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Multifactor Productivity Growth Cycles at the Industry Level

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The views expressed in this paper are those of the staff involved and do not necessarily reflect the views of the Productivity Commission.

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Preface

This staff working paper examines multifactor productivity growth cycles at the industry level in Australia. There is considerable variation in industry-specific cycles across industries and the market sector. Moreover, the cycles chosen to examine industry MFP growth can have a considerable effect on the interpretation of industry productivity performance over time.

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The views expressed in this paper are those of the author and are not necessarily those of the Productivity Commission or of the people and external organisations who provided assistance.

Abbreviations

ABS	Australian Bureau of Statistics
ACF	autocorrelation function
ADF	Augmented Dickey-Fuller
AFF	Agriculture, forestry & fishing
AFS	Accommodation & food services
ANZSIC06	Australian and New Zealand Standard Industrial Classification, 2006 edition
ANZSIC93	Australian and New Zealand Standard Industrial Classification, 1993 edition
ARS	Arts & recreation services
BLS	Bureau of Labor Statistics (US)
CON	Construction
DOC	Department of Commerce (US)
EGWW	Electricity, gas, water & waste services
FIS	Financial & insurance services
GDP	gross domestic product
GST	goods and services tax
H(11)	Henderson 11-term filter
HP	Hodrick-Prescott
IMT	Information, media & telecommunications
MAN	Manufacturing
MFP	multifactor productivity
MIN	Mining
NBER	National Bureau of Economic Research
OECD	Organisation for Economic Cooperation and Development
PACF	partial autocorrelation function

PC	Productivity Commission
RT	Retail trade
SIC	Schwarz Information Criterion
SNZ	Statistics New Zealand
TPW	Transport, postal & warehousing
VA	value added
WT	Wholesale trade

OVERVIEW

Key points

- Understanding productivity performance and its drivers at the aggregate market sector level requires a closer examination of the underlying productivity performance of individual industry sectors. But interpreting movements in both aggregate and industry productivity measures is not entirely straightforward.
- Year-to-year changes in measured multifactor productivity (MFP) reflect not only technological progress, but also many other temporary influences.
  - One important such influence is change in the utilisation rate of capital that, because of limited data, is not measured as a change in inputs but instead appears as a change in measured MFP.
- A common approach when interpreting movements in MFP is to attempt to abstract from these temporary influences through longer-term averaging of measured growth. The Australian Bureau of Statistics (ABS) identifies periods over which to best examine market sector MFP. These are called 'MFP growth cycles' or 'peak-to-peak periods'.
  - The ABS identifies these periods by reference to peak deviations from trend MFP and to general economic conditions at the time.
  - It is potentially misleading to use MFP cycles for the aggregate market sector for analysing industry MFP over time, as the influences affecting deviations from trend vary across industries.
- Detailed industry studies would be able to provide information to aid in the identification of industry cycles. However, in the absence of such information, the ABS method for identifying MFP growth cycles for the market sector can be made more mechanical and generic so it can be applied to a range of industries. This modified approach includes:
  - a uniform set of rules for selecting which peak deviations are to be used in industry MFP growth cycles — including taking account of the robustness of peak deviations to alternative trend estimates
  - flagging where the selection of specific peak deviations may benefit from further investigation in industry-specific studies.
- Applying this modified approach at the industry level suggests that there is considerable variation in industry-specific cycles.
  - Less than a quarter of the industry cycles coincide with market sector cycles. For example, industries including Agriculture, forestry & fishing, Mining, and Wholesale trade have no cycles in common with the market sector, while all cycles identified for Manufacturing coincide with those for the market sector.
  - For both Mining and Wholesale trade, a period of negative MFP growth over a market sector cycle is actually a period of positive MFP growth over the closest industry-specific cycle.
- This approach provides a generic method for the identification of industry cycles, but the paper also notes the scope for further refinement in the identification of cycles where more detailed industry-specific information is available.

Overview

Growth in productivity is a key determinant of long-term economic growth and hence income growth. As Australia's prospective productivity performance will affect its future prosperity, recent significant declines in productivity growth understandably have been of concern. However, as the Productivity Commission noted in its submission to a recent parliamentary inquiry into productivity, understanding precisely what has affected productivity in practice and how it can be influenced is not straightforward (PC 2009).

Closer analysis of productivity growth in the individual industries that make up the economy, and of the underlying drivers of that productivity growth, is important to a proper understanding of aggregate outcomes. But, in addition to the many economic factors that influence productivity growth, productivity estimates can also reflect a variety of measurement issues, including variations in capacity utilisation.

The presence of such 'cyclical' issues means that year-to-year variations in productivity tend to be a poor guide to underlying technological progress. Because of this, most official statistical agencies, including the Australian Bureau of Statistics (ABS), advise that some longer-term averaging of measured productivity growth is likely to provide better insights.

To help avoid comparisons of multifactor productivity (MFP) growth rates across inappropriate points of time, the ABS identifies what it calls market sector MFP growth cycles. These cycles are periods over which average growth in market sector MFP can be most appropriately compared. Understanding the extent, nature and causes of industry contributions to market sector MFP growth over these cycles is crucial to a proper appreciation of any associated policy implications. But cyclical influences can vary across industries, so the periods over which it is appropriate to compare market sector MFP are not necessarily those that will provide a good indication of the development of technological change *within* an industry.[1]

1 Measured MFP growth can diverge from being a measure of technological change for a number of reasons. Measured as the growth in value added not explained by growth in combined inputs, MFP growth is a residual. It will include the effect of any approximations in measurement of output and inputs and of any violations of underlying assumptions (such as scale effects and non-marginal cost pricing).

This study identifies MFP growth cycles that are industry-specific, by applying an approach consistent with that used by the ABS at the more aggregate market sector level. (In this paper, the term market sector refers to 12 (core) industry divisions in the *Australian and New Zealand Standard Industrial Classification 2006* as listed in table 1.) Such industry-specific cycles are fundamental to detailed industry studies in which productivity analysis plays a vital role.

Table 1 **Market sector[a] industries**

Industry division	*Abbreviation used in this paper*
Agriculture, forestry & fishing	AFF
Mining	MIN
Manufacturing	MAN
Electricity, gas, water & waste services	EGWW
Construction	CON
Wholesale trade	WT
Retail trade	RT
Accommodation & food services	AFS
Transport, postal & warehousing	TPW
Information, media & telecommunications	IMT
Financial & insurance services	FIS
Arts & recreation services	ARS

a While the ABS has recently expanded its market sector to cover 16 industries, insufficient disaggregated data are available for the extra four industries to be included in this study.

This study finds that industry-specific cycles vary across industries and from those for the market sector as a whole. And for some industries the use of industry-specific growth cycles provides a quite different interpretation of industry MFP performance from that provided by analysing growth in industry MFP over aggregate market sector cycles.

Capacity utilisation change affects measured MFP growth

Year-to-year variations in measured MFP can be caused in part by factors such as short-term shifts in demand, or transitory supply shocks (for example, strikes or droughts). These types of short-term deviations differ from other shocks that may cause long-term changes in productivity trends, such as new technologies. These short-term shocks may result in a change in the rate of utilisation of inputs.

Ideally, all changes in the rate of utilisation of inputs would be measured as changes in inputs in the calculation of MFP. However, in many cases there is insufficient information to determine appropriate changes to input service flows. Instead the change is captured as a variation in conventional estimates of MFP rather than as a change in inputs.

In these circumstances, the change in measured MFP may diverge from being a measure of technological change. Going into a downturn, measured MFP growth is likely to be overly depressed as a result of underutilised inputs that are still fully included in measured inputs. In an upturn, measured MFP growth can rebound in part as a result of hitherto underutilised inputs being used to generate new output growth.

Peak-to-peak analysis reduces distorted comparisons of MFP growth

The ABS identifies MFP growth cycles for the market sector of the Australian economy to allow better analysis of the drivers of growth in different periods. These growth cycles are chosen with reference to peak deviations from trend MFP and to general economic conditions at the time. By analysing average annual productivity growth between selected peaks, the ABS aims to minimise the effects of some of the short-term influences that are captured in year-to-year changes in measured productivity (ABS 2008). In particular, the peaks are assumed to be periods of high capacity utilisation and therefore provide the basis for more consistent comparisons.

At the industry level, analysis of industry-specific MFP growth is sometimes conducted over ABS market sector cycles. This is appropriate when decomposing market sector MFP cycle growth into industry contributions, but it is not as suitable for analysis of MFP growth *within* specific industries.

Cyclical factors, including those that affect capacity utilisation, will generally differ across industries — for example, Agriculture is affected by droughts, Mining is affected by resources booms, and Electricity, gas & water is affected by droughts and an evolving policy and regulatory environment. As highlighted in the Commission's submission to the House of Representatives Economics Committee inquiry into '*raising the level of productivity growth in the Australian economy*' (PC 2009), such factors have had a significant influence on the recent performance of overall market sector productivity. It is therefore useful to investigate industry-specific MFP growth cycles as an aid to better interpretation of the underlying drivers of MFP growth at the industry level.

The ABS aggregate approach can be modified for application at the industry level

This study applies an approach at the industry level that is consistent with the aggregate level approach taken by the ABS. The aim is to provide a general approach to examining industry MFP, rather than an ideal method for each specific industry. (A detailed industry study would be a better vehicle for consideration of a more refined approach to the identification of productivity cycles for each individual industry.) The more subjective element of the ABS approach (the consideration of general economic conditions) is therefore replaced in this study with a more mechanical method that can be applied to all industries.

This more mechanical approach (illustrated in figure 1) includes:

- selecting which peak deviations from trend will form the MFP growth cycles on the basis of
  - robustness to variations in the method of trend identification
  - the relative size of peak deviations that are close together (where selecting both peak deviations would result in short cycles that are not particularly useful for analysis)
- flagging the selected peaks for further consideration, where industry-specific knowledge is available, if they
  - are only ‘weakly robust’
  - are small in size
  - have been selected from a pair of close together peaks.

