C Growth accounting

This appendix describes the methodology used in this paper to construct new growth accounting results for the market sector. These have been calculated using the three different definitions of capital detailed in chapter 5. The first definition includes all intangible and tangible assets. The second definition contains the same capital assets as the Australian Bureau of Statistics (ABS) national accounts, while the third definition of capital excludes all intangible assets.

Section C.1 details the methodology for constructing new capital services indexes for the market sector including intangible assets. This includes detailing how the new rental prices were calculated and how a rate of return for all assets including the new intangible assets was calculated. Section C.2 details changes to other terms in the production function. This includes output, labour inputs and the factor income shares.

Unpublished ABS data have been used for all of the tangible assets as well as for the intangible assets already capitalised in the national accounts (computer software, artistic originals and mineral exploration).[1] The capital services indexes including the new intangible assets (those not already capitalised in the national accounts) have been constructed using the intangible capital stock series estimated as described in chapter 4.

C.1 Construction of capital services indexes

To measure the impact of intangible investment on multifactor productivity (MFP) growth, new estimates of capital services growth need to be constructed for the market sector. Capital services reflect the amount of 'service' each asset provides during a set period. For each asset, the services provided are directly proportional to the asset's productive capital value. Aggregate capital services indexes are created using the volume index of the productive capital stock of each asset weighted using rental prices.

[1] All published and unpublished national accounts data used in the growth accounting in this paper are from the dataset underlying ABS *Australian System of National Accounts, 2006-07* (Cat. no. 5204.0).

The *productive capital stock* of an asset is the real stock of capital, adjusted for efficiency losses related to age (according to the relevant age-efficiency profile). The productive capital stock of each asset type is weighted and summed to form an aggregate capital services measure. For the purposes of this paper, the real economic capital stock (net capital stock) and the productive capital stock for new intangible assets are assumed to be equal.[2] The use of the net rather than productive capital stock means that the capital stock for intangible assets is understated.

The weights used in the summation of productive capital stocks are based on the *rental prices* for each asset type. Rental prices can be thought of as estimates of the rates each asset type would attract if leased under a commercial agreement. The use of rental prices as weights assumes that the rental price reflects the marginal product of an asset, hence more productive assets have a higher rental price and therefore a higher weight in the aggregate capital services measure. The compilation of rental prices is discussed below.

Aggregate estimates of capital services for the market sector are formed by combining estimates of the productive capital stock and rental price for each asset type into a Tornqvist[3] index of aggregate capital services. For some asset types[4], capital is also split by industry and institutional sector — this is not shown for simplicity. The flow of aggregate capital services $\dot{K}$ equals the product of the change in the capital stock of each asset K_j, weighted by the rental price weight of each asset w_j.

$$\dot{K} = \prod_j \left[\frac{K_j}{K_{j(t-1)}} \right]^{w_j} - 1 \qquad \text{(C.1)}$$

The rental price weight for each asset is based on its share of total market sector capital rent. Capital rent is the rental price r_{jt} multiplied by the real productive capital stock K_j.

2 The productive value and the economic value of an asset are slightly different. The productive capital stock represents an age-efficiency function while the net capital stock represents an age-price function. Because an asset's value depreciates faster than its productive capacity, the net capital stock is invariably smaller than the productive capital stock (ABS 2000).

3 A Tornqvist index is the weighted geometric mean of the component growth rates.

4 For the tangible assets and the national account intangibles, assets are split by type, industry and institutional sector (corporate, unincorporated). Splitting the new intangibles by industry and institutional sector has not been possible due to data limitations.

$$w_j = 0.5 * \left(\frac{r_j . K_j}{\sum_j r_j . K_{ij}} + \frac{r_{jt-1} . K_{jt-1}}{\sum_j r_{jt-1} . K_{jt-1}} \right) \quad \text{(C.2)}$$

This methodology differs from the ABS methodology because all assets in all industries are aggregated in a single stage. The ABS constructs capital services indexes for each of the twelve market sector industries separately, then weights these indexes together using the gross operating surplus (GOS) of each industry as a weight (see ABS 2000, chapter 27 for further details). It has not been possible to estimate the intangible assets for each industry due to data limitations, so the single stage aggregation had to be used. Because of this difference in methodology, the capital services indexes used in this paper differ from published ABS estimates.

