,r) = sum(j,PROD_COMM, SHRIFM(i,j,r) * qfm(i,j,r))
          + SHRIPM(i,r) * qpm(i,r) + SHRIGM(i,r) * qgm(i,r) ;

```

```

EQUATION MKTCLDOM

```

```

! this equation assures market clearing for domestic output (HT#3)!

```

```

(all,i,TRAD_COMM)(all,r,REG)

```

```

qds(i,r) = sum(j,PROD_COMM, SHRDFM(i,j,r) * qfd(i,j,r))
          + SHRDPM(i,r) * qpd(i,r) + SHRDGM(i,r) * qgd(i,r) ;

```

```

EQUATION MKTCLENDWM

```

```

! In each of the regions, this equation assures market clearing in the markets
  for endowment goods which are perfectly mobile among uses. (HT#4) !

```

```

(all,i,ENDWM_COMM)(all,r,REG)

```

```

IF[IS_CAP(i)=0,

```

```

  VOM(i,r) * qo(i,r) - sum(j,PROD_COMM, VFM(i,j,r) * qfe(i,j,r))] =

```

```

IF[IS_CAP(i)=1,

```

```

  VOM(i,r) * (pm(i,r)!+kr(r)!)-

```

```

  sum(j,TRAD_COMM, VFM(i,j,r) * (rp(j,r)!+qfe(i,j,r)!))]

```

```

+ VOM(i,r) * endwslack(i,r) ;

```

```

EQUATION MKTCLENDWS

```

```

! In each of the regions, this equation assures market clearing in the markets
  for endowment goods which are imperfectly mobile among uses.(HT#5)!

```

```

(all,i,ENDWS_COMM)(all,j,PROD_COMM)(all,r,REG)

```

---

goes(i,j,r) = qfe(i,j,r);

!-----!

! For Equation 6 (zero profits condition) see the Behavioral Equations for !

! Producers below. !

!-----!

!-----!

! Equation 7 generates a price index for transportation services based on !

! zero profits. Refer to the Global Shipping Industry Equations below. !

!-----!

EQUATION PRIVATEXP

! This equation computes private household expenditure as household income

less savings less government expenditures. (HT#8)!

(all,r,REG)

! Link private consumption to income

PRIVEXP(r) \* yp(r) = INCOME(r) \* y\_r(r)

- SAVE(r) \* [ psave(r) + qsave(r) ]

- sum(i,TRAD\_COMM, VGA(i,r) \* [pg(i,r) + qg(i,r)])!

yp(r) = y\_r(r) + privslack(r) ;

EQUATION KEND

! Ending capital stock equals beginning stock plus net investment. (HT#10)!



---

(all, r, REG)

$$ke(r) = INVKERATIO(r) * qcgds(r) + \\ [1.0 - INVKERATIO(r)] * kb(r) ;$$

!-----!  
! Equation 11 computes changes in global investment. Refer to Equation 11' !  
! in the Investment Equations section below. !  
!-----!

EQUATION WALRAS\_S

! This is an extra equation which simply computes change in supply in the  
omitted market. (modified from HT#12 to reflect the value, as opposed to  
quantity change)!

$$walras\_sup = pcgdsfld + globalcgds ;$$

EQUATION WALRAS\_D

! This is an extra equation which simply computes change in demand in the  
omitted market. (modified from HT#13 to reflect the value, as opposed to  
quantity change)!

$$GLOBINV * walras\_dem = sum(r,REG, SAVE(r) * [psave(r) + qsave(r)]) ;$$

EQUATION WALRAS

! This equation checks Walras Law. The value of the endogenous slack  
variable should be zero. (HT#14)!

---

walras\_sup = walras\_dem + walraslack ;

!-----!  
! The following equations serve to link prices in different markets taking !  
! into account taxes/subsidies. There are 6 types of taxes in this model: !  
! import taxes, source-generic variable levies on inter-regional imports, !  
! output taxes, export taxes, destination-generic variable export subsidies !  
! on inter-regional exports, income taxes, primary factor taxes on firms, !  
! and commodity taxes levied both on households and firms. These correspond !  
! to the Price Linkage Equations in Table 2 of the documentation. !  
!-----!

#### EQUATION SUPPLYPRICES

! This equation links pre- and post-tax supply prices for all  
industries.

This captures the effect of output taxes.(HT#15)!

(all,i,NSAV\_COMM)(all,r,REG)

ps(i,r) + to(i,r) = pm(i,r) ;

#### EQUATION REALRETURN

! This equation defines the real rate of return to primary factor i  
in region r

(new).!

(all,i,ENDW\_COMM)(all,s,REG)

---

$pfactreal(i,s) = pm(i,s) - ppriv(s) ;$

EQUATION MPFACTPRICE

! This equation links domestic and firm demand prices. It holds for Mobile endowment goods and captures the effect of taxation of firms' usage of primary factors. (HT#16)!

(all,i,ENDWM\_COMM)(all,j,PROD\_COMM)(all,r,REG)

$pfe(i,j,r) = tf(i,j,r) + pm(i,r) +$   
 $sum\{k,ENDWC\_COMM:k eq i,f\_pfek(j,r)\};$

EQUATION SPFACTPRICE

! This equation links domestic and firm demand prices. It holds for Sluggish endowment goods and captures the effect of taxation of firms' usage of primary factors. (HT#17)!

(all,i,ENDWS\_COMM)(all,j,PROD\_COMM)(all,r,REG)

$pfe(i,j,r) = tf(i,j,r) + pmes(i,j,r) ;$

EQUATION PHHDPRICE

! This equation links domestic market and private household prices. It holds only for domestic goods and it captures the effect of commodity taxation of private households. (HT#18) !

(all,i,TRAD\_COMM)(all,r,REG)

$ppd(i,r) = tpd(i,r) + pds(i,r) ;$

---

EQUATION GHHDPRICE

!This equation links domestic market and government household prices.

It holds only for domestic goods and it captures the effect of commodity  
taxation of government households. (HT#19) !

(all,i,TRAD\_COMM)(all,r,REG)

$pgd(i,r) = tgd(i,r) + pds(i,r) ;$

EQUATION DMNDDPRICE

! This equation links domestic market and firm prices.

It holds only for domestic goods and it captures the effect of commodity  
taxation of firms. (HT#20)!

(all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

$pf(i,j,r) = tfd(i,j,r) + pds(i,r) ;$

EQUATION PHHIPRICES

! This equation links domestic market and private household prices. It holds  
only for imports and it captures the effect of commodity taxation of private  
households. (HT#21)!

(all,i,TRAD\_COMM)(all,r,REG)

$ppm(i,r) = tpm(i,r) + pid(i,r) ;$

EQUATION GHHIPRICES

! This equation links domestic market and government household prices. It  
holds only for imports and it captures the effect of commodity taxation of

---

government households. (HT#22)!

(all,i,TRAD\_COMM)(all,r,REG)

$pgm(i,r) = tgm(i,r) + pid(i,r) ;$

EQUATION DMNDIPRICES

! This equation links domestic market and firm prices. It holds only for imported goods and it captures the effect of commodity taxation of firms. (HT#23)!

(all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

$pfm(i,j,r) = tfm(i,j,r) + pid(i,r) ;$

EQUATION MKTPRICES

! This equation links domestic and world prices. It includes a source-generic import levy. (HT#24)!

(all,i,TRAD\_COMM)(all,r,REG)(all,s,REG)

$pms(i,r,s) = tm(i,s) + tms(i,r,s) + pcif(i,r,s) ;$

!-----!

! In order to implement a variable levy, it is necessary to define !  
! a domestic price target. This is the ratio of domestic to average !  
! imported goods' price. Note that the way this price ratio is defined, it !  
! includes intraregional imports as well. In most applications, regions will !  
! represent groups of individual countries. In the case of the E\_U, we have !  
! eliminated intraregional trade, so that this aspect is not relevant there. !

---

!-----!

EQUATION PRICETGT

! This equation defines the target price ratio to be attained via the  
variable levy. (HT#25)!

(all,i,TRAD\_COMM)(all,s,REG)

$pr(i,s) = pm(i,s) - pim(i,s) ;$

!-----!

! For Equation 26 refer to the equations on the Global Shipping Industry !  
! given above. !

!-----!

! The next equations pertain to export price linkage. Here, the option  
is available for applying a destination-generic export subsidy (tx) to  
maintain producer price levels. !

EQUATION EXPRICES

! This equation links agent's and world prices. In addition to tx we  
have ts which embodies both production taxes (all s) and export taxes  
(r not equal to s) (HT#27)!

(all,i,TRAD\_COMM)(all,r,REG)(all,s,REG)

$pfob(i,r,s) = pxs(i,r,s) + tx(i,r) + txs(i,r,s) ;$

---

```

!-----!
! Composite Imports Nest: Table 3 of Hertel and Tsigas      !
!-----!

```

EQUATION DPRICEIMP

! Price for aggregate imports. (HT#28)!

(all,i,TRAD\_COMM)(all,s,REG)

$$\begin{aligned}
 \text{pim}(i,s) &= \text{sum}(k,REG, \text{MSHRS}(i,k,s) * \text{pms}(i,k,s)) \\
 &+ \text{IF} (\text{VIM}(i,s) = 0, \text{pfactwld});
 \end{aligned}$$

```

!-----!
! We now turn to the behavioral equations for firms. The following picture !
! describes factor demands. The first set of equations describe demands for !
! primary factors.          (See table 4 of the documentation.)      !
!-----!

```

```

!-----!
! Production structure      !
!
!           qo(j,r) [ao(j,r)]      !
!
!           /\      !
!           / \ <----- Leontief      !
!           /   \      !
!           /     \      !

```





---

!-----!

EQUATION ICOMPRICE

! Industry price for composite commodities. (HT#30) !

(all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

pf(i,j,r) = IF{FDI\_FLAG1(j,r)=0,  
FMSHR(i,j,r)\*pfm(i,j,r) + [1 - FMSHR(i,j,r)]\*pfd(i,j,r)}+  
IF{FDI\_FLAG1(j,r) ne 0,f\_pf(i,PROD2FDI(j),REG2FDI(r))};

EQUATION INDIMP

! Industry j demands for composite import i. (HT#31)!

(all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,s,REG)

qfm(i,j,s) =  
IF{FDI\_FLAG1(j,s)=0,qf(i,j,s)  
- ESUBD(i) \* [pfm(i,j,s) - pf(i,j,s)]}+  
IF{FDI\_FLAG1(j,s) ne 0,f\_qfm(i,PROD2FDI(j),REG2FDI(s))};

EQUATION INDDOM

! Industry j demands for domestic good i. (HT#32)!

(all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,s,REG)

qfd(i,j,s) =

---

```

IF{FDI_FLAG1(j,s)=0,qf(i,j,s)
    - ESUBD(i) * [pfd(i,j,s) - pf(i,j,s)]}+
IF{FDI_FLAG1(j,s) ne 0,f_qfd(i,PROD2FDI(j),REG2FDI(s))};

```

```

!-----!
! Value-added Nest !
!-----!

```

EQUATION VAPRICE

!(Effective) price of primary factor composite in each sector/region.

(HT#33)!

(all,j,PROD\_COMM)(all,r,REG)

pva(j,r) = sum(k,ENDW\_COMM, SVA(k,j,r) \* [pfe(k,j,r) - afe(k,j,r)])+

IF[sum(k,ENDW\_COMM,SVA(k,j,r))=0,pfactwld];

EQUATION E\_o\_qfe

(all,i,ENDW\_COMM)(all,j,PROD\_COMM)(all,r,REG)

o\_qfe(i,j,r) =

- afe(i,j,r) + qva(j,r) - ESUBVA(j) \* [pfe(i,j,r) - afe(i,j,r) - pva(j,r)];

EQUATION E\_afe

---

```

(all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)

IF[(EVFA(i,j,r)=0) or (FDI_FLAG1(j,r)=0),afe(i,j,r)]=f_afe(i,j,r)+

IF[(EVFA(i,j,r) ne 0) and (FDI_FLAG1(j,r) ne 0),o_qfe(i,j,r)-qfe(i,j,r)];

```

```

EQUATION ENDWDEMAND

```

```

! Demands for endowment commodities (HT#34) !

```

```

(all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)

```

```

qfe(i,j,r) =

IF{FDI_FLAG1(j,r)=0, - afe(i,j,r) + qva(j,r)

- ESUBVA(j) * [pfe(i,j,r) - afe(i,j,r) - pva(j,r)] }+

IF{FDI_FLAG1(j,r) ne 0,

sum[k,LABOR:k eq i,f_qfel(k,PROD2FDI(j),REG2FDI(r))]+

sum[k,ENDWC_COMM:k eq i,f_qfek(k,PROD2FDI(j),REG2FDI(r))]+

sum[k,LAND:k eq i,f_qfen(k,PROD2FDI(j),REG2FDI(r))]+

sum[k,NATRES:k eq i,f_qfenr(k,PROD2FDI(j),REG2FDI(r))]};

```

```

!-----!

! Total Output Nest !

!-----!

```

```

EQUATION VADEMAND

```

```

! Sector demands for primary factor composite. This equation differs

```

```

from HT#35 due to the presence of intermediate input substitution.!

```

```

(all,j,PROD_COMM)(all,r,REG)

```

---


$$\begin{aligned}
qva(j,r) &= -ava(j,r) + qo(j,r) - ao(j,r) \\
&\quad - ESUBT(j) * [pva(j,r) - ava(j,r) - ps(j,r)] ;
\end{aligned}$$

EQUATION INTDEMAND

! Industry demands for intermediate inputs, including cgds. This equation  
differs from HT#36 due to the presence of intermediate input substitution. !

(all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

$$\begin{aligned}
qf(i,j,r) &= IF\{FDI\_FLAG1(j,r)=0,- af(i,j,r) + qo(j,r) - ao(j,r) \\
&\quad - ESUBT(j) * [pf(i,j,r) - af(i,j,r) - ps(j,r)]\}+ \\
&\quad IF\{FDI\_FLAG1(j,r) \neq 0,f\_qf(i,PROD2FDI(j),REG2FDI(r))\} ;
\end{aligned}$$

EQUATION E\_af

! Industry demands for intermediate inputs, including cgds. This equation  
differs from HT#36 due to the presence of intermediate input substitution. !

(all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

$$\begin{aligned}
0 &= IF\{FDI\_FLAG1(j,r) \neq 0,-qf(i,j,r)-af(i,j,r)+qo(j,r)-ao(j,r) \\
&\quad - ESUBT(j) * [pf(i,j,r) - af(i,j,r) - ps(j,r)]\}+ \\
&\quad IF\{FDI\_FLAG1(j,r)=0,af(i,j,r)\} ;
\end{aligned}$$

! .....

! Next comes the zero profits equations !

! .....

EQUATION ZEROPROFITS

---

! Industry zero pure profits condition. This condition permits us to  
determine the endogenous output level for each of the non-endowment  
sectors. The level of activity in the endowment sectors is exogenously  
determined. (HT#6)!

(all,j,PROD\_COMM)(all,r,REG)

VOA(j,r) \* [ps(j,r) + qo(j,r)] =

sum(i,ENDW\_COMM, VFA(i,j,r) \* [pfe(i,j,r) + qfe(i,j,r)])

+ sum(i,TRAD\_COMM, VFA(i,j,r) \* [pf(i,j,r) + qf(i,j,r)])

+ VOA(j,r) \* profitslack(j,r);

!.....!

! The household behavior equations follow. This corresponds to Table5. !

!.....!

!.....!

! Aggregate Utility !

!.....!

EQUATION UTILITY

! computation of per capita regional utility (HT#37). Note that private  
utility has already been defined on a percapita basis. !

(all,r,REG)

INCOME(r) \* u(r) = PRIVEXP(r) \* up(r)

+ GOVEXP(r) \* [ ug(r) - pop(r) ]

---

+ SAVE(r) \* [ qsave(r) - pop(r)] ;

! .....!  
!  
! Regional Savings !  
! .....!

EQUATION SAVINGS

! regional demand for savings -- generated from aggregate Cobb-Douglas  
utility function where the pop(r) terms again cancel (HT#38)!

(all,r,REG)

PRIVEXP(r) \* yp(r) = INCOME(r) \* y\_r(r)  
- SAVE(r) \* [ psave(r) + qsave(r) ]  
- sum(i,TRAD\_COMM, VGA(i,r) \* [pg(i,r) + qg(i,r)])  
+ saveslack1(r)

!Determine savings as a residual

qsave(r) = y\_r(r) - psave(r) + saveslack(r) ! ;

! .....!  
!  
! Government Purchases !  
! .....!

EQUATION GOVERTU

! Computation of utility from regional government consumption. In

some closures this index of gov't activity may be fixed, in which case govslack is endogenized. In this case the mix of regional expenditures changes and the aggregate utility index no longer applies. (HT#39)!

(all,r,REG)

$$ug(r) = y_r(r) - pgov(r) + govslack(r) ;$$

```
! .....!
! Demand for Composite Goods !
! .....!
```

EQUATION GPRICEINDEX

! definition of price index for aggregate gov't purchases (HT#40)!

(all,r,REG)

$$pgov(r) = \text{sum}(i, \text{TRAD\_COMM}, [\text{VGA}(i,r)/\text{GOVEXP}(r)] * pg(i,r)) ;$$

EQUATION GOVDMNDS

! Government household demands for composite commodities. Note that the pop(r) argument in per capita income and that in per capita consumption cancel due to homotheticity. (HT#41)!

(all,i,TRAD\_COMM)(all,r,REG)

$$gg(i,r) = ug(r) - [ pg(i,r) - pgov(r) ] ;$$

```
! .....!
! Composite Tradeables !
```

---

! .....

EQUATION GCOMPRICE

! Government household price for composite commodities (HT#42)!

(all,i,TRAD\_COMM)(all,s,REG)

$pg(i,s) = GMSHR(i,s) * pgm(i,s) + [1 - GMSHR(i,s)] * pgd(i,s) ;$

EQUATION GHHLDAGRIMP

! Government household demand for aggregate imports. (HT#43)!

(all,i,TRAD\_COMM)(all,s,REG)

$qgm(i,s) = qg(i,s) + ESUBD(i) * [pg(i,s) - pgm(i,s)] ;$

EQUATION GHHLDDOM

! Government household demand for domestic goods. (HT#44)!

(all,i,TRAD\_COMM)(all,s,REG)

$qgd(i,s) = qg(i,s) + ESUBD(i) * (pg(i,s) - pgd(i,s)) ;$

! .....

! Private Household Demands !

! .....

EQUATION PRIVATEU

! This equation determines private consumption utility for a representative household in region r, based on the per capita private expenditure function.



```

      (HT#45) !

(all,r,REG)

yp(r) = sum(i,TRAD_COMM, (CONSHR(i,r) * pp(i,r)))
      + sum(i,TRAD_COMM, (CONSHR(i,r) * INCPAR(i,r))) * up(r)
      + pop(r) ;

! .....!
! Composite Demands !
! .....!

EQUATION PRIVDMNDS

! Private household demands for composite commodities. Demand system
is on a
per capita basis. Here, yp(r) - pop(r) is % change in per capita
income. (HT#46)!

(all,i,TRAD_COMM)(all,r,REG)

qp(i,r) = sum(k,TRAD_COMM, EP(i,k,r) * pp(k,r))
      + EY(i,r) * [ yp(r) - pop(r) ]
      + pop(r) ;

! .....!
! Composite Tradeables !
! .....!

```

---

EQUATION PCOMPRICE

! Private household price for composite commodities (HT#47)!

(all,i,TRAD\_COMM)(all,s,REG)

$pp(i,s) = PMSHR(i,s) * ppm(i,s) + [1 - PMSHR(i,s)] * ppd(i,s) ;$

EQUATION PHHLDDOM

! Private household demand for domestic goods. (HT#48)!

(all,i,TRAD\_COMM)(all,s,REG)

$qpd(i,s) = qp(i,s) + ESUBD(i) * [pp(i,s) - ppd(i,s)] ;$

EQUATION PHHL DAGRIMP

! Private household demand for aggregate imports. (HT#49)!

(all,i,TRAD\_COMM)(all,s,REG)

$qpm(i,s) = qp(i,s) + ESUBD(i) * [pp(i,s) - ppm(i,s)] ;$

! .....

! We continue with determination of supplies and composite price for sluggish!

! primary factors corresponding to the equations in Table 7 of documentation.!

! (Table 6 reports the formulae for calculating the CDE elasticities.) !

! .....

EQUATION ENDW\_PRICE

! This equation generates the composite price for sluggish

endowments. (HT#50)!

---

(all,i,ENDWS\_COMM)(all,r,REG)

pm(i,r) = sum(k,PROD\_COMM, REVSHR(i,k,r) \* pmes(i,k,r)) ;

EQUATION ENDW\_SUPPLY

! This equation distributes the sluggish endowments across sectors.

(HT#51)!

(all,i,ENDWS\_COMM)(all,j,PROD\_COMM)(all,r,REG)

IF[VFM(i,j,r)=0,pmes(i,j,r)-pfactwld]=

IF[VFM(i,j,r) ne 0,

    goes(i,j,r) -{qo(i,r) - endwslack(i,r) + ETRAE(i) \*

    [pm(i,r) - pmes(i,j,r)]}];

! .....

! Capital stock and rate of return equations follow. They correspond !

! to the Investment Equations of Table 8 in the documentation !

! .....

EQUATION KAPSVCES

! This equation defines a variable for capital services, for convenience.

(There is really only one capital services item.) (HT#52)!

(all,r,REG)

    ksvces(r) =

    sum(h,ENDWC\_COMM, [VOA(h,r) / sum(k,ENDWC\_COMM, VOA(k,r))] \*

    qo(h,r)) ;

---

EQUATION KAPRENTAL

! This equation defines a variable for capital rental rate. (HT#53)!

(all,r,REG)

rental(r) =

sum(h,ENDWC\_COMM, [VOA(h,r) / sum(k,ENDWC\_COMM, VOA(k,r))] \*

ps(h,r)) ;

EQUATION CAPGOODS

! This equation defines a variable for gross investment, for  
convenience.

There is really only one capital goods item. ) (HT#54)!

(all,r,REG)

qcgds(r) =

sum(h,CGDS\_COMM, [VOA(h,r) / REGINV(r)] \* qo(h,r)) ;

EQUATION PRCGOODS

! This equation defines the price of cgds for convenience. (HT#55)!

(all,r,REG)

pcgds(r) = sum(h,CGDS\_COMM, [VOA(h,r) / REGINV(r)] \* ps(h,r)) ;

EQUATION KBEGINNING

! This equation associates any change in capital services during the  
period with a change in capital stock. Full capacity utilization is

---

assumed. (HT#56)!

(all,r,REG)

kb(r) = ksvces(r) ;

EQUATION RORCURRENT

! This generates the current rate of return on capital in region r.

(HT#57)!

(all, r, REG)

rorc(r) = GRNETRATIO(r) \* [rental(r) - pcgds(r)] ;

EQUATION ROEXPECTED

! Expected rate of return depends on the current return and

investment.(HT#58)!

(all, r, REG)

rore(r) = rorc(r) - RORFLEX(r) \* [ke(r) - kb(r)] ;

! .....

!           The following equations hold for the world as a whole           !

! .....

! The following two equations determine the international allocation of       !

! investment. These are now commented out and are replaced by SALTER       !

! equations SG16 TO SG21. These are located in the ICM module appended to   !

! the end of the original GTAP tab file.                                       !

! .....

---

EQUATION RORGLOBAL

! This equation computes alternatively the global supply of capital goods

or the global rental rate on investment. (HT#59) !

(all,r,REG)

$$\begin{aligned} & \text{RORDELTA} * \text{rore}(r) + \\ & [1 - \text{RORDELTA}] * \{ [\text{REGINV}(r) / \text{NETINV}(r)] * \text{qcgds}(r) \\ & \quad - [\text{VDEP}(r) / \text{NETINV}(r)] * [\text{deprate}(r) + \text{kb}(r)] \} \\ & = \text{RORDELTA} * \text{rorg} + [1 - \text{RORDELTA}] * \text{globalcgds} + \text{cgdslack}(r) ; \end{aligned}$$

EQUATION GLOBALINV

! This equation computes:

either the change in global investment (when RORDELTA=1),

or the change in the expected global rate of return on capital

(when RORDELTA=0) (HT#11') !

$$\begin{aligned} & \text{RORDELTA} * \text{globalcgds} + [1 - \text{RORDELTA}] * \text{rorg} = \\ & \text{RORDELTA} * [ \text{sum}(r, \text{REG}, \{ \text{REGINV}(r) / \text{GLOBINV} \} * \text{qcgds}(r) \\ & \quad - \{ \text{VDEP}(r) / \text{GLOBINV} \} * \{ \text{deprate}(r) + \text{kb}(r) \} ) ] \\ & + [1 - \text{RORDELTA}] * [ \text{sum}(r, \text{REG}, \{ \text{NETINV}(r) / \text{GLOBINV} \} * \text{rore}(r)) ] ; \end{aligned}$$

EQUATION PRICGDS

! This equation generates a price index for the aggregate

global cgds composite. (HT#60) !

$$\text{pcgds} = \text{sum}(r, \text{REG}, [ \text{NETINV}(r) / \text{GLOBINV} ] * \text{pcgds}(r)) ;$$

---

!.....!

! The following equations determine behavior in the global shipping industry.!

! This corresponds to Table 9 of the documentation. !

!.....!

!.....!

! First we consider the "production function" for the composite transport !

! services input. This is Cobb Douglas in form, and is represented here !

! by two equations. In the first, the composite price index is computed. !

! In the second, the derived demand for inputs from the various regions are !

! generated. Here the elasticity of substitution is zero. !

!.....!

EQUATION PTRANS

! This equation generates a price index for transportation services based on  
 zero profits. (NOTE Sales to international transportation are not subject to  
 export tax. This is why we base the costs to the transport sector on market  
 prices of the goods sold to international transportation.) (HT#7)!

$$VT * pt = \text{sum}(i, \text{TRAD\_COMM}, \text{sum}(r, \text{REG}, \text{VST}(i,r) * \text{pst}(i,r)));$$

EQUATION TRANSVCES

! This equation generates the demand for regional supply of global  
 transportation services. It reflects a unitary elasticity of

---

substitution

between transportation services inputs from different regions.

(HT#61)!

(all,i,TRAD\_COMM)(all,r,REG)

$$qst(i,r) = qt + [pt - pst(i,r)] ;$$

! .....!  
! Next we develop the equations describing the uses of the composite !  
! transport services QT. This composite input is used in fixed proportion !  
! to shipments along each route. It is here that we introduce the potential !  
! for input-augmenting technical change,  $atr(i,r,s)$ , which is commodity and !  
! route specific. Thus, in the levels,  $ATR(i,r,s)*QTS(i,r,s) = QS(i,r,s)$ , !  
! where  $QTS(i,r,s)$  is the amount of QT used along this route. Therefore, !  
!  $atr(i,r,s) > 0$  reduces the composite input required along this route, and !  
! it also dampens the cost of shipping, thereby lowering the cif price !  
! implied by a given fob value. !  
! .....!

EQUATION QTRANS

! This equation computes the global demand for international transportation  
services (i.e., variable  $qt$ ). It reflects the fact that the demand for  
services along any particular route is proportional to the quantity of  
merchandise shipped [i.e., variable  $qxs(i,r,s)$  ]. (HT#62)!

$$VT * qt = \text{sum}(i, \text{TRAD\_COMM}, \text{sum}(r, \text{REG},$$





---

+ VST(i,r) \* pst(i,r) ;

EQUATION REGDEMPRICE

! This equation estimates the change in the index of prices paid for tradeable products used in r. (modified from HT#65 to eliminate savings)!

(all,r,REG)

VIWREGION(r) \* pdw(r) = sum(i,TRAD\_COMM, sum(k,REG, VIWS(i,k,r)\*pcif(i,k,r))) ;

! .....

! This completes the listing of equations documented in Hertel and Tsigas. As!

! with most computer code, the code is ahead of the documentation. The !

! following equations do not affect the equilibrium structure of the model. !

! However, they calculate many useful summary statistics. The user is !

! encouraged to go over these in some detail. Note that quantity indices !

! are always derived by differencing the change in value and price. !

! .....

EQUATION TOTeq

! Terms of trade equation computed as difference in psw and pdw.

(HT#66) !

(all,r,REG) tot(r) = psw(r) - pdw(r) ;

EQUATION compvaladeq (all,i,PROD\_COMM)(all,r,REG)

! track change in composition of value added !

---

compvalad(i,r) = qo(i,r) - qgdp(r) ;

! .....

! Now compute welfare measures. !

! .....

EQUATION EVREG (all,r,REG)

! computes regional EV which is the money metric welfare change

(HT#67)!

EV(r) = [INC(r)/100] \* [URATIO(r) \* POPRATIO(r)] \* [u(r) + pop(r)] ;

EQUATION EVWLD

! computes EV for the world (HT#68)!

WEV - sum(r,REG, EV(r)) = 0 ;

! .....

! This is the private consumer's price index. !

! .....

EQUATION PHHLINDEX (all,r,REG)

! computes change in price index for private household expenditures

(HT#69)!

PRIVEXP(r) \* ppriv(r) = sum(i,TRAD\_COMM, VPA(i,r)\* pp(i,r));

---

! .....!  
! Now come value, price and quantity indices for GDP, by region. !  
! .....!

EQUATION VGDP\_r

! change in value of GDP (HT#70)!

(all,r,REG)

$$\begin{aligned} \text{GDP}(r) * \text{vgdp}(r) = & \text{sum}(i, \text{TRAD\_COMM}, \text{VGA}(i,r) * \\ & [\text{qg}(i,r) + \text{pg}(i,r) ] \\ & + \text{sum}(i, \text{TRAD\_COMM}, \text{VPA}(i,r) * \\ & [\text{qp}(i,r) + \text{pp}(i,r) ] \\ & + \text{REGINV}(r) * [\text{qcgds}(r) + \text{pcgds}(r) ] \\ & + \text{sum}(i, \text{TRAD\_COMM}, \text{sum}(s, \text{REG}, \text{VXWD}(i,r,s) * \\ & [\text{qxs}(i,r,s) + \text{pfob}(i,r,s)]) \\ & + \text{sum}(i, \text{TRAD\_COMM}, \text{VST}(i,r) * [\text{qst}(i,r) + \text{pst}(i,r) ] \\ & - \text{sum}(i, \text{TRAD\_COMM}, \text{sum}(s, \text{REG}, \text{VIWS}(i,s,r) * \\ & [\text{qxs}(i,s,r) + \text{pcif}(i,s,r)]) ) ; \end{aligned}$$

EQUATION PGDP\_r

! gdp price index (HT#71)!

(all,r,REG)

$$\begin{aligned} \text{GDP}(r) * \text{pgdp}(r) = & \text{sum}(i, \text{TRAD\_COMM}, \text{VGA}(i,r) * \text{pg}(i,r) ) \\ & + \text{sum}(i, \text{TRAD\_COMM}, \text{VPA}(i,r) * \text{pp}(i,r) ) \\ & + \text{REGINV}(r) * \text{pcgds}(r) \end{aligned}$$

---

```

+ sum(i,TRAD_COMM, sum(s,REG, VXWD(i,r,s) * pfob(i,r,s) ))
      + sum(i,TRAD_COMM, VST(i,r) * pst(i,r) )
- sum(i,TRAD_COMM, sum(s,REG, VIWS(i,s,r)* pcif(i,s,r))) ;

```

```
EQUATION QGDP_r
```

```
! gdp quantity index (HT#72)!
```

```
(all,r,REG)
```

```
qgdp(r) = vgdpr(r) - pgdp(r) ;
```

```
! .....
```

```
! Next compute price and quantity indexes for aggregate trade figures.      !
```