This modified approach is more ‘mechanical’ than the ABS approach. Where the ABS considers general economic conditions, this study employs multiple filters and a rule about close together peaks to eliminate some peaks from use in the MFP growth cycles. However, in examining an individual industry in detail, industry-specific knowledge should be used to augment this mechanical approach.

Figure 1 **Process for selecting MFP cycles to use in analysis**

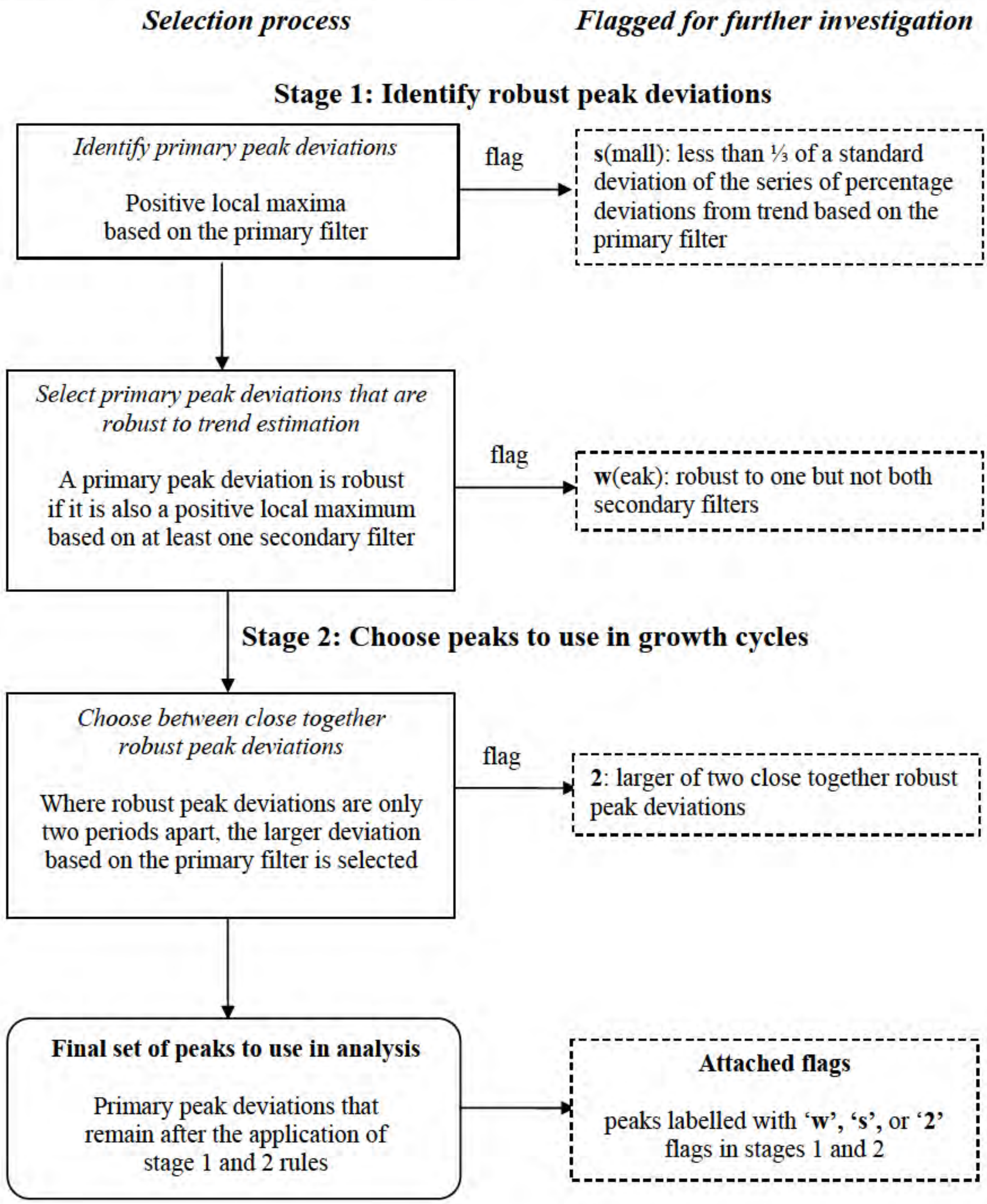


Table 2 Peaks identified for use in industry-specific MFP growth cycles[a]

Shaded rows are market sector peak years

Industry[b]	AFF	MIN	MAN	EGWW	CON	WT	RT	AFS	TPW	IMT	FIS	ARS	Peaks per year
1985-86													**c**
1986-87													0
1987-88		✓			✓						✓		3
1988-89			✓2			✓			✓				3
1989-90								✓		✓w2			2
1990-91	✓			✓w									2
1991-92		✓					✓w2						2
1992-93										✓2			1
1993-94	✓		✓2		✓			✓	✓s		✓		6
1994-95						✓w							1
1995-96		✓											1
1996-97	✓						✓		✓				3
1997-98				✓		✓							2
1998-99			✓w		✓			✓		✓			4
1999-00											✓		1
2000-01	✓	✓											2
2001-02													0
2002-03				✓s2	✓	✓s		✓s	✓				5
2003-04			✓2				✓2			✓	✓w		4
2004-05													0
2005-06	✓					✓2							2
2006-07		✓2		✓				✓	✓				4
2007-08			✓		✓2					✓	✓		4
2008-09													**c**
Peaks per industry	5	5	5	4	5	5	3	5	5	5	5	na	**52**

a Revisions by the ABS to its official industry MFP time series, as well as additional years of data, may also lead to revisions to the industry cycles identified and average annual growth rates over these cycles. **b** Industry labels: AFF is Agriculture, forestry & fishing; MIN is Mining; MAN is Manufacturing; EGWW is Electricity, gas, water & waste services; CON is Construction; WT is Wholesale trade; RT is Retail trade; AFS is Accommodation & food services; TPW I s Transport, postal & warehousing; IMT is Information, media & telecommunications; FIS is Financial & insurance services; ARS is Arts & recreation services. **c** Insufficient observations are available to identify peaks in these years. **na** peaks were not identified for this industry. **w** indicates weakly robust. **s** indicates a small deviation. **2** indicates a peak selected from a pair of close together peaks.

MFP growth cycles vary considerably across industries

This study uses industry MFP index data from the ABS *Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09*. Data for each of the twelve (core) industries are available for the period 1985-86 to 2008-09. Before applying the above method, the properties of these time series were tested to check that the chosen filters could be validly applied. It was found that for Arts & recreation services this was not the case, so cycles for this industry are not identified in this paper.

Among the 11 industries for which cycles were examined, there are a total of 52 peaks identified (table 2). Of these, 21 peaks (that is, less than half) occur at declared peak years for the market sector. The differences are not uniform across industries. They range from Mining, where no industry peaks coincide with market sector peaks, to Manufacturing, where all industry and market sector peaks coincide. (The mechanical approach used in this paper yields the same cycles over this period for the market sector as the ABS declared cycles, although 1993-94 is flagged as weakly robust.)

The set of cycles used to examine industry MFP growth can have a considerable effect on the pattern found

In some industries, the use of industry-specific cycles, rather than market sector cycles, can lead to a change from negative to positive average annual industry MFP growth (or vice versa) and/or a large change in the magnitude of MFP growth. This is particularly likely where a market sector peak is actually a trough year for the individual industry being examined. An example of this is Mining (where the switch is circled in figure 2).

Figure 2 **Average annual MFP growth in Mining, over industry-specific cycles compared with over market sector cycles**

Per cent per year

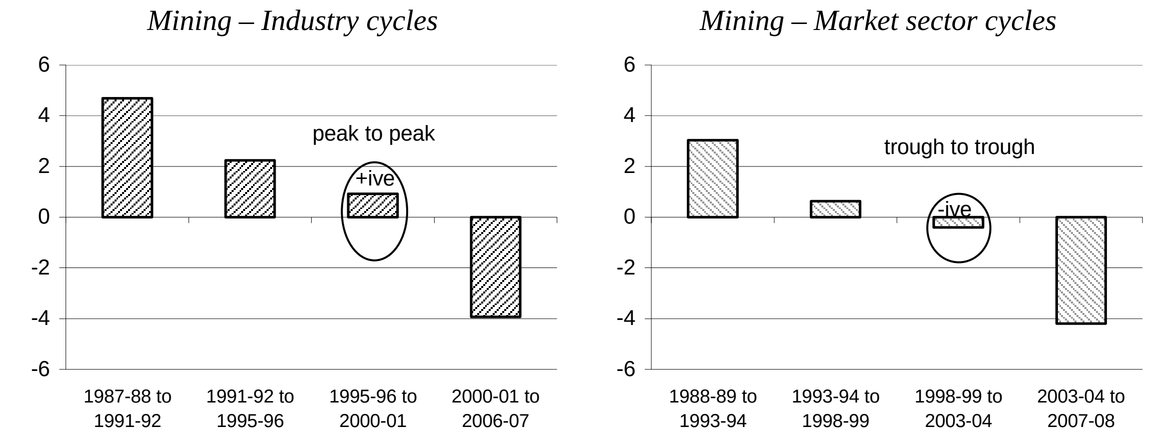
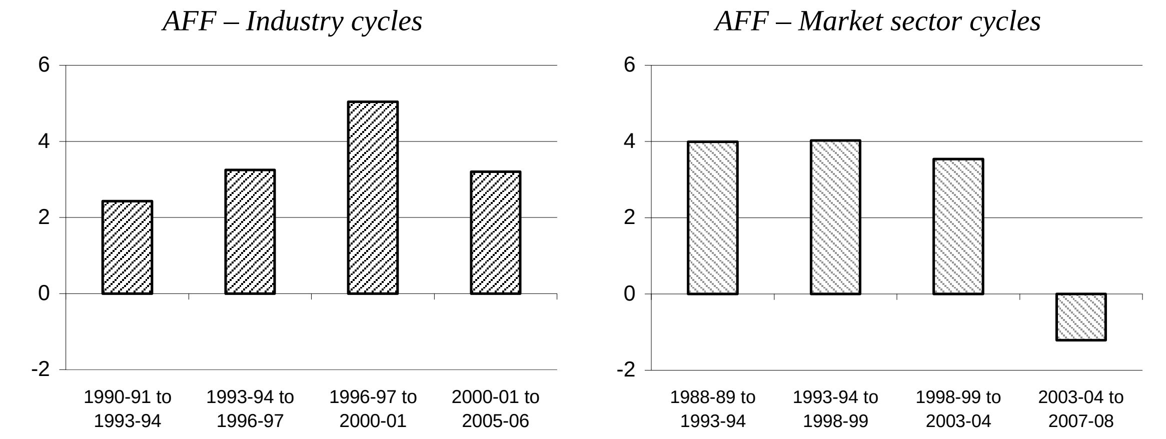


