PRODUCTIVITY GROWTH AND AUSTRALIAN MANUFACTURING INDUSTRY

Paul Gretton
Bronwyn Fisher

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Preface

This study examines the contribution that productivity improvements have made to growth in the Australian economy over the last two decades. Productivity growth is first placed in a national context through a comparative analysis of ten broad industry sectors. The study then focuses on the output and productivity growth of eight manufacturing industry subdivisions.

There are many factors that can affect productivity growth and the contribution it makes to living standards. One of these factors is assistance afforded industry. To investigate the link between industry assistance and productivity, output and productivity measures are presented both in a traditional format and with the effects of assistance removed. The implications of productivity growth for employment and average labour productivity are also considered.

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Abbreviations

ABS	Australian Bureau of Statistics
ANZSIC	Australian and New Zealand Standard Industry Classification
ASIC	Australian Standard Industry Classification
BEA	Bureau of Economic Analysis
BIE	Bureau of Industry Economics
BLS	Bureau of Labour Statistics
CEC	Commission of European Communities
GDP	Gross domestic product
GFCE	Gross fixed capital expenditure
GFCF	Gross fixed capital formation
GP	Gross product
IC	Industry Commission
IEDB	International economic data bank
LHS	Left hand side
MFP	Multifactor productivity
OECD	Organisation for Economic Co-operation and Development
PIM	Perpetual inventory method
RBA	Reserve Bank of Australia
RHS	Right hand side
TFP	Total Factor Productivity
TCF	Textiles, clothing, footwear and leather goods
UNIDO	United Nations Industrial Development Organisation
US	United States of America

OVERVIEW

Productivity growth is a fundamental way for society to improve its living standards. It reflects both technological change (including new ways of producing goods and services) and organisational change (better ways of using available resources and technology). Both processes operate simultaneously and, in practice, it is difficult to distinguish between their effects.

Analysis of productivity growth by industry provides an important means of assessing how individual activities contribute to changing living standards. While much of the information needed to undertake the analysis is available from traditional sources, key data series for capital inputs are not available for each activity considered.

This study has therefore established a generalised method of measuring capital inputs by industry. The methodology takes into account the possibility that asset efficiency does not decline at a uniform rate over its commissioned life, and allows for the possibility that assets can be scrapped or sold before they are fully depreciated.

Scope of the study

This study examines the contribution of productivity improvements to growth in the ‘market sector’ of the Australian economy. The market sector accounts for about two-thirds of national output and includes primary, manufacturing and selected service activities. Data needed to analyse productivity are not available for non-market sector activities, such as government, financial and business services.

Market sector output and productivity growth is disaggregated into ten broad industry sectors. Within manufacturing, the study looks at the growth of eight manufacturing industry subdivisions and the effect of industry assistance on productivity growth.

The economy-wide perspective

Productivity growth has directly accounted for around half of economic growth in the market sector. However, the indirect effects of productivity (including additional saving and investment from higher national income) are likely to have made this contribution much higher.

Average labour productivity has increased substantially. The total employment requirements per million dollars of market sector output (in 1989–90 prices) declined from 27 to 19 persons between 1974–75 and 1994–95. Over the same period, output grew by over 2 per cent per annum. The net effect of:

- labour productivity improvements — which reduced labour requirements per unit of output; and
- output growth — which increased labour demand

was an increase in market sector employment of over 12 per cent.

Sectoral contributions to growth

Manufacturing activity — the largest component of the market sector — experienced above average productivity growth over the 20 years to 1994–95. But the highest rates of productivity growth were achieved by the utilities, transport, storage and communications activities.

High productivity growth has not necessarily been associated with high output growth. For example, accommodation, cafes and restaurants, and cultural and recreational service activities had above average output growth but slightly negative productivity growth.

The slowest growing manufacturing activities over the period were TCF and transport equipment. These activities were amongst the most highly assisted activities in 1968–69, had the smallest assistance reductions and, with slow output growth, the largest employment losses.

The effects of assistance on measured productivity

Care needs to be exercised in interpreting traditional measures of output and productivity growth when assistance to industry is changing.

Traditionally, output is deflated by domestic transactions prices (ie assisted prices) when used in the measurement of productivity growth. However, to draw inferences about the underlying social value of output growth, it is more meaningful to deflate output to unassisted prices.

Using output measures deflated to unassisted prices, real productivity growth is lower than conventional measures indicate when assistance is rising. Conversely, productivity growth is higher than conventionally measured when assistance is falling.

Assistance for most manufacturing industries was reduced substantially during the 1970s and 1980s. Over this period, the policy induced changes in traditional output-price deflators would have masked the underlying true output changes. After removing the effects of assistance changes from those deflators, the ‘real’ social value of output rose faster than traditionally measured. This growth reflects improvements in the competitiveness of local industries.

For the TCF and transport equipment industries, assistance rose from 1968–69 to the mid-1980s and declined subsequently. For these industries, real output and productivity grew slower than conventionally measured to the mid-1980s and faster since then, as assistance has been reduced.

There are many other influences besides assistance that can influence industry output, productivity and employment growth. In order to disentangle the relative importance of assistance and other factors, a causal analysis is needed. This study provides important information needed to undertake such an analysis.

PART A: ANALYSIS

1 INTRODUCTION

Productivity growth is a fundamental means for society to improve its living standards.

Productivity growth comes from technological change (new ways of producing goods and services) and better organisation of production (better ways of using available resources given available technology, including economies of scale). Both processes operate simultaneously and, in practice, it is difficult to distinguish between the effects of each process. The processes are dynamic and affect individual activities differently over time.

This study examines the contribution productivity improvements have made to growth in the Australian economy over two decades. Productivity growth is first placed in a national context through a comparative analysis of ten broad industry sectors. The study then uses detailed manufacturing industry time series information to examine productivity growth for eight industry subdivisions within the manufacturing sector over the period 1968–69 to 1994–95. The manufacturing analysis draws on a new capital input series prepared by the Commission.

The study also provides important information needed for an examination of the determinants of productivity growth and the effects of government actions on growth at the economy-wide level.

1.1 Scope and methodology

As a backdrop for the paper, this chapter sets out the industry coverage of the study and some key measurement concepts relevant to subsequent discussions. The remaining chapters in Part A examine and interpret the productivity measures derived in the study.

Industry coverage

Data limitations make it impracticable to analyse productivity growth for the economy as a whole. Productivity analysis is therefore limited to those industries for which relevant information on industry inputs and outputs is available. These industries are collectively termed the ‘market sector’ (see Table 1.1). This sector accounts for about two-thirds of national output and employment. Other activities (or the ‘non-market’ sector) are excluded from the analysis because their output cannot be measured directly (eg health and education) — the ABS estimates outputs for these activities on the basis of changes in labour inputs. The lack of an independent measure of output makes it impractical to disaggregate output growth of non-market sector activities into capital, labour and productivity components.

Table 1.1: **Economy-wide industry classification adopted** [a]

Market sector	***Other activities***
Agriculture, forestry, fishing and hunting	Finance and insurance
Mining	Property and business services
Manufacturing	Government administration and defence
Electricity, gas and water	Education
Construction	Health and community services
Wholesale trade	Personal and other services
Retail trade	Ownership of dwellings
Accommodation, cafes and restaurants	*Plus*
Transport, storage and communication	Import duties
Cultural and recreational services	Imputed bank service charges[b]

a This definition of the market sector is adopted in ABS Cat. No. 5234.0 (see, for example, ABS 1997d) . For additional details concerning the industry classification adopted in this study, see Appendix A.

b ABS productivity analysis distinguishes between Imputed bank service charges on the market and non-market sectors, respectively. This study includes all imputed charges with other activities.

For the purpose of this study, the manufacturing industry sector has been disaggregated into eight industry subdivisions (Table 1.2).

Table 1.2: **Manufacturing industry classification adopted** [a]

- Food beverages and tobacco
- Textiles, clothing, footwear and leather
- Printing, publishing and recorded media
- Petroleum, coal, chemicals and associated products
- Basic metal products
- Structural and sheet metal products
- Transport equipment
- Other manufacturing

a For additional details concerning the industry classification adopted in this study, see Appendix A.

Output concepts

The output concept used throughout this study is value added in production. It is measured by subtracting from gross output an estimate of intermediate material inputs and services used in production.

Changes in output can be decomposed into changes arising from growth of inputs and growth due to other factors, normally referred to as productivity growth. At a general level, productivity growth can be measured by subtracting the contributions attributable to growth in inputs from output growth.

This study focuses on productivity of the main primary factors — labour and capital — in generating value added. Productivity defined in this way is referred to in this paper as 'multifactor productivity' (MFP). It differs from 'total factor productivity' (TFP) — a measure that recognises intermediate transactions in materials and services, along with capital and labour, as production inputs, and uses gross output as its measure of output.[1]

At the national level, gross domestic product (GDP) is the standard measure of value added. Productivity improvements that raise real per capita GDP are generally interpreted as providing higher living standards, other things being equal. The comparable concept at the industry/sectoral level is gross product (GP). Thus, the output of the market sector is the sum of the GP of individual industries within that sector. Gross domestic product and industry gross product are traditionally valued at domestic transactions prices.

Although gross product is a standard measure of value added output, it is not a comprehensive measure of all human activity or sources of welfare change. For example, it excludes most of the activity that takes place in households or is otherwise not registered in market transactions. Similarly, it does not take into account externalities such as environmental degradation or environmental improvements not factored into business costs. In addition, because gross product is valued at domestic transactions prices, it is not adjusted for the effects of changes in the level of industry assistance and may therefore give a misleading measure of changes in the social value of output. This latter problem is addressed in Chapter 3.

In addition, to arrive at a measure of income from production it is necessary to deduct depreciation in the value of fixed capital used and take into account the effects of terms of trade or net foreign income flows (ie net interest, dividends

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[1] This section gives particular meanings to the terms multifactor productivity and total factor productivity. These definitions are used throughout this paper. Often, the terms are used interchangeably.

and other transfers) on the level of income available to residents for consumption and investment. These issues are not taken up in this study.

Measuring output and input growth

The conventional approach to estimating value added for most market sector industries (including manufacturing) is to estimate industry value added for some base period for which detailed information is available on intermediate inputs (1989–90 in the current series), and extrapolate this measure forward according to trends in industry turnover of goods and services. This method, referred to as the ‘gross output method’, depends on the assumption that the proportional use of intermediate inputs (materials and services) and primary factor inputs (labour and capital) does not change substantially over time (Box 1.1).

In this study, labour input growth is measured as changes in hours worked by employed persons, while capital input growth is measured by changes in installed capital capacity. These measures cannot be directly aggregated because they are recorded in different units (ie person hours worked and monetary units). The unit weights would not accord with the relative contribution of each factor to industry production. The aggregation problem is overcome by weighting the growth in labour and capital inputs by the share of production returned to each factor. Under certain conditions, these labour and capital factor shares also measure the contribution of each input to output growth (Appendix B).

In principle, improvements in the quality of output, and of labour and capital inputs should be recorded as output or input growth, respectively. In practice, this may not always be the case due to difficulties inherent in separating quality changes from price and volume changes in underlying statistical series (Box 1.1). Quality improvements not captured in estimated capital and labour services are captured instead in the measures of productivity growth — growth in multifactor productivity could be upwardly biased when input quality is improving. Conversely, multifactor productivity would be downwardly biased when output quality improvements are not captured in measures of output growth.

Box 1.1: Some key measurement issues

The gross output method for estimating constant price gross product

Growth in value added by industry is estimated using the gross output method for most industries in the market sector (ABS 1990). The gross output method begins with a direct estimate of gross product for a single 'base' year (in this case 1989–90). From this base, gross product in other years is estimated by assuming that real gross product (unobserved for those years) grows at the same rate as constant price gross output. Gross output is broadly equivalent to sales plus increases in stocks at constant 1989–90 prices. The method therefore makes the Leontief assumption that the ratio of intermediate inputs to gross output, both valued at constant prices, is stable. However, if the ratios rise (eg due to labour shedding and contracting out), gross output would rise relative to labour and capital inputs, even though the underlying gross product may not. Mis-estimation of gross product would bias multifactor productivity estimates. Industry restructuring involving contracting out could double count output, artificially raising multifactor productivity growth estimates.

Changes in quality embodied in output, and labour and capital inputs

In principle, growth coming from technical and quality change embodied in capital, and improvements in the quality of labour (eg through education and on the job training) should be attributed to increases in factor services. Improvements in output quality should be reflected by an increase in the level of output. In practice, the extent to which quality improvements are reflected in relevant output and input series varies.

Labour and capital services are combined by weighting direct input measures (ie hours worked and capital capacity installed) by their respective contributions to output. Use of hours worked to measure labour input means that changes in the service flow arising from changes in skill requirements by industry are not generally reflected in the growth of labour inputs. Measures of capital input are derived from investment series. When the relevant investment series is not adjusted for quality changes, measures of capital input do not properly reflect the changing quality of capital goods (see Chapter 5).

On the output side, quality improvements are captured to the extent that constant price gross output measures are adjusted for quality changes. This is the case when indexes of price change are used to revalue industry gross outputs from current to constant prices and those price indexes are adjusted for quality changes. For example, the producer price indexes used to revalue manufacturing industry outputs are adjusted for quality changes and, as such, meet this conceptual requirement of productivity analysis. However, it is not the case when output is projected forward by direct volume indicators that are not quality adjusted, as is the case for many service activities (eg movie tickets sold) (ABS 1990).

As estimation problems can have both positive and negative effects on measured productivity growth, the net effect entering into the final results is not clear. The estimates presented in Chapter 2 and 3 of this paper should be interpreted against the backdrop of the underlying measurement conventions and difficulties associated with the separation of quality from other changes.

1.2 Background to capital stock estimation in Australia

A central data requirement for productivity studies is a capital input series. However, capital input measures are not available for each activity considered. This study has therefore developed a generalised method of measuring capital inputs by industry. The development of such series was a major conceptual and technical undertaking and builds on a substantial body of previous studies of capital stocks in Australia.

Haig (1980) estimated a series of capital stock in manufacturing for 9 industry groups for the period 1920 to 1977 in order to analyse the relative importance of factors lying behind changes in output. Hourigan (1980) provided snapshot estimates of capital stocks of reproducible assets at current replacement cost for 112 input-output industries for the reference year 1971–72, in order to model the demand for investment goods at the industry level.

The ABS provided exploratory estimates of capital stocks of fixed, tangible, reproducible assets at current replacement cost for the period 1966–67 to 1976–77. The main objective of this study was to provide estimates of depreciation on the same valuation basis as the rest of the Australian National Accounts (Bailey 1981). The ABS revised and updated this study in 1985 to produce a time series for the period 1966–67 to 1981–82 (Walters and Dipplesman 1985). The series provided separate estimates for public and private capital, with details for 10 industry divisions. The revised estimates subsequently provided the basis for annual current and constant price estimates of capital stock and depreciation in the Australian national accounts (ABS 1997a, c). With some adaptation, the value series have also been used in ABS productivity studies (ABS 1997d).

The BIE (1985) estimated a capital stock series for the period 1954–55 to 1981–82 for 34 manufacturing industries to enable investigations into productivity growth. Lattimore (1989) extended the BIE capital stock series to 1987–88 for the same 34 industries to investigate the pace of capital formation in the manufacturing sector. This series estimated capital stock on a replacement cost basis at constant 1984–85 prices.

Chand, Forsyth, Sang and Vousden (forthcoming) have also estimated a capital stock series. Their study covers eleven selected manufacturing industry groups and subdivisions and total manufacturing for the years 1969–70 to 1986–87. It supports a fourteen-country investigation of productivity trends.

The Reserve Bank has estimated capital stocks for nine manufacturing industry subdivisions for the period 1959–60 to 1992–93 (RBA 1996a). The unpublished estimates were intended to provide an input into studies of economic growth and structural change.

The present study contributes to this substantial stream of work in a number of ways. First, the study develops a flexible method for estimating capital stocks that is derived directly from the theory upon which analyses of productivity and capital value are based. It provides a framework into which new information about capital and its use can be readily incorporated (see Chapter 5). Second, it disaggregates manufacturing industry division capital stocks information published by the ABS to provide a basis for industry-based analyses of changes in industry structure and growth. Finally, its estimates of capital at the manufacturing industry subdivision level can be maintained into the future.[2]

1.3 Developments in ABS national accounting statistics

This study is primarily based on ABS national accounting series, supplemented with data from the ABS manufacturing industry and labour force collections, Commission estimates of manufacturing capital stocks by industry subdivision, and Commission estimates of assistance to manufacturing industries.

The ABS is currently undertaking a comprehensive review of its national accounts series in preparation for the implementation of the 1993 System of National Accounts (CEC *et al.* 1993). Coincidently, the ABS is also reviewing its capital stocks series and productivity measures, including the possible extension of productivity measures into the service industries not currently covered by the market sector. These are important developments that will affect the coverage and nature of national accounting series and supporting data series.

It is expected that the elements of these reviews will provide improved information about capital and productivity growth by Australian industry.

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[2] The BIE methodology, although providing more detailed industry information, cannot be extended at this stage because of a major pause by the ABS in the collection of investment data at that level of industry detail.

1.4 Structure of this report

Part A of the report analyses productivity growth with particular emphasis on manufacturing industry. Part A comprises this chapter and Chapters 2 to 4. Chapter 2 examines contributions to national productivity growth by key sectors of the Australian economy as a backdrop to a more detailed analysis of productivity growth in eight major manufacturing industries. Chapter 3 investigates the effects of industry assistance on measures of industry output and productivity growth, while Chapter 4 discusses the employment implications of growth in manufacturing.

Part B is concerned with methodological issues associated with extending productivity analysis from the industry division to the manufacturing industry subdivision level of detail. Chapter 5 of Part B presents detailed information on the sources and methods used in the study, with particular emphasis placed on the methodology employed to estimate capital inputs. Supporting details are provided in Part C — the appendixes to the report. The time series data underlying the productivity estimates are presented in a statistical annex available from the Commission’s homepage (*http://www.indcom.gov.au/*) or on request to the Commission.

2 CONTRIBUTIONS TO OUTPUT, PRODUCTIVITY AND EMPLOYMENT GROWTH

2.1 Introduction

This chapter investigates the contribution of the manufacturing sector to national output, productivity and employment growth. The chapter first places growth in the manufacturing sector in an economy-wide context. It uses new information on productivity growth for eight manufacturing industry subdivisions to examine the contribution of individual activities to growth in the sector as a whole.

The analysis uses a traditional national growth accounting framework which examines the productivity of labour and capital in terms of gross product at constant domestic transactions prices (ie 1989–90 prices). The analysis of manufacturing industry is extended in Chapter 3 to correct for the effect of government interventions on domestic prices and the measured productivity of labour and capital.

2.2 Productivity growth in Australia

The economy-wide perspective

Output data show that the market sector grew on average by around 2.4 per cent a year between 1974–75 and 1994–95.[1] There has also been a small net growth of around 0.5 per cent a year in labour inputs, as measured by an index of total hours worked, while capital inputs are estimated to have grown at an average annual rate of over 2.3 per cent.

In any one year, the productivity of labour and capital inputs can be improved through technological change and better organisation of production. When this occurs, growth in output cannot be fully explained by growth in labour and capital inputs — any difference provides a measure of multifactor productivity growth (Appendix D).

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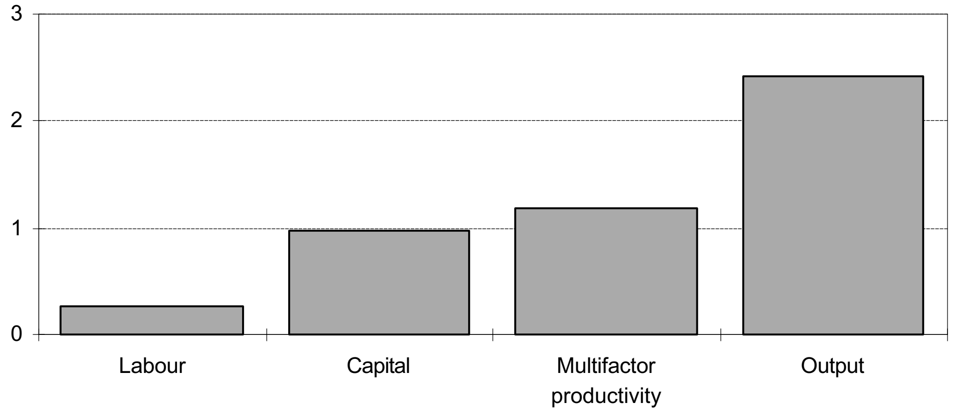
[1] Refer to Table 1.1 for a definition of the market sector.

Figure 2.1 takes this feature of economic growth into account and shows that, over the 20-year period investigated, growth in multifactor productivity contributed around half the growth in market sector output. Growth in capital inputs contributed about 1 percentage point to average output growth in the market sector. Labour contributed 0.3 percentage points to output growth.

Figure 2.1: **Average annual contribution of labour, capital and multifactor productivity to market sector output growth, 1974–75 to 1994–95** (per cent)



Source: Commission estimates based on ABS data.

After taking into account growth in multifactor productivity and increases in the relative use of capital, the average productivity of labour grew substantially. The total employment requirements per million dollars of market sector output (in average 1989–90 prices) declined from 28 to 19 persons.

For the economy as a whole, total employment is determined by the interaction of labour productivity improvements (reducing the labour requirements per unit of output) and output growth (raising labour demand). The net effect of these factors saw employment in the market sector grow by over 12 per cent, to reach a total of nearly 4.9 million persons in 1994–95. There was even larger employment growth in the non-market sector (around 80 per cent from 1974–75 levels), giving total Australia-wide employment in 1994–95 of around 8 million persons — up from around 6 million persons in 1974–75.

In dollar terms, Australian GDP (in average 1989–90 dollars) grew from $229 billion in 1974–75 to $406 billion in 1994–95. The market sector contributed nearly $100 billion, or more than half of the increase in GDP.

Multifactor productivity improvements in the market sector directly contributed around $46 billion, or nearly half of the market sector growth.

However, these measures are based purely on year-to-year changes in outputs and inputs. The framework takes no account of induced economy-wide effects on growth as productivity improvements raise income levels, saving and investment, inducing further rounds of output growth. Once these induced effects are considered, the contribution of productivity improvements to growth is likely to exceed $46 billion. At the extreme, if it is assumed that the whole of the difference between market sector output growth and labour input growth is attributable to the direct and indirect effects of productivity improvements, productivity would have contributed $84 billion, or 86 per cent of market sector growth.[2] As other factors (such as net foreign investment inflows) can also contribute positively to output growth in Australia, this estimate of the productivity contribution to growth represents an upper bound.

The estimated upper and lower bounds suggest that productivity growth in the market sector has contributed between $2600 and $4650 to per capita GDP over the last 20 years.[3] [4]

Sectoral contributions to growth

Market sector productivity growth can be traced back to its industry sources using a decomposition of national estimates.

An industry's contribution to national productivity growth depends on the size of the industry and its own productivity growth. Either small growth from a large industry, or large growth from a small industry, can make a significant contribution to national growth.

Manufacturing industry was the main contributor to market sector output over the period examined (Figure 2.2). However, because it had below average

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[2] This is estimated by assuming no capital deepening occurs in the absence of productivity growth, that is, capital capacity increases at the same rate as labour inputs (as measured by hours worked by employed persons).

[3] Per capita productivity growth is estimated by dividing the total contribution of productivity (at average 1989–90 prices) to growth by the Australian population in 1994–95 (ie 18 million persons) (EconData 1997).

[4] In its associated analysis — Assessing Australia's Productivity Performance (IC 1997) — the Commission decomposes the year-to-year changes in real income per capita over the period 1964–65 to 1995–96. This analysis also shows that multifactor productivity and increased use of capital per unit of labour (capital deepening) were the main factors contributing to rising per capita income.

output growth (1.5 per cent a year against 2.4 per cent for the market sector as a whole), its share of market sector output declined. Transport and communications had the strongest growth (around 5 per cent a year) and, as a result, its share of output in the market sector grew substantially by around 6 percentage points.

Growth in agriculture, manufacturing, electricity, gas and water (utilities), and transport, storage and communications has been underpinned by growth in multifactor productivity (Figure 2.3). In each case, the labour required to produce given levels of output has remained almost constant or has declined in absolute terms, indicating substantial improvements in average labour productivity.

Growth in some service industries — wholesale and retail trade, and accommodation, cultural and recreational services — has been facilitated almost entirely by growth in labour and capital inputs. This is reflected in Figure 2.3 by a low (or negative) contribution of productivity to output growth. Nevertheless, output growth in these sectors has been equal to or above the market sector average. The dominance of labour and capital input growth as sources of expansion in these industries indicates that community demands have been focused on services requiring higher levels of inputs (eg more elaborate shopping environments or higher staffing levels for some services), rather than obtaining standard services with successively lower levels of input.[5]

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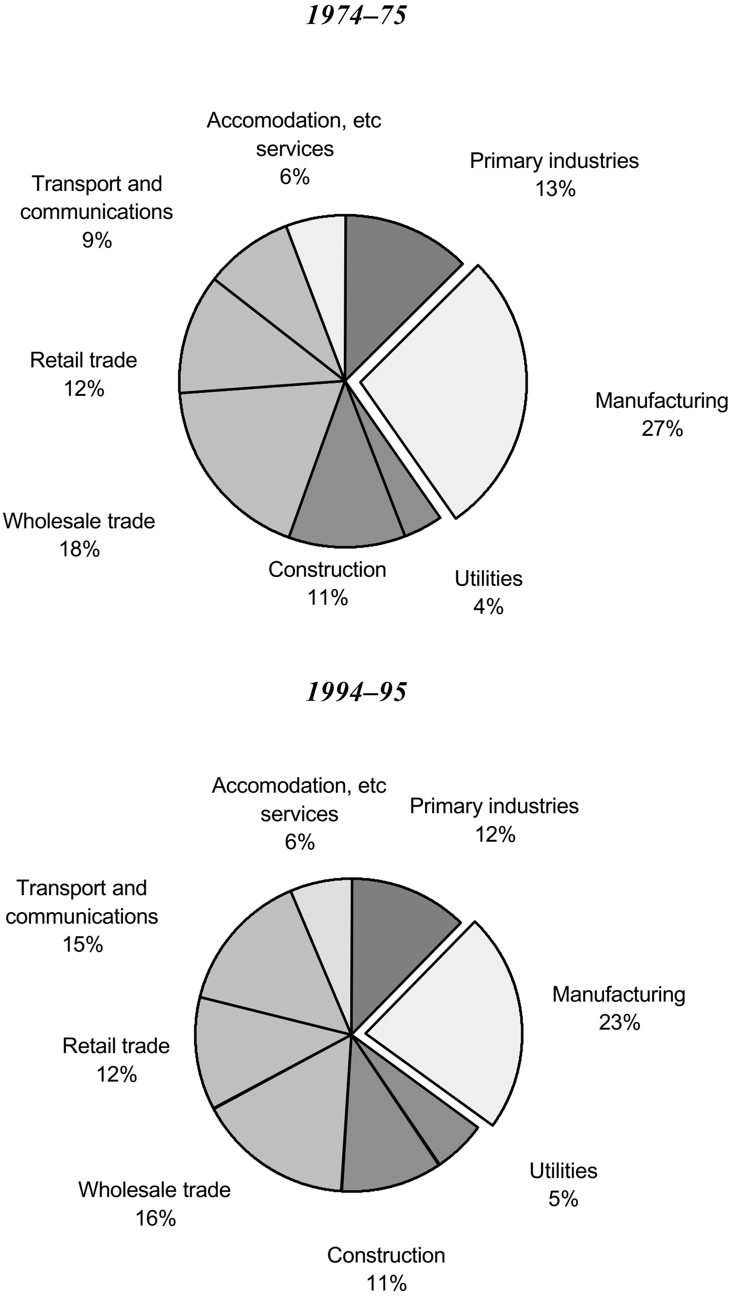
[5] In principle, higher service levels should be treated as quality improvements in output. However, when using the gross output method for estimating constant price gross product growth, quality improvements may not be measured and included in output growth (see Box 1.1). However, differences in apparent productivity growth occurring for measurement reasons have an economic interpretation. Expansion of activities providing more elaborate services at a higher resource cost per unit of output — which can be indicated by low or negative measured productivity growth in some service industries — requires the employment of additional labour and capital inputs. Productivity growth in other activities reduces the resource requirements per unit of output in those activities and provides one means of enabling factors to enter expanding activities without reducing output elsewhere.