```
! .....
```

```
! First come the value changes. !
```

```
EQUATION VREGEX_ir (all,i,TRAD_COMM)(all,r,REG)
```

```
! the change in FOB value of exports of commodity i from r (HT#73)!
```

```
VXW(i,r) * vxwfob(i,r) = sum(s,REG, VXWD(i,r,s) *
```

```
[qxs(i,r,s) + pfob(i,r,s)])
```

```
      + VST(i,r) * [qst(i,r) + pst(i,r)] ;
```

```
EQUATION VREGIM_is (all,i,TRAD_COMM)(all,s,REG)
```

```
! the change in CIF value of imports of commodity i into s (HT#74)!
```

```
VIW(i,s) * viwcif(i,s) = sum(r,REG, VIWS(i,r,s) *
```

---

[pcif(i,r,s) + qxs(i,r,s)] ;

EQUATION VREGEX\_r (all,r,REG)

! computes % change in value of merchandise exports, by region

(HT#75)!

VXWREGION(r) \* vxwreg(r) = sum(i,TRAD\_COMM, VXW(i,r) \* vxwfob(i,r)) ;

EQUATION VREGIM\_s (all,s,REG)

! computes % change in value of imports, cif basis, by region

(HT#76)!

VIWREGION(s) \* viwreg(s) = sum(i,TRAD\_COMM, VIW(i,s) \* viwcif(i,s)) ;

EQUATION VWLDEX\_i (all,i,TRAD\_COMM)

! computes % change in fob value of global exports, by commodity

(HT#77)!

VXWCOMMOD(i) \* vxwcom(i) = sum(r,REG, VXW(i,r) \* vxwfob(i,r)) ;

EQUATION VWLDIM\_i (all,i,TRAD\_COMM)

! computes % change in value of global imports, by commodity (HT#78)!

VIWCOMMOD(i) \* viwcom(i) = sum(s,REG, VIW(i,s) \* viwcif(i,s)) ;

EQUATION VWLDEX

! computes % change in value of global exports (HT#79)!

VXWLD \* vxwld = sum(r,REG, VXWREGION(r) \* vxwreg(r)) ;

---

EQUATION VWLDOUT

! change in value of world output of commodity i at fob prices

(HT#80)!

(all,i,TRAD\_COMM)

VWOW(i) \* valuew(i) = sum(r,REG, VOW(i,r) \* [pxw(i,r) + qo(i,r)]) ;

EQUATION VWLDOUTUSE

! change in value of world output of commodity i at user prices

(new)!

(all,i,TRAD\_COMM)

VWOU(i) \* valuewu(i) = sum{s,REG, VPA(i,s) \* [pp(i,s) + qp(i,s)]  
+ VGA(i,s) \* [pg(i,s) + qg(i,s)]  
+ sum{j,PROD\_COMM, VFA(i,j,s) \* [pf(i,j,s) + qf(i,j,s)]}} ;

! Next come the price indices. !

EQUATION PREGEX\_ir (all,i,TRAD\_COMM)(all,r,REG)

! the change in FOB price index of exports of commodity i from r

(HT#81)!

VXW(i,r) \* pxw(i,r) = sum(s,REG, VXWD(i,r,s) \* pfob(i,r,s))  
+ VST(i,r) \* pst(i,r) ;

EQUATION PREGIM\_is (all,i,TRAD\_COMM)(all,s,REG)

---

! the change in cif price index of imports of commodity i into s

(HT#82)!

$VIW(i,s) * piw(i,s) = \text{sum}(r,REG, VIWS(i,r,s) * pcif(i,r,s)) ;$

EQUATION PRIMFACTPR (all,r,REG)

! computes % change in price index of primary factors, by region

(new)!

$VENDWREG(r) * pfactor(r) = \text{sum}(i,ENDW\_COMM, VOM(i,r) * pm(i,r)) ;$

EQUATION PREGEX\_r (all,r,REG)

! computes % change in price index of exports, by region (HT#83)!

$VXWREGION(r) * pxwreg(r) = \text{sum}(i,TRAD\_COMM, VXW(i,r) * pxw(i,r)) ;$

EQUATION PREGIM\_s (all,s,REG)

! computes % change in price index of imports, by region (HT#84)!

$VIWREGION(s) * piwreg(s) = \text{sum}(i,TRAD\_COMM, VIW(i,s) * piw(i,s)) ;$

EQUATION PWLDEX\_i (all,i,TRAD\\_COMM)

! computes % change in price index of exports, by commodity (HT#85)!

$VXWCOMMOD(i) * pxwcom(i) = \text{sum}(r,REG, VXW(i,r) * pxw(i,r)) ;$

EQUATION PRIMFACTPRWLD

! computes % change in global price index of primary factors (new)!

$VENDWWLD * pfactwld = \text{sum}(r,REG, VENDWREG(r) * pfactor(r)) ;$



---

EQUATION PWLDIM\_i (all,i,TRAD\_COMM)

! computes % change in price index of imports, by commodity (HT#86)!

VIWCOMMOD(i) \* piwcom(i) = sum(s,REG, VIW(i,s) \* piw(i,s)) ;

EQUATION PWLDEX

! computes % change in price index of global exports (HT#87)!

VXWLD \* pxwwld = sum(r,REG, VXWREGION(r) \* pxwreg(r)) ;

EQUATION PWLDOUT

! change in index of world prices, fob, for total production of i

(HT#88)!

(all,i,TRAD\_COMM)

VWOW(i) \* pw(i) = sum(r,REG, VOW(i,r) \* pxw(i,r)) ;

EQUATION PWLDUSE

! change in index of user prices for deflating world production of

i(new)!

(all,i,TRAD\_COMM)

VWOU(i) \* pwu(i) = sum{s,REG, VPA(i,s) \* pp(i,s)  
+ VGA(i,s) \* pg(i,s)  
+ sum[j,PROD\_COMM, VFA(i,j,s) \* pf(i,j,s)]} ;

! And finally the quantity indices. !

---

EQUATION QREGEX\_ir (all,i,TRAD\_COMM)(all,r,REG)

! The change in volume of exports of commodity i from r.

This is generated by deflating a value aggregate. (HT#89)!

$qxw(i,r) = vxwfob(i,r) - pxw(i,r) ;$

EQUATION QREGIM\_is (all,i,TRAD\_COMM)(all,s,REG)

! The change in volume of imports of commodity i into s.

This is generated by deflating a value aggregate. (HT#90)!

$qiw(i,s) = viwcif(i,s) - piw(i,s) ;$

EQUATION QREGEX\_r (all,r,REG)

! computes % change in quantity index of exports, by region (HT#91)!

$qxwreg(r) = vxwreg(r) - pxwreg(r) ;$

EQUATION QREGIM\_s (all,s,REG)

! computes % change in quantity index of imports, by region (HT#92)!

$qiwreg(s) = viwreg(s) - piwreg(s) ;$

EQUATION QWLDEX\_i (all,i,TRAD\_COMM)

! computes % change in quantity index of exports, by commodity

(HT#93)!

$qxwcom(i) = vxwcom(i) - pxwcom(i) ;$

---

EQUATION QWLDIM\_i (all,i,TRAD\_COMM)

! computes % change in quantity index of imports, by commodity

(HT#94)!

qiwcom(i) = viwcom(i) - piwcom(i) ;

EQUATION QWLDEX

! computes % change in quantity index of global exports (HT#95)!

qxwwld = vxwwld - pxwwld ;

EQUATION QWLDOUT

! change in index of world production of i (HT#96)!

(all,i,TRAD\_COMM)

qow(i) = valuew(i) - pw(i) ;

EQUATION QWLDOUTU

! change in index of world production of i evaluated at user prices

(new)!

(all,i,TRAD\_COMM)

qowu(i) = valuewu(i) - pwu(i) ;

EQUATION TRADEBAL\_i (all,i,TRAD\_COMM)(all,r,REG)

! computes change in trade balance by commodity and by region (HT#97)!

DTBALi(i,r) = [VXW(i,r)/100] \* vxwfob(i,r)

- [VIW(i,r)/100] \* viwcif(i,r) ;

---

EQUATION TRADEBALANCE (all,r,REG)

! computes change in trade balance (X - M), by region (HT#98)!

DTBAL(r) = [VXWREGION(r)/100] \* vxwreg(r) - [VIWREGION(r)/100]

\* viwreg(r) ;

! ----- !

! END OF FILE !

! ----- !

! ----- !

! START OF WELMRNS.TAB !

! ----- !

! .....

! TABLO code for multi-region non-static welfare decomposition that can also !

! be used for the static version of the GTAP model. Append to GTAP.TAB. !

! !

! Written by Karen M. Huff !

! .....

COEFFICIENT (all,i,NSAV\_COMM)(all,r,REG) PTAX(i,r)

! Output tax on good i in region r ! ;

---

FORMULA (all,i,NSAV\_COMM)(all,r,REG)

PTAX(i,r) = VOM(i,r) - VOA(i,r) ;

COEFFICIENT (all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

IFTAX(i,j,r)

! Tax on use of imported int. good i in industry j in  
region r ! ;

FORMULA (all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

IFTAX(i,j,r) = VIFA(i,j,r) - VIFM(i,j,r) ;

COEFFICIENT (all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

DFTAX(i,j,r)

! Tax on use of domestic int. good i in industry j in  
region r ! ;

FORMULA (all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

DFTAX(i,j,r) = VDFA(i,j,r) - VDFM(i,j,r) ;

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) IPTAX(i,r)

! Tax on private consumption of imported good i in region r ! ;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

IPTAX(i,r) = VIPA(i,r) - VIPM(i,r) ;

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) DPTAX(i,r)

! Tax on private consumption of domestic good i in region r ! ;

---

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

$$DPTAX(i,r) = VDPA(i,r) - VDPM(i,r) ;$$

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) IGTAX(i,r)

! Tax on government consumption of imported good i in region r ! ;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

$$IGTAX(i,r) = VIGA(i,r) - VIGM(i,r) ;$$

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) DGTAX(i,r)

! Tax on government consumption of domestic good i in region r ! ;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

$$DGTAX(i,r) = VDGA(i,r) - VDGM(i,r) ;$$

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG)(all,s,REG) XTAXD(i,r,s)

! Tax on exports of good i from source r to destination s ! ;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)(all,s,REG)

$$XTAXD(i,r,s) = VXWD(i,r,s) - VXMD(i,r,s) ;$$

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG)(all,s,REG) MTAX(i,r,s)

! Tax on imports of good i from source r in destination s ! ;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)(all,s,REG)

$$MTAX(i,r,s) = VIMS(i,r,s) - VIWS(i,r,s) ;$$

COEFFICIENT (all,r,REG) INCRATIO(r)

---

! ratio of INCOME(r) to INC(r) times URATIO(r) times POPRATIO(r) ! ;

FORMULA (all,r,REG)

INCRATIO(r) = INCOME(r)/[INC(r)\*URATIO(r)\*POPRATIO(r)] ;

! ..... !

EQUATION EV\_DECOMPOSITION (all,r,REG)

EV\_ALT(r) =

[.01/INCRATIO(r)] \*

[ sum(i,PROD\_COMM, PTAX(i,r) \* qo(i,r))

+ sum(i,NONCAP\_COMM, PTAX(i,r) \* qo(i,r))

+ sum(i,ENDWC\_COMM, PTAX(i,r) \* kr(r))

+ sum(i,ENDW\_COMM, sum(j,PROD\_COMM, ETAX(i,j,r) \* qfe(i,j,r)))

+ sum(j,PROD\_COMM, sum(i,TRAD\_COMM, IFTAX(i,j,r) \* qfm(i,j,r)))

+ sum(j,PROD\_COMM, sum(i,TRAD\_COMM, DFTAX(i,j,r) \* qfd(i,j,r)))

+ sum(i,TRAD\_COMM, IPTAX(i,r) \* qpm(i,r))

+ sum(i,TRAD\_COMM, DPTAX(i,r) \* qpd(i,r))

+ sum(i,TRAD\_COMM, IGTAX(i,r) \* qgm(i,r))

+ sum(i,TRAD\_COMM, DGTAX(i,r) \* qgd(i,r))

+ sum(i,TRAD\_COMM, sum(s,REG, XTAXD(i,r,s) \* qxs(i,r,s)))

+ sum(i,TRAD\_COMM, sum(s,REG, MTAX(i,s,r) \* qxs(i,s,r)))

+ sum(i,ENDW\_COMM, VOA(i,r) \*

[qo(i,r)-sum{k,ENDWC\_COMM:k eq i,qo(i,r)-kr(r)}])

---

```

- VDEP(r) * [deprate(r)+kb(r)]

+ sum(i,TRAD_COMM, VOA(i,r) * ao(i,r))

+ sum(i,ENDW_COMM, sum(j,PROD_COMM, VFA(i,j,r)

*[afe(i,j,r)+ava(j,r)]))

+ sum(j,PROD_COMM, sum(i,TRAD_COMM, [VIFA(i,j,r)

+VDFA(i,j,r)]*af(i,j,r)))

+ sum(i,TRAD_COMM, sum(s,REG, VTWR(i,s,r) * atr(i,s,r)))

+ sum(i,TRAD_COMM, sum(s,REG, VXWD(i,r,s) * pfob(i,r,s)))

+ sum(i,TRAD_COMM, VST(i,r) * pst(i,r))

+ NETINV(r) * pcgds(r)

- sum(i,TRAD_COMM, sum(s,REG, VXWD(i,s,r) * pfob(i,s,r)

+ VTWR(i,s,r) * pt))

- SAVE(r) * psave(r)

+ sum(i,TRAD_COMM, VPA(i,r) - VPA(i,r) * INCPAR(i,r)) * up(r)

+ YCR(r)*qyir(r) + YCITR(r)*y_r(r)

+ 100*yfdi_h__(r)+100*yank_h__(r)+100*yanp_h__(r)];

```

EQUATION WORLDEV

```
WEV_ALT = sum(r,REG, EV_ALT(r)) ;
```

EQUATION CONT\_EV\_bondr0 (All,r,REG)

```
CNTbondr0(r)=[.01/INCRATIO(r)]*
```

```
{YCR(r)*qyir(r) + YCITR(r)*[y_r(r)-prentb(r)]};
```



---

EQUATION CONT\_EV\_intrater (All,r,REG)

CNTintrater(r)=[.01/INCRATIO(r)]\*ASBDR(r)\*rbr(r);

EQUATION CONT\_EV\_bondr (All,r,REG)

CNTbondr(r)=[.01/INCRATIO(r)]\*

{YCR(r)\*qyir(r) + YCITR(r)\*[y\_r(r)-pbr(r)]}-CNTintrater(r);

EQUATION CONT\_EV\_fyr (All,r,REG)

CNTfyr(r)=[.01/INCRATIO(r)]\*{YCR(r)\*qyir(r) + YCITR(r)\*y\_r(r)};

EQUATION CONT\_WEV\_qor (all,r,REG)

CNTqor(r) = sum(i,NSAV\_COMM,

PTAX(i,r) \* [.01/INCRATIO(r)] \* qo(i,r) );

EQUATION CONT\_WEV\_qoir (all,i,NSAV\_COMM)(all,r,REG)

CNTqoir(i,r) = PTAX(i,r) \* [.01/INCRATIO(r)] \* qo(i,r) ;

EQUATION CONT\_WEV\_qfer (all,r,REG)

CNTqfer(r) = sum(i,ENDW\_COMM, sum(j,PROD\_COMM,

ETAX(i,j,r) \* [.01/INCRATIO(r)] \* qfe(i,j,r) )) ;

EQUATION CONT\_WEV\_qfeir (all,i,ENDW\_COMM)(all,r,REG)

CNTqfeir(i,r) = sum(j,PROD\_COMM,

---

```

      ETAX(i,j,r) * [.01/INCRATIO(r)] * qfe(i,j,r) ) ;

EQUATION  CONT_WEV_qfej_r (all,j,PROD_COMM)(all,r,REG)

      CNTqfej_r(j,r) = sum(i,ENDW_COMM,

      ETAX(i,j,r) * [.01/INCRATIO(r)] * qfe(i,j,r) ) ;

EQUATION  CONT_WEV_qfeij_r

(all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)

      CNTqfeij_r(i,j,r) = ETAX(i,j,r) * [.01/INCRATIO(r)] * qfe(i,j,r) ;

EQUATION  CONT_WEV_qfmr (all,r,REG)

      CNTqfmr(r) = sum(j,PROD_COMM, sum(i,TRAD_COMM,

      IFTAX(i,j,r) * [.01/INCRATIO(r)] * qfm(i,j,r) )) ;

EQUATION  CONT_WEV_qfmir (all,i,TRAD_COMM)(all,r,REG)

      CNTqfmir(i,r) = sum(j,PROD_COMM,

      IFTAX(i,j,r) * [.01/INCRATIO(r)] * qfm(i,j,r) );

EQUATION  CONT_WEV_qfmjr (all,j,PROD_COMM)(all,r,REG)

      CNTqfmjr(j,r) = sum(i,TRAD_COMM,

      IFTAX(i,j,r) * [.01/INCRATIO(r)] * qfm(i,j,r) );

EQUATION  CONT_WEV_qfmi_j_r

(all,i,TRAD_COMM)(all,j,PROD_COMM)(all,r,REG)

```

---

CNTqfmijr(i,j,r) = IFTAX(i,j,r) \* [.01/INCRATIO(r)] \* qfm(i,j,r) ;

EQUATION CONT\_WEV\_qfdr (all,r,REG)

CNTqfdr(r) = sum(j,PROD\_COMM, sum(i,TRAD\_COMM,  
DFTAX(i,j,r) \* [.01/INCRATIO(r)] \* qfd(i,j,r) )) ;

EQUATION CONT\_WEV\_qfdir (all,i,TRAD\_COMM)(all,r,REG)

CNTqfdir(i,r) = sum(j,PROD\_COMM,  
DFTAX(i,j,r) \* [.01/INCRATIO(r)] \* qfd(i,j,r) ) ;

EQUATION CONT\_WEV\_qfdjr (all,j,PROD\_COMM)(all,r,REG)

CNTqfdjr(j,r) = sum(i,TRAD\_COMM,  
DFTAX(i,j,r) \* [.01/INCRATIO(r)] \* qfd(i,j,r) ) ;

EQUATION CONT\_WEV\_qfdijr

(all,i,TRAD\_COMM)(all,j,PROD\_COMM)(all,r,REG)

CNTqfdijr(i,j,r) = DFTAX(i,j,r) \* [.01/INCRATIO(r)] \* qfd(i,j,r) ;

EQUATION CONT\_WEV\_qpmr (all,r,REG)

CNTqpmr(r) = sum(i,TRAD\_COMM,  
IPTAX(i,r) \* [.01/INCRATIO(r)] \* qpm(i,r) ) ;

EQUATION CONT\_WEV\_qpmir (all,i,TRAD\_COMM)(all,r,REG)

CNTqpmir(i,r) = IPTAX(i,r) \* [.01/INCRATIO(r)] \* qpm(i,r) ;

---

EQUATION CONT\_WEV\_qpdr (all,r,REG)

$$\text{CNTqpdr}(r) = \text{sum}(i, \text{TRAD\_COMM}, \\ \text{DPTAX}(i,r) * [.01/\text{INCRATIO}(r)] * \text{qpd}(i,r) ) ;$$

EQUATION CONT\_WEV\_qpdir (all,i,TRAD\_COMM)(all,r,REG)

$$\text{CNTqpdir}(i,r) = \text{DPTAX}(i,r) * [.01/\text{INCRATIO}(r)] * \text{qpd}(i,r) ;$$

EQUATION CONT\_WEV\_qgmr (all,r,REG)

$$\text{CNTqgmr}(r) = \text{sum}(i, \text{TRAD\_COMM}, \\ \text{IGTAX}(i,r) * [.01/\text{INCRATIO}(r)] * \text{qgm}(i,r) ) ;$$

EQUATION CONT\_WEV\_qgmir (all,i,TRAD\_COMM)(all,r,REG)

$$\text{CNTqgmir}(i,r) = \text{IGTAX}(i,r) * [.01/\text{INCRATIO}(r)] * \text{qgm}(i,r) ;$$

EQUATION CONT\_WEV\_qgdr (all,r,REG)

$$\text{CNTqgdr}(r) = \text{sum}(i, \text{TRAD\_COMM}, \\ \text{DGTAX}(i,r) * [.01/\text{INCRATIO}(r)] * \text{qgd}(i,r) ) ;$$

EQUATION CONT\_WEV\_qgdir (all,i,TRAD\_COMM)(all,r,REG)

$$\text{CNTqgdir}(i,r) = \text{DGTAX}(i,r) * [.01/\text{INCRATIO}(r)] * \text{qgd}(i,r) ;$$

EQUATION CONT\_WEV\_qxsr (all,r,REG)

$$\text{CNTqxsr}(r) = \text{sum}(i, \text{TRAD\_COMM}, \text{sum}(s, \text{REG}, \\ \text{XTAXD}(i,r,s) * [.01/\text{INCRATIO}(r)] * \text{qxs}(i,r,s) )) ;$$

---

EQUATION CONT\_WEV\_qxsir (all,i,TRAD\_COMM)(all,r,REG)

CNTqxsir(i,r) = sum(s,REG,  
XTAXD(i,r,s) \* [.01/INCRATIO(r)] \* qxs(i,r,s)) ;

EQUATION CONT\_WEV\_qxsrs (all,r,REG)(all,s,REG)

CNTqxsrs(r,s) = sum(i,TRAD\_COMM,  
XTAXD(i,r,s) \* [.01/INCRATIO(r)] \* qxs(i,r,s) ) ;

EQUATION CONT\_WEV\_qxsirs (all,i,TRAD\_COMM)(all,r,REG)(all,s,REG)

CNTqxsirs(i,r,s) = XTAXD(i,r,s) \* [.01/INCRATIO(r)] \* qxs(i,r,s) ;

EQUATION CONT\_WEV\_qimr (all,r,REG)

CNTqimr(r) = sum(i,TRAD\_COMM, sum(s,REG,  
MTAX(i,s,r) \* [.01/INCRATIO(r)] \* qxs(i,s,r) )) ;

EQUATION CONT\_WEV\_qimir (all,i,TRAD\_COMM)(all,r,REG)

CNTqimir(i,r) = sum(s,REG,  
MTAX(i,s,r) \* [.01/INCRATIO(r)] \* qxs(i,s,r) ) ;

EQUATION CONT\_WEV\_qimsr (all,s,REG)(all,r,REG)

CNTqimsr(s,r) = sum(i,TRAD\_COMM,  
MTAX(i,s,r) \* [.01/INCRATIO(r)] \* qxs(i,s,r) ) ;

---

EQUATION CONT\_WEV\_qimistr (all,i,TRAD\_COMM)(all,s,REG)(all,r,REG)

CNTqimistr(i,s,r) = MTAX(i,s,r) \* [.01/INCRATIO(r)] \* qxs(i,s,r) ;

EQUATION CONT\_EV\_alleffr (all,r,REG)

CNTalleffr(r) = [.01/INCRATIO(r)] \*

[ sum(i,PROD\_COMM, PTAX(i,r) \* qo(i,r))

+ sum(i,NONCAP\_COMM, PTAX(i,r) \* qo(i,r))

+ sum(i,ENDWC\_COMM, PTAX(i,r) \* kr(r))

+ sum(i,ENDW\_COMM, sum(j,PROD\_COMM, ETAX(i,j,r) \* qfe(i,j,r)))

! Allocative efficiency from capital must be represented in terms of qfes and  
qfed. !

! - sum(i,ENDWC\_COMM, sum(j,PROD\_COMM, ETAX(i,j,r) \* qfe(i,j,r)))!

+ sum(j,PROD\_COMM, sum(i,TRAD\_COMM, IFTAX(i,j,r) \* qfm(i,j,r)))

+ sum(j,PROD\_COMM, sum(i,TRAD\_COMM, DFTAX(i,j,r) \* qfd(i,j,r)))

+ sum(i,TRAD\_COMM, IPTAX(i,r) \* qpm(i,r))

+ sum(i,TRAD\_COMM, DPTAX(i,r) \* qpd(i,r))

+ sum(i,TRAD\_COMM, IGTAX(i,r) \* qgm(i,r))

+ sum(i,TRAD\_COMM, DGTAX(i,r) \* qgd(i,r))

+ sum(i,TRAD\_COMM, sum(s,REG, XTAXD(i,r,s) \* qxs(i,r,s)))

+ sum(i,TRAD\_COMM, sum(s,REG, MTAX(i,s,r) \* qxs(i,s,r))) ]

+ CNTallefffdi(r) ;

EQUATION CONT\_EV\_alleffir (all,i,TRAD\_COMM) (all,r,REG)

CNTalleffir(i,r) = [.01/INCRATIO(r)] \*

---

```

[ PTAX(i,r) * qo(i,r)

+ sum(j,PROD_COMM, IFTAX(i,j,r) * qfm(i,j,r))

+ sum(j,PROD_COMM, DFTAX(i,j,r) * qfd(i,j,r))

+ IPTAX(i,r) * qpm(i,r)

+ DPTAX(i,r) * qpd(i,r)

+ IGTAX(i,r) * qgm(i,r)

+ DGTAX(i,r) * qgd(i,r)

+ sum(s,REG, XTAXD(i,r,s) * qxs(i,r,s))

+ sum(s,REG, MTAX(i,s,r) * qxs(i,s,r)) ] ;

```

EQUATION CONT\_EV\_totr (all,r,REG)

```

CNTtotr(r) = [.01/INCRATIO(r)] *

[ sum(i,TRAD_COMM, sum(s,REG,{VXWD(i,r,s) * pfob(i,r,s)}))

+ sum(i,TRAD_COMM, VST(i,r) * pst(i,r))

- sum(i,TRAD_COMM, sum(s,REG,{VIWS(i,s,r) *

[FOBSHR(i,s,r)*pfob(i,s,r) + TRNSHR(i,s,r)*pt]} ))];

```

EQUATION CONT\_EV\_cgdsr (all,r,REG)

```

CNTcgdsr(r) =

[.01/INCRATIO(r)] * [NETINV(r) * pcgds(r)

-SAVE(r) * psave(r)] ;

```

EQUATION CONT\_EV\_pricer0 (All,r,REG)

```

CNTpricer0(r)=CNTcgdsr(r)+CNTtotr(r)+CNTpcapr(r)+

```

---


$$[.01/INCRATIO(r)]*[YCITR(r)*prentb(r)];$$

EQUATION CONT\_EV\_pricer1 (All,r,REG)

$$\begin{aligned} \text{CNTpricer1}(r) &= \text{CNTcgdsr}(r) + \text{CNTtotr}(r) + \text{CNTpcapr}(r) + \\ & \quad [.01/INCRATIO(r)]*[YCITR(r)*pbr(r)]; \end{aligned}$$

EQUATION CONT\_EV\_pbr (All,r,REG)

$$\text{CNTpbr}(r) = [.01/INCRATIO(r)]*[NETINV(r) - \text{SAVE}(r) + \text{YCITR}(r)]*pbr(r);$$

EQUATION CONT\_EV\_pricer (All,r,REG)

$$\text{CNTpricer}(r) = \text{CNTtotr}(r) + \text{CNTpcapr}(r) + \text{CNTpbr}(r);$$

EQUATION CONT\_EV\_endwr (all,r,REG)

$$\begin{aligned} \text{CNTendwr}(r) &= [.01/INCRATIO(r)] * [ \text{sum}(i, \text{ENDW\_COMM}, \\ & \quad \text{VOA}(i,r) * \\ & \quad [qo(i,r) - \text{sum}\{k, \text{ENDWC\_COMM}:k \text{ eq } i, qo(i,r) - kr(r)\}]]]; \end{aligned}$$

EQUATION CONT\_EV\_endwir (all,i,ENDW\_COMM)(all,r,REG)

$$\begin{aligned} \text{CNTendwir}(i,r) &= [.01/INCRATIO(r)] * [ \text{VOA}(i,r) * \\ & \quad (qo(i,r) - \text{sum}\{k, \text{ENDWC\_COMM}:k \text{ eq } i, qo(i,r) - kr(r)\}]]]; \end{aligned}$$

EQUATION CONT\_EV\_techr (all,r,REG)

$$\begin{aligned} \text{CNTtechr}(r) &= [.01/INCRATIO(r)] * \\ & \quad [ \text{sum}(i, \text{PROD\_COMM}, \text{VOA}(i,r) * \text{ao}(i,r)) \end{aligned}$$



---

```

+ sum(i,ENDW_COMM,sum(j,PROD_COMM,VFA(i,j,r) *
[afe(i,j,r) + ava(j,r)])
+ sum(j,PROD_COMM,sum(i,TRAD_COMM,{VIFA(i,j,r) +
VDFA(i,j,r)}*af(i,j,r)))
+ sum(i,TRAD_COMM, sum(s,REG,{VTWR(i,s,r) * atr(i,s,r)} )) ]
-CNTallefffdi(r);

```

```

EQUATION CONT_EV_tech_aor (all,r,REG)

```

```

CNTtech_aor(r) = [.01/INCRATIO(r)] *
[ sum(i,PROD_COMM, VOA(i,r) * ao(i,r)) ] ;

```

```

EQUATION CONT_EV_tech_aoir (all,i,PROD_COMM)(all,r,REG)

```

```

CNTtech_aoir(i,r) = [.01/INCRATIO(r)] * VOA(i,r) * ao(i,r) ;

```

```

EQUATION CONT_EV_tech_afer (all,r,REG)

```

```

CNTtech_afer(r) = [.01/INCRATIO(r)] *
[ sum(i,ENDW_COMM,sum(j,PROD_COMM,VFA(i,j,r) * afe(i,j,r) )) ] ;

```

```

EQUATION CONT_EV_tech_afeir (all,i,ENDW_COMM)(all,r,REG)

```

```

CNTtech_afeir(i,r) = [.01/INCRATIO(r)] *
[ sum(j,PROD_COMM,VFA(i,j,r) * afe(i,j,r) ) ] ;

```

```

EQUATION CONT_EV_tech_afejr (all,j,PROD_COMM)(all,r,REG)

```

```

CNTtech_afejr(j,r) = [.01/INCRATIO(r)] *

```

---

[ sum(i,ENDW\_COMM,VFA(i,j,r) \* afe(i,j,r) ) ] ;

EQUATION CONT\_EV\_tech\_afeijr

(all,i,ENDW\_COMM)(all,j,PROD\_COMM)(all,r,REG)

CNTtech\_afeijr(i,j,r) = [.01/INCRATIO(r)] \* VFA(i,j,r) \*  
afe(i,j,r) ;

EQUATION CONT\_EV\_tech\_avar (all,r,REG)

CNTtech\_avar(r) = [.01/INCRATIO(r)] \*

[ sum(i,ENDW\_COMM,sum(j,PROD\_COMM,VFA(i,j,r) \* ava(j,r) )) ] ;

EQUATION CONT\_EV\_tech\_avair (all,i,ENDW\_COMM)(all,r,REG)

CNTtech\_avair(i,r) = [.01/INCRATIO(r)] \*

[ sum(j,PROD\_COMM,VFA(i,j,r) \* ava(j,r) ) ] ;

EQUATION CONT\_EV\_tech\_avajr (all,j,PROD\_COMM)(all,r,REG)

CNTtech\_avajr(j,r) = [.01/INCRATIO(r)] \*

[ sum(i,ENDW\_COMM,VFA(i,j,r) \* ava(j,r) ) ] ;

EQUATION CONT\_EV\_tech\_avaijr

(all,i,ENDW\_COMM)(all,j,PROD\_COMM)(all,r,REG)

CNTtech\_avaijr(i,j,r) = [.01/INCRATIO(r)] \* VFA(i,j,r) \* ava(j,r) ;

EQUATION CONT\_EV\_tech\_afr (all,r,REG)

---

```

CNTtech_afrr(r) = [.01/INCRATIO(r)] *

[ sum(j,PROD_COMM,sum(i,TRAD_COMM,{VIFA(i,j,r) + VDFA(i,j,r)}
*af(i,j,r)))] ;

EQUATION CONT_EV_tech_afjr (all,j,PROD_COMM)(all,r,REG)

CNTtech_afjr(j,r) = [.01/INCRATIO(r)] *

[ sum(i,TRAD_COMM,{VIFA(i,j,r) + VDFA(i,j,r)}*af(i,j,r) ) ] ;

EQUATION CONT_EV_tech_afir (all,i,TRAD_COMM)(all,r,REG)

CNTtech_afir(i,r) = [.01/INCRATIO(r)] *

[ sum(j,PROD_COMM,{VIFA(i,j,r) + VDFA(i,j,r)}*af(i,j,r) ) ] ;

EQUATION CONT_EV_tech_afijr

(all,i,TRAD_COMM)(all,j,PROD_COMM)(all,r,REG)

CNTtech_afijr(i,j,r) = [.01/INCRATIO(r)] *

[VIFA(i,j,r) + VDFA(i,j,r)] * af(i,j,r) ;

EQUATION CONT_EV_tech_atrr (all,r,REG)

CNTtech_atrr(r) = [.01/INCRATIO(r)] *

[ sum(i,TRAD_COMM, sum(s,REG,{VTWR(i,s,r) * atr(i,s,r)} ) ) ] ;

EQUATION CONT_EV_tech_atrir (all,i,TRAD_COMM)(all,r,REG)

CNTtech_atrir(i,r) = [.01/INCRATIO(r)] *

[ sum(s,REG,{VTWR(i,s,r) * atr(i,s,r)} ) ] ;

```

---

EQUATION CONT\_EV\_tech\_atrsr (all,s,REG)(all,r,REG)

CNTtech\_atrsr(s,r) = [.01/INCRATIO(r)] \*  
[ sum(i,TRAD\_COMM,{VTWR(i,s,r) \* atr(i,s,r)} ) ] ;

EQUATION CONT\_EV\_tech\_atrisr (all,i,TRAD\_COMM)(all,s,REG)(all,r,REG)

CNTtech\_atrisr(i,s,r) = [.01/INCRATIO(r)] \* VTWR(i,s,r) \*  
atr(i,s,r) ;

EQUATION CONT\_EV\_kbr (all,r,REG)

CNTkbr(r) = - [.01/INCRATIO(r)] \* VDEP(r) \* [deprate(r)+kb(r)] ;

EQUATION CONT\_EV\_MUr (all,r,REG)

CNT\_MUr(r) = [.01/INCRATIO(r)] \*  
[ sum(i,TRAD\_COMM, VPA(i,r) - VPA(i,r) \* INCPAR(i,r)) \* up(r) ] ;

EQUATION CONT\_EV\_MUir (all,i,TRAD\_COMM) (all,r,REG)

CNT\_MUir(i,r) = [.01/INCRATIO(r)] \*  
[ (VPA(i,r) - VPA(i,r) \* INCPAR(i,r)) \* up(r) ] ;

! .....!  
! Welfare decomposition for FDI extension !  
! .....!

---

! Foreign capital means capital which I own in other regions.

Foreign owned capital means capital which foreigners own in my region. !

EQUATION

CONT\_EV\_ror\_hhi (All,i,TRAD\_COMM)(All,s,HOME)(All,d,host)

CNTror\_hhi(i,s,d)=[.01/INCRATIO(s)]\*VFDI\_HHI(i,s,d)\*c\_trr\_hhi(i,s,d);

CONT\_EV\_ror\_\_hi (All,i,TRAD\_COMM)(All,d,host)

CNTror\_\_hi(i,d)=-sum{s,HOME,INCRATIO(s)/INCRATIO(d)\*CNTror\_hhi(i,s,d)};

CONT\_EV\_ror\_h\_i (All,i,TRAD\_COMM)(All,s,HOME)

CNTror\_h\_i(i,s)=sum{d,dest,CNTror\_hhi(i,s,d)};

CONT\_EV\_ror\_hh\_ (All,s,HOME)(All,d,host)

CNTror\_hh\_(s,d)=sum{i,TRAD\_COMM,CNTror\_hhi(i,s,d)};

CONT\_EV\_ror\_\_h\_ (All,d,host)

CNTror\_\_h\_(d)=-sum{s,HOME,INCRATIO(s)/INCRATIO(d)\*CNTror\_hh\_(s,d)};

CONT\_EV\_ror\_h\_\_ (All,s,HOME)

CNTror\_h\_\_(s)=sum{d,dest,CNTror\_hh\_(s,d)};

---

CONT\_EV\_cap\_hhi (All,i,TRAD\_COMM)(All,s,HOME)(All,d,host)

CNTcap\_hhi(i,s,d)=[.01/INCRATIO(s)]\*VINC\_HHI(i,s,d)\*k\_hhi(i,s,d);

CONT\_EV\_cap\_\_hi (All,i,TRAD\_COMM)(All,d,host)

CNTcap\_\_hi(i,d)=-sum{s,HOME,INCRATIO(s)/INCRATIO(d)\*CNTcap\_hhi(i,s,d)};

CONT\_EV\_cap\_h\_i (All,i,TRAD\_COMM)(All,s,HOME)

CNTcap\_h\_i(i,s)=sum{d,dest,CNTcap\_hhi(i,s,d)};

CONT\_EV\_cap\_hh\_ (All,s,HOME)(All,d,host)

CNTcap\_hh\_(s,d)=sum{i,TRAD\_COMM,CNTcap\_hhi(i,s,d)};

CONT\_EV\_cap\_\_h\_ (All,d,host)

CNTcap\_\_h\_(d)=-sum{s,HOME,INCRATIO(s)/INCRATIO(d)\*CNTcap\_hh\_(s,d)};

CONT\_EV\_cap\_h\_\_ (All,s,HOME)

CNTcap\_h\_\_(s)=sum{d,dest,CNTcap\_hh\_(s,d)};

CONT\_EV\_pcap\_hhi (All,i,TRAD\_COMM)(All,s,HOME)(All,d,host)

CNTpcap\_hhi(i,s,d)=[.01/INCRATIO(s)]\*VINC\_HHI(i,s,d)\*pcgds(d);

CONT\_EV\_pcap\_\_hi (All,i,TRAD\_COMM)(All,d,host)

CNTpcap\_\_hi(i,d)=-sum{s,HOME,INCRATIO(s)/INCRATIO(d)\*CNTpcap\_hhi(i,s,d)};

---

CONT\_EV\_pcap\_h\_i (All,i,TRAD\_COMM)(All,s,HOME)

CNTpcap\_h\_i(i,s)=sum{d,dest,CNTpcap\_hhi(i,s,d)};

CONT\_EV\_pcap\_hh\_ (All,s,HOME)(All,d,host)

CNTpcap\_hh\_(s,d)=sum{i,TRAD\_COMM,CNTpcap\_hhi(i,s,d)};

CONT\_EV\_pcap\_\_h\_ (All,d,host)

CNTpcap\_\_h\_(d)=-sum{s,HOME,INCRATIO(s)/INCRATIO(d)\*CNTpcap\_hh\_(s,d)};

CONT\_EV\_pcap\_h\_\_ (All,s,HOME)

CNTpcap\_h\_\_(s)=sum{d,dest,CNTpcap\_hh\_(s,d)};

CONT\_EV\_ror (All,s,REG)

CNTror(s)=CNTror\_h\_\_(s)+CNTror\_\_h\_(s);

CONT\_EV\_capr (All,s,REG)

CNTcapr(s)=CNTcap\_h\_\_(s)+CNTcap\_\_h\_(s);

CONT\_EV\_pcapr (All,s,REG)

CNTpcapr(s)=CNTpcap\_h\_\_(s)+CNTpcap\_\_h\_(s);

E\_check\_EV\_FDI (All,s,HOME)

check\_EV\_FDI(s)=yfdi\_h\_\_(s)-INCRATIO(s)\*

{CNTror\_h\_\_(s)+CNTror\_\_h\_(s)+

---

```
CNTcap_h__(s)+CNTcap__h_(s)+  
CNTpcap_h__(s)+CNTpcap__h_(s)};
```

```
EQUATION E_check_EV (All,r,REG)
```

```
check_EV(r)=EV(r)-{CNTalleffr(r)+CNTendwr(r)+CNTpricer(r)+CNTkbr(r)+  
CNTbondr(r)+CNTintrater(r)+CNT_MUr(r)+  
CNTcapr(r)+CNTror(r)+
```

```
!FTAP ADD: Need to include technical efficiency as some tech change variables  
must be endogenised in FTAP to ensure internal consistency of the  
GTAP module
```

```
!
```

```
CNTanrr_h__(r)+CNTanend_h__(r)+CNTanpk_h__(r)+  
CNTtechr(r)+CNTanto_h__(r)+CNTanqo_h__(r)+CNTanpo_h__(r)  
!+CNTqfes__h_(r)!};
```

```
! ----- !
```

```
! END OF WELMRNS.TAB !
```

```
! ----- !
```

```
! ----- !
```

```
! TOT.TAB !
```

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! ----- !
```

```
! .....
```



---

! Computations for decomposition the terms-of-trade effect !