Figure 3 **Changes in the pattern of average annual MFP growth in Agriculture, forestry & fishing under industry-specific cycles**

Per cent per year



Also particularly notable is the difference in industry level and market sector cycles for Agriculture, forestry & fishing (AFF) (figure 3). Considered over the industry cycles, AFF MFP growth is exceptionally strong in the late 1990s cycle, followed by a return to more average MFP growth in the 2000s. However, over the market sector cycles it might be concluded that there was a steep downward trend in MFP growth in the 2000s. When there is a drought, the associated fall in measured MFP and the rebound after the drought are both included in a single industry-specific cycle, but a market sector cycle may include the fall but not the full rebound. When additional years are eventually added to the AFF time series and the next complete industry-specific cycle can be identified, it will also partly overlap with the last market sector cycle in figure 3.

Industry cycles aid better interpretation of productivity performance and further refinement is possible

Closer analysis of industry productivity is key to understanding aggregate productivity performance and to providing policy-relevant insights into how to influence it.

The industry-specific cycles presented in this paper, and the methodology for identifying them, are tools that can assist in understanding industry productivity performance. This initial set of cycles, while not intended to be definitive, provides the basis for more refined examinations of productivity in individual industries. The methodology outlined provides a generic approach to the identification of industry cycles, but the results also flag the scope for further refinement of the cycles where more detailed industry-specific information is available.

1 Introduction and background

Growth in productivity is a key determinant of long-term economic growth and hence income growth. As such, Australia's prospective productivity performance will affect its future prosperity and its capacity to fund initiatives designed to address various longer-term challenges, such as population ageing and climate change.

Productivity measures indicate how efficiently an economy (or any other defined economic entity) is operating. Multifactor productivity (MFP), in particular, is a measure of the amount of output obtained from a combined unit of labour and capital. In principle, it reflects the part of economic growth over and above that resulting from growth in hours worked and growth in capital employed, and is frequently taken to be an indicator of technological progress. MFP growth is the primary measure employed by the Productivity Commission because, as a comprehensive measure, it contributes better policy-relevant insights into the various determinants of economic growth (PC 2009).

Given the longer-term importance of productivity to living standards, recent significant declines in MFP growth in Australia have understandably been of concern (MFP growth in the market sector of the economy has averaged around -0.5 per cent from 2003-04 to 2009-10).[1] However, as the Productivity Commission noted in its submission to the House of Representatives Economics Committee inquiry into '*raising the level of productivity growth in the Australian economy*', understanding precisely what has affected productivity in practice and how it can be influenced is not straightforward (PC 2009).

Closer analysis of productivity growth in the individual industries that make up the market sector, and of the underlying drivers of that productivity growth, is important to a proper understanding of aggregate market sector outcomes. For example, Productivity Commission analysis suggests that the productivity performance of three industry sectors explains much of the recent decline in market

[1] In this paper, the term market sector refers to the 12 core industry sectors of the economy for which inputs and outputs can be most confidently measured for the purposes of MFP estimation (see table 2.1). Average growth based on official ABS MFP estimates (ABS 2010a).

sector productivity growth. And largely identifiable developments in those three sectors underlie their poor performance (PC 2009, 2010).

However, in addition to the many economic factors that influence productivity growth, productivity estimates can also reflect a variety of measurement issues, including variations in capacity utilisation. These measurement issues can undermine the validity of interpreting MFP growth as an indicator of technological progress. For example, productivity tends to slow during dips in the business cycle, and can sometimes also slow during early stages of rapid investment growth and then accelerate as output from that investment 'catches up'.

The presence of such 'cyclical' issues means that year-to-year variations in productivity tend to be a poor guide to underlying technological progress. Because of this, most official statistical agencies, including the Australian Bureau of Statistics (ABS), advise that some longer-term averaging of measured productivity growth is likely to provide better insights into the underlying rate of technological change (see box 1.1 below). To help avoid comparisons of productivity growth rates across inappropriate points of time, the ABS identifies and publishes what it calls market sector MFP growth cycles — periods over which average growth in market sector MFP can be most appropriately compared. In its analysis of market sector MFP growth the Productivity Commission focuses on developments in average annual MFP growth rates across these productivity cycles.

As noted above, 'unpacking' individual market sector productivity cycles into the contributions of each of their industry components is often where a more detailed analysis of MFP starts. Indeed, understanding the extent, nature and causes of such contributions and their heterogeneity is crucial to a proper appreciation of any associated policy implications. Importantly, however, it does not follow that average annual MFP growth rates of individual industry sectors across aggregate market sector cycles provide a good indication of the development of technological change *within* those sectors.

As capacity utilisation and other cyclical influences on productivity estimates vary across industry sectors, an understanding of the development of technological change within those sectors requires identification of appropriate industry-specific productivity cycles. Just as is the case for the aggregate market sector, industry-specific productivity cycles should provide periods over which annual average MFP growth rates for each particular industry sector can be more appropriately compared.

This study identifies MFP growth cycles that are industry-specific, by applying an approach similar to that used by the ABS at the more aggregate market sector level.

It also examines how the use of industry-specific growth cycles may affect the interpretation of industry MFP performance.

1.1 Background

As noted above, year-to-year variations in measured MFP growth can be caused by factors such as short-term shifts in demand, or transitory supply shocks (for example, strikes or droughts). These types of short-term deviation differ from other shocks that may cause a long-term change in productivity trend, such as new technologies. As MFP growth is measured as a residual (that is, growth in output less growth in combined inputs of capital and labour), it will also include the effect of any approximations in measurement of output and inputs and of any violations of underlying assumptions.[2]

Short-term shocks may result in a change in the rate of utilisation of inputs. Ideally, all changes in the rate of utilisation of inputs would be measured as changes in inputs in the calculation of MFP, but in many cases there is insufficient information to determine appropriate changes in input service flows. Therefore, where the change in the rate of utilisation cannot be measured, the change is captured as a variation in conventional estimates of MFP rather than as a change in inputs.

For example, if firms expect a downturn in the economy to be temporary, they may not fully adjust their input use in the short term.

- Firms may ‘hoard’ some of their labour in anticipation of an upturn, generally to avoid hiring costs and particularly in the case of skilled labour that may be difficult to replace (because it is in short supply in the long term) or costly to train. While labour input measured in hours worked will reflect changes in the number of hours employees work, where labour is hoarded some of the measured hours worked may reflect employees who are retained at work but are underutilised. Labour inputs may therefore be overstated during a downturn.
- Capital inputs are generally less flexible in a downturn than labour and a greater proportion is likely to be underutilised. Lack of information on utilisation rates means that measured MFP is based on the assumption that capital is utilised at a constant rate, so capital inputs may also be overstated from time to time.

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2 The approach to measuring productivity adopted by the ABS is founded on a neo-classical production framework (ABS 2000a). The underlying assumptions include profit maximising equilibrium in the presence of: constant returns to scale; competitive product and factor markets; and fully divisible and fully utilised inputs. An alternative approach to measuring productivity used by Statistics Netherlands is not based on these assumptions and MFP growth is interpreted as inclusive of changes in scale and other factors (Bergen et al. 2008).

In these circumstances, the change in measured MFP may diverge from being a measure of technological change. Going into a downturn, measured MFP growth is likely to be overly depressed as a result of underutilised inputs that are still fully included in measured inputs. In an upturn, measured MFP growth can rebound in part as a result of output growth due to increased utilisation of previously underutilised inputs, without a measured increase in inputs.

Mismeasurement of input utilisation is one of the reasons suggested for aggregate MFP being observed to be procyclical and it is common to attempt to abstract from this type of short-run deviation when interpreting productivity change. However, other factors have also been suggested as leading to procyclical MFP — for example, violations of other assumptions underlying MFP measures (such as widespread imperfect competition and increasing returns to scale). The relative importance of various factors underlying the procyclical nature of MFP has been the subject of empirical investigation (see, for example, Basu and Fernald 2000). However, for this paper the focus is on abstracting from short-run deviations from trend rather than identifying their cause, and this issue is not discussed further.

The approach of statistical agencies

As noted above, a common approach when interpreting movements in market sector MFP is to attempt to abstract from some of these factors by looking at average annual growth over several years (box 1.1). In the case of the Australian market sector, the ABS identifies ‘MFP growth cycles’ or ‘peak-to-peak periods’ for this purpose.