The new methodology has been used to construct new capital services indexes for each of the three capital definitions described above — the existing national accounts assets, tangible assets only and tangibles plus all intangible assets. Constructing all the indexes using the new methodology allows a direct comparison of the change in the growth rate of capital services due to the treatment of intangibles as capital. The implications of changing the capital services methodology are discussed in detail below.

Rental prices

The rental price of an asset is equivalent to the user cost of capital.[5] It is the implicit price for employing or obtaining the productive value of a unit of capital for one period. Because the majority of capital is owned by its user rather than rented in the market, the rental price for the asset is an estimate of what the market rental price of the asset would be. The rental price includes most of the measurable costs incurred in the use of that asset. It covers the expected return on the asset, represented by the internal rate of return; the loss in market value of the good due to ageing; the capital gains or losses due to asset price inflation/deflation; a non-income tax parameter and adjustments for tax concessions made to correct for distortions in rental prices due to differential tax treatment across capital items.

[5] The rental price formula used in this paper is based on that used in the ABS's standard methodology for measuring capital services (see ABS 2000, chapter 27). This approach to the measurement of rental prices may differ from that used elsewhere. For a discussion of alternative rental price methodologies used in capital services measures see OECD (2001, chapter 9).

The rental price is derived using the following formula

$$r_j = T_j(i.p_j + d_j.p_j - p_j + p_{j(t-1)}) + p_j.x \qquad \text{(C.3)}$$

where for asset type j, the rental price r is a function of the income tax rate T; the internal rate of return i; the price deflator p; the depreciation rate d; and the non-income tax parameter x (which is assumed to be the same for all j).[6]

For existing tangible assets and the intangible assets currently capitalised in the national accounts, most of the above data have been provided by the ABS. However, capitalising the new intangible assets will change two of the parameters for the tangible assets and existing intangibles — the internal rate of return and the non-income tax parameter. The methodology used for calculating the rate of return is discussed below.

Because there is very little existing data about the new intangible assets, assumptions need to be made about the parameters to be used for them in the rental price calculations. Assumptions have been made for the depreciation rate, the income tax parameter, the deflator and the effective average non-income tax rate on production.

In this paper, the depreciation rates used for the new intangible assets are those used in Corrado, Hulten and Sichel (CHS 2006) and for the national accounts intangibles the ABS rates are used (table C.1). These depreciation rates are relatively high, which reflects the assumption that intangible investment has a relatively short productive life.

6 There is some debate as to whether or not all of the functions in the rental price equation should be included for intangible assets due to the nature of those assets. Sensitivity tests, detailed in appendix D, have been performed on several parts of the rental price equation for the new intangibles.

Table C.1 **Rental price components for intangible assets**
Average 1975-2006

	Depreciation rate[a]	*Income tax parameter*[b]
Computerised information	0.2	1.51
Business R&D	0.2	0.85
Mineral exploration	0.1	1.52
Artistic originals	0.6	0.62
Financial product development	0.2	1.67
New architectural and engineering designs	0.2	1.67
Advertising	0.6	1.67
Market research	0.6	1.67
Firm specific human capital	0.4	1.67
Purchased organisational capital	0.4	1.67
Own account organisational capital	0.4	1.67

[a] Depreciation rates are constant for the new intangibles and vary over time for the intangibles already capitalised in the national accounts (software, mineral exploration, and artistic originals). [b] A more detailed discussion of the assumptions behind this parameter is in appendix D.

Sources: CHS (2006); authors' estimates; ABS unpublished national accounts data.

