A Growth accounting framework and data sources

## A.1 Growth accounting framework

The growth accounting framework, is an accounting exercise that breaks down output growth into input growth and attributes the residual to technical change. It examines *growth* in output rather than the *level* of output.

In the ABS official estimates of multifactor productivity (MFP) growth for Australia, output is measured as gross value added (gross output less intermediate inputs). In this case, the growth accounting framework says that value added growth is equal to a weighted average of capital growth and labour growth plus a residual not explained by growth in combined inputs. The residual is commonly referred to as MFP growth.[[1]](#footnote-1) Although MFP growth is sometimes interpreted as a measure of technical progress, in practice it measures much more than this. Other influences on annual MFP growth include: economies of scale; changes in management practices and the skill of the labour force; climate, water and other natural resource availability; variations in capacity utilisation; and any errors in the measurement of inputs and outputs.

Growth accounting is based on a number of important assumptions:

* constant returns to scale in the underlying production function
* output markets are competitive
* inputs markets are competitive (that is, factor inputs are paid their marginal products)
* inputs are fully divisible
* inputs are fully utilised
* the economy is in equilibrium.

The following sections discuss the methodology and data sources used to estimate the variables required to calculate MFP growth at the subsector level.

## A.2 Industry classification

MFP estimates for Manufacturing in aggregate are available from 1985‑86 to 2010‑11 in ABS *Experimental Estimates of Industry Multifactor Productivity, 2010‑11* (Cat. no. 5260.0.55.002). These estimates are the industry division of Manufacturing as defined in the 2006 edition of the *Australian and New Zealand Standard Industrial Classification* (ANZSIC06) (ABS 2006b).

The main disaggregation of Manufacturing used in this paper is based on the eight Manufacturing subsectors reported in the annual ABS National Accounts publication (Cat. no. 5204.0). Table A.1 shows the relationship between these eight subsectors and the Manufacturing subdivisions in the ANZSIC06. These subdivisions include a wide range of activities (box A.1).

Table A.1 Manufacturing subsectors and ANZSIC06 Manufacturing subdivisions

|  |  |
| --- | --- |
| Manufacturing subsectors  (ANZSIC06 National Accounts groupings) | ANZSIC06 Manufacturing subdivisions |
| Food, beverage & tobacco products (FBT) | 11 Food product manufacturing |
|  | 12 Beverage & tobacco product manufacturing |
| Textile, clothing & other manufacturing (TCO) | 13 Textile, leather, clothing & footwear mfg |
|  | 25 Furniture & other manufacturing |
| Wood & paper products (WP) | 14 Wood product manufacturing |
|  | 15 Pulp, paper & converted paper product mfg |
| Printing & recorded media (PRM) | 16 Printing (incl. reproduction of recorded media) |
| Petroleum, coal, chemical & rubber products | 17 Petroleum & coal product manufacturing |
| (PCCR) | 18 Basic chemical & chemical product mfg |
|  | 19 Polymer product & rubber product mfg |
| Non-metallic mineral products (NM) | 20 Non-metallic mineral product manufacturing |
| Metal products (MP) | 21 Primary metal & metal product manufacturing |
|  | 22 Fabricated metal product manufacturing |
| Machinery & equipment (ME) | 23 Transport equipment manufacturing |
|  | 24 Machinery & equipment manufacturing |

|  |
| --- |
| Box A.1 ANZSIC06 Manufacturing subdivisions and groups |
| **11 Food product mfg** 111 Meat & meat product mfg 112 Seafood processing  113 Dairy product mfg 114 Fruit & vegetable processing 115 Oil & fat mfg 116 Grain mill & cereal product mfg 117 Bakery product mfg 118 Sugar & confectionery mfg  119 Other food product mfg |
| **12 Beverage & tobacco product mfg** 121 Beverage mfg 122 Cigarette & tobacco product mfg |
| **13 Textile, leather, clothing & footwear mfg** 131 Textile mfg 132 Leather tanning, fur dressing & leather 133 Textile product mfg 134 Knitted product mfg  135 Clothing & footwear mfg |
| **14 Wood product mfg** 141 Log sawmilling & timber dressing 149 Other wood product mfg |
| **15 Pulp, paper & converted paper product mfg** 151 Pulp, paper & paperboard mfg 152 Converted paper product mfg |
| **16 Printing (including the reproduction of recorded media)** 161 Printing & printing support services 162 Reproduction of recorded media |
| **17 Petroleum & coal product mfg** 170 Petroleum & coal product mfg |
| **18 Basic chemical & chemical product mfg** 181 Basic chemical mfg 182 Basic polymer mfg 183 Fertiliser & pesticide mfg 184 Pharmaceutical & medicinal product mfg 185 Cleaning compound & toiletry prep’n mfg 189 Other basic chemical product mfg |
| **19 Polymer product & rubber product mfg** 191 Polymer product mfg 192 Natural rubber product mfg |
| **20 Non-metallic mineral product mfg** 201 Glass & glass product mfg 202 Ceramic product mfg 203 Cement, lime, plaster & concrete Prod. 209 Other non-metallic mineral prod. mfg |
| **21 Primary metal & metal product mfg** 211 Basic ferrous metal mfg 212 Basic ferrous metal product mfg 213 Basic non-ferrous metal mfg 214 Basic non-ferrous metal product mfg |
| **22 Fabricated metal product mfg**  221 Iron & steel forging 222 Structural metal product mfg 223 Metal container mfg 224 Sheet metal product mfg 229 Other fabricated metal product mfg |
| **23 Transport equipment mfg**  231 Motor vehicle & motor vehicle part mfg 239 Other transport equipment mfg |
| **24 Machinery & equipment mfg**  241 Professional & scientific equipment mfg 242 Computer & electronic equipment mfg 243 Electrical equipment mfg 244 Domestic appliance mfg 245 Pump, compressor, heating & ventilation 246 Specialised machinery & equipment mfg 249 Other machinery & equipment mfg |
| **25 Furniture & other Mfg**  251 Furniture mfg 259 Other mfg |
| *Source*: ABS (*Australian and New Zealand Standard Industrial Classification 2006,* Cat. no. 1292.0). |
|  |
|  |

To construct a time series from 1985‑86 to 2010‑11 for some of the variables required to estimate subsector MFP, it was necessary to use some data collected under the previous industry classifications. Subsector data based on ANZSIC06 were backcast to earlier years using the growth rate in data under the 1993 edition of the *Australian and New Zealand Standard Industrial Classification* (ANZSIC93) and *Australian Standard Industrial Classification* (ASIC). In a broad sense, the Manufacturing subdivisions under previous industry classifications correspond fairly closely to the eight subsectors under ANZSIC06. Table A.2 provides the broad correspondence between the two industry classifications that was used. Precise concordances were not possible due to limited availability of data.

Table A.2 ANZSIC93 correspondence to ANZSIC06 Manufacturing subsectors**a**

|  |  |  |
| --- | --- | --- |
| ANZSIC06-based subsectors | Main corresponding  ANZSIC93 subdivision(s)a | Main corresponding  ASIC subdivision(s) |
| Food, beverage & tobacco products (FBT) | 21 Food, beverage & tobacco mfg | 21 Food, beverages & tobacco |
| Textile, clothing & other manufacturing (TCO) | 22 Textile, clothing, footwear & leather mfg | 23 Textiles  24 Clothing & footwear |
|  | 29 Other manufacturing | 34 Miscellaneous mfg |
| Wood & paper products (WP) | 23 Wood & paper product mfg | 25 Wood, wood products & furniture |
| Printing & recorded media (PRM) | 24 Printing, publishing & recorded mediab | 26 Paper, paper products, printing & publishingc |
| Petroleum, coal, chemical & rubber products (PCCR) | 25 Petroleum, coal, chemical & associated product mfg | 27 Chemical, petroleum & coal products |
| Non-metallic mineral products (NM) | 26 Non-metallic mineral product mfg | 28 Non-metallic mineral products |
| Metal products (MP) | 27 Metal product mfg | 29 Basic metal products  31 Fabricated metal products |
| Machinery & equipment (ME) | 28 Machinery & equipment mfg | 32 Transport equipment  33 Other machinery & equip’t |

a Although this correspondence is assumed to provide a reasonable basis for ascertaining broad industry trends, there are a number of individual activities that moved between sectors with the introduction of ANZSIC06. Details of these moves are presented in ABS (Cat. no. 1292.0). b ‘Publishing’ was moved from the Manufacturing division under ANZSIC93 to the Information, media and telecommunications division under ANZSIC06. c Paper products was moved to Wood and paper under ANZSIC93/06.