Box 1.1 **MFP growth cycle analysis in other countries**

A number of national statistical agencies acknowledge the cyclical nature of measured productivity changes and advise against looking at changes from year to year. For example:

> Productivity change measures are highly sensitive to business cycles. … For robust analyses of productivity change it is therefore advisable to calculate average productivity change over longer periods of time instead of following year-to-year changes. (Statistics Netherlands 2010, pp. 9–10).

> Since the cyclical fluctuations generally shown by the standard productivity growth measures are often used to make inferences about long-term economic performance, users should be cautious about inferring long-run trends from changes on a yearly basis. To reduce the influence of the cycle on economic performance, users are encouraged to consider a peak-to-peak or a trough-to-trough analysis of productivity growth rates. (Statistics Canada 2001, p. 174)

> … year-to-year changes in productivity growth should not be interpreted *prima facie* as shifts in disembodied technology. For this purpose it is preferable to examine productivity growth over longer periods of time — and best between years that mark the same position in the business cycle. (OECD 2001, p. 119)

> Breaking the series down into cycles allows for more meaningful comparisons between sub-periods, because year-by-year comparisons can be problematic, due to issues such as the variation of capacity utilisation over cycle. (Statistics New Zealand 2010b, p. 37)

> Short-term movements in productivity and unit labor costs often result from cyclical variation in output … and may also reflect unusual events such as drought. These short-term movements are sometimes substantially greater or smaller than long-term averages of productivity and cost movements. For example, productivity growth for 1 or 2 years can be substantially greater than the average for the business cycle that includes these years. (US Bureau of Labor Statistics 1997, p. 94).

The ABS declares MFP growth cycles for the market sector of the Australian economy to allow better analysis of the drivers of growth in different periods. These growth cycles are chosen with reference to peak deviations from trend MFP.[3] By analysing average annual productivity growth between peaks, the ABS aims to minimise the effects of some of the short-term influences that are captured in year-to-year changes in measured productivity (ABS 2008).[4] The link between this type

3 Others have argued for a different basis for determining periods over which to analyse productivity trends (see, for example, Quiggin 2001, who refers to the use of business cycles based on GDP rather than productivity cycles). A wide range of alternatives are discussed below in section 1.2, but an assessment of alternative methods for determining periods for analysis of trend is beyond the scope of this paper.

4 Other non-cyclical measurement issues may still be reflected in MFP growth as the residual — for example, where it has not been possible to fully measure quality change as a change in output.

of approach and assumptions about capacity utilisation is well summarised by Statistics New Zealand:

> Cycles are defined using a peak-to-peak definition, meaning that cycles are considered to commence at points where the deviation above the trend is highest ... The rationale for this is that for consistent comparisons it is ideal to compare productivity between periods of similar capacity utilisation, and the peaks are assumed to be periods of high capacity utilisation. (SNZ 2007, p. 8)

In this context, the term trend refers to the long-term behaviour of the data series and it is estimated by a form of smoothing of the original series. The purpose of the trend is to provide a 'base' from which to identify peaks in the short-term deviations of the original series from that trend. (It should be noted that any MFP trends derived for this purpose are not intended for use in forecasting MFP growth.) The phrase MFP growth cycle refers to the period between selected peak deviations from trend over which average annual growth in the original MFP series is calculated. The phrase 'MFP growth cycle' does not refer to a separately identified cyclical component of the original series.

The practice of analysing average productivity growth over cycles or an extended period, rather than from year to year, is recommended by a number of national statistical agencies, including Statistics Canada, Statistics Netherlands, Statistics New Zealand, US Bureau of Labor Statistics, and the OECD (see box 1.1 above). However, not all agencies take the same approach. Only the ABS and Statistics New Zealand explicitly identify cycle periods in MFP. Other agencies examine average annual productivity growth over aggregate business cycles or over uniform periods (for example, five year intervals), or do not suggest specific periods for analysis.

While the ABS releases experimental estimates of MFP for individual industries within the market sector, it does not identify industry-specific growth cycles. Statistics New Zealand reports average MFP growth for individual industries over cycle periods for its aggregate measured sector. While acknowledging that individual industries will not necessarily have the same growth cycles, Statistics New Zealand uses the same measured sector cycles for all industries to allow comparability across industries and with the measured sector over the same periods (Statistics New Zealand 2010a). Statistics Netherlands reports average MFP growth over aggregate business cycles for individual industries and the commercial sector in total (Statistics Netherlands 2010).

Industry-specific cyclical factors

Looking at year-to-year variations in MFP at the industry level is potentially misleading, as it is at the aggregate market sector level. In an effort to overcome this, analysis of industry MFP growth is sometimes conducted over ABS market sector cycles, but this is not necessarily the right approach. While market sector cycles are appropriate for decomposing market sector MFP growth to examine the individual industry contributions, market sector MFP cycles are typically not appropriate for analysis of MFP growth within specific industries over time.[5] Cyclical factors, including those that affect capacity utilisation, will generally differ across industries — for example, Agriculture is affected by droughts, Mining is affected by resources booms, and Electricity, gas & water is affected by droughts and an evolving policy and regulatory environment.

Other Commission work has also highlighted the importance of industry-specific factors in explaining patterns of industry MFP growth. Topp et al. (2008) found that capital/output lags and resource depletion were key factors in explaining patterns of MFP growth in Mining and the market sector. A Commission study of Manufacturing (PC 2003) also found that cyclical effects may have different timing for different sectors — for example, changes in MFP were more closely correlated with contemporaneous changes in unemployment for the market sector than for Manufacturing, but changes in MFP were more highly correlated with the lagged value of the change in the unemployment rate for Manufacturing than for the market sector. PC (2003) noted that, because of the different cyclical influences across industries, MFP growth cycles or peak-to-peak periods are probably best constructed on a sector by sector basis.

It is therefore useful to investigate industry-specific MFP growth cycles as an aid to better interpretation of the underlying drivers of MFP growth at the industry level, and to the formulation of microeconomic reform that has industry-specific impacts.

The ABS carried out some preliminary work on MFP cycles at the industry level in Australia (Zhang and Conn 2007), identifying some variation in cycles across industries. However, the main focus of the work was on alternative techniques for identifying cycles at the market sector level. Consequently, a set of industry cycles

5 Another approach is to examine growth in industry *trend* MFP. Again, this is more relevant to comparisons across industries than analysis of growth within a specific industry. Because industry cycles differ, comparisons across industries using these periods are difficult. PC (2011) notes that '[i]f the objective is to compare underlying productivity growth in different industries, the use of trend rates of growth has advantages over the peak-to-peak productivity cycle method. … Because short-term fluctuations have been smoothed out from the trend series, the start and end points of periods for comparison of growth rates can be selected flexibly and without introducing spurious effects.'

was not specified, nor was average annual growth in industry MFP examined over industry-specific cycles.

1.2 Objectives

The overall objective of this study is to examine appropriate periods over which to analyse MFP growth in individual market sector industries. This is a first step to gaining a better understanding of the drivers of industry level productivity growth and the implications for microeconomic reform.

In particular, this paper aims to:

- identify MFP growth cycles for individual industries within the market sector, using (in broad terms) the ABS methodology for identifying cycles at the market sector level
- estimate average annual growth in industry MFP (as well as growth in value added and inputs) over these industry-specific cycles and compare them with average annual growth in industry MFP calculated over market sector cycle periods.

In this paper, the term market sector refers to 12 (core) industries under the 2006 edition of the *Australian and New Zealand Standard Industrial Classification* (ANZSIC06).[6]

This study will contribute to a broad understanding of the nature of cycles at the industry level, which can be used in more refined examinations of specific factors in detailed studies of productivity in individual industries. However, it is not intended that this study provide a comprehensive assessment of the basis for using cycles to analyse MFP growth or that it identify the 'preferred' methodology for determining such cycles. Because the ABS already declares official MFP growth cycles for the market sector, this study applies an approach at the industry level that is consistent with the aggregate level approach taken by the ABS.

The industry-specific cycles identified in this study will provide a good basis for analysing productivity within an industry, with the possibility of further refinement to the cycles where more detailed industry-specific information is available. The cycles identified may also assist in identifying industry-specific trends that warrant investigation and in facilitating the more detailed work in industry-specific studies.

6 Table 2.1 in chapter 2 lists the individual industries. While the ABS has recently expanded its market sector to cover 16 industries, the time series currently available for these extra four industries are too short for inclusion in the analysis in this study.

This study is a continuation of the Commission's stream of research into measured MFP growth. It builds on previous and current Commission research on the interpretation of industry MFP estimates in situations where there are measurement difficulties. For example, Topp et al. (2008) looked at the impact of capital/output lags and resource depletion on measures of MFP for the mining industry, and the current study into Electricity, gas, water & waste services is examining the effect of the drought and a major increase in new capital investment (among other matters) on measures of MFP for that industry. The Commission's examination of MFP growth cycles in Agriculture (PC 2005) and Manufacturing (PC 2003) is also extended in this study of cycles.

1.3 The rest of the paper

The remainder of this paper is organised as follows.

- Chapter 2 outlines the methodology for identifying industry MFP cycles and the properties of the industry MFP time series.
- Chapter 3 identifies the industry MFP growth cycles and the extent to which these cycles differ from cycles at the market sector level.
- Chapter 4 discusses the implications of differences between industry and market sector cycles for the interpretation of MFP growth patterns. It also discusses the implications of the possible refinement of industry productivity cycles.
- Appendix A provides more details relating to the methodology, the industry MFP data and the industry-specific cycles identified.

2 Methodology and data

This chapter introduces the methodology and data used in chapter 3 to identify industry level multifactor productivity (MFP) growth cycles. Section 2.1 outlines the methodology that the Australian Bureau of Statistics (ABS) uses to identify growth cycles for the market sector as a whole, and how this is adapted for use with industry level data in this study. Section 2.2 presents the data used, and summarises the properties of the data that guide the application of the methodology at the industry level.