The income tax parameter is calculated by using the corporate profit tax rate adjusted for depreciation allowances and other additional allowances (table C.1). For most of the new intangible assets it has been assumed that the income tax parameter is derived only from the corporate tax rate because there are currently no additional tax allowances for most intangibles. However, for business expenditure on research and development, an allowance has been included for the R&D tax incentive scheme (Australian Government 2008a, 2008b). Adjusting the tax rate to reflect the R&D tax concession lowers the effective income tax rate on R&D investment. (See appendix D for a discussion of the suitability of the tax parameter for intangibles.)

The deflator used for most intangible assets is the implicit price deflator (IPD) for market sector gross value added. For financial product development investment, the Finance & insurance gross value added IPD has been used. For firm specific human capital a wage price deflator has been used. These are the same deflators used in compiling the real capital stocks from the nominal investment series in chapter 3.

The effective average non-income tax rate on production is derived by the ABS by dividing the total non-income taxes allocated to capital for the market sector by the total net capital stock. The non-income tax parameter is therefore the same for every asset. The total taxes will not change after the inclusion of intangible assets but the total net capital stock will increase, hence the new non-income tax rate will be lower. Non-income taxes include land tax, local government authority rates, stamp

duties and other miscellaneous taxes (ABS 2000, chapter 27). Given the ABS method for allocating non-income taxes, the non-income tax rate changes for all assets when intangible capital is included — therefore rental prices for all tangible and existing intangible assets will also change.

All new intangible capital is allocated to the corporate sector because the required data are not available to split the intangibles between sectors. The corporate sector is much larger than the unincorporated sector and is likely to represent the bulk of investment in intangibles (if not all, in cases such as financial product development). However, it should be noted that the assumption that all intangible investment is contained within the corporate sector will overstate the impact of intangibles in the capital services index because rental prices for the unincorporated sector are derived as a function of corporate rental prices and are invariably lower.

Rental prices for the unincorporated sector are derived by the ABS as a function of the corporate rental price weighted by the ratio of unincorporated capital income to proprietors' labour income. This methodology is maintained in this paper as there will be no change in proprietors' labour income and no change in the unincorporated capital because all intangibles were allocated to the corporate sector.

Occasionally, rental prices calculated using equation (C.3) can be negative. If this occurs the approach used by the ABS is to set these rental prices to a very small positive number, usually 0.001. This is to prevent negative rental prices from causing complications in the later growth rate calculations. This approach is also followed in this paper. When calculating rental prices, only a limited number of asset types, such as agricultural land, regularly display negatives. Of the intangible assets, either national accounts or new, only software has a negative rental price in any year.

Internal rate of return

The rate of return represents the expected return on a unit of an asset after adjusting for all other price factors, taxes and depreciation. Normally the ABS calculates the rate of return for all assets in each particular industry, but for this paper a new rate of return had to be calculated for the entire market sector.[7] The rate of return for the market sector has been recalculated for each of the three definitions of capital, as the treatment of intangibles as capital will change the rate of return for all assets.

[7] The Jorgenson-Griliches methodology for estimating the rate of return as a common rate across all assets (both tangibles and intangibles) has been used. This assumes that businesses arbitrage their investments across all types of capital, investing in each type until the rate of return for all assets is equal (CHS 2006). This assumes there is no risk differential.

The rate of return for an asset can be either calculated or assumed. An endogenous rate of return can be calculated by assuming that capital income, or adjusted gross operating surplus, is equal to capital rent. Alternatively, an exogenous rate of return can be used, usually based on an external variable such as the consumer price index (CPI). The ABS currently uses a hybrid system, using an endogenous rate of return for each industry, but with an exogenous floor rate of return of the CPI growth plus 4 per cent as a lower limit (ABS 2000). This paper uses the same lower limit when deriving a rate of return for all market sector assets.