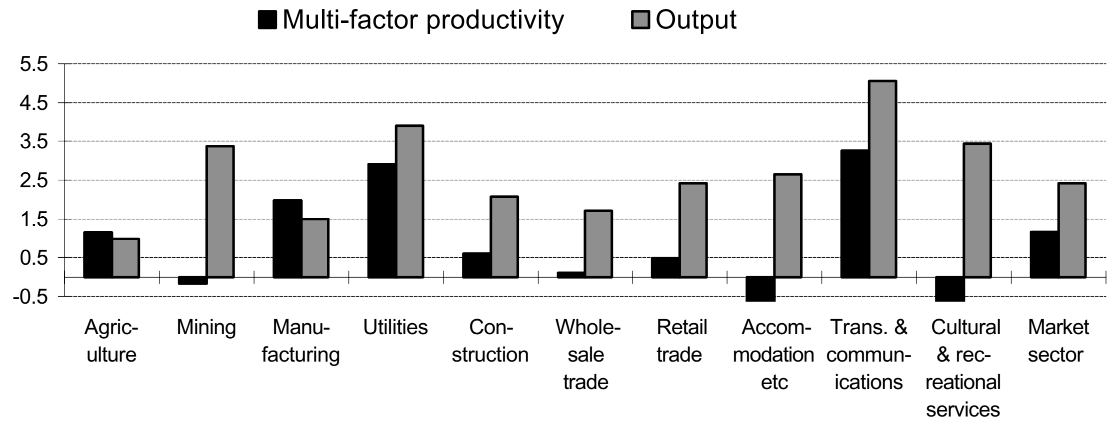
Figure 2.2: **Share of market sector output by industry, 1974–75 and 1994–95** (per cent)



a Measured at average 1989–90 prices.

Source: Commission estimates based on ABS data.

Figure 2.3: **Average annual output and productivity growth by industry, 1974–75 to 1994–95** (per cent)



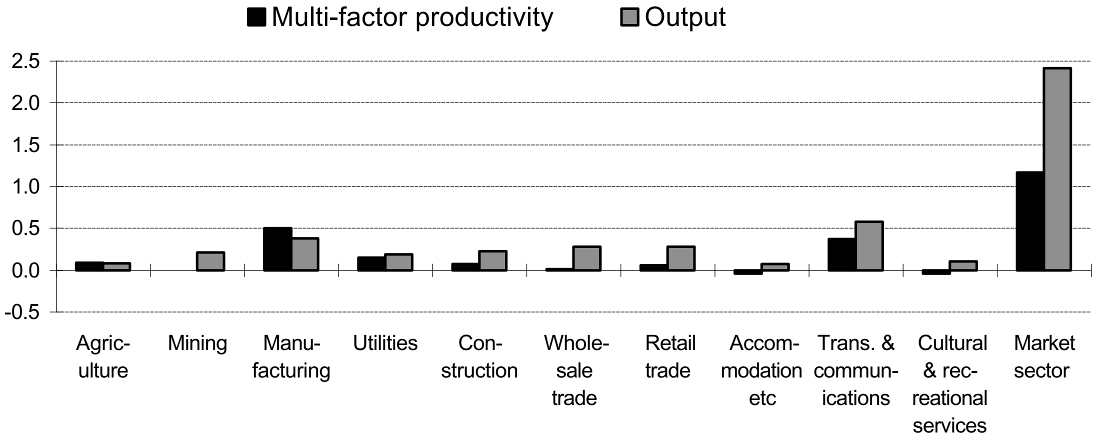
Source: Commission estimates based on ABS data.

Growth in the mining and construction industries mainly reflects the deployment of additional capital in those activities.

In the mining industry, however, the long lead times associated with bringing new investment into full production, as well as the large value of individual projects, can raise capital per unit of output in the short term. Implicit in this characteristic is a downward bias in year-to-year measures of multifactor productivity growth. This downward bias can mask the substantial technological innovations and organisational improvements in the use of labour and capital needed to bring new projects on stream and maintain the viability of others. In the construction industry, by contrast, there is likely to be only short lags between the timing of new investment and its engagement in production. This additional investment feeds quickly through to additional output.

Overall, the largest percentage contribution to market sector productivity growth has been made by manufacturing industry (Figure 2.4). This reflects the size of the sector (Figure 2.2) and the contribution productivity has made to manufacturing industry growth (Figure 2.3). The utilities, and transport and communications industries have also been substantial contributors to productivity growth in the market sector. Nevertheless, because these industries have been working from smaller bases, their contributions have been less than that of manufacturing (even though they have experienced higher rates of own-industry productivity growth).

Figure 2.4 **Average annual contributions to market sector output and productivity growth by industry, 1974–75 to 1994–95** (percentage points)



Source: Commission estimates based on ABS data.

The key message that emerges is that the pattern of productivity and output growth depends on the conditions facing the respective industry. In an economy-wide setting, low levels of measured productivity growth do not necessarily indicate that an industry is slow to grow, or that its competitive position has deteriorated. Relatively high levels of output growth have therefore been associated with both high and low rates of productivity growth.

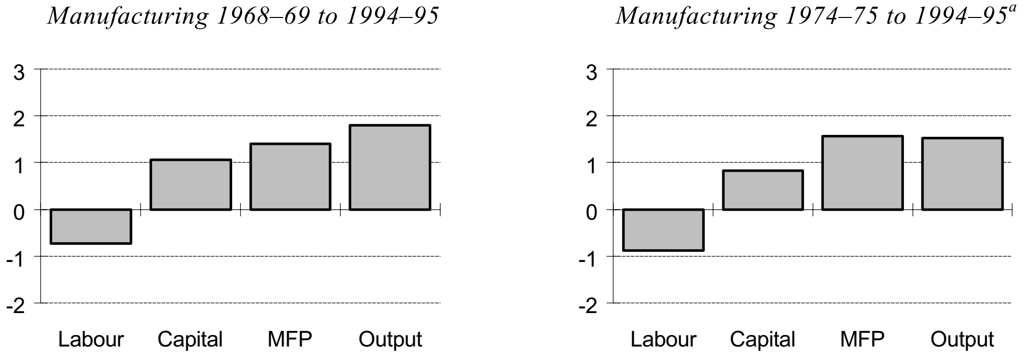
2.3 Productivity growth within manufacturing

The divisional perspective

Productivity growth in the manufacturing sector has been examined using a new series of capital stocks for eight manufacturing industry subdivisions, and other information on industry costs, labour inputs and output (see Chapter 5 and supporting appendixes for a detailed discussion of the development of these series). The analysis of manufacturing has been extended beyond the period examined in the previous section to a 26-year period between 1968–69 and 1994–95.

The growth picture for both periods is similar (Figure 2.5). Nevertheless, when the longer time frame is adopted, the growth contribution of capital appears to be fractionally higher than for the shorter period, while the growth contribution of productivity is similar (contributing over 1 percentage point a year to manufacturing growth in each time frame). In both periods, growth in output has been underpinned by capital growth and productivity improvements, so that total labour input requirements have declined.

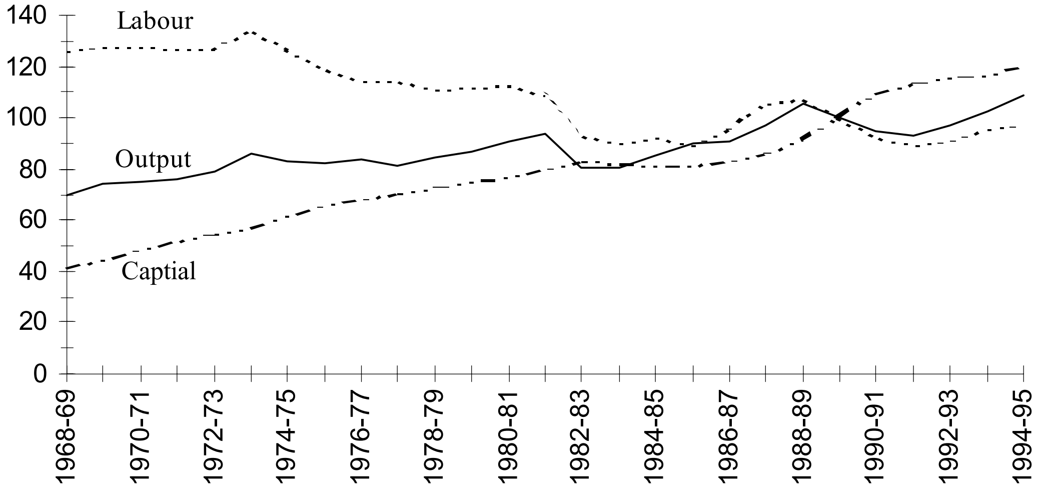
Figure 2.5: **Contributions to average annual growth in output, manufacturing sector, 1968–69 to 1994–95 and 1974–75 to 1994–95** (percentage points)



Source: Commission estimates based on ABS data.

The decline in labour input requirements was most pronounced during the 1970s. Subject to period-to-period variations, manufacturing industry labour input requirements have remained fairly flat since the early 1980s (Figure 2.6). On the other hand, output has grown throughout the period, with the peaks in 1973–74, 1981–82, 1984–85 and 1988–89 coinciding with peaks in the national growth cycle. Installed capital capacity has increased ahead of output throughout the period.

Figure 2.6: **Labour, capital and output growth in the manufacturing sector, 1968–69 to 1994–95** (indexes 1989–90=100)



Source: Commission estimates based on ABS data.

Industry decomposition of manufacturing industry productivity growth

Industry contributions to manufacturing output

The contribution that productivity growth in an individual activity makes to increases in manufacturing sector productivity growth depends on its share of manufacturing output and productivity growth in that particular activity. Table 2.1 shows that there have been some changes in the relative importance of the eight industries considered over the 26-year period. Output in the printing and publishing, chemical products and basic metals areas has grown ahead of the manufacturing average, increasing the output shares of these activities.

Output for textiles, clothing, footwear and leather (TCF), and transport equipment has grown below the manufacturing average, as has the output of structural metal products. Reflecting this slower than average growth, the relative contribution to total manufacturing output of these activities has declined.

Coinciding with changes in output contributions, there have been substantial changes in the levels of assistance afforded individual manufacturing activities (Table 2.1). Assistance to the chemical and basic metal industries was below the manufacturing average over the period, while assistance to printing and publishing activities had the largest proportional decline within manufacturing. In 1968–69, assistance to the TCF, structural and sheet metal products and transport equipment subdivisions was substantially above the manufacturing average. While there was a substantial reduction in assistance to most manufacturing activities, the reductions to TCF and transport equipment were proportionately less than the reductions in other manufacturing activities. As a result, by 1994–95, assistance to TCF was 5 times, and transport equipment 3 times, the manufacturing average. Assistance to structural and sheet metal products was also above the manufacturing average in 1994–95.

Table 2.1: **Average annual output growth, output shares and effective rates of assistance by manufacturing industry subdivision, 1968–69 and 1994–95** [a] (per cent)

Industry	*Average annual output growth*	*Output shares*		*Effective rates of assistance* [b]	
		1968-69	*1994-95*	*1968-69*	*1994-95*
Food, beverages and tobacco	1.8	18	18	16	2
Textiles, clothing, footwear and leather	-0.2	8	5	65	46
Printing, publishing and recorded media	3.2	6	8	51	3
Petroleum, coal, chemicals etc	3.0	11	15	30	7
Basic metal products	2.4	10	11	32	5
Structural and sheet metal products	0.9	9	7	61	10
Transport equipment	0.9	13	10	50	28
Other manufacturing	1.7	26	26	33	7
Total manufacturing	**1.8**	100	100	**36**	**9**

a Output measured in 1989–90 prices.

b The effective rate of assistance is a measure of industry support afforded by government interventions. It takes into account assistance both to outputs and inputs. The measure is defined as the percentage increase in returns to an activity's (or industry's) value added per unit of output, relative to the hypothetical situation of no assistance.

Source: Commission estimates.

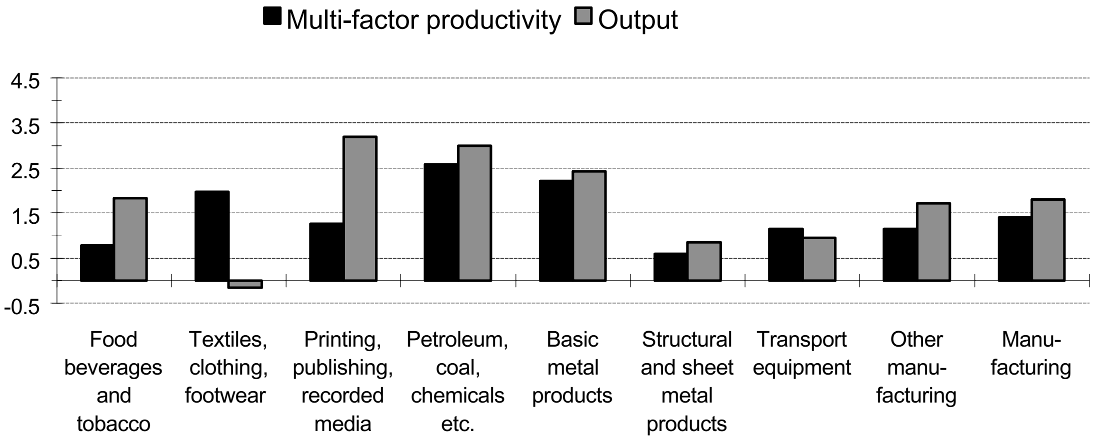
Overall, the most highly assisted activities in 1968–69 generally had the smallest percentage assistance reduction over the period. However, these suffered the largest loss in share of manufacturing industry output. Industries with the largest percentage declines and/or the lowest assistance levels in both periods were the activities to maintain or expand their share of manufacturing output.

Multifactor productivity growth by industry

Productivity growth has been an important contributor to output growth for each manufacturing subdivision (Figure 2.7).

Whereas there appeared to be no clear correlation between output growth and productivity growth at the sectoral level, the story is different at lower levels of aggregation within the manufacturing sector. Activities with above average output growth generally have had above average productivity growth. However, a relatively high contribution of productivity growth to output growth does not necessarily translate to high output growth relative to other industries. For example, TCF productivity has increased substantially while output has actually declined.

Figure 2.7: **Average annual output and productivity growth by manufacturing industry subdivision, 1968–69 and 1994–95** (percentage)

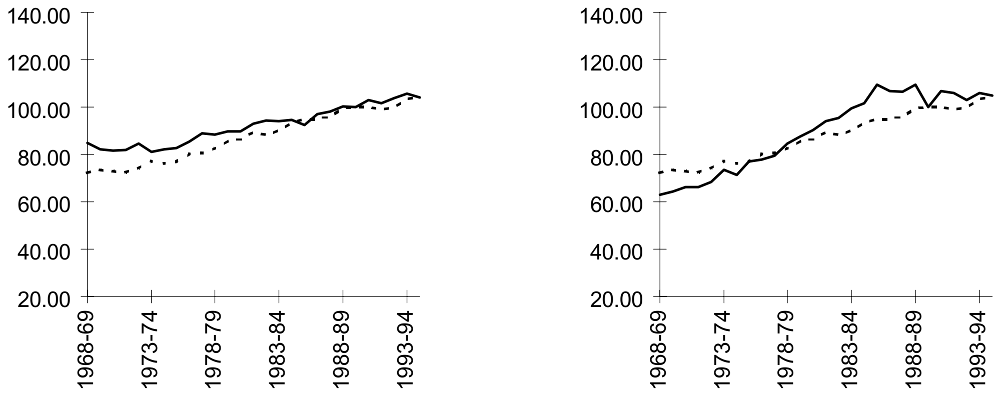


Source: Commission estimates based on ABS data.

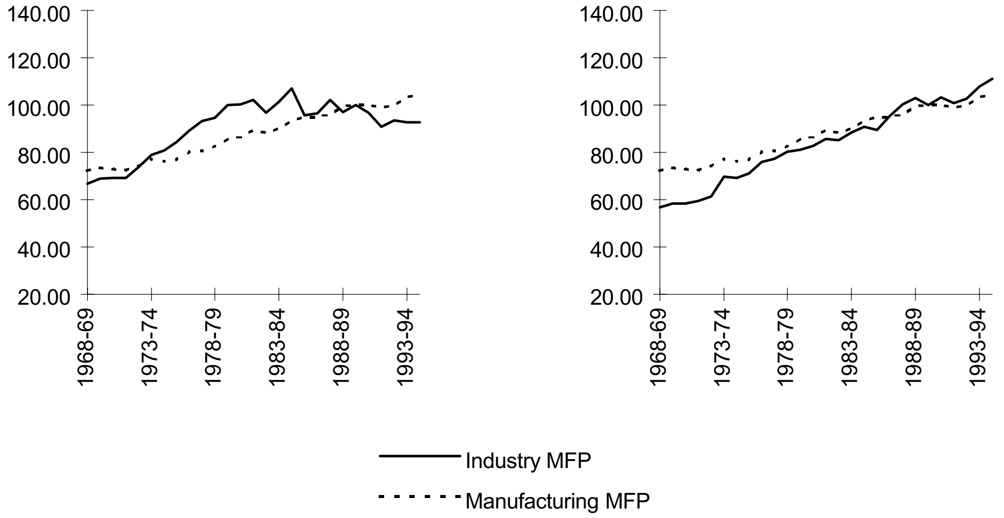
Behind these overall industry figures, there has been substantial year-to-year variations in productivity growth (Figure 2.8). For example, productivity growth for the food, beverages and other manufacturing activities has broadly followed the trend for total manufacturing. For printing and publishing, productivity growth was concentrated in the period to the mid-1980s.

Figure 2.8: **Multifactor productivity (MFP) by manufacturing industry subdivision, 1968–69 to 1994–95**
(indexes 1989–90=100)

Food, beverages and tobacco *Textiles, clothing footwear and leather goods*



Printing, publishing and recorded media *Petroleum, coal, chemicals and associated products*

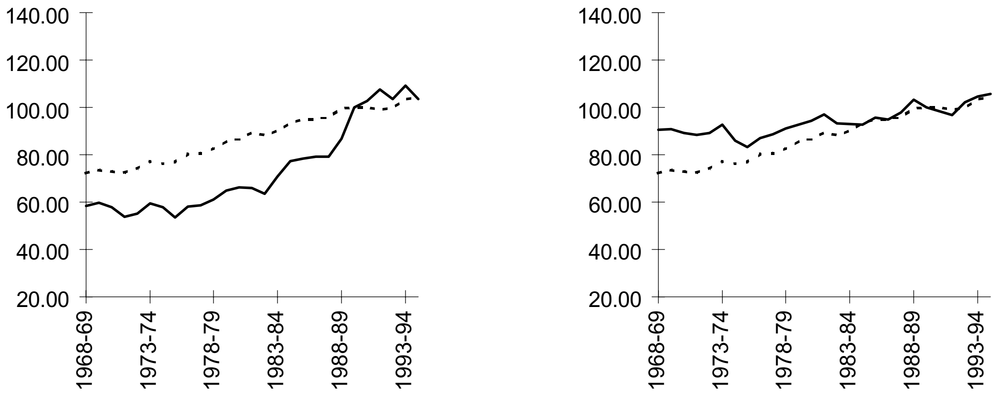


For footnotes see end of figure.

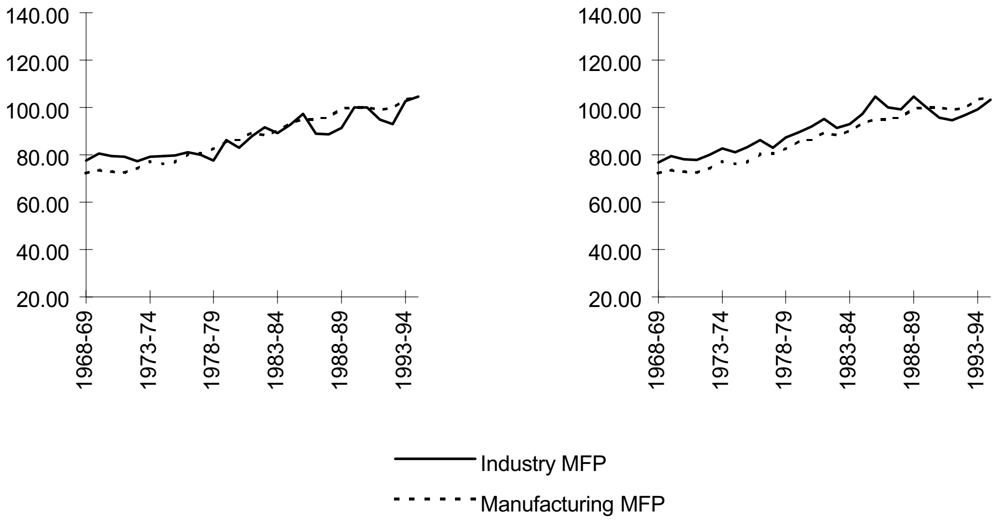
.../ Continued

Figure 2.8: **Multifactor productivity (MFP) by manufacturing industry subdivision, 1968–69 to 1994–95** (indexes 1989–90=100) Continued

Basic metal products *Structural and sheet metal products*



Transport equipment *Other manufacturing*[a]



a Includes ANZSIC subdivisions: 23 Wood and paper products; 26 Non-metallic mineral products; 29 Other manufacturing; and ANZSIC groups 283–6 other machinery and equipment activities.

Source: Commission estimates.

The lower growth activities of transport equipment and structural metal products are estimated to have had below average growth in multifactor productivity throughout the period. Nevertheless, in the most recent growth cycle, productivity growth in these two activities exceeded the manufacturing average (Figure 2.8). This occurred against a backdrop of substantial industry investment in Australian manufacturing capacity and rising output. However, assistance for both activities, and transport equipment in particular, has remained above the assistance afforded most other manufacturing activities.

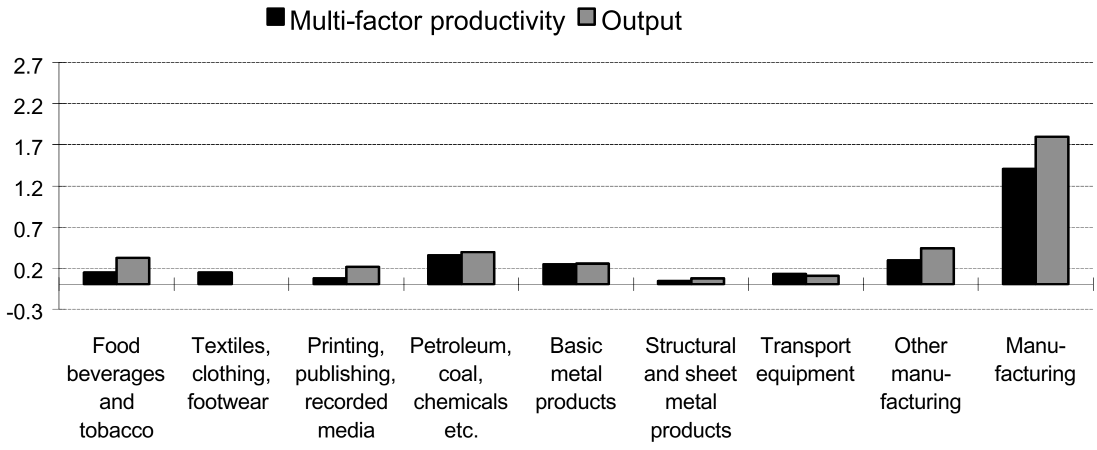
The TCF industry provides a somewhat different industry growth perspective. Productivity rose ahead of the manufacturing average until 1987–88. This development occurred within an environment of high levels of government support. However, since then, assistance to the industry has been reduced, and the international viability of previous investment and employment decisions has been increasingly tested in the world trading environment. Coinciding with higher levels of international competition, TCF output declined by around 4 per cent a year over the six-year period to 1994–95. The measured decline in output since the late 1980s indicates that earlier investment and employment decisions did not generally favour internationally competitive activities.

The decline in TCF output, a less than proportional decline in labour inputs and some major increments to capital stock, reversed the upward trend in productivity growth. However, for high assistance activities, the direction of productivity change is sensitive to the deflation method used to assess output growth. Chapter 3 considers the effects of changes in industry assistance on output and productivity growth.

Industry contributions to manufacturing growth

With above-average output and productivity growth, the petroleum, coal chemicals and related products and basic metal products industries together contributed about one half of manufacturing productivity growth (Figure 2.9) — well above these industries' average output contribution (Table 2.1).

Figure 2.9 **Average annual contributions to manufacturing sector output and productivity growth by industry subdivision, 1968–69 to 1994–95** (percentage points)



Source: Commission estimates based on ABS data.

As the majority of the products of manufacturing industries are traded on world markets, longer-term output growth and employment in these sectors depends on the industries' capacity to remain internationally competitive. Productivity growth is an important component of this process as it enables industries to deliver products at successively lower resource costs. To the extent that productivity growth maintains or improves the international competitiveness of industry, it can also contribute to industry growth. Nevertheless, it is evident that the connection between productivity and output growth, although close, is not perfect, even within manufacturing. Other factors will also play a role in determining competitiveness. For example, the provision of more elaborate design or service-enhanced items may improve competitiveness. However, these may come at a higher resource cost than items traditionally produced by the local industry. Such items could raise output, although because more labour and capital inputs are need to produce that output, may not give a proportional productivity increase.

2.4 Summing up

Productivity growth has directly contributed around half of year-to-year output growth in the market sector. When the indirect effects of productivity are taken into account, this contribution is likely to be much higher — according to this analysis, up to 86 per cent of growth in the market sector could have come from productivity growth.

The correlation between output growth and year-to-year productivity growth has not been very strong in the market sector. While the manufacturing division was the main contributor to market sector productivity growth, other divisions — particularly in the services areas — provided the strongest output growth. Except for transport, storage, communication and utilities, service industries' output growth has been supported mainly by the employment of additional labour and capital.

At the manufacturing subdivisional level, productivity growth has been a major contributor to the output growth of each activity. Nevertheless, high productivity growth alone does not guarantee an individual industry will make above average contributions to manufacturing industry output growth.

Manufacturing industries with relatively low assistance, or assistance reductions early in the 26-year period examined, showed the strongest average annual output growth over the period. Conversely, the most highly assisted activities in both 1968–69 and 1994–95 had the slowest growth in output over the period. Despite the maintenance of high assistance over the period, their share of manufacturing output dropped.

The link between industry assistance and productivity growth is investigated in more detail in the next chapter, while the links between output, productivity and employment growth are examined in the subsequent chapter.

3 EFFECTS OF INDUSTRY ASSISTANCE ON MEASURES OF PRODUCTIVITY GROWTH

3.1 Introduction

Industry assistance encourages resources away from relatively lowly assisted activities to those receiving the higher levels of support. In doing so, it affects the development and performance of all Australian industries. This chapter investigates the link between industry assistance, output and productivity growth.

The first section discusses the conceptual framework used to make this link. The next section presents measures of output and productivity growth adjusted to remove the effects of assistance on growth.

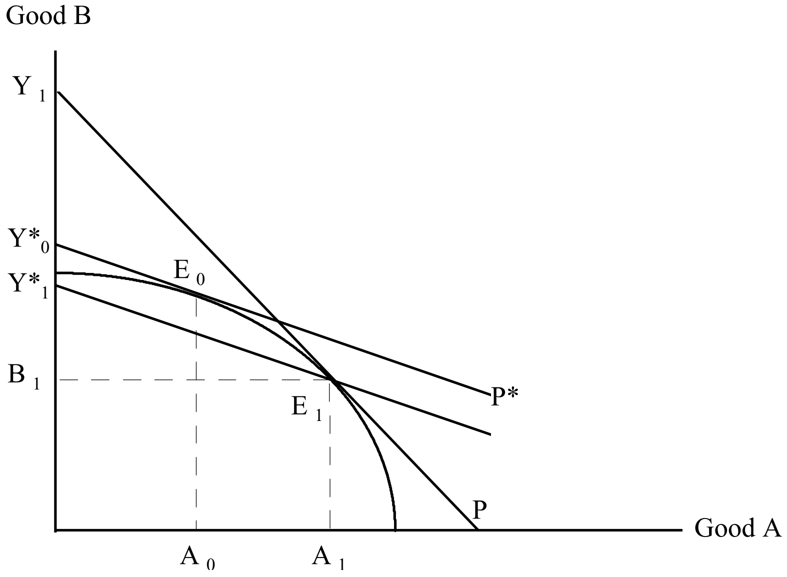
3.2 The need for adjustment of value added to unassisted prices

Traditionally, value added has been revalued from current domestic transactions prices to constant domestic prices to provide a measure of changes in the 'real' gross product of labour and capital. The resulting constant price series are not pure physical measures of output — with output in any one industry category constituting a range of different products, such pure physical measures are impossible.

Instead, 'real' gross product is measured in terms of units of exchange. For example, the price ratio traditionally used for revaluation is the ratio between the domestic transactions price per unit of output in some reference period (1989–90 in this study) and other periods in the series. The resulting real measure of output shows how many units of base-period output the current period level of output would exchange for at domestic transactions prices. Measures prepared on this traditional basis were used in Chapter 2.