! Reference: Rob McDougall, SALTER No. 12 Working Paper !

! .....

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG)(all,s,REG) SX\_IRS(i,r,s)

! share of exports of good i from region r to s ! ;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)(all,s,REG)

SX\_IRS(i,r,s) = VXWD(i,r,s) / [ sum(k, REG, VXWD(i,r,k))

+ VST(i,r) ] ;

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) SXT\_IR(i,r)

! share of margins in exports of good i from region r ! ;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

SXT\_IR(i,r) = VST(i,r) / [ sum(k, REG, VXWD(i,r,k))

+ VST(i,r) ] ;

COEFFICIENT (all,i,TRAD\_COMM) VSTCOMM(i)

# margin exports of commodity i # ;

FORMULA (all,i,TRAD\_COMM) VSTCOMM(i) = sum{r, REG, VST(i,r)} ;

COEFFICIENT GLOBVST

# global margins supply # ;

FORMULA GLOBVST = sum{r, REG, sum{i, TRAD\_COMM, VST(i,r)}} ;

---

COEFFICIENT (all,i,TRAD\_COMM) SSMARG\_I(i)

# share of commodity i in global margins supply # ;

FORMULA (all,i,TRAD\_COMM)

SSMARG\_I(i) = VSTCOMM(i) / GLOBVST ;

COEFFICIENT (all,r,REG) VTI(r)

! value of total costs for imports into region r ! ;

FORMULA (all,s,REG)

VTI(s) = sum(r, REG, sum(i,TRAD\_COMM, VTWR(i,r,s)));

COEFFICIENT (all,i,TRAD\_COMM)(all,s,REG) VTICOMM(i,s)

# margin usage of commy i in provision of imports to region s # ;

FORMULA (all,i,TRAD\_COMM)(all,s,REG)

VTICOMM(i,s) = SSMARG\_I(i) \* VTI(s) ;

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG)(all,s,REG) SM\_IRS(i,r,s)

! share of imports of good i into s from r,

valued at FOB prices ! ;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)(all,s,REG)

SM\_IRS(i,r,s) = VXWD(i,r,s) / [sum(k, REG, VXWD(i,k,s)) +

VTICOMM(i,s)];

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) SMT\_IR(i,r)

---

! share of transport cost in imports of margin

commodity ! ;

FORMULA (all,i,TRAD\_COMM)(all,s,REG)

$$SMT\_IR(i,s) = VTICOMM(i,s) / [\text{sum}(k, REG, VXWD(i,k,s)) + VTICOMM(i,s)] ;$$

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) SX\_IR(i,r)

! share of good i in total exports from r ! ;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

$$SX\_IR(i,r) = [ \text{sum}(s, REG, VXWD(i,r,s)) + VST(i,r) ] / [ \text{sum}(m, TRAD\_COMM, \text{sum}(s, REG, VXWD(m,r,s)) + VST(m,r)) ] ;$$

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) SM\_IR(i,r)

! share of good i in total imports into r ! ;

FORMULA (all,i,TRAD\_COMM)(all,s,REG)

$$SM\_IR(i,s) = [ \text{sum}(r, REG, VXWD(i,r,s)) + VTICOMM(i,s) ] / [ \text{sum}(m, TRAD\_COMM, \text{sum}(r, REG, VXWD(m,r,s)) + VTI(s) ] ;$$

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) SW\_IR(i,r)

! share of region r exports in world total for good i ! ;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

$$SW\_IR(i,r) = [ \text{sum}(s, REG, VXWD(i,r,s)) + VST(i,r) ] / [ \text{sum}(k,REG, \text{sum}(s, REG, VXWD(i,k,s)) + VST(i,k)) ] ;$$

---

COEFFICIENT (all,i,TRAD\_COMM)

SW\_I(i)

! share of exports of i in world total ! ;

FORMULA (all,i,TRAD\_COMM)

SW\_I(i) =[sum(r,REG, sum(s, REG, VXWD(i,r,s)) + VST(i,r))] /

[ sum(k,TRAD\_COMM, sum(r,REG, sum(s, REG, VXWD(k,r,s)) + VST(k,r)))];

! .....

EQUATION EXPPRICE1

! Price index for total exports of i from r !

(all,i,TRAD\_COMM)(all,r,REG)

px\_ir(i,r) = sum(s,REG, SX\_IRS(i,r,s) \* pfob(i,r,s))

+ SXT\_IR(i,r) \* pst(i,r) ;

EQUATION IMPPRICE1

! Price index for total imports of i in s !

(all,i,TRAD\_COMM)(all,s,REG)

pm\_ir(i,s) = sum(r,REG, SM\_IRS(i,r,s) \* pfob(i,r,s))

+ SMT\_IR(i,s) \* pt ;

EQUATION WRLDPRICEi

! world export price index for good i !

---

(all,i,TRAD\_COMM)

px\_i(i) = sum(r,REG, SW\_IR(i,r) \* px\_ir(i,r)) ;

EQUATION WRLDPRICE

! world export price index for all goods !

px\_ = sum(i, TRAD\_COMM, SW\_I(i) \* px\_i(i)) ;

EQUATION c1\_irEQ

! contribution of world export price index of good i to ToT for  
region r !

(all,i,TRAD\_COMM)(all,r,REG)

c1\_ir(i,r) = [SX\_IR(i,r) - SM\_IR(i,r)] \* [px\_i(i) - px\_] ;

EQUATION c2\_irEQ

! contribution of regional export price of good i for region r !

(all,i,TRAD\_COMM)(all,r,REG)

c2\_ir(i,r) = SX\_IR(i,r) \* [px\_ir(i,r) - px\_i(i)] ;

EQUATION c3\_irEQ

! contribution of imports price index of good i for region r !

(all,i,TRAD\_COMM)(all,r,REG)

c3\_ir(i,r) = SM\_IR(i,r) \* [pm\_ir(i,r) - px\_i(i)] ;

EQUATION c1\_rEQ



---

! ----- !

! ----- !

! ICM.TAB !

! ----- !

! ..... !

! This module follows the ICM extension made to SALTER as documented in  
McDougall, R., (1993) "Incorporating International Capital Mobility into  
SALTER", SALTER working paper no.21, Industry Commission, Canberra, June.  
To aid in understanding this extension with respect to SALTER, SALTER  
variable/coefficient/parameter and equation names have been used. Where  
new names have been created it has only been due to the name having  
already been declared in the original GTAP tab file. SALTER variables/  
coefficients which have GTAP equivalents are set equal to these, and the  
SALTER variable/coefficient names are retained in the new equations. Thus,  
the new equations are as similar as possible to the original equations in  
SALTER. !

! ..... !

! ----- !

! ICM coefficients !

! ----- !

---

COEFFICIENT (all,r,REG) RTIVKPR(r)

# ratio of investment to capital, by region #;

COEFFICIENT (all,r,REG) RTKPANR(r)

# average rate of abnormal return on capital, by region #;

COEFFICIENT (all,r,REG) ENANKPR(r)

# abnormal earnings of capital, by region #;

COEFFICIENT (all,r,REG) RTKPGRR(r)

# average gross rate of return on capital, by region #;

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG)

RTKPANRI(i,r)

# rate of abnormal return on capital, by region and industry #;

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) SKT(i,r)

# share of industry i in capital stock of region r #;

COEFFICIENT (all,r,REG) YCHHPVR(r)

# household pre-transfer income, by region #;

COEFFICIENT EPCS # world consumption expenditure #;



---

COEFFICIENT (all,r,REG) SVR(r) # saving, by region #;

COEFFICIENT (all,r,REG) SPGVR(r)

# government surplus on current transactions, by region #;

COEFFICIENT (all,r,REG) OLGVR(r)

# government current outlays, by region #;

COEFFICIENT (all,r,REG) CEACWTGV02R(r)

# government wealth accumulation coefficient #;

COEFFICIENT (all,r,REG) CEACWTGV01R(r)

# government wealth accumulation coefficient #;

COEFFICIENT (all,r,REG) CEACWTHH02R(r)

# household wealth accumulation coefficient #;

COEFFICIENT (all,r,REG) SVT(r)

# private household savings, by region #;

COEFFICIENT (all,r,REG) CEACWTHH01R(r)

# household wealth accumulation coefficient #;

---

COEFFICIENT (all,r,REG) ASHHR(r)

# private household wealth, by region #;

COEFFICIENT (all,r,REG) ASEQR(r)

# equity in productive assets, by region #;

COEFFICIENT (all,r,REG) ASLNR(r) # value of land, by region #;

COEFFICIENT (all,r,REG) ASLNRR(r)

# value of natural resources, by region #;

COEFFICIENT (all,r,REG) ASGVR(r)

# net government ownership of bonds, by region #;

COEFFICIENT (all,r,REG) ASHHBDR(r)

# net household ownership of bonds, by region #;

COEFFICIENT ASBD # world net ownership of bonds #;

COEFFICIENT YC # world nominal income #;

COEFFICIENT (all,j,TRAD\_COMM)(all,r,REG) COSTINP(j,r)

# tot cost of inps to ind excl ind taxes, by ind and reg #;

---

COEFFICIENT (all,r,REG) YCEQR(r)

# equity (in productive assets) income, by region #;

COEFFICIENT (all,j,TRAD\_COMM)(all,r,REG) RTKPGRRI(j,r)

# gross rate of return on capital, by region and industry #;

COEFFICIENT (all,r,REG) RVTXYCR(r) # income tax, by region #;

COEFFICIENT (all,j,TRAD\_COMM)(all,r,REG) ENANKPRI(j,r)

# abnormal earnings of capital, by region and industry #;

COEFFICIENT (all,r,REG) YCHHR(r) # household income, by region #;

COEFFICIENT (all,j,TRAD\_COMM)(all,r,REG) LAB(j,r)

! payments to labour(tax-incl), by industry and region ! ;

FORMULA (all,j,TRAD\_COMM)(all,r,REG)

LAB(j,r) = sum(l,LABOR, VFM(l,j,r));

COEFFICIENT (all,j,TRAD\_COMM)(all,r,REG) LND(j,r)

!returns to land (tax-excl), by industry and region!;

FORMULA (all,j,TRAD\_COMM)(all,r,REG)

LND(j,r) = sum(n,LAND, VFM(n,j,r));

---

COEFFICIENT (all,j,TRAD\_COMM)(all,r,REG) NRS(j,r)

!returns to land (tax-excl), by industry and region!;

FORMULA (all,j,TRAD\_COMM)(all,r,REG)

NRS(j,r) = sum(nr,NATRES, VFM(nr,j,r));

COEFFICIENT (all,j,TRAD\_COMM)(all,r,REG) CAP(j,r)

# fixed capital earnings, by region and industry #;

FORMULA (all,j,TRAD\_COMM)(all,r,REG)

CAP(j,r) = sum(k,ENDWC\_COMM, VFM(k,j,r));

COEFFICIENT (all,r,REG) LTT(r) # labour income, by region #;

FORMULA (all,r,REG) LTT(r) = sum(j,TRAD\_COMM, LAB(j,r));

COEFFICIENT (all,r,REG) KTT(r) # agg returns to capital, by region #;

FORMULA (all,r,REG) KTT(r) = sum(j,TRAD\_COMM, CAP(j,r));

COEFFICIENT (all,r,REG) MTT(r) #agg returns to land, by region #;

FORMULA (all,r,REG) MTT(r) = sum(j,TRAD\_COMM, LND(j,r));

COEFFICIENT (all,r,REG) NTT(r) #agg returns to natural res, by reg#;

FORMULA (all,r, REG) NTT(r) = sum(j,TRAD\_COMM, NRS(j,r));

COEFFICIENT (all,r,REG) YCHHPPR(r) # hhold prop income, by region #;

---

COEFFICIENT (all,r,REG) YCHHPPRTAX(r)

#household property income which is taxed#;

(All,r,REG) YOUTIMPTAX(r);

(All,r,REG) YKAPIMPTAX(r);

COEFFICIENT (all,r,REG) YCHHPPRLOC(r)

# hhold prop income less FDI income, by region #;

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) DINV(i,r)

! tax-exclusive invst expen on domestic commodity i in region r !;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

DINV(i,r) = sum(c,CGDS\_COMM, VDFM(i,c,r));

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) TIRD(i,r)

! commodity taxes on DINV !;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

TIRD(i,r) = sum(c,CGDS\_COMM, DFTAX(i,c,r));

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) IINV(i,r)

! tax-exclusive investment expenditure on domestic commodity

i in region r !;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

---

IINV(i,r) = sum(c,CGDS\_COMM, VIFM(i,c,r));

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) TIRI(i,r)

! commodity taxes on IINV !;

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

TIRI(i,r) = sum(c,CGDS\_COMM, IFTAX(i,c,r));

COEFFICIENT (all,r,REG) RTEQR(r)

# real rate of return on equity, by region #;

COEFFICIENT (all,r,REG) YFNT(r) # net (of depreciation) factor inc #;

FORMULA (all,r,REG)

YFNT(r) = LTT(r) + KTT(r) + MTT(r) + NTT(r) - VDEP(r);

! FTAP - Share of output rent which is tax revenue. Used for income  
accounting with respect to revenue from output impediments.

!

! WARNING: This equation is very hard-wired at the moment. It sets SHPTAX  
constant at 1 for everything except commodity 3, which is constant  
at 0. This suits the three commodity aggregation where all output  
rents from Tertiary are due to impediments to continued operations.  
Warning applies to SHXTAX also.

!

---

FORMULA (Initial) & EQUATION (Levels) E\_c\_SHPTAX (All,i,PROD\_COMM)(All,r,REG)

SHPTAX(i,r)=1-!0\*!IF[\$POS(i,PROD\_COMM)=3,1];

FORMULA (Initial) (All,i,TRAD\_COMM)(All,s,SOURCE)(All,d,DEST)

SHXTAXD(i,s,d)=1-IF[\$POS(i,TRAD\_COMM)=3,1-TYPR\_L(s)];

EQUATION E\_c\_SHXTAXD (All,i,TRAD\_COMM)(All,s,SOURCE)(All,d,DEST)

c\_SHXTAXD(i,s,d)=0.01\*TYPR\_L(s)\*typr(s);

COEFFICIENT (all,r,REG) GRCOMT(r)

# total government revenue from commodity taxes #;

FORMULA (all,r,REG)

GRCOMT(r) = sum(i,TRAD\_COMM, sum(j,TRAD\_COMM, DFTAX(i,j,r)))

+ sum(i,TRAD\_COMM, sum(j,TRAD\_COMM, IFTAX(i,j,r)))

+ sum(i,TRAD\_COMM, TIRD(i,r)) + sum(i,TRAD\_COMM, TIRI(i,r))

+ sum(i,TRAD\_COMM, DPTAX(i,r)) + sum(i,TRAD\_COMM, IPTAX(i,r))

+ sum(i,TRAD\_COMM, sum(s,REG, XTAXD(i,r,s)))

+ sum(i,TRAD\_COMM, DGTAX(i,r)) + sum(i,TRAD\_COMM, IGTAX(i,r))

+ sum(i,TRAD\_COMM, sum(s,REG, MTAX(i,s,r)))

+ sum(i,TRAD\_COMM, SHPTAX(i,r)\*PTAX(i,r));

COEFFICIENT (all,r,REG) SLYF(r)

# share of labour in agg net factor income #;

---

FORMULA (all,r,REG) SLYF(r) = LTT(r) / YFNT(r) ;

COEFFICIENT (all,j,TRAD\_COMM)(all,r,REG) SKYF(j,r)

# share of capital in agg net factor income, by ind and reg #;

FORMULA (all,j,TRAD\_COMM)(all,r,REG)

SKYF(j,r) = CAP(j,r) / YFNT(r);

COEFFICIENT (all,r,REG) SMYF(r)

# share of land in agg net factor income, by region #;

FORMULA (all,r,REG) SMYF(r) = MTT(r) / YFNT(r);

COEFFICIENT (all,r, REG) SNYF(r)

#share of natural resources in agg net factor income, by region#;

FORMULA (all,r,REG) SNYF(r) = NTT(r) / YFNT(r);

COEFFICIENT (all,r,REG) SDDDF(r)

# share of depreciation in agg net factor income #;

FORMULA (all,r,REG) SDDDF(r) = VDEP(r) / YFNT(r);

COEFFICIENT (all,r,REG) EPCSR(r)

# aggregate consumption expenditure, by region #;

FORMULA (all,r,REG) EPCSR(r) = PRIVEXP(r) + GOVEXP(r);

COEFFICIENT (all,r,REG) RECIP\_GRCOMT(r) # reciprocal of GRCOMT(r) #;



---

FORMULA (all,r,REG) RECIP\_GRCOMT(r) = 1/GRCOMT(r);

ZERODIVIDE (ZERO\_BY\_ZERO) DEFAULT 0.0;

ZERODIVIDE (NONZERO\_BY\_ZERO) DEFAULT 0.0;

FORMULA RCLGPRSM = 1.0/LGPRSM;

! Pre-tax rate of return on equity !

FORMULA

(All,r,REG) RTEQR(r)={sum[i,ENDWC\_COMM,VOM(i,r)]-VDEP(r)}/VKB(r);

!equity (in productive assets) income, by region!

FORMULA (all,r,REG) YCEQR(r) = KTT(r) + MTT(r) + NTT(r) - VDEP(r);

!income tax, by region!

FORMULA (all,r,REG) RVTXYCR(r) = RVTXYCLBR(r) + RVTXYCPPR(r);

!capital tax, by region!

FORMULA (All,r,REG) RVTXYCKR(r)=sum[i,ENDWC\_COMM,VOM(i,r)-VOA(i,r)];

!normal capital earnings, by region!

FORMULA (all,r,REG) KTT(r) = sum(i,TRAD\_COMM, CAP(i,r));

ZERODIVIDE DEFAULT RTBD;

---

!gross rate of return on capital, by region and industry!

FORMULA (all,j,TRAD\_COMM)(all,r,REG)

RTKPGRRI(j,r) = CAP(j,r)/VKBI(j,r);

! total costs of inputs to industry excluding indirect taxes,

by industry and region !

FORMULA (all,j,TRAD\_COMM)(all,r,REG) COSTINP(j,r)

= sum(i,TRAD\_COMM, VDFM(i,j,r)) + sum(i,TRAD\_COMM, VIFM(i,j,r))

+ sum(i,TRAD\_COMM, DFTAX(i,j,r)) + sum(i,TRAD\_COMM, IFTAX(i,j,r))

! FTAP: Include abnormal rentals to capital in cost of inputs. !

+sum(i,ENDW\_COMM,ETAX(i,j,r))

+ LAB(j,r) + CAP(j,r) + LND(j,r) + NRS(j,r);

!government receipts, by region!

FORMULA (all,r,REG) RCGVR(r) = RVTXYCR(r) + GRCOMT(r) + RCGVITR(r);

!net government ownership of bonds, by region!

FORMULA (all,r,REG) ASGVR(r) = RCGVITR(r)/RTBD;

!value of land, by region!

FORMULA (all,r,REG) ASLNR(r) = MTT(r)/RR\_LAND(r);

! Value of natural resources by region !

FORMULA (all,r,REG) ASLNRR(r) = NTT(r)/RR\_NATRES(r);

---

!equity in productive assets, by region!

FORMULA (all,r,REG) ASEQR(r) = VKT(r) + ASLNR(r) + ASLNRR(r) ;

ZERODIVIDE DEFAULT 1.0;

!household wealth accumulation coefficient!

FORMULA (all,r,REG)

CEACWTHH01R(r)

= (1.0 - EXP(-GTYCHHRLR(r)\*LGPRSM))/(GTYCHHRLR(r)\*LGPRSM);

ZERODIVIDE DEFAULT 0.5;

!household wealth accumulation coefficient!

FORMULA (all,r,REG)

CEACWTHH02R(r) = (GTYCHHRLR(r)\*LGPRSM - 1.0

+ EXP(-GTYCHHRLR(r)\*LGPRSM))/(GTYCHHRLR(r)\*LGPRSM)^2;

ZERODIVIDE DEFAULT 1.0;

!government wealth accumulation coefficient!

FORMULA (all,r,REG)

CEACWTGV01R(r)

= (1.0 - EXP(-GTYCGVRLR(r)\*LGPRSM))/(GTYCGVRLR(r)\*LGPRSM);

ZERODIVIDE DEFAULT 0.5;

!government wealth accumulation coefficient!

---

FORMULA (all,r,REG)

CEACWTGV02R(r) = (GTYCGVRLR(r)\*LGPRSM - 1.0

+ EXP(-GTYCGVRLR(r)\*LGPRSM))/(GTYCGVRLR(r)\*LGPRSM)^2;

!government current outlays, by region!

FORMULA (all,r,REG)

OLGVR(r) = GOVEXP(r) + URGVHHR(r) +

sum[i,TRAD\_COMM,sum[d,DEST, (1-SHXTAXD(i,r,d))\*XTAXD(i,r,d)]];

!government surplus on current transactions, by region!

FORMULA (all,r,REG) SPGVR(r) = RCGVR(r) - OLGVR(r);

!world consumption expenditure!

FORMULA EPCS = sum(r,REG, EPCSR(r)!/ECRT(r)!);

!share of industry i in capital stock of region r!

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

SKT(i,r) = CAP(i,r)/KTT(r);

!abnormal returns on capital, by region and industry!

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

ENANKPRI(i,r)=sum[k,ENDWC\_COMM,EVFA(k,i,r)-VFM(k,i,r)];

ZERODIVIDE DEFAULT RTBD;

---

!rate of abnormal return on capital, by region and industry!

FORMULA (all,i,TRAD\_COMM)(all,r,REG)

RTKPANRI(i,r) = ENANKPRI(i,r)/VKBI(i,r);

!average gross rate of return on capital, by region!

FORMULA (all,r,REG) RTKPGRR(r) = KTT(r)/VKB(r);

!abnormal earnings of capital, by region!

FORMULA (all,r,REG) ENANKPR(r) = sum(i,TRAD\_COMM, ENANKPRI(i,r));

!average rate of abnormal return on capital, by region!

FORMULA (all,r, REG)

RTKPANR(r) = ENANKPR(r)/VKB(r);

!ratio of investment to capital, by region!

FORMULA (all,r,REG) RTIVKPR(r) = REGINV(r)/VKB(r);

COEFFICIENT ASKP # world capital stock #;

COEFFICIENT WINVTT # world investment expenditure #;

COEFFICIENT WNCIL # world net capital inflow #;

COEFFICIENT YCIT # world net interest income #;

COEFFICIENT WGPL # world gross product #;

COEFFICIENT (all,r,REG) NCIL(r) # net capital inflow #;

COEFFICIENT (all,r,REG) GNPL(r) # gross national product #;

---

COEFFICIENT (all,r,REG) GNEL(r) # gross national expenditure #;

COEFFICIENT

pre\_tax\_rr #Is 1 if pre-tax RoRs used in asset supply function#;

host\_tax\_ank #Is 1 if host country taxes capital impediment rents#;

host\_tax\_anp #Is 1 if host country taxes output impediment rents#;

FORMULA

(Initial) post\_tax\_rr=IF{post\_tax\_rr ne 0,1};

(Initial) home\_tax\_ank=IF{home\_tax\_ank ne 0,1};

(Initial) home\_tax\_anp=IF{home\_tax\_anp ne 0,1};

pre\_tax\_rr=1-post\_tax\_rr;

host\_tax\_ank=1-home\_tax\_ank;

host\_tax\_anp=1-home\_tax\_anp;

! Add duplicate definitions written in terms of GTAP data and variables as

a means of checking !

COEFFICIENT (all,r,REG) GRCOMT1(r)

# total government revenue from commodity taxes #;

COEFFICIENT (All,r,REG) CHECK\_GRCOMT(r)

#Check that SALTER com.tax.rev. = GTAP#;

---

```

FORMULA (all,r,REG)

GRCOMT1(r) = sum(i,PROD_COMM, SHPTAX(i,r)*[VOM(i,r) - VOA(i,r)])

+ sum(i,ENDWM_COMM,sum(j,PROD_COMM, VFA(i,j,r)- VFM(i,j,r)))

! Exclude abnormal rentals to capital !

- sum(i,ENDWC_COMM,sum(j,PROD_COMM, VFA(i,j,r)- VFM(i,j,r)))

+ sum(i,ENDWS_COMM,sum(j,PROD_COMM, VFA(i,j,r) - VFM(i,j,r)))

+ sum(j,PROD_COMM, sum(i,TRAD_COMM, VIFA(i,j,r) - VIFM(i,j,r)))

+ sum(j,PROD_COMM, sum(i,TRAD_COMM, VDFA(i,j,r) - VDFM(i,j,r)))

+ sum(i,TRAD_COMM, VIPA(i,r) - VIPM(i,r))

+ sum(i,TRAD_COMM, VDPA(i,r) - VDPM(i,r))

+ sum(i,TRAD_COMM, VIGA(i,r) - VIGM(i,r))

+ sum(i,TRAD_COMM, VDGA(i,r) - VDGM(i,r))

+ sum(i,TRAD_COMM, sum(s,REG, VXWD(i,r,s) - VXMD(i,r,s)))

+ sum(i,TRAD_COMM, sum(s,REG, VIMS(i,s,r) - VIWS(i,s,r)));

```

```

FORMULA (All,r,REG) CHECK_GRCOMT(r)=GRCOMT(r)-GRCOMT1(r);

```

```

DISPLAY CHECK_GRCOMT;

```

```

COEFFICIENT (all,j,PROD_COMM)(all,r,REG) VVA(j,r)

```

```

#value-added of ind i in region r #;

```

```

FORMULA (all,j,PROD_COMM)(all,r,REG)

```

```

VVA(j,r) = sum(i,ENDW_COMM, EVFA(i,j,r));

```

---

COEFFICIENT (all,r,REG) GDPFCL(r)! GDPFC AT FACTOR COST ! ;

FORMULA (all,r,REG) GDPFCL(r) = LTT(r) + KTT(r) + MTT(r) + NTT(r);

COEFFICIENT (all,r,REG) SLGDP(r)! SLGDP OF (4.89) ! ;

FORMULA (all,r,REG) SLGDP(r) = LTT(r)/ GDPFCL(r) ;

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) SKGDP(i,r)! SKGDP OF (4.89)!;

FORMULA (all,i,TRAD\_COMM)(all,r,REG) SKGDP(i,r) = CAP(i,r)/GDPFCL(r);

COEFFICIENT (all,r,REG) SMGDP(r)! SMGDP OF (4.89) ! ;

FORMULA (all,r,REG) SMGDP(r) = MTT(r) / GDPFCL(r) ;

COEFFICIENT (all,r,REG) SNGDP(r)! SNGDP OF (4.89) ! ;

FORMULA (all,r,REG) SNGDP(r) = NTT(r) / GDPFCL(r) ;

COEFFICIENT (All,r,REG) ANKTAX(r)

#Regional income from abnormal capital earnings#;

FORMULA (All,r,REG) ANKTAX(r)=sum[i,ENDWC\_COMM,sum[j,PROD\_COMM,ETAX(i,j,r)]];

COEFFICIENT (All,r,REG) ANKTAX\_H\_\_(r)

#Regional income from FDI abnormal capital earnings#;

COEFFICIENT (All,r,REG) ANPTAX(r)

#Regional income from output impediments#;



---

COEFFICIENT (All,r,REG) ANPTAX\_H\_\_(r)

#Regional income from FDI output impediments#;

COEFFICIENT (All,i,TRAD\_COMM)(All,o,HOME)(All,l,HOST) ANKTAX\_HHI(i,o,l)

#X#;

COEFFICIENT (All,i,TRAD\_COMM)(All,o,HOME)(All,l,HOST) ANPTAX\_HHI(i,o,l)

#X#;

COEFFICIENT (All,s,home) VINC\_H\_\_(s)

#Home region income from FDI#;

!-----!

! ICM equations !

!-----!

!-----!

! 1. International allocation of capital !

!-----!