As mentioned above, under an endogenous model capital rent is assumed to equal capital income. If an endogenous model was used for the rates of return, with no lower limit as used by the ABS, then the sum of the rental prices for each asset multiplied by the productive capital stocks for each asset class would equal capital income.[8]

$$Q = \sum_j r_j . K_j \tag{C.4}$$

summed across assets j

Using this assumption, calculating the endogenous rates of return[9] is simply a case of reorganising the rental price equation to include capital income and the productive capital stock.

$$i = \frac{Q - \sum_j K_j (T_j (d_j . p_j - p_j + p_{j(t-1)}) + p_j . x)}{\sum_j K_j . T_j . p_j} \tag{C.5}$$

where Q is capital income (including non-income taxes attributed to capital) and K is the real productive capital stock.[10]

8 Provided all the endogenous rental prices are positive, as a negative rental price forced to zero would also affect the total capital income.

9 This rate of return takes account of taxes and capital gains/losses due to asset price inflation that may not be included in rates of return calculated for other purposes.

10 ABS (2007, p. 107) notes that there is a question as to whether the productive capital stock or the net capital stock should be used to estimate the endogenous rate of return. Currently the ABS uses the real productive capital stock but has noted that it will consider changing its approach in the future.

Figure C.1 **Internal rate of return for the market sector[a], all intangibles treated as capital**

a Using the ABS hybrid methodology, which is an endogenous rate with a floor of the CPI growth plus 4 per cent. Because the endogenous internal rate of return (IRR) rarely rose above this floor rate for the market sector in practice, the IRR is exogenous in most years.

Data sources: Authors' estimates; ABS unpublished national accounts data.

This paper follows the ABS method of using the hybrid rate of return (figure C.1). However, in practice this means that the paper uses mainly uses an exogenous rate of return as the endogenous rate only exceeds the exogenous rate in a few years (2004-05 and 2005-06 when all intangibles are treated as capital). The growth accounting results were sensitivity tested using a purely endogenous rate of return (as used in CHS 2006) and the results are presented in appendix D, section D.1. The rate of capital deepening, and hence the rate of MFP growth, is considerably changed by the use of the endogenous rate of return. However, the use of the endogenous rate of return creates problems with negative rental prices and is inconsistent with existing ABS productivity estimates for Australia.

Methodological issues

The differences in methodology between this paper and the ABS national accounts leads to different results for the market sector capital services index. As noted above, the difference is caused by the use of a single stage aggregation process to construct a market sector capital services index, rather than using industry capital services indexes aggregated using GOS weights.

There are several reasons for the difference in results between the two methods. The first difference is the effect of the new internal rate of return used in this paper. The

rate of return used in the estimates in this paper is calculated as a single rate for the market sector. This rate of return is generally equal to the minimum rate of return under the ABS methodology. Because the ABS calculates a separate rate of return for each industry, some of these rates of return exceed the minimum rate in some years. Therefore the average rate of return across all industries under the ABS methodology will be higher than the rate of return used in this paper, which is nearly always equal to the minimum ABS rate. If the gap between the ABS average rate of return and the minimum rate of return is increasing, then a capital services index calculated using rental prices based on the minimum rate of return will grow more slowly than that using the ABS average rate. An analysis of the results shows this to be the case, mainly due to strong growth in the internal rates of return calculated for assets in Construction and Finance & insurance.

The second difference between the methodologies concerns the rental price weight of each asset in the aggregate market sector capital services index. The ABS compiles indexes of capital services for each industry and then weights these together using GOS weights. However, because the intangible assets cannot be split between industries, in this paper the market sector capital services index is compiled in a single stage. Under the ABS methodology the rental price weight of an asset in the final market sector capital service index is equal to its weight in its relevant industry capital services index multiplied by that industry's GOS weight. Under the new methodology an asset's weight in the market sector capital services index is equal to its rental price weight in total industry capital income. The change of weighting will change the growth rate of market sector capital services.

The change in the rate of return will also affect the relative weight of each asset in the aggregate capital services index. Using a single rate of return across all industries will mean that some assets have their rental price weight affected by the change in the rate of return.

C.2 Growth accounting components

This section details the methodology and data sources used for the other (non-capital) parameters in the growth accounting framework.