Box 3.1: Stylised illustration of the effects of assistance

Because 'real' measures of output are in fact measured in units of exchange, care must be taken in interpreting the results of productivity studies when the price ratios used for revaluation are influenced by changes in government policies (Chand 1997). This is shown in the following figure where the curve passing through E_0 and E_1 shows all combinations of two different goods — A and B — that can be produced domestically with available resources.



In the absence of government policies, with the relative prices of the two goods given by the line P*, producers would choose the combination E_0. However, a tariff (for example) on good A would move domestic relative prices from P* to P. Producers would then choose combination E_1. Using the domestic price ratio P to measure constant price output, national output measured in terms of good B would rise from Y^*_0 to Y_1. But at the unchanged international price ratio P*, national output would fall from Y^*_0 to Y^*_1.

Using this illustration it can be seen that if there were productivity improvements that moved the production possibilities curve outwards, the measurement of the increase in the output of good A in terms of good B could be 'understated' if it were measured in domestic relative prices over a period in which the tariff on good A was reduced. In this case, the move in the domestic price line back from P to P* would tend to offset the effect of the outward movement in the production possibilities frontier. Conversely, productivity improvements could be 'overstated' if measured using domestic prices over periods in which tariffs were increasing.

Traditional measures of productivity evaluated at domestic prices would accurately reflect domestic exchange opportunities at the time. However, problems can arise when productivity is measured over a period in which domestic exchange opportunities are *changing*, say, because of government policy changes. When 'real' output growth is measured using deflators which are themselves changing because of government policy changes, the policy-induced changes in the price deflator can mask the underlying true output changes (Box 3.1).

Assistance instruments such as tariffs, quotas and production subsidies are measures which affect domestic exchange opportunities. Ideally, the effects of changes in assistance should be removed from the underlying price deflators before they are used to derive 'real' output measures for use in measuring productivity changes. Any *behavioural* impact of assistance on productivity performance can then be examined more clearly.

To explore the link between assistance and multifactor productivity in this paper, industry gross product has been revalued from domestic to unassisted prices using the Commission's estimates of effective rates of assistance to manufacturing industry (Box 3.2). The revised estimates are free from the effects of assistance induced changes included in the traditional measures of value added at constant prices.

3.3 Effects of industry assistance on measured productivity

The effects of assistance on measured output and productivity growth is evident for all industries within the manufacturing sector. As assistance has been generally declining, output and productivity at unassisted prices have been rising ahead of output at assisted domestic prices (Figure 3.1). Within manufacturing, some substantially different growth patterns occur between industries.

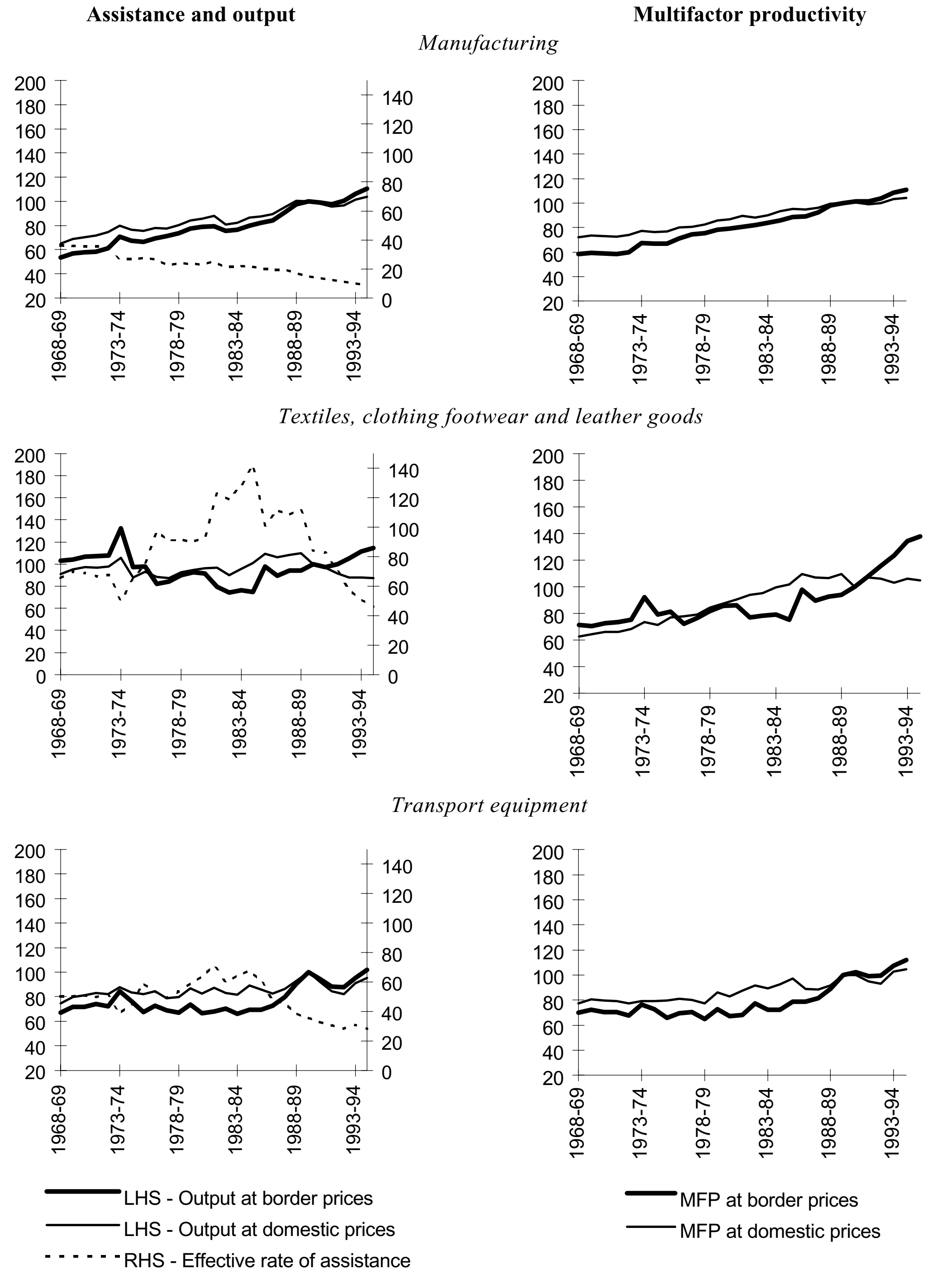
Assistance to TCF and transport equipment rose substantially over the 1970s to the mid 1980s (Figure 3.1, left-hand panel). The rise in assistance generated an increase in domestic prices relative to border prices. The social value of output at border prices was accordingly lower than reflected by domestic transaction prices and, accordingly, multifactor productivity at border prices grew less than multifactor productivity at domestic transaction prices (Figure 3.1, right-hand panel). For TCF, the apparent improvement in technical efficiency evident in domestic-price multifactor productivity calculations during the first half of the 1980s did not translate to a proportional increase in the social value of output.

Box 3.2: Methodology for adjusting industry output and multifactor productivity measures from domestic transactions prices to border prices

Gross product at factor cost measured in domestic prices incorporates the effect of government assistance on relative prices. The Commission's estimates of effective rates of assistance attempt to measure net effects of assistance on industry value added. Measures of the effective rate of assistance by industry have been used in this study to revalue gross product at factor cost at constant domestic transaction prices, to gross product at unassisted prices (ie border prices), using the relation $Y_j^{t,b} = Y_j^t \big/ (1+\tau_j^t)$ where Y_j^t and $Y_j^{t,b}$ are gross product at domestic and unassisted prices, respectively, for industry *j* in period *t*, and τ_j^t is the effective rate of assistance. For any year, therefore, gross product at average 1989–90 border prices is defined as: $Y_j^{t,b} = \dfrac{1}{(1+\tau_j^t)} * \dfrac{P_j^{1989-90}}{P_j^t} * Y_j^t$, where $P_j^{1989-90} \big/ P_j^t$ is the inverse of the implicit price deflator for each industry subdivision. This adjustment is necessary to ensure that the border price measures are at constant 1989–90 domestic transaction prices rather than at current transactions prices. To take account of the changing composition of manufacturing industry, the effective rate price indexes have been rebased for the years 1971–72, 1974–75, 1977–78, 1983–84 and 1989–90 (IC 1995c).

On the other hand, from the mid-1980s, assistance to TCF and transport equipment has been declining. Whereas domestic production measured in domestic prices declined, that measured at border prices increased, especially for TCF (Figure 3.1, left-hand panel). There has been an associated increase in the productivity of labour and capital at border prices per unit of output, leading to a rise in measured multifactor productivity at border prices (Figure 3.1, right-hand panel).

Figure 3.1: **Effective rates of assistance, output and multifactor productivity growth by manufacturing industry subdivision, 1968–69 to 1994–95** (indexes 1989–90 = 100; effective rate of assistance, percent)



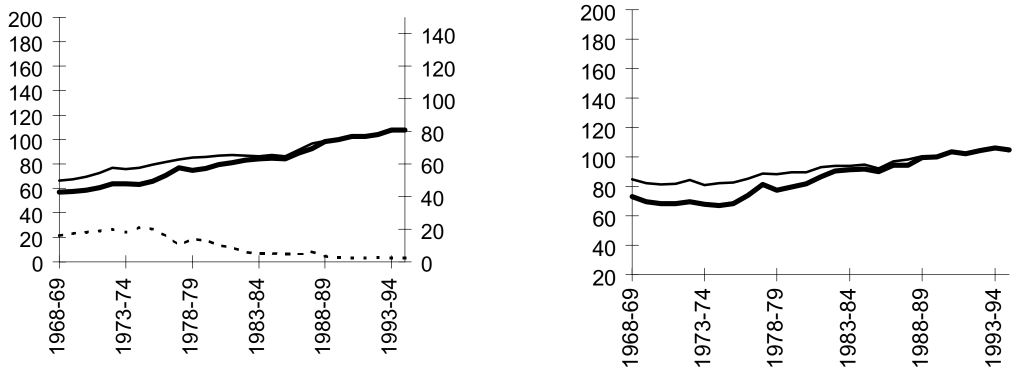
Source: Commission estimates.

.../ continued

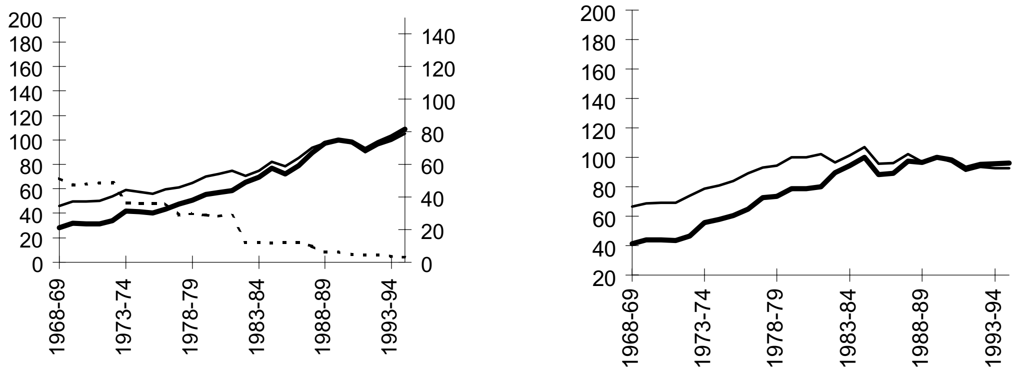
Figure 3.1: **Effective rates of assistance, output and multifactor productivity growth by manufacturing industry subdivision, 1968–69 to 1994–95** (indexes 1989–90 = 100; effective rate of assistance, percent) Continued

Assistance and output **Multifactor productivity**

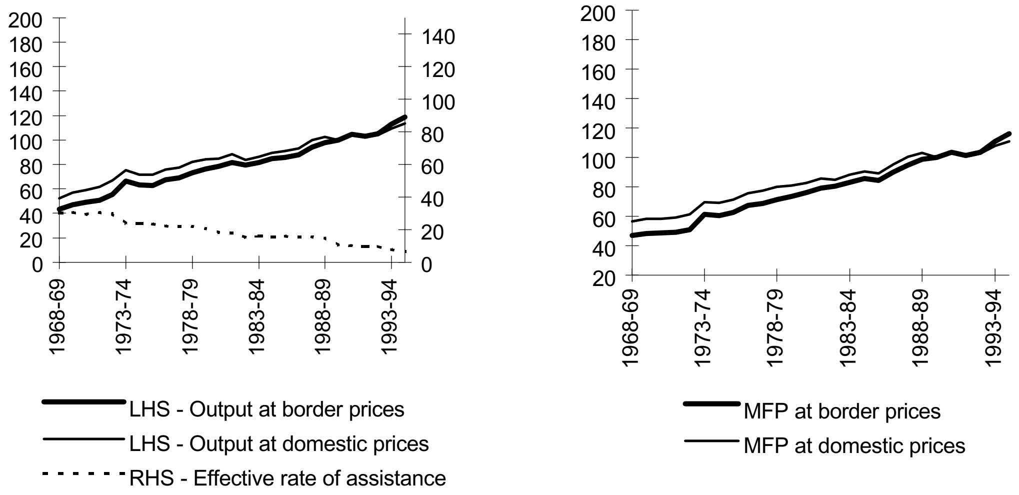
Food beverages and tobacco



Printing, publishing and recorded media



Petroleum, coal, chemicals and related products



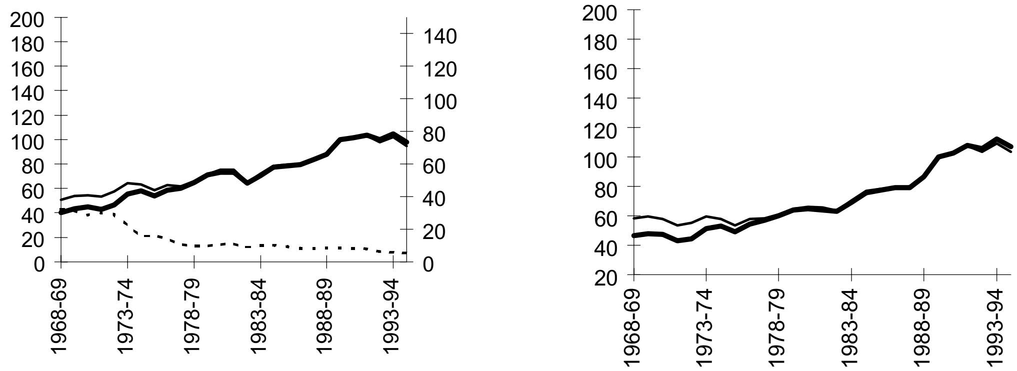
Source: Commission estimates.

.../ continued

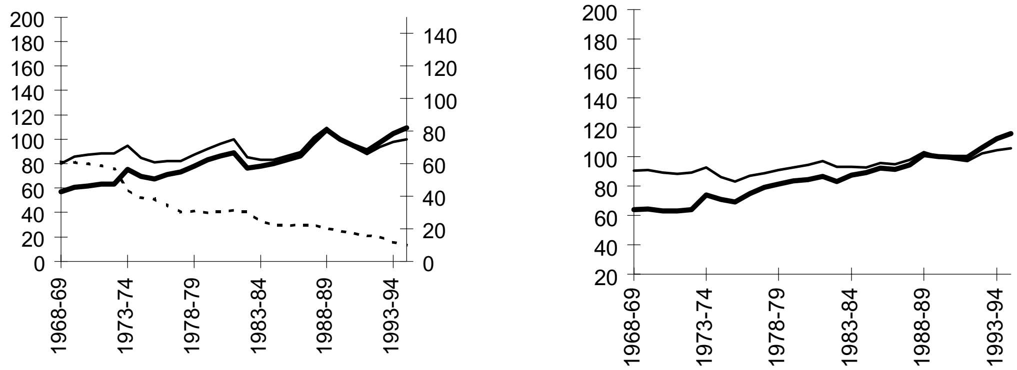
Figure 3.1: **Effective rates of assistance, output and multifactor productivity growth by manufacturing industry subdivision, 1968–69 to 1994–95** (indexes 1989–90 = 100; effective rate of assistance, percent) Continued

Assistance and output **Multifactor productivity**

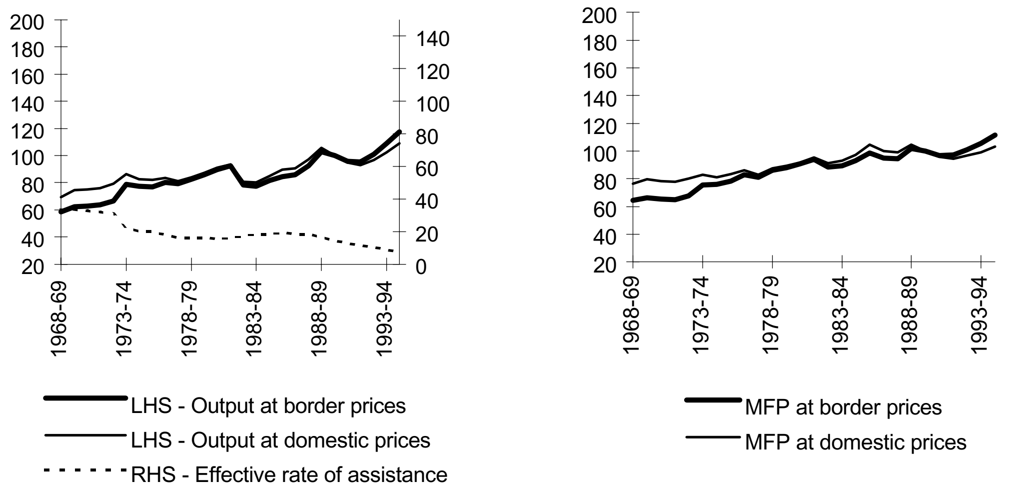
Basic metal products



Structural and sheet metal product



Other manufacturing



Source: Commission estimates.

These illustrations show that, when considering the international competitiveness of highly assisted industries, it is important to measure their productivity at unassisted prices rather than at domestic transactions prices. These revaluations show that the international competitiveness of TCF and transport equipment has improved as assistance has been reduced. Investment and employment decisions over the last decade have occurred against the background of declining assistance per unit of output and rising production valued at international prices. It would be expected that future growth prospects for the industries were being strengthened as investment and employment decisions were increasingly based on the expectation that domestic output would be sold at internationally competitive prices.

Other activities received assistance around (or in some cases above) the levels of TCF and transport equipment in 1968–69 (Table 2.1). However, following the 25 per cent across the board tariff reduction in 1973 and subsequent assistance reductions, support for these other industries has fallen to levels which are now well below the TCF and transport equipment levels (Figure 3.1). Output at both domestic and border prices for these industries has generally grown throughout the period — though subject to some short-term cyclical fluctuations. With the reductions in assistance and improved competitiveness, output and multifactor productivity at border prices has risen faster than the comparable measures valued at domestic prices.

The comparison across industries shows that high assistance has not been associated with faster growing manufacturing activities. Indeed, the opposite has been the case. High assistance appears to be a poor means of maintaining output levels, achieving growth or improving the social value of productive activities. In addition, while it is true that manufacturing industry employment has declined over the 26-year period examined, those declines have been greatest in the more highly assisted areas (see Chapter 4).

3.4 Summing up

Traditionally, productivity measures are undertaken in a framework where production is valued at domestic transactions (ie assisted) prices. This chapter examined these estimates against alternative measures revalued to remove the effects of assistance on measured output and productivity growth.

When output is valued at unassisted prices, the productivity growth of highly assisted activities, such as TCF and transport equipment, is lower than conventionally measured when assistance is rising. Conversely, productivity growth is higher than conventionally measured when assistance is falling. For most manufacturing industries, reductions in assistance had the strongest positive effects on output and productivity growth in the 1970s.

In addition to these links, there are many other influences that can influence industry output, productivity and employment growth. In order to disentangle the relative importance of assistance and other factors, a causal analysis is needed. This study provides some important information needed to further analyse these issues.

4 IMPLICATIONS FOR EMPLOYMENT GROWTH IN MANUFACTURING INDUSTRY

4.1 Introduction

This chapter examines the link between employment growth and output and productivity growth for the manufacturing industry and its subdivisions.

The first section examines the factors influencing employment growth in the manufacturing industry and details employment changes by industry subdivision. Section 4.3 investigates the implications of these changes for labour productivity growth in manufacturing industries. The final section sums up the discussion.

4.2 Employment growth in manufacturing

The division-wide perspective

Manufacturing industry output has grown by over 40 per cent between 1968–69 and 1994–95. If each unit of output required the same amount of labour input in 1994–95 as it did in 1968–69, manufacturing industry employment would have also increased by over 40 per cent. However, there have been many other factors at work — such as the substitution of capital for labour, changing working hours and productivity improvements. Once all factors are taken into account, manufacturing industry employment actually fell by around 27 per cent (see Box 4.1).

This section disentangles the main factors that have been associated with employment changes (Box 4.2). In doing so, it provides a statistical decomposition rather than a causal analysis. Therefore, an increase in the amount of capital per person employed, for example, will show up in the decomposition as a reduction in labour requirements. However, the new capital may have introduced new techniques that may have caused an increase in competitiveness and contributed to increased output and an overall improvement in employment opportunities in the industry.

Box 4.1: Estimates of employment growth

Employment (and output) growth estimates are based on data from ABS manufacturing industry statistics (see Appendix B). The employment and output series are consistent with national accounting series which provide the basis for the economy-wide analysis in Chapter 2.

A Reserve Bank (RBA 1996b) compilation of ABS Labour Force Survey data back to 1968–69 also suggests that employment in manufacturing fell from 1968–69 levels. However, its compilation shows a decline of about 14 per cent from 1968–69 levels which compared to the 27 per cent shown in manufacturing industry statistics. A large part of the disparity in growth arises from differing trends since the late 1980s. Over the period 1988–89 to 1994–95, manufacturing industry statistics employment declined by 2.4 per cent per year, whereas the labour force employment series declined by 0.8 per cent per year.

Part of that statistical difference represents conceptual differences between the Labour Force Survey and the Manufacturing Industry Survey. Problems in updating the ABS Business Register have contributed to the increased difference observed since the late 1980s. The ABS is rectifying these problems on the Business Register and is revising progressively many previously published series. Other structural changes in the labour market, such as increased contracting out which blurs the distinction between place of employment and employer, also may have contributed to the increased difference in recent years. The ABS is currently investigating these labour market issues and their implications for industry data.

Of the factors examined, the positive effect of output growth is singly the most important element affecting employment in manufacturing. However, other factors which contribute to the productivity of labour and lower labour input requirements per unit of output together have dominated the output effects so that overall employment in manufacturing activities declined (Table 4.1).

The main factors leading to lower labour requirements have been the use of additional capital per unit of labour input and improvements in multifactor productivity. These two factors explain approximately two-thirds of the reduction in labour input requirements. An increase in average hours worked by persons employed in manufacturing and the relocation of labour to more capital intensive activities have further reduced employment requirements in manufacturing.

Box 4.2: Decomposing changes in output per person employed

The methodology used to decompose growth in output per person employed is based on an analysis of changes in employment, outputs, and capital and labour inputs. Changes in output per person employed can be decomposed into the following components:

- growth in labour inputs per person employed — an increase in the hours worked per person employed would raise output per person employed;
- relocation of labour inputs between industries — relocation of labour to industries where labour inputs per person employed were growing faster than the industry average would also increase average output per person employed;
- growth in capital inputs per unit of labour input would raise the level of output per person employed, with the influence of changes in hours worked by individuals being captured by the first two items; and
- relocation of capital from more labour intensive activities to less labour intensive activities would raise the level of output per person employed.

For additional details of the disaggregation methodology, see Appendix B.

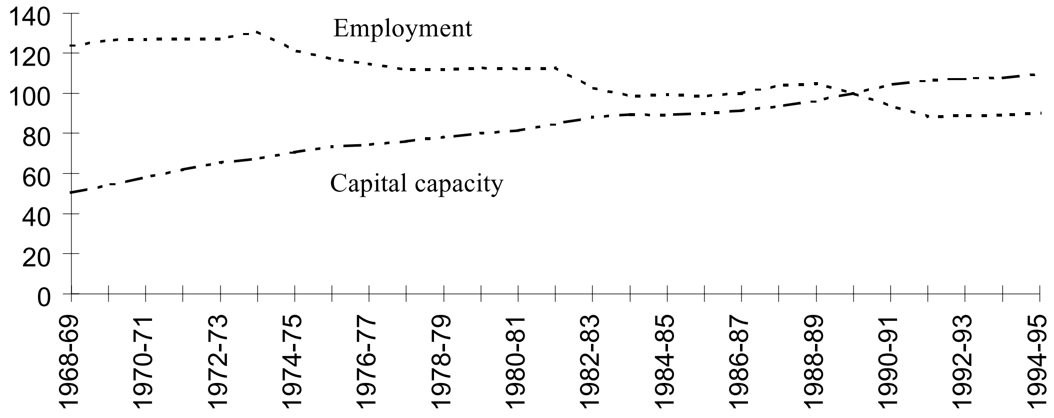
Table 4.1: **Decomposition of changes in employment within the manufacturing sector, 1968–69 to 1994–95** (thousand persons)

Employment 1968-69		**1265**
Changes due to:		
Output growth		550
Input growth and usage		
Growth in labour input per person	-174	
Reallocation of labour	-11	
Growth in capital per unit of labour input	-341	
Reallocation of capital	-20	
Growth in multifactor productivity	-336	
Other	-8	
Total		-891
Net change (outputs and inputs)		**-341**
Employment 1994-95		**924**

Source: Commission estimates.

Although manufacturing industry labour requirements have declined throughout the period examined, the largest changes have been focused in the years immediately following peaks in the national growth cycles, that is 1973–74, 1981–82 and 1988–89 (Figure 4.1). The changes have coincided with a steady increase in the level of capital capacity in manufacturing. Because capital capacity is an accumulation of past and present investment decisions, the effects of short-run variations in investment are not strongly evident in measures of capital capacity growth over time.

Figure 4.1: **Persons employed and capital capacity in the manufacturing sector, 1968–69 to 1994–95** (indexes 1989–90=100)



Source: Commission estimates based on ABS data.

Industry subdivision employment contributions

Over the period 1968–69 to 1994–95, there has been a net reduction in employment requirements in all manufacturing subdivisions, with the exception of printing, publishing and recorded media (Table 4.2). The largest proportional changes in employment have occurred in TCF and transport equipment, where employment has declined from 1968–69 levels by around 60 per cent and 40 per cent, respectively. These changes compare with a 27 per cent decline for manufacturing as a whole.

Productivity improvements and capital deepening which were evident in all manufacturing industries would have contributed to the declining employment in the TCF and transport equipment industries. However, output growth for these industries has been lower than the manufacturing average (Chapter 2), and the employment decline has exceeded the average for manufacturing as a whole.

Table 4.2: **Employment changes by manufacturing industry subdivision,1968–69 to 1994–95** (thousand persons)

Industry	*Persons empl'd. 1968-69*	*Changes over period*				*Persons empl'd. 1994-95*
		1968-69 to 1974-75	*1974-75 to 1981-82*	*1981-82 to 1988-89*	*1988-89 to 1994-95*	
Food, beverages and tobacco	185.6	12.4	-19.3	-2.4	-13.8	162.5
Textiles, clothing, footwear and leather	189.3	-49.8	-21.3	-9.1	-32.9	76.2
Printing, publishing and recorded media	72.0	1.2	5.2	11.4	0.2	89.9
Petroleum, coal, chemicals etc	106.5	5.2	-3.3	-7.6	-10.8	89.9
Basic metal products	86.2	9.4	0.5	-25.4	-16.4	54.3
Structural and sheet metal products	112.9	-3.7	3.8	-8.1	-10.1	94.7
Transport equipment	144.4	2.9	-15.8	-15.2	-34.6	81.7
Other manufacturing	368.1	1.3	-38.8	-25.7	-30.5	274.4
Manufacturing	**1265.0**	**-21.1**	**-89.2**	**-82.2**	**-148.9**	**923.6**

Source: Industry Commission estimates based on ABS data.

While experiencing declining industry employment and below average output growth, the TCF and transport equipment subdivisions have received high levels of protection relative to other manufacturing industries (Chapters 2 and 3). When these trends are considered in a broad industry framework, it appears that higher protection has not improved longer-term employment prospects in these assisted activities.

Industry protection may have reduced temporarily the decline in industry employment opportunities in some instances, for example, in the TCF manufacturing industries. Therefore, there may be short-term associations between changing assistance and employment. However, as industry employment trends are influenced by a range of factors including technological change, business cycle fluctuations and general changes in conditions of supply and demand (eg consumer preferences) as well as industry assistance, such an association does not establish causal links between assistance and employment opportunities, particularly in the longer run.