*Sources*: Authors’ estimates based on ABS (*Australian and New Zealand Standard Industrial Classification 2006,* Cat. no. 1292.0); ABS (*Concordance Between the Australian Standard Industrial Classification (ASIC) and the* *Australian and New Zealand Standard Industrial Classification (ANZSIC), 1993,* Cat. no. 1292.0.15.004).

## A.3 Value added

For the measurement of MFP, output *volume* measures are required. The ABS uses gross value added (gross output less intermediate inputs) as the output measure for its aggregate Manufacturing MFP estimates. This is also the measure used for the disaggregated estimates in this study.

The ABS uses gross value added chain volume measures (GVA CVMs) from the National Accounts (ABS Cat. no. 5204.0) in its estimates of MFP for Manufacturing in total. The ABS National Accounts also include GVA CVMs for Manufacturing divided into eight subsectors (based on ANZSIC06) from 1985‑86 to 2010‑11. GVA CVMs are not available for all 15 ANZSIC06 Manufacturing subdivisions. This limited the level of disaggregation that was possible in this study.

From 1995‑96, the annual ABS chain volume measures of GVA at the industry level have been derived using the double deflation method, that is as the difference between volume estimates of output and intermediate input (see ABS 2000a, para. 10.30 for further details). Prior to 1995‑96, it was assumed that the volume measure of gross value added grew at the same rate as the volume measure of output (that is, the output indicator method). This method is based on the underlying assumption that in volume terms the ratio of intermediate input to output is stable. This was carried out at as detailed a level as practicable and the volume indexes were weighted together using the current price estimate of GVA, so as to ameliorate the effects of departures from this assumption (ABS 2000a, para. 10.32).[[2]](#footnote-2)

## A.4 Hours worked

The labour input measure used by the ABS in its aggregate Manufacturing MFP estimates is an index of annual hours worked, based on data from the ABS *Labour Force Survey*. Hours worked indexes for each of the eight subsectors were derived from this aggregate Manufacturing series, using information (from the same survey) about the distribution of hours worked across Manufacturing subsectors.[[3]](#footnote-3)

The ABS publishes an hours worked index for the Manufacturing division in *Experimental Estimates of Industry Multifactor Productivity, 2010‑11* (Cat. no. 5260.0.55.002). This index is based on data from the ABS *Labour Force Survey* that has been annualised and adjusted for changes in survey methodology to improve consistency over time.

* The *Labour Force Survey* collects hours worked data in reference weeks, not every week of the year. The ABS annualises hours worked by making adjustments for events such public and school holidays. For details of this ABS method see ABS (2006c) and Baker and von Sanden (2006).
* Changes in survey methodology include the *Labour Force Survey* questionnaire redesign in 2000‑01 (ABS 2000b).

The hours worked level series underlying this aggregate Manufacturing index is unpublished but was provided by the ABS. This total number of hours worked in Manufacturing was allocated across subsectors using ratios of each subsector’s hours worked to Manufacturing’s total hours worked from the quarterly *Labour Force Survey*.[[4]](#footnote-4) This is the same method the ABS applies to allocate its estimate of total economy hours worked to industry divisions (ABS 2006c). The resulting subsector series differ from simple aggregations of the published *Labour Force Survey* data.[[5]](#footnote-5)

The quarterly *Labour Force Survey* data were available from November 1984 for all 15 Manufacturing subdivisions on an ANZSIC06 basis. (Data back to 1994 were available from Cat. no. 6291.0.55.003, August 2011[[6]](#footnote-6); data prior to 1994 were obtained as a special data request). The subdivisions were aggregated into the eight subsectors being used in this study (as listed in table A.1).

## A.5 Capital services

### Summary

Capital services is a flow measure of capital inputs, which is used by the ABS and in this paper to calculate MFP. For any asset, capital services represents the amount of service provided in a given period — in this case, annual data are used. The capital services provided in a period by an asset is assumed by the ABS to be proportional to the value of the productive capital stock.

Productive capital stock, in turn, is calculated through the use of a perpetual inventory method (PIM). This involves compiling a rolling inventory of capital stocks, with investment in new assets each year added to stocks, retired assets deducted, and the value of remaining assets adjusted according to ageing. A variety of assumptions, such as how long it takes different capital types to fully depreciate, and the manner in which they do so is required, along with investment data.

A single capital services measure for an industry or subsector is then calculated by weighting the growth in the productive capital stocks of different assets by using their relative volumes and rental prices. Figure A.1 shows a stylised representation of the stocks and flows that affect capital services.

Figure A.1 A stylised representation of capital services**a**

|  |
| --- |
| Productive capital stock of asset B  Productive capital stock of asset A |

a This figure shows the flows (circles) and stocks (squares) at a particular point in time. Investment adds to the productive capital stock, while depreciation subtracts. The amount of productive capital stock then defines the flow of capital services for that point in time. Here, only two asset types are presented; in practice there can be any number of asset types.

Capital input growth cannot be calculated as the average annual growth in investment between start and end points of productivity cycles. This is because the investments that occur within a cycle will affect the productive capital stock and the growth of capital services by the end of the cycle. This is discussed in greater detail in box A.2.

|  |
| --- |
| Box A.2 Investment over cycles |
| Investment in each year adds to productive capital stock, and thus affects the growth rate of capital services. It is not possible to simply examine investment at the beginning and end of the cycle and conclude the effect on capital services. Capital services growth over a cycle is affected by the existing stock and investment in each year of the cycle. A simple example of this is presented in the figure below.  time  investment  A  B  Cycle start  Cycle end  The figure to the left shows two investment profiles (A and B) over a productivity cycle.  The average annual growth rate between the start- and end-points is negative for A, but positive for B. However, between the cycle start- and end-points, there is much greater investment by A relative to B (the area under each curve).  Broadly speaking, capital services growth under ‘A’ would be stronger than under ‘B’ over the productivity cycle, even though the average annual growth rates between the start- and end-points would suggest otherwise.  The initial capital stock and age of that capital stock should also be considered when interpreting the impact of investment on capital services. |
|  |
|  |

The ABS estimates a capital services index for Manufacturing in aggregate, but not for the subsectors within Manufacturing. For this study, capital services indexes for the subsectors were estimated using a broadly similar methodology to that used by the ABS for Manufacturing as a whole, in order to be as consistent as possible.

However, due to data limitations, there are some important differences in the approach taken to estimating capital services for the subsectors. One difference is that fewer asset types were included in the subsector estimates than are used by the ABS for Manufacturing in aggregate (table A.3). The ABS includes twelve different asset types in its Manufacturing division-level estimates, but in the subsector estimates only the four asset types were able to be included (one of which aggregates six ‘machinery and equipment’ asset types considered separately by the ABS).

Table A.3 Comparison of asset types included in capital services

|  |  |
| --- | --- |
| For ABS Manufacturing estimates | For subsector estimates |
| Computer software | Computer software |
| Research & development | Research & development |
| Inventories - Non-farm | *(unavailable)* |
| Land | *(unavailable)* |
| Machinery & equipment - Computers | Machinery & equipment (jointly)a |
| Machinery & equipment - Electrical & Electronic Equipment |
| Machinery & equipment - Industrial Machinery & Equipment |
| Machinery & equipment - Other Plant & Equipment |
| Machinery & equipment - Other Transport Equipment |
| Machinery & equipment - Road Vehicles |
| Non-dwelling construction | Non-dwelling construction |
| Ownership transfer costs | *(unavailable)* |

a All machinery and equipment types are aggregated together into a single asset type as the data are unavailable to split the aggregate to the subsector level.

*Sources*: ABS (*Experimental Estimates of Industry Multifactor Productivity, 2010‑11*, Cat. no.5260.0.55.002); ABS (*Australian System of National Accounts: Concepts, Sources and Methods, 2000*, Cat. no. 5216.0).

Another difference is the source of data. Gross fixed capital formation (GFCF), the measure of capital investment from the National Accounts used to derive productive capital stock (and, in turn, capital services), are not available at the subsector level. Instead, alternative data sources were used to calculate subsector shares of investment that were then applied to apportion GFCF for Manufacturing in aggregate across the different subsectors (table A.4). For investment in ‘non-dwelling construction’, ‘machinery and equipment’ and software, subsector data on private new capital expenditure (PNCE) was used to apportion Manufacturing GFCF for these asset types across subsectors. Business expenditure on research and development (R&D) by subsector was used to apportion Manufacturing R&D GFCF across subsectors.