Output

For the all intangibles case, output is equal to existing market sector gross value added (GVA) plus investment in the new intangible assets. For each of the new intangible assets expenditure series were constructed (as described in chapter 3) and these expenditure series were then used to calculate an investment series for

intangible assets. A new chain volume measure of value added for the market sector was calculated by adding this investment series to current price GVA for the existing market sector. This was then deflated using a market sector IPD and individual price deflators for each intangible asset.

Output for the market sector including only the existing national accounts intangible assets is equal to market sector GVA supplied by the ABS.

Output excluding all intangible assets was constructed by deducting current price investment in the existing intangible assets from existing market sector GVA.[11] The result was then deflated using a market sector IPD.[12]

Income shares

The inclusion of intangibles investment increases the level of capital income, which in turn increases the capital share of total income with an equivalent fall in the labour income share. The impact on the income shares is outlined in more detail in appendix B, section B.2.

Total factor income as currently measured in the national accounts was provided by the ABS.

- Capital income in the ABS national accounts is gross operating surplus (GOS) plus the capital share of Gross Mixed Income (GMI) and taxes.
- Labour income is Compensation of Employees (COE) plus the labour share of GMI and taxes.
- Labour and capital income estimates were supplied with GMI and taxes already split between capital and labour income.

11 Current price gross fixed capital formation (GFCF) for the existing national accounts intangible assets (computer software, artistic originals and mineral exploration) was used as the investment estimate for the national accounts intangibles.

12 When market sector output was reinflated after the exclusion of current price investment in the existing intangible assets, the market sector IPD was used to reinflate the output estimates. No adjustment was made to the IPD to reflect the removal of those intangible assets. Sufficient data were not available to construct an IPD for the reduced scope of output. However, testing was performed to approximately measure the impact of removing these assets on the price deflator using an adjustment based on the corporate sector asset price deflators only, without also including the unincorporated sector asset deflators. The outcome of this testing showed that adjusting for the removal of the existing intangible assets from the market sector price deflator had little effect on the market sector IPD and therefore little effect on total market sector output. It was therefore decided that using the original market sector IPD would be sufficient for calculating real output for the market sector minus the national accounts intangible assets.

Because this paper assumes all intangible assets are in the corporate sector, no change to the split of GMI (income of the unincorporated sector) was required when treating intangibles as capital.

Capital income for the three capital definitions are as follows.

- For the case including all intangible assets, capital income is equal to national accounts capital income (adjusted GOS) plus all investment in new intangibles.
- For the existing national accounts definition of capital, capital income is GOS adjusted for GMI and taxes (as outlined above).
- For the case excluding all intangible assets, capital income is equal to national accounts capital income minus GFCF in the national accounts intangible assets.

As detailed in chapter 5 and appendix B, investment in intangibles will increase total factor income and capital income while labour income is unchanged. Therefore treating intangibles as capital will decrease the labour income share while increasing the capital income share. For the case excluding all intangible assets, the reverse is true.

Labour inputs

The labour inputs index used in the growth accounting is the growth in hours worked for the market sector from the ABS national accounts. In chapters 5 and 6, a labour composition component has been included in the growth accounting results. This is calculated using a quality adjusted labour inputs index (QALI) supplied by the ABS for the period 1982-83 to 2005-06. This index is used to construct MFP estimates that are adjusted to take account of general improvements in the experience, education and training of the workforce. The ABS constructs this quality-adjusted index of hours worked by disaggregating total hours worked on the basis of educational attainment and potential workforce experience and weighting these hours by wages (see ABS 2001 and ABS 2005 for details).[13]

The contribution of QALI to MFP is included in tables 5.3, 6.3 and 6.4 from 1984-85. The contribution of QALI to MFP growth will stay constant with the treatment of intangibles as capital — therefore as the total rate of MFP growth falls with the treatment of intangibles as capital, the contribution of QALI to labour productivity growth will also fall.

[13] See chapter 3 for a discussion of the potential overlap between QALI and the firm-specific training intangible.