Over the whole period considered, there appears, if anything, to be a negative link between industry assistance and employment growth — both for the assisted activities in isolation and relative to other activities.

4.3 Implications for average labour productivity in manufacturing

Changes in output per person employed can be seen as the outcome of production, employment and capital investment decisions. As such the measure provides one means of summarising the outcome of a range of different decisions.

However, it has sometimes been viewed as an indicator of the potential for real wages growth. As such, it is an imperfect indicator. Output per person employed is a measure of the average level of production per person employed. As such, it does not measure the additional output generated by an additional unit of labour at the margin, on which competitive wages should be set.

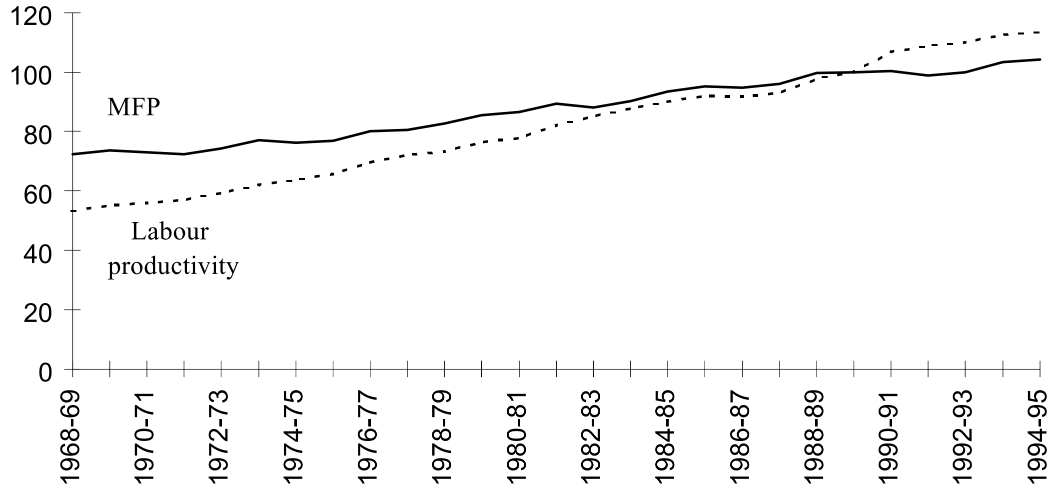
Therefore, in principle, the potential for real wage increases should be based on the *marginal* contribution of labour to an additional unit of output. Growth in the average labour productivity would not be a meaningful indicator of the growth in the marginal product of labour, except under very restrictive assumptions. For example, it would assume that there were no changes in the composition of the industrial labour force. As the current analysis combines all labour effort into a single category, it does not distinguish between labour offering different levels of technical skill or experience. Measures of changes in average labour productivity would not show how the contribution of different groups was changing over time.

This current analysis, nevertheless, does provide information on the factors influencing average labour productivity. This information is derived from a decompositional analysis of the relative growth of labour and capital inputs, output and multifactor productivity. Over the medium term, average labour productivity can be improved by:

- employing labour in the same activity more efficiently or by transferring labour effort to activities which afford higher output per unit of labour input;
- increased commitment of capital; and
- technological change and the better organisation of production (ie multifactor productivity).

Reflecting the joint operation of all of these processes, value added per hour worked in the manufacturing sector has increased at an average annual rate of 3 per cent over the 26 year period to 1994–95 (Figure 4.2). Through the employment of additional capital, labour productivity has grown at a faster rate than multifactor productivity.

Figure 4.2: **Labour productivity and multifactor productivity in the manufacturing sector, 1968–69 to 1994–95** [a] (indexes 1989–90=100)



a Average labour productivity is measured as output (at average 1989–90 prices) per hour worked by employed persons.

Source: Commission estimates.

The relative contribution of each of the above factors can be disentangled through an analysis of growth trends (Table 4.3).

The relocation of labour and capital between manufacturing industries has had little overall impact on average labour productivity over the last three decades. With some variation between growth cycles, the main sources of labour productivity growth have come from growth in the use of capital and from multifactor productivity growth.

Nevertheless, the balance between factors has differed between periods. For example, over the period 1984–85 to 1988–89, manufacturing industry capital stocks grew below the industry output trend. The continued growth in output and relatively stable capital stocks levels afforded an improvement in capital productivity that contributed to multifactor productivity growth.

A different pattern emerged between 1988–89 and 1994–95. Manufacturing enterprises expanded capital capacity ahead of output growth. There was an associated increase in labour productivity due to the growth in capital inputs. However, because there was a higher overall level of factor inputs, multifactor productivity improvements did not contribute greatly to improvements in labour productivity.

Table 4.3: **Decomposition of changes in output per person employed within the manufacturing sector, 1968–69 to 1994–95**[a] (average annual change)

Industry	*1968-69 to 1994-95*	*Subperiods* *1973-74 to 1981-82*	*1981-82 to 1984-85*	*1984-85 to 1988-89*	*1988-89 to 1994-95*
Growth in output per person employed	2.94	2.98	3.61	2.62	3.10
Changes due to					
Growth in labour input per person	0.10	-0.55	0.48	0.45	0.53
Reallocation of labour	0.01	-0.01	0.04	0.46	-0.27
Growth in capital per unit of labour input	1.39	1.28	1.56	0.04	1.89
Reallocation of capital	0.03	-0.02	0.04	0.08	0.20
Growth in multifactor productivity	1.41	2.28	1.49	1.59	0.75

a For details of the disaggregation methodology, see Appendix B.
Source: Commission estimates based on ABS data.

Output per person employed in manufacturing also depends on the hours individuals commit to employment. An increase in hours worked by individual workers increases output per person employed, other things being equal. A decline in hours worked has the opposite effect. In the manufacturing industries, increases in the hours worked per person has raised output per person in three of the four growth cycles, although the relative importance of this change has varied from cycle to cycle. Over the 1973–74 to 1981–82 cycle, the number of hours worked by persons employed declined, contributing to lower measured growth in output per person.

4.4 Summing up

In most manufacturing industry subdivisions, employment declined over the period as the influence of output growth was outweighed by the improvements in average labour productivity over the period. The most important contributions to average labour productivity growth have come from growth in capital per unit of labour and from multifactor productivity growth. Average labour productivity growth, however, is an imperfect measure of the scope for real wage increases. Such increases need be based on changes in the marginal productivity of labour.

PART B: METHODOLOGY

5 INDUSTRY CLASSIFICATION AND THE MEASUREMENT OF CAPITAL

5.1 Introduction

The major focus of this chapter and supporting appendixes is on the definition and measurement of manufacturing industry capital. A priority has been to establish as long a manufacturing industry time series as possible at the industry subdivision level of detail. The ABS does not publish at the disaggregated level, although it provides such a series for manufacturing as a whole.

The study presents a 20 series covering each industry division in the market sector and a 26 year series for each manufacturing industry subdivision. In establishing such long time series, the industry classification of data source information plays a pivotal role in determining the classification adopted. Accordingly, this chapter also discusses the principles of industry classification and the application of standard Australian classifications to the assembly of output and input information by industry.

Section 5.2 discusses industry classifications relating to the industry sector and manufacturing industry subdivision components of the study. Section 5.3 links the concept of capital stocks, as conventionally measured, to the concepts of capital capacity and capital services required for productivity analyses. Section 5.4 then discusses the implementation of these principles to the measurement of capital inputs to production. The measurement of economic depreciation and the value of capital are discussed in Section 5.5, while Section 5.6 sums up the discussion.

5.2 Industry classification

Classification framework

Productivity analyses focus on the relationship between the output of goods and services and use of inputs in production processes. To assist in the analysis of the processes of production and distribution, firms engaged in common activities are divided into industries.

Three basic levels of industry classification are adopted. At the highest level, industries are divided into the ‘market’ and ‘non-market’ sectors (see Chapter 1). This distinction is one of measurement convenience. It has enabled productivity analysis to proceed for some industries (ie the market sector), while recognising that data limitations preclude measurement of productivity for the remainder of the economy (ie the non-market sector).

At the second level of classification, activities are allocated to divisions according to the broad nature of activities and the position of those activities in the production and distribution chain. The market sector is divided into ten industry divisions. These divisions are suitable for gauging general growth trends and industry structure, but are generally too broad to facilitate detailed activity analyses. Accordingly, industry classifications provide a third level of industry detail, that is, industry subdivision, group and class categories to enable progressively more detailed information about industrial activities to be shown. In this study, it has been possible to extend the productivity analysis for manufacturing to eight industry subdivisions.

The remainder of this section discusses in general terms the industry classification developments as they affect this study and the classification of outputs and inputs. The section is supported by Appendix A, which provides additional details of the application of available industry classifications to this study.

The application of standard industry classifications

Two principal industry classifications apply over the period of the current analysis. The Australian Standard Industry Classification (ASIC) which was first applied to 1969 data (ABS 1973) underwent extensive revision in 1978 (ABS 1979) and a partial revision in 1983 (ABS 1985). Throughout these revisions, the industry division structure of the ASIC remained relatively stable, although in some instances individual activities were reclassified across ASIC industry division boundaries. For example, establishments mainly engaged in minor repairs to aircraft, railway and tramway rolling stock and classified to the transport industry division under the 1978 ASIC were reclassified to the manufacturing transport equipment subdivision in the 1983 edition of ASIC.

The ASIC was superseded in 1993 with the introduction of the Australian and New Zealand Standard Industry Classification (ANZSIC) (ABS 1993). This classification was developed for use in both countries for the collection and analysis of industry statistics. The divisional structure of the new classification has a number of similarities to the ASIC divisional structure. In particular, it includes separate divisions for agriculture, forestry and fishing, mining, and manufacturing industries. Nevertheless, there are also some significant changes. For example, wholesale and retail trade, previously in one ASIC division, was divided into two ANZSIC divisions. In addition, a new division was created for accommodation, cafes and restaurants, previously included as a subdivision within the ASIC division recreation, personal and other services. The ASIC personal and other services group, inclusive of video hire, photographic studies and funeral directors, is now included in the ANZSIC services division personal and other services, which also includes religious organisations, interest groups, police, prisons and fire brigades. Because independent estimates of labour and capital inputs and output are not available for most of the activities in the ANZSIC personal services division, all activities in that division are classified to the non-market sector.

Within the manufacturing division, some major restructuring has occurred with the move from the ASIC to the ANZSIC. These changes substantially influence the nature of subdivision data available for this study. In particular:

- the group paper and paper products has been reclassified from the ASIC subdivision paper, paper products, printing and publishing to the ANZSIC subdivision wood and paper products;
- the groups rubber products and plastic products have been reclassified from the ASIC subdivision other manufacturing to the ANZSIC subdivision petroleum, coal, chemical and associated manufacturing;
- the group leather products has been reclassified from the ASIC subdivision other manufacturing to the ANZSIC subdivision textiles, clothing footwear and leather products; and
- transport equipment, a subdivision in ASIC, has been combined within a new manufacturing subdivision machinery and equipment manufacturing.

In this study, ANZSIC based classifications are adopted for the full period under study. This has necessitated the joint use of published ANZSIC series and ASIC based information linked to ANZSIC. Where ANZSIC data are not available for the full period of the analysis, trends for the closest related ASIC industry have been used to project ANZSIC industry data backwards (Appendix A). While this has been relatively straightforward for industry divisions, it is less so for manufacturing subdivisions. To improve the match between data in this area, the ANZSIC subdivisions: wood and paper products; non-metallic mineral products; other machinery and equipment; and other manufacturing have been aggregated to form an 'other manufacturing' group. Because of the exposure of the transport equipment sector to changes in industry policy, it has been retained as a separate 'subdivision' to enable separate analysis of trends in this industry.

5.3 Capital stock and capital service measures

Capital assets have a productive life that extends beyond the period of acquisition. They differ from intermediate goods and services which are generally produced and used within a single period (eg in one year). Underlying the value of capital stock is an expected stream of productive services and possibly some scrap or second hand sales value when the asset is retired.

The basic definition of the value of capital stock adopted in Australia and overseas and applied in this study is:

> ... the value, at a given point in time, of the capital assets that are installed in producers' establishments. Capital assets consist of the various durable goods that are included in gross fixed capital formation (GFCF) in the national accounts. ... In general, goods included are **durable** (lasting more than one year), **tangible** (intangible assets like patents and copyrights are excluded), **fixed** (inventories and work-in-progress are excluded — although mobile equipment is included) and **reproducible** (natural forests, land and mineral deposits are excluded). The following goods types are included in GFCF: machinery and equipment, vehicles, residential and other buildings ... . (OECD 1993, p. 8)

This is a limited definition of 'capital' as it might be applied to the measurement of wealth or the estimation of the total resources available for production and consumption. In particular, it excludes intangible produced assets such as patents, licences and copyrights. It also excludes non-produced assets such as land and natural resources.[1]

There are two distinct measures of capital. The first measure is capital capacity which reflects the level of capital input available in a particular year. The second measure is the value of capital to individual owners or, when aggregated, an industry or the nation. The two measures are linked because the value of capital at any point in time is dependent on its expected productive potential at that point and into the future. Both measures of capital are stock concepts. Nevertheless, the concepts underlying the measurement of capital (and labour) for productivity analysis are conventionally interpreted as flow concepts.

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[1] The importance of natural resources to economic analysis and management is now formally recognised by the inclusion of natural resources in a system of satellite accounts to the internationally recognised System of National Accounts (CEC *et al.* 1993). In addition, balance sheet accounts are now being developed to include tangible non-produced assets (ie environmental assets and natural resources) (see ABS 1997e). However, these developments have not as yet provided information on natural resources integrated with industry data that would support studies of industry productivity growth in the current context.

Relationship between capital capacity and capital services

The difficulty in estimating capital services derives from the fact that capital items are durable and generally used by owners. If all capital were rented, transactions in the rental markets would fix the price and quantity of capital services in each period. However, such markets do not always exist and relevant market data are not generally available to estimate the price and quantity of capital services. Hence, indirect methods have been devised for inferring these service values.

The link between capital capacity and capital service flows may be established simply by assuming capital services are proportional to installed capacity. In this case, capital utilisation could be a constant proportion of installed capacity and growth in the level of available capital inputs could be representative of the change in service flows. However, the actual service flow coming from that capacity in any one year is likely to vary with the business cycle and other market fluctuations, lags between the installation and commissioning of capital, changes in technology and changes in market interventions.

One approach to overcome this problem would be to adjust the estimated capacity for the influences of these factors. In practice, this may be a difficult task due to problems in obtaining a workable definition of utilisation. For example, is a machine being utilised when it is processing material but not waiting on material from another part of a production process; is a building utilised only during business hours or for the whole period that it provides storage and protection facilities; is a road being utilised when it is being driven on or for the whole period it provides a service amenity? Even if an adequate definition could be devised, the problem would shift from one of measuring available capacity to one of measuring capacity utilisation.

An alternative approach is to use a direct estimate of the productivity of capital capacity to assign a service weight to the estimated capacity level. One method of estimating capacity service weights is to use econometric techniques to regress growth in output against growth in capital and labour inputs, and other factors influencing growth. The relevant weights over the sample period would be given by the regression coefficients.

Another direct method is to use capital and labour income shares in value added as weights. Under the assumptions of constant returns to scale and perfect competition, the respective income shares are equal to the output elasticities of capital and labour. Information on labour and capital input shares are available from industry data sources and are widely used in growth accounting exercises to estimate the output elasticities of labour and capital input. The growth accounting model and the data sources used in this study to estimate the relevant capital and labour input shares are described in Appendix B. A detailed derivation of the growth accounting model is provided in Appendix D.

To the extent that changes in capacity utilisation are due to cyclical conditions, technological or structural change are reflected in changing income shares. They are also reflected in estimates of the service flows provided by capital inputs.

Estimating capital capacity

Survey estimates of capital capacity are not available at either the industry division or the manufacturing industry subdivision levels of aggregation. It is therefore conventional for such measures to be obtained from investment information and assumptions concerning the likely pattern of productivity decline and retirement of investment (ie asset age/efficiency profiles). Such techniques are collectively known as perpetual inventory methods (PIM).

Capital capacity series can be obtained directly from investment information using PIM procedures. They can also be obtained indirectly from value of capital series using simplifying assumptions about the relationship between capital capacity and the value of capital stocks. A majority of OECD countries now use the PIM approach to make estimates of the value of capital stocks. In Australia, value of capital series derived using the PIM approach are available at the industry division level of aggregation. The industry divisional productivity analysis presented in this paper utilises this information, and simplifying assumptions, to translate information on value of capital to capital capacity measures (Appendix B).

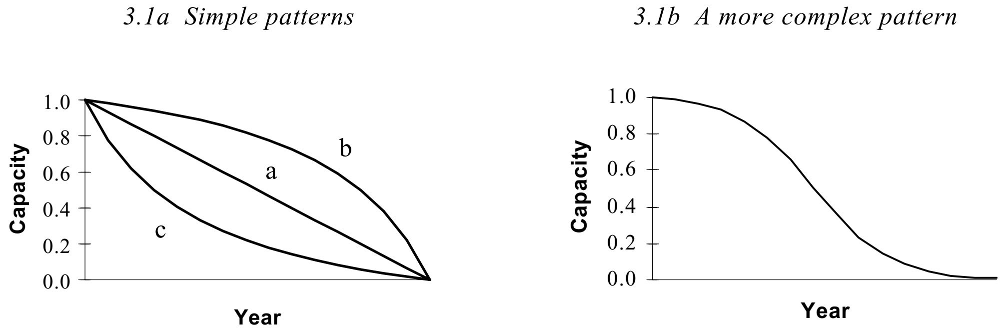
For manufacturing industry subdivisions, neither value of capital nor capital capacity series are available. The Commission has therefore estimated such series using the sources and methods discussed below. Greatest emphasis has been placed on the development of capital capacity series. The following discussion is supported by Appendix C, which provides a more technical exposition of the procedures followed.

Selection of an age efficiency profile

The basic issue in the application of the PIM estimation of capital capacity is the selection of an appropriate asset age/efficiency profile for capital items. This age/efficiency profile is determined by factors such as expected wear and tear, technological change and the organisation of industry.

One of three broad approaches may be considered, depending on views concerning how the productivity of an asset declines over its life. In one case it is assumed that productivity declines in a straight line fashion with an equal absolute loss of productivity occurring in each period (Figure 5.1a, case a). Under this approach, the proportional decline in capacity is greatest towards the end of the working life of an asset. Secondly, it may be assumed that capacity declines most rapidly towards the end of the life of the asset (case b). Thirdly, it may be assumed that capital capacity declines most rapidly in the earlier stages of the life of an asset (case c). A light globe is an extreme example of the second case, as it is expected to glow as brightly (for practical purposes) on the last day of its useful life as on the first, with its service life suddenly coming to an end when it blows or is replaced. An extreme example of the third case is an intermediate good which is used up in the same period that it is produced. However, such items would not be included in estimates of capital stock because they do not meet the durability criterion applied through the definition of capital stocks.[2]

Figure 5.1: **Possible capital asset age/efficiency profiles**



In principle, asset age/efficiency profiles need not be restricted to one of these simplifying cases. For example, the decline in capital capacity could follow a pattern that characterises the growth and decay of natural systems (Figure 5.1b). Asset efficiency of use could decline slowly at first, as the capital good represents the producer's preferred technology and operates with minimum

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[2] A one-year rule is frequently applied to distinguish capital from intermediate goods. Under the one year rule, if an item will be used "...repeatedly or continuously in other processes of production for more than one year" it would be treated as a fixed asset. If it is used for one year or less, it would be an intermediate good (see CEC *et al.* 1993, p. 222).

attention. As the capital good ages, the rate of efficiency decline would reach some maximum as newer, more efficient models come onto the market and as an increasing number of parts wear out and refurbishment begins. The decline in efficiency could taper as refurbishment and/or repair and maintenance inputs reach relatively high levels. At some point, refurbishment, repairs and maintenance no longer support continued operation of the asset in production. In this set up, the capital good would cease to be economically viable when the present value of expected revenues are exceeded by the expected repair, maintenance and refurbishment costs or net benefits of alternative activities.

Coincidently, these approaches to measuring capital capacity correspond to the procedure for the measurement of the value of capital stocks using the PIM. However, they are not equivalent except in the case of the geometric decay of assets (ie case ‘c’ in Figure 5.1a). Under geometric decay, the dual relationship between declining productivity and declining asset value is captured by a common depreciation parameter. On the other hand, straight line depreciation in the value of capital, which is commonly applied in national accounting studies and studies of wealth (see CEC *et al.* 1993), does not generally translate to straight line asset capacity decay (Appendix C).

At this stage, there are no agreed patterns or rates of capacity decay that can be applied at the industry level. A number of studies have adopted a geometric pattern of capacity decay based on evidence that asset values decline, if anything, according to a geometric pattern (see discussion on economic depreciation below and Appendix C). Imputation of geometric asset decay functions has been a convenient way of reflecting this price information through the capital capacity series.

In its assessment of the patterns of decay of asset efficiency, the United States Bureau of Labour Statistics concluded, after consultation with industry, that it is most appropriate to assume that capacity declines more rapidly as an asset ages (case ‘a’, Figure 5.1a) (BLS 1983). In the BLS methodology, the asset decay function was used directly to obtain a series of capital capacity. The ABS uses a linear approximation to the BLS’s preferred asset decay function (Appendix C).

In another approach to the problem of estimating capital capacity for OECD productivity work, Meyer-Zu-Schloctern and Meyer-Zu-Schloctern (1994) used gross capital stock data as a measure of capital input in the production process. Gross capital stocks were estimated by a delayed decay method, whereby scrapping begins 5 years after the capital asset has been installed and continues according to a straight line schedule until all assets of a particular vintage are scrapped. This method gives an age efficiency pattern which approximates the more complex age efficiency profile presented in Figure 5.1b.

In this study, growth in capital capacity is estimated using the more complex (or generalised logistical) method. This method embodies key features of the alternative methods while maintaining more flexibility than the alternatives for incorporating new information. It captures the gradual efficiency decline in the early years of assets' effective working lives — a feature of the methods adopted by the BLS, OECD and ABS. In addition, it captures some attenuation in the later part of the asset decay series which is a feature also found in the OECD, ABS and geometric decay methods. Coincidently, the asset price information that is implicit in the generalised logistical formulation (along with the hyperbolic decay formulation) declines geometrically over a certain range. These methods therefore are not inconsistent, in principle, with empirical information suggesting that second hand asset prices decline geometrically (Appendix C).

Despite the substantial conceptual differences between the alternative methods, measured year-to-year growth in capital input growth over the 26 year period examined differs little (Appendix E). This is not the case with the level of capital values. This issue is discussed below in the context of economic depreciation and the value of capital.

5.4 Implementation of capital stock measurement principles for manufacturing industry

Investment series

The first step involved in constructing a capital capacity and associated value of capital series for the manufacturing industry subdivisions (in common with any other level of industry aggregation) is to estimate gross fixed capital expenditure.

The ABS, in its capital stocks estimation work, uses a measure of gross fixed capital expenditure for the manufacturing division derived from income taxation statistics that provide separate annual information for equipment. It also uses building activity and engineering construction survey information for its estimates of gross fixed capital expenditure on non-dwelling construction. These series are updated annually. Lattimore (1989) used measures from the ABS annual manufacturing census for plant and equipment and building and structures. However, between 1984–85 and 1992–93, census-based capital expenditure data are only available for 1989–90. To overcome this data gap, Lattimore used information for 9 industries from the ABS survey of new capital expenditure to project 34-industry census measures forward from 1984–85 to

1987–88 (the last year in his series). Chand *et al.* also used gross fixed capital expenditure from the census of manufacturing establishments obtained from UNIDO Industrial Statistics via the Australian National University's International Economic Data Bank (IEDB).

In principle, production and capital input data for productivity analysis should be drawn from the same basic data source. As relevant production information is drawn from the ABS's annual census of manufacturing industry, this source would also be the favoured source for capital expenditure information. However, given the non-availability of investment data over the 1984–85 to 1992–93 period, other sources need to be considered.[3] Income taxation based estimates reported in the national accounts do not provide the industry detail required and are therefore not a feasible alternative.

This study therefore uses information from the quarterly survey of private new fixed capital expenditure that provides investment information for the two commodity groups, buildings and structures, and equipment, plant and machinery. The quarterly survey has the advantage that it provides a long time series, and new information each quarter. It therefore provides a reliable source for updating and extending the capital stocks series estimated in this study.

However, the series also has a number of disadvantages. First, it refers to only new capital expenditure and, in so doing, does not reflect the effects of sales of second hand assets among the nine manufacturing industry sectors adopted. Accordingly, it is assumed that assets are only acquired when new. In addition, based on input-output data, it is assumed that assets are retired when the implicit value (at constant prices) is equal to 7.5 per cent of the relevant acquisition value (see Appendix C).

Second, the series refers to private investment and does not include investment by public sector enterprises within manufacturing subdivisions. This study assumes that changes in private enterprise capital stocks (the dominant ownership group in manufacturing) are representative of the industry subdivision total.[4]

Finally, as discussed above, the surveys of private new capital expenditure are management unit (or enterprise) surveys. As such, the methodology used here

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[3] It should be noted that the collection of gross fixed capital expenditure was resumed in the 1992–93 manufacturing census, the year the ANZSIC industry classification was introduced. The resumption of capital expenditure data collection offers the prospect that capital stocks estimates could be based on census data in the future.

[4] This assumption may lead to discontinuities in the estimated series as public enterprises are privatised. The methodology adopted in the current study does not allow for the shifting of assets between the private and public sectors due to changes of ownership.

has assumed that capital expenditure predominantly relates to industry activities in which the enterprises are mainly engaged.

Despite these definitional differences, the year-to-year changes in the national accounts capital expenditure measures and the private new investment series used in this study parallel each other. As might be expected, the level of capital expenditure in the private new capital expenditure series is somewhat lower than the national accounting series, although the gap has been narrowing.

Choice of price indexes and changing quality of assets

For estimation of capital capacity using a PIM methodology (including the generalised logistical method adopted in this study), investment flows must be revalued to constant prices to enable capital capacity and the implicit value of capital to be aggregated across vintages for each period.[5] If there are no changes in asset quality and price changes for all investment items are the same, a single fixed weighted investment price index would suffice to revalue investment from current to constant prices. However, if the quality of investment items and relative prices change over time, more complex formulations are required.

Ideally, the constant price estimates of investment should include the positive effects of quality improvements and the negative effects of declines. Consistent with this principle, available price index information is compiled according to a ‘user cost’ pricing principle. The ABS describes this principle in the following way:

> The objective of the price indexes published by the ABS is to measure changes over time in the price of the same items, which means items of the same quality. (ABS 1990, Appendix IX)

This study uses ABS investment price deflators for components of the national accounting aggregate private gross fixed capital expenditure. The price deflators incorporate, to varying degrees, the effects of underlying quantity

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[5] Using 1989–90 as the reference year for prices, manufacturing industry investment at constant 1989–90 prices is estimated by revaluing current period investment flows by an appropriate price deflator. $I^{ij}_{t,1989-90} = \frac{P^{ij}_{1989-90}}{P^{ij}_{t}} I^{ij}_{t}$ where $I^{ij}_{t,1989-90}$ is investment by manufacturing industry j in investment commodity i in year t valued at 1989–90 prices, P^{ij}_{t} is the investment price index for investment in commodity i by industry j in period t.

weight changes and, to a lesser extent, quality changes (ABS 1990, Appendix IX).[6]

Price indexes for non-dwelling construction are estimated by the ABS indirectly using indexes of costs, including builders' margins, of inputs into the relevant investment commodities (eg the cost of steel, bricks and mortar to building construction). The relevant input prices are weighted together using a combination of fixed and variable input weights determined for each of the investment commodities included in the aggregate price index. Once the individual investment-good price indexes are formed, they are weighted together to form an aggregate investment-good price index using output weights. Under the assumptions of perfect competition and market clearing, appropriately weighted input price indexes should be representative of indexes of the price of investment-good supply. However, the input cost method does not directly capture quality changes embodied in investment goods and generally, adjustments to investment-good price indexes for such quality changes are not made in the estimation process.

Deflators for plant and equipment are estimated directly using the price indexes for the supply of imported and domestically produced items. A combination of fixed and variable weighted indexes are used to capture changes in the composition of investment commodities supplied. Under this approach, quality changes embodied in investment goods are taken into account when the relevant supply price indexes are measured net of quality improvements. Special adjustments are made by the ABS for major shifts in quality. For example, quality improvements in computer equipment are incorporated by the use of a US Bureau of Economic Analysis (BEA) quality adjusted computer price index.