2.1 Methodology for identifying MFP cycles

The ABS determines MFP growth-cycle peaks for the market sector by comparing annual MFP estimates with their corresponding long-term trend estimates. The trend is calculated by the application of a linear filter, a weighted moving average, to the original estimates. The peak deviations between the two series (that is, the highest deviations in percentage terms) are the primary indicators of growth-cycle peaks, but more general economic conditions at the time, such as the state of output and labour markets, are also considered.

This study is an initial exploration of cycles at the industry level. As such, it starts with the ABS approach and adapts it for implementation at the industry level. However, this is not the only possible approach. Alternatives for the analysis of changes in MFP in individual industries include:

- estimation of average MFP growth in individual industries over
  - uniform fixed periods, for example five or ten year periods
  - the same cycles as identified by the ABS for market sector MFP
  - aggregate economy business cycles
  - cycle periods in industry value added
- identification of industry MFP trends using econometric techniques that separately identify trend, cycle and noise components of MFP

- detailed industry analyses which identify and, where possible, adjust for, industry-specific factors that cause short-term deviations in MFP in individual industries.

The assessment of alternative methodologies is beyond the scope of this paper, which, for consistency, applies an industry level approach based on the ABS aggregate level methodology.

Before detailing the specific approach used in this paper, it is useful to examine the ABS approach and the meaning of growth cycles in that context.

The ABS approach to growth cycles

The aim of the ABS in identifying what it calls MFP growth cycles, or peak-to-peak periods, is to identify points of comparability in measured MFP for the market sector. These points are years between which change in measured MFP is more likely to reflect technological change than to reflect measurement issues (such as changes in capital utilisation that are actually a change in inputs that has not been able to be measured). Peaks are more likely to represent periods of high capacity utilisation that are more comparable.

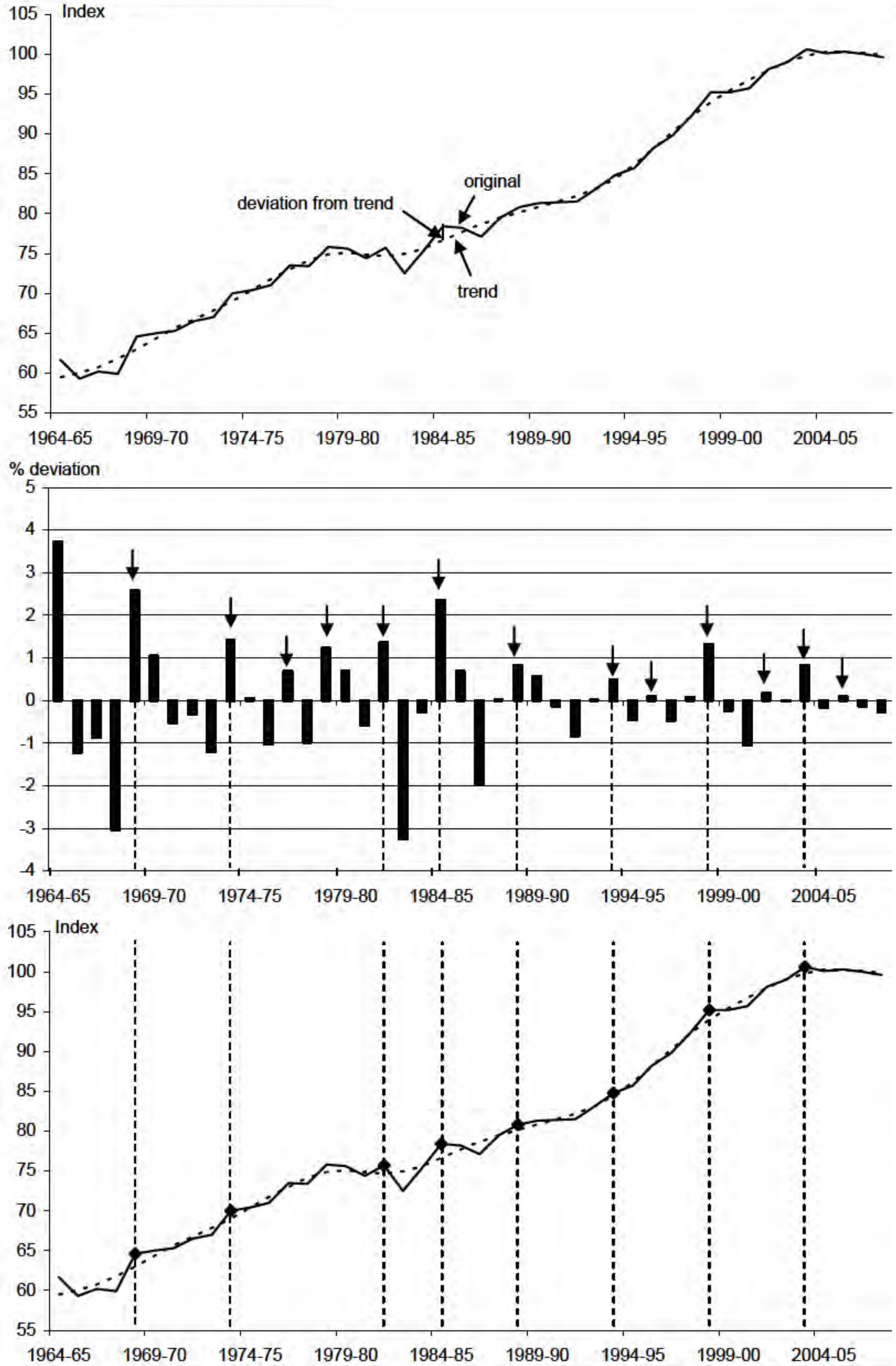
As noted above, the ABS approach to determining MFP growth cycles for the market sector has two stages:

1. the identification of years in which measured MFP peaks in its deviation above the estimated long-term trend
2. an assessment of the suitability of the peaks identified in stage 1 for use in growth cycle analysis, by reference to general economic conditions at the time.

The ABS does not publish the specific details of its implementation of stage 2 of this approach. However, figure 2.1 illustrates how the approach can be implemented, using, as an example, the ABS series of MFP estimates for the market sector.[1] The top and middle panels show the process of stage 1 and the bottom panel shows the final growth cycles identified in stage 2.

1 The *Australian and New Zealand Standard Industrial Classification, 1993 edition* (ANZSIC93) market sector MFP index series (index 2006-07 = 100) is used for demonstration purposes because it extends further back than the market sector series available under the new 2006 edition of ANZSIC (which only goes back to 1985-86). The ANZSIC93 market sector industries are listed in figure 3.1. The ANZSIC06 industry dataset is used for the industry level analysis in the remainder of this paper because it is now the official ABS dataset.

Figure 2.1 **Deviations from MFP trend and growth cycle identification — market sector**



Data source: Author's estimates based on ABS national accounts data.

In the top panel, the solid line is the original series of MFP estimates and the dotted line is the estimated trend. This trend is estimated by applying a filtering technique (a weighted moving average) — the Henderson 11-term filter — to smooth the original estimates.[2] The vertical difference between the two lines is the deviation from trend in that year (1984-85 is marked as an example). These deviations are converted into percentage deviations in the middle panel, and the positive local maxima[3] in this series are identified (marked with arrows).

The bottom panel shows the outcome of stage 2 — the peaks that were declared by the ABS as growth cycle start/end points, after reference to general economic conditions, are marked with a diamond. The vertical dotted lines show the link between stage 1 and 2 — highlighting that a number of peaks identified in stage 1 were not declared as growth cycle peaks. (Box 2.1 provides more details of the nature of the consideration of general economic conditions by the ABS and by Statistics New Zealand.) These 'rejected' local maxima are not necessarily small deviations (for example, 1978-79), although several small peaks close to larger peaks are amongst those that are rejected (for example, 1995-96, 2001-02 and 2005-06).

2 The Henderson filter is described below in the sub-section *Stage 1: application of the filters* and appendix A.

3 In this study, a positive local maximum is an observation whose value is positive and is higher than the observations immediately before it and immediately after it.

Box 2.1 Consideration of general economic conditions when identifying MFP growth cycles

In identifying MFP growth cycles at the market sector level, the Australian Bureau of Statistics (ABS) and Statistics New Zealand (SNZ) consider a range of general economic conditions, in addition to statistical peaks generated by filtering techniques.

Australia

ABS (2005b, p. 6) notes that determining the declaration (or otherwise) of a peak in 1976-77, 1978-79 and 1993-94 required consideration of 'other economic information such as information on employment, prices and general economic circumstances'. Zhang and Conn (2007, p. 17) lists real output (GDP), the unemployment rate and business expectations as part of the range of other economic information considered.

Earlier ABS publications provided some discussion of the role of economic conditions in the selection or non-selection of particular peaks for use in growth cycles.

- 1976-77 was rejected 'after having taken account of the general economic situation at that time, including the relatively depressed labour market' (ABS 1997, p. 9).
- 1994-95 was provisionally identified 'after taking account of the general economic situation at the time, including the relatively high level of capacity utilisation' (ABS 1996, p. 2). Subsequently, 1994-95 was provisionally replaced by 1995-96 — on the basis of a large revision to market sector value added for 1994-95 and 'after taking account of the relatively high level of capacity utilisation' (ABS 1997, p. 9). Later both these years were replaced by 1993-94 as a peak.
- 2001-02 was not identified as a peak in 2003. 'It is possible that 2001-02 is a growth cycle peak but it has not been identified as one at this stage due to the nature of the economic conditions that prevailed at the time' (ABS 2003b, p. 48).