Table A.4 Apportionment of Manufacturing gross fixed capital formation to subsectors

|  |  |  |
| --- | --- | --- |
| Manufacturing division-level GFCF asseta | Data used to apportion to Manufacturing subsectors |  |
| Non-dwelling construction | The ‘buildings’ asset type from Private New Capital Expenditure (from ABS 5625.0)b and PC(2003) |  |
| Machinery & equipment | The ‘plant, machinery and equipment’ asset type from Private New Capital Expenditure (from ABS 5625.0)b and PC (2003) |  |
| Research & development | Current business expenditure from Research and Experimental Development, Businesses, Australia (from ABS 8104.0) and Shanks and Zheng (2006) |  |
| Computer software | As for machinery & equipment, abovec |  |

a These are the broad asset categories detailed in the ABS National Accounts (ABS Cat. no. 5204.0). b Includes unpublished data sourced from the ABS that disaggregates expenditure by asset type. c There is no data on expenditure on computer software and an imputation based on machinery and equipment was used instead. This is discussed in greater detail later in this section.

This provided the investment series for each Manufacturing subsector, which, in addition to information on the prices of capital types and other parameters, allowed the derivation of capital services at this lower level of aggregation.

The aggregate of the subsector capital services indexes in this paper does not exactly match that published by the ABS for Manufacturing in total (figure A.2). This is because of the different asset types considered and assumptions made regarding the investment series where subsector data were unavailable.

Figure A.2 shows the discrepancy between the aggregate of the capital services series in this paper and that published by the ABS for Manufacturing in total. The question raised by these differences is how much of the discrepancy is being driven by the difference in asset coverage as opposed to errors in the PIM?

While the additional asset types used by the ABS cannot be included in the subsector estimates of capital services, it is possible to remove those assets from the ABS series for Manufacturing in total to derive another series that is more comparable. Growth in this series is shown in the last column of figure A.2 and is, generally speaking, more consistent with the aggregate of the subsector estimates in this paper. There are still large differences over the incomplete cycle.

In short, much of the discrepancy between the published ABS series and that derived in this paper can be attributed to the different asset coverage. The remainder of this section details the derivation of capital services more formally, including the data sources used, and the differences between the published ABS series and estimates presented in this paper.

Figure A.2 Capital services discrepancy

Index 2009‑10 = 100 and average annual growth rate (per cent)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | *Cycle* | *ABS  total mfg* | *Aggregate  of subsectors* | *ABS with assets removed*b |
|  | % py | % py | % py |
| 1988‑89 to 1993-94 | 2.8 | 3.7 | 3.5 |
| 1993‑94  to 1998-99 | 3.7 | 3.2 | 3.6 |
| 1998‑99  to 2003-04 | 3.4 | 3.7 | 3.7 |
| 2003‑04  to 2007-08 | 5.6 | 6.0 | 6.1 |
| 2007‑08  to 2010‑11a | 1.8 | 2.9 | 2.1 |
| *Full period* |  |  |  |
| 1985‑86  to 2010-11 | 3.6 | 4.2 | 3.9 |

a Incomplete productivity cycle. b Refers to ABS series without those assets for which data were unavailable at the subsector level.

*Data sources*: Authors’ estimates; ABS (*Experimental Estimates of Industry Multifactor Productivity, 2010‑11,* Cat. no. 5260.0.55.001).

### Method and data

#### Calculating capital services

According to the ABS

Capital services reflect the amount of 'service' each asset provides during a period. For each asset, the services provided in a period are directly proportional to the asset's productive capital value in the period. As an asset ages and its efficiency declines so does the productive capital value and the services the asset provides. In equilibrium, the value of capital services is equal to the gross returns (or rentals) to owners of capital. … The relationship between the capital services provided by an asset and the asset's productive value is fixed over the asset's life. However, this relationship varies from asset to asset and it depends on an asset's expected life, the discount rate, and the rate of decline in the asset's efficiency. (ABS 2012c, p. 360)

Growth in capital services is taken as the rate of growth in the productive capital stock for each asset type, weighted by the product of the rental price and productive capital stock as a share of total returns to capital; averaged over the period.

(A1)

where (A2)

Where KS denotes capital services flow over the period, PKS denotes the real productive capital stock, R the rental price, and i, j and t denote industry, asset and time, respectively.

In this paper, the ‘industry’ subscript denotes the eight subsectors described in section A.2. That is, capital services were calculated on the basis of the rate of change in the productive capital stock over time for each subsector-asset, weighted by the rental prices for those subsector-assets.

The assets included in this paper are ‘machinery and equipment’, ‘non-dwelling construction’, ‘research and development’ and ‘computer software’. As noted above, this is fewer asset types than considered by the ABS and includes an aggregation of the machinery and equipment types (table A.3).

#### Calculating productive capital stock

##### Method

The ABS calculates productive capital stocks for each asset through the use of a perpetual inventory model:

The perpetual inventory model (PIM) involves the compilation of a 'rolling' inventory of capital stocks; in any particular period, investment in capital assets is added to stocks, and retired assets are deducted. To apply the PIM, the following are generally required:

* gross fixed capital formation (GFCF) for the period for which the capital stock estimate is required and for periods prior to that period equal to the maximum life of the asset;
* price indexes for the entire timespan of GFCF;
* the average length of asset lives, i.e. average of the length of time they are used in production;
* the age-efficiency function of assets (used to derive productive capital stock estimates);
* the extent to which assets are retired before, on or after the average asset life for that asset – the retirement distribution. Alternatively, retirements can be expressed as a survival function; and
* the age-price function of assets (used to derive net capital stock estimates and estimates of consumption of fixed capital). (ABS 2012c, p. 360)

The real investment series, derived from GFCF and its associated price indexes, was used to calculate the productive capital stock via the PIM. The formula used to calculate productive capital stock is:

(A3)

Where denotes productive capital stock for industry *i* at time *t*; is the age efficiency function discussed above; is the retirement function discussed above[[7]](#footnote-7); nominal investment; and a price deflator for investment.

This ABS method was followed in broad terms for the subsector estimates presented in this paper. However, there have been some modifications due to data limitations.

##### Data and parameters

###### Nominal investment

The ABS does not estimate GFCF by asset for subsectors on a National Accounts basis.[[8]](#footnote-8) In order to be consistent with the ABS estimates for capital services for Manufacturing in total, Manufacturing GFCF was apportioned across subsectors using subsector shares of investment from alternative sources (as described below).

###### Non-dwelling construction and machinery and equipment

For non-dwelling construction and machinery and equipment, data for PNCE were used to derive subsector shares. Unpublished quarterly PNCE data from the ABS *Survey of New Capital Expenditure* (Cat. no. 5625.0) were obtained from the ABS by Manufacturing ANZSIC06 subdivision for these two asset types over the period 1987‑88 to 2010‑11. These data were backcast to 1974‑75 using index data regarding PNCE for non-dwelling construction and machinery and equipment from PC (2003).

The levels of GFCF and PNCE for Manufacturing in aggregate are considerably different (figure A.3). While GFCF is the measure used for national accounting purposes (including the calculation of industry-level MFP estimates), there are no GFCF data consistent at a subsector level. PNCE data, however, provide information regarding the share of total Manufacturing investment undertaken by each subsector.

Figure A.3 Current price investment measures**a** for Manufacturing

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| --- |
|  |

a PNCE only includes expenditure on Machinery and equipment and Non-dwelling construction asset types, and so GFCF for those asset types is presented here for comparison.

*Data sources*: ABS (unpublished Survey of New Capital Expenditure data); ABS (*Australian System of National Accounts, 2010‑11*,Cat. no.5204.0).

GFCF and PNCE can differ for a number of reasons.

* GFCF is a measure that takes into account the purchase and disposal of second-hand assets, whereas PNCE does not.
* The survey used to determine GFCF for non-dwelling construction differs from that used for ‘Buildings’ in PNCE.
* GFCF is calculated in aggregate as part of the ABS supply-use framework and then apportioned to industry divisions. PNCE is surveyed at the subdivision level for manufacturing, and then summed to get an aggregate industry division measure.