Because investment price indexes underlying the national accounting investment aggregates are not always available by industry, some recourse must be made to aggregate price indexes as proxy measures for industry flows. This practical approach is necessarily followed in this study, as it was, to varying degrees, in Walters and Dipplesman (1985), Lattimore (1989) and Chand, Forsyth, Sang, and Vousden (forthcoming). The approach is justified on the grounds that movements in component investment price series tend to be highly correlated with aggregate investment price changes.

Overall, when technological change and product improvement is embodied in capital and relevant price growth is not discounted to reflect such

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[6] Price changes in exiting assets due to obsolescence and wear and tear are brought into account in the PIM through depreciation. The change in value of existing assets, at constant prices, is therefore determined by the selection of asset life rather than investment price indexes. The selection of asset lives is discussed below.

improvements, capital capacity valued at constant prices would be understated. When capital input growth is understated, output growth due to product improvements embodied in new investment would be measured as a multifactor productivity improvement for industry, other things being equal.

Average asset lives

> Information about how long assets remain in capital stock, ie asset service lives, is both crucial to the overall accuracy of the stock estimates and is usually of poor quality. (OECD 1993, p. 9)

Australia does not have any comprehensive empirically based data on the asset life of capital. The ABS used Australian taxation lives, information about asset lives in OECD countries and other information to arrive at average asset lives during the 1960s of 19 years for manufacturing industry private machinery and equipment, and 39 years for non-dwelling construction (Walters and Dipplesman 1985, pp. 59–62). This benchmark asset life is then reduced by 5 per cent for each subsequent decade to allow for the effects of accelerating technological change and industry restructuring (see below).

Taking into account the assumed reduction in asset lives over time, the implicit rate for the 1980s is around 17 years for machinery and equipment, fractionally below the (arithmetic) average for selected OECD countries (Table 5.1). There is, however, substantial variation between individual country estimates. The Australian average falls below the averages for countries such as Canada and the United Kingdom, above the average for Japan, but is similar to the measure for the United States. A Bureau of Industry Economics (BIE 1985) study suggested average asset lives of 13 years — estimates that are below other estimates for Australia and well below the OECD average.

Table 5.1: **Comparison of asset service lives of machinery and equipment by ANZSIC sector, circa 1980s** [a]

			OECD countries [b]						
Industry	*ABS*	*BIE* [c]	*Canada*	*USA*	*Japan*	*UK*	*OECD average* [d]	*ABS average/ BIE relativities*	*ABS average/ OECD relativities*
Food, beverages and tobacco	17	15	22	21	11	26	20	20	18
Textiles, clothing footwear and leather	17	10	21	15	10	25	18	14	17
Printing, publishing and recorded media	17	11	30	15	12	32	20	15	18
Petroleum, coal, chemicals and associated products	17	12	20	17	10	24	18	16	17
Metal products	17	14	22	26	12	26	21	19	19
Transport equipment	17	12	30	16	11	27	19	16	17
Machinery and equipment (excluding transport equipment)	17	10	19	18	11	25	19	14	17
All other manufacturing									
Wood and paper products	17	11	24	14	11	28	18	15	16
Non-metallic mineral products	17	15	26	19	9	24	19	21	17
Other manufacturing	17	11	20	16	11	24	18	15	16
All other manufacturing[d]	17	12	23	16	10	25	18	17	17
Total manufacturing [d]	17	13	22	17	11	26	19	18	17

a As published by OECD 1993. It is assumed that these rates were applied in the respective studies or countries during the 1980s. ABS and BIE data for Australia include vehicles. The ABS applies a benchmark asset service life of 19 years for the 1960s; this benchmark asset life is then reduced by 5 per cent each decade to give about 17 per cent in the 1980s.

b OECD countries included in the study are: Canada, United States, Japan, Australia, Austria, Belgium, Finland, France , Germany, Iceland, Italy, Norway, Sweden and the United Kingdom.

c Service lives obtained by taking arithmetic average of lives for plant and equipment for 34 manufacturing groups reported in BIE 1985 and applied in Lattimore 1989. The estimates were originally developed in Karpouzis and Offner (1983), where it was judged that US Internal Revenue Service service lives provided the best proxies for comparable Australian industries.

d Arithmetic averages.

Sources: Walters and Dipplesman 1985, BIE 1985 and OECD 1993.

Approaches to estimating asset lives differ between studies, with data sources varying between expert opinion, industry surveys, statistical analysis and taxation requirements. It is hard to tell whether reported differences reflect actual differences in country practices, or are statistical artefacts reflecting different estimation approaches or timing.

For the asset group machinery and equipment, the approach taken in this study is to adopt the arithmetic average applied by the ABS to maintain consistency with ABS economy-wide studies of capital stocks. In order to reflect the likelihood that asset lives differ between industries, the industry relativities indicated in Lattimore (1989) are adopted in this study. The resulting estimates suggest a range of 14 years for the industry subdivisions textiles etc and machinery and equipment, to 21 years for non-metallic mineral products. Age relativities implicit in OECD information provide a somewhat narrower range, from 16 years for wood and paper products and other manufacturing to 19 years for metal products.

Sensitivity testing shows that the net value of capital over the range of asset lives considered are quite sensitive to alternative asset life assumptions (Appendix E). On the other hand, annual growth in capital stocks are not very sensitive to alternative asset life assumptions.

Information about asset lives for non-dwelling construction for different manufacturing subdivisions is not available. In its review of asset lives for non-dwelling construction, the ABS provided a single average of 39 years weighted across new buildings (45 years), construction (other than building) (60 years), and alterations and additions (25 years). BIE (1985) and Lattimore (1989) both assumed a uniform asset life of 40 years for all building and structures across all industries.

Following the ABS, a uniform asset life of 39 years for all manufacturing industry subdivisions is applied in this study to non-dwelling construction.

Changing asset lives over time

The average asset life for an industry or asset group may be subject to technological change (eg adoption of computer based technologies), economic change (eg a change in the composition of industries) and changes in the relative cost of acquiring new capital compared to the cost of repairing the old. In principle, these changes may lengthen or shorten average asset lives. Walters and Dipplesman (1985) interpreted fragmentary evidence to suggest that, on average, these changes have favoured a shift towards shorter asset lives. This view has been implemented in this study, with average asset lives for equipment shortening by around 5 per cent each decade (ie around 0.5 per cent a year). This procedure gives implicit asset lives for equipment for the 1990s of around 16 years. For non-dwelling construction, the ABS makes no adjustment in asset lives over time because evidence of declining asset lives was not as strong for this sector as for others (Walters and Dipplesman 1985).

The United Kingdom also assumes that asset lives have declined since the 1950s and Germany has made one-time reductions in service lives for some assets to reflect premature retirements in declining industries (OECD 1993). For most other countries, service lives are assumed constant over time. The

OECD survey found evidence for service lives fluctuating, but no longer-term trends supporting changing asset lives in either direction. Nevertheless, it concluded:

> Even if service lives of assets of a given type are not changing, it would still be right to assume declining service lives in PIM estimates **if** the asset mix of their capital stocks is changing to include more relatively short-lived assets **and if** the service lives used in the model are ‘overall’ averages each covering several different types of assets. (OECD 1993, p. 30)

Computers and related equipment are often referred to as generally having shorter lives than other assets and as becoming a more important item in the asset mix of industries. The ABS adjustment applies a judgement that there has been a systematic shift along these lines in Australia, shortening average asset lives.

Lattimore (1989) found that if obsolescence was accelerated by 0.5 per cent per year, trend growth rates of the net value of capital stocks would be about 4.2 per cent over the 34 year period 1954–55 to 1988–89, compared with 4.7 per cent over the same period with no accelerated obsolescence. On the grounds that different asset lives, varying rates of obsolescence and different rates of quality augmentation make little impression on the reported changes, Lattimore assumed no change in asset lives in his analysis. (He also assumed that existing price deflators completely reflect any increases in the quality of new assets.)

In this study, the assumption of declining service lives is applied to each manufacturing subdivision at the same rate as is applied to the estimation of capital stocks of equipment for manufacturing by the ABS. Although this treatment is of conceptual importance in determining the nature and determinants of structural adjustment in industry, sensitivity testing confirms Lattimore’s finding that alternative assumptions have little effect upon capital stock and growth measures (Appendix E).

Other issues

Asset retirement functions

A number of different assumptions can be made concerning the profile of asset retirement around the mean asset life. Four methods are conventionally identified (OECD 1993, pp. 18–21):

- linear retirement pattern for which it is assumed that assets are discarded at the same rate each year until twice the average service life. This method is applied in the United Kingdom;

- delayed linear retirement assumes assets are discard over a shorter period than under the linear method. This method is applied in New Zealand where it is assumed that assets are retired over a period of ± 20 per cent of the average life;
- bell shaped retirement which allows for degrees of skewness or peakiness. Variants of this method are applied in France, Germany, Austria, Finland, United States, Australia, Sweden and Canada (alternative estimates); and
- simultaneous exit, where all assets are retired at the same age. This method is applied in Canada, Japan and Norway.

Because the plans of individual firms differ and because of unforeseen events, there is almost certainly some difference in the retirement of individual assets. The linear, delayed linear and bell shaped retirement functions attempt to reflect this.

In common with a number of countries, the ABS adopts bell shaped 'Winfrey' curves that were obtained from studies of the retirement of industrial assets in the 1920s and 1930s. Others use non-linear mathematical functions. The particular Winfrey curve adopted by the ABS has three quarters of manufacturing assets being retired within 30 per cent of the asset mean life. The ABS tested the sensitivity of its estimates to alternative asset life distributions. It found that, for 1979–80, the net capital stock of private manufacturing equipment estimated according to its preferred Winfrey distribution was within 5 per cent of the value of capital stock, assuming simultaneous exit. Growth over the 10 year period 1969–70 to 1979–80 was almost identical between the two methods, as intuition would suggest (Walters and Dipplesman 1985, p. 72). Due to the added computational complexity, dated empirical information and likely small statistical effect, the present study adopts the simultaneous exit approach, as have Lattimore and Chand *et al.*

Treatment of second hand assets

In principle, investment should be measured as the purchases of new and second hand assets less disposals. The ABS define investment or gross fixed capital formation in the following manner:

> Gross fixed capital formation is the expenditure on additions to durable goods (purchases, both new and second-hand and own account production) *less* sales of similar second hand goods. (ABS 1990, p. 59)

In this study, investment data by manufacturing industry subdivision is measured as new capital expenditure by private businesses in Australia:

> New fixed tangible assets refers to the acquisition of new tangible assets either on own account or under financial lease and includes major improvements,

> alterations and additions. In general, this is expenditure charged to fixed tangible assets accounts excluding expenditure on second hand assets unless these are imported for the first time. (ABS 1996b, p. 15)

Such a measure proxies gross fixed capital formation at the manufacturing industry subdivision level to the extent that there are either no transactions in second hand assets, or that sales and purchases of such assets are between businesses in the same industry subdivision (eg between businesses in the food, beverages and tobacco industry subdivision). When there are inter-subdivision or inter-division sales, the resulting capital stocks estimates would be biased. If an industry is expanding through the acquisition of second hand assets, there would be a downward bias in the level and growth of capital stocks by ignoring such acquisitions. When an industry is contracting through the sale of second hand assets, there would be an upward bias due to a failure to take account of existing assets. The size of the bias depends on the initial value of assets and the age of assets when they enter the second hand market. The older an item, the smaller the impact on industry aggregates.

The ABS estimates gross fixed capital expenditure based on statistics of depreciable assets available from the Taxation Commissioner. The resulting measures incorporate the effect of transactions in second hand assets. The estimates by BIE and Lattimore are based on data from the ABS census of manufacturing establishments which also take into account transactions in second hand assets. The close and narrowing correspondence between the ABS gross fixed and private new capital expenditure series (Appendix E) indicates that, at least at this level of aggregation, any second-hand asset bias is likely to be small.

Treatment of leased plant and equipment

Broadly, there are two types of leasing arrangement — operational leases and financial leases. Operating leases are a form of production in which the owner, the lessor, provides a service to the user, the lessee, the output of which is valued by the rental which the lessee pays the lessor (see CEC *et al.* 1993, p. 139). In the case of operating leases, it is the lessor who undertakes investment and the lessee who obtains a service covering the use of machinery, equipment and structures.

In contrast, financial leasing is not a process of production but rather an alternative method of financing investment:

> Financial leases may be distinguished by the fact that the risks and rewards of ownership are, de facto, transferred from the legal owner of the good, the lessor, to the user of the good, the lessee. In order to capture the economic reality of such arrangements, a change of ownership from the lessor to the lessee is deemed

> to take place ... The lessor is treated as making a loan to the lessee which enables the latter to finance the acquisition of the equipment. (CEC *et al.* 1993, p. 139)

The incidence of financial leasing of capital goods has grown considerably and Australian accounting standards were changed in the mid-1980s to incorporate a financial treatment of such leases (see Australian Accounting Standard 17 (Accounting for Leases)). Implementation of this standard was phased in over the period 1986 to 1989. The standard was implemented by the ABS in its series of private new capital expenditure from 1985–86 (ABS 1996b). Data were collected on an industry of ownership and industry of use basis for the years 1985–86 and 1986–87 and used to revise capital expenditure series back to 1979. Data used in this study are therefore provided according to the earlier accounting standards to 1978, and to the new standards subsequently.

The prevailing accounting standards and attendant treatment of financial and operating leases are incorporated into capital stocks estimates for the manufacturing industry in this study. In an assessment of the treatment of financial leases, the ABS advised that few significant financial leases occurred in manufacturing before the accounting change (see IC 1995c). To the extent that this is the case, investment and capital stocks measures for the manufacturing industry derived using the generalised logistical approach (or other PIM approach) would not be significantly understated in the period before the change in accounting standards.

The distinction between operation and financial leases adopted in this study is also adopted in ABS capital stock estimation, overseas studies that are based on international national accounting standards (see CEC *et al.* 1993) and is implicit in the methods adopted by Chand *et al.* (forthcoming).

Another approach was adopted in BIE (1995) and Lattimore (1989), whereby capital used indirectly by the manufacturing industry through all kinds of lease arrangements was brought into account in manufacturing capital stock measures. A logistic function was used to take into account the rapid growth in the rent and leasing of plant and equipment during the 1960s and 1970s and its leveling out in the 1980s. The resultant investment calculation found that, in 1984–85, leased plant and capital accounted for 13 per cent of the level of plant and equipment. However, because capital stocks increased gradually as a result of structural change, the year-to-year growth in capital stocks was not sensitive to the inclusion of hired equipment (Lattimore 1989).

Nevertheless, the approach adopted in this study conforms to an economy-wide view in which it should be possible to aggregate across industries (including the manufacturing and leased goods industries) to form a national measure of capital stocks. Such measures could then be used, without gaps or overlaps, to analyse capital growth, changing productivity and output at the national level.

5.5 Economic depreciation of the value of capital

In general, the income earning capacity of an asset and, hence, its capital value, will decline as it approaches the end of its effective working life. The above discussion has focused on measuring the quantum of capital capacity available in any one year for productive activities. On the other side of the capital equation is the value of capital, which is conceptualised as the present value of the expected income stream from surviving assets. Studies with a national accounting or national wealth focus are concerned with this aspect of capital measurement (CEC *et al.* 1993, p. 287). Current information available from the Australian national accounts is also primarily concerned with value of capital series.

The two basic methods commonly used to trace out the decline in the net value of an asset are the straight line method and the geometric decay (or diminishing balance) method. Under the straight line method of depreciation, the value of assets are depreciated by equal amounts each year, so the decline in asset value is proportionately less in the earlier years of existence than in the later years. The geometric decay, or diminishing balance method, assumes that the net value of assets declines in equal proportions in successive years rather than in equal amounts. The method assumes that assets suffer their largest fall in value in the early periods after commissioning.

The straight line method, which has been adopted by the ABS as providing a reasonable approximation to plausible assumptions concerning the decline in asset values, is in line with contemporary overseas PIM estimates and coincides with international statistical standards (Walters and Dipplesman 1985). The straight line approach remains the main PIM adopted in official studies (OECD 1993) and was also applied in the Lattimore (1989) and the earlier BIE (1985) studies.

The rationale underlining the declining balance approach is that empirical evidence suggests that the market price for second hand assets, if anything, could be represented by geometric patterns (see Hulten and Wykoff 1981 and Hulten 1990). Hulten also suggests that the same rate of decay traces the decline in asset value (ie economic depreciation) and the decay in capital capacity.

The declining balance method to jointly estimate capital value and capital capacity series has been adopted in a number of US studies including Fraumeni and Jorgenson (1986), Jorgensen, Gallop and Fraumeni (1987), Boskin, Robinson and Huber (1989) and Boskin, Robinson and Roberts (1989) who use the Hulten and Wykoff depreciation parameters. The approach was also used by Leamer (1988) in a cross country study and Chand *et al.* (forthcoming) in their multi-country study of productivity growth.

The approach adopted in this study for the manufacturing industry is to first estimate asset age/efficiency profiles according to the method outlined above and then to measure the value of capital as the present value of the expected income stream implied by the age/efficiency profile (Appendix C). Economic depreciation is then equal to the change in the value of assets in successive periods. For non-manufacturing industries in the market sector, value of capital estimates obtained by the ABS using the straight line method have been adopted.

Overall, while there are important conceptual differences between the methods, the choice has very little effect on the rate of growth in the value of capital (Appendix E). Estimates of the level of capital stocks are also similar, although methods which assume convex asset age/price profiles (ie the declining balance and logistical methods) yield values of capital that are lower than the straight line method. This reflects the fact that the age/price profiles for these methods lie around or under the straight line age price/profile (Appendix C).

Gross and net recording of the value of capital

The value of capital can be measured in gross or net terms. Gross capital stock represents the accumulated acquisition cost of existing physical productive assets available at a particular time. Gross capital stock may be expressed in current or constant base-period prices. Net capital stock measures the depreciated value of the existing gross capital stock and, in competitive equilibrium, is equal to the value of owning the asset, which in turn is equal to the present value of the expected rents to be produced over the remaining life of the asset. Measures of net capital stock are related to assets' productivity, although, except under special conditions discussed above, they do not also measure the productive capacity of capital in the current period.

In this study, gross and net values of capital stocks are used, under simplifying assumptions, to provide one estimate of capital capacity for sensitivity testing of alternative methods (Appendix E).

5.6 Summing up

This chapter has established a generalised method of measuring capital capacity by industry. It has shown that it is possible to apply a single set of procedures to estimate both the capital capacity available for production and the value of capital. The integrated method uses available information about changes in the relative efficiency and value of assets over time. However, the study shows that there are many gaps and deficiencies in available information. Filling gaps, such as assets lives and changes in expected lives and quality between asset vintages, would substantially improve our general understanding of the processes of capital formation and growth.

Examination of different estimation methods and data assumptions shows that estimates of capital levels are sensitive to measurement assumptions and conventions. However, measures of year-to-year capital growth are relatively insensitive to different assumptions. Estimates of the growth in capital inputs are the key item used in productivity analyses presented in this paper.

PART C: APPENDIXES

APPENDIX A
INDUSTRY CLASSIFICATIONS FOR THE ANALYSIS OF PRODUCTIVITY

A.1 Introduction

Chapters 1 and 5 discuss the pivotal role industry classification plays in productivity analysis. The industry classification adopted in this study is the Australian and New Zealand Industrial Classification, 1993 (Cat. No. 1292.0) (ANZSIC). This classification was introduced into the Australian National Accounts, a central data source for this study, in 1993–94 (ABS 1997a) when ANZSIC based series replaced the previous ASIC based series.

The availability of information from national accounting and other basic data series is a constraining factor in applying the ANZSIC classification. This appendix sets out the industry sector (1-digit ANZSIC codes) and the manufacturing industry subdivision-division (2-digit ANZSIC codes) classifications adopted. Because ASIC based data series are used to project ANZSIC based series back in time, this appendix also presents a working correspondence between the ANZSIC and ASIC industry classifications.

Data sources for the economy-wide and manufacturing industry productivity measures and the joint use of ASIC and ANZSIC data are outlined in Appendix B.

A.2 Industry sector

In the Australian national accounts, information about industry outputs and inputs is available for 16 ANZSIC 1-digit sectors plus the non-ANZSIC industry ownership of dwellings and the nominal industry (for the imputed bank service charge). This information forms the basis for sectoral analyses for the period 1974–75 to 1994–95.

However, for some sectors (eg some financial and business services and government services), measures of output growth are estimated from trends in input usage. As productivity measurement depends on independent estimates of both output and inputs, it is not possible to estimate productivity for these ANZSIC sectors. In order to obtain a workable framework for applied productivity analysis, industry sectors are therefore divided into two groups.

For the first group, independent estimates of output and input are available and productivity measurement is possible. This group comprises 10 ANZSIC divisions and is termed the ‘market sector’ (Table A.1). For the remaining 6 ANZSIC industries plus the two non-ANZSIC national accounting industries, independent estimates of output and input are not available. Consequently, this study does not estimate productivity for these industries.

A further practical problem is that some key series are only available on an ANZSIC basis from the early 1980s to the present (see Appendix B). For these series, it has been necessary to backcast some ANZSIC based data from the early 1980s to the first year in the series — 1974–75. ASIC-based information was used to project relevant ANZSIC series back to 1974–75. The ANZSIC-ASIC link used for these projections is also shown in Table A.1. Most ANZSIC sectors in the market sector have an obvious matching category in the ASIC classification. However, the ANZSIC industries: wholesale trade and retail trade; accommodation, cafes and restaurants; and cultural and recreational services; can only be linked to the broader ASIC industries wholesale and retail trade, and recreation, personal and other services. In the absence of some key information before the early 1980s for the new 1-digit ANZSIC sectors, supplementary data on ASIC subdivisional industries were used to project ANZSIC based series back to 1974–75 (see Appendix B).

There are also several ANZSIC 1-digit industries in the non-market sector that do not closely correspond to 1-digit ASIC industries (Table A.1).

Table A.1: **Industries in the market sector, ANZSIC (1993) based**

	ANZSIC classification		*Main corresponding ASIC sector*[a]
Market sector[b]			
A	Agriculture, forestry, fishing and hunting	A	Agriculture, forestry, fishing and hunting
B	Mining	B	Mining
C	Manufacturing	C	Manufacturing
D	Electricity, gas and water supply	D	Electricity, gas and water supply
E	Construction	E	Construction
F	Wholesale trade	F	Wholesale and retail trade (part)
G	Retail trade	F	Wholesale and retail trade (part)
H	Accommodation, cafes and restaurants	L	Recreation, personal and other services (part)
I,J	Transport, storage and communication services	G,H	Transport, storage and communication services
P	Cultural and recreational services	L	Recreation, personal and other services (part)
Other activities			
K	Finance and insurance	I	Finance, property and business services (part)
L	Property and business services	I	Finance, property and business services (part)
M	Government administration and defence	J	Public administration and defence
N	Education	K	Community services (part)
O	Health and community services	K	Community services (part)
P	Personal and other services	K	Community services (part)
	Ownership of dwellings		Ownership of dwellings
	Imputed bank service charge		Imputed bank service charge

a Although this correspondence is assumed to provide a reasonable basis for ascertaining broad industry trends for the projection of ANZSIC data for productivity analysis, there are a number of individual activities that moved between sectors with the introduction of the ANZSIC. Details of these moves are presented in ABS (1993).

b This definition of the market sector is adopted in ABS Cat. No. 5234.0.

Sources: ABS (1993) and ABS (1997d).

A.3 Manufacturing industry subdivision

There were substantial revisions to industry subdivision definitions in the manufacturing sector with the adoption of the ANZSIC classification (see ABS 1993). The joint use of recent ANZSIC data for manufacturing and earlier ASIC based data to obtain productivity series for the period 1968–69 to 1994–95 has therefore not been straightforward.

The approach adopted in this study has been to first define an ANZSIC based classification that provides details for as many subdivisional industries as possible over the full period. Because relevant ASIC data are available for most of the period, retention of some subdivision categories from the ASIC classification has helped in meeting that objective. For example, the ASIC subdivisions basic metal products (ASIC code 29) and fabricated metal products (code 31) are combined in the ANZSIC subdivision metal products (ANZSIC code 27). In this study, separate details are retained for the two industries (see Table A.2).

Secondly, the approach has been to retain detail for activities that have attracted higher than average levels of government support through border assistance and other measures. Accordingly, separate details for the activities textiles, clothing and footwear and transport equipment are retained in this study (Table A.2). For the ANZSIC industry textiles, clothing, footwear and leather goods, this has involved the rearrangement of some ASIC data from the previous ASIC subdivisions textiles and clothing and footwear and the ASIC group leather and leather products (Table A.2). For the transport equipment industry, it has involved dividing the ANZSIC subdivision machinery and equipment (code 28) into two components — transport equipment (ANZSIC codes 281–2) and other machinery and equipment (ANZSIC codes 283–6). Both the ASIC and ANZSIC based classifications include other machinery and equipment in the residual ‘other manufacturing’ category.

Finally, to improve the correspondence between the ASIC and ANZSIC based subdivisional classifications, some activities have been moved between subdivisions. For example, to align ANZSIC printing, publishing and recorded media (code 24) and ASIC paper, paper products, printing and publishing (ASIC code 26), the activity paper and paper products (ASIC code 263) was shifted from ASIC code 26 to other manufacturing (Table A.2). Similarly, rubber and plastic products was reclassified from the ASIC other manufacturing to the ANZSIC petroleum, coal, chemicals and associated products. The focus of these data reclassifications has been at the 2-digit industry subdivision or 3-digit industry group levels of industry aggregation. The major reclassifications in this study have been affected using 2 and 3-digit categories. However, it was not possible to reclassify some individual activities between industry subdivisions due to data limitations (for details see ABS 1993).

As much of the data provided by the ABS has been presented on an ANZSIC basis from the early 1980s and, in many cases earlier, remaining classification problems relate to the earlier years of the series presented. Taking into account the ASIC–ANZSIC classification data matching undertaken as part of this study, the final classifications adopted should provide a sound basis for reporting future industry growth and productivity trends.

Table A.2: **Manufacturing ANZSIC based industry classification and correspondence to ASIC**

ANZSIC classification		*Main corresponding ASIC industry(s)*	
21	Food beverages and tobacco	21	Food beverages and tobacco
22	Textiles, clothing, footwear and leather	23	Textiles
		24	Clothing and footwear
		plus ASIC group	
		345	Leather and leather products
24	Printing, publishing and recorded media	26	Paper, paper products, printing and publishing
		less ASIC group	
		263	Paper and paper products
25	Petroleum, coal, chemicals and associated products	27	Petroleum, coal, chemicals and associated products
		plus ASIC groups	
		346	Rubber products
		347	Plastic and related products
271,2,3	Basic metal products	29	Basic metal products
274,5,6	Fabricated metal products	31	Fabricated metal products
281,2	Transport equipment	32	Transport equipment
	Other manufacturing		Other manufacturing
Including		*Including*	
	23 Wood and paper products		25 Wood, wood products and furniture
	26 Non-metallic mineral products		28 Non-metallic mineral products
	283,6 Other machinery and equipment		33 Other machinery and equipment
	29 Other manufacturing	*plus*	263 Paper and paper products,
		less	345 Leather and leather products
			346 Rubber products
			347 Plastic and related products

Source: ABS (1993).

APPENDIX B

METHODOLOGY AND DATA USED IN PRODUCTIVITY ANALYSIS

B.1 Introduction

The growth accounting model adopted in this study is based on the neoclassical growth model formulated by Swan (1956) and Solow (1956). This model is concerned with tracing out the growth in output relative to the growth in inputs to production, thereby identifying productivity improvements in the use of those inputs. The model is concerned with longer-run trends. Within a growth accounting framework, the challenge is to prepare estimates of output growth and labour and capital input growth that conform as closely as possible to the economic concepts underlying the model. This study gives particular attention to expanding the information base by estimating a new series on manufacturing industry capital capacity by industry subdivision (see Chapter 3 and Appendix C). The other major challenge is to understand the processes underlying productivity and growth changes. This second issue is the motivation behind so called 'new growth theories', but is not the main focus of this study.

This study focuses on the contribution of productivity and other factors to growth, with particular reference to manufacturing industry. This appendix sets out the basic neoclassical growth accounting model and the key data sources used in the study.

B.2 The basic model

A standard approach to studying the productivity of labour and capital in production begins with an aggregate production function of the form:

$$Y = Af(K, L^*) \qquad \text{(B1)}$$

where Y is output measured in terms of value added (ie gross product) and K and L^* are measures of capital and labour inputs (the latter measured in total hours worked), f is a constant returns to scale function of factor inputs K and L^* that defines the expected level of output in year t, given the conditions and technology in the base period, and A is a productivity shift term reflecting influences such as technical change, unmeasured changes in the quality of labour and capital and the intensity with which capital and labour are used.