EQUATION !SG11! INTERNL\_INTT\_PARY

---

```

# International interest parity # (all,r,REG)

rbr(r) = rb;

!SG12! EQY_BOND_PARY

# Equity-bond parity #

(all,r,REG)

rkr(r) = rbr(r) + frer(r);

!SG14! RENTL_PRICE_CAPL

# Rental price of capital #

(all,i,TRAD_COMM)(all,r,REG)

rkri(i,r) = RTKPGRRI(i,r)*(rp(i,r) - pcgds(r));

EQUATION E_rm # Pre-tax rental price of LAND #

(all,r,REG)

rm(r) = sum(n,LAND,pm(n,r));

EQUATION E_nrp # Pre-tax rental price of NATURAL RESOURCES #

(all,r,REG)

nrp(r) = sum(nr,NATRES,pm(nr,r));

EQUATION E_w # Region-wide wage rate #

(all,r,REG)

w(r) = sum (l,LABOR, VOM(l,r)/sum (l_,LABOR, VOM(l_,r))*pm(l,r));

```



---

EQUATION E\_mt

# Capital usage by region #

(all,r,REG) mt(r) = sum(n,LAND,qo(n,r));

EQUATION E\_nru

# Natural resources usage by region #

(all,r,REG) nru(r) = sum(nr,NATRES,qo(nr,r));

EQUATION E\_lt\_

# Labour usage by region #

(all,r,REG)

lt\_(r) = sum (l,LABOR, VOM(l,r))/sum (l\_,LABOR, VOM(l\_,r))\*qo(l,r);

!SG6! VALUE\_CAPL

# value of physical capital, by region #

(all,r,REG)

akr(r) = pk\_h\_\_(r) + kt(r);

!SG7! VALUE\_LAND

# value of land, by region #

(all,r,REG)

anr(r) = pnr(r) + mt(r);

E\_anrr

---

```

# value of natural resources, by region #

(all,r,REG)

anrr(r) = pnrr(r) + nru(r);

!SH11! DEP_CAPITAL

# depreciation of capital stock, by region #

(all,r,REG)

VDEP(r)*depr(r) = 100*c_VDEP(r);

!SG4! EQY

# equity in productive assets, by region #

(all,r,REG)

ASEQR(r)*aer(r) = VKT(r)*akr(r) + ASLNR(r)*anr(r) + ASLNRR(r)*anrr(r);

!-----!

3. Wealth accumulation

!-----!

!SG8! HHOLD_WEALTH_ACCN

# household wealth accumulation, by region #

(all,r,REG) ASHHR(r)*ahr(r)

= (ASHHR(r) - CEACWTHH01R(r)*SVT(r)*LGPRSM)*ipahr(r)

+ CEACWTHH01R(r)*YCHHDPR(r)*LGPRSM*qyhsr(r)

```

---

$+ \text{CEACWTHH01R}(r) * \text{SVT}(r) * \text{LGPRSM} * \text{ppriv}(r)$   
 $+ \text{CEACWTHH02R}(r) * \text{SVT}(r) * \text{LGPRSM} * (\text{yhdr}(r) - \text{ppriv}(r));$

!SG10! GOVT\_WEALTH\_ACCN # government wealth accumulation, by region #

(all,r,REG)

$\text{RCGVR}(r) * \text{qrgbr}(r) + \text{ASGVR}(r) * \text{rgr}(r)$   
 $= (\text{ASGVR}(r) - \text{CEACWTGV01R}(r) * \text{SPGVR}(r) * \text{LGPRSM}) * (\text{pbr}(r) !+ \text{er}(r)!)$   
 $+ \text{CEACWTGV01R}(r) * \text{RCGVR}(r) * \text{LGPRSM} * \text{qrgrsr}(r)$   
 $+ \text{CEACWTGV01R}(r) * \text{SPGVR}(r) * \text{LGPRSM} * \text{pgov}(r)$   
 $+ \text{CEACWTGV02R}(r) * \text{SPGVR}(r) * \text{LGPRSM} * (\text{rgr}(r) - \text{pgov}(r));$

!SG9! HHOLD\_ASST\_PRINDEX # household asset price index # (all,r,REG)

$\text{ASHHR}(r) * \text{ipahr}(r) = \text{ASEQR}(r) * \text{iper}(r) + \text{ASHHBDR}(r) * (\text{pbr}(r) !+ \text{er}(r)!);$

!SH28! NATL\_CONSN\_PRINDEX

# national consumption price index # (all,r,REG)

$\text{YCR}(r) * \text{ipcr}(r) = \text{PRIVEXP}(r) * \text{ppriv}(r) + \text{GOVEXP}(r) * \text{pgov}(r) + \text{SVR}(r) * \text{pcgds}(r);$

!SJ3! WORLD\_CONSN\_PRINDEX # world consumption price index # EPCS\*ipc

$= \text{sum}(r, \text{REG}, (\text{EPCSR}(r) !/ \text{ECRT}(r)!) * (\text{ipcr}(r) ! - \text{er}(r)!));$

!-----

#### 4. National income and saving

---

-----!

!SH4! NET\_FACT\_INC # net factor income, by region #

(all,r,REG)

yfn(r)

= SLYF(r)\*(w(r) + lt\_(r)) + sum(j,TRAD\_COMM, (SKYF(j,r)\*(rp(j,r)  
+ kk(j,r)))) + SMYF(r)\*(rm(r) + mt(r)) + SNYF(r)\*(nrp(r) + nru(r))  
- SDDDF(r)\*depr(r);

!The SALTER variable k has been renamed kk in this equation as k has  
already been used as an index in the original GTAP tab file and,  
thus, cannot be used again!

!SH24! NATL\_INCOME # national income, by region # (all,r,REG)

YCR(r)\*[y\_r(r)-incomeslack(r)]  
= YFNT(r)\*yfn(r) + YCR(r)\*qyir(r)+  
! Add abnormal returns to capital !  
100\*yankr(r)+100\*yank\_h\_\_(r)+  
! Add output impediment rents !  
100\*yanpr(r)+100\*yanp\_h\_\_(r)+  
+ YCITR(r)\*y\_r(r) + GRCOMT(r)\*rc(r) + 100\*yfdi\_h\_\_(r);

!SH25! INTT\_INCOME\_REGN # interest income, by region # (all,r,REG)

---

$YCR(r)*qyir(r) = ASBDR(r)*rbr(r) + RTBD*YCR(r)*qybr(r);$

!SH27! NAT\_SAVINGS # national saving, by region # (all,r,REG)

$YCR(r)*qysr(r) + SVR(r)*y_r(r) = YCHDPR(r)*qyhsr(r) + SVT(r)*yhdr(r)$   
 $+ RCGVR(r)*qrgsr(r) + SPGVR(r)*rgr(r);$

E\_saveslack # Equate IC95 savings with GTAP savings # (all,r,REG)

$SAVE(r)*[psave(r)+qsave(r)] = YCR(r)*qysr(r) + SVR(r)*y_r(r)$   
 $+ SAVE(r)*saveslack(r);$

!SH29! REAL\_NATL\_INCOME # real national income # (all,r,REG)

$y_r(r) = ipcr(r) + yr_r(r);$

!SJ2! WORLD\_INCOME  $YC*yn = SUM(r,REG, (YCR(r)!/ECRT(r)!)*y_r(r));$

!SJ4! WORLD\_REAL\_INCOME # world real income #  $yn = ipc + yr;$

!-----!

5. Household income

-----!

!SD7! HHOLD\_DISPBLE\_INCOME # household disposable income, by region #



---

(all,r,REG)

YCHHDPR(r)\*yhdr(r) = YCHHR(r)\*yhr(r) - RVTXYCR(r)\*rtyr(r);

!SD1! HHOLD\_INCOME # household income, by region # (all,r,REG)

YCHHR(r)\*yhr(r) =

LTT(r)\*ylr(r) + YCHHPPR(r)\*yhpr(r) + URGVHHR(r)\*ughr(r) + d\_ughr\_(r);

!SD2! LABR\_INCOME # labour income, by region # (all,r,REG)

ylr(r) = w(r) + lt\_(r);

!SD3! PROPY\_INCOME # property income, by region # (all,r,REG)

YCHHPPR(r)\*yhpr(r) =100\*yankr(r)+100\*yank\_h\_\_(r)+

! Add output impediment rents !

100\*yanpr(r)+100\*yanp\_h\_\_(r)+

YCEQR(r)\*yer(r) + YCHHDPR(r)\*qyhir(r) + YCHHITR(r)\*yhdr(r) + 100\*yfdi\_h\_\_(r);

!SD4! EQY\_INCOME

# income from ownership of productive assets, by region #

(all,r,REG) YCEQR(r)\*yer(r)

= KTT(r)\*fke(r) + MTT(r)\*(rm(r) + mt(r)) + NTT(r)\*(nrp(r) +

nru(r)) - VDEP(r)\*depr(r);

!SD5! FIXD\_CAPL\_EARNINGS#(nom) agg earnings of fixed capital, by reg#

(all,r,REG) KTT(r)\*fke(r) = sum(j,TRAD\_COMM, CAP(j,r)\*(rp(j,r) + kk(j,r)));

---

!SD6! HHOLD\_INTT\_INCOME # household net interest income, by region #

(all,r,REG) YCHHDPR(r)\*qyhir(r) =

ASHHBDR(r)\*rbr(r) + RTBD\*YCHHDPR(r)\*qyhbr(r);

!SD8! DISPN\_HHOLD\_INCOME

# disposition of household disposable income # (all,r,REG)

YCHHDPR(r)\*yhdr(r)

= PRIVEXP(r)\*yp(r) + YCHHDPR(r)\*qyhsr(r) + SVT(r)\*yhdr(r);

!SD9! HHOLD\_PRIVTE\_INCME # household pre-transfer income, by region #

(all,r,REG)

YCHHPVR(r)\*yhvr(r)=LTT(r)\*ylr(r)+YCHHPPR(r)\*yhpr(r)-RVTXYCR(r)\*rtyr(r);

E\_yoit (All,r,REG) yoit(r)=

IF{host\_tax\_anp ne 0,host\_tax\_anp\*{

-sum[i,TRAD\_COMM,sum[d,DEST,

[1-TYPR\_L(d)]\*yanp\_hhi(i,r,d)-

0.01\*ANPTAX\_HHI(i,r,d)\*TYPR\_L(d)\*typr(d)]

+sum[i,TRAD\_COMM,sum[s,HOME,

[2-TYPR\_L(r)]\*yanp\_hhi(i,s,r)-

0.01\*ANPTAX\_HHI(i,s,r)\*TYPR\_L(r)\*typr(r)]}]};

E\_ykit (All,r,REG) ykit(r)=

---

```

IF{host_tax_ank ne 0,host_tax_ank*{
  -sum[i,TRAD_COMM,sum[d,DEST,
    [1-TYPR_L(d)]*yank_hhi(i,r,d)-
    0.01*ANKTAX_HHI(i,r,d)*TYPR_L(d)*typr(d)]]
  +sum[i,TRAD_COMM,sum[s,HOME,
    [2-TYPR_L(r)]*yank_hhi(i,s,r)-
    0.01*ANKTAX_HHI(i,s,r)*TYPR_L(r)*typr(r)]]}};

```

```
E_yhprtax # property income which is taxed # (all,r,REG)
```

```
YCHHPPRTAX(r)*yhprtax(r)=YCHHPPR(r)*yhpr(r)+100*[yoit(r)+ykit(r)-yfdi_h__(r)];
```

```
E_yhprloc # property income less net FDI income # (all,r,REG)
```

```
YCHHPPR(r)*yhpr(r) = 100*yfdi_h__(r) + YCHHPPRLOC(r)*yhprloc(r);
```

```
!-----
```

## 6. Government receipts and outlays

```
-----!
```

```
!SE1! GOVT_RECTS # government receipts, by region # (all,r,REG)
```

```

RCGVR(r)*rgr(r)
= RVTXYCR(r)*rtyr(r) + GRCOMT(r)*rc(r)
+ RCGVR(r)*qrgir(r) + RCGVITR(r)*rgr(r);

```

---

!SE2! INCOME\_TAX # income tax, by region # (all,r,REG)

$RVTXYCR(r)*rtyr(r) = RVTXYCLBR(r)*rtylr(r) + RVTXYCPPR(r)*rtypr(r);$

!SE3! TAX\_LABR\_INCOME # tax on labour income, by region # (all,r,REG)

$rtylr(r) = tylr(r) + ylr(r);$

!SE4! TAX\_PROPY\_INCOME

# tax on property income, by region # (all,r,REG)

$rtypr(r) = typr(r) + yhpntax(r);$

!SE16! RATE\_TAX\_LABR\_INCOME

# labour income tax rate, by region # (all,r,REG)

$tylr(r) = ftyr(r) + ftylr(r);$

!SE17! RATE\_TAX\_PRPY\_INCOME

# property income tax rate, by region # (all,r,REG)

$typr(r) = ftyr(r) + ftypr(r);$

!SE15! GOVREVCMM # revenue from commodity taxes, by region #

(all,r,REG)

$rc(r)$

$= grsub(r) + grint(r) + grinv(r) + grcon(r) + grexp(r)$

---

+ grgov(r) + grdut(r);

!SE10! REVINDT

!# contribution of a change in indirect (output) taxes#

!(subsidies) to the per cent change in agg commodity tax revenue,#

#by region #! (all,r,REG)

grsub(r) = (RECIP\_GRCOMT(r))\*sum(i,TRAD\_COMM,  
SHPTAX(i,r)\*[(COSTINP(i,r)\*to(i,r))+PTAX(i,r)\*(qo(i,r)+pm(i,r))]+  
100\*PTAX(i,r)\*c\_SHPTAX(i,r));

!SE6! REVINT

(all,r,REG) !# contribution of a change in taxes on sales as interm#

#usage to the per cent change in aggregate commodity tax revenue #!

grint(r)

= (RECIP\_GRCOMT(r))\*(sum(i,TRAD\_COMM, sum(j,TRAD\_COMM, (VDFM(i,j,r)  
+ DFTAX(i,j,r)) \* tfd(i,j,r) + DFTAX(i,j,r) \* (qfd(i,j,r) + pds(i,r))))  
+ sum(i,TRAD\_COMM, sum(j,TRAD\_COMM, (VIFM(i,j,r) + IFTAX(i,j,r))  
\* tfm(i,j,r) + IFTAX(i,j,r) \* (qfm(i,j,r) + pid(i,r)))));

!SE9! REVINV

(all,r,REG)! # contribution of a change in taxes on sales as invst to#

#the per cent change in aggregate commodity tax revenue #!

grinv(r) = (RECIP\_GRCOMT(r))\*(sum(i,TRAD\_COMM, (DINV(i,r)  
+ TIRD(i,r))\*tinvd(i,r)

---

```

+ TIRD(i,r)*(invd(i,r) + pds(i,r))

+ sum(i,TRAD_COMM, (IINV(i,r) + TIRI(i,r))*tinvi(i,r)

+ TIRI(i,r)*(invi(i,r) + pid(i,r))));

```

```

EQUATION E_tinvd (all,i,TRAD_COMM)(all,r,REG)

```

```

tinvd(i,r) = sum(c,CGDS_COMM,tfd(i,c,r));

```

```

EQUATION E_invd (all,i,TRAD_COMM)(all,r,REG)

```

```

invd(i,r) = sum(c,CGDS_COMM,qfd(i,c,r));

```

```

EQUATION E_tinvi (all,i,TRAD_COMM)(all,r,REG)

```

```

tinvi(i,r) = sum(c,CGDS_COMM,tfm(i,c,r));

```

```

EQUATION E_invi (all,i,TRAD_COMM)(all,r,REG)

```

```

invi(i,r) = sum(c,CGDS_COMM,qfm(i,c,r));

```

```

!SE7! REVCON

```

```

(all,r,REG) !# contribution of a change in taxes on sales of goods#

```

```

#for priv hhold cons to the per cent change in aggregate commodity tax#

```

```

#revenue #!

```

```

grcon(r) = (RECIP_GRCOMT(r))*(sum(i,TRAD_COMM, (VDPM(i,r)

```

```

+ DPTAX(i,r))*tpd(i,r)

```

```

+ DPTAX(i,r)*(qpd(i,r) + pds(i,r)))

```

---

```

+ sum(i,TRAD_COMM, (VIPM(i,r) + IPTAX(i,r))*tpm(i,r)
+ IPTAX(i,r)*(qpm(i,r) + pid(i,r))));

```

```
!SE11! REVEXP (all,r,REG)
```

```
!# contrib of a change in exp taxes to the per cent#
```

```
# change in aggregate commodity tax revenue #!
```

```
gexp(r) =
```

```

(RECIP_GRCOMT(r))*sum(i,TRAD_COMM, sum(s,REG, VXWD(i,r,s))*
[tx(i,r)+txs(i,r,s)]
+ XTAXD(i,r,s)*(qxs(i,r,s) + pxs(i,r,s))));

```

```
!SE8! REVGGOV
```

```
(all,r,REG) !# contrib of a change in taxes on goods for government#
```

```
#cons to the per cent change in agg commodity tax revenue, by region #!
```

```
grgov(r)
```

```

= (RECIP_GRCOMT(r))*(sum(i,TRAD_COMM, (VDGM(i,r)
+ DGTAX(i,r))*tgd(i,r)
+ DGTAX(i,r)*(qgd(i,r) + pds(i,r)))
+ sum(i,TRAD_COMM, (VIGM(i,r) + IGTAX(i,r))*tgm(i,r)
+ IGTAX(i,r)*(qgm(i,r) + pid(i,r))));

```

```
!SE12! REVIMP (all,s,REG)
```

---

```

!# contribution of a change in tariffs to the per cent change#

#      in aggregate commodity tax revenue, by region #!

grdut(s)

= (RECIP_GRCOMT(s))*sum(i,TRAD_COMM, sum(r,REG, (VIWS(i,r,s)

+ MTAX(i,r,s))

* [tm(i,s)+tms(i,r,s)] + MTAX(i,r,s)*(!er(r) +! pcif(i,r,s) + qxs(i,r,s)))));

!SE5! GOVT_INTT_RECTS

# government interest receipts, by region # (all,r,REG)

RCGVR(r)*qrgir(r) = ASGVR(r)*rbr(r) + RTBD*RCGVR(r)*qrgbr(r);

!SE14! GOVT_CURRNT_OUTLS

# current government outlays, by region # (all,r,REG)

OLGVR(r)*ogr(r) = GOVEXP(r)*zg(r) + URGVHHR(r)*ughr(r) + d_ughr_(r);

!SH12! VALGOVDEMCOM # govt expend on commodities #

(all,r,REG)    zg(r) = pgov(r) + ug(r) ;

!SE18! TRANSFRS_GOVT_HHOLD

! transfer payments from governments to households,

by region ! (all,r,REG) ughr(r) = fughr(r) + yhvr(r);

E_d_ughr_ (All,r,REG) d_ughr_(r)=d_ughr(r)+

```



---

```

sum[i,TRAD_COMM,sum[d,DEST,
(1-SHXTAXD(i,r,d))*{VXWD(i,r,d)*[pfob(i,r,d)+qxs(i,r,d)]-
VXMD(i,r,d)*[pxs(i,r,d)+qxs(i,r,d)]}-
100*XTAXD(i,r,d)*c_SHXTAXD(i,r,d)]];

```

```
!SE13! DISPN_GOVRT_RECTS
```

```
# disposition of government receipts, by region #
```

```
(all,r,REG) RCGVR(r)*rgr(r)
```

```
= OLGVR(r)*ogr(r) + RCGVR(r)*qrgsr(r) + SPGVR(r)*rgr(r);
```

```
!-----
```

```
7. International allocation of investment
```

```
-----!
```

```
!SG21! EXPD_BOND_RATE
```

```
# expected rate of change in bond rate, by region #
```

```
(all,r,REG) ercrbr(r) = ercrb;
```

```
!SG20! EXPD_RATE_RETN_EQY
```

```
# expected rate of change in rate of return on equity #
```

```
(all,r,REG) ercrer(r) = ercrbr(r) + ercfrer(r);
```

```
!SG18! EQN_RATE_RETN_CAPL
```

---

# equilibration of rates of return on capital #

(all,r,REG) ercrkr(r) = ercrer(r) - CEAJRTKPR(r)\*rar(r);

!SG16! EXPD\_RATE\_RETN\_CAPL

# expected rate of change in average rate of return on capital #

(all,r,REG) ercrkr(r) = EL\_ERCRK\_K\_R(r)\*RTKPGRR(r)\*RTIVKPR(r)

\*(qcgds(r) - kb!t!(r)) + EL\_ERCRK\_K\_R(r)\*(RTIVKPR(r) - DEPRREG(r)

- GTSSKPR(r))\*rkr(r);

!SG19! AVGE\_ABNL\_RETN\_CAPL

# average rate of abnormal return on capital, by region #

(all,r,REG) rar(r) = sum(i,TRAD\_COMM, SKT(i,r)\*rari(i,r))

+ sum(i,TRAD\_COMM, RTKPANRI(i,r)\*SKT(i,r)\*kk(i,r))

- RTKPANR(r)\*kb!t!(r);

!The SALTER variable k has been renamed kk in this equation as k has

already been used as an index in the original GTAP tab file and,

thus, cannot be used again!

EQUATION E\_kk (all,j,TRAD\_COMM)(all,r,REG)

kk(j,r) = sum(k,ENDWC\_COMM,qfe(k,j,r));

!SG17! AVGE\_RATE\_RETN\_CAPL

# average rate of return on capital, by region #

---

(all,r,REG) rkr(r) = RTKPGRR(r)\*{sum[k,ENDWC\_COMM,pm(k,r)]-pcgds(r)};

!-----

8. ADDITIONAL DESCRIPTIVE MACRO VARIABLES TO SALTER

-----!

!SH3! GROSS\_NATL\_EXPRES # gross national expenditure #

(all, r, REG) GNEL(r)\*gne(r)  
= PRIVEXP(r)\*yp(r) + GOVEXP(r)\*zg(r) + REGINV(r)\*invt(r);

!SH20! PRICE\_INDX\_GNE # price index for gross national expenditure #

(all, r, REG) GNEL(r)\*gnepi(r)  
= PRIVEXP(r)\*ppriv(r) + GOVEXP(r)\*pgov(r) + REGINV(r)\*pcgds(r);

!SH6! REAL\_GNE # gross national expenditure, real # (all, r, REG)

GNEL(r)\*gner(r) = PRIVEXP(r)\*ctr(r) + GOVEXP(r)\*ug(r) + REGINV(r)\*qcgds(r);

!SH1! EXPRES\_GDP # expenditure on gross domestic product, by region #

(all, r, REG) GDP(r)\*gdpe(r)  
= PRIVEXP(r)\*yp(r) + GOVEXP(r)\*zg(r) + REGINV(r)\*invt(r) +  
VXWREGION(r)\*vxwreg(r) - VIWREGION(r)\*(!er(r) +! viwreg(r));

!SH19! PRICE\_INDEX\_GDP # price index for gross domestic product #

---

```

      (all, r, REG)      GDP(r)*gdppi(r)

= PRIVEXP(r)*ppriv(r) + GOVEXP(r)*pgov(r) + REGINV(r)*pcgds(r) +

  VXWREGION(r)*pxwreg(r) - VIWREGION(r)*(!er(r) + !piwreg(r));

!SH5! REAL_GDP # real gdp # (all, r, REG)  GDP(r)*gdpr(r)

= PRIVEXP(r)*ctr(r) + GOVEXP(r)*ug(r) + REGINV(r)*qcgds(r) +

  VXWREGION(r)*qxwreg(r) - VIWREGION(r)*qiwreg(r);

!SH22! GROSS_DOMC_PRODT # gross domestic product, nominal #

(all, r, REG)      !GDP(r)*!gdpn(r)

= !LTT(r)*(w(r) + lt_(r)) + KTT(r)*fke(r) + MTT(r)*(rm(r) + mt(r))

  + GRCOMT(r)*rc(r)! vgdpr(r);

!SH23! GROSS_NATL_PRODT # gross national product # (all, r, REG)

GNPL(r)*gnp(r) =GDP(r)*gdpn(r) + GDP(r)*nyas(r) + YCITR(r)*gdpn(r);

!NB This equation is just nom gdp plus income earned from bonds sold
domestically and overseas!

! Include FDI income in balance of payments. !

EQUATION E_bop (all,r,REG)

  bop(r)=bts(r)+nyas(r)+nkis(r)+nyfdirat(r)+nyank_h__(r)+nyanp_h__(r);

EQUATION E_qvar (all,r,REG) sum(j,PROD_COMM, VVA(j,r))*qvar(r) =

```

---

```

sum(i,PROD_COMM,
    IF[FDI_FLAG1(i,r)=0,VVA(i,r)*qva(i,r)]+
    sum(i_,FDI_COMM:i eq i_,sum(r_,FDI_DEST:r eq r_,
        IF[FDI_FLAG1(i_,r_) ne 0,VVA(i_,r_)*f_qva(i_,r_)]]));

```

```

EQUATION!21.5! GDPFACTCOST ! GDP AT FACTOR COST ! (all,r,REG)

```

```

gdpfc(r) = SLGDP(r)*(w(r) + lt_(r)) + sum(i,TRAD_COMM, SKGDP(i,r)*
(rp(i,r) + kk(i,r)) + SMGDP(r)*(rm(r) + mt(r)) +
SNGDP(r)*(nrp(r) + nru(r)));

```

```

EQUATION!20.4! REALDISPY! REAL AGGREGATE HOUSEHOLD DISPOSABLE INCOME !

```

```

(all,r,REG) ydr(r) = yhdr(r) - ppriv(r) ;

```

```

! Define rental price of bonds for use in price and bond EV contributions !

```

```

EQUATION E_prentb #Rental price of bonds# (All,r,REG)

```

```

rbr(r)=RTBD*[prentb(r)-pbr(r)];

```

```

!-----

```

```

9. ADDITIONAL DESCRIPTIVE GLOBAL MACRO VARIABLES TO SALTER

```

```

-----!

```

---

!SJ1! WORLD\_GROSS\_PRODCT # world gross product #

$$\text{WGPL} * \text{wgp} = \text{SUM}(r, \text{REG}, \text{GDP}(r) * \text{gdpn}(r));$$

!SJ5! WORLD\_NET\_Y\_ABROAD # world net income from abroad #

$$\text{WGPL} * \text{wnyas} + \text{YCIT} * \text{wgp}$$

$$= \text{SUM}(r, \text{REG}, \text{GDP}(r) * \text{nyas}(r)) + \text{SUM}(r, \text{REG}, \text{YCITR}(r) * \text{gdpn}(r));$$

!SJ6! WORLD\_NET\_CAPL\_INFLW # world net capital inflow #

$$\text{WGPL} * \text{wnkis} + \text{WNCIL} * \text{wgp}$$

$$= \text{SUM}(r, \text{REG}, \text{GDP}(r) * \text{nkis}(r)) + \text{SUM}(r, \text{REG}, \text{NCIL}(r) * \text{gdpn}(r));$$

!SJ7! WORLD\_CAPL\_STOCK # world capital stock #

$$\text{ASKP} * \text{wkt} = \text{SUM}(r, \text{REG}, (\text{VKB}(r) / \text{ECRT}(r)) * \text{kb}(r));$$

!SJ8! WORLD\_REAL\_INVNT # world real investment #

$$\text{WINVTT} * \text{winvtr} = \text{SUM}(r, \text{REG}, (\text{REGINV}(r) / \text{ECRT}(r)) * \text{qcgds}(r));$$

EQUATION E\_wr (all,r,REG) wr(r) = w(r) - ppriv(r);

! .....

! 10. Code required for looking at sim results !

! .....

---

EQUATION E\_qfel (all,l,LABOR)(all,j,PROD\_COMM)(all,r,REG)

qfel(l,j,r) = qfe(l,j,r);

EQUATION E\_qfek (all,j,PROD\_COMM)(all,r,REG)

qfek(j,r) = sum[k,ENDWC\_COMM,qfe(k,j,r)];

EQUATION E\_qfen (all,j,PROD\_COMM)(all,r,REG)

qfen(j,r) = SUM(n, LAND, qfe(n,j,r)) ;

EQUATION E\_qfenr (all,j,PROD\_COMM)(all,r,REG)

qfenr(j,r) = SUM(nr, NATRES, qfe(nr,j,r)) ;

! .....!  
! 11. Equations for checking of consistency between !  
! GTAP and SALTER definitions !  
!  
! .....!

EQUATION

LAB\_TAX #Link GTAP and SALTER labour income tax variables#

(All,i,LABOR)(All,r,REG)

to(i,r)=[VOM(i,r)-VOA(i,r)]/VOA(i,r)\*tylr(r);

---

NON\_LAB\_TAX #Link GTAP and SALTER property income tax variables#

(All,i, NONLAB\_ENDW)(All,r,REG)

to(i,r)=[VOM(i,r)-VOA(i,r)]/VOA(i,r)\*typr(r);

EQUATION!SE15! E\_rc1 # revenue from commodity taxes, by region #

(all,r,REG) GRCOMT1(r)\*rc1(r)=

sum(i,PROD\_COMM, SHPTAX(i,r)\*{VOM(i,r) \* [pm(i,r) + qo(i,r)]-  
VOA(i,r) \* [ps(i,r) + qo(i,r)]}+  
100\*PTAX(i,r)\*c\_SHPTAX(i,r))

+ sum(j,PROD\_COMM, sum(i,TRAD\_COMM,{VIFA(i,j,r) \* [pfm(i,j,r) + qfm(i,j,r)]  
- {VIFM(i,j,r) \* [pid(i,r) + qfm(i,j,r)]}}))

+ sum(j,PROD\_COMM, sum(i,TRAD\_COMM,{VDFA(i,j,r) \* [pfd(i,j,r) + qfd(i,j,r)]  
- {VDFM(i,j,r) \* [pds(i,r) + qfd(i,j,r)]}}))

+ sum(i,TRAD\_COMM, {VIPA(i,r) \* [ppm(i,r) + qpm(i,r)]  
- {VIPM(i,r) \* [pid(i,r) + qpm(i,r)]}})

+ sum(i,TRAD\_COMM, {VDPA(i,r) \* [ppd(i,r) + qpd(i,r)]  
- {VDPM(i,r) \* [pds(i,r) + qpd(i,r)]}})

+ sum(i,TRAD\_COMM, {VIGA(i,r) \* [pgm(i,r) + qgm(i,r)]  
- {VIGM(i,r) \* [pid(i,r) + qgm(i,r)]}})

+ sum(i,TRAD\_COMM, {VDGA(i,r) \* [pgd(i,r) + qgd(i,r)]  
- {VDGM(i,r) \* [pds(i,r) + qgd(i,r)]}})

+ sum(i,TRAD\_COMM, sum(s,REG,{VXWD(i,r,s) \* [pfob(i,r,s) + qxs(i,r,s)]  
- {VXMD(i,r,s) \* [pxs(i,r,s) + qxs(i,r,s)]}}))

+ sum(i,TRAD\_COMM, sum(s,REG,{VIMS(i,s,r) \* [pms(i,s,r) + qxs(i,s,r)]})



---

- {VIWS(i,s,r) \* [pcf(i,s,r) + qxs(i,s,r)]});

EQUATION E\_check\_rc (All,r,REG) check\_rc(r)=rc(r)-rc1(r);

EQUATION E\_grexp1 (All,r,REG)

GRCOMT1(r)\*grexp1(r)=

sum(i,TRAD\_COMM, sum(s,REG,{VXWD(i,r,s) \* [pfob(i,r,s) + qxs(i,r,s)]}  
- {VXMD(i,r,s) \* [pxs(i,r,s) + qxs(i,r,s)]}));

EQUATION E\_grdut1 (All,r,REG)

GRCOMT1(r)\*grdut1(r)=

sum(i,TRAD\_COMM, sum(s,REG,{VIMS(i,s,r) \* [pms(i,s,r) + qxs(i,s,r)]}  
- {VIWS(i,s,r) \* [pcf(i,s,r) + qxs(i,s,r)]}));

EQUATION E\_grsub1 (All,r,REG)

GRCOMT1(r)\*grsub1(r)=

sum(i,PROD\_COMM, SHPTAX(i,r)\*{VOM(i,r) \* [pm(i,r) + qo(i,r)]-  
VOA(i,r) \* [ps(i,r) + qo(i,r)]}+  
100\*PTAX(i,r)\*c\_SHPTAX(i,r));

EQUATION E\_check\_grdut

---

(All,r,REG) check\_grdut(r)=grdut(r)-grdut1(r);

EQUATION E\_check\_grexp

(All,r,REG) check\_grexp(r)=grexp(r)-grexp1(r);

EQUATION E\_check\_grsub

(All,r,REG) check\_grsub(r)=grsub(r)-grsub1(r);

EQUATION E\_grcon1 (All,r,REG) GRCOMT1(r)\*grcon1(r)=

sum(i,TRAD\_COMM, {VIPA(i,r) \* [ppm(i,r) + qpm(i,r)]}  
- {VIPM(i,r) \* [pid(i,r) + qpm(i,r)]})  
+ sum(i,TRAD\_COMM, {VDPA(i,r) \* [ppd(i,r) + qpd(i,r)]}  
- {VDPM(i,r) \* [pds(i,r) + qpd(i,r)]});

EQUATION E\_grgov1 (All,r,REG) GRCOMT1(r)\*grgov1(r)=

sum(i,TRAD\_COMM, {VIGA(i,r) \* [pgm(i,r) + qgm(i,r)]}  
- {VIGM(i,r) \* [pid(i,r) + qgm(i,r)]})  
+ sum(i,TRAD\_COMM, {VDGA(i,r) \* [pgd(i,r) + qgd(i,r)]}  
- {VDGM(i,r) \* [pds(i,r) + qgd(i,r)]});

EQUATION E\_check\_grcon

(All,r,REG) check\_grcon(r)=grcon(r)-grcon1(r);

EQUATION E\_check\_grgov

(All,r,REG) check\_grgov(r)=grgov(r)-grgov1(r);

---

EQUATION E\_grint1 (All,r,REG) GRCOMT1(r)\*grint1(r)=

$$\begin{aligned} & \text{sum}(j, \text{TRAD\_COMM}, \text{sum}(i, \text{TRAD\_COMM}, \{ \text{VIFA}(i, j, r) * [\text{pfm}(i, j, r) + \text{qfm}(i, j, r)] \} \\ & \quad - \{ \text{VIFM}(i, j, r) * [\text{pid}(i, r) + \text{qfm}(i, j, r)] \})) \\ & + \text{sum}(j, \text{TRAD\_COMM}, \text{sum}(i, \text{TRAD\_COMM}, \{ \text{VDFA}(i, j, r) * [\text{pfd}(i, j, r) + \text{qfd}(i, j, r)] \} \\ & \quad - \{ \text{VDFM}(i, j, r) * [\text{pds}(i, r) + \text{qfd}(i, j, r)] \})); \end{aligned}$$

EQUATION E\_check\_grint

(All,r,REG) check\_grint(r)=grint(r)-grint1(r);

EQUATION E\_grinv1 (All,r,REG) GRCOMT1(r)\*grinv1(r)=

$$\begin{aligned} & \text{sum}(j, \text{CGDS\_COMM}, \text{sum}(i, \text{TRAD\_COMM}, \{ \text{VIFA}(i, j, r) * [\text{pfm}(i, j, r) + \text{qfm}(i, j, r)] \} \\ & \quad - \{ \text{VIFM}(i, j, r) * [\text{pid}(i, r) + \text{qfm}(i, j, r)] \})) \\ & + \text{sum}(j, \text{CGDS\_COMM}, \text{sum}(i, \text{TRAD\_COMM}, \{ \text{VDFA}(i, j, r) * [\text{pfd}(i, j, r) + \text{qfd}(i, j, r)] \} \\ & \quad - \{ \text{VDFM}(i, j, r) * [\text{pds}(i, r) + \text{qfd}(i, j, r)] \})); \end{aligned}$$

EQUATION E\_check\_grinv

(All,r,REG) check\_grinv(r)=grinv(r)-grinv1(r);

EQUATION E\_check\_qgdp (All,r,REG) check\_qgdp(r)=qgdp(r)-gdpr(r);

EQUATION E\_check\_vgdp (All,r,REG) check\_vgdp(r)=vgdp(r)-gdpr(r);

EQUATION E\_check\_pgdp (All,r,REG) check\_pgdp(r)=pgdp(r)-gdppi(r);

---

!-----!