The approach taken in this paper, following consultation with the ABS, was to use the quarterly PNCE data to apportion the financial-year GFCF data for the Manufacturing division across the subsectors by asset type. This approach allows measures of capital services to be estimated that are broadly consistent with those of the ABS.[[9]](#footnote-9) (The effect on the capital services measure of using PNCE data instead is discussed in box A.3.)

|  |
| --- |
| Box A.3 Effect of using an alternative capital measure |
| The PNCE data available at the subdivision level were used to apportion GFCF data from the division level to each of the Manufacturing subsectors. GFCF was used as it is the investment measure used by the ABS for their aggregate and division-level productivity estimates.  An alternative approach would be to use the PNCE data itself to derive capital services for Manufacturing productivity analysis at the subdivision level. The growth rates in each capital services measure (authors’ estimates based on PNCE-based, GFCF‑based and the ABS published capital services index) are presented. Over the last two productivity cycles, the main period of interest of this paper, the GFCF-based measures match those of the ABS much more closely.  **Average annual growth in Manufacturing capital services measures by cycle**   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | |  | Cycle 1 | Cycle 2 | Cycle 3 | Cycle 4 | Difference between  cycles 3 and 4 | |  | % py | % py | % py | % py | % pts | | GFCF-baseda | 3.7 | 3.2 | 3.7 | 6.0 | 2.4 | | PNCE-baseda | 3.1 | 3.7 | 2.1 | 3.3 | 1.3 | | ABS published | 2.8 | 3.7 | 3.4 | 5.6 | 2.2 |   a Authors’ estimates. Compares the growth in capital services indexes whether NDC and PME capital asset types are estimated using GFCF-apportioned data or PNCE-level data.  *Sources*: Authors estimates; ABS (*Experimental Estimates of Industry Multifactor Productivity, 2010‑11*, Cat. no. 5260.0.55.002).  The main effect of using a PNCE measure was that capital services growth was much slower over the last two productivity cycles, relative to the GFCF-based and ABS measures. (This should be expected, given that the PNCE data records slower growth in key asset types for Manufacturing, as seen in figure A.3, above.) |
|  |
|  |

Financial-year totals were constructed from the quarterly PNCE data. Some missing observations (due to ABS confidentiality requirements) had to be imputed. A summary of the missing observations by subdivision-asset pair is shown in table A.5. Around 7 per cent of observations are missing by asset type, but less than 1 per cent of observations were missing for total capital expenditure. All of the missing observations occur after the September quarter 2006.

Table A.5 Missing PNCE data by Manufacturing subdivision and asset type, 1987‑88 to 2010‑11

Quarters not publisheda

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| ANZSIC06 subdivision | Equipment | Buildings | Total of equipment  and buildings |  |  |  |
| Food product mfg | 0 | 0 | 0 |  |  |  |
| Beverage & tobacco product mfg | 0 | 0 | 0 |  |  |  |
| Textile, leather, clothing & footwear mfg | 15 | 15 | 3 |  |  |  |
| Wood product mfg | 10 | 9 | 1 |  |  |  |
| Pulp, paper & converted paper product mfg | 16 | 16 | 0 |  |  |  |
| Printing (incl. reproduction of recorded media) | 11 | 11 | 2 |  |  |  |
| Petroleum & coal product mfg | 19 | 18 | 2 |  |  |  |
| Basic chemical & chemical product mfg | 0 | 0 | 0 |  |  |  |
| Polymer product & rubber product mfg | 9 | 9 | 0 |  |  |  |
| Non-metallic mineral product mfg | 2 | 2 | 0 |  |  |  |
| Primary metal & metal product mfg | 0 | 0 | 0 |  |  |  |
| Fabricated metal product mfg | 3 | 3 | 0 |  |  |  |
| Transport equipment mfg | 1 | 1 | 0 |  |  |  |
| Machinery & equipment mfg | 3 | 2 | 1 |  |  |  |
| Furniture & other mfg | 14 | 14 | 6 |  |  |  |
| **Total**b | **103** | **100** | **15** |  |  |  |

a Not published is defined by the ABS as ’not available for publication but included in totals where applicable, unless otherwise stated’. b The total number of observations is 1470 (98 quarters by 15 industry subdivisions).

*Source*: ABS (unpublished Survey of New Capital Expenditure data).

Where data were available for one of the two asset types and for the total of both asset types, the missing value was imputed as the difference between the total and the value of the investment in the asset for which there were data. In many cases, however, there were total values but missing observations for both asset types. The imputation method in that case is discussed in box A.4.

|  |
| --- |
| Box A.4 Imputing missing observations in private new capital expenditure data |
| The following process was followed in order to clean the PNCE data received by the ABS. In any quarter for a particular asset in a particular subdivision if there were data available it was kept ‘as is’. Where data were missing:   1. If there was a missing value, the most recent, previous available value for the asset-subdivision in question was used to derive a ratio of the total of subdivision asset expenditure in that previously available quarter. This ratio was then applied to the total value for the quarter where there was the missing data in order to impute a value. This solved for the majority of missing values.   For example: There was missing data for equipment capital expenditure in the September 2006 quarter for Textiles, leather, clothing and footwear. In the previous quarter, there was expenditure of $47 million. Total capital expenditure for Textiles, leather, clothing and footwear for the June 2006 quarter was $50 million, meaning that equipment manufacturing comprised 94 per cent of total capital expenditure. The data indicate that there was $37 million in total capital expenditure for Textiles, leather, clothing and footwear in the September 2006 quarter. Applying the same ratio of 94 per cent to this number imputes equipment capital expenditure for September 2006 as $34.7 million.   1. If data were missing both for an asset and total within a subdivision, then the total could often be recovered by consulting the published PNCE data, which had fewer missing observations than that received from the data request from the ABS.\* With the totals, step 2 could then be carried out to impute missing values for asset‑subsector pairs. 2. For the remaining missing observations, the total of multiple missing values was derived as the difference between the published total PNCE for Manufacturing (which includes the value of the missing data in aggregate) and the sum of the reported values by asset type. This total for missing values was then split across industry subdivisions using the proportions from the most recent previous data.   For example: There was missing data for total capital expenditure in the June 2007 quarter for both Petroleum and Other manufacturing. The total capital expenditure for this quarter as published was $2901 million, while the sum of the asset data is $2792 million — a difference of $109 million. Petroleum accounted for 82 per cent of Petroleum and Other manufacturing PNCE in the March quarter of 2007, and it was this proportion that was applied to the $109 million for Petroleum in the June quarter of 2007.  This process imputed all the missing values.  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  \* The discrepancy between the missing observations for total subdivision PNCE in the published and purchased data arises as the ABS has a stricter policy on quality surrounding purchased data. |
|  |
|  |

The complete PNCE data series was used to calculate the subsector shares of total Manufacturing investment for non-dwelling construction and for machinery and equipment. These shares were then applied to the relevant GFCF asset type in order to generate GFCF by subsector for the purposes of the PIM.

###### R&D capital

As with the tangible asset types above, there is no subsector-level disaggregation of R&D GFCF. A similar process to that used for apportioning total Manufacturing GFCF for non-dwelling construction and machinery and equipment was used. Current[[10]](#footnote-10) business expenditure on R&D (BERD) is used to derive the subsector shares. Two sources of data were used:

1. Current BERD from ABS (*Survey of Research and Experimental Development*, Cat. no. 8104.0) from 1992‑93 to 2010‑11.
2. *Total* BERD (including both current and capitalised) from Shanks and Zheng (2006), from 1968‑69 to 2002‑03. The overlap over the period between 1992‑93 and 2002‑03 with the data source above was used to determine the proportion of total BERD that is current BERD.

Data were concorded into ANZSIC06 where necessary (box A.5).