For any industry, (B1) can be written in percentage changes as:

$$y = a + s_k k + (1 - s_k) l^* \qquad \text{(B2)}$$

where y, a, k and $l^*$are the percentage changes in Y, A, K, and L^*, respectively, and s_k is the elasticity of Y with respect to K. Assuming:

- constant returns to scale, so that s_k plus $(1\text{-}s_k)$ sum to one; and
- capital and labour are paid according to their marginal products,

s_k is the capital share in the value of output.

Additional technical details about the growth model and its application to the estimation of capital inputs are provided in Appendix C and D.

Decomposition of changes in labour productivity and employment

For an individual industry i, by subtracting the change in employment, denoted by l (distinct from l^* used to denote labour inputs in terms of total hours worked), from both sides of equation (B2) and rearranging, the percentage changes in output per person employed can be shown as:

$$y_i - l_i = (l_i^* - l_i) + s_{ik}(k_i - l_i^*) + a_i \qquad \text{(B3)}$$

Equation (B3) expresses the percentage change in output per person employed as the sum of three terms:

- $(l_i^* - l_i)$ is the percentage change in labour input per person employed. An additional unit of labour input from each person would increase output per person employed. By adding and subtracting the term $(l^* - l)$ for the industry sector as a whole, this change can be disaggregated to show the change coming from increased hours worked by all people in the sector and the relocation of labour between industries in the industry sector. That is, $(l_i^* - l_i) = (l^* - l) + \{(l_i^* - l_i) - (l^* - l)\}$. (B4)
- $s_{ik}(k_i - l_i^*)$ is the percentage change in the capital to labour ratio $(k_i - l_i^*)$ multiplied by the elasticity of output with respect to capital input (s_{ik}). An additional unit of capital relative to labour would have an increasing effect on the level of output per person employed. This change can be disaggregated to show the change coming from increased capital inputs

in the market and manufacturing sectors and the relocation of capital between industries in the market and manufacturing sectors. That is,

$$s_{ik}(k_i - l_i^*) = s_{ik}(k - l^*) + \{s_{ik}(k_i - l_i^*) - s_{ik}(k - l^*)\} \qquad \text{(B5)}$$

- a_i is the percentage change in multifactor productivity. An increase in multifactor productivity would increase the level of output per person employed.

Having obtained changes in output per person employed, it becomes possible to also obtain changes in employment for each industry in the manufacturing and market sectors which, when aggregated, provide changes in employment for the sector as a whole.

B.3 Data sources

Economy-wide information

Data for the economy-wide study of productivity growth are available from the Australian national accounts (in particular, ABS Catalogue no. 5204.0). These data are on the EconData's electronic data dissemination service (EconData 1997) on an ANZSIC basis either for the full period (ie 1974–75 to 1994–95), or for a subperiod beginning in the early to mid-1980s to the present. To complete the series required for the current analysis, it was therefore necessary to project some ANZSIC based data back to 1974–75 using trends in ASIC industry series. The industry classification and the link between the ASIC and ANZSIC classifications adopted for this purpose are discussed in Appendix A. This section details the individual series used in this study and the assumptions adopted in completing these series.

Output by industry is estimated as gross product (at market prices) at average 1989–90 prices.[1] Gross product is calculated by the ABS by taking the market value of goods and services produced by an industry (ie gross output) and deducting the cost of goods and services used up by the industry in the productive process (ie intermediate consumption). Data for output by ANZSIC industry division are available for the full period of the study.

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[1] Gross product is valued at market prices in the ANZSIC division series published by the ABS and, for consistency with those series, the market price valuation principle is adopted in the ANZSIC divisional component of the current study. For manufacturing subdivisions, gross product is valued at factor cost. For consistency with published series, the factor cost valuation convention is adopted for the manufacturing subdivision analysis.

The ABS rebases its constant price gross product series fairly frequently (about once every five years) to take account of relative price changes (including terms of trade effects) over time (ABS 1990). The base years for constant price estimates by industry (including manufacturing industry subdivisions) used in this study are: 1974–75; 1979–80; 1984–85 and 1989–90. The successive series pertaining to each base year overlap, enabling the latest series (at average 1989–90 prices) to be chain linked back in time to provide a full series referenced to average 1989–90 prices. The convention adopted by the ABS is to link each series on the successive base years. Therefore, data from the 1989–90 based series are chain linked to data from the 1984–85 based series for the reference year 1984–85. Then, data from the 1984–85 series are linked to the 1979–80 series in 1979–80 and so on.

Employment is measured as the average for the year of all labour engaged in the production of goods and services by industry. This information is available on dX on an ANZSIC basis for the period 1984–85 to 1994–95. For industries where there is a close alignment between ASIC and ANZSIC, employment data from the earlier ASIC based series were used to project ANZSIC based employment series by industry back from 1984–85 to 1974–75. For industries where there is not a close alignment, data was supplied on special request from the ABS.

Labour inputs are measured by the number of hours worked by persons employed in each industry per year. Information was provided on special request by the ABS on an ANZSIC basis for the years 1984–85 to 1994–95. ABS collect the number of hours worked in a ‘representative’ week four times a year — in August, November, February and May. The data provided was the sum of these 4 representative weeks. Annual data were derived by multiplying the data 13.045.[2,3] This ANZSIC-based series was projected back to 1974–75 using indexes of the number of hours worked by ASIC industry available from the Australian national accounts and supplementary data on hours worked in the wholesale trade, retail trade, restaurants, hotels and clubs, entertainment and recreational services from the Labour Force Survey (ABS 1997g).

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[2] Standardised monthly data is obtained for national accounting purposes by multiplying Labour Force survey week data by 4.348 (ie 365.25 divided by 84 (7*12) — the average number of weeks in a month). Standardised quarterly data is obtained by further multiplication by a factor of 3 (3 standard months in a quarter). The adjustment therefore accounts for the fact that the number of days in individual months differs.

[3] The annualisation of hours worked data effects the level of hours worked and hence is relevant to any measures of GDP per hour worked that may be made. However, the annualisation does not effect indexes of hours worked. It is the indexes of hours worked that are used in multifactor productivity measurement calculations.

Capital capacity by industry is derived from ABS calculations of gross and net capital stock at average 1989–90 prices. Gross capital stock is measured as the accumulation of past investment flows (ie gross fixed capital expenditure) less retirements, at 30 June each year. Net capital stock is measured as gross capital stock less accumulated capital consumption. The value of agricultural land, a third input recognised in agriculture, forestry, fishing and hunting, is set equal to a constant $64.5 billion in constant 1989–90 prices (ABS 1997d). To allow for the fact that the service life of assets does not decline in direct proportion to the depreciated value of the asset, measures of capital capacity by industry are obtained from a weighted average of available net and gross capital stock series. In this study, the capacity measure assigns equal weight to the gross value and net value of capital stocks.[4] Capital stock data are available on an ANZSIC basis for the years 1982–83 to 1994–95. These ANZSIC measures were projected back to 1974–75 using data from the earlier ASIC industry series.

Labour and capital input shares by industry are estimated as the share of wages, salaries and supplements, and gross operating surplus in gross product at factor cost. These series were available on dX on an ANZSIC basis for the years 1982–83 to 1994–95. To complete the series, factor shares over the period 1974–75 to 1981–82 were derived from projections based on ASIC industry information.

In addition, an estimate of imputed wages of owner operators is deducted from the gross operating surplus of industries showing a concentration of unincorporated businesses (ie agriculture, wholesale and retail trade, and construction) and added to wages, salaries and supplements for the same industries. Information on the importance of imputed wages is taken from the Commission’s ORANI model database (Kenderes and Strzelecki 1991) and is based on population census data.

Manufacturing industry information

Information necessary to undertake an analysis of capital stocks and productivity by manufacturing industry subdivision is not available from a single source. Nevertheless, there is a range of sources that individually provide components of the information necessary to undertake the analysis. This appendix describes the individual series used in the study. Because of the focus on industry subdivision details, the information used in the manufacturing

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[4] In its estimation of capital capacity for the market sector, the ABS has takes a weighted average of the gross and net capital stock estimates. It assigns equal weights to gross and net stocks of buildings and structures and weights of 0.25 and 0.75 respectively, for equipment (Aspen 1990).

component of this study is drawn from data sources different from those used in the economy-wide setting. The key difference is the adoption of capital capacity measures derived using the Commission's capital capacity estimation method (Appendix C). There are other differences. Nevertheless, sensitivity testing of trends in manufacturing industry sector output, employment and labour inputs shows that those totals are highly correlated with trends evident from the economy-wide series.

Due to the long time series adopted for the manufacturing study, that is 1968–69 to 1994–95, there inevitably has been changes in conventions adopted in the compilation and presentation of source data series. As noted, a major change was the introduction of the ANZSIC by the ABS in 1992–93. To complete the full series required for the analysis, the ASIC and ANZSIC series have been linked using the industry concordance presented in Appendix A. In addition to changes in industry classification, some information needed for the study is not directly available from published series and recourse has been made to unpublished data. This section describes the assumptions made in linking data from ASIC and ANZSIC series and the use of unpublished data.

Output by manufacturing industry is measured as the value of gross product at factor cost. Gross product at factor cost is defined as the ex-factory value of goods and services produced by an industry (ie gross output) less the cost of goods and services used by the industry in the production process (ie intermediate consumption). Gross product at factor cost is net of the indirect taxes that are included in measures valued at market prices, and is generally preferred to market price measures for productivity studies. Gross product at factor cost by manufacturing sub-industry was provided by the ABS on special request (also see ABS Catalogue no. 8221.0). Data for the years 1970–71 and 1985–86 were not included in the original series. Output trends for these years were obtained from gross product at market prices (see ABS Catalogue no. 5206.0). The reference year for this study is 1989–90 and all flows have been expressed in terms of the prices for that year. However, not all data source information is provided on this basis by the ABS. Specifically, basic information in 1974–75 constant prices is available for the years 1968–69 to 1974–75, 1979–80 prices for the years 1974–75 to 1977–78, 1984–85 prices for the years 1977–78 to 1984–85 and 1989–90 prices in subsequent years. The constant 1989–90 price series was chain-linked with the earlier series to provide an output series over the period 1968–69 to 1994–95.

Employment is measured as the number of working proprietors and employees on the payroll, including those working at separately located administrative offices and ancillary units at 30 June. The number of persons employed was obtained from the ABS census of manufacturing (see ABS Catalogue no. 8221.0 for original data and IC (1995c) for a consolidated series from 1968–69 to 1991–92). Employment data were not available from this source for the years 1970–71 and 1985–86. Data for these years were estimated using employment trends for the manufacturing industry from the Australian National Accounts (see ABS Catalogue no. 5204.0).

Labour inputs by manufacturing industry is measured as the total hours worked in a year by persons employed in each industry. These data were derived in a number of steps. First, data on average hours worked in a labour force survey week, by employed persons were provided by ABS on special request for the period 1975–76 to 1994–95 (ABS 1997g, see also ABS Catalogue no. 6203.0). In general, total hours worked in each year was calculated from this information by summing the estimated hours worked for survey weeks in the quarters ending at August, November, February and May (for 1975–76 and 1977–78, only data for the August quarter were provided) and multiplying this sum by 13.045 to derive an annual measure of hours worked for employed persons. Second, average annual hours worked per person employed was obtained by dividing total hours worked just estimated, by the average number of persons employed (Labour Force Survey based estimate). Finally, in order to reference the hours worked series to manufacturing industry activity and employment, as indicated by the manufacturing industry census, average hours worked per person employed in step two, was multiplied by manufacturing industry census employment.

It was possible to estimate an hours worked series back to 1975–76 on the above basis. To complete the series, estimates of hours worked were projected back to 1968–69 using corresponding employment trends.

Capital capacity is estimated using a generalised perpetual inventory method (PIM). The detailed estimation method (ie the generalised logistical method) is provided in Appendix C. The data assumptions are discussed in Chapter 5 and Appendix C. To apply the method, investment in machinery and equipment and non-dwelling construction by industry was obtained from the ABS by special request (also see ABS Catalogue no. 5625.0). The series was provided on a quarterly ASIC basis from June 1963 to June 1986 and on an ANZSIC basis in subsequent quarters. To link the two series, additional information on new capital expenditure for the years 1968–69 to 1985–86 was obtained from the manufacturing industry census. To complete the series, investment was projected back to September 1959 using trends in quarterly new capital expenditure supplied by the RBA by special request. The starting quarter for the PIM was June 1959. Initial capital stocks for this starting quarter were obtained from ABS factory census information.

Indexes of capital-good prices, for machinery and equipment and non-dwelling construction, used to convert current price investment to constant 1989–90 prices for the quarters June 1987 to June 1995 were obtained from ABS catalogue 5206.0. For previous quarters (ie back to 1959), Reserve Bank price data were used (RBA 1996a).

Labour and capital input shares by manufacturing industry are estimated from information available from the ABS census of manufacturing establishments and the related enterprise statistics series. The cost of labour was estimated as wages and salaries from the industry census, plus superannuation payments by industry of enterprise. At the subdivision level of aggregation used in this study, it was assumed that industry of enterprise (see ABS Catalogue no. 8103.0) is representative of flows classified by industry of establishment. Industry gross product at factor cost was approximated by value added as estimated in the manufacturing census, less business expenses (including land tax, rates and payroll tax, travelling expenses, accounting and legal expenses, insurance premiums, advertising and bank charges) from industry of enterprise statistics. Payments to capital including depreciation (ie approximate gross operating surplus) was estimated by deducting payments to labour from industry value added. Information on superannuation payments and business expenses were available for the years 1968–69, 1974–75 and 1977–78 to 1986–87. The series were completed by projecting the relevant data forward on trends in industry wages and salaries.

APPENDIX C

LINKING MEASURES OF THE VALUE OF CAPITAL STOCKS AND CAPITAL CAPACITY

C.1 Introduction

Chapter 5 distinguished between the value of capital stocks and capital capacity. It was found that the value of capital stocks is commonly estimated using the PIM method and used to obtain approximate measures of capital capacity. Capital capacity is then used to derive changes in capital inputs to production for productivity studies.

This appendix formalises the distinction between the value of capital and capital capacity (section C.2) and uses a stylised model to illustrate the dual relationship between the decay of capital capacity and depreciation in asset value (section C.3). Section C.4 brings this analysis together to outline the approach adopted in this study. Section C.5 sums up the findings of this appendix.

The presentation used in this appendix is adapted from Hulten (1990) and Walters and Dipplesman (1985). A fuller treatment of the concepts relating capital capacity to the value of capital stocks and the use of these measures in analyses of productivity is provided in Hulten (1990) and Triplett (1996).

C.2 Conceptual background

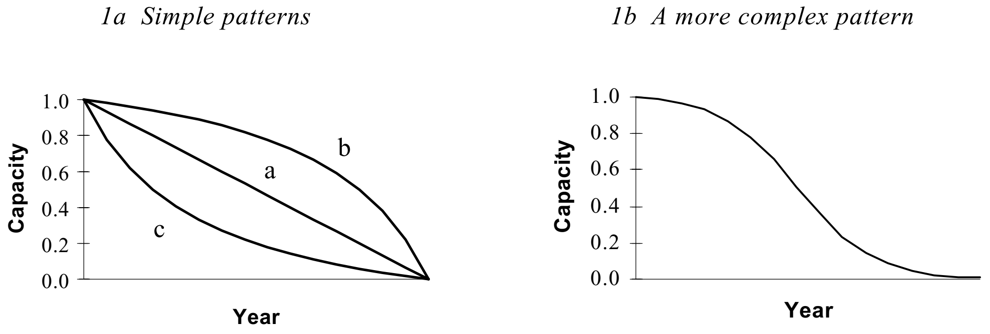
Capital capacity of any one period comprises assets from all surviving vintages. In a perpetual inventory framework, investment in all surviving vintages would be weighted to allow for the possibility that older capital is less productive than its newer counterparts. The weighted investment series can then be added to form a total measure of capital capacity. For a single period, this concept can be expressed as:

$$K_t = \phi_0 I_t + \phi_1 I_{t-1} + \ldots + \phi_L I_{t-L} \equiv \sum_{i=0}^{L} \phi_i I_{t-i} \tag{C1}$$

where K_t is capital capacity in period t, I_t is the quantity of new capital stock added in each period and $_t$ is a parameter that allows for declining efficiency over time. L is the productive life of capital, so that $v=t-L$ defines the date of the oldest surviving asset.[1] In this set up, capital is a net concept that is defined in terms of efficiency units. The decline in efficiency would occur either through a loss of output efficiency, as more efficient models become available (ie through obsolescence), or through a loss of input efficiency as the repair and maintenance expenses needed to maintain a given level of output increase.

A difficulty in applying this concept is determining the likely productive life of capital and the functional form attached to the series of parameters . Many possibilities exist for defining the age/efficiency relationship. On one hand, it may be assumed that efficiency declines according to a regular pattern over the life of an asset. Three basic age/efficiency profiles are possible (Figure C.1a). Case *a* of Figure C.1a depicts straight line asset decay in which productive capacity declines by a constant amount each year. Case *b* (the concave case) depicts the case in which capacity declines slowly at first, but increases as the asset ages. The light globe example is an extreme example of a concave age/efficiency profile. The convex case is depicted by *c*. In this case, productive capacity declines rapidly at first, with the decline decreasing as the asset ages. An intermediate good or service which is fully utilised in current production is an extreme case of a convex age/efficiency profile. Alternatively, the decline in capital capacity could follow a pattern that characterises the growth and decay of natural systems (Figure C.1b and Pearce and Turner 1990).

Figure C.1: **Possible capital asset age/efficiency profiles**



1a Simple patterns

1b A more complex pattern

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[1] It is conventional to measure expected asset lives in years. The benchmark asset life for machinery and equipment is 17 years in the 1980s and, for non-dwelling construction, 39 years. In the current study, quarterly investment information is used to derive measures of capital stocks for each year.

The economic value of a unit of capital is equal to the value to the owner of holding each piece of capital. This in turn is equal to the present value of the expected gross rents generated over the (remaining) life of the asset. In competitive equilibrium, the cost of producing the asset, or sale price of second hand assets, is equal to the expected income stream. This concept can be expressed as an equilibrium purchase price per unit of capital:

$$P_{t,s}^{I} = \sum_{\tau=0}^{L-s} \frac{R_{t+\tau,s+\tau}}{(1+r)^{\tau+1}} \tag{C2}$$

where $P_{t,s}^{I}$ is the price of a unit of capital investment of age s surviving at time t, $R_{t+\tau,s+\tau}$ is the expected annual gross income generated in year $t+$ by the asset of age s when it is years old, and r is the internal rate of return for firms employing capital. The value of the stock of capital at any one time is the asset value of all items of capital, the amount that would be expected from selling each piece of capital at market prices, that is,

$$V_{t}^{K} = \sum_{s=0}^{v} P_{t,s}^{I} I_{s} \tag{C3}$$

where V_{t}^{K} is the value of the capital stock in period t, $P_{t,s}^{I}$ is the price per unit of investment of item of age s surviving in period t, and I_{s} is the units of investment installed in period s. Economic depreciation occurs as each asset ages and moves along its age/efficiency profile. The closer an asset vintage gets to the end of its effective working life, the lower its economic value. Depreciation per unit of capital of a given vintage in year t is defined as the change in the price of the asset, that is

$$D_{t} = \delta_{t} P_{t,s-1} = P_{t,s-1} - P_{t,s} \tag{C4}$$

where ${}_{t}$ is the rate of depreciation in period t, $P_{t,s-1}$ is the unit price of assets surviving in period t when they were one year younger (ie s-1) and $P_{t,s}$ is the unit price in the current period. The rate of depreciation in any one year will depend on the asset age/efficiency profile. When the efficiency of the asset declines by a constant proportion each year (represented by case c in Figure C.1) the rate of depreciation would be exactly equal to the firm’s internal rate of return. The link between the asset age/efficiency profile and the value of net capital stocks is illustrated below by reference to a straight line decline in asset efficiency.

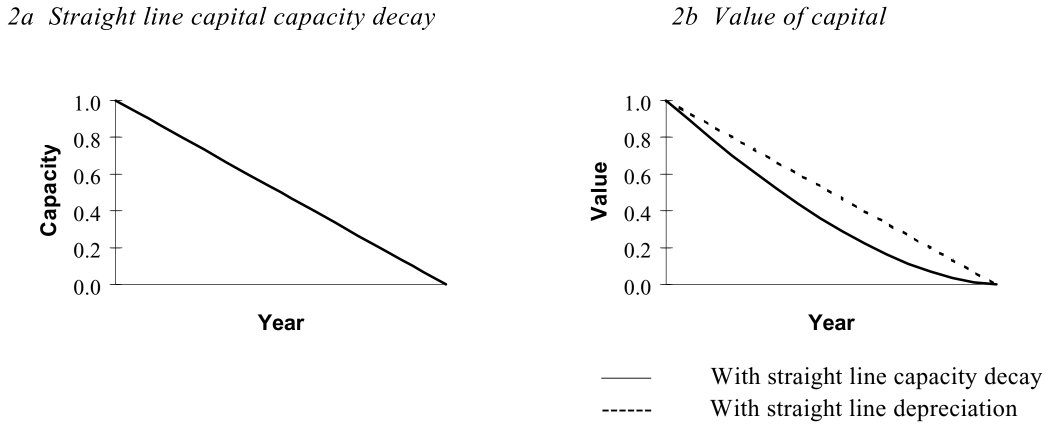
Illustration of the conceptual framework using straight line decline in asset efficiency

Once the rate of efficiency decline and asset life are determined, it is possible to work forward to estimate depreciation in each period. This involves:

- solving for the relative efficiency of the asset in each period (ie $_t$ in equation C1);
- taking the present value of the expected gross returns per unit of capital in each period implied by the relative efficiency levels (ie $P^I_{t,s}$ in equation C2); and
- finding the depreciation in each period over the life of the asset represented as the decline in the value of the asset (D_t in equation C4).

Application of this stylised model illustrates that the assumption of straight line decline in asset efficiency (Figure C.1a) is not equivalent to assuming straight line depreciation (Figure C.2b). This reflects the fact that the proportional loss of capacity, and hence income earning potential, is largest during the later part of the asset's life with straight line decay. Example 2b shows that straight depreciation is only a linear approximation to the depreciation implicit in a straight line capital capacity decline.

Figure C.2: **Stylised representation of straight line capital capacity decline and associated asset values** [a]


2a Straight line capital capacity decay

2b Value of capital

a Assuming an internal rate of return of 10per cent and a unit value of the asset when new normalised to $1. A higher discount rate would imply a higher valuation of production in the earlier years of an asset's life. Adoption of higher discount rates would raise asset values and reduce economic depreciation in the initial periods of operation. Conversely, lower discount rates would correspond to lower asset values and higher depreciation in earlier years.

C.3 Implementation of the model

At the present time, there is very little information available to determine the age/efficiency profiles of the capital assets at the industry level and how these profiles may be changing over time. As a result, economy-wide and industry studies have used a variety of sources and approaches to complete estimates of capital capacity for productivity studies.

The approach adopted by the US Bureau of Labour Statistics

The US Bureau of Labour Statistics (BLS) assumed a concave asset decay function (ie case *b* of Figure C.1a). The reasoning behind this decision is summarised in the following way:

> The assumption of a concave form was settled on because of the cursory observation that many capital assets do not tend to decay rapidly during the initial years. In addition, members of the BLS Business Research Advisory Council canvassed their organisations and reported similar experiences with the capital assets owned by the firms they represent. (BLS 1983, p. 43)

To implement this approach, the BLS has represented the age/efficiency relationship by a hyperbolic function:

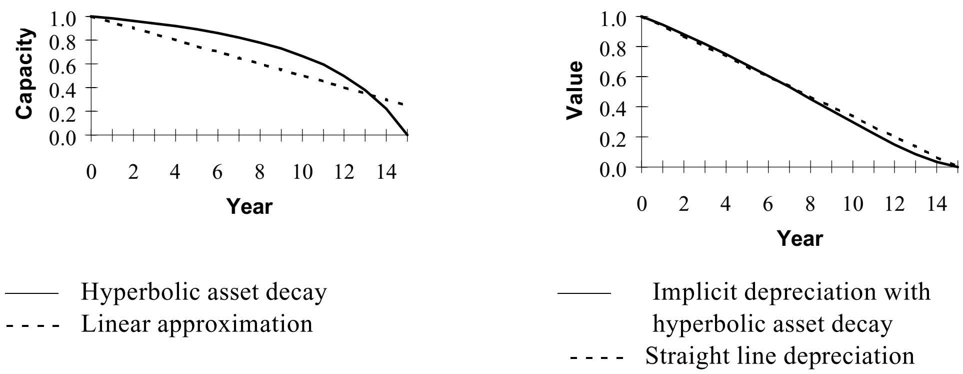
$$ {}_t = \frac{L -}{L -} \qquad \text{(C5)} $$

where $_t$ is the relative efficiency of the asset in period *t*, *L* is the length of the asset's life, is the age of the asset and is the asset decay parameter. The variable defined by this function measures the decline in asset efficiency relative to the case when the asset is new. It is therefore the equivalent of the parameter represented by the same symbol in equation (C1). In applying this model, the BLS assumed that the value of beta lay between zero and one, that is, between the straight line and constant productivity (light globe) forms. Using US information about asset lives and second-hand asset prices, the BLS determined beta values of 0.75 for structures and 0.5 for equipment (BLS 1983). In arriving at this decision, it determined that

> ... the best statistical fit to the Hulten and Wykoff data using a hyperbolic functional form resulted in an efficiency function which declines initially at one-half the straight line depreciation rate for equipment, and at one-fourth the straight line rate for structures. (BLS 1983, p. 43)

Because the hyperbolic asset decay function (illustrated in Figure C.3a) was applied by the BLS to broad types of assets, each representing a variety of capital goods, a distribution of asset lives was adopted. This was done by constructing a cohort efficiency function which weights together efficiency profiles of assets of different ages. The weights were determined by a BLS asset discard distribution.

Figure C.3: **Stylised representation of concave capital capacity decline and associated asset values**



3a Capital capacity decay[a]

3b Value of capital[b]

a The hyperbolic asset decay assumes $\beta = 0.75$ and an asset life of 15 years. The linear approximation is estimated by weighting gross and net capital stocks in the ratio 25:75; the underlying net capital stocks are estimated using the straight line depreciation method.

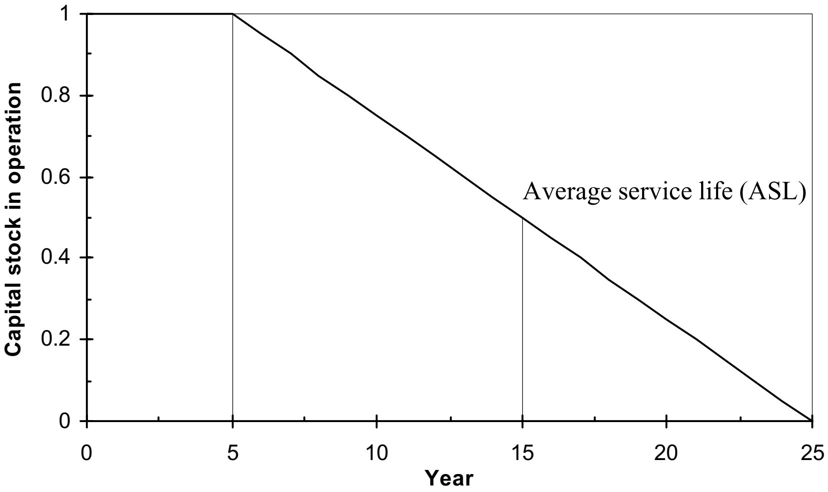
b For depreciation implicit to the hyperbolic asset decay schedule, an internal rate of return of 10 per cent and a unit value the asset when new normalised to $1 are assumed.

The approaches adopted in other studies

There is a general presumption in studies estimating capital inputs for productivity studies that asset decay is not straight line. However, the approaches adopted differ. Notional concave functions underlie the estimates of capital capacity in the ABS productivity studies (Aspen 1990) and the study by the Meyer zu Schlochterns (1994). However, these studies do not implement the hyperbolic asset efficiency function directly. The ABS makes a linear approximation to the function by taking a weighted average of gross and net capital stocks (illustrated in Figure C.3a). The weights adopted by the ABS are 50:50 for non-dwelling construction and 25:75 for machinery and equipment to provide a linear approximation to the age/efficiency profiles adopted by the BLS (Aspen 1990).