New Zealand

SNZ (2007) notes that estimated growth cycles have clearly been affected by economic shocks and reforms, leading to cycles of varying length. The SNZ methodology for identifying cycles includes: a timeline of key economic events and reforms (which identifies shocks to the economy); and graphs of a range of economic indicators (which provide some explanation of the growth in economic activity over the period). The economic indicators include: consumer price index, trade weighted index, 10 year government bond yield, 3 month bank bill yield, NZ/USD exchange rate, terms of trade, and unemployment rate.

SNZ (2007, p. 11) provides the following examples of the use of this information.

- The 1987 peak was not selected because it was close to the 1985 peak — 'although there were events in the economy that caused a downturn around 1987, the deviation from trend growth rate in MFP was minimal'.
- The 1997 peak was selected rather than 1995 peak — 'the economic events around 1997, including the Asian currency crisis and the severe droughts around this period provide more rationale for the turning point to be around 1997'.
- The 1990 peak was selected even though it was not particularly pronounced — 'the significant economic events and reforms that occurred around this period provide some economic rationale for a cycle to begin around this time'.

The meaning of ‘growth cycles’

While the meaning of ‘growth cycles’ can differ with the context of the analysis, in this study the ABS definition is used. As noted above, the ABS uses the phrase ‘MFP growth cycles’ to refer to periods between selected peak deviations of annual MFP estimates from their corresponding long-term trend estimates.

In this context, MFP growth cycles are simply the periods over which to calculate average annual growth in MFP (using the original MFP estimates, not the long-term trend estimates). The purpose of the ABS exercise is to identify these periods by reference to deviations from trend, not to separately identify the trend, cycle and noise components of the annual MFP series.[4] Nor is it to provide an MFP trend for forecasting purposes. The purpose of the trend is to provide a ‘base’ from which to identify peaks in the short-term deviations of the original series from that trend.

The approach in this study

While the starting point for this study is the ABS approach, that approach needs to be modified to apply it at the industry level. In particular, the more subjective element of the ABS approach (the consideration of general economic conditions when determining the importance of a peak deviation) is replaced with a more mechanical method that can be applied systematically to all industries. As already noted, the consideration of industry-specific conditions is better undertaken in individual, detailed industry studies rather than in a generic exercise designed to provide a ‘first pass’ at identifying MFP growth cycles for each of the 12 core industries within the market sector.

Mechanical rules for identifying cycles have been used in the literature, although these tend to be context specific. Rules are widely used in the literature on business cycles (box 2.2) and earlier Productivity Commission studies also used mechanical methods to identify MFP cycles (box 2.3). These rules are based on the numbers of periods of increase/decrease between peaks and/or the size of deviations from trend.

4 All deviations from trend are considered jointly. No attempt is made to separate the non-trend component of the series into a cyclical component and a noise component. The trend and non-trend components are sometimes referred to as the permanent and transitory components (see, for example, Harding and Pagan 2005). However, as this study is based on the ABS methodology it will also use the ABS terminology. See appendix A for further details.

Box 2.2 **Decision rules used in business cycle dating**

A number of organisations engage in complex procedures to produce 'official' business cycles. Canova (1999, p. 126) remarks

> In standard practice NBER [US National Bureau of Economic Research] or DOC [US Department of Commerce] growth cycles are extracted using elaborate and ad-hoc procedures which are hard to reproduce, involve a substantial amount of judgmental decisions by the researchers and a number of ex-post revisions as more information is obtained over time.

Other researchers have attempted to reproduce the official cycles using more mechanical selection rules. Whether the results of these mechanical methods are dependent on the method of extracting the trend from the data to leave the cyclical component and the particular selection rules used is the subject of much investigation. For example, Canova (1999, pp. 127–8) identifies the following rules:

Rule 1: '… a peak is defined by two consecutive increases followed by a decline.'

Rule 2: '… selects a quarter as a … (peak) if there have been at least two consecutive … (positive) spells in the cycle over a three quarter period.'

These rules have been applied to quarterly data but can in principle be applied to annual data. Canova found that with the first rule peaks were robust to a range of methods for extracting the trend, but this was not the case with the second rule.

Harding and Pagan (2002) suggest that at a minimum an algorithm for detecting business cycles needs to perform three tasks including:

- determination of a potential set of turning points (that is, peaks and troughs)
- a procedure for ensuring that peaks and troughs alternate
- a set of 'censoring rules' in order to satisfy pre-determined criteria concerning the duration and amplitude of cycles.

Under the first task, they suggest that for quarterly data a local maximum should be defined as an observation that has a value greater than the two observations on either side of it. Under the third task, they used a minimum cycle duration of four quarters.

Box 2.3 Decision rules for selecting MFP growth cycles used in Productivity Commission studies

The ABS selects MFP growth cycles by reference to peak deviations from trend *and* general economic conditions at the time. Previous Productivity Commission studies replaced the consideration of general economic conditions with other decision rules.

- PC (2003) used the relative size of the percentage deviations from trend rather than general economic conditions when selecting MFP growth cycles for Australian Manufacturing.
  - Percentage deviations from trend were determined using the same methodology as the ABS. Deviations that were local maxima were selected for use in growth cycles if the deviation was greater than a selected threshold value.
  - The threshold value was set at one standard deviation of the series of percentage deviations from trend — this led to 7 major peaks being identified over the period 1954-55 to 2001-02. An alternative of 0.66 of a standard deviation was used for analysis of shorter periods — this led to the identification of an additional 7 smaller peaks.
- PC (2005) examined cycles in Agricultural MFP, following a similar approach to PC (2003) but using the Hodrick-Prescott filter instead of the Henderson filter to identify the trend.
  - For Agriculture, the use of one standard deviation as the threshold value led to the identification of only 2 peaks over the period 1974-75 to 2003-04. This was considered to be an insufficient number for analysis.
  - The decision rule was relaxed to be at least one-third of a standard deviation — this led to an additional three smaller peaks being identified.

These Commission studies were not primarily focused on determining industry cycles and, therefore, did not involve an in-depth study of the rules for determining peaks. Size rules were used as a straightforward and simple way of safeguarding against the potential of individual filters to generate false cycles, and potentially unreliable comparison periods.

In this study, the ABS approach has been modified in two main ways for application at the industry level.

- Stage 1: follows the ABS's first stage by identifying peak deviations from a filtered trend, but with the addition of testing their robustness to different filters. This robustness testing is a mechanical set of rules used to identify and eliminate the least robust peak deviations and to flag weakly robust and small peak deviations that may warrant further investigation in industry-specific studies.
- Stage 2: assesses the suitability of close together peak deviations for use in growth cycle analysis by using another mechanical rule, rather than considering industry-specific knowledge (which would be equivalent to the consideration of

general economic conditions in the ABS's second stage). Peaks that are close together result in short cycles, which are not particularly useful for analysis. In this study, the choice between close together peak deviations is based on relative size (discussed below in sub-section *Stage 2: final selection of cycles*).

Overall, this modified approach is more 'mechanical' than the ABS approach. Where the ABS considers general economic conditions, in this study multiple filters and a rule about close together peaks are used to eliminate some peaks from use in the MFP growth cycles. However, in examining an individual industry in detail, industry-specific knowledge should be used to augment this mechanical approach.

The implementation of these two stages is discussed further in the following sub-sections, with additional technical details provided in appendix A.

Stage 1: application of the filters

The ABS uses the Henderson 11-term filter, or H(11) filter, to estimate the long-term trend in market sector MFP. The Henderson filter belongs to the class of linear filters, which estimate a point on the trend of the series as a weighted average of observations in the series. Due to this averaging behaviour, linear filters are best described as *smoothing* the series.

The H(11) filter weights 11 observations to estimate a point on the trend. The trend estimate for a particular year is the weighted average of the observation for that year and the 5 observations either side of it. Not all observations have equal weight. Provided there are 5 observations available on each side of the year being estimated, the weights are symmetrical and time invariant — that is, the same set of weights is applied on each side of the year being estimated and the same weights are applied throughout the time series. At either end of the series (the first five and last five observations), the weights are modified to take account of the smaller number of observations available. Appendix A provides further details of the H(11) filter and the weights used in this study.

The choice of filter can affect the estimated trend and different filters have different advantages and disadvantages for particular datasets. For example, in an ABS research paper Zhang and Conn (2007) applied a number of filters to the market sector MFP series. They found that a specific Hodrick-Prescott (HP) filter may be preferable for use on that MFP series, although it would make relatively little difference to the MFP growth cycles identified.

The HP filter is also a linear filter, but the process of extracting the trend from the time series does depend on the number of observations. It is based on solving a function which aims to maximise the fit of the trend to the series while minimising the change in the trend's slope (see appendix A). The HP filter can be applied with different smoothing parameters, with the estimated trend becoming smoother and more linear as the parameter is increased. For annual data HP filters with smoothing parameters of 6.25, 25 and 100, HP(6.25), HP(25) and HP(100), are commonly used.

Although consistency with the ABS market sector methodology is the basis for this paper, some checking of the robustness of the results of the H(11) filter to an alternative filter is warranted. Indeed, the use of multiple filters in order to counterbalance any pitfalls of a particular filter is an approach that has been proposed by other researchers (see, for example, Canova and Ferroni 2011).[5] Statistics New Zealand (2007) estimates MFP cycles using the HP filter, but also considers the results of other filters (including the H(11) filter) in finalising these cycles.[6]

In this study, the reliance on a single filter is reduced by testing the robustness to secondary filters. Following the ABS, the H(11) filter is used as the primary filter. The secondary filters are the HP(6.25) and the HP(25).[7]

The primary filter, H(11), is applied to the MFP time series to estimate a trend. A series of percentage deviations from trend is then calculated and the peak deviations (that is, positive local maxima in the series of percentage deviations) are identified (as illustrated in figure 2.1). This process is also followed for both of the secondary filters.