###### Software capital investment

There is no readily available data source for software investment at the Manufacturing subsector level of disaggregation. Total Manufacturing software GFCF was simply apportioned in the same ratio of each subsector’s share of total machinery and equipment investment. Because the lifespan assumed by the ABS for computer software varies depending on whether the software is ‘purchased’ or developed ‘in-house’, another imputation has to be made regarding what proportion of computer software is ‘purchased’ relative to ‘developed in-house’. Due to a lack of data, the developed in-house proportion for a subdivision was taken to be the same as the proportion of total investment made up by R&D (on the grounds that R&D intensive industries are more likely to develop their own software).[[11]](#footnote-11)

|  |
| --- |
| Box A.5 ANZSIC concordance issues related to business expenditure on R&D |
| Business expenditure on R&D (BERD) is not published on an ANZSIC06 basis prior to 2005‑06, but there is an overlap between ANZSIC93 and ANZSIC06 BERD data for the years 2005‑06 and 2006‑07. An inspection of this data indicates that there are large differences in the BERD between the ANZSIC93 divisions Printing, publishing and recorded media, Textile, clothing, footwear and leather manufacturing, and Other manufacturing with their ANZSIC06 subdivision counterparts. (See table A.2 for concordances.)  These differences make it unfeasible to simply ‘splice’ the historical ANZSIC93 to the post-2005‑06 ANZSIC06 data without making an adjustment for the change in classifications. The proportion that publishing (ANZSIC93 group 242) makes of the ANZSIC93 Printing, publishing and recorded media subdivision in the overlap years was removed back through the series to make the BERD data consistent with the ANZSIC06 subdivision for Printing and recorded media (see figure). |
| **BERD in Printing and recorded media**  $m (current prices)   |  | | --- | |  |   A similar method was used to adjust for changes in Textile, clothing, footwear and leather manufacturing, and Other manufacturing. |
| *Sources*: Authors’ estimates based on ABS (*Research and Experimental Development, Businesses, Australia*, various issues, Cat. no. 8104.0); and Shanks and Zheng (2006). |
|  |
|  |

###### Deflation of current price capital series

The nominal investment series, as estimated above, are deflated using implicit price deflators supplied by the ABS.[[12]](#footnote-12) A specific deflator for each asset type (non‑dwelling construction, machinery and equipment, R&D, and computer software) was applied across all Manufacturing subsectors. No subsector-specific price deflators are available.

###### PIM assumptions

The real investment series discussed above were used in the PIM to generate productive capital stocks for each asset in each subsector. The PIM uses the following parameters (table A.6). The same assumptions were used for each of the subsectors — data were not available to derive subsector specific parameters.

One key difference between the ABS PIM and the PIM used in this paper relates to the use of a retirement function. The ABS includes such a function, which allows for some proportion of assets to be retired before and after the mean asset lives listed above. The subsector estimates in this paper do not use a retirement function on the grounds that the additional complexity is not warranted given that previous studies found that it did not significantly change the results (Gretton and Fisher 1997).

Table A.6 PIM parameters used by the ABS and in this paper

|  |  |  |
| --- | --- | --- |
| Parameter | Used by ABS for Manufacturing in aggregate | Used in this paper for each of the subsectors |
| Mean asset life |  |  |
| Non-dwelling construction | 38 years | 38 years |
| Machinery & equipment | 14.4 yearsa | 14.4 years |
| Research & development | 11 years | 11 years |
| Software | 4-8 yearsb | 4-8 years |
|  |  |  |
| Age efficiency profilec |  |  |
| Non-dwelling construction | 0.75 | 0.75 |
| Machinery & equipment | 0.50 | 0.50 |
| Research & development | 0.50d | 0.50 |
| Software | 0.50 | 0.50 |
|  |  |  |
| Retirement function | Yes (Winfrey distribution) | No retirement function |
|  |  |  |
| Real discount ratee | 4 per cent | 4 per cent |

a The weighted average of the mean asset life for machinery and equipment was published in the earlier edition of concepts, sources and methods. In practice, the ABS uses a different asset life for a larger number of machinery and equipment assets, while the productive capital stock measures derived here use this weighted average for a single machinery and equipment asset class. b The mean asset life for software depends on when the investment was made, and whether it was made on in-house software or purchased software. The parameters used in the paper match those of the ABS exactly in this regard. c The ABS uses a hyperbolic age efficiency profile, where efficiency is defined as [(M – t)/(M – bt)], where M is the mean asset life, t is the age of the asset at a particular point in time and b is efficiency reduction parameter detailed in the table. d This value is not published, but was determined via correspondence with the ABS. e The net present value of future capital services can be calculated by discounting the capital services flow using this discount rate, chosen by the ABS. This allows the construction of net capital stocks, the difference of which between consecutive years is equal to the depreciation.

*Source*: ABS (*Australian System of National Accounts: Concepts, Sources and Methods,* Cat. no. 5216.0, 2000 and 2012 editions).

###### Initial capital stocks

The PIM also requires an initial stock of capital for each asset and an assumption about the average age of that stock. The PIM constructed for this paper starts in 1973‑74 and used the following assumptions regarding initial capital stocks and their ages:

* For non-dwelling construction and machinery and equipment, the net capital stock values available from PC (2003) were used. The average age of these two assets is chosen to be 14 and 7 years, respectively, based on ABS assumptions from ABS (2000a).
* For R&D, data from Shanks and Zheng (2006) was used as the capital stock for R&D. The starting stock of R&D is assumed to be 0 years old.
* For computer software, the total constant price value of capital stock is known for 1973‑74, but there is no information about its disaggregation. The total, was therefore apportioned by the distribution of software investment in the following year (1974‑75). A further distribution was then needed to apportion computer software investment between ‘in-house’ and ‘purchased’. The in-house investment was assumed to be the same proportion of total computer software investment as R&D investment comprises of total investment within an industry. The starting stock of software capital is assumed to be 0 years old.

###### Net capital stock and depreciation

The PIM allows the calculation of productive capital stock for each period of time. The productive capital stock can then be discounted over the remaining productive life for different vintages of assets to derive net capital stock — which is the net present value of future capital services from the productive capital stock. This is detailed by the ABS:

The age-efficiency function describes the decline in the flow of capital services of an asset as it ages. Using the discount rate, the net present value of future capital services can be readily calculated. For instance, when multiplied by a suitable scalar, the first value of the age-price function represents the present discounted value of the capital services provided by an asset over its entire life. The second value of the age-price function represents the present discounted value of the capital services provided by an asset from the end of its first year until the end of its life. The third value represents the present discounted value of the capital services provided by an asset from the end of its second year until the end of its life, and so on. … When the net present values of the different assets are aggregated for a particular period, they form the net capital stock for that period. (ABS 2012c, p. 363)

A discount rate is, therefore, needed to derive net capital stock — the ABS uses 4 per cent, and this parameter was adopted in this paper for all assets and subsectors as well.

The change in net present value for each vintage of asset between periods defines economic depreciation. This depreciation, taken as a share of net capital stock for a given period defines the depreciation rate. Depreciation rates are needed as part of the calculation of the rental prices.

#### Calculating rental prices

Productive capital stocks for different asset types are not simply added together to derive capital services, but are instead weighted according to the relative rental price and relative volumes of productive capital stock of each asset (see equation A2). The methodology used by the ABS to calculate rental prices is followed as closely as possible. For a subsector i with asset type j in time t, the rental price is given as:

(A4)

Where R denotes the rental price, T an income tax parameter, p the price of the asset, i the nominal internal rate of return of the asset, d the rate of deprecation, g the change in price of the asset and x the indirect tax parameter. Effectively, the rental price represents the replacement cost of capital in that it embodies the value of the asset (its internal rate of return and cost to cover depreciation, less any increase in the value of the asset).

The components of the rental price equation are sourced from a variety of sources.

* The income tax parameter (T) were sourced from unpublished ABS data and is the same across each Manufacturing subsector.
* The indirect tax parameter (x) was calculated from ABS data (specifically, other taxes less subsidies as a share of current price net capital stock) and is the same across each Manufacturing subsector.
* The price deflator data (p) were sourced from ABS National Accounts data and unpublished data — it is the same across each Manufacturing subsector.
* Depreciation (d) was calculated in the process of determining productive capital stock from the PIM (discussed previously) — accordingly, it is different across each Manufacturing subsector.

In practice, equation A4 is solved ‘endogenously’ for the rate of return i by assuming that capital income is equal to the rental price R multiplied by the productive capital stock:

(A5)

‘Gross operating surplus’, the income that accrues to capital (discussed below) was used to calculate the internal rate of return, and, by extension, rental prices.

In the calculation of rental prices, the ABS applies two restrictions and this process was also used in this paper:

* the internal rate of return i may not be lower than the Consumer Price Index plus 4 percentage points
* rental prices are strictly positive (and are given a value of 0.001 where the estimated value of equation A4 is non-positive).

These rental price weights were then used (as per equation A2) to create a weighted Tornqvist index of capital services for each subsector, as well as for Manufacturing as a whole, as detailed above.