End of ICM.TAB

-----!

! FDI extension to GTAPICM !

! ===== !

! Introductory comments

~~~~~

I have varied the Petri specification of capital supply slightly. The price of capital is now the reciprocal of  $\exp(\text{rate\_of\_return})$  rather than the reciprocal of  $\text{rate\_of\_return}$ . This allows negative rates of return, which may well be possible at such a disaggregate level.

Since the international capital mobility extension endogenises total private wealth, with

$$\begin{aligned} \text{wealth} &= \text{bonds} + \text{equity} \\ &= \text{bonds} + \text{capital} + \text{land} \end{aligned}$$

I have extended the Petri nesting higher to include an allocation of wealth between bonds and equity, and equity between capital and land.

---

The case of bonds is interesting. The Petri price of bonds depends on whether the region is a net debtor or net creditor. To see how this is implemented, it helps to think of two types of bonds. Each region holds a non-negative quantity of either debt bonds or credit bonds, and none of the other type of bonds. Debt bonds have a negative rate of return and credit bonds a positive rate of return. Hence, in the equation determining the division of wealth between bonds and equity, the rate of return on bonds enters with a negative or positive sign depending on whether the region is a net debtor or net creditor respectively. Since the quantity of bonds cannot change sign under a CET allocation mechanism, it is possible to introduce a variable for the percentage change in the quantity of bonds. Also, if a region is defined as a debtor or creditor based on positive or negative bond holdings, it will always remain a debtor or creditor.

It should be noted, however, that bonds in the extended model cannot be compared to bonds in SALTER. Bonds in SALTER represent the excess (deficit) of total assets above (below) productive assets residing in a region.

The counterpart in the extended model would be bonds plus domestic capital plus foreign capital owned by the region plus land minus local capital owned by foreigners.

!

---

!-----!

ZERODIVIDE (ZERO\_BY\_ZERO) OFF;

ZERODIVIDE (NONZERO\_BY\_ZERO) OFF;

COEFFICIENT (All,s,home) CHK\_RR\_LAND(s)

#Check positivity of initial rate of return on land#;

COEFFICIENT (All,s,home) RTBDR(s)

#Regional rate of return on bonds#;

! The next block of coefficients are peculiar. They are equal to quantities of assets times prices = the reciprocals of exp(rates of return). They are the values of the assets in the Petri nested CET supply function for capital. At the beginning of the simulation they equal asset values but at the end of the simulation they will NOT be equal to asset values. !

COEFFICIENT (All,s,home) VK\_H\_\_(s)

#Petri asset value of capital by home region#;

COEFFICIENT (All,s,home)(All,i,TRAD\_COMM) VK\_H\_I(i,s)

#Petri asset value of capital by industry and home region#;

---

COEFFICIENT (All,s,home)(All,i,TRAD\_COMM) VKF\_H\_I(i,s)

#Petri asset value of foreign capital by industry and home region#;

COEFFICIENT (All,s,home) CRED\_DEBT(s)

#Is -1 for debtor and +1 for creditor region#;

FORMULA (Initial)(All,s,home) CRED\_DEBT(s)=1-2\*IF(YCHHITR(s)<0,1);

! Calculating / initialising Petri asset values !

FORMULA (All,s,home)(All,i,TRAD\_COMM) VKF\_H\_I(i,s)=sum(d,dest,VK\_HHI(i,s,d));

FORMULA (All,s,home)(All,i,TRAD\_COMM) VK\_H\_I(i,s)=VKD\_H\_I(i,s)+VKF\_H\_I(i,s);

FORMULA (All,s,home) VK\_H\_\_(s)=sum(i,TRAD\_COMM,VK\_H\_I(i,s));

! Initially set rate of return on land and natural resources to average rate  
of return on capital !

FORMULA (Initial)(All,s,home) RR\_LAND(s)=

IF[VLAND(s)=0 and VKB(s) ne 0,

sum{i,TRAD\_COMM,VKD(i,s)\*max{0,RRD\_H\_I(i,s)}+

sum[d,dest,VFDI\_HHI(i,s,d)\*max{0,RR\_HHI(i,s,d)}]

}/VKB(s)]+

IF[VLAND(s)=0 and VKB(s)=0,RTBD]+

IF[VLAND(s) ne 0,RR\_LAND(s)];

---

FORMULA (All,s,home)

CHK\_RR\_LAND(s)=IF[VLAND(s)=0,RR\_LAND(s)]+IF[VLAND(s) ne 0,1];

ASSERTION #Initial rate of return on land is positive#

(All,s,home) CHK\_RR\_LAND(s)>0;

FORMULA (Initial)(All,s,home)

RR\_NATRES(s)=IF[VNATRES(s)=0,RR\_LAND(s)]+IF[VNATRES(s) ne 0,RR\_NATRES(s)];

! Calculate Petri asset value of land (natural resources) from rate of return  
on land (natural resources) and land (natural resources) rentals from the  
GTAP database. !

FORMULA (Initial)(All,s,home)

VLAND(s)=IF[VLAND(s)=0,exp(-RR\_LAND(s))\*sum[k,LAND,VOM(k,s)]]+  
IF[VLAND(s) ne 0,VLAND(s)];

FORMULA (Initial)(All,s,home)

VNATRES(s)=IF[VNATRES(s)=0,  
exp(-RR\_NATRES(s))\*sum[k,NATRES,VOM(k,s)]]+  
IF[VNATRES(s) ne 0,VNATRES(s)];

! End of calculating / initialising Petri asset values !

FORMULA ! Bond rates equal across regions !



---

(Initial)(All,s,home) RTBDR(s)=RTBD;

UPDATE (change)(All,s,home) RTBDR(s)=rbr(s)/100;

!.....!

EQUATION

! In the following equations the price of each aggregate has been defined by the condition that the share weighted sum of the quantities constituting the aggregate equals the aggregate quantity. This is valid for any CRS aggregator function. In the future if we wish to generalise beyond CES (eg. CRESH) we are able to do so without needing to alter the definitions of aggregate prices. (The capital supply functions are in fact written in CRESH form, except for the upper levels - wealth --> bonds,equity and equity --> capital,land,natural resources.) !

! section 1 was removed !

! Section 2 - Supply of capital

~~~~~ ~

!

! Section 2.1 - Quantities supplied determined by nested CET supply

---

(4.2) function as in Petri !

E\_qhr #Private real wealth# (All,s,home)  $ipahr(s)=ahr(s)-qhr(s);$

E\_qbr #Private ownership of bonds# (All,s,home)

$qhr(s)-qbr(s)=KTRA\_H\_\_(s)*[rhr(s)+CRED\_DEBT(s)*r\_rbr(s)];$

E\_qer #Private ownership of equity# (All,s,home)

$qhr(s)-qer(s)=KTRA\_H\_\_(s)*[rhr(s)-rer(s)];$

! Delete SALTER equation for pnr and pnrr!

E\_pnr #Purchase price of land# (All,r,REG)

$mt(r)-qer(r)=KTRA\_H\_\_(r)*[-r\_rr\_land(r)-rer(r)];$

E\_pnrr #Purchase price of natural resources# (All,r,REG)

$nru(r)-qer(r)=KTRA\_H\_\_(r)*[-r\_rr\_natres(r)-rer(r)];$

E\_k\_h\_\_ #Aggregate supply of capital by home region# (All,s,home)

$k\_h\_\_(s)-qer(s)=KTRA\_H\_\_(s)*[c\_rr\_h\_\_(s)-rer(s)];$

E\_kt #SALTER quantity of capital kt is capital owned by home#

(All,r,REG)  $k\_h\_\_(r)=kt(r);$

E\_kb

---

#GTAP quantity of capital kb is capital residing in the host, asset weights#

(All,d,host)

sum(i,TRAD\_COMM,sum(s,home,VFDI\_HHI(i,s,d))+VKD(i,d))\*kb(d)=

sum(i,TRAD\_COMM,sum(s,home,VFDI\_HHI(i,s,d)\*k\_hhi(i,s,d))+

VKD(i,d)\*kd\_h\_i(i,d))+

f\_kb(d);

E\_k\_h\_i (All,i,TRAD\_COMM)(All,s,home)

k\_h\_i(i,s)-k\_h\_\_(s)=KTRA\_H\_I(i,s)\*[c\_rr\_h\_i(i,s)-c\_rr\_h\_\_(s)];

E\_kd\_h\_i (All,i,TRAD\_COMM)(All,s,home)

kd\_h\_i(i,s)-k\_h\_i(i,s)=KTRAD\_H\_I(i,s)\*[-r\_rrd\_h\_i(i,s)-c\_rr\_h\_i(i,s)];

E\_kf\_h\_i (All,i,TRAD\_COMM)(All,s,home)

kf\_h\_i(i,s)-k\_h\_i(i,s)=KTRAF\_H\_I(i,s)\*[c\_rrf\_h\_i(i,s)-c\_rr\_h\_i(i,s)];

E\_k\_hhi (All,i,TRAD\_COMM)(All,s,home)(All,d,host)

k\_hhi(i,s,d)-kf\_h\_i(i,s)=KTRA\_HHI(i,s,d)\*[-r\_rr\_hhi(i,s,d)-c\_rrf\_h\_i(i,s)];

! Section 2.2 - Define rates of return and asset prices !

! 4.3 !

E\_c\_rr\_hhi (All,i,TRAD\_COMM)(All,s,home)(All,d,host)

---

$c_{rr\_hhi}(i,s,d)=[RR\_HHI(i,s,d)+DEPRIND(i,d)]*[rps(i,s,d)-pcgds(d)];$

E\_c\_trr\_hhi (All,i,TRAD\_COMM)(All,s,home)(All,d,host)

$c_{trr\_hhi}(i,s,d)=$

$[1-TYPR\_L(d)]*[RR\_HHI(i,s,d)+DEPRIND(i,d)]*[psks(i,s,d)-pcgds(d)];$

E\_r\_rr\_hhi (All,i,TRAD\_COMM)(All,s,home)(All,d,host)

$r_{rr\_hhi}(i,s,d)=-[post\_tax\_rr*c_{trr\_hhi}(i,s,d)+pre\_tax\_rr*c_{rr\_hhi}(i,s,d)];$

E\_c\_rrd\_h\_i (All,i,TRAD\_COMM)(All,s,home)

$c_{rrd\_h\_i}(i,s)=[RRD\_H\_I(i,s)+DEPRIND(i,s)]*[rpd(i,s)-pcgds(s)];$

E\_c\_trrd\_h\_i (All,i,TRAD\_COMM)(All,s,home)

$c_{trrd\_h\_i}(i,s)=$

$[1-TYPR\_L(s)]*[RRD\_H\_I(i,s)+DEPRIND(i,s)]*[pskd(i,s)-pcgds(s)];$

E\_r\_rrd\_h\_i (All,i,TRAD\_COMM)(All,s,home)

$r_{rrd\_h\_i}(i,s)=-[post\_tax\_rr*c_{trrd\_h\_i}(i,s)+pre\_tax\_rr*c_{rrd\_h\_i}(i,s)];$

E\_c\_rr\_land (All,s,home)  $c_{rr\_land}(s)=RR\_LAND(s)*[rm(s)-pnr(s)];$

E\_c\_trr\_land (All,s,home)  $c_{trr\_land}(s)=$

$[1-TYPR\_L(s)]*RR\_LAND(s)*[psland(s)-pnr(s)];$

---

E\_rr\_land (All,s,home)

r\_rr\_land(s)=-[post\_tax\_rr\*c\_trr\_land(s)+pre\_tax\_rr\*c\_rr\_land(s)];

E\_c\_rr\_natres (All,s,home) c\_rr\_natres(s)=RR\_NATRES(s)\*[nrp(s)-pnrr(s)];

E\_c\_trr\_natres (All,s,home) c\_trr\_natres(s)=

[1-TYPR\_L(s)]\*RR\_NATRES(s)\*[psnatres(s)-pnrr(s)];

E\_rr\_natres (All,s,home)

r\_rr\_natres(s)=-[post\_tax\_rr\*c\_trr\_natres(s)+pre\_tax\_rr\*c\_rr\_natres(s)];

E\_rbrpt (All,r,REG) rbrpt(r)=[1-TYPR\_L(r)]\*rbr(r)-RTBDR(r)\*TYPR\_L(r)\*typr(r);

E\_r\_rbr (All,s,home) r\_rbr(s)=-[post\_tax\_rr\*rbrpt(s)+pre\_tax\_rr\*rbr(s)];

E\_rhr (All,s,home)

[VK\_H\_\_(s)+VLAND(s)+VNATRES(s)+VBR(s)]\*qhr(s)=

[VK\_H\_\_(s)+VLAND(s)+VNATRES(s)]\*qer(s)+VBR(s)\*qbr(s);

E\_rer (All,s,home)

VK\_H\_\_(s)\*k\_h\_\_(s)+VLAND(s)\*mt(s)+VNATRES(s)\*nru(s)=

[VK\_H\_\_(s)+VLAND(s)+VNATRES(s)]\*qer(s);

E\_c\_rr\_h\_\_ (All,s,home)

---

```

IF{VK_H__(s) ne 0,
    sum(i,TRAD_COMM,VK_H_I(i,s)*[k_h_i(i,s)-k_h__(s)])}=
IF{VK_H__(s)=0,c_rr_h__(s)};

```

```

E_c_rr_h_i (All,i,TRAD_COMM)(All,s,home)

```

```

IF{VK_H_I(i,s) ne 0,
    VKD_H_I(i,s)*kd_h_i(i,s)+VKF_H_I(i,s)*kf_h_i(i,s)
    -VK_H_I(i,s)*k_h_i(i,s)}=
IF{VK_H_I(i,s)=0,c_rr_h_i(i,s)};

```

```

E_c_rrf_h_i (All,i,TRAD_COMM)(All,s,home)

```

```

IF{VKF_H_I(i,s) ne 0,
    sum(d,dest,VK_HHI(i,s,d)*[k_hhi(i,s,d)-kf_h_i(i,s)])}=
IF{VKF_H_I(i,s)=0,c_rrf_h_i(i,s)};

```

! 4.4 Rental prices of capital !

```

E_pskd (All,i,TRAD_COMM)(All,r,REG)

```

```

rpd(i,r)=pskd(i,r)+sum(k,ENDWC_COMM,to(k,r));

```

```

E_pskd (All,i,TRAD_COMM)(All,s,home)(All,d,host)

```

```

rps(i,s,d)=psks(i,s,d)+sum(k,ENDWC_COMM,to(k,d));

```

---

E\_pfeda (All,i,TRAD\_COMM)(All,r,REG)

pfeda(i,r)=tfda(i,r)+toad(r)+toa(r)+rpd(i,r)+

sum(k,ENDWC\_COMM,tf(k,i,r));

E\_pfesa (All,i,TRAD\_COMM)(All,s,home)(All,d,host)

pfesa(i,s,d)=tfsa(i,s,d)+toas(s,d)+tfia(i,d)+toai(d)+toa(d)+rps(i,s,d)+

sum(k,ENDWC\_COMM,tf(k,i,d));

E\_pfeia (All,i,TRAD\_COMM)(All,d,host)

sum(s,home,EVIFAS(i,s,d)\*[(pfesa(i,s,d)+qfes(i,s,d))-(pfeia(i,d)+qfei(i,d))])=

IF[EVIFA(i,d)=0,pfeia(i,d)-pfactwld];

E\_f\_pfek (All,i,TRAD\_COMM)(All,r,REG)

EVDFa(i,r)\*(pfeda(i,r)+qfed(i,r))+EVIFA(i,r)\*(pfeia(i,r)+qfei(i,r))-

sum[k,ENDWC\_COMM,EVFA(k,i,r)\*(pfe(k,i,r)+qfe(k,i,r))]=

IF{sum[k,ENDWC\_COMM,EVFA(k,i,r)]=0,f\_pfek(i,r)};

! 4.5 Asset Price !

E\_pk\_h\_\_ (All,s,home)

{sum(d,dest,sum(i,TRAD\_COMM,VFDI\_HHI(i,s,d)))+

sum(i,TRAD\_COMM,VKD(i,s))}\*

[pk\_h\_\_(s)+k\_h\_\_(s)]=

sum(d,dest,sum(i,TRAD\_COMM,VFDI\_HHI(i,s,d))\*[pcgds(d)+k\_hhi(i,s,d)])+

---

sum(i,TRAD\_COMM,VKD(i,s)\*[pcgds(s)+kd\_h\_i(i,s)]);

E\_pbr #Bond price# (All,s,REG) pbr(s)=pb;

E\_pb #World bond price#

0=sum{s,REG,ASHHBDR(s)\*[pbr(s)+qbr(s)]-

[YCHHDPR(s)\*qyhbr(s)+ASHHBDR(s)\*yhdr(s)]};

EQUATION SAVEPRICE

! savings price -- (new). The price of savings is now region-specific and is equal to the price of regional investment, plus an adjustment factor which accounts for the fact that regional savings and investment are not equal. !

(all,r,REG)

SAVE(r)\*psave(r) = NETINV(r)\*pcgds(r) + [SAVE(r)-NETINV(r)]\*pbr(r)

+ SAVE(r)\*psaveslack(r) ;

! Remove SALTER definitions of ipahr and iper !

E\_iper (All,r,REG) iper(r)=aer(r)-qer(r);

! Section 3 - Supply equals demand for capital - determination of rental

price of capital

(4.6) Market clearing for capital



---

!

E\_rps #Supply equals demand for capital by host, home and industry#

(All,i,TRAD\_COMM)(All,s,home)(All,d,host) k\_hhi(i,s,d)=qfes(i,s,d);

E\_rpd #Supply equals demand for domestic capital by industry#

(All,i,TRAD\_COMM)(All,s,home) kd\_h\_i(i,s)=qfed(i,s);

E\_rp (All,i,TRAD\_COMM)(All,r,REG)

IF{CAP(i,r) ne 0,

CAP(i,r)\*(rp(i,r)+qfek(i,r))-

[EVDFM(i,r)\*(rpd(i,r)+qfed(i,r))+

sum(s,home,EVIFMS(i,s,r)\*(rps(i,s,r)+qfes(i,s,r)))]}=

IF{CAP(i,r)=0,rp(i,r)-pfactwld};

! Section 4 - FDI income flows

~~~~~ ~

(4.7)

!

E\_yfdi\_hhi (All,i,TRAD\_COMM)(All,s,REG)(All,d,REG)

100\*yfdi\_hhi(i,s,d)= VFDI\_HHI(i,s,d)\*c\_trr\_hhi(i,s,d) +

VINC\_HHI(i,s,d)\*[pcgds(d)+k\_hhi(i,s,d)];

---

! The FDI income must be included as a term in the equation defining income,

SALTER equation NATL\_INCOME !

E\_yfdi\_h\_\_ (All,r,REG)

yfdi\_h\_\_(r)=

sum(i,TRAD\_COMM,sum(d,dest,yfdi\_hhi(i,r,d)))-

sum(i,TRAD\_COMM,sum(s,home,yfdi\_hhi(i,s,r)));

! Section 5 - Links to SALTER and GTAP variables

~~~~~ ~

!

E\_pcap #SALTER asset price of capital pcap is price of capital owned by home#

(All,r,REG)

pcap(r)=pk\_h\_\_(r);

E\_kr

#Quantity of capital kr is capital residing in the host, rental weights#

(All,d,host) 0=

sum[i,ENDWC\_COMM,

VOM(i,d) \* (pm(i,d)+kr(d))-

sum(j,TRAD\_COMM, VFM(i,j,d) \* (rp(j,d)+qfe(i,j,d)))];

---

! Section 6 - Asset value of capital and aggregate depreciation

~~~~~ ~

!

E\_c\_VFDI\_HHI (All,i,TRAD\_COMM)(All,s,home)(All,d,host)

100\*c\_VFDI\_HHI(i,s,d)=VFDI\_HHI(i,s,d)\*[pcgds(d)+k\_hhi(i,s,d)];

E\_c\_VKD (All,i,TRAD\_COMM)(All,s,home)

100\*c\_VKD(i,s)=VKD(i,s)\*[pcgds(s)+kd\_h\_i(i,s)];

! The update of the GTAP coefficient VDEP needs to be changed so that it is updated with the variable c\_VDEP. This accounts for changes in the aggregate depreciation rate due to changes in the industrial composition. Any GTAP or SALTER code formed under the assumption of a constant aggregate depreciation rate will need to be changed. It is assumed in the current code that industry specific depreciation rates are constant. !

E\_c\_VDEP (All,d,REG)

c\_VDEP(d)=sum(i,TRAD\_COMM,DEPRIND(i,d)\*  
[c\_VKD(i,d)+sum(s,home,c\_VFDI\_HHI(i,s,d))]);

E\_deprate (All,r,REG) depr(r)=deprate(r)+pcgds(r)+kb(r);

---

!----- Apend FTCRUSOE.TAB -----!

! CRUSOE: a simplified General Equilibrium Model adapted to GTAP data !

!-----!

!.....!

! Data coefficients relating to basic commodity flows for industry input !

! demands !

!.....!

Coefficient (All,c,COM)(All,s,SRC)(All,i,IND) V1BAS(c,s,i)

#Intermediate inputs #;

Coefficient (All,c,COM)(All,s,SRC)(All,i,IND) V1TAX(c,s,i)

# Taxes on Basic Intermediate flows # ;

Coefficient (All,i,IND) V1CAP(i) #capital rentals#;

Coefficient (All,i,IND)(All,l,LABOR) V1LAB\_S(i,l) #wage bills#;

Coefficient (All,i,IND) V1LAB(i) #wage bills#;

Coefficient (All,i,IND) V1LND(i) #land rentals#;

Coefficient (All,i,IND) V1NR(i) #natural resource rentals#;

Coefficient (All,i,IND) V1OCT(i) #other cost tickets#;

Read

V1BAS From File KDATA Header "1BAS";

V1TAX From File KDATA Header "1TAX";

---

V1CAP From File KDATA Header "1CAP";

V1LAB\_S From File KDATA Header "1LAB";

V1LND From File KDATA Header "1LND";

V1NR From File KDATA Header "1NR";

V1OCT From File KDATA Header "1OCT";

Update

(All,c,COM)(All,s,SRC)(All,i,IND) V1BAS(c,s,i) = p0(c,s,i)\*x1(c,s,i);

Update (Change)(All,c,COM)(All,s,SRC)(All,i,IND)

V1TAX(c,s,i) = V1TAX(c,s,i)\*{x1(c,s,i) + p0(c,s,i)}/100 +

{V1BAS(c,s,i) + V1TAX(c,s,i)}\*t1(c,s,i)/100;

Update

(All,i,IND) V1CAP(i) = p1cap(i)\*x1cap(i);

(All,i,IND)(All,l,LABOR)

V1LAB\_S(i,l) = p1lab\_s(i,l)\*x1lab\_s(i,l);

(All,i,IND) V1LND(i) = p1lnd(i)\*x1lnd(i);

(All,i,IND) V1NR(i) = p1nr(i)\*x1nr(i);

Formula

(All,i,IND) V1LAB(i)=sum[l,LABOR,V1LAB\_S(i,l)];

Coefficient (All,c,COM) V0IMP(c) #Total basic - value imports of good c#;

! formula appears later !

---

! Household and Labour Addups !

Coefficient

V1LAB\_I #total labour bill#;

Formula

V1LAB\_I = Sum(i,IND, V1LAB(i));

! .....!  
!           Aggregates and shares of flows at purchasers' prices           !  
! .....!

Coefficient ! Flows at Purchasers prices !

(All,c,COM)(All,s,SRC)(All,i,IND) V1PUR(c,s,i) #Intermediate#;

(All,c,COM)(All,s,SRC)                   V2PUR(c,s)   #Investment#;

(All,c,COM)(All,s,SRC)                   V3PUR(c,s)   #Households#;

(All,c,COM)                               V4PUR(c)     #Export#;

(All,c,COM)(All,s,SRC)                   V5PUR(c,s)   #Other Demand#;

Formula

(All,c,COM)(All,s,SRC)(All,i,IND)

V1PUR(c,s,i) = V1BAS(c,s,i) + V1TAX(c,s,i);

Coefficient ! Flows at Purchaser's prices: Domestic + Imported Totals !

(All,c,COM)(All,i,IND) V1PUR\_S(c,i);

(All,c,COM)                   V2PUR\_S(c)   ;

---

(All,c,COM) V3PUR\_S(c) ;

Formula

(All,c,COM)(All,i,IND) V1PUR\_S(c,i) = Sum(s,SRC,V1PUR(c,s,i));

Coefficient ! Source Shares in Flows at Purchaser's prices !

(All,c,COM)(All,s,SRC)(All,i,IND) S1(c,s,i);

(All,c,COM)(All,s,SRC) S2(c,s);

(All,c,COM)(All,s,SRC) S3(c,s);

Zerodivide Default 0.5;

Formula

(All,c,COM)(All,s,SRC)(All,i,IND) S1(c,s,i) = V1PUR(c,s,i)/V1PUR\_S(c,i);

Zerodivide Off;

!.....!  
!  
! Cost and usage aggregates !  
!.....!

Coefficient ! Industry - Specific Cost Totals !

(All,i,IND) V1PRIM(i) #total factor input to industry i#;

(All,i,IND) V1TOT(i) #total cost in each industry#;

(All,i,IND) V1TOT\_EO(i) #total cost in each industry excluding other costs#;

(All,i,IND) R1OCT(i)

#Ratio of other costs incl. to other cost excl. total costs#;

---

(All,i,IND) R1OCT0(i)

#Initial value of ratio of other costs incl. to other cost excl. total costs#;

(All,i,IND) V2TOT(i) #total capital created for each industry#;

Formula

(All,i,IND) V1PRIM(i) = V1LAB(i) + V1CAP(i) + V1LND(i)+ V1NR(i);

(All,i,IND) V1TOT\_EO(i) = Sum(c,COM, V1PUR\_S(c,i)) + V1PRIM(i) ;

(All,i,IND) V1TOT(i) = V1TOT\_EO(i) + V1OCT(i);

(All,i,IND) R1OCT(i) = V1TOT(i)/V1TOT\_EO(i);

(Initial)(All,i,IND) R1OCT0(i) = R1OCT(i);

Update

(Change)(All,i,IND) V1OCT(i) = {V1OCT(i)\*[p1tot(i)+x1tot(i)]+  
[V1TOT(i)-V1OCT(i)]\*p\_r1oct(i)}/100;

Coefficient (All,c,COM)

DOMSALES(c) #Total domestic sales of domestic commodity c#;

! FTAP CHANGE: Only include V1BAS in DOMSALES !

Formula (All,c,COM)

DOMSALES(c) = Sum(i,IND,V1BAS(c,"dom",i)) !+ V2BAS(c,"dom") + V3BAS(c,"dom")  
+ V5BAS(c,"dom")!;

Coefficient (All,c,COM)

SALES(c) #Total sales of domestic commodity c#;



---

Formula (All,c,COM) SALES(c) = DOMSALES(c) !+ V4BAS(c)!;

! FTAP CHANGE: Only include V1BAS in V0IMP !

Formula (All,c,COM) V0IMP(c) =

Sum(i,IND,V1BAS(c,"imp",i))

!+ V2BAS(c,"imp") + V3BAS(c,"imp") + V5BAS(c,"imp")!;

Coefficient (All,c,COM) V0CIF(c) #Total ex - duty imports of good c#;

!.....!

!                    Income - Side Components of GDP                    !

!.....!

Coefficient ! Aggregate Indirect Tax Revenues !

V1TAX\_CSI    #Aggregate Indirect Tax Revenue from Intermediate#;

V2TAX\_CSI    #Aggregate Indirect Tax Revenue from Investment#;

V3TAX\_CS     #Aggregate Indirect Tax Revenue from Households#;

V4TAX\_C      #Aggregate Indirect Tax Revenue from Export#;

V5TAX\_CS     #Aggregate Indirect Tax Revenue from Other Demand#;

V0TAR\_C      #Aggregate Tariff Revenue#;

V0TAX\_CSI    #Aggregate Indirect Tax Revenue#;

Formula

V1TAX\_CSI = Sum(c,COM,Sum(s,SRC,Sum(i,IND, V1TAX(c,s,i))));

---

Coefficient ! All - Industry Factor Cost Aggregates !

V1CAP\_I #total payments to capital#;  
V1LND\_I #total payments to land#;  
V1OCT\_I #total other cost ticket payments#;  
V1PRIM\_I #total primary factor payments#;  
V0GDPINC #nominal gdp from income side#;

Formula

V1CAP\_I = Sum(i,IND,V1CAP(i));  
V1LND\_I = Sum(i,IND,V1LND(i));  
V1OCT\_I = Sum(i,IND,V1OCT(i));  
V1PRIM\_I = V1LAB\_I + V1CAP\_I + V1LND\_I;

!\*\*\*\*\*!

! Expenditure-side components of GDP !

Coefficient ! Expenditure Aggregates at Purchaser's Prices !

V0CIF\_C #Total dollar import costs, excluding tariffs#;  
V0IMP\_C #Total basic - value imports (includes tariffs)#;  
V2TOT\_I #Total investment usage#;  
V3TOT #Total purchases by households#;  
V4TOT #Total export earnings#;  
V5TOT #total value of other demands#;  
V0GDPEXP #Nominal GDP from expenditure side#;

---

! Primary factor proportions !

Coefficient (All,i,IND) SIGMA1PRIM(i) #CES substitution, primary factors#;

Formula

(All,i,IND) SIGMA1PRIM(i)=ESUBVA(IND2COMM(i));

! .....!

! 5.1 CRUSOE Input Demand Qeuations for all Domestic and !

! Foreign owned Industries !

! !

! .....!

! FTAP NOTE: Output tax on FDI industries will be introduced

via other costs !

! FTAP CHANGE: Rewrite zero pure profits equations in terms of prices and  
quantities to more easily accomodate the altered specification  
of other costs

!

Equation E\_pltot #Zero pure profits in production #

(All,i,IND)

---


$$\begin{aligned}
& (TINY + V1TOT(i)) * \{p1tot(i) + x1tot(i) - f_p1tot(i)\} = \\
& \text{Sum}(c, \text{COM}, V1PUR\_S(c, i) * \{p1\_s(c, i) + x1\_s(c, i)\}) \\
& + V1PRIM(i) * \{p1prim(i) + x1prim(i)\} + \\
& \{V1OCT(i) * [p1tot(i) + x1tot(i)] + [V1TOT(i) - V1OCT(i)] * p\_r1oct(i)\};
\end{aligned}$$

Equation E\_p1tot\_eo #Other costs exclusive price of output#

(All, i, IND)

$$\begin{aligned}
& (TINY + V1TOT\_EO(i)) * \{p1tot\_eo(i) + x1tot(i)\} = \\
& V1TOT(i) * \{p1tot(i) + x1tot(i)\} - \\
& \{V1OCT(i) * [p1tot(i) + x1tot(i)] + [V1TOT(i) - V1OCT(i)] * p\_r1oct(i)\};
\end{aligned}$$

!\*\*\*\*\*!

! Top nest of industry input demands !

Equation E\_x1\_s #Demands for Commodity Composites #

(All, c, COM)(All, i, IND)

$$x1\_s(c, i) - altot(i) = x1tot(i);$$

Equation E\_x1prim #Demands for primary factor composite #

(All, i, IND)

$$x1prim(i) - alprim(i) - altot(i) = x1tot(i);$$

Equation E\_p1\_s #Effective Price of Commodity Composite #

(All, c, COM)(All, i, IND)

---

$pl\_s(c,i) = \text{Sum}(s, \text{SRC}, S1(c,s,i) * \{pl(c,s,i)\});$

Equation E\_plprim #Effective price term for factor demand equations #

$(\text{All}, i, \text{IND})(\text{TINY} + V1\text{PRIM}(i)) * pl\text{prim}(i) =$

$V1\text{LAB}(i) * \{pl\text{lab}(i)\} + V1\text{CAP}(i) * \{pl\text{cap}(i)\} + V1\text{LND}(i) * \{pl\text{ld}(i)\} +$

$V1\text{NR}(i) * \{pl\text{nr}(i)\};$

! .....

! Import/domestic composition of intermediate demands !

!  $X1\_S(c,i) = \text{CES}(\text{All}, s, \text{SRC}: X1(c,s,i))$  !

Coefficient  $(\text{All}, c, \text{COM}) \text{SIGMA1}(c)$  #Armington elasticities: Intermediate#;

Formula

$(\text{All}, c, \text{COM}) \text{SIGMA1}(c) = \text{ESUBD}(c);$

! .....

Equation E\_x1 #Source - Specific Commodity Demands #

$(\text{All}, c, \text{COM})(\text{All}, s, \text{SRC})(\text{All}, i, \text{IND})$

$x1(c,s,i) = x1\_s(c,i) - \text{SIGMA1}(c) * \{pl(c,s,i) - pl\_s(c,i)\};$

! FTAP CHANGE: Value coefficients need not occur in the following equation.

Their presence can lead to some components of t1 not occurring in the model, which is not convenient since t1 is an endogenous variable in FTAP2 (see equation E\_t1).

---

!

Equation E\_p1 #purchasers prices - producers #

(All,c,COM)(All,s,SRC)(All,i,IND)

$p1(c,s,i) = p0(c,s,i) + t1(c,s,i) ;$

Equation E\_xllab #Industry demands for effective labour #

(All,i,IND) xllab(i) =

$xlprim(i) - SIGMA1PRIM(i)*\{p1lab(i) - plprim(i)\};$

! FTAP ADD: Demand for labour by skill!

Equation E\_xllab\_s #Industry demands for skilled and unskilled labour#

(All,i,IND)(All,l,LABOR) xllab\_s(i,l) =

$xllab(i) - SIGMA1PRIM(i)*\{p1lab_s(i,l) - p1lab(i)\};$

! FTAP ADD: Industry specific wage!

Equation E\_p1lab #Industry specific wage#

(All,i,IND)  $\{TINY+V1LAB(i)\}*p1lab(i) =$

$sum[l,LABOR,V1LAB_S(i,l)*p1lab_s(i,l)];$

Equation E\_plcap #Industry demands for capital #

(All,i,IND) x1cap(i) =

$xlprim(i) - SIGMA1PRIM(i)*\{plcap(i) - plprim(i)\};$

---

Equation E\_p1lnd #Industry demands for land #

(All,i,IND) x1lnd(i) =

x1prim(i) - SIGMA1PRIM(i)\*{p1lnd(i) - p1prim(i)};

! FTAP ADD: Demands for natural resources !

Equation E\_p1nr #Industry demands for natural resources#

(All,i,IND) x1nr(i) =

x1prim(i) - SIGMA1PRIM(i)\*{p1nr(i) - p1prim(i)};

! End of CRUSOE Tablo Input File !

!-----!

! !

! FTAP EXTENSION !

! !

!-----!

!.....!

Coefficient

(All,c,TRAD\_COMM)(All,s,HOME)(All,d,host) FDI\_OUTTAX(c,s,d);

---

Formula