5 For further discussion of the use of multiple filters, see appendix A.

6 SNZ (2007, p. 9) reports that the results for the filters it tested (Hodrick-Prescott, Henderson, and Baxter-King) generally matched well for the New Zealand MFP measured sector series.

7 These two smoothing parameters were selected because: 6.25 is the annual data equivalent to the 'standard' parameter for quarterly data and is used by Statistics New Zealand with MFP data for its aggregate measured sector; and 25 is preferred for use with Australian market sector MFP in Zhang and Conn (2007) (see appendix A). The HP(100) was also trialled for selected industries (where tests on the properties of the time series, as discussed below in section 2.2, suggested a more linear trend may be appropriate). These additional results, which made a small difference to the peak-to-peak periods identified, are reported in chapter 3.

In this study, a peak deviation is defined to be ‘robust’ if it is:

- a positive local maximum of the series of percentage deviations from the H(11) trend; and
- a positive local maximum in the series of percentage deviations from *at least* one of the HP(6.25) trend and the HP(25) trend.

If the peak deviation under the primary filter is not a positive local maximum for *either* of the HP filters, it is rejected for use as an MFP growth cycle start/end year.

A robust peak deviation may be ‘flagged’ (to indicate that it may warrant further investigation if an industry-specific study is being undertaken) as:

- **w**(eak) — if it is robust to only one but not both of the HP filters
- **s**(mall) — if it is less than ⅓ of a standard deviation of the series of percentage deviations from the H(11) filtered trend.[8]

Stage 2: final selection of cycles

Short cycles are not very useful for analysis and some filters have a tendency to produce spurious short cycles. Some of the peak deviations rejected by the ABS as MFP growth cycle start/end points are only two years from the next closest peak deviation (as shown in figure 2.1). The ABS considers general economic conditions in selecting between peak deviations in this situation. But in this study, where robust peak deviations identified in stage 1 are only two years apart, the largest peak deviation (under the primary filter) is selected.[9] The selected peak is given a flag, ‘2’, to indicate the peak was selected from two close together peaks.

Summary

The end product of these two stages is a set of MFP growth cycles for each industry, with flags attached where applicable. These MFP growth cycles are defined to be the periods between consecutive peak deviations selected via the two stage process outlined above. Figure 2.2 summarises the selection process.

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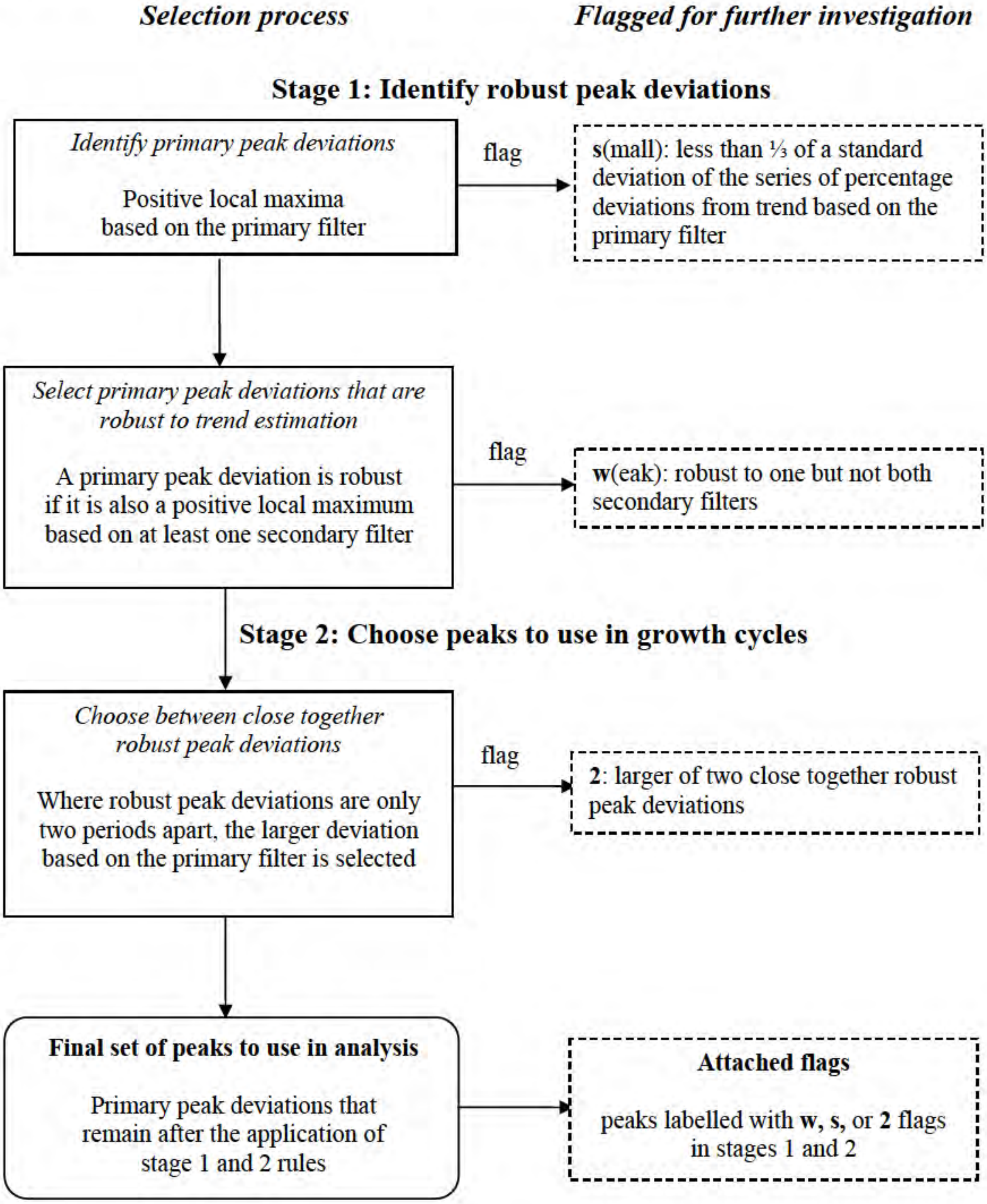
8 It is acknowledged that the choice of ⅓ of a standard deviation as the threshold level for all industries is somewhat arbitrary. It is the level used in the Commission study of Agriculture (PC 2005). All peaks for the market sector, declared by the ABS after consideration of general economic conditions, are above it (that is, they would not be flagged as small).

9 If the two peak deviations are exactly equal in size, the deviation selected is closest to the middle year between the peak years either side of this pair of peak deviations. If the two peak deviations are equidistant from this middle year, the second peak deviation is selected.

In a detailed industry study, industry-specific knowledge should be used to decide whether or not to use the flagged peaks as MFP growth cycle start/end points. However, in this study, all flagged peaks are included in the MFP growth cycles used for analysis in chapter 4.

Figure 2.2 **Process for selecting MFP cycles to use in analysis**



2.2 Industry MFP data and its properties

The extent to which the use of filters to determine trends is valid for industry MFP time series depends on the properties of those series. The data used in this study and the results of the tests on that data are discussed in this section.

The industry MFP dataset

This study uses industry MFP index data from the ABS *Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09* (Cat. no. 5260.0.55.002). The industries examined are those in the market sector of the Australian economy, as listed in table 2.1. In this paper, the term market sector refers to 12 (core) industry divisions in the *Australian and New Zealand Standard Industrial Classification 2006* (ANZSIC06). Under ANZSIC06, compared with the earlier industry classification (ANZSIC93), the ABS has expanded its market sector to 16 industries. However, the time series available for the extra four industries are too short for the type of analysis undertaken in this study. The term market sector as used in this paper therefore refers to the 12 rather than 16 industries.

Table 2.1 **Market sector (core) industries[a] under ANZSIC06**

Industry division	*Abbreviation used in this paper*
Agriculture, forestry & fishing	AFF
Mining	MIN
Manufacturing	MAN
Electricity, gas, water & waste services	EGWW
Construction	CON
Wholesale trade	WT
Retail trade	RT
Accommodation & food services	AFS
Transport, postal & warehousing	TPW
Information, media & telecommunications	IMT
Financial & insurance services	FIS
Arts & recreation services	ARS

a Under ANZSIC06, compared with ANZSIC93, the ABS has expanded the market sector to 16 industries. This expanded market sector also includes Rental, hiring & real estate services, Professional, scientific & technical services, Administrative & support services, and Other services. However, disaggregated MFP data for these four industries were not available in the 2008-09 ABS industry data cube used in this study. The 2009-10 data cube includes data for these four industries but only back to 1994-95 — too short a period for the type of analysis in this study.