## A.6 Income shares

Subsector factor income shares are required to combine the growth rates of capital services and hours worked. Subsector capital income levels are also required for the calculation of capital services (as discussed in section A.5).

To estimate factor income shares, data are required for labour income (including labour-related net taxes on production), capital income (including capital-related net taxes on production) and value added at basic prices.

At the aggregate level, the ABS uses factor incomes from the National Accounts in estimating Manufacturing MFP growth. However, subsector level factor incomes are not available from that source. Therefore, labour income and value added data at the subsector level were compiled from ABS surveys covering Manufacturing.[[13]](#footnote-13) Capital income was derived as the difference between these two series. The factor income levels were then expressed as shares of value added.

Over the period from 1984‑85, Manufacturing was included in three separate surveys. To compile a time series, data were taken from the following surveys:

* 2006‑07 to 2010‑11 from *Australian Industry* (ABS Cat. no. 8155.0).
* 1987‑88 to 2005‑06 from *Manufacturing Industry, Australia* (ABS Cat. no. 8221.0) — this is a census of Manufacturing so was used in preference to 8155.0 in the latter years when both surveys were published.
* 1984‑85 and 1986‑87 from *Enterprise Statistics, Australia* (ABS Cat. no. 8103.0) — no survey was conducted in 1985‑86.[[14]](#footnote-14)

### Labour income

The measure of labour income required includes ‘on costs’ such as superannuation, payroll tax and fringe benefits tax. While wages and salaries is available from each of the surveys listed above, the reporting of ‘on costs’ varies.

Data for wages and salaries and different types of ‘on costs’ were available from 1997‑98. Prior to this, wages and salaries data were scaled up using an ‘on costs’ percentage based on the data from 1997‑98. The 1997‑98 percentage was adjusted to reflect changes over time in fringe benefits tax and the superannuation guarantee. Fringe benefits tax was not introduced until 1986 and was excluded prior to that. The percentage for superannuation was adjusted each year according to Australian Taxation Office information (ATO 2011) and the *Superannuation Guarantee (Administration) Act 1992*, as listed in the table A.7.

Table A.7 Superannuation assumptions used in income shares

|  |  |
| --- | --- |
| Year | Proportion of wages and salaries |
| 1984‑85 (assume half workforce covered at 3 per cent) | 0.015 |
| 1985‑86 (assume linear growth to 1989‑90) | 0.016 |
| 1986‑87 (assume linear growth to 1989‑90) | 0.017 |
| 1987‑88 (assume linear growth to 1989‑90) | 0.018 |
| 1988‑89 (assume linear growth to 1989‑90) | 0.019 |
| 1989‑90 (assume 2/3 workforce covered at 3 per cent) | 0.02 |
| 1990‑91 (assume 2/3 workforce covered at 3 per cent) | 0.02 |
| 1991‑92 (assume 2/3 workforce covered at 3 per cent) | 0.02 |
| 1992‑93 (Superannuation Guarantee Administration Act) | 0.03 |
| 1993‑94 (Superannuation Guarantee Administration Act) | 0.03 |
| 1994‑95 (Superannuation Guarantee Administration Act) | 0.04 |
| 1995‑96 (Superannuation Guarantee Administration Act) | 0.05 |
| 1996‑97 (Superannuation Guarantee Administration Act) | 0.06 |

*Sources*: ATO (2011); *Superannuation Guarantee (Administration) Act 1992.*

The explanatory notes to the surveys also indicate that the inclusion of ‘in kind’ wages has changed over time. However, no data appear to be available to enable an adjustment for this.

### Value added

The definition of value added reported in the ABS industry surveys varies from that used by ABS National Accounts and changes over time.

From 1997‑98 to 2010‑11 a measure of value added (broadly in line with that used by ABS National Accounts) was published in Cat. nos 8221.0 and 8155.0. Prior to 1997‑98, value added (as measured in this way) was not available. From 1996‑97 back to 1989‑90, value added was imputed based on related data, as follows:

* Turnover was reported in Cat. no. 8221.0 from 1989‑90 to 1997‑98. The turnover growth rate was applied to 1997‑98 estimate of value added to backcast value added to 1989‑90.[[15]](#footnote-15)

Data prior to 1989‑90 was either not reported for value added or reported for a different definition of value added.

* For 1984‑85 and 1986‑87 ABS published ‘adjusted value added’. A number of intermediate expenses, including land tax and payroll tax, were deducted by the ABS in estimating this measure. For consistency of the time series being used in this paper, land tax and payroll tax (for which data were also separately available) were added back to ‘adjusted value added’. This provided a measure closer to the National Accounts definition of value added.
* For 1987‑88 and 1988‑89 no value added measure was published. Growth in turnover was applied to adjusted value added for 1986‑87 to impute adjusted value added for 1987‑88 and 1988‑89.

An additional difference in the definition of value added for Petroleum refining prior to 1989‑90 is also noted by the ABS (1993, p. 74).

Prior to this census, most commodities produced in the petroleum refining industry (ASIC Class 2770) were manufactured on commission for non-manufacturing businesses from materials owned and supplied by those businesses. In these cases, manufacturing turnover reflected only the value of commission earned by the manufacturing establishments involved (not the gross value of the commodities produced). Due to a change in accounting practices, a number of businesses have changed to reporting gross value of production. This change has significantly affected the comparability of turnover and value added statistics between 1989‑90 and previous years for Industry Subdivision 27.

In the absence of an overlapping year of data for the two definitions of value added, value added for 1988‑89 was derived by assuming that the ratio of labour income to value added was the same in 1988‑89 as in 1989‑90. Value added for 1984‑85 to 1987‑88 was then backcast using the growth rate in the unadjusted value added series as derived using the method applied to all other subsectors.

### Other breaks in series

In addition to the various changes outlined above, there are some other breaks in series that affect both variables. These breaks, and whether it was possible to adjust for them, is discussed below.

#### Industry classification

The data compiled were in ASIC from 1984‑85 to 1988‑89, ANZSIC93 from 1989‑90 to 2003‑04, ANZSIC06 from 2004‑05 to 2009‑10.[[16]](#footnote-16) Data were available for 1989‑90 in ASIC and ANZSIC93 and for 2004‑05 in ANZSIC93 and ANZSIC06.

For each subsector, the closest corresponding subsector on the previous classification was identified. For each subsector (and total Manufacturing) the ratio of the data under each classification for 1989‑90 and 2004‑05 was used to crudely ‘concord’ the data into the new classification. (This process was applied twice to convert the ASIC data into ANZSIC06). These ratios were calculated for labour income and for value added (table A.8).

It is acknowledged that this approach based on a single year of ‘overlapping’ data may yield less accurate results the further back in time it is applied (to the extent that the composition of the subsector has changed over time).

One way of assessing the likely accuracy of the backcast series derived using these factors is to look at the change in the composition of the subsectors (at the class level) over time. This was done for the subsectors with the adjustment factors that deviated most from one (Printing and recorded media, and Textile, clothing and other manufacturing). In both cases, the classes within the ANZSIC93 subdivision that mapped most closely to the corresponding ANZSIC06 subsector were a fairly stable share (in aggregate) of the ANZSIC93 subdivision total over time.