```
(All,c,TRAD_COMM)(All,s,HOME)(All,d,host) FDI_OUTTAX(c,s,d)=  
sum[i,IND:(IND2COMM(i) eq c) and (HOME_REG(i) eq s) and (DEST_REG(i) eq d),  
(RIOCT(i)-1)*100];
```

DISPLAY FDI\_OUTTAX;

Coefficient

```
(All,c,TRAD_COMM)(All,j,FDI_COMM)(All,r,FDI_DEST) CHK_VDFM(c,j,r);  
(All,c,TRAD_COMM)(All,j,FDI_COMM)(All,r,FDI_DEST) CHK_VIFM(c,j,r);  
(All,c,TRAD_COMM)(All,j,FDI_COMM)(All,r,FDI_DEST) CHK_VDFA(c,j,r);  
(All,c,TRAD_COMM)(All,j,FDI_COMM)(All,r,FDI_DEST) CHK_VIFA(c,j,r);  
(All,i,TRAD_COMM)(All,s,home)(All,d,host) CHK_EVIFAS(i,s,d);  
(All,i,TRAD_COMM)(All,r,REG) CHK_EVDFA(i,r);  
(All,i,TRAD_COMM)(All,r,REG) CHK_PTAX(i,r);  
(All,i,TRAD_COMM)(All,r,REG) CHK_VOA(i,r);
```

Formula

```
(All,c,TRAD_COMM)(All,j,FDI_COMM)(All,d,FDI_DEST)  
CHK_VDFM(c,j,d)=0;  
(All,c,TRAD_COMM)(All,j,FDI_COMM)(All,d,FDI_DEST:FDI_FLAG1(j,d)>0)  
CHK_VDFM(c,j,d)=abs{VDFM(c,j,d)-  
sum[i,IND:(IND2COMM(i) eq j) and (DEST_REG(i) eq d),V1BAS(c,"dom",i)]};  
(All,c,TRAD_COMM)(All,j,FDI_COMM)(All,d,FDI_DEST)
```



---

```

CHK_VIFM(c,j,d)=0;

(All,c,TRAD_COMM)(All,j,FDI_COMM)(All,d,FDI_DEST:FDI_FLAG1(j,d)>0)

CHK_VIFM(c,j,d)=abs{VIFM(c,j,d)-
sum[i,IND:(IND2COMM(i) eq j) and (DEST_REG(i) eq d),V1BAS(c,"imp",i)]};

(All,c,TRAD_COMM)(All,j,FDI_COMM)(All,d,FDI_DEST)

CHK_VDFA(c,j,d)=0;

(All,c,TRAD_COMM)(All,j,FDI_COMM)(All,d,FDI_DEST:FDI_FLAG1(j,d)>0)

CHK_VDFA(c,j,d)=abs{VDFA(c,j,d)-
sum[i,IND:(IND2COMM(i) eq j) and (DEST_REG(i) eq d),V1PUR(c,"dom",i)]};

(All,c,TRAD_COMM)(All,j,FDI_COMM)(All,d,FDI_DEST)

CHK_VIFA(c,j,d)=0;

(All,c,TRAD_COMM)(All,j,FDI_COMM)(All,d,FDI_DEST:FDI_FLAG1(j,d)>0)

CHK_VIFA(c,j,d)=abs{VIFA(c,j,d)-
sum[i,IND:(IND2COMM(i) eq j) and (DEST_REG(i) eq d),V1PUR(c,"imp",i)]};

(All,j,TRAD_COMM)(All,s,home)(All,d,host)

CHK_EVIFAS(j,s,d)=abs{EVIFAS(j,s,d)-
sum[i,IND:(IND2COMM(i) eq j) and
(HOME_REG(i) eq s) and
(DEST_REG(i) eq d) and
(NOT_DOM(i) eq 1),
V1CAP(i)]};

(All,j,TRAD_COMM)(All,r,REG)

```

---

CHK\_EVDFA(j,r)=0;

(All,j,TRAD\_COMM)(All,r,REG:FDI\_FLAG1(j,r)>0)

CHK\_EVDFA(j,r)=abs{EVDFA(j,r)-

sum[i,IND:(IND2COMM(i) eq j) and

(HOME\_REG(i) eq r) and

(DEST\_REG(i) eq r) and

(NOT\_DOM(i) eq 0),

V1CAP(i)]};

(All,j,TRAD\_COMM)(All,r,REG)

CHK\_PTAX(j,r)=0;

(All,j,TRAD\_COMM)(All,r,REG:FDI\_FLAG1(j,r)>0)

CHK\_PTAX(j,r)=abs{[VOM(j,r)-VOA(j,r)]-

sum[i,IND:(IND2COMM(i) eq j) and

(DEST\_REG(i) eq r),

V1OCT(i)]};

(All,i,TRAD\_COMM)(All,r,REG) CHK\_VOA(i,r)=0;

(All,i,TRAD\_COMM)(All,r,REG:FDI\_FLAG1(i,r)>0) CHK\_VOA(i,r)=

VOA(i,r)-sum[j,IND:(DEST\_REG(j) eq r) and (IND2COMM(j) eq i),V1TOT\_EO(j)];

---

WRITE CHK\_VDFM TO FILE chk\_file HEADER "VDFM";

WRITE CHK\_VIFM TO FILE chk\_file HEADER "VIFM";

WRITE CHK\_VDFA TO FILE chk\_file HEADER "VDFA";

WRITE CHK\_VIFA TO FILE chk\_file HEADER "VIFA";

WRITE CHK\_EVIFAS TO FILE chk\_file HEADER "EVAS";

WRITE CHK\_EVDFA TO FILE chk\_file HEADER "EVDA";

WRITE CHK\_PTAX TO FILE chk\_file HEADER "PTAX";

WRITE CHK\_VOA TO FILE chk\_file HEADER "VOA";

!-----!

COEFFICIENT (all,i,TRAD\_COMM)(all,o,HOME)(all,s,REG)(all,d,REG)

FOBSHRL2(i,o,s,d) ;

(all,i,TRAD\_COMM)(all,s,REG)(all,d,REG) FOBSHR2(i,s,d) ;

COEFFICIENT (all,i,TRAD\_COMM)(all,h,HOME)(all,s,REG)(all,d,REG)

VTWR\_D(i,h,s,d) ;

(all,i,TRAD\_COMM)(all,s,REG)(all,d,REG) VTWR\_DD(i,s,d) ;

COEFFICIENT (all,i,TRAD\_COMM)(all,l,REG)(all,s,REG) TRNSHR2(i,l,s);

COEFFICIENT (all,i,TRAD\_COMM)(all,o,HOME)(all,l,REG)(all,d,REG)

TRNSHRL2(i,o,l,d) ;

---

ZERODIVIDE DEFAULT 0 ;

FORMULA (all,i,TRAD\_COMM)(all,s,REG)(all,d,REG)

FOBSHR2(i,s,d) = VXWD\_DD(i,s,d)/VIWS\_DD(i,s,d) ;

FORMULA (all,i,TRAD\_COMM)(all,o,HOME)(all,s,REG)(all,d,REG)

FOBSHRL2(i,o,s,d) = VXWD\_D(i,o,s,d)/VIWS\_D(i,o,s,d) ;

FORMULA (all,i,TRAD\_COMM)(all,s,REG)(all,d,REG)

VTWR\_DD(i,s,d) = VIWS\_DD(i,s,d) - VXWD\_DD(i,s,d) ;

FORMULA (all,i,TRAD\_COMM)(all,o,HOME)(all,s,REG)(all,d,REG)

VTWR\_D(i,o,s,d) = VIWS\_D(i,o,s,d) - VXWD\_D(i,o,s,d) ;

FORMULA (all,i,TRAD\_COMM)(all,l,REG)(all,s,REG)

TRNSHR2(i,l,s) = VTWR\_DD(i,l,s)/VIWS\_DD(i,l,s) ;

FORMULA (all,i,TRAD\_COMM)(all,o,HOME)(all,l,REG)(all,s,REG)

TRNSHRL2(i,o,l,s) = VTWR\_D(i,o,l,s)/VIWS\_D(i,o,l,s) ;

ZERODIVIDE (ZERO\_BY\_ZERO) OFF ;

COEFFICIENT (all,nl,NONLAB\_ENDW)(all,r,REG) NONLABSHR(nl,r)

#share of non lab endw nl in tot non labour endw earnings in reg r#;

COEFFICIENT (all,r,REG)

TOTNONLAB(r)

---

#total non labour endowment earnings in region r#;

COEFFICIENT (All,i,TRAD\_COMM)(All,r,REG) VODA(i,r)

#Agents value of output of domestic industry#;

COEFFICIENT (All,i,TRAD\_COMM)(All,o,HOME)(All,r,REG) VOHA(i,o,r)

#Agents value of output of foreign industry#;

COEFFICIENT (All,i,TRAD\_COMM)(All,r,REG) VODM(i,r)

#Market value of output of domestic industry#;

COEFFICIENT (All,i,TRAD\_COMM)(All,o,HOME)(All,r,REG) VOHM(i,o,r)

#Market value of output of foreign industry#;

COEFFICIENT (All,i,PROD\_COMM)(All,o,HOME)(All,r,REG) PHTAX(i,o,r)

#Output tax of foreign industry#;

COEFFICIENT (All,i,TRAD\_COMM)(All,r,REG) VXDM(i,r)

#Market value of exports of domestic industry#;

COEFFICIENT (All,i,TRAD\_COMM)(All,o,HOME)(All,r,REG) VXHM(i,o,r)

#Market value of exports of foreign industry#;

---

COEFFICIENT (all,i,TRAD\_COMM)(all,r,REG) CHK\_VDM(i,r);

COEFFICIENT (All,i,TRAD\_COMM)(All,r,REG) VDDM(i,r)

#Market value of domestic use of domestic industry output#;

COEFFICIENT (All,i,TRAD\_COMM)(All,o,HOME)(All,r,REG) VDHM(i,o,r)

#Market value of domestic use of foreign industry output#;

COEFFICIENT (All,i,TRAD\_COMM)(All,o,HOME)(All,d,DEST) VIHDM(i,o,d)

#Market value of imports by comm, owner of producing ind. and destination#;

COEFFICIENT (All,i,TRAD\_COMM)(All,d,DEST) VIDM(i,d)

#Market value of imports by commodity and destination#;

COEFFICIENT (All,d,host)(All,i,TRAD\_COMM) VKF\_\_HI(i,d)

#Petri asset value of foreign capital in destination region by industry#;

COEFFICIENT (All,d,host) VKF\_\_H\_(d)

#Petri asset value of foreign capital in destination region#;

COEFFICIENT (All,d,host) VKD\_\_H\_(d)

#Petri asset value of domestic capital by region#;

COEFFICIENT (All,r,REG) CHECK\_TYPR(r);



---

```
(All,i,TRAD_COMM)(All,o,HOME)(All,r,REG) VOHM(i,o,r)=
sum[j,IND:(IND2COMM(j) eq i) and (DEST_REG(j) eq r) and
(HOME_REG(j) eq o) and (NOT_DOM(j)=1),V1TOT(j)];
```

FORMULA

```
(All,i,PROD_COMM)(All,o,HOME)(All,r,REG) PHTAX(i,o,r)=0;
(All,i,TRAD_COMM)(All,o,HOME)(All,r,REG) PHTAX(i,o,r)=VOHM(i,o,r)-VOHA(i,o,r);
```

! Formulae for income accounting moved from above since must include  
rent from output impediments in income. !

```
(All,r,REG) ANPTAX(r)=sum[i,PROD_COMM,PTAX(i,r)*(1-SHPTAX(i,r))];
```

FORMULA (All,i,TRAD\_COMM)(All,o,HOME)(All,l,HOST)

```
ANKTAX_HHI(i,o,l)=EVIFAS(i,o,l)-EVIFMS(i,o,l);
```

FORMULA (All,i,TRAD\_COMM)(All,o,HOME)(All,l,HOST)

```
ANPTAX_HHI(i,o,l)=(1-SHPTAX(i,l))*{VOHM(i,o,l)-VOHA(i,o,l)};
```

FORMULA

```
(All,r,REG) CHECK_TYPR(r)=TYPR_L(r);
```

! First define AN[KP]TAX\_H\_\_ as the amounts of income subject to tax in the



---

home country.

!

FORMULA (All,r,REG)

ANKTAX\_H\_\_(r)=

IF{home\_tax\_ank ne 0, home\_tax\_ank\*{  
  
sum[i,TRAD\_COMM,sum[d,DEST,ANKTAX\_HHI(i,r,d)]]-  
  
sum[i,TRAD\_COMM,sum[s,HOME,ANKTAX\_HHI(i,s,r)]]}}+

IF{host\_tax\_ank ne 0, host\_tax\_ank\*{  
  
sum[i,TRAD\_COMM,sum[s,HOME,ANKTAX\_HHI(i,s,r)]]}};

FORMULA (All,r,REG)

ANPTAX\_H\_\_(r)=

IF{home\_tax\_anp ne 0, home\_tax\_anp\*{  
  
sum[i,TRAD\_COMM,sum[d,DEST,ANPTAX\_HHI(i,r,d)]]-  
  
sum[i,TRAD\_COMM,sum[s,HOME,ANPTAX\_HHI(i,s,r)]]}}+

IF{host\_tax\_anp ne 0, host\_tax\_anp\*{  
  
sum[i,TRAD\_COMM,sum[s,HOME,ANPTAX\_HHI(i,s,r)]]}};

FORMULA (all,r,REG) TOTNONLAB(r) =

sum(nl, NONLAB\_ENDW, VOM(nl,r))-VDEP(r)+

[YCHHITR(r)+ANKTAX(r)+ANKTAX\_H\_\_(r)+ANPTAX(r)+ANPTAX\_H\_\_(r)];

---

! Now define AN[KP]TAX\_H\_\_ as the amounts of income received in the  
home country.

!

FORMULA (All,r,REG)

ANKTAX\_H\_\_(r)=

IF{home\_tax\_ank ne 0, home\_tax\_ank\*{  
sum[i,TRAD\_COMM,sum[d,DEST,ANKTAX\_HHI(i,r,d)]]-  
sum[i,TRAD\_COMM,sum[s,HOME,ANKTAX\_HHI(i,s,r)]]}}+

IF{host\_tax\_ank ne 0, host\_tax\_ank\*{  
sum[i,TRAD\_COMM,sum[d,DEST,[1-TYPR\_L(d)]\*ANKTAX\_HHI(i,r,d)]]-  
sum[i,TRAD\_COMM,sum[s,HOME,[1-TYPR\_L(r)]\*ANKTAX\_HHI(i,s,r)]]}};

FORMULA (All,r,REG)

ANPTAX\_H\_\_(r)=

IF{home\_tax\_anp ne 0, home\_tax\_anp\*{  
sum[i,TRAD\_COMM,sum[d,DEST,ANPTAX\_HHI(i,r,d)]]-  
sum[i,TRAD\_COMM,sum[s,HOME,ANPTAX\_HHI(i,s,r)]]}}+

IF{host\_tax\_anp ne 0, host\_tax\_anp\*{  
sum[i,TRAD\_COMM,sum[d,DEST,[1-TYPR\_L(d)]\*ANPTAX\_HHI(i,r,d)]]-  
sum[i,TRAD\_COMM,sum[s,HOME,[1-TYPR\_L(r)]\*ANPTAX\_HHI(i,s,r)]]}};

---

FORMULA (all,nl,NONLAB\_ENDW)(all,r,REG)

NONLABSHR(nl,r) = VOM(nl,r) / TOTNONLAB(r);

FORMULA (INITIAL) (all,nl,NONLAB\_ENDW)(all,r,REG)

EVOA(nl,r) = EVOA(nl,r) - IF[FIRST>0.5,(RVTXYCPPR(r)\*NONLABSHR(nl,r))];

ASSERTION #check EVOA(i,r) greater than zero#

(all,i,ENDW\_COMM)(all,r,REG) EVOA(i,r)>0;

FORMULA

(All,r,REG) TYPR\_L(r)=RVTXYCPPR(r)/TOTNONLAB(r);

(All,r,REG) TCHHITR(r)=TYPR\_L(r)\*YCHHITR(r);

(All,r,REG) TDEP(r)=TYPR\_L(r)\*VDEP(r);

FORMULA

(All,r,REG) CHECK\_TYPR(r)=CHECK\_TYPR(r)-TYPR\_L(r);

FORMULA (All,r,REG)

CHK\_CAPTAX(r)=TYPR\_L(r)\*KTT(r)-sum[i,ENDWC\_COMM,VOM(i,r)-VOA(i,r)];

DISPLAY CHK\_CAPTAX; CHECK\_TYPR;

---

! Calculate FDI income !

FORMULA

(All,i,TRAD\_COMM)(All,s,home)(All,d,host)  
  
VINC\_HHI(i,s,d)=[1-TYPR\_L(d)]\*RR\_HHI(i,s,d)\*VFDI\_HHI(i,s,d);  
  
(All,r,REG) VINC\_H\_\_(r)=  
  
sum(i,TRAD\_COMM,sum(d,dest,VINC\_HHI(i,r,d)))-  
  
sum(i,TRAD\_COMM,sum(s,home,VINC\_HHI(i,s,r)));

FORMULA (INITIAL) (all,r,REG)

SAVE(r)=SAVE(r)+IF[FIRST>0.5,RCGVITR(r)+YCHHITR(r)+ANKTAX\_H\_\_(r)+VINC\_H\_\_(r)];

!household property income, by region!

FORMULA (all,r,REG)

YCHHPPR(r)=YCEQR(r)+YCHHITR(r)+ANKTAX(r)+ANKTAX\_H\_\_(r)+  
  
ANPTAX(r)+ANPTAX\_H\_\_(r)+VINC\_H\_\_(r);

!household income, by region!

FORMULA (all,r,REG) YCHHR(r) = LTT(r) + YCHHPPR(r) + URGVHHR(r)+  
  
sum[i,TRAD\_COMM,sum[d,DEST,  
  
(1-SHXTAXD(i,r,d))\*XTAXD(i,r,d)]];

!private household disposable income, by region!

FORMULA (all,r,REG) YCHHDR(r) = YCHHR(r) - RVTXYCR(r);

---

```

!private household savings, by region!

FORMULA (all,r,REG) SVT(r) = YCHHDPR(r) - PRIVEXP(r) ;

!household pre-transfer income, by region!

FORMULA (all,r,REG) YCHHPVR(r) = LTT(r) + YCHHPPR(r) - RVTXYCR(r);

!household property income less FDI income, by region!

FORMULA (all,r,REG) YCHHPRLOC(r)=YCHHPPR(r)-VINC_H__(r);

(All,r,REG) YOUTIMPTAX(r)=

  IF{host_tax_anp ne 0,host_tax_anp*{

    -sum[i,TRAD_COMM,sum[d,DEST,[1-TYPR_L(d)]*ANPTAX_HHI(i,r,d)]]

    +sum[i,TRAD_COMM,sum[s,HOME,[2-TYPR_L(r)]*ANPTAX_HHI(i,s,r)]]}};

(All,r,REG) YKAPIMPTAX(r)=

  IF{host_tax_ank ne 0,host_tax_ank*{

    -sum[i,TRAD_COMM,sum[d,DEST,[1-TYPR_L(d)]*ANKTAX_HHI(i,r,d)]]

    +sum[i,TRAD_COMM,sum[s,HOME,[2-TYPR_L(r)]*ANKTAX_HHI(i,s,r)]]}};

!household property income which is taxed!

FORMULA (all,r,REG)

  YCHHPRTAX(r)=YCHHPPR(r)+YOUTIMPTAX(r)+YKAPIMPTAX(r)-VINC_H__(r);

!net interest income, by region!

```

---

FORMULA (all,r,REG) YCITR(r) = YCHHITR(r) + RCGVITR(r);

!net ownership of bonds, by reg!

FORMULA (all,r,REG) ASBDR(r) = YCITR(r)/RTBD;

!world net ownership of bonds!

FORMULA ASBD = sum(r,REG, ASBDR(r)!/ECRT(r)!);

!net household ownership of bonds, by region!

FORMULA (all,r,REG) ASHHBDR(r) = YCHHITR(r)/RTBD;

!private household wealth, by region!

FORMULA (all,r,REG) ASHHR(r) = ASEQR(r) + ASHHBDR(r);

!nominal income, by region!

FORMULA (all,r,REG)

YCR(r)=YFNT(r)+YCITR(r)+GRCOMT(r)+VINC\_H\_\_(r)+ANKTAX\_H\_\_(r)+ANKTAX(r)+  
ANPTAX(r)+ANPTAX\_H\_\_(r);

FORMULA (all,r,REG) CHECK\_YCR(r) = YCR(r)-INCOME(r);

DISPLAY CHECK\_YCR;

!world nominal income!

---

FORMULA YC = sum(r,REG, YCR(r)!/ECRT(r)!);

!saving, by region!

FORMULA (all,r,REG) SVR(r) = YCR(r) - EPCSR(r);

FORMULA (all,r,REG)

GNEL(r) = PRIVEXP(r) + GOVEXP(r) + REGINV(r);

FORMULA (all,r,REG) GNPL(r) = GDP(r) + YCITR(r);

FORMULA (all,r,REG) NCIL(r) = NETINV(r) - SVR(r) ;

FORMULA WGPL = sum(r,REG, GDP(r));

FORMULA YCIT = sum(r,REG, YCITR(r));

FORMULA WNCIL = sum(r,REG, NCIL(r));

FORMULA ASKP = sum(r,REG, VKB(r));

FORMULA WINVTT = sum(r,REG, REGINV(r));

FORMULA (All,i,TRAD\_COMM)(All,s,SOURCE) VXDM(i,s)=sum[d,DEST,VXMD\_DD(i,s,d)];

FORMULA (All,i,TRAD\_COMM)(All,r,REG) VDDM(i,r)=VODM(i,r)-VXDM(i,r)-VDST(i,r);

FORMULA (All,i,TRAD\_COMM)(All,o,HOME)(All,l,HOST)

VXHM(i,o,l)=sum[d,DEST,VXMD\_D(i,o,l,d)];

FORMULA (All,i,TRAD\_COMM)(All,o,HOME)(All,r,REG)

VDHM(i,o,r)=VOHM(i,o,r)-VXHM(i,o,r)-VHST(i,o,r);

---

FORMULA (All,i,TRAD\_COMM)(All,r,REG)

CHK\_VDM(i,r)=VDM(i,r)-{VDDM(i,r)+sum[o,HOME,VDHM(i,o,r)]};

FORMULA (All,i,TRAD\_COMM)(All,o,HOME)(All,d,DEST)

VIHDM(i,o,d)= sum[l,HOST:(o ne d) or (l eq d),VIMS\_D(i,o,l,d)]+

VDHM(i,o,d)+VIMS\_DD(i,o,d);

FORMULA (All,i,TRAD\_COMM)(All,d,DEST)

VIDM(i,d)=sum[o,HOME,VIHDM(i,o,d)];

FORMULA (All,d,host)(All,i,TRAD\_COMM)

VKF\_\_HI(i,d)=sum[s,home,VK\_HHI(i,s,d)];

FORMULA (All,d,host) VKF\_\_H\_(d)=sum[i,TRAD\_COMM,VKF\_\_HI(i,d)];

FORMULA (All,d,host) VKD\_\_H\_(d)=sum[i,TRAD\_COMM,VKD\_H\_I(i,d)];

WRITE CHK\_VDM TO FILE chk\_file HEADER "VDM";

! .....

! 5.2 Integration of CRUSOE and GTAP !

! One-to-One Correspondence Equations !





---

(DEST\_REG(j) eq d) and (NOT\_DOM(j)=1),

pltot(j)-pfactwld];

! The next two equations imply that the tax on each intermediate input is uniform within each group of FDI industries producing the same commodity.

!

Equation E\_p0 #Define basic prices p0 in terms of pds and pid#

(All,c,COM)(All,s,SRC)(All,i,IND)

p0(c,s,i)=IF{IS\_DOM(s)=1,pds(c,DEST\_REG(i))}+

IF{IS\_DOM(s)=0,pid(c,DEST\_REG(i))};

Equation E\_t1 #Define purchasers prices p1 in terms of pfd and pfm#

(All,c,COM)(All,s,SRC)(All,i,IND)

p1(c,s,i)=IF{IS\_DOM(s)=1,pfd(c,IND2COMM(i),DEST\_REG(i))}+

IF{IS\_DOM(s)=0,pfm(c,IND2COMM(i),DEST\_REG(i))};

! Link changes in other costs ie. FDI industry output impediments, to the variables remotax\* which facilitate easy shocking of these impediments. !

E\_p\_rloct (All,i,IND)

RLOCT(i)\*p\_rloct(i)=

IF{(NOT\_DOM(i)=1) or (HOME\_REG(i) ne DEST\_REG(i)),

---

```

R1OCT(i)*tof(IND2COMM(i),HOME_REG(i),DEST_REG(i))+
[1-R1OCT0(i)]*remotaxf(IND2COMM(i),HOME_REG(i),DEST_REG(i))}+
IF{(NOT_DOM(i)=0) and (HOME_REG(i) eq DEST_REG(i)),
R1OCT(i)*tod(IND2COMM(i),HOME_REG(i))+
[1-R1OCT0(i)]*remotaxd(IND2COMM(i),HOME_REG(i))};

```

! Equate CRUSOE and FTAP versions of all other primary factor demand prices. This implies that the taxes on non-capital primary factor inputs are uniform within each group of FDI industries producing the same commodity.

!

```
E_p1lab_s (All,i,IND)(All,l,LABOR)
```

```
p1lab_s(i,l)=pfe(l,IND2COMM(i),DEST_REG(i));
```

```
E_x1lnd (All,i,IND)
```

```
p1lnd(i)=sum[l,LAND,pfe(l,IND2COMM(i),DEST_REG(i))];
```

```
E_x1lnr (All,i,IND)
```

```
p1lnr(i)=sum[l,NATRES,pfe(l,IND2COMM(i),DEST_REG(i))];
```

! Equate Output in CRUSOE to output in FTAP !

---

E\_xltot (All,i,IND)

xltot(i)=IF{NOT\_DOM(i)=0,qod(IND2COMM(i),DEST\_REG(i))}+

IF{NOT\_DOM(i)=1,qoh(IND2COMM(i),HOME\_REG(i),DEST\_REG(i))};

! Demand for capital !

! Equate the demand for capital in CRUSOE industries

with the demand for capital in foreign and domestic industries in FTAP.

!

E\_xlcap (All,i,IND)

xlcap(i)=IF[NOT\_DOM(i)=1,qfes(IND2COMM(i),HOME\_REG(i),DEST\_REG(i))]+

IF[NOT\_DOM(i)=0,qfed(IND2COMM(i),HOME\_REG(i))];

! Equate the price of capital in CRUSOE industries

with the price of capital in foreign and domestic industries in FTAP.

Consequently, drop FTAP equations E\_qfes and E\_qfed.

!

E\_qfes (All,c,TRAD\_COMM)(All,s,home)(All,d,host)

pfesa(c,s,d)-pfactwld=

sum[i,IND:(IND2COMM(i) eq c) and (HOME\_REG(i) eq s) and

```

                (DEST_REG(i) eq d) and (NOT_DOM(i)=1),

    plcap(i)-pfactwld];

E_qfed (All,c,TRAD_COMM)(All,r,REG)

    IF{FDI_FLAG1(c,r)>0,

        pfeda(c,r)-pfactwld-

        sum[i,IND:(IND2COMM(i) eq c) and (HOME_REG(i) eq r) and

            (DEST_REG(i) eq r) and (NOT_DOM(i)=0), plcap(i)-pfactwld]}=

    IF{FDI_FLAG1(c,r)=0,qfed(c,r)-sum[k,ENDWC_COMM,qfe(k,c,r)]};

```

! In FTAP qfei is defined as a share weighted aggregate, rather than as an input in the nested CES demand for different types of capital.

!

```

E_qfei (All,i,TRAD_COMM)(All,d,host)

    {EVIFA(i,d)+IF[EVIFA(i,d)=0,1]}*qfei(i,d)=

    sum[s,home:EVIFAS(i,s,d)>0,EVIFAS(i,s,d)*qfes(i,s,d)];

```

! .....

! 5.3 Integration of CRUSOE and GTAP code redefinition of !

! GTAP variables as aggregate of CRUSOE variables !

! .....

---

! Summing across inputs into FDI industries !

! Define FTAP intermediate inputs and primary factor demands by  
industry as sums across CRUSOE industries.

!

E\_f\_qf (All,c,TRAD\_COMM)(All,i,FDI\_COMM)(All,r,FDI\_DEST)

$$\text{VFA}(c,i,r)*f\_qf(c,i,r)=\text{sum}\{j,\text{IND}:(\text{DEST\_REG}(j) \text{ eq } r) \text{ and} \\ (\text{IND2COMM}(j) \text{ eq } i), \\ \text{V1PUR\_S}(c,j)*x1\_s(c,j)\};$$

E\_f\_qfd (All,c,TRAD\_COMM)(All,i,FDI\_COMM)(All,r,FDI\_DEST)

$$\text{VDFM}(c,i,r)*f\_qfd(c,i,r)=\text{sum}[j,\text{IND}:(\text{DEST\_REG}(j) \text{ eq } r) \text{ and} \\ (\text{IND2COMM}(j) \text{ eq } i), \\ \text{V1BAS}(c,"dom",j)*x1(c,"dom",j)];$$

E\_f\_qfm (All,c,TRAD\_COMM)(All,i,FDI\_COMM)(All,r,FDI\_DEST)

$$\text{VIFM}(c,i,r)*f\_qfm(c,i,r)=\text{sum}[j,\text{IND}:(\text{DEST\_REG}(j) \text{ eq } r) \text{ and} \\ (\text{IND2COMM}(j) \text{ eq } i), \\ \text{V1BAS}(c,"imp",j)*x1(c,"imp",j)];$$

E\_f\_qva (All,i,FDI\_COMM)(All,r,FDI\_DEST)

$$\text{VVA}(i,r)*f\_qva(i,r)=\text{sum}\{j,\text{IND}:(\text{DEST\_REG}(j) \text{ eq } r) \text{ and}$$

---

```

                                (IND2COMM(j) eq i),
                                V1PRIM(j)*x1prim(j)};

E_f_qfel (All,c,LABOR)(All,i,FDI_COMM)(All,r,FDI_DEST)

EVFA(c,i,r)*[pfe(c,i,r)+f_qfel(c,i,r)-pfactwld]=

sum{j,IND:(DEST_REG(j) eq r) and

                                (IND2COMM(j) eq i),

                                V1LAB_S(j,c)*[p1lab_s(j,c)+x1lab_s(j,c)-pfactwld]};

E_f_qfek (All,c,ENDWC_COMM)(All,i,FDI_COMM)(All,r,FDI_DEST)

EVFA(c,i,r)*f_qfek(c,i,r)=

sum{j,IND:(DEST_REG(j) eq r) and

                                (IND2COMM(j) eq i),

                                V1CAP(j)*x1cap(j)};

E_f_qfen (All,c,LAND)(All,i,FDI_COMM)(All,r,FDI_DEST)

IF[EVFA(c,i,r)=0,f_qfen(c,i,r)]=

IF[EVFA(c,i,r) ne 0,

EVFA(c,i,r)*[pfe(c,i,r)+f_qfen(c,i,r)-pfactwld]-

sum{j,IND:(DEST_REG(j) eq r) and

                                (IND2COMM(j) eq i),

                                V1LND(j)*[p1lnd(j)+x1lnd(j)-pfactwld]}};

E_f_qfenr (All,c,NATRES)(All,i,FDI_COMM)(All,r,FDI_DEST)

```

---

```

IF[EVFA(c,i,r)=0,f_qfenr(c,i,r)]=

IF[EVFA(c,i,r) ne 0,

EVFA(c,i,r)*[pfe(c,i,r)+f_qfenr(c,i,r)-pfactwld]-

sum{j,IND:(DEST_REG(j) eq r) and

(IND2COMM(j) eq i),

V1NR(j)*[p1nr(j)+x1nr(j)-pfactwld]}];

E_f_pf (All,c,TRAD_COMM)(All,i,FDI_COMM)(All,r,FDI_DEST)

[VFA(c,i,r)+IF(VFA(c,i,r)=0,1)]*[f_pf(c,i,r)-pfactwld]=

sum{j,IND:(DEST_REG(j) eq r) and (IND2COMM(j) eq i),

V1PUR_S(c,j)*[p1_s(c,j)-pfactwld]}];

! Output !