The Meyer zu Schlochterns (1994) take a different approach. Rather than measure the age/efficiency profile of surviving assets, they measure the total volume of the existing physical capital assets available in the production process in respective OECD countries. To do this, they adopt a delayed asset retirement pattern in which it is assumed that assets are not scrapped in the first five years of service, but are then scrapped according to a straight line fashion thereafter (Figure C.4). As capital inputs are measured by reference to physical capital available for production, the method abstracts from changes in output and input efficiency, and from the age/efficiency profiles of assets.

Figure C.4: **Stylised representation of delayed linear asset retirement function**[a]



a Based on an average asset service life of 15 years.
Source: Following OECD 1996.

However, the OECD work does adopt different average asset service lives for the countries and industries examined. These asset service lives were taken from national authorities. Concerning the veracity of service life data, the OECD observes:

> The scrapping rate assumptions used by different national authorities tend to differ widely, for reasons which reflect the method of estimation used rather than fundamental differences in the nature of capital goods or their utilisation. ... To analyse in greater detail the importance of such differences for estimation of total factor productivity, some preliminary tests were carried out: factor productivity estimates were first calculated, by sector, using capital stocks estimates based on cross-country mean average service life for each sector; these were then compared with alternative estimates of country-specific scrapping rate assumptions. The resulting differences in estimates were found to be quite significant for the levels of capital stock estimates but relatively minor for factor productivity growth. (OECD 1996, p. 17)

Other studies, however, have assumed that the efficiency of an asset declines most rapidly in the earlier years of service, but that the decline levels off as the asset ages, that is, the pattern of capital capacity decline is convex (case c in Figure C.1a). The assumption has the theoretical attraction that, if it is assumed that both capital capacity and the value of capital decline by a constant proportion each time period, then the two rates of decline coincide. That is,

$$K_t \equiv V_t^K = \sum_{s=v}^{t} I_{s,t} (1-\delta)^{t-s} \qquad \text{(C6)}$$

where δ is the geometric rate of decay and $_t = (1- \quad)^{t-s}$ for all *t*. K_t is capital capacity as defined above and V_t^K is the net value of capital in period *t*, $I_{s,t}$ is the level of investment in year *s* still operating in period *t*, while *v* is the oldest vintage of capital in operation. When *t*=*s* the asset is new and the value of the net capital stock is equal to the value of investment. Once asset lives are determined, the equality between the rate of capital capacity decay and economic depreciation substantially simplifies the application of the perpetual inventory model for estimating both capital capacity and capital stock.

C.4 Approach adopted in this study

The approach adopted in this study has been to blend features of other studies with some judgements made in this study. The need for judgment arises because of a significant lack information at the industry level about asset age/efficiency profiles and the valuation of assets held by businesses. The framework therefore should be regarded as tentative — it is intended to encourage further discussion and analysis. Nevertheless, the framework adopted has been devised to exploit the dual relationship between capital capacity and asset valuations in a way that may assist in making the best use of additional information once it is available.

This study has adopted the convention that generally the capital capacity of assets tends not to decay rapidly during the initial years. In addition, it assumes that the asset age/efficiency profile is generally more complex than that depicted by the hyperbolic decay function adopted by the BLS. In particular, allowance has been made for the possibility that, at some point in an asset's life, there is a larger than average decline in capacity as the original equipment shows signs of wear and the program of refurbishment, repairs and maintenance is increased to compensate for that decline, while keeping the whole plant operating at commercial levels. Once any refurbishment and maintenance program is in place, the capacity decline again occurs at a slower rate. This concept is captured by the logistic function discussed above. To implement this approach, the age/efficiency relationship is represented by the function:

$$\phi_t = constant + \frac{e^{\alpha t} - e^{-\alpha t}}{e^{\alpha t} + e^{-\alpha t}} \qquad \text{(C7)}$$

where $_t$ is the coefficient of relative efficiency (normalised to 1 at time t=0), while the parameter determines the estimated pattern of efficiency decline over time.

The actual function adopted to model the concepts discussed and the parameters selected is an empirical problem. The functional form presented in equation C7 has been selected in this study because of its flexibility to model the concepts discussed and because it can be readily parameterised to reflect judgements made concerning the age/efficiency profile of assets. In order to implement the model, the following judgements have been made.

First, it is assumed that assets are sold or scrapped by businesses before they completely lose all of their functionality or value. For the profit maximising firm, this would occur when the productive value of the asset to the firm is equal to or less than its scrap value. Alternatively, the assets may have a value to private consumers (eg motor vehicles sold from fleets) or a breakup value (eg for parts or scrap) that exceeds the current productive value of the asset to firms.

There is limited information available at the industry level about the average value of assets when they are decommissioned from national capital stocks. Nevertheless, there is some information at the national level available from the ABS input-output tables. These tables show the acquisition of new assets and the sales of second hand assets (referred to as sales by final buyers) (see ABS 1997b). In 1992–93, the value of net asset disposals was estimated to be around \$4.6 billion, which amounted to around 5.6 per cent of new capital expenditure (of about \$85 billion) and around 0.4 per cent of net capital stock (of \$1 100 billion). Around three quarters of these sales were to private final consumption expenditure (eg including motor cars sold from business fleets to households) while most of the remainder were to the steel industry (eg as scrap). Analysis of earlier input-output tables indicates that these broad relations have been similar in other years.

The ratio of the scrap/sales value to the value of new investment (ie 5.6 per cent) represents a lower bound to the ratio of scrap/sales value to original purchase cost (evaluated at constant prices), as the assets sold by businesses in 1992–93 were purchased some years before, when investment levels were lower. In the absence of detailed empirical information with which to measure industry average values for assets sold and scrapped, it is assumed that the average value at the time of final sale or scrapping is about 7.5 per cent of the acquisition cost evaluated at constant prices. In practice, it is expected that the final value at sale or scrapping would vary, possibly substantially, around any industry average.

The approach adopted in this study for the treatment of the residual value of capital assets differs from that adopted in other studies. The BLS assumes that assets have no residual value at final sale or scrapping. In doing so, the BLS assumes that assets of the older vintages have a lower weight in measures of capital capacity than is the case in this study. On the other hand, the approach adopted in this study is similar to the linear approximation approach adopted by the ABS, which implicitly assumes that productive capacity is not completely exhausted at final sale. Although the ABS method for estimating capital capacity implicitly assumes that capital has some residual value at scrapping, this assumption is not carried forward to standard straight line estimates of depreciation and capital asset value. Finally, the approach in this study is similar to that adopted by Chand *et al.* although, following Leamer (1988), they assume a residual value of around 13 per cent of the value of the initial investment.

Link between asset capacity decline and the decline in asset values

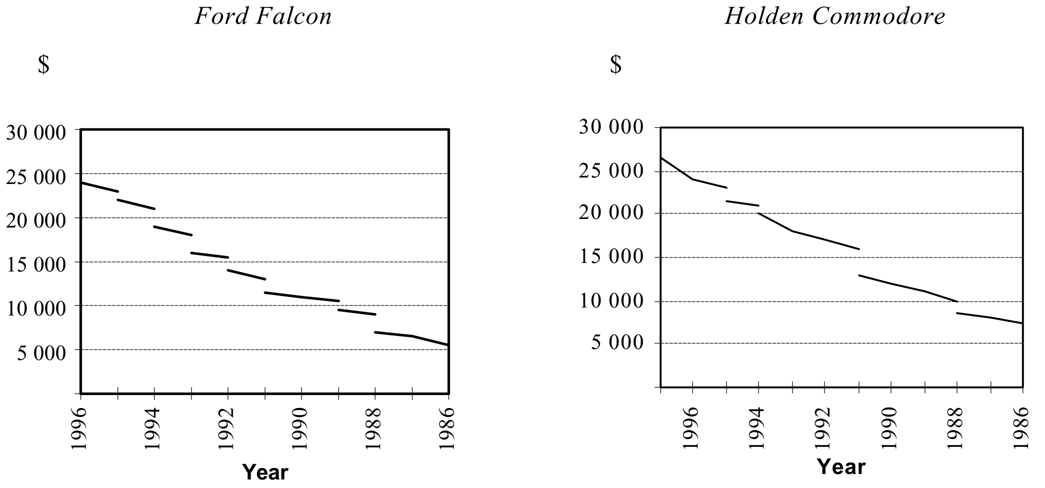
The alternative value of a capital asset for an individual firm is the sale or scrap value at the factory gate. This value differs from the point of acquisition value of a similar asset because of trade and transport costs, sales taxes and stamp duties that may be levied on second hand asset transactions.

Point of sale acquisition costs may also be below the value of installed assets of a similar kind due to search, delivery, installation and commissioning costs that are not included in the point of sale price of second hand assets. In addition, potential asset buyers may have imperfect information about the precise condition and, hence, likely service life of second hand items, which would lead them to price second hand goods as if they were faulty and requiring greater than normal servicing and refurbishment. For these reasons, there could be a substantial margin between the in situ value of assets and the value of similar assets on second hand asset markets.

Nevertheless, in a competitive market, the buying and selling prices of assets would be expected to indicate the likely profile of asset prices. Such information would provide one test on the veracity of the capital value age/price profile of assets in situ, and thereby on the likely capital capacity age/efficiency profile. There is a general lack of information about the age/price profiles of capital assets at the national or industry level. Nevertheless, there is some limited information about specific asset markets and some information from overseas markets.

In Australia, Glass's Guide provides information on second hand asset acquisition prices for passenger vehicles, caravans and campers and boats. Although the Guide focuses on items for sale for household and recreational use, assets in each category are used by both households and businesses. They provide one source of information about likely capital asset age/price profiles. Information on second hand prices in Australia for two models popular amongst commercial fleet owners — the Ford Falcon and the Holden Commodore — shows that second hand asset prices are convex for these items (Figure C.5).

Figure C.5: **Age/price profiles for selected durable items**



Source: Glass's Guide (1997)

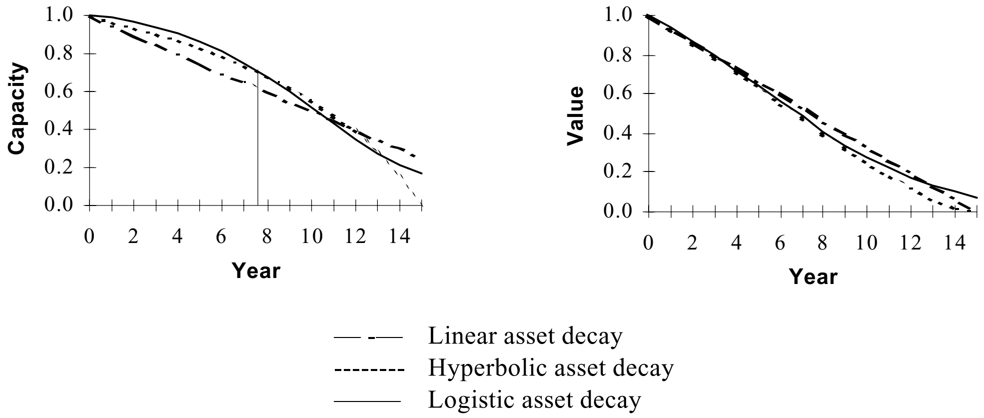
This information lends support to the idea that the age/price profile of assets is convex.

Hulten and Wykoff (1981) undertook a major study of vintage price data for commercial and industrial structures. The vintage price function gives the acquisition price of an asset at a particular time, as a function of age and the price of a new good of the same type. This provides a means of estimating asset age/price profiles. In the study, the price of surviving assets was represented by the acquisition cost in the second hand market, while the net acquisition cost of assets scrapped in the period was assumed to be zero.

The study found that the pattern of depreciation does not strictly follow any common forms, such as straight line or geometric decay (Hulten and Wykoff 1981, p. 369). However, the estimated pattern of depreciation was accelerated compared with the straight line method and, on average, the geometric pattern provided a reasonably close approximation to observed age/price profiles. The results for structures (reported in detail in the paper) conformed to similar findings for specific assets — automobiles, trucks and tractors.

Figure C.6: **Stylised representation of logistic, concave and linear capital capacity age/efficiency profiles and associated asset values**

5a Capital capacity decay[a] *5b Value of capital*[b]



a The hyperbolic asset decay assumes $\beta = 0.75$ and an asset life of 15 years. The logistic capital capacity age/efficiency profile is drawn to intersect the BLS hyperbolic asset decay line half way through the life of the asset. The closing capacity level is constrained so that the residual value of the asset is equal to 7.5 per cent of the acquisition cost. The initial value of the asset is normalised to $1.

b Assuming an internal rate of return of 10 per cent. A higher internal rate of return would reduce the curvature on the value of capital line for the hyperbolic and logistic asset decay schedules, as producers give a higher valuation to remaining production. Lower discount rates would increase the curvature, as the asset value schedules more closely approximated the respective asset capacity schedules.

On the basis of the limited information available, it is assumed that it is most appropriate to adopt an asset age/efficiency profile that yields a convex age/price profile, at least over certain ranges. The generalised logistic age/efficiency profile meets this requirement (Figure C.6).

Aggregation of capital

The objective of the capital capacity exercise is to obtain a measure of capacity by industry and for manufacturing as a whole. To meet this objective it is necessary to undertake three kinds of aggregation. First, it is necessary to aggregate the stocks of different vintages to form a money metric measure of capital by type of asset for a single reference period. Second, it is necessary to aggregate the different types of capital — machinery and equipment and non-dwelling construction — to form a single measure of capital capacity by industry. Finally, it will be useful to obtain a measure of aggregate capacity for total manufacturing or some other level of industry aggregation.

For productivity studies and other analyses of production, it is appropriate to weight together the different vintages of capital according to their relative productive capacity (see Appendix D). For the aggregation of vintages over time, relative productive capacity, that is, marginal products of different vintages of each type of capital, are provided by the age/efficiency profiles discussed above. Assuming perfect substitutability between vintages, capital capacity in any one year can be estimated as:

$$K_{it} = \sum_{s=0}^{v} \phi_s^i I_{st}^i \tag{C8}$$

where K_{it} is capital capacity of capital good i in period t, ϕ_s^i is the anticipated relative efficiency of capital good i after l years of operation where $l=t-s$, I_{st}^i is investment in good i in period s that is still surviving in period t and $v=t-L$ is the age of the oldest surviving asset.

The aggregation of the types of capital to form a single industry aggregate measure is more problematic. One possible approach is to adopt the simplifying assumption that the productivity of each type of capital is the same. In this case, each type of capital good can be summed to form a measure of aggregate capital capacity by manufacturing industry subdivision, that is:

$$K_t = \sum_{i=1}^{2} K_{it} \,. \tag{C9}$$

In principle, the appropriate weight for each type of capital may not be proportional to the estimated level of installed capacity. One identifiable reason why the appropriate weights may not be proportional to capacity is because of differences in the rates of depreciation in the value of assets. In this study, average asset lives for machinery and equipment vary around 17 years, while average asset lives for non-dwelling construction are assumed to be 39 years (see Chapter 5). Other reasons why returns differ between categories of capital asset include different risk premiums attached to different assets or the same assets in different circumstances, and different tax treatments and other government support arrangements by industry.

Another approach is therefore to estimate the rental prices of capital directly from available information and use those estimates as weights. By equating the expected asset price of a unit of capital with the expected stream of income, the anticipated rental price of capital in production is generally written, without time or industry subscripts, as:

$$p = q(r + \delta) - \dot{q} \qquad \text{(C10)}$$

where p is the rental price of capital, q is the expected price of a unit of capital, r is the nominal rate of return, δ is the rate of depreciation and $\dot{q}$ is the expected change in the price of the capital good over the period. In this framework, the expected rental price of a unit of capital for production in a period is equal to the depreciation in the value of the asset over the period due to use in production, returns to management net of depreciation, less any revaluation of the nominal value of the asset due to inflation or other price changes.

Information on expected prices, or indeed expected production inputs and output, is not available, so it is necessary to draw on available statistical information to approximate the underlying concepts. Harper *et al.* (1989) review a number of possible empirical approaches to estimating the rental price of metal working machinery using US data for 21 manufacturing industry subdivisions over the period 1948 to 1981. These approaches use information about returns to capital and depreciation and capital gains for each year to estimate rental prices. However, the approaches considered vary in the treatment of capital gains and whether the rate of return is determined internally from the basic data or external from sources such as the Moody Baa bond rate. The study found substantial differences between the alternative measures of rental prices, so the method chosen for MFP analysis remained a matter of judgement.

The BLS (1983) use information on capital costs to estimate the rental prices of items of capital for the corporate sector. Non-corporate rental prices are then set equal to the corporate rental prices for individual commodities and industries. The ABS also estimates rental prices from information about industry costs in the following way:

$$P_{it}^{k} = F_{it}(r_t + \delta_{it}) - (F_{it-1} - F_{it}) \qquad \text{(C11)}$$

where P_{it}^{k} is the rental price of capital good i in period t, F_{it} is the price deflator for new capital good i in period t (or t-1), r_t is the nominal internal rate of return on capital employed, and δ_{it} is the rate of depreciation in a year and is equal to the value of economic depreciation divided by the value of net capital stock at the end of the year (Aspen 1990). The ABS computes the implicit nominal internal rate of return on capital from information in capital income, the rate of depreciation and capital gains as:

$$r_t = \frac{Y_t^k}{V_t^k} - \delta_t - \dot{f} \tag{C12}$$

where Y_t^k is the value of capital income estimated by the national accounting aggregate gross operating surplus, V_t^k is the value of net capital stocks at the beginning of the year and $\dot{f}$ is the proportional growth in prices of capital goods. The ABS convention of including the implicit rate of return in the rental price calculations was found necessary because the rate of capital-good price change in any one year can be larger than a market (ie external) interest rate plus the rate of depreciation. Using this information and estimates of the level of capital capacity, the single period factor share weights for each type of capital are then defined as:

$$s_{it}^k = \frac{P_{it}^k K_{it}}{\sum_i P_{it}^k K_{it}} \tag{C13}$$

which is the capital-good component of the weighting pattern appropriate to the model of MFP defined in equation D9 of Appendix D.

The OECD estimates total productive capital stocks used in its productivity studies by adding capital stocks of machinery and equipment, and building and construction (OECD 1996). Estimates of the stocks of the two types of capital goods are estimated by the PIM as described above. Chand *et al.* (forthcoming) adopted a single category of capital and therefore aggregation was not an issue for that study. Lattimore (1989) was concerned with the value of capital stocks rather than productive capacity. Appropriately, the separate estimates obtained in that study for the value of plant and equipment, and buildings and structures were directly aggregated using unit prices (and not rental prices) as weights.

Application of rental price weights to estimated changes in capital capacity levels

The level of capital capacity employed in an industry changes continuously in response to relative price changes, as does the mix between labour and capital inputs. The adoption of fixed weighted indexes is often regarded as too restrictive an assumption for the aggregation of changes in capital inputs for productivity analysis. For example, when price and quantity relativities are negatively correlated (the normal case), a base period weighted or Laspeyres index will overstate actual changes in quantities of capital (or labour) employed. To overcome the problems inherent in the adoption of fixed weighted indexes, a number of practical alternative indexes have been suggested. Although the underlying theoretical index may be unknown, the Fisher index system (which is the geometric mean of the Laspayres (base weighted) and Paasche (current weighted) indexes and the Tornqvist index are viewed as providing a much closer approximation to the underlying index than either the Laspeyres or Paasche indexes (see CEC *et al.* 1993, p. 383 for a general discussion of the index number problem).

The Tornqvist index is commonly used to measure volume changes for the purposes of productivity measurement. This index places no prior restrictions on the substitution elasticities among the goods being aggregated (see Diewert 1976 and Caves, Christensen and Diewert 1982). It therefore can be viewed as a close approximation (in logarithms) to an arbitrary production or cost function. With the Tornqvist index, the change in aggregate capital service is the weighted sum of the changes in individual items of capital stock, where the weights are the relative cost shares:

$$\frac{\dot{K}_t}{K_{t-1}} = \ln\left(\frac{K_t}{K_{t-1}}\right) = \sum_i \bar{s}_{it} \ln\left(\frac{K_{it}}{K_{it-1}}\right)$$

where (C14)

$$\bar{s}_{it}^{k} = \frac{s_{it-1}^{k} + s_{it}^{k}}{2}$$

and where the individual year shares are defined in equation C13 above.

This system of weighting the growth in inputs is also applied to the aggregation of labour and capital for the estimation of multifactor productivity (Appendix D).

C.5 Summing up

There is clearly a need to obtain empirical information about the age/efficiency profiles of assets that can be used in the context of industry and economy-wide studies of productivity. Because of the dual relationship between changes in capital capacity and economic depreciation, additional information about either the age/efficiency or the age/price profiles of assets should assist in the estimation of both capital capacity and the value of capital stocks. The generalised logistical method developed in this appendix provides an integrated approach to measuring capacity and the value of capital stocks, and to using additional information about either aspect of capital measurement to improve estimates of both.

APPENDIX D
MULTIFACTOR PRODUCTIVITY GROWTH ACCOUNTING

D.1 Growth accounting framework

The multifactor productivity growth accounting equation used throughout this study is derived from the neoclassical theory of costs and production. The appropriate shares for aggregating different categories of inputs and types of capital are derived from this basic theory which is set out below.

The neoclassical growth model is based on a production function with constant returns to scale, capital and labour substitutability and diminishing marginal productivities of inputs. The production function can be written:

$$Y = Af(K, L) \tag{D1}$$

where Y is the measure of output in period t, K and L are effective inputs of capital and labour and $A = A(t)$ is a shift term reflecting influences such as changes in technology, the intensity with which labour and capital are used and organisational improvements through time. Differentiating the production function with respect to time gives:

$$\frac{dY}{dt} = f\frac{dA}{dt} + A\frac{\partial f}{\partial K}\cdot\frac{dK}{dt} + A\frac{\partial f}{\partial L}\cdot\frac{dL}{dt} \tag{D2}$$

Thus, the change in output over time can be attributed to increases in the deployment of effective inputs of labour and capital (ie $\frac{dK}{dt}$ and $\frac{dL}{dt}$), plus organisational improvements that raise the level of production over time (ie $\frac{dA}{dt}$). If measures of the relative productivity of labour and capital (ie $\frac{\partial f}{\partial K}$ and $\frac{\partial f}{\partial L}$) were available, such measures could be used directly to obtain a total measure of inputs. Similarly, various components of capital and labour could be weighted together according to relative productivities.

However, measures of labour and capital productivity and multifactor productivity growth are not directly observable, and it is necessary to use information about underlying production relationships to obtain measures that can be used in studies of growth. This is done in several steps. Dividing both sides by Y, the level of output, to show changes per unit of output, noting the definition of Y in equation D1, and multiplying the capital and labour terms on the right hand side by $1=\frac{K}{K}=\frac{L}{L}$ gives the expression:

$$\frac{dY}{dt}\frac{1}{Y}=\frac{1}{A}\frac{dA}{dt}+\frac{\partial f}{\partial K}\frac{K}{f}\frac{1}{K}\frac{dK}{dt}+\frac{\partial f}{\partial L}\frac{L}{f}\frac{1}{L}\frac{dL}{dt} \tag{D3}$$

By defining the proportional growth in output, capital and labour as y, k and l and $A_t = A_0e^{\lambda t}$ with $a=\frac{1}{A}\frac{dA}{dt}=\lambda$ (D3) can be written simply as:

$$y=a+\varepsilon_k k+\varepsilon_l l \tag{D4}$$

where $\varepsilon_k=\frac{\partial f}{\partial K}\frac{K}{f}$ and $\varepsilon_l=\frac{\partial f}{\partial L}\frac{L}{f}$ are the elasticities of output with respect to a change in capital or labour inputs, respectively. Under the constant returns to scale assumption adopted in conventional growth accounting models $\varepsilon_k+\varepsilon_l=1$.

D.2 Aggregating factors of production using factor shares

Assuming competitive pricing of factor inputs, each factor would be paid according to its marginal product, in which case the elasticity of output for individual factors is also the factor share in output. For capital inputs:

$$\varepsilon_k=\frac{\partial f}{\partial K}\frac{K}{f}=\frac{rK}{f}=capital\,share\,of\;output=s_k \tag{D5}$$

where r is the real return per unit of capital inputs to production and $s_k+s_l=1$. The capital and labour shares in output can be readily obtained from basic data sources, providing a basis for aggregating inputs to production and obtaining estimates of multifactor productivity using equation D4. This formulation, however, is expressed in real terms while the capital share of output in basic data sources is normally expressed in nominal terms. The application of this approach therefore also depends on the simplifying assumption that input and output prices move concurrently, which may not always be the case.

There is a somewhat more general assumption that can be made that enables factor input shares to be used as weights for the aggregation of inputs, at the same time allowing relative prices between inputs to vary. The simple use of factor shares in MFP growth calculations defines MFP as:

$$MFP = y - \sum \frac{P_i X_i}{C} \cdot x_i \tag{D6}$$

where the x are the proportional growth of inputs to production (capital and labour in this study) and C is the cost of production. For equation D6 to be equivalent to equation D4, it is necessary for:

$$\sum \frac{P_i X_i}{C} \cdot x_i \approx \sum s_i x_i = \sum \varepsilon_i x_i \tag{D7}$$

which is the case when constant returns to scale are assumed (eg see Harper *et al.* 1989).

D.3 Aggregating factor input components using rental prices

In productivity studies, several different types of capital are often examined. In this study, manufacturing industry capital is divided into two categories — plant and equipment and non-dwelling construction — while labour is available according to only one category by manufacturing industry subdivision. Capital and labour shares are available from basic data sources (Appendix B) and these shares are used in the aggregation process (see equation D6 above). Information is only available for one category of labour, so these shares can be used directly to weight labour inputs to production.

However, the shares are available only for capital in total, and therefore do not provide information with which to weight the contribution of the individual components of capital. One approach is to assume that the returns from each category of capital are proportional to capital capacity (measured in dollars) and estimate industry capital capacity (ie K_j) as the simple sum of the components. In this case, capital inputs to production would be:

$$s_{kj} K_j = s_{kj} \sum_i K_{ij} \tag{D8}$$

where K_{ij} is the estimated capital capacity of capital good i in industry j and the s_{kj} are the relevant capital income shares for each industry j, as defined above in equation D6. This effectively would assume that the rental price (P_i) of a unit of capital in equation D8 is the same between all types of capital. In this study, manufacturing industry rental prices have been estimated for the two types of capital (see Appendix C, equations C11 and C12). Information to complete similar estimates for industry divisions is not currently available. The relevant rental price weighted measure of capital inputs is therefore defined as:

$$s_{kj} K_j = s_{kj} \sum_i s_i^k K_{ij} \tag{D9}$$

where s_i^k is the rental price weight of each type of capital i (with separate weights being calculated for each year t) (see equations C11 and C12 and supporting discussion concerning rental price weighting of capital inputs).

D.4 Aggregating factor inputs using a generalised weighting system

Factors are aggregated at several levels in this study. First, items of capital are aggregated to form a composite capital good for each industry. Second, labour and capital inputs are aggregated using factor shares to provide a measure of total factor inputs into each industry. Finally, inputs are aggregated across industries to form a market sector or manufacturing division total, as appropriate. Factor shares could be used directly in this process. However, those shares and the factor input measure to which they relate (ie hours worked for labour and constant dollars for capital) refer to a single period (or a point in time in a single period in the case of capital). In order to provide more generalised indexes of inputs, it is common to form divisia indexes from the information available for successive periods. Broadly, such indexes use information from adjacent periods to form an average index that is not biased to production technologies adopted in either period. They are symmetric indexes that are an average of the two situations being compared (ie successive years in productivity analysis) and differ from fixed weighted indexes that weight change according to the situation in either the first or the second period.

The Tornqvist index is commonly used to measure volume changes for the purposes of productivity measurement.[1] It is the measure used for aggregating inputs by the BLS (1983) and ABS (see Aspen 1990). The Tornqvist volume index of factor inputs is defined as:

$$T_x = \prod_l \left(\frac{X_t}{X_{t-1}} \right)^{\bar{s}_{lt}} \qquad \text{(D10)}$$

where $\bar{s}_{lt} = \frac{1}{2}\left(s_{l,t-1} + s_{l,t}\right)$ is the average relative factor share pertaining to the respective inputs and X_t represents the relevant input (eg labour and capital) to production in year t, or $t-1$ as the case may be. The component shares are the factor income or rental price shares, as defined above. Expressing the

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[1] Another generalised index which has similar properties to the Tornqvist is the Fisher ideal index (see *CEC et al.* 1993, p. 379 and Diewert 1976).

proportional changes in logarithms, multifactor productivity growth of each industry can be expressed as:

$$a_t \equiv mfp_t = y_t - \bar{s}_t^k \cdot k_t - \bar{s}_t^l \cdot l_t$$

where (D11)

$$y_t = \ln\left(\frac{Y_t}{Y_{t-1}}\right),\; k_t = \ln\left(\frac{K_t}{K_{t-1}}\right), \text{ and } \; l_t = \ln\left(\frac{L_t}{L_{t-1}}\right)$$

This formulation is applied in this study to estimate MFP growth by industry division in the market sector and manufacturing industry subdivision. From the definition of A_t above, the chain linked index of productivity levels over time is then defined as:

$$A_t \equiv MFP_t = MFP_{t-1}e^{mfp_t} \qquad \text{(D12)}$$

where the reference period is the first year of the series, that is, 1974–75 for industry divisions and 1968–69 for manufacturing subdivisions with $A_0=1$. The final estimates are obtained by re-referencing the series to 1989–90, the reference year for other series examined in this study.