Table A.8 Conversion factors: ASIC/ANZSIC93 and ANZSIC93/06

|  |  |  |
| --- | --- | --- |
| Subdivisionb | Turnover/value added factora | Labour costs  factor |
| *ASIC to ANZSIC93 (1989‑90)* | *Turnover factor* |  |
| ASIC 21 Food, beverage & tobacco to  ANZSIC93 21 Food, beverage & tobacco | 1.01 | 1.00 |
| ASIC 23+24 Textiles, Clothing & footwear to  ANZSIC93 22 Textiles, clothing, footwear & leather mfg | 1.07 | 1.06 |
| ASIC 25 Wood, wood products & furniture to  ANZSIC93 23 Wood & paper product mfg | 1.15 | 0.95 |
| ASIC 26 Paper, printing & publishing to  ANZSIC93 24 Printing, publishing & recorded media | **0.76** | **0.81** |
| ASIC 27 Chemical, petroleum & coal products to  ANZSIC 25 Petroleum, coal, chemical & assoc’d product mfg | **1.29** | **1.66** |
| ASIC 28 Non-metallic mineral products to  ANZSIC93 26 Non-metallic mineral product mfg | 1.03 | 1.03 |
| ASIC 29+31 Basic metal products, Fabricated metal products to ANZSIC93 27 Metal product mfg | 0.99 | 0.99 |
| ASIC 32+33 Transport equip, Other machinery & equipment to ANZSIC93 28 Machinery & equipment mfg | 1.01 | 1.01 |
| ASIC 34 Misc mfg to ANZSIC93 29 Other mfg | **0.69** | **0.83** |
| Total Manufacturing | 1.01 | 1.02 |
| *ANZSIC93 to ANZSIC06 (2004‑05)* | *Value added factor* |  |
| ANZSIC93 21 Food, beverages & tobacco to  ANZSIC06 11+12 Food product mfg; Beverage & tobacco mfg | 1.01 | 1.06 |
| ANZSIC93 22 Textiles, clothing, footwear & leather mfg to ANZSIC06 13 Textile, leather, clothing & footwear mfg | 0.94 | 1.01 |
| ANZSIC93 23 Wood & paper product mfg to  ANZSIC06 14+15 Wood prod. mfg; Pulp, paper & conv. paper mfg | 1.08 | 1.13 |
| ANZSIC93 24 Printing, publishing & recorded media to  ANZSIC06 16 Printing (including recorded media) | **0.37** | **0.44** |
| ANZSIC93 25 Petroleum, coal, chemical & assoc’d product mfg to  ANZSIC06 17+18+19 Petroleum & coal prod. mfg; Basic chemical & chemical prod. mfg; Polymer product & rubber prod. mfg | 0.98 | 1.01 |
| ANZSIC93 26 Non-metallic mineral product mfg to  ANZSIC06 20 Non-metallic mineral product mfg | 0.92 | 0.97 |
| ANZSIC93 27 Metal product mfg to  ANZSIC06 21+22 Primary metal & metal prod. mfg; Fabricated metal product mfg | 1.00 | 0.97 |
| ANZSIC93 28 Machinery & equipment mfg to  ANZSIC06 23+24 Transport equip. mfg; Machinery & equip. mfg | 0.92 | 0.95 |
| ANZSIC93 29 Other mfg to ANZSIC06 25 Furniture & other mfg | **0.53** | **0.60** |
| Total Manufacturing | 0.90 | 0.93 |

a Turnover used where overlapping value added data not available. b Some movements in classification were between Textiles, clothing and footwear and Other manufacturing. ‘Textile, clothing and other manufacturing’ is a single subsector in this study, so adjustment factors were calculated for this aggregate — ASIC to ANZSIC93 0.89 turnover; 0.96 labour costs; ANZSIC93 to ANZSIC06 0.70 value added; 0.77 labour costs.

*Sources*: Authors’ estimates based on ABS (*Australian Industry*, various issues, Cat. no. 8155.0); ABS (*Manufacturing Industry Australia*, various issues, Cat. no. 8221.0); ABS (*Enterprise Statistics, Australia*, various issues, Cat. no. 8103.0).

#### Changes in survey

##### Move from Cat. no. 8103.0 to 8221.0 and Cat. no. 8221.0 to 8155.0

Data were available from Cat. no. 8221.0 for most of the time series, but the ABS income shares for Manufacturing from Cat. no. 5260.0.55.002 appeared to be more closely aligned to the Cat. no. 8155.0 series. The compiled data from Cat. no. 8221.0 were scaled to match the coverage of Cat. no. 8155.0 using a ratio calculated from data from both surveys for 2006‑07 (table A.9). The Cat. no. 8155.0 data used were those reported in 2009‑10 issue, which included revisions to data back to 2006‑07 (largely related to improvements in the sample design and other aspects of survey methodology).

Table A.9 Conversion factors: Cat. no. 8221.0 to Cat. no. 8155.0

|  |  |  |
| --- | --- | --- |
| Subsectora | Value added | Labour costs |
| Food, beverage & tobacco products | 1.02 | 1.00 |
| Textile, clothing & other manufacturing | 1.04 | 1.00 |
| Wood & paper products | 1.02 | 0.99 |
| Printing & recorded media | 1.02 | 0.95 |
| Petroleum, coal, chemical & rubber products | 1.17 | 0.98 |
| Non-metallic mineral products | 1.03 | 1.00 |
| Metal products | 1.04 | 0.99 |
| Machinery & equipment manufacturing | 1.02 | 1.00 |
| **Total Manufacturing** | **1.03** | **1.00** |

a Aggregated to subsectors from ANZSIC06 industry subdivisions.

*Sources*: Authors’ estimates based on ABS (*Manufacturing Industry, Australia, 2006‑07*, Cat. no. 8221.0); and ABS (*Australian Industry, 2006‑07*, Cat. no. 8155.0).

The 1989‑90 issue of Cat. no. 8221.0 refers to a change in the coverage compared with earlier surveys and provides a table of conversion factors (table A.10). It appears that these have already been applied to data from 1987‑88 published in later issues of Cat. no. 8221.0. Therefore the conversion factors were applied to 1986‑87 and 1984‑85 data. The Cat. no. 8221.0 to 8155.0 factors were then applied to this converted data.

Table A.10 Conversion factors: Cat. no. 8103.0 to Cat. no. 8221.0

|  |  |
| --- | --- |
| Subsectora | Conversion factor |
| Food, beverage & tobacco products | 1.01 |
| Textile, clothing & other manufacturing | 1.03 |
| Wood & paper products | 1.04 |
| Printing & recorded media | 1.03 |
| Petroleum, coal, chemical & rubber products | 1.02 |
| Non-metallic mineral products | 1.02 |
| Metal products | 1.02 |
| Machinery & equipment manufacturing | 1.02 |
| **Total Manufacturing** | **1.03** |

a Aggregated to subsectors from ANZSIC93 industry subdivisions based on value added shares for 1986‑87.

*Source*: Authors’ estimates based on ABS (*Manufacturing Industry, Australia, 1989‑90*, Cat. no. 8221.0, table 12).

##### Change in establishment size

Prior to 1987‑88, single establishment Manufacturing enterprises with less than four employed were excluded from the survey. Insufficient data were available to adjust the series for this change.

##### Change from establishments to management units

The 2000‑01 issue of Cat. no. 8221.0 notes the change from measuring establishments to measuring management units. The two concepts are defined as follows.

The establishment is the smallest accounting unit of a business, within a state or territory, controlling its productive activities and maintaining a specified range of detailed data … In general, an establishment covers all operations at a physical location, but may consist of groups of locations provided they are within the same state or territory. The majority of establishments operate at one location only.

The management unit is the highest-level accounting unit within a business, having regard to industry homogeneity, for which accounts are maintained. In nearly all cases, it coincides with the legal entity owning the business … In the case of large diversified businesses, however, there may be more than one management unit, each coinciding with a 'division' or 'line of business'. A division or line of business is recognised where separate and comprehensive accounts are compiled for it. A management unit consists of one or more establishments.

A management unit can therefore be a more aggregated unit — it may include more than one establishment.

The main implication of this change is that some activities will be allocated to a different industry classification on the basis of management units than on the basis of establishments. A management unit is allocated to an industry classification based on its predominate activity, but the data collected for it will cover all its activities. Where a management unit includes activities that are, for example, in different subdivisions of Manufacturing, all activities will be allocated to the subdivision of the predominant activity.

Prior to this change to management units, data had been collected for some years for both establishments and management units. Using this data the ABS provided bridging factors for conversion of data on an establishment basis to a management units basis (table A.11). The ABS appears to have already applied these factors back as far as 1995‑96 and included these revised years of data in the 2000‑01 issue. These factors were therefore applied to the compiled data from 1994‑95 to 1988-89. Prior to 1988‑89 the definition of the unit measured appears more similar to the management unit definition so the bridging factors were not applied.

Table A.11 Bridging factors: establishments to management units

|  |  |  |
| --- | --- | --- |
| ANZSIC93 subdivisions | Value added | Wages and salaries |
| Food, beverage & tobacco mfg | 1.010 | 1.213 |
| Textiles, clothing, footwear & leather mfg | 0.920 | 0.989 |
| Wood & paper product mfg | 1.126 | 1.091 |
| Printing, publishing & recorded media | 1.048 | 1.011 |
| Petroleum, coal, chemical & assoc’d product mfg | 1.007 | 1.107 |
| Non-metallic mineral product mfg | 1.084 | 1.186 |
| Metal product mfg | 1.105 | 1.040 |
| Machinery & equipment mfg | 1.006 | 1.054 |
| Other manufacturing | 1.007 | 1.003 |
| **Total Manufacturing** | **1.035** | **1.084** |

*Source*: Authors’ estimates based on ABS (*Manufacturing Industry, 2000‑01,* Cat. no. 8221.0, appendix 3).