! Replaces equation MKTCLTRD which is nullified by endogenising variable
tradslack. !

E_qo (All,i,TRAD_COMM)(All,r,REG) [VOM(i,r)+IF(VOM(i,r)=0,1)]*qo(i,r)=

IF{VOM(i,r) ne 0,

VODM(i,r)*qod(i,r)+sum[o,HOME,VOHM(i,o,r)*qoh(i,o,r)]};

E_qoa (All,i,TRAD_COMM)(All,r,REG) [VOA(i,r)+IF(VOA(i,r)=0,1)]*qoa(i,r)=

IF{VOA(i,r) ne 0,

VODA(i,r)*qod(i,r)+sum[o,HOME,VOHA(i,o,r)*qoh(i,o,r)]};

```



---

! FTAP market price of output pm is a share weighted sum of  
 CRUSOE industry output prices pltot. This is ensured by endogenising  
 FTAP output taxes on industries so that they move consistently with  
 CRUSOE other costs.

!

E\_to\_FDI (All,i,TRAD\_COMM)(All,r,REG)

IF{FDI\_FLAG1(i,r)>0,

VOM(i,r)\*{pm(i,r)+qo(i,r)}-sum[j,IND:(DEST\_REG(j) eq r) and

(IND2COMM(j) eq i),

V1TOT(j)\*{pltot(j)+x1tot(j)}]}=

IF{FDI\_FLAG1(i,r)=0,to(i,r)-to\_shk(i,r)};

E\_tof (All,i,TRAD\_COMM)(All,o,HOME)(All,l,HOST)

tof(i,o,l)=to\_shk(i,l)+f\_tof(i,o,l);

E\_tod (All,i,TRAD\_COMM)(All,r,REG) tod(i,r)=to\_shk(i,r);

EQUATION E\_check\_evfa (All,c,ENDW\_COMM)(All,j,FDI\_COMM)(All,r,FDI\_DEST)

check\_evfa(c,j,r)=

IF{(FDI\_FLAG1(j,r) ne 0) and (EVFA(c,j,r)>0),

---

```

pfe(c,j,r)+qfe(c,j,r)-
sum[i,IND:(IND2COMM(i) eq j) and (DEST_REG(i) eq r),
sum[k,ENDWC_COMM:k eq c,
V1CAP(i)/EVFA(c,j,r)*(p1cap(i)+x1cap(i))]+
sum[k,LABOR:k eq c,
V1LAB_S(i,k)/EVFA(c,j,r)*(p1lab_s(i,k)+x1lab_s(i,k))]+
sum[k,LAND:k eq c,
V1LND(i)/EVFA(c,j,r)*(p1lnd(i)+x1lnd(i))]+
sum[k,NATRES:k eq c,
V1NR(i)/EVFA(c,j,r)*(p1nr(i)+x1nr(i))]
]};

```

```

EQUATION E_check_vdfm (All,c,TRAD_COMM)(All,j,FDI_COMM)(All,r,FDI_DEST)

```

```

check_vdfm(c,j,r)=
IF{(FDI_FLAG1(j,r) ne 0) and (VDFM(c,j,r)>0),
pds(c,r)+qfd(c,j,r)-
sum[i,IND:(IND2COMM(i) eq j) and (DEST_REG(i) eq r),
V1BAS(c,"dom",i)/VDFM(c,j,r)*(p0(c,"dom",i)+x1(c,"dom",i))]};

```

```

EQUATION E_check_vdfa (All,c,TRAD_COMM)(All,j,FDI_COMM)(All,r,FDI_DEST)

```

```

check_vdfa(c,j,r)=
IF{(FDI_FLAG1(j,r) ne 0) and (VDFA(c,j,r)>0),
pfd(c,j,r)+qfd(c,j,r)-
sum[i,IND:(IND2COMM(i) eq j) and (DEST_REG(i) eq r),

```

---

```

V1PUR(c,"dom",i)/VDFA(c,j,r)*(p1(c,"dom",i)+x1(c,"dom",i))}};

EQUATION E_check_vifm (All,c,TRAD_COMM)(All,j,FDI_COMM)(All,r,FDI_DEST)

check_vifm(c,j,r)=

IF{(FDI_FLAG1(j,r) ne 0) and (VIFM(c,j,r)>0),

pid(c,r)+qfm(c,j,r)-

sum[i,IND:(IND2COMM(i) eq j) and (DEST_REG(i) eq r),

V1BAS(c,"imp",i)/VIFM(c,j,r)*(p0(c,"imp",i)+x1(c,"imp",i))}};

EQUATION E_check_vifa (All,c,TRAD_COMM)(All,j,FDI_COMM)(All,r,FDI_DEST)

check_vifa(c,j,r)=

IF{(FDI_FLAG1(j,r) ne 0) and (VIFA(c,j,r)>0),

pfm(c,j,r)+qfm(c,j,r)-

sum[i,IND:(IND2COMM(i) eq j) and (DEST_REG(i) eq r),

V1PUR(c,"imp",i)/VIFA(c,j,r)*(p1(c,"imp",i)+x1(c,"imp",i))}};

EQUATION E_check_vfa (All,c,TRAD_COMM)(All,j,FDI_COMM)(All,r,FDI_DEST)

check_vfa(c,j,r)=

IF{(FDI_FLAG1(j,r) ne 0) and (VFA(c,j,r)>0),

pf(c,j,r)+qf(c,j,r)-

sum[i,IND:(IND2COMM(i) eq j) and (DEST_REG(i) eq r),

V1PUR_S(c,i)/VFA(c,j,r)*(p1_s(c,i)+x1_s(c,i))}};

EQUATION E_check_oct (All,i,FDI_COMM)(All,r,FDI_DEST)

```

---

```

100*check_oct(i,r)=

IF{(FDI_FLAG1(i,r) ne 0) and (PTAX(i,r) ne 0),

[VOM(i,r)/PTAX(i,r)*[pm(i,r)+qo(i,r)]-VOA(i,r)/PTAX(i,r)*[ps(i,r)+qo(i,r)]]-

sum[j,IND:(IND2COMM(j) eq i) and (DEST_REG(j) eq r),

VLOCT(j)/PTAX(i,r)*(pltot(j)+xltot(j))+

(V1TOT(j)-VLOCT(j))/PTAX(i,r)*p_rloct(j)]};

EQUATION E_see_foct (All,i,FDI_COMM)(All,s,HOME)(All,d,FDI_DEST)

see_foct(i,s,d)=sum[j,IND:(NOT_DOM(j)=1) and (IND2COMM(j) eq i) and

(HOME_REG(j) eq s) and (DEST_REG(j) eq d),

p_rloct(j)];

EQUATION E_see_doct (All,i,FDI_COMM)(All,r,FDI_DEST)

see_doct(i,r)=sum[j,IND:(NOT_DOM(j)=0) and (IND2COMM(j) eq i) and

(HOME_REG(j) eq r) and (DEST_REG(j) eq r),

p_rloct(j)];

EQUATION E_check_voa (All,i,FDI_COMM)(All,r,FDI_DEST)

check_voa(i,r)=

IF{(FDI_FLAG1(i,r) ne 0) and (VOA(i,r)>0),

{ps(i,r)+qo(i,r)}-sum[j,IND:(DEST_REG(j) eq r) and

(IND2COMM(j) eq i),

Sum(c,COM, V1PUR_S(c,j)/VOA(i,r)*{pl_s(c,j)+xl_s(c,j)})

+ V1PRIM(j)/VOA(i,r)*{plprim(j) + xlprim(j)} ]};

```

---

```

!.....!
!      Welfare decomposition written in terms of FTAP      !
!      variables from the CRUSOE portion of the code.      !
!.....!

```

EQUATION

E\_alleff\_csi (All,i,COM)(All,s,SRC)(All,j,IND)

alleff\_csi(i,s,j)=[.01/INCRATIO(DEST\_REG(j))]\*V1TAX(i,s,j)\*x1(i,s,j);

E\_alleff\_ei (All,i,ENDW\_COMM)(All,j,IND) alleff\_ei(i,j)=

[.01/INCRATIO(DEST\_REG(j))]\*

sum[k,LABOR:(k eq i) and (V1LAB\_S(j,k)>0),

V1LAB\_S(j,k)\*

{EVFA(i,IND2COMM(j),DEST\_REG(j))-VFM(i,IND2COMM(j),DEST\_REG(j))}/

EVFA(i,IND2COMM(j),DEST\_REG(j))\*x1lab\_s(j,k)]+

sum[k,LAND:(k eq i) and (V1LND(j)>0),

V1LND(j)\*

{EVFA(i,IND2COMM(j),DEST\_REG(j))-VFM(i,IND2COMM(j),DEST\_REG(j))}/

---

```

EVFA(i,IND2COMM(j),DEST_REG(j))*x1lnd(j)]+
sum[k,NATRES:(k eq i) and (V1NR(j)>0),
V1NR(j)*
{EVFA(i,IND2COMM(j),DEST_REG(j))-VFM(i,IND2COMM(j),DEST_REG(j))}/
EVFA(i,IND2COMM(j),DEST_REG(j))*x1nr(j)]+
sum[k,ENDWC_COMM:(k eq i) and (NOT_DOM(j)=1),
{EVIFAS(IND2COMM(j),HOME_REG(j),DEST_REG(j))-
EVIFMS(IND2COMM(j),HOME_REG(j),DEST_REG(j))}*x1cap(j)]+
sum[k,ENDWC_COMM:(k eq i) and (NOT_DOM(j)=0),
{EVDFA(IND2COMM(j),DEST_REG(j))-
EVDFM(IND2COMM(j),DEST_REG(j))}*x1cap(j)];

E_alleff_o (All,j,IND)
alleff_o(j)=[.01/INCRATIO(DEST_REG(j))]*V1OCT(j)*x1tot(j);

EQUATION
E_falleffd_ci (All,c,TRAD_COMM)(All,i,FDI_COMM)(All,r,FDI_DEST)
falleffd_ci(c,i,r)=sum[j,IND:(IND2COMM(j) eq i) and (DEST_REG(j) eq r),
alleff_csi(c,"dom",j)];

E_falleffi_ci (All,c,TRAD_COMM)(All,i,FDI_COMM)(All,r,FDI_DEST)
falleffi_ci(c,i,r)=sum[j,IND:(IND2COMM(j) eq i) and (DEST_REG(j) eq r),
alleff_csi(c,"imp",j)];

```

---

E\_falleff\_ei (All,c,ENDW\_COMM)(All,i,FDI\_COMM)(All,r,FDI\_DEST)

falleff\_ei(c,i,r)=sum[j,IND:(IND2COMM(j) eq i) and (DEST\_REG(j) eq r),  
alleff\_ei(c,j)];

E\_falleff\_o (All,i,FDI\_COMM)(All,r,FDI\_DEST)

falleff\_o(i,r)=sum[j,IND:(IND2COMM(j) eq i) and (DEST\_REG(j) eq r),  
alleff\_o(j)];

E\_falleff (All,r,FDI\_DEST)

falleff(r)=falleff\_et(r)+falleffd\_t(r)+falleffi\_t(r)+falleff\_ot(r);

E\_falleff\_et (All,r,FDI\_DEST)

falleff\_et(r)=sum[i,FDI\_COMM,sum[c,ENDW\_COMM,falleff\_ei(c,i,r)]];

E\_falleffd\_t (All,r,FDI\_DEST)

falleffd\_t(r)=sum[i,FDI\_COMM,sum[c,TRAD\_COMM,falleffd\_ci(c,i,r)]];

E\_falleffi\_t (All,r,FDI\_DEST)

falleffi\_t(r)=sum[i,FDI\_COMM,sum[c,TRAD\_COMM,falleffi\_ci(c,i,r)]];

E\_falleff\_ot (All,r,FDI\_DEST)

falleff\_ot(r)=sum[i,FDI\_COMM,falleff\_o(i,r)];

---

EQUATION E\_galleffr (all,r,REG)

galleffr(r) = [.01/INCRATIO(r)] \*  
[ sum(i,PROD\_COMM:FDI\_FLAG1(i,r)=0, PTAX(i,r) \* qo(i,r))  
+ sum(i,NONCAP\_COMM, PTAX(i,r) \* qo(i,r))  
+ sum(i,ENDWC\_COMM, PTAX(i,r) \* kr(r))  
+ sum(i,ENDW\_COMM, sum(j,PROD\_COMM:FDI\_FLAG1(j,r)=0,  
ETAX(i,j,r) \* qfe(i,j,r)))  
+ sum(j,PROD\_COMM:FDI\_FLAG1(j,r)=0,  
sum(i,TRAD\_COMM, IFTAX(i,j,r) \* qfm(i,j,r)))  
+ sum(j,PROD\_COMM:FDI\_FLAG1(j,r)=0,  
sum(i,TRAD\_COMM, DFTAX(i,j,r) \* qfd(i,j,r)))  
+ sum(i,TRAD\_COMM, IPTAX(i,r) \* qpm(i,r))  
+ sum(i,TRAD\_COMM, DPTAX(i,r) \* qpd(i,r))  
+ sum(i,TRAD\_COMM, IGTAX(i,r) \* qgm(i,r))  
+ sum(i,TRAD\_COMM, DGTAX(i,r) \* qgd(i,r))  
+ sum(i,TRAD\_COMM, sum(s,REG, XTAXD(i,r,s) \* qxs(i,r,s)))  
+ sum(i,TRAD\_COMM, sum(s,REG, MTAX(i,s,r) \* qxs(i,s,r))) ] ;

! Account for abnormal returns to capital. !

! Define contributions to EV from abnormal returns. !

E\_CNTanrr\_hhi (All,i,TRAD\_COMM)(All,s,HOME)(All,d,host)

CNTanrr\_hhi(i,s,d)=[.01/INCRATIO(s)]\*VFDI\_HHI(i,s,d)\*anrrk\_hhi(i,s,d);



---

E\_CNTanend\_hhi (All,i,TRAD\_COMM)(All,s,HOME)(All,d,host)

CNTanend\_hhi(i,s,d)=[.01/INCRATIO(s)]\*[1-host\_tax\_ank\*TYPR\_L(d)]\*

ANKTAX\_HHI(i,s,d)\*qfes(i,s,d);

E\_CNTanpk\_hhi (All,i,TRAD\_COMM)(All,s,HOME)(All,d,host)

CNTanpk\_hhi(i,s,d)=[.01/INCRATIO(s)]\*[1-host\_tax\_ank\*TYPR\_L(d)]\*

ANKTAX\_HHI(i,s,d)\*pcgds(d);

E\_CNTqfed\_i (All,i,TRAD\_COMM)(All,r,REG)

CNTqfed\_i(i,r)=[.01/INCRATIO(r)]\*

sum[k,ENDWC\_COMM:EVFA(k,i,r)>0,ETAX(k,i,r)/EVFA(k,i,r)]\*

EVDFA(i,r)\*qfed(i,r);

E\_CNTqfed (All,r,REG)

CNTqfed(r)=sum[i,TRAD\_COMM,CNTqfed\_i(i,r)];

E\_CNTqfes\_hhi (All,i,TRAD\_COMM)(All,s,HOME)(All,d,host)

CNTqfes\_hhi(i,s,d)=[.01/INCRATIO(d)]\*

sum[k,ENDWC\_COMM:EVFA(k,i,d)>0,ETAX(k,i,d)/EVFA(k,i,d)]\*

EVIFAS(i,s,d)\*qfes(i,s,d);

E\_CNTqfes\_\_hi (All,i,TRAD\_COMM)(All,d,host)

CNTqfes\_\_hi(i,d)=sum[s,HOME,CNTqfes\_hhi(i,s,d)];

---

E\_CNTqfes\_\_h\_\_ (All,d,host)

CNTqfes\_\_h\_\_(d)=sum[i,TRAD\_COMM,CNTqfes\_\_hi(i,d)];

E\_CNTanrr\_h\_\_ (All,r,REG)

CNTanrr\_h\_\_(r)=sum[i,TRAD\_COMM,sum[d,DEST,CNTanrr\_hhi(i,r,d)]]-

[1/INCRATIO(r)]\*

sum[i,TRAD\_COMM,sum[s,HOME,INCRATIO(s)\*CNTanrr\_hhi(i,s,r)]];

E\_CNTanend\_h\_\_ (All,r,REG)

CNTanend\_h\_\_(r)=sum[i,TRAD\_COMM,sum[d,DEST,CNTanend\_hhi(i,r,d)]]-

[1/INCRATIO(r)]\*

sum[i,TRAD\_COMM,sum[s,HOME,INCRATIO(s)\*CNTanend\_hhi(i,s,r)]];

E\_CNTanpk\_h\_\_ (All,r,REG)

CNTanpk\_h\_\_(r)=sum[i,TRAD\_COMM,sum[d,DEST,CNTanpk\_hhi(i,r,d)]]-

[1/INCRATIO(r)]\*

sum[i,TRAD\_COMM,sum[s,HOME,INCRATIO(s)\*CNTanpk\_hhi(i,s,r)]];

! .....!  
!  
! Demands for FDI Differentiated Products !  
! .....!

EQUATION

---

E\_qdd (All,i,TRAD\_COMM)(All,r,REG)

qdd(i,r)=qds(i,r)-ESUBM!L!(i!,r!)\*[pdd(i,r)-pds(i,r)];

E\_qdh (All,i,TRAD\_COMM)(All,o,HOME)(All,l,HOST)

qdh(i,o,l)=IF{VDHM(i,o,l) ne 0,

qds(i,l)-ESUBM!L!(i!,l!)\*[pdh(i,o,l)-pds(i,l)]};

E\_qid (All,i,TRAD\_COMM)(All,d,DEST) qid(i,d)=qim(i,d);

E\_qisd (All,i,TRAD\_COMM)(All,s,SOURCE)(All,d,DEST)

qisd(i,s,d)=IF{VIMS(i,s,d) ne 0,

qid(i,d)-ESUBM!O!(i!,d!)\*[pisd(i,s,d)-pid(i,d)]};

E\_qxdd (All,i,TRAD\_COMM)(All,s,SOURCE)(All,d,DEST)

qxdd(i,s,d)=IF{VIMS\_DD(i,s,d) ne 0,

qisd(i,s,d)-ESUBM!L!(i!,d!)\*[pild(i,s,d)-pisd(i,s,d)]};

E\_qxhd (All,i,TRAD\_COMM)(All,o,HOME)(All,l,HOST)(All,d,DEST)

qxhd(i,o,l,d)=IF[VIMS\_D(i,o,l,d) ne 0,

qisd(i,l,d)-ESUBM!L!(i!,d!)\*[pihld(i,o,l,d)-pisd(i,l,d)]};

! 6.2 International Freight !

E\_qdst (All,i,TRAD\_COMM)(All,r,REG)

---

qdst(i,r)=IF{VDST(i,r) ne 0,qst(i,r)-[pod(i,r)-pst(i,r)]};

E\_qhst (All,i,TRAD\_COMM)(All,o,HOME)(All,l,HOST)

qhst(i,o,l)=IF{VHST(i,o,l) ne 0,qst(i,l)-[poh(i,o,l)-pst(i,l)]};

E\_pst (All,i,TRAD\_COMM)(All,r,REG)

IF{VST(i,r) ne 0,VST(i,r)\*[pst(i,r)!+qst(i,r)!]-(  
VDST(i,r)\*[pod(i,r)!+qdst(i,r)!]+  
sum[o,HOME,VHST(i,o,r)\*[poh(i,o,r)!+qhst(i,o,r)!])}]=  
IF{VST(i,r)=0,pst(i,r)-pfactwld};

! 6.4 Market clearing conditions !

E\_qod (All,i,TRAD\_COMM)(All,r,REG) [VODM(i,r)+IF(VODM(i,r)=0,1)]\*qod(i,r)=

IF[VODM(i,r) ne 0,

VXDM(i,r)\*qxd(i,r)+VDDM(i,r)\*qdd(i,r)+VDST(i,r)\*qdst(i,r)];

E\_qoh (All,i,TRAD\_COMM)(All,o,HOME)(All,l,HOST)

[VOHM(i,o,l)+IF(VOHM(i,o,l)=0,1)]\*qoh(i,o,l)=IF[VOHM(i,o,l) ne 0,

VXHM(i,o,l)\*qxh(i,o,l)+VDHM(i,o,l)\*qdh(i,o,l)+VHST(i,o,l)\*qhst(i,o,l)];

E\_qxd (All,i,TRAD\_COMM)(All,s,SOURCE)

[VXDM(i,s)+IF(VXDM(i,s)=0,1)]\*qxd(i,s)=IF{VXDM(i,s) ne 0,

sum[d,DEST,VXMD\_DD(i,s,d)\*qxdd(i,s,d)]};

---

```

E_qxh (All,i,TRAD_COMM)(All,o,HOME)(All,l,HOST)

[VXHM(i,o,l)+IF(VXHM(i,o,l)=0,1)]*qxh(i,o,l)=IF{VXHM(i,o,l) ne 0,

sum[d,DEST,VXMD_D(i,o,l,d)*qxhd(i,o,l,d)}];

```

! 6.3 Price Definition and Transmission Equations !

```

E_pdd (All,i,TRAD_COMM)(All,r,REG)

pdd(i,r)=pod(i,r)!+tdd(i,r)!;

```

```

E_pxd (All,i,TRAD_COMM)(All,r,REG)

pxd(i,r)=pod(i,r)!+txd(i,r)!;

```

```

E_pdh (All,i,TRAD_COMM)(All,o,HOME)(All,l,HOST)

pdh(i,o,l)=poh(i,o,l)!+tdh(i,o,l)!;

```

```

E_pxh (All,i,TRAD_COMM)(All,o,HOME)(All,l,HOST)

pxh(i,o,l)=poh(i,o,l)!+txh(i,o,l)!;

```

```

E_pds (All,i,TRAD_COMM)(All,r,REG)

IF{VDM(i,r) ne 0,

VDM(i,r)*qds(i,r)-{

sum[o,HOME,VDHM(i,o,r)*qdh(i,o,r)]+

```

---

```

VDDM(i,r)*qdd(i,r)}=

IF{VDM(i,r)=0,pds(i,r)-pfactwld};

E_pid (All,i,TRAD_COMM)(All,d,DEST)

IF{VIM(i,d)=0,pid(i,d)-pfactwld}=

IF{VIM(i,d) ne 0,

VIM(i,d)*qid(i,d)-sum[s,SOURCE,VIMS(i,s,d)*qisd(i,s,d)]};

E_pisd (All,i,TRAD_COMM)(All,s,SOURCE)(All,d,DEST)

IF{VIMS(i,s,d)=0,pisd(i,s,d)-pfactwld}=

IF{VIMS(i,s,d) ne 0,VIMS(i,s,d)*qisd(i,s,d)-[

VIMS_DD(i,s,d)*qxdd(i,s,d)+sum[o,HOME,VIMS_D(i,o,s,d)*qxhd(i,o,s,d)]]};

E_pxdd (All,i,TRAD_COMM)(All,s,SOURCE)(All,d,DEST)

pxdd(i,s,d)=pxd(i,s)+tx(i,s)+txsd(i,s,d);

E_pxhd (All,i,TRAD_COMM)(All,o,HOME)(All,l,HOST)(All,d,DEST)

pxhd(i,o,l,d)=pxh(i,o,l)+tx(i,l)+txsd(i,l,d)+txhd(i,o,l,d);

E_pildw (All,i,TRAD_COMM)(All,s,SOURCE)(All,d,DEST)

pildw(i,s,d)= FOBSHR2(i,s,d) * pxdd(i,s,d) + TRNSHR2(i,s,d) *

[pt - atsd(i,s,d)] + IF[FOBSHR2(i,s,d)+TRNSHR2(i,s,d)=0,pfactwld];

E_pihldw (All,i,TRAD_COMM)(All,o,HOME)(All,l,HOST)(All,d,DEST)

```

---

```

pihldw(i,o,l,d) = FOBSHRL2(i,o,l,d) * pxhd(i,o,l,d) + TRNSHRL2(i,o,l,d) *
[pt-atsd(i,l,d)-athsd(i,o,l,d)]+
IF[FOBSHRL2(i,o,l,d)+TRNSHRL2(i,o,l,d)=0,pfactwld];

E_pild (All,i,TRAD_COMM)(All,s,SOURCE)(All,d,DEST)

pild(i,s,d)=pildw(i,s,d)+tm(i,d)+tmsd(i,s,d);

E_pihld (All,i,TRAD_COMM)(All,o,HOME)(All,l,HOST)(All,d,DEST)

pihld(i,o,l,d)=pihldw(i,o,l,d)+tm(i,d)+tmsd(i,l,d)+tmhs(i,o,l,d);

! 6.5      Link to GTAP variables. !

! Replaces equation IMPORTDEMAND !

E_qxs (All,i,TRAD_COMM)(All,s,SOURCE)(All,d,DEST)

IF{VXMD(i,s,d) gt 0,
  VXMD(i,s,d)*qxs(i,s,d)-{
  sum[o,HOME,VXMD_D(i,o,s,d)*qxhd(i,o,s,d)]+
  VXMD_DD(i,s,d)*qxdd(i,s,d)}}=
IF{VXMD(i,s,d) le 0,qxs(i,s,d)};

E_pxs (All,i,TRAD_COMM)(All,s,SOURCE)(All,d,DEST)

IF{VXMD(i,s,d) gt 0,
  VXMD(i,s,d)*[pxs(i,s,d)+qxs(i,s,d)]-{

```

---

```

sum[o,HOME,VXMD_D(i,o,s,d)*[pxh(i,o,s)+qxhd(i,o,s,d)]]+
VXMD_DD(i,s,d)*[pxd(i,s)+qxdd(i,s,d)]]}=
IF{VXMD(i,s,d) le 0,pxs(i,s,d)-pfactwld};

E_txs (All,i,TRAD_COMM)(All,s,SOURCE)(All,d,DEST)

IF{VXWD(i,s,d) gt 0,
VXWD(i,s,d)*[pfob(i,s,d)+qxs(i,s,d)]-
sum[o,HOME,VXWD_D(i,o,s,d)*[pxhd(i,o,s,d)+qxhd(i,o,s,d)]]+
VXWD_DD(i,s,d)*[pxdd(i,s,d)+qxdd(i,s,d)]]}=
IF{VXWD(i,s,d) le 0,txs(i,s,d)};

! Replaces GTAP equation FOBCIF (I don't think so now). !

E_atr (All,i,TRAD_COMM)(All,s,SOURCE)(All,d,DEST)

IF{VTWR(i,s,d) gt 0,
VIWS(i,s,d)*[pcif(i,s,d)+qxs(i,s,d)]-
sum[o,HOME,VIWS_D(i,o,s,d)*[pihldw(i,o,s,d)+qxhd(i,o,s,d)]]+
VIWS_DD(i,s,d)*[pildw(i,s,d)+qxdd(i,s,d)]]}=
IF{VTWR(i,s,d) le 0,atr(i,s,d)};

E_tms (All,i,TRAD_COMM)(All,s,SOURCE)(All,d,DEST)

IF{VIMS(i,s,d) gt 0,
VIMS(i,s,d)*[pms(i,s,d)+qxs(i,s,d)]-
sum[o,HOME,VIMS_D(i,o,s,d)*[pihld(i,o,s,d)+qxhd(i,o,s,d)]]+
VIMS_DD(i,s,d)*[pild(i,s,d)+qxdd(i,s,d)]]}=

```



---

IF{VIMS(i,s,d) le 0,tms(i,s,d)};

! 6.6           Checking Equations           !

E\_check\_qisd (All,i,TRAD\_COMM)(All,s,SOURCE)(All,d,DEST)

  check\_qisd(i,s,d)=qxs(i,s,d)-qisd(i,s,d);

E\_check\_pisd (All,i,TRAD\_COMM)(All,s,SOURCE)(All,d,DEST)

  check\_pisd(i,s,d)=pms(i,s,d)-pisd(i,s,d);

E\_frt (All,i,TRAD\_COMM)(All,s,SOURCE)(All,d,DEST)

  frt(i,s,d)=pcif(i,s,d)-pfob(i,s,d);

E\_check\_frt (All,i,TRAD\_COMM)(All,o,HOME)(All,l,HOST)(All,d,DEST)

  check\_frt(i,o,l,d) = pihldw(i,o,l,d)-pxhd(i,o,l,d)-frt(i,l,d);

E\_check\_pid (All,i,TRAD\_COMM)(All,d,DEST) check\_pid(i,d)=pid(i,d)-pim(i,d);

! .....

! 6.7           Firm-level Product Differentiation           !

! .....

! Add endogenous technical change to represent substitution between the

---

output of different firms. !

EQUATION

E\_altot #Endog tech change from firm choice for FDI industries#

(All,i,IND) altot(i)=-ETECH\*xltot(i)+f\_altot(i);

E\_ao #Endog tech change from firm choice for purely local industries#

(All,i,TRAD\_COMM)(All,r,REG)

ao(i,r)=IF{FDI\_FLAG1(i,r)=0,ETECH\*qo(i,r)}+f\_ao(i,r);

E\_altot\_f (All,i,TRAD\_COMM)(All,o,HOME)(All,l,HOST) altot\_f(i,o,l)=

sum[j,IND:(IND2COMM(j) eq i) and (HOME\_REG(j) eq o) and

(DEST\_REG(j) eq l) and (NOT\_DOM(j)=1),altot(j)];

E\_altot\_d (All,i,TRAD\_COMM)(All,r,REG) altot\_d(i,r)=

sum[j,IND:(IND2COMM(j) eq i) and (HOME\_REG(j) eq r) and

(DEST\_REG(j) eq r) and (NOT\_DOM(j)=0),altot(j)];

! .....

!        7.2        New allocative efficiency effect.        !

! .....

EQUATION E\_CNTallefffdi (All,r,REG)

CNTallefffdi(r)=[0.01/INCRATIO(r)]\*

---

```

sum{i,TRAD_COMM,
    [VOA(i,r)/VOM(i,r)*VODM(i,r)-VODA(i,r)]*qod(i,r)+
sum{o,HOME,
    [VOA(i,r)/VOM(i,r)*VOHM(i,o,r)-VOHA(i,o,r)]*qoh(i,o,r)}
};

```

```

!.....!
!           Account for output impediment rents.           !
!.....!

```

EQUATION

```
E_yanpr (All,r,REG) yanpr(r)=sum{j,TRAD_COMM,yanpri(j,r)};
```

```
E_yanpri (All,i,TRAD_COMM)(All,r,REG)
```

```

100*yanpri(i,r)=
(1-SHPTAX(i,r))*{VOM(i,r)*[pm(i,r)+qo(i,r)]-
    VOA(i,r)*[ps(i,r)+qo(i,r)]}-

```

```
100*PTAX(i,r)*c_SHPTAX(i,r);
```

```
E_yanp_hhi (All,i,TRAD_COMM)(All,s,HOME)(All,d,host)
```

```

100*yanp_hhi(i,s,d)=IF[PHTAX(i,s,d) ne 0,
(1-SHPTAX(i,d))*{VOHM(i,s,d)*[poh(i,s,d)+qoh(i,s,d)]-
    VOHA(i,s,d)*[psh(i,s,d)+qoh(i,s,d)]}-

```

---

100\*PHTAX(i,s,d)\*c\_SHPTAX(i,d)];

E\_yanp\_h\_\_ (All,r,REG)

yanp\_h\_\_(r)=

IF{home\_tax\_anp ne 0,home\_tax\_anp\*{

sum[i,TRAD\_COMM,sum[d,DEST,yanp\_hhi(i,r,d)]]-

sum[i,TRAD\_COMM,sum[s,HOME,yanp\_hhi(i,s,r)]]}+}

IF{host\_tax\_anp ne 0,host\_tax\_anp\*{

sum[i,TRAD\_COMM,sum[d,DEST,

[1-TYPR\_L(d)]\*yanp\_hhi(i,r,d)-

0.01\*ANPTAX\_HHI(i,r,d)\*TYPR\_L(d)\*typr(d)]]-

sum[i,TRAD\_COMM,sum[s,HOME,

[1-TYPR\_L(r)]\*yanp\_hhi(i,s,r)-

0.01\*ANPTAX\_HHI(i,s,r)\*TYPR\_L(r)\*typr(r)]]}+}

!.....!

! 8.2 Welfare Effects of Income from Output Impediments !

!.....!

E\_anrro\_hhi (All,i,TRAD\_COMM)(All,s,HOME)(All,d,host)

IF[VFDI\_HHI(i,s,d)=0,anrro\_hhi(i,s,d)]=

IF[VFDI\_HHI(i,s,d)>0,

100\*[

IF{home\_tax\_anp ne 0,home\_tax\_anp\*yanp\_hhi(i,s,d)}+}

---