APPENDIX E
SENSITIVITY OF CAPITAL STOCK ESTIMATES TO ALTERNATIVE ASSUMPTIONS

E.1 Introduction

As discussed in Chapter 5, there are many different approaches and conventions that can be used to estimate capital capacity and net capital stocks. This appendix reports the sensitivity of capital values to key data and methodological assumptions.

The first sensitivity analysis, outlined in section E.2, is a comparison of alternative investment data. Section E.3 assesses the effect of different methodologies on capital capacity measures, while section E.4 examines the effects of alternative asset depreciation methods and asset life assumptions. Section E.5 gives a comparison of Commission capital stocks with ABS estimates. A final section sums up the appendix.

In each of the sensitivity tests, the Commission's generalised logistic, private net capital stock series, is used as the basis for comparison. Estimates for the capital categories machinery and equipment and non-dwelling construction are considered in this appendix. However, as machinery and equipment dominates capital expenditure (accounting for about 82 per cent of new capital expenditure), most sensitivity tests are reported for that capital item.

E.2 Alternative investment data

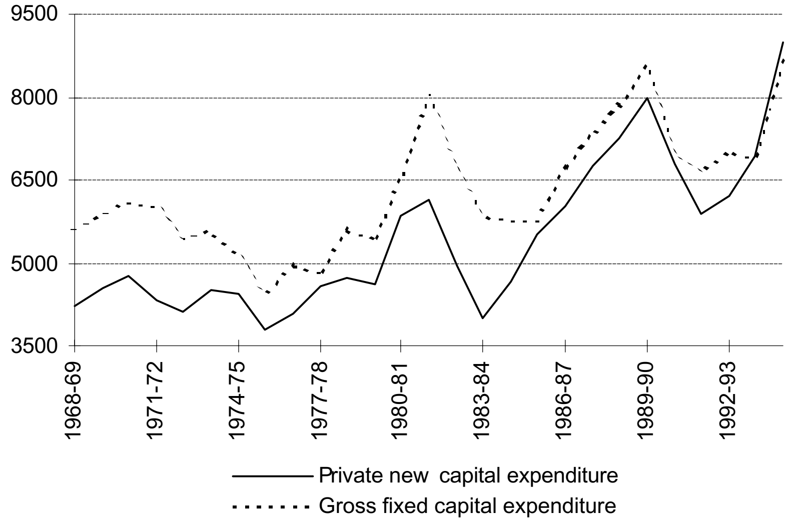
The quarterly survey of private new fixed capital expenditure currently provides the most suitable basis for continuing productivity analysis at the disaggregated manufacturing level. In particular, it provides the industry detail required for this study. The information is available over a long time period, and is updated regularly from quarterly collections. Data by manufacturing subdivision over the extended period are not available from any alternative source.

As discussed in Chapter 5, the new fixed capital series has a number of disadvantages when compared with the ABS measure of gross fixed capital expenditure for total manufacturing. On average, gross capital expenditure is approximately 15 per cent higher than net capital expenditure, although the gap has narrowed over the period (Figure E.1). The main reasons for this discrepancy are:

- the new capital expenditure series only records new investment and does not take into account the sales and purchases of second hand assets;
- the gross fixed capital expenditure series measures both private and public investment, while new capital expenditure is a measure of only private investment; and
- the ABS gross fixed capital expenditure data are derived from income taxation statistics, while new capital expenditure data are based on enterprise surveys of the major activity undertaken by each industry.

Although the series differ in levels, the year to year changes are closely related. As a result, in change form, capital and productivity estimates are likely to be insensitive to the investment series used.

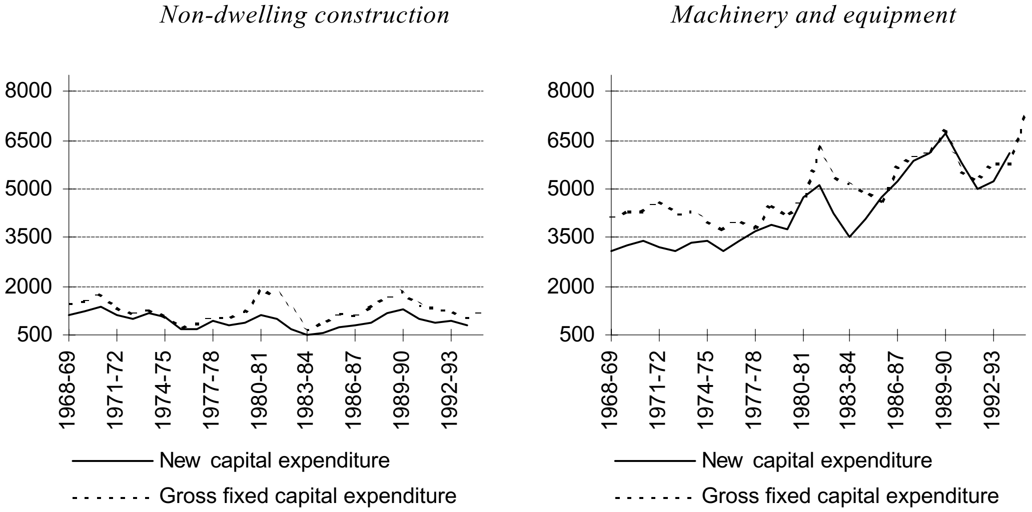
Figure E.1: **Comparison of investment measures, total manufacturing, 1968–69 to 1994–95** ($ million)



Sources: ABS special request and ABS catalogue 5221.0.

While the gap between the respective estimates for machinery and equipment has narrowed since the mid 1980s, the gap for non-dwelling construction, if anything, has widened over the same period (Figure E.2).

Figure E.2: **Comparison of investment measures, non-dwelling construction and machinery and equipment, total manufacturing, 1968–69 to 1994–95** ($ million)



Sources: ABS special request and ABS catalogue 5221.0.

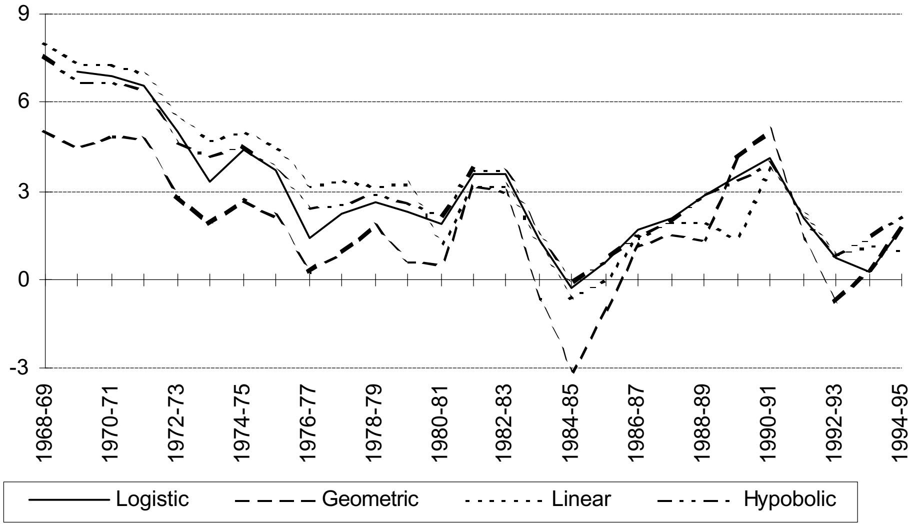
E.3 Capital capacity

To examine the sensitivity of capital capacity values to alternative assumptions, capital capacity series were estimated on four bases, the linear combination of the net and gross value capital stocks, geometric decline, hyperbolic decline and logistic decline.

Figure E.3 and Table E.1 show that alternate methodologies have little impact on the annual change in the level of capital capacity. Nevertheless, the geometric decay approach appears to differ more from the other methods than they do from one another. Under the geometric decay approach, asset capacity is assumed to decay more in the earlier years of service than under other methods. This lowers the estimated level of installed capital capacity, resulting in greater year-to-year volatility than evident from other approaches. In addition, it results in annual capacity growth under this method generally lying below growth implied by the other methods considered.

Results from the Commission's logistic approach is also highly correlated with the linear, geometric and hyperbolic approaches at the industry level. The sensitivity of Commission estimates to alternative depreciation assumptions is discussed further in Section E.4.

Figure E.3: **Capital capacity based on alternative methodologies, total manufacturing, 1968–69 to 1994–95** [ab] (annual growth, per cent)



a The linear and logistic efficiency decline approaches assume the assets have some residual value at retirement, whereas the geometric and hyperbolic approaches assume a zero residual value. With the exception of the logistic method introduced in this study, these conventions correspond to the common applications of these methods.

Source: Commission estimates.

E.4 Value of capital stocks

The Commission uses capital capacity as its capital input measure for MFP studies. Nevertheless, many studies of capital stocks are more concerned with the value of capital rather than available capital capacity. These studies are generally presented within a national income and wealth framework. Value of capital series can be derived from capital capacity data or estimated directly using the PIM (Chapter 5). For sensitivity testing, capital value series have been derived for the logistic and hyperbolic asset age/efficiency profiles. These measures of capital stock can be compared with the measures obtained directly using the straight line and geometric decay methods. In addition, value of capital measures derived from the Commission's logistic model have been used to examine the sensitivity of model results to alternative compilation assumptions.

Table E.1: **Capital capacity based on alternative methodologies, manufacturing industry subdivision, 1968–69 to 1994–95**[ab] (average annual growth, per cent)

Industry	*Logistic*	*Linear*		*Geometric*		*Hypobolic*	
Food, beverages and tobacco	3.419	3.333	*0.961*	2.191	*0.872*	3.505	*0.979*
Textiles, clothing, footwear and leather	0.945	1.504	*0.806*	-0.090	*0.872*	1.258	*0.697*
Printing, publishing and recorded media	4.750	4.301	*0.946*	3.769	*0.949*	5.479	*0.936*
Petroleum, coal, chemical and associated products	1.488	1.835	*0.896*	0.392	*0.864*	1.643	*0.974*
Basic metal products	3.017	3.116	*0.970*	1.697	*0.949*	3.070	*0.988*
Fabricated metal products	2.128	2.410	*0.963*	0.867	*0.955*	2.285	*0.995*
Transport equipment	3.036	3.140	*0.930*	1.489	*0.888*	3.202	*0.983*
Other manufacturing	3.967	4.074	*0.942*	2.974	*0.945*	4.075	*0.982*
Total manufacturing	2.887	3.007	*0.925*	1.721	*0.891*	3.050	*0.983*

a The linear and logistic efficiency decline approaches assume the assets have some residual value at retirement, whereas the geometric and hyperbolic approaches assume a zero residual value. With the exception of the logistic method introduced in this study, these conventions correspond to the common applications of these methods.

b Figures in italics represent the correlation coefficient between the logistic and the straight line, geometric decay and hyperbolic series, respectively.

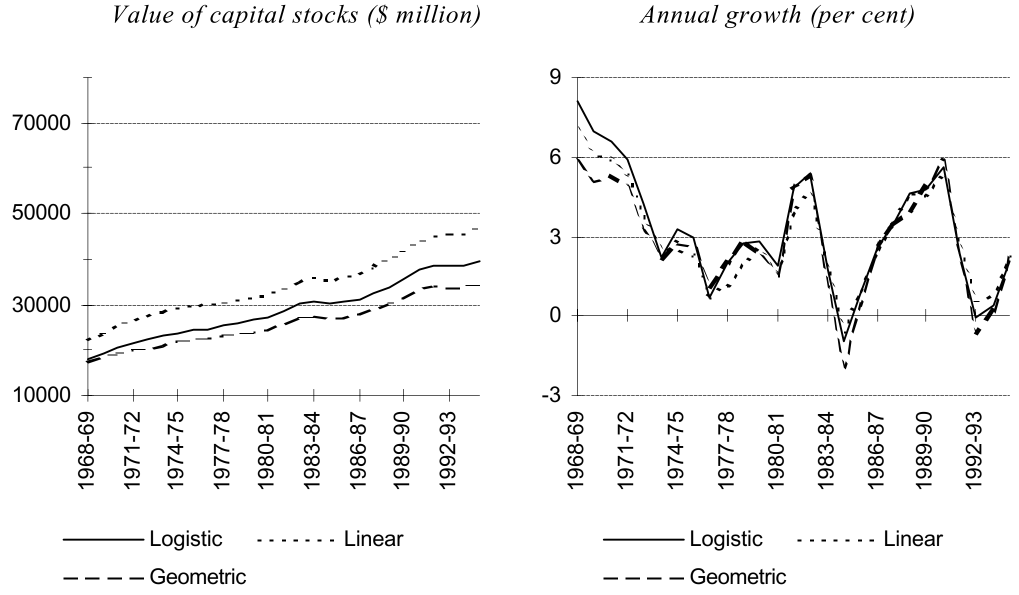
Source: Commission estimates.

Although compilation assumptions are tested in a capital value framework, the conclusions should also apply to capital capacity measures, as appropriate. Although conceptually different, the conclusions should extend across both frameworks as the value of capital series are derived from the capital capacity series and the profiles of each are broadly similar (Appendix C).

Alternative depreciation methods

Depreciation, or the consumption of capital, is the reduction in the value of capital assets arising from use and obsolescence. The two main direct measures of depreciation used in studies of the value of capital are the straight line (or linear) and geometric decay (or diminishing balance) methods. In addition, both generalised logistic and hyperbolic methods for estimating capital capacity provide implicit values for net capital stock and depreciation. This section examines the sensitivity of capital value series to the alternative direct and implicit estimation methods of depreciation (Figure E.4).

Figure E.4: **Net capital stocks based on alternative depreciation methods, machinery and equipment, total manufacturing, 1968–69 to 1994–95** [abc]



a Capital stocks at 30 June in each year.

b Estimates assume Commission’s estimated asset lives and shortening of asset lives over time.

c The logistic and hyperbolic series overlap almost entirely. The results for the hyperbolic series are not explicitly shown.

Source: Commission estimates.

Under the linear approach, assets are depreciated by equal amounts each year and, as a result, the decline in an asset’s value is proportionately less in the earlier years of its life. The geometric, logistic and hyperbolic approaches adopt convex asset age/value profiles, although it is only under the geometric decay method that the asset value declines in equal proportions in successive years. This means that, under these three approaches, asset values are assumed to fall faster than under the straight line method.

As a result, the straight line capital stock values for plant and equipment are larger than the values estimated using alternative approaches — estimates of net capital stock using the linear approach are about 20 per cent higher than Commission estimates based on the logistic approach. However, in change form, the hyperbolic, linear and geometric decay results are all highly correlated with the results from the Commission’s logistic approach, both in aggregate and at the industry subdivision levels of aggregation (Figure E.4 and Table E.2).

Table E.2: **Net capital stocks based on alternative depreciation methods, machinery and equipment, by manufacturing industry subdivision, 1968–69 to 1994–95** [abc] (average annual growth, per cent)

Industry	*Logistic*	*Linear*		*Geometric*		*Hypobolic*	
Food, beverages and tobacco	3.837	3.546	*0.980*	3.285	*0.935*	4.325	*0.957*
Textiles, clothing, footwear and leather	1.644	1.081	*0.952*	1.149	*0.965*	1.839	*0.988*
Printing, publishing and recorded media	7.101	5.070	*0.927*	5.495	*0.971*	8.152	*0.919*
Petroleum, coal, chemical and associated products	1.295	1.176	*0.977*	1.037	*0.973*	1.384	*0.981*
Basic metal products	2.566	2.310	*0.994*	1.959	*0.979*	3.204	*0.980*
Fabricated metal products	2.035	2.241	*0.992*	1.777	*0.985*	2.187	*0.995*
Transport equipment	4.589	4.312	*0.983*	4.152	*0.983*	4.845	*0.977*
Other manufacturing	4.812	4.483	*0.991*	4.382	*0.985*	5.050	*0.986*
Total manufacturing	**3.253**	**2.989**	***0.986***	**2.802**	***0.961***	**3.558**	***0.976***

a Capital stocks at 30 June in each year.

b Estimates assume Commission’s estimated asset lives and shortening of asset lives over time.

c Figures in italics represent the correlation coefficient between the Commission’s estimates and the series undergoing the sensitivity test.

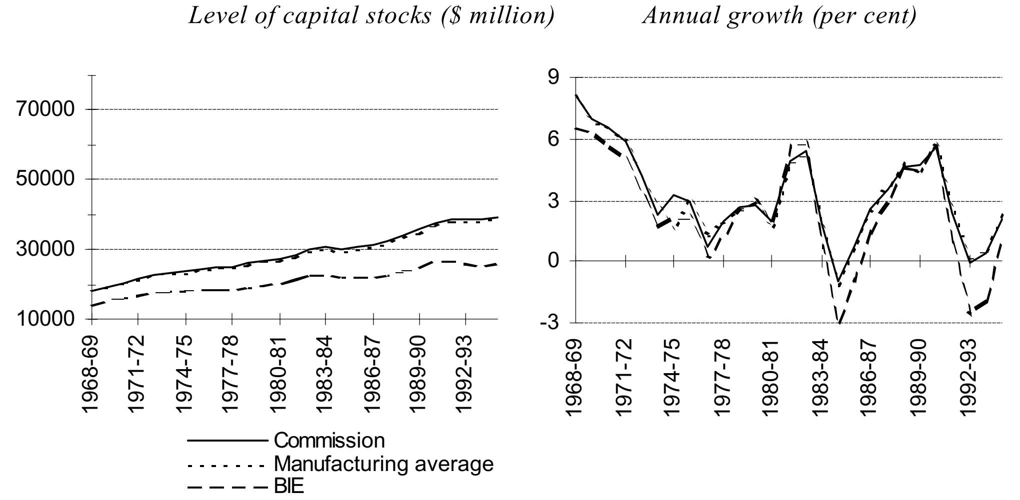
Source: Commission estimates.

Alternative assumptions about asset lives

In this study, the asset life for each manufacturing industry is based on the ABS average with BIE industry relativities. In order to test the sensitivity of capital stock estimates to alternative asset life assumptions, the value of capital stocks have also been estimated using the ABS 1980s average of 17 years for all industries and the BIE estimates of asset lives for each industry subdivision. These alternative assumptions are examined using the Commission’s logistic methodology.

The Commission’s estimates of the level of manufacturing industry net capital stock are quite sensitive to asset life assumptions. Under BIE assumptions, capital is retired earlier than under either the Commission’s or the ABS’s assumptions, resulting in a lower level of net capital stocks (Figure E.5).

Figure E.5: **Net capital stock based on different asset lives, machinery and equipment, total manufacturing, 1968–69 to 1994–95**[ab]



a Capital stocks at 30 June in each year.

b Estimates assume logistic age/efficiency profiles and implied depreciation, and shortening of asset lives over time.

Source: Commission estimates.

Although the adoption of variable asset lives between industries affects the level of capital, it does not necessarily impact on the estimated rate of capital growth. There are many factors at work in the translation of investment growth into capital stock growth. For example, assets with longer service lives would raise the unit value of capital in any one year, relative to shorter service lives. A unit reallocation of investment to activities with longer lived assets could therefore be associated with slower capital growth than a relocation of investment to activities with shorter lived capital. The reverse would be the case for industries with shorter lived capital.

These trends are exhibited in Table E.3. Under BIE assumptions, capital is retired earlier than under the Commission's assumptions. As a result, BIE yearly growth in the net capital stock is more negative or positive than Commission estimates. For those industries which have had mainly positive yearly growth rates over the period, BIE estimates are larger than IC estimates. This is the case for printing, publishing and recorded media. For industries which have predominantly negative or low positive yearly growth rates, such as petroleum, coal, chemical and associated products, the Commission's average annual growth rate estimates are higher than those of the BIE.

Table E.3: **Net capital stock based on alternative asset life assumptions, machinery and equipment, by manufacturing industry subdivision, 1968–69 to 1994–95** [abc] (average annual growth, per cent)

Industry	*IC*	*Manufacturing average*		*BIE*	
Food, beverages and tobacco	3.837	3.541	*0.966*	3.437	*0.952*
Textiles, clothing, footwear and leather	1.644	1.889	*0.981*	1.004	*0.919*
Printing, publishing and recorded media	7.101	6.730	*0.962*	7.439	*0.923*
Petroleum, coal, chemical and associated products	1.295	1.397	*0.992*	0.143	*0.950*
Basic metal products	2.566	2.327	*0.995*	1.951	*0.990*
Fabricated metal products	2.035	1.743	*0.996*	1.229	*0.983*
Transport equipment	4.589	4.667	*0.991*	3.422	*0.973*
Other manufacturing	4.812	4.872	*0.994*	3.849	*0.978*
Total manufacturing	**3.253**	**3.202**	***0.984***	**2.449**	***0.966***

a Capital stocks as measured at 30 June in each year.

b Estimates assume logistic age/efficiency profiles and shortening of asset lives over time.

c Figures in italics represent the correlation coefficient between the Commission's estimates and the series undergoing the sensitivity test.

Source: Commission estimates.

Changing asset lives over time

In this study, the assumption that asset lives decline five per cent each decade is adopted. Sensitivity testing suggests that, if no asset life shortening was assumed, it would have virtually no effect on the measured growth in net capital stocks (Table E.4). Nevertheless, no shortening of asset lives yields fractionally higher estimates of capital stock.

Table E.4: **Net capital stock based on alternative assumptions of asset life shortening, machinery and equipment, by manufacturing industry subdivision, 1968–69 to 1994–95**[abc] (average annual growth, per cent)

Industry	*Asset shortening*	*No asset shortening*	
Food, beverages and tobacco	3.837	4.129	*0.999*
Textiles, clothing, footwear and leather	1.644	2.216	*0.998*
Printing, publishing and recorded media	7.101	7.484	*0.999*
Petroleum, coal, chemical and associated products	1.295	1.829	*0.998*
Basic metal products	2.566	3.107	*1.000*
Fabricated metal products	2.035	2.561	*0.999*
Transport equipment	4.589	5.108	*0.999*
Other manufacturing	4.812	5.285	*0.999*
Total manufacturing	3.253	3.711	*0.999*

a Capital stocks at 30 June in each year.

b Estimates assume logistic age/efficiency profiles and the Commission’s estimated asset lives.

c Figures in italics represent the correlation coefficient between the Commission’s estimates and the series where assets lives have not been shortened over time.

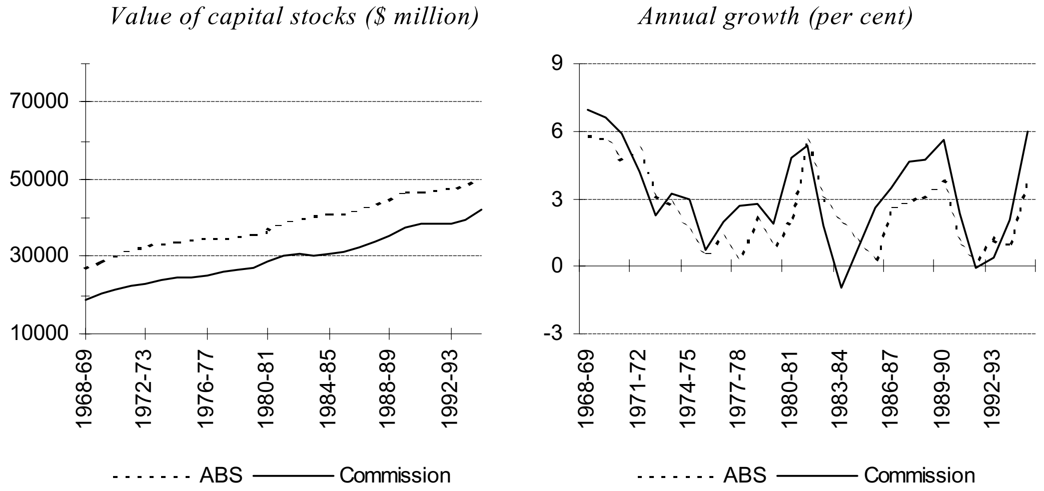
Source: Commission estimates.

Comparison of value of capital stocks with ABS estimates

The Commission’s approach to compiling capital stock estimates differs from that of the ABS in terms of methodology and investment data used. The ABS calculates capital stock estimates for manufacturing using gross fixed capital expenditure, while the Commission is constrained to using new capital expenditure to calculate capital stocks at the disaggregated manufacturing subdivision level. Both studies assume that asset lives decline five per cent each decade. However, the ABS assumes straight line depreciation and uniform asset life across all industries (reference 17 years in the 1980s), while the Commission applies a generalised logistic model with asset lives based on the ABS average with BIE industry subdivision relativities.

Prior sensitivity tests found that gross fixed capital expenditure and straight line depreciation produced higher measured net capital stocks than those produced using new capital expenditure and depreciation implicit in logistic age/efficiency profiles. As a result, the ABS level of capital stocks is higher than Commission estimates. However, in growth form, the two series follow similar paths (Figures E.6 and E.7).

Figure E.6: **ABS and Commission estimates of net capital stocks, machinery and equipment, total manufacturing, 1968–69 to 1994–95**[ab]

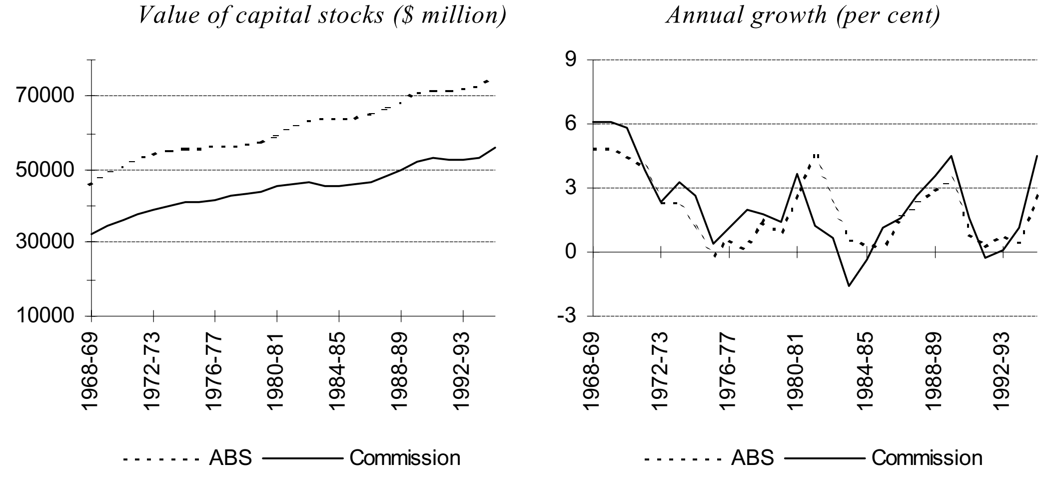


a Capital stocks as measured at 30 June in each year.

b The ABS assumes straight line depreciation and uniform asset lives across all manufacturing industries. The Commission assumes logistic age/efficiency profiles and different asset lives between manufacturing industry subdivisions. Both series assume that asset lives are shortened by 5 per cent each decade.

Sources: ABS 1997c, Commission estimates.

Figure E.7: **ABS and Commission estimates of net capital stocks, total manufacturing, 1968–69 to 1994–95**[ab]



a Capital stocks as measured at 30 June in each year.

b The ABS assumes straight line depreciation and uniform asset lives across all industries and that asset lives are shortened by 5 per cent each decade. The Commission assumes logistic depreciation, different asset lives between manufacturing industries and that asset lives are shortened by 5 per cent each decade.

Sources: ABS 1997c, Commission estimates.

E.5 Summing up

While different investment data, alternative depreciation methods and varying asset lives can have a substantial effect on the estimated level of capital, they have only a limited impact on year-to-year changes in estimates of capital capacity and the value of net capital stock.

In terms of the individual sensitivity tests conducted, the Commission's estimated value of net capital stock obtained from its generalised logistic method differs most from estimates based on linear depreciation. Estimated levels are also sensitive to alternative assumptions about asset lives. However, alternative depreciation and asset life assumptions have little effect on the average annual growth in the value of net capital stocks, which are primarily driven by changes in investment.

As alternative investment series follow similar trends, the Commission's final estimates of annual growth in capital capacity and the value of net capital stock compare closely with estimates based on alternative data sources.

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