#### Benchmarking of level estimates

Finally, the series for value added levels for each subsector produced using the above method were benchmarked to the National Accounts estimates of subsector GVA CVM for the base year (2009‑10) — the base year effectively being a current price estimate.[[17]](#footnote-17) The earlier year estimates were derived using the growth rate in unadjusted series. The proportion of value added that were capital income and labour income were preserved, with new factor income levels being derived. The income shares were therefore unchanged.

As a result of data limitations, there is a discrepancy between the aggregate of the subsector factor income shares and the ABS income shares for ABS Manufacturing as a whole. Figure A.4 compares the two different series of capital income shares. It is the average cycle shares that are used in the MFP estimates, and the discrepancy between the two series is relatively small. The MFP growth estimates are not significantly affected by this difference.

Figure A.4 Capital income shares**a**

Share of value added

|  |
| --- |
|  |

a Capital income share plus labour income share add to one.

*Data sources*: Authors’ estimates based on ABS (*Experimental Estimates of Industry Multifactor Productivity, 2010‑11,* Cat. no. 5260.0.55.002); ABS (*Australian Industry,* various issues,Cat. no. 8155.0); ABS (*Manufacturing Industry, Australia,* various issues,Cat. no. 8221.0); ABS (*Enterprise Statistics, Australia,* various issues,Cat. no. 8103.0); and ABS (*Australian System of National Accounts, 2010‑11*, Cat. no. 5204.0).

## A.7 Multifactor productivity

MFP growth is calculated as the difference in the rate of output growth less the rate of input growth. Output is measured by growth in gross value added in this paper. Inputs are measured as a Tornqvist index calculated using the average relative factor income shares to weight growth in hours worked and capital services.

where *At*represents MFP, *Vt* represents real output and *It*the Tornqvist index of factor inputs:

where *Kt*represents capital services, *Lt*represents hours worked, and the *Wkt* and *Wlt*represent the average relative income shares of capital and labour over the two periods, respectively:

This then implies that growth in MFP is equal to growth in outputs less the income-weighted shares of capital and labour inputs:

As noted in sections A.5 and A.6, data limitations have resulted in some discrepancies between the aggregate of the subsector estimates and the ABS estimates for capital services and factor income shares for Manufacturing as a whole. The resulting difference in the MFP indexes is shown in figure A.5.

Figure A.5 MFP discrepancy

Index 2009‑10 = 100 and average annual growth rate (per cent)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | *Cycle* | *ABS  total mfg* | *Aggregate  of subsectors* | *ABS with assets removed*b |
|  | % py | % py | % py |
| 1988‑89 to 1993-94 | 0.0 | -0.4 | -0.3 |
| 1993‑94  to 1998-99 | 0.6 | 0.9 | 0.6 |
| 1998‑99  to 2003-04 | 1.3 | 1.4 | 1.2 |
| 2003‑04  to 2007-08 | -1.4 | -1.5 | -1.7 |
| 2007‑08  to 2010‑11a | -0.8 | -1.3 | -0.9 |
| *Full period* |  |  |  |
| 1985‑86  to 2010-11 | 0.3 | 0.1 | 0.1 |

a Incomplete productivity cycle. b Refers to ABS series without those assets for which data are unavailable at the subsector level.

*Data sources*: Authors’ estimates; ABS (*Experimental Estimates of Industry Multifactor Productivity, 2010‑11,* Cat. no. 5260.0.55.002).

As discussed in section A.5, while the additional asset types used by the ABS cannot be included in the subsector estimates of capital services (and therefore MFP), it is possible to remove those assets from the ABS series for Manufacturing as a whole to derive another MFP series that is more comparable. Growth in this MFP series is shown in the last column of figure A.5 and is, generally speaking, more consistent with the aggregate of the subsector MFP estimates in this paper. There is still a large difference over the incomplete cycle.

In short, much of the discrepancy between the published ABS MFP series and that derived in this paper can be attributed to the different asset coverage. Further testing of the sensitivity of the subsector MFP estimates is included in appendix E.

1. Growth accounting can also be done in terms of labour productivity growth (growth in output per hour worked) rather than output growth, in which case labour productivity growth is equal to capital income share weighted growth in the capital-labour ratio (capital deepening) plus MFP growth. [↑](#footnote-ref-1)
2. The ABS deflates output for petroleum production using a combination of price deflators and additional data regarding physical volumes of production. Quality adjustments are made to the deflator, which reflect certain characteristics of fuel (such as the volume of ethanol), but does not reflect any changes in environmental standards. [↑](#footnote-ref-2)
3. Comparability of employment data from the ABS *Labour Force Survey* and the ABS *Economic Activity Survey* is discussed for FBT in appendix G and for MP in appendix H. Connolly et al. (2013) found that the difference between employment numbers in the *Labour Force Survey* and *Economic Activity Survey* for Manufacturing as a whole were relatively small compared with most ANZSIC industry divisions (on average between 2007-08 to 2011‑12). [↑](#footnote-ref-3)
4. Estimates of hours worked for selected ANZSIC subdivisions and groups are also presented in this paper. These estimates were derived using the same method. [↑](#footnote-ref-4)
5. In the *Labour Force Survey*, where there is insufficient detail collected from the survey respondent to allocate to an ANZSIC subdivision within Manufacturing, a Manufacturing 'not further defined' (nfd) code is used. Since 2000, there has been some growth in allocations to this nfd category as a result of changes to coding practices (ABS 1999, 2003, 2005). The subsector estimates in this paper assume that this Manufacturing nfd is distributed across subsectors in proportion to *Labour Force Survey* responses that were able to be allocated to specific subdivisions. [↑](#footnote-ref-5)
6. This is the last issue released prior to the construction of the ABS Manufacturing hours worked index used underlying the MFP estimates in the 2010-11 issue of ABS *Experimental Estimates of Industry Multifactor Productivity, 2010-11*, Cat. no. 5260.0.55.002. [↑](#footnote-ref-6)
7. While the ABS include a retirement function in its calculation of productive capital stocks, this paper does not use such a function. This is discussed in greater detail following table A.6. [↑](#footnote-ref-7)
8. A measure of gross fixed capital formation is published in *Australian Industry* (ABS Cat. no. 8155.0), but this is not consistent with the National Accounts measure that is used by the ABS for productivity estimates, nor is it separated by asset type. [↑](#footnote-ref-8)
9. Consistent in that the same investment series are used, but not the case that all the same assets are available. Specifically, the estimates here are based on a single measure of investment for machinery and equipment, where the ABS disaggregates machinery and equipment into six different types. The data to do such a split at the subsector level were unavailable. [↑](#footnote-ref-9)
10. ‘Current’ in this context does not refer to current price expenditure, but rather expenditure on R&D that is *not* capitalised. Capitalised BERD is already accounted for in GFCF in the relevant, tangible asset type. [↑](#footnote-ref-10)
11. This is a very rough imputation. However, computer software, relative to the other categories of investment is very small, comprising at most 2 per cent of total manufacturing investment. [↑](#footnote-ref-11)
12. In practice, these deflators are the same as the ones implied by comparing current price GFCF and CVM GFCF from the National Accounts. [↑](#footnote-ref-12)
13. In this paper, these are collectively referred to as the ABS *Economic Activity Survey* (which is the name of the current ABS survey which underlies the data in Cat. no. 8155.0). [↑](#footnote-ref-13)
14. For 1985-86 labour and capital income levels were assumed to be the average of 1984-85 and 1986-87 levels. [↑](#footnote-ref-14)
15. ABS (Cat. no. 8221.0, 1997-98 issue) notes a change in definition of turnover to include intellectual property royalties from then on. However, the increase due to this change in definition was listed as 0 per cent for most subsectors and a maximum of 0.3 per cent for one subsector. This effect was considered too small to make the complexities of further adjustment worthwhile. [↑](#footnote-ref-15)
16. Estimates for 2004-05 and 2005-06 were converted from ANZSIC93 to ANZSIC06 by the ABS. [↑](#footnote-ref-16)
17. Time series of current price value added by subsector are not available from the National Accounts. [↑](#footnote-ref-17)