```

IF{host_tax_anp ne 0,host_tax_anp*[
    [1-TYPR_L(d)]*yanp_hhi(i,s,d)-
    0.01*ANPTAX_HHI(i,s,d)*TYPR_L(d)*typr(d)]}-
    {[1-host_tax_anp*TYPR_L(d)]*ANPTAX_HHI(i,s,d)*[pcgds(d)+qfes(i,s,d)]+
    VFDI_HHI(i,s,d)*anrro_hhi(i,s,d)}
];

```

```

E_anto_hhi (All,i,TRAD_COMM)(All,s,HOME)(All,d,host)

```

```

IF[VFDI_HHI(i,s,d)=0,anto_hhi(i,s,d)]=
IF[VFDI_HHI(i,s,d)>0,
    100*yanp_hhi(i,s,d)-
    {[1-SHPTAX(i,d)]*[VOHM(i,s,d)-VOHA(i,s,d)]*[pcgds(d)+qfes(i,s,d)]+
    VFDI_HHI(i,s,d)*anto_hhi(i,s,d)}
];

```

```

E_anto_h_i (All,i,TRAD_COMM)(All,r,REG)

```

```

IF[VKD(i,r)=0,anto_h_i(i,r)]=
IF[VKD(i,r)>0,
    100*{yanpri(i,r)-sum[s,HOME,yanp_hhi(i,s,r)]}-
    {[1-SHPTAX(i,r)]*[VODM(i,r)-VODA(i,r)]*[pcgds(r)+qfed(i,r)]+
    VKD(i,r)*anto_h_i(i,r)}
];

```

---

! .....!  
!           Income from Capital Impediments           !  
! .....!

EQUATION

E\_yankr (All,r,REG) yankr(r)=sum[j,TRAD\_COMM,yankri(j,r)];

E\_yankri (All,j,TRAD\_COMM)(All,r,REG)

$$100*yankri(j,r)=sum\{i,ENDWC\_COMM,EVFA(i,j,r)*[pfe(i,j,r)+qfe(i,j,r)]- \\ VFM(i,j,r)*[rp(j,r)+qfe(i,j,r)]\};$$

E\_yank\_hhi (All,i,TRAD\_COMM)(All,s,HOME)(All,d,host)

$$100*yank\_hhi(i,s,d)=EVIFAS(i,s,d)*[pfesa(i,s,d)+qfes(i,s,d)]- \\ EVIFMS(i,s,d)*[rps(i,s,d)+qfes(i,s,d)];$$

E\_yank\_h\_\_ (All,r,REG)

yank\_h\_\_(r)=

IF{home\_tax\_ank ne 0,home\_tax\_ank\*{  
sum[i,TRAD\_COMM,sum[d,DEST,yank\_hhi(i,r,d)]]-  
sum[i,TRAD\_COMM,sum[s,HOME,yank\_hhi(i,s,r)]]}+}

IF{host\_tax\_ank ne 0,host\_tax\_ank\*{  
sum[i,TRAD\_COMM,sum[d,DEST,

---

```

[1-TYPR_L(d)]*yank_hhi(i,r,d)-
0.01*ANKTAX_HHI(i,r,d)*TYPR_L(d)*typr(d)]]-
sum[i,TRAD_COMM,sum[s,HOME,
[1-TYPR_L(r)]*yank_hhi(i,s,r)-
0.01*ANKTAX_HHI(i,s,r)*TYPR_L(r)*typr(r)]]}];

```

```

!.....!
! 8.4   Welfare effects of Income from Capital Impediments   !
!.....!

```

```

E_anrrk_hhi (All,i,TRAD_COMM)(All,s,HOME)(All,d,host)

IF[VFDI_HHI(i,s,d)=0,anrrk_hhi(i,s,d)]=

IF[VFDI_HHI(i,s,d)>0,

100*[

IF{home_tax_ank ne 0,home_tax_ank*yank_hhi(i,s,d)}+

IF{host_tax_ank ne 0,host_tax_ank*{

[1-TYPR_L(d)]*yank_hhi(i,s,d)-

0.01*ANKTAX_HHI(i,s,d)*TYPR_L(d)*typr(d)}}]]-

{[1-host_tax_ank*TYPR_L(d)]*

ANKTAX_HHI(i,s,d)*[pcgds(d)+qfes(i,s,d)]+

VFDI_HHI(i,s,d)*anrrk_hhi(i,s,d)}

];

```

---

!.....!

! 8.5 Income from Export Impediments !

!.....!

!.....!

COEFFICIENT (All,o,HOME)(All,l,HOST) TYPR\_L\_ANK(o,l)

#Property tax rate to be applied to capital impediment income flow#;

COEFFICIENT (All,o,HOME)(All,l,HOST) TYPR\_L\_ANP(o,l)

#Property tax rate to be applied to output impediment income flow#;

COEFFICIENT (All,s,home)(All,i,TRAD\_COMM) L\_anrrd\_h\_i(i,s)

#Abnormal component of rate of return on domestic capital by industry#;

COEFFICIENT (All,s,home)(All,d,host)(All,i,TRAD\_COMM) L\_anrr\_hhi(i,s,d)

#Abnormal component of rate of return on foreign capital#;

COEFFICIENT (All,i,TRAD\_COMM)(All,s,HOME)(All,d,host) L\_anto\_hhi(i,s,d)

#Output impediment rate of return for foreign industries#;

COEFFICIENT (All,i,TRAD\_COMM)(All,r,REG) L\_anto\_h\_i(i,r)





---

! .....

EQUATION E\_typr\_ank (All,o,HOME)(All,l,HOST)

TYPR\_L\_ANK(o,l)\*typr\_ank(o,l)=

home\_tax\_ank\*TYPR\_L(o)\*typr(o)+host\_tax\_ank\*TYPR\_L(l)\*typr(l);

EQUATION E\_typr\_anp (All,o,HOME)(All,l,HOST)

TYPR\_L\_ANP(o,l)\*typr\_anp(o,l)=

home\_tax\_anp\*TYPR\_L(o)\*typr(o)+host\_tax\_anp\*TYPR\_L(l)\*typr(l);

! Welfare decomposition for rentals from output impediments. !

EQUATION

E\_CNTanto\_hhi (All,i,TRAD\_COMM)(All,s,HOME)(All,d,host)

CNTanto\_hhi(i,s,d)=[.01/INCRATIO(s)]\*VFDDI\_HHI(i,s,d)\*anrro\_hhi(i,s,d);

E\_CNTanqo\_hhi (All,i,TRAD\_COMM)(All,s,HOME)(All,d,host)

CNTanqo\_hhi(i,s,d)=[.01/INCRATIO(s)]\*[1-host\_tax\_anp\*TYPR\_L(d)]\*

ANPTAX\_HHI(i,s,d)\*qfes(i,s,d);

---

E\_CNTanpo\_hhi (All,i,TRAD\_COMM)(All,s,HOME)(All,d,host)

CNTanpo\_hhi(i,s,d)=[.01/INCRATIO(s)]\*[1-host\_tax\_anp\*TYPR\_L(d)]\*

ANPTAX\_HHI(i,s,d)\*pcgds(d);

E\_CNTanto\_h\_\_ (All,r,REG)

CNTanto\_h\_\_(r)=sum[i,TRAD\_COMM,sum[d,DEST,CNTanto\_hhi(i,r,d)]]-

[1/INCRATIO(r)]\*

sum[i,TRAD\_COMM,sum[s,HOME,INCRATIO(s)\*CNTanto\_hhi(i,s,r)]];

E\_CNTanqo\_h\_\_ (All,r,REG)

CNTanqo\_h\_\_(r)=sum[i,TRAD\_COMM,sum[d,DEST,CNTanqo\_hhi(i,r,d)]]-

[1/INCRATIO(r)]\*

sum[i,TRAD\_COMM,sum[s,HOME,INCRATIO(s)\*CNTanqo\_hhi(i,s,r)]];

E\_CNTanpo\_h\_\_ (All,r,REG)

CNTanpo\_h\_\_(r)=sum[i,TRAD\_COMM,sum[d,DEST,CNTanpo\_hhi(i,r,d)]]-

[1/INCRATIO(r)]\*

sum[i,TRAD\_COMM,sum[s,HOME,INCRATIO(s)\*CNTanpo\_hhi(i,s,r)]];

! .....

! Summary trade variables in line with data summary program TRADE.TAB. !

COEFFICIENT (all,i,TRAD\_COMM)(all,s,SOURCE) GXMD(i,s)

---

# Total Exports from s, domestic price# ;

COEFFICIENT (all,i,TRAD\_COMM)(all,s,SOURCE) GXWD(i,s)

# Total Exports from s, FOB price# ;

COEFFICIENT (all,i,TRAD\_COMM)(all,d,DEST) GVIW(i,d)

# Total Imports to d, CIF price # ;

COEFFICIENT (all,i,TRAD\_COMM)(all,d,DEST) GVIM(i,d)

# Total Imports to d, tariff inclusive price # ;

COEFFICIENT (all,i,TRAD\_COMM)(all,h,HOME)(all,s,SOURCE) X\_FDI\_MD(i,h,s)

# Exports of fdi ind to third countries, domestic price# ;

COEFFICIENT (all,i,TRAD\_COMM)(all,h,HOME)(all,s,SOURCE) X\_FDI\_WD(i,h,s)

# Exports of fdi ind to third countries, FOB price# ;

COEFFICIENT (all,i,TRAD\_COMM)(all,h,HOME) X\_MD(i,h)

# Exports of fdi ind to third countries, domestic price# ;

COEFFICIENT (all,i,TRAD\_COMM)(all,h,HOME) X\_WD(i,h)

# Exports of fdi ind to third countries, FOB price# ;

COEFFICIENT (all,i,TRAD\_COMM)(all,h,HOME)(all,d,DEST) M\_FDI\_WS(i,h,d)

---

# Imports from third country fdi ind, CIF price# ;

COEFFICIENT (all,i,TRAD\_COMM)(all,h,HOME)(all,d,DEST) M\_FDI\_MS(i,h,d)

# Imports from third country fdi ind, tariff incl price# ;

COEFFICIENT (all,i,TRAD\_COMM)(all,d,DEST) M\_WS(i,d)

# Imports from third country fdi ind, CIF price# ;

COEFFICIENT (all,i,TRAD\_COMM)(all,d,DEST) M\_MS(i,d)

# Imports from third country fdi ind, tariff incl price# ;

COEFFICIENT (All,i,TRAD\_COMM)(All,r,REG) VTOTDHM(i,r)

# Total market value of domestic use of foreign industry output#;

COEFFICIENT (all,i,TRAD\_COMM)(all,r,HOST) VTOTOHM(i,r)

#Total output of foreign firms in host country # ;

COEFFICIENT (all,i,TRAD\_COMM)(all,r,HOME) VTOTOWN\_OS(i,r)

#Total output of firms located abroad # ;

!~~~~~!

FORMULA (all,i,TRAD\_COMM)(all,s,SOURCE)

---

GXMD(i,s) = SUM(d,DEST, (SUM(h,HOME, VXMD\_D(i,h,s,d)) + VXMD\_DD(i,s,d)) ) ;

FORMULA (all,i,TRAD\_COMM)(all,s,SOURCE)

GXWD(i,s) = SUM(d,DEST, (SUM(h,HOME, VXWD\_D(i,h,s,d)) + VXWD\_DD(i,s,d)) ) ;

FORMULA (all,i,TRAD\_COMM)(all,d,DEST)

GVIW(i,d) = SUM(s,SOURCE, (SUM(h,HOME,VIWS\_D(i,h,s,d)) + VIWS\_DD(i,s,d)) ) ;

FORMULA (all,i,TRAD\_COMM)(all,d,DEST)

GVIM(i,d) = SUM(s,SOURCE, (SUM(h,HOME,VIMS\_D(i,h,s,d)) + VIMS\_DD(i,s,d)) ) ;

FORMULA (all,i,TRAD\_COMM)(all,h,HOME)(all,s,SOURCE)

X\_FDI\_WD(i,h,s) = SUM(d,DEST: (d ne h) and (h ne s), VXWD\_D(i,h,s,d)) ;

FORMULA (all,i,TRAD\_COMM)(all,h,HOME)(all,s,SOURCE)

X\_FDI\_MD(i,h,s) = SUM(d,DEST: d ne h, VXMD\_D(i,h,s,d)) ;

FORMULA (all,i,TRAD\_COMM)(all,h,HOME)(all,d,DEST)

M\_FDI\_WS(i,h,d) = SUM(s,SOURCE: s ne h, VIWS\_D(i,h,s,d)) ;

FORMULA (all,i,TRAD\_COMM)(all,h,HOME)(all,d,DEST)

M\_FDI\_MS(i,h,d) = SUM(s,SOURCE: s ne h, VIMS\_D(i,h,s,d)) ;

FORMULA (all,i,TRAD\_COMM)(all,h,HOME)

---

X\_WD(i,h) = SUM(s,SOURCE, X\_FDI\_WD(i,h,s) ) ;

FORMULA (all,i,TRAD\_COMM)(all,h,HOME)

X\_MD(i,h) = SUM(s,SOURCE, X\_FDI\_MD(i,h,s) ) ;

FORMULA (all,i,TRAD\_COMM)(all,d,DEST)

M\_WS(i,d)= SUM(h,HOME, M\_FDI\_WS(i,h,d) ) ;

FORMULA (all,i,TRAD\_COMM)(all,d,DEST)

M\_MS(i,d)= SUM(h,HOME, M\_FDI\_MS(i,h,d) ) ;

FORMULA (All,i,TRAD\_COMM)(All,r,REG)

VTOTDHM(i,r)= SUM(o,HOME, VDHM(i,o,r) ) ;

FORMULA (all,i,TRAD\_COMM)(all,r,HOST)

VTOTOHM(i,r) = SUM(o,HOME, VOHM(i,o,r) ) ;

FORMULA

(all,i,TRAD\_COMM)(all,o,HOME)

VTOTOWN\_OS(i,o) = SUM(r,DEST, VOHM(i,o,r));

WRITE

---

GXMD to file trade\_dat header "GXMD" ;  
GXWD to file trade\_dat header "GXWD" ;  
GVIW to file trade\_dat header "GVIW" ;  
GVIM to file trade\_dat header "GVIM" ;  
X\_WD to file trade\_dat header "X\_WD" ;  
X\_MD to file trade\_dat header "X\_MD" ;  
M\_WS to file trade\_dat header "M\_WS" ;  
M\_MS to file trade\_dat header "M\_MS" ;  
VTOTDHM to file trade\_dat header "ALHM" ;  
  
X\_FDI\_WD to file trade\_dat header "XWD" ;  
X\_FDI\_MD to file trade\_dat header "XMD" ;  
M\_FDI\_WS to file trade\_dat header "MWS" ;  
M\_FDI\_MS to file trade\_dat header "MMS" ;  
VDHM to file trade\_dat header "VDHM" ;

![[[ If users want to extract these trade data for table prepared by

Excel Macro spreadsheet, here is the option to export data

File (Text,New,Spreadsheet) trade\_text "trade.csv" ;

Write

GXMD to file trade\_text ;

GXWD to file trade\_text ;



---

X\_WD to file trade\_text ;  
X\_MD to file trade\_text ;  
GVIW to file trade\_text ;  
GVIM to file trade\_text ;  
M\_WS to file trade\_text ;  
M\_MS to file trade\_text ;  
VTOTDHM to file trade\_text ;  
X\_FDI\_WD to file trade\_text ;  
X\_FDI\_MD to file trade\_text ;  
M\_FDI\_WS to file trade\_text ;  
M\_FDI\_MS to file trade\_text ;  
VDHM to file trade\_text ;

!]]!

!-----!  
! Chapter 9 Miscellaneous equations !  
!-----!

! Some trade flow and output variables !

EQUATION

E\_ggxmd #Total Real exports from s, domestic price wgts#

---

```

(all,i,TRAD_COMM)(all,s,SOURCE)

IF[GXMD(i,s)=0,qqxmd(i,s)]+

GXMD(i,s)*qqxmd(i,s) =

SUM(d,DEST, (SUM(h,HOME, VXMD_D(i,h,s,d)*qxhd(i,h,s,d)) +
                VXMD_DD(i,s,d)*qxdd(i,s,d)) ) ;

```

E\_qgxwd #Total Real exports from s, FOB price wgts#

```

(all,i,TRAD_COMM)(all,s,SOURCE)

IF[GXWD(i,s)=0,qqxwd(i,s)]+

GXWD(i,s)*qqxwd(i,s) =

SUM(d,DEST, (SUM(h,HOME, VXWD_D(i,h,s,d)*qxhd(i,h,s,d)) +
                VXWD_DD(i,s,d)*qxdd(i,s,d)) ) ;

```

E\_qgviw #Total Real imports to d, CIF price wgts#

```

(all,i,TRAD_COMM)(all,d,DEST)

IF[GVIW(i,d)=0,qqgviw(i,d)]+

GVIW(i,d)*qqgviw(i,d) =

SUM(s,SOURCE, (SUM(h,HOME,VIWS_D(i,h,s,d)*qxhd(i,h,s,d)) +
                VIWS_DD(i,s,d)*qxdd(i,s,d)) ) ;

```

E\_qgvim #Total Real imports to d, tariff inclusive price#

```

(all,i,TRAD_COMM)(all,d,DEST)

IF[GVIM(i,d)=0,qqgvim(i,d)]+

GVIM(i,d)*qqgvim(i,d) =

```

---

SUM(s,SOURCE, (SUM(h,HOME,VIMS\_D(i,h,s,d)\*qxhd(i,h,s,d)) +  
VIMS\_DD(i,s,d)\*qxdd(i,s,d)) ) ;

E\_qx\_fdi\_wd #Real exports of fdi ind to third countries, FOB price wgts#

(all,i,TRAD\_COMM)(all,h,HOME)(all,s,SOURCE)

IF[X\_FDI\_WD(i,h,s)=0,qx\_fdi\_wd(i,h,s)]+

X\_FDI\_WD(i,h,s)\*qx\_fdi\_wd(i,h,s) =

SUM(d,DEST: (d ne h) and (h ne s),

VXWD\_D(i,h,s,d)\*qxhd(i,h,s,d)) ;

E\_qx\_fdi\_md #Real exports of fdi ind to third countries, domestic price wgts#

(all,i,TRAD\_COMM)(all,h,HOME)(all,s,SOURCE)

IF[X\_FDI\_MD(i,h,s)=0,qx\_fdi\_md(i,h,s)]+

X\_FDI\_MD(i,h,s)\*qx\_fdi\_md(i,h,s) =

SUM(d,DEST: d ne h, VXMD\_D(i,h,s,d)\*qxhd(i,h,s,d)) ;

E\_qm\_fdi\_ws #Real imports from third country fdi ind, CIF price wgts#

(all,i,TRAD\_COMM)(all,h,HOME)(all,d,DEST)

IF[M\_FDI\_WS(i,h,d)=0,qm\_fdi\_ws(i,h,d)]+

M\_FDI\_WS(i,h,d)\*qm\_fdi\_ws(i,h,d) =

SUM(s,SOURCE: s ne h, VIWS\_D(i,h,s,d)\*qxhd(i,h,s,d)) ;

E\_qm\_fdi\_ms #Real imports from third country fdi ind, tariff incl price wgts#

(all,i,TRAD\_COMM)(all,h,HOME)(all,d,DEST)

---

```

IF[M_FDI_MS(i,h,d)=0,qm_fdi_ms(i,h,d)]+

M_FDI_MS(i,h,d)*qm_fdi_ms(i,h,d) =

SUM(s,SOURCE: s ne h, VIMS_D(i,h,s,d)*qxhd(i,h,s,d)) ;

```

```
!~~~~~!
```

```
E_qx_wd #Real exports of fdi ind to third countries, FOB price wgts#
```

```
(all,i,TRAD_COMM)(all,h,HOME)
```

```
IF[X_WD(i,h)=0,qx_wd(i,h)]+
```

```
X_WD(i,h)*qx_wd(i,h) = SUM(s,SOURCE, X_FDI_WD(i,h,s)*qx_fdi_wd(i,h,s)) ;
```

```
E_qx_md #Real exports of fdi ind to third countries, domestic price wgts#
```

```
(all,i,TRAD_COMM)(all,h,HOME)
```

```
IF[X_MD(i,h)=0,qx_md(i,h)]+
```

```
X_MD(i,h)*qx_md(i,h) =
```

```
SUM(s,SOURCE, X_FDI_MD(i,h,s)*qx_fdi_md(i,h,s)) ;
```

```
E_qm_ws #Real imports from third country fdi ind, CIF price wgts#
```

```
(all,i,TRAD_COMM)(all,d,DEST)
```

```
IF[M_WS(i,d)=0,qm_ws(i,d)]+
```

```
M_WS(i,d)*qm_ws(i,d)=
```

```
SUM(h,HOME, M_FDI_WS(i,h,d)*qm_fdi_ws(i,h,d)) ;
```

```
E_qm_ms #Real imports from third country fdi ind, tariff incl price wgts#
```

---

(all,i,TRAD\_COMM)(all,d,DEST)

IF[M\_MS(i,d)=0,qm\_ms(i,d)]+

M\_MS(i,d)\*qm\_ms(i,d)=

SUM(h,HOME, M\_FDI\_MS(i,h,d)\*qm\_fdi\_ms(i,h,d)) ;

!~~~~~!

E\_qvxhm #Real exports of foreign-owned industry, domestic price wgts#

(All,i,TRAD\_COMM)(All,o,HOME)(All,l,HOST)

IF[VXHM(i,o,l)=0,qvxhm(i,o,l)]+

VXHM(i,o,l)\*qvxhm(i,o,l)=sum[d,DEST,VXMD\_D(i,o,l,d)\*qxhd(i,o,l,d)];

E\_qvtotdhm #Real domestic use of foreign industry output#

(All,i,TRAD\_COMM)(All,r,REG)

IF[VTOTDHM(i,r)=0,qvtotdhm(i,r)]+

VTOTDHM(i,r)\*qvtotdhm(i,r)=

SUM(o,HOME, VDHM(i,o,r)\*qdh(i,o,r)) ;

E\_qvtotohm #Real output of foreign firms in host country#

(all,i,TRAD\_COMM)(all,r,HOST)

IF[VTOTOHM(i,r)=0,qvtotohm(i,r)]+

VTOTOHM(i,r)\*qvtotohm(i,r) = SUM(o,HOME, VOHM(i,o,r)\*qoh(i,o,r)) ;

E\_qvtotown\_os #Real output of firms located abroad#

---

(all,i,TRAD\_COMM)(all,o,HOME)

IF[VTOTOWN\_OS(i,o)=0,qvtotown\_os(i,o)]+

VTOTOWN\_OS(i,o)\*qvtotown\_os(i,o) = SUM(r,DEST, VOHM(i,o,r)\*qoh(i,o,r));

! Convenience variables !

EQUATION

E\_psland (All,s,home) psland(s)=sum[k,LAND,ps(k,s)];

E\_psnatres (All,s,home) psnatres(s)=sum[k,NATRES,ps(k,s)];

! Some extra capital stock and rate of return variables. !

EQUATION E\_kf\_\_hi (All,i,TRAD\_COMM)(All,d,REG)

IF{VKF\_\_HI(i,d) ne 0,

sum(s,home,VK\_HHI(i,s,d)\*[k\_hhi(i,s,d)-kf\_\_hi(i,d)])=

IF{VKF\_\_HI(i,d)=0,kf\_\_hi(i,d)};}

EQUATION E\_kd\_\_h\_ (All,d,REG)

IF{VKD\_\_H\_(d) ne 0,

sum(i,TRAD\_COMM,VKD\_H\_I(i,d)\*[kd\_h\_i(i,d)-kd\_\_h\_(d)])=

IF{VKD\_\_H\_(d)=0,kd\_\_h\_(d)};}

EQUATION E\_kf\_\_h\_ (All,d,REG)

IF{VKF\_\_H\_(d) ne 0,

---

```

sum(i,TRAD_COMM,VKF__HI(i,d)*[kf__hi(i,d)-kf__h_(d)])=
IF{VKF__H_(d)=0,kf__h_(d)};

EQUATION E_c_rrf__hi (All,i,TRAD_COMM)(All,d,host)

IF{VKF__HI(i,d) ne 0,

sum(s,home,VK_HHI(i,s,d)*[-r_rr_hhi(i,s,d)-c_rrf__hi(i,d)])=

IF{VKF__HI(i,d)=0,c_rrf__hi(i,d)};

EQUATION E_c_rrd__h_ (All,d,host)

IF{VKD__H_(d) ne 0,

sum(i,TRAD_COMM,VKD_H_I(i,d)*[-r_rrd_h_i(i,d)-c_rrd__h_(d)])=

IF{VKD__H_(d)=0,c_rrd__h_(d)};

EQUATION E_c_rrf__h_ (All,d,host)

IF{VKF__H_(d) ne 0,

sum(i,TRAD_COMM,VKF__HI(i,d)*[c_rrf__hi(i,d)-c_rrf__h_(d)])=

IF{VKF__H_(d)=0,c_rrf__h_(d)};

E_anrr_hhi (All,i,TRAD_COMM)(All,s,HOME)(All,d,host)

IF[VFDI_HHI(i,s,d)=0,anrr_hhi(i,s,d)]=

IF[VFDI_HHI(i,s,d)>0,

100*yank_hhi(i,s,d)-

{[EVIFAS(i,s,d)-EVIFMS(i,s,d)]*[pcgds(d)+qfes(i,s,d)]+

VFDI_HHI(i,s,d)*anrr_hhi(i,s,d)}

```

---

];

E\_anrrd\_h\_i (All,i,TRAD\_COMM)(All,r,REG)

IF[VKD(i,r)=0,anrrd\_h\_i(i,r)]=

IF[VKD(i,r)>0,

100\*{yankri(i,r)-sum[s,HOME,yank\_hhi(i,s,r)]}-

{[EVDFFA(i,r)-EVDFM(i,r)]\*[pcgds(r)+qfed(i,r)]+}

VKD(i,r)\*anrrd\_h\_i(i,r)}

];

! Checking equations for income and income tax revenue !

E\_rtykr

# tax on capital income, by region # (All,r,REG)

rtykr(r) = typr(r) + fke(r);

E\_check\_inctax (All,r,REG)

RVTXYCR(r)\*check\_inctax(r)=RVTXYCR(r)\*rtyr(r) - {

sum(i,NONCAP\_COMM, {VOM(i,r) \* [pm(i,r) + qo(i,r)]})

- {VOA(i,r) \* [ps(i,r) + qo(i,r)]})+}

sum(i,ENDWC\_COMM, {VOM(i,r) \* [pm(i,r) + kr(r)]})

- {VOA(i,r) \* [ps(i,r) + kr(r)]})+}

TYPR\_L(r)\*{YCHHDPR(r)\*qyhir(r) + YCHHITR(r)\*yhdr(r)}+}

TCHHITR(r)\*typr(r)-}



---

TDEP(r)\*{typr(r)+depr(r)}+

! Add capital impediment rents !

TYPR\_L(r)\*100\*[yankr(r)+yank\_h\_\_(r)+ykit(r)]+

[ANKTAX(r)+ANKTAX\_H\_\_(r)+YKAPIMPTAX(r)]\*TYPR\_L(r)\*typr(r)+

! Add output impediment rents !

TYPR\_L(r)\*100\*[yanpr(r)+yanp\_h\_\_(r)+yoit(r)]+

[ANPTAX(r)+ANPTAX\_H\_\_(r)+YOUTIMPTAX(r)]\*TYPR\_L(r)\*typr(r)};

E\_check\_captax (All,r,REG)

RVTXYCKR(r)\*check\_captax(r)=RVTXYCKR(r)\*rtykr(r) -

sum(i,ENDWC\_COMM, {VOM(i,r) \* [pm(i,r) + kr(r)]}

- {VOA(i,r) \* [ps(i,r) + kr(r)]});

E\_check\_capinc (All,r,REG)

KTT(r)\*check\_capinc(r)=KTT(r)\*fke(r)-

sum(i,ENDWC\_COMM, {VOM(i,r) \* [pm(i,r) + kr(r)]});

E\_check\_labtax (All,r,REG)

RVTXYCLBR(r)\*check\_labtax(r)=RVTXYCLBR(r)\*rtylr(r) -

sum(i,LABOR, {VOM(i,r) \* [pm(i,r) + qo(i,r)]}

- {VOA(i,r) \* [ps(i,r) + qo(i,r)]});

! .....

---

```

!      Miscellaneous equations from FTAP      !
!
! These equations define various useful ratios. Some of the foreign income to !
! GDP ratios are used to modify the BOP equation from GTAPICM for FTAP.      !
!.....!

```

```
E_qaer  #Equity to income ratio#
```

```
(all,r,REG) qaer(r)=ASEQR(r)/YCR(r)*[aer(r)-y_r(r)];
```

```
E_qyanp_h__
```

```
#ratio of net output impediment rents to national income#
```

```
(all,r,REG) INCOME(r)*qyanp_h__(r)+ANPTAX_H__(r)*y_r(r)=100*yanp_h__(r);
```

```
E_qyank_h__
```

```
#ratio of net capital impediment rents to national income#
```

```
(all,r,REG) INCOME(r)*qyank_h__(r)+ANKTAX_H__(r)*y_r(r)=100*yank_h__(r);
```

```
E_qyfdirat
```

```
# ratio of net FDI income to national income#
```

```
(all,r,REG) INCOME(r)*qyfdirat(r)+VINC_H__(r)*y_r(r)=100*yfdi_h__(r);
```

```
E_nyanp_h__ #ratio of net output impediment rents to gdp#
```

```
(all,r,REG) GDP(r)*nyanp_h__(r)+ANPTAX_H__(r)*gdpn(r)=100*yanp_h__(r);
```



---

!SH9! REALCONS # real aggregate private consumption #

(all,r,REG) ctr(r) = yp(r) - ppriv(r) ;

!SI2! RATIO\_YCAB\_GDP # ratio of bond income to gdp #

(all, r, REG) GDP(r)\*nyas(r) + YCITR(r)\*gdpn(r)  
= YCR(r)\*qyir(r) + YCITR(r)\*y\_r(r);

!SI3! RATIO\_GCUAS\_GDP #ratio of govt current account surplus to gdp #

(all, r, REG) GDP(r)\*gcass(r) + SPGVR(r)\*gdpn(r)  
= RCGVR(r)\*qrgsr(r) + SPGVR(r)\*rgr(r);

!SI4! RATIO\_NET\_CAPL\_INFLW # ratio of net capital inflow to gdp #

(all, r, REG) VDEP(r)\*depr(r) + YCR(r)\*qysr(r) + SVR(r)\*y\_r(r)  
+ GDP(r)\*nkis(r) + NCIL(r)\*gdpn(r) = REGINV(r)\*invtr(r);

!SI5! RATIO\_BAL\_TRADE\_GDP # ratio of the balance of trade to gdp #

(all, r, REG) GDP(r)\*bts(r) + BTL(r)\*gdpn(r)  
= VXWREGION(r)\*vxwreg(r) - VIWREGION(r)\*viwreg(r);

!SH10! AGGINV # nominal aggregate investment #

(all,r,REG) invtr(r) = pcgds(r) + qcgds(r) ;

---

!SH26! NATL\_CONSN\_EXPRES

# national consumption expenditure, by region #

(all,r,REG) EPCSR(r)\*ecr(r) = PRIVEXP(r)\*yp(r) + GOVEXP(r)\*zg(r);

---

# J Changes in FTAP

## J.1 FTAP version 2

In version 1 of FTAP nominal private bonds by region determined from the asset supply nest does not equal the value of nominal private bonds defined in terms of GTAPICM variables. The latter is used in determining income flows from private bonds. The equality does hold globally, however.

In the current corrected version, the equation (page 70, chapter 4)

E\_pb #World bond price#      **! Deleted in FTAP version 2, Appendix J !**

$$0 = \sum\{s, \text{REG}, \text{ASHHBDR}(s) * [\text{pbr}(s) + \text{qbr}(s)] - \\ [\text{YCHHDPR}(s) * \text{qyhbr}(s) + \text{ASHHBDR}(s) * \text{yhdr}(s)]\};$$

which ensures the global equality, is changed to

E\_f\_ipahr #Equate GTAPICM and FTAP private bonds by region# (All,s,REG)

$$\text{ASHHBDR}(s) * [\text{pbr}(s) + \text{qbr}(s)] = \\ [\text{YCHHDPR}(s) * \text{qyhbr}(s) + \text{ASHHBDR}(s) * \text{yhdr}(s)];$$

to ensure the regional equality.

As may be clear from the change in the name of this equation, there has also been a change in the function of this equation within the system. Whereas previously the global equation was used to determine the globally uniform price of bonds, now it is used to determine the private wealth price index (variable ipahr), an index that was previously (and uncomfortably) determined simply as a share weighted sum of other price indices. The equation for ipahr (page 32, chapter 3) is altered thus:

!SG9! HHOLD\_ASST\_PRINDX # household asset price index # (all,r,REG)

$$\text{ASHHR}(r) * [\text{ipahr}(r) + \text{f\_ipahr}(r)] = \\ \text{ASEQR}(r) * \text{iper}(r) + \text{ASHHBDR}(r) * (\text{pbr}(r)! + \text{er}(r)!);$$

---

with `f_ipahr` being set endogenously (that is, the equation is turned off).

As may also be clear, there is now no equation for determining the global price of bonds (variable `pb`). The bond price cannot be determined independently of the rate of return on bonds, so it is set exogenously at 0, except for a homogeneity test where it is tied to the numeraire. To accommodate these two possibilities, the equation:

$$E\_pb \text{ pb} = \text{pfactwld} + \text{f\_pb};$$

is introduced. Variable `pb` is exogenous in policy simulations, but variable `f_pb` is exogenous for doing the homogeneity test (as indicated, for example, at the bottom of the command file `ter.cmf` that is contained in the model ZIP file `ftapsoftware.zip` on the Commission's web site).

The file `changes_to_ftap.tab`, which is contained in the model ZIP file `ftapsoftware.zip` on the Commission's web site, is an UNIX file difference between the TABLO code of FTAP versions 1 and 2.