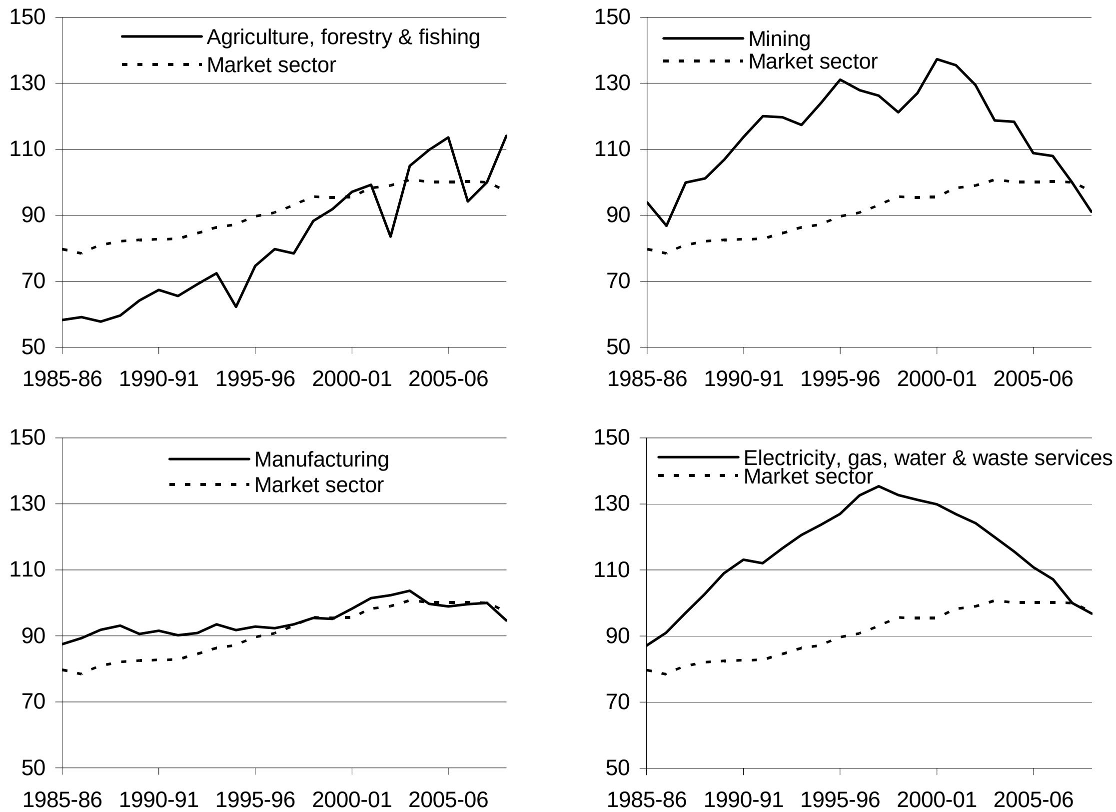
Data for each of these 12 ANZSIC06 industries are available for 1985-86 to 2008-09. Under ANZSIC93, industry MFP series are available from 1974-75 to 2007-08. But these series are not directly comparable with the ANZSIC06 series because of changes in the industry classification and other methodological changes introduced by the ABS at the same time as the new ANZSIC06 classification. Since new data will only be generated under ANZSIC06, this is the primary dataset used in this study.

Properties of the industry MFP time series

Some insight into the properties of the industry MFP time series is provided by plots of the data (figure 2.3). These plots show that the industries had very different patterns of MFP change over the period 1985-86 to 2008-09.

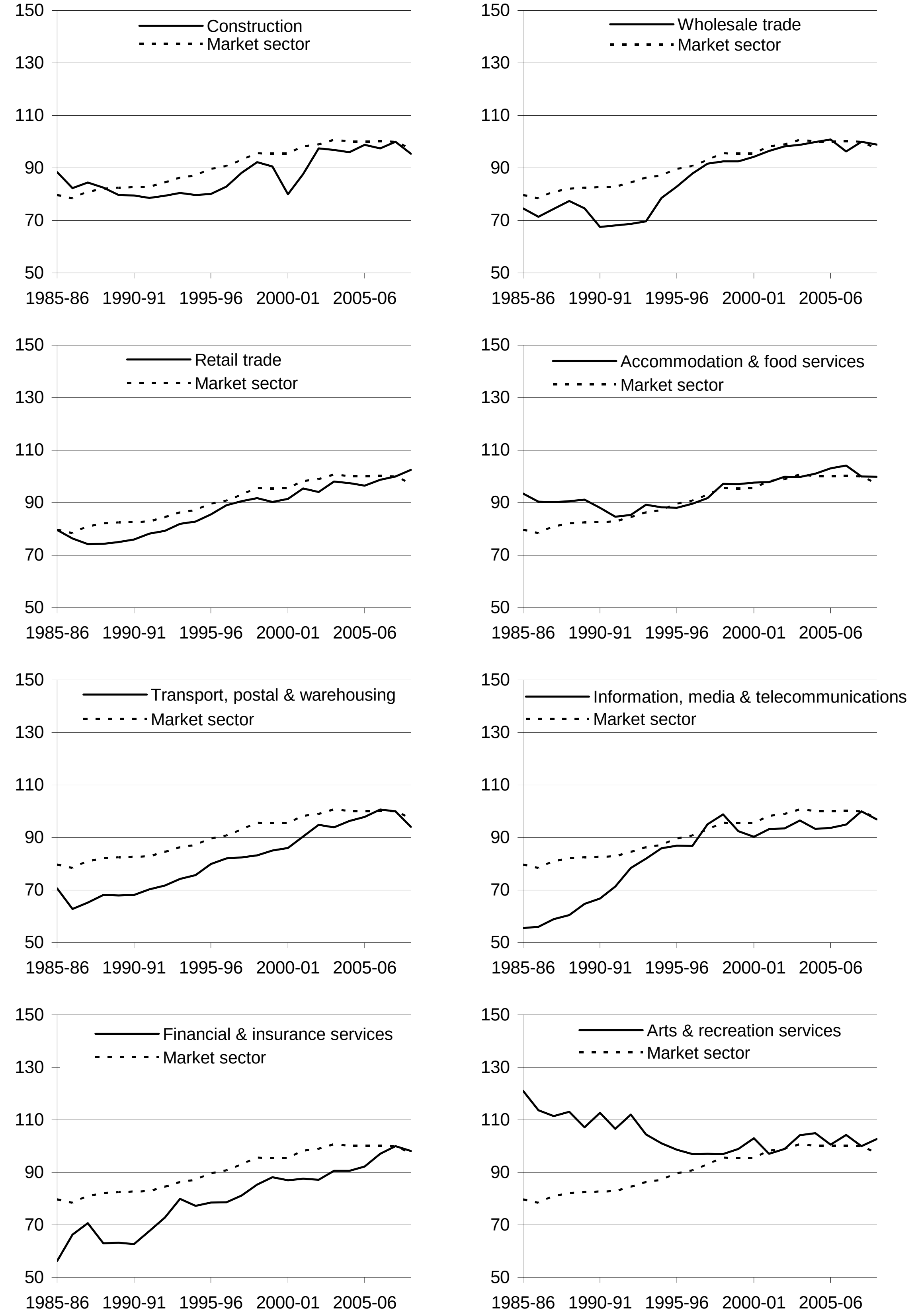
Figure 2.3 **MFP time series, market sector and by industry**

Index 2007-08 = 100



(continued on next page)

Figure 2.3 **(continued)**



Data source: ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09*, Cat. no. 5260.0.55.002).

Most industries display a different pattern to that for the market sector. MFP for Mining and for Electricity, gas water & waste services (EGWW) have inverted U-shapes. Mining's inverted U has considerably more volatility than EGWW. Manufacturing is most similar to the market sector.

Other industries also show different degrees of volatility in MFP. For example, Agriculture, forestry & fishing shows a growth trend but one interrupted by marked volatility associated with droughts. Transport, postal & warehousing also shows a growth trend, but with much less volatility. Wholesale trade shows periods of substantial MFP growth, which are not reflected in Retail trade. Arts & recreation services shows pronounced volatility but not necessarily a trend over the entire period.

Observation alone cannot quantify the differences in the properties of the industry MFP time series. Therefore, time series tests were used to examine the industry MFP time series for:

1. the existence of a trend, and whether it is more appropriate to estimate the trend for the level of MFP or for MFP growth[10]
2. the nature of the trend, specifically whether or not the trend includes a stochastic (or random) component.[11]

First, a trend must exist for it to be appropriate to apply a filter to estimate the trend. In the absence of a trend, the method outlined in section 2.1 is likely to identify cycles that are spurious. The tests on the industry MFP series indicated that a trend exists for all market sector industries, except for Arts & recreation services (ARS). On this basis, no attempt is made to identify MFP growth cycles for ARS.

For all industries for which a trend exists, it was found that the trend can be modelled in the *levels* of the MFP series. This is also the approach used by the ABS for the market sector.

Second, whether or not the trend has a stochastic component is relevant to the appropriate smoothing parameter for the HP filter. If there is no stochastic component, then this suggests the volatility in the data is best ascribed to the

[10] This was assessed by looking at whether the MFP series was non-stationary and if so, its order of integration. The tests used are described in appendix A.

[11] Stock and Watson (1988) define a stochastic trend as one which increases each period by a fixed amount on average but in any given period the change in the trend will deviate from its average by some unforecastable random amount. This is in contrast to a deterministic linear time trend which increases by a fixed amount each period. Augmented Dickey-Fuller unit root tests were used to assess whether or not there was a stochastic trend. Refer to appendix A for further details.

cyclical component rather than the trend component. This is achieved by the use of a larger smoothing parameter, which leads to a smoother and more linear estimated trend. Testing could not reject the existence of a stochastic component to the trend in each of the industries, with the exception of Agriculture, forestry & fishing (AFF), Transport, postal & warehousing (TPW), and Financial & insurance services (FIS). For these three industries, the tests gave evidence to reject the presence of a stochastic component, suggesting that a higher smoothing parameter that estimates a more linear trend may be appropriate.[12]

Overall, the results of the testing suggest that for most industries it is appropriate to apply the filters to the level of MFP and to use low smoothing parameters for the HP filter. Therefore, the uniform approach to identifying MFP growth cycles, as outlined in section 2.1, is applied to each market sector industry (except for ARS, which is not examined). The cycles identified are reported in chapter 3. For AFF, TPW and FIS, where the tests suggested it may be appropriate to vary the uniform approach, alternatives were also examined.

[12] For details of the tests, see appendix A. For Transport, postal & warehousing and Retail trade, the reliability of the tests was reduced — the inclusion of the appropriate number of lags for these industries decreased the degrees of freedom below the minimum required.

3 Industry MFP growth cycles

This chapter presents the industry multifactor productivity (MFP) growth cycles derived from the application of the mechanical rules presented in chapter 2. Before the industry results are presented, section 3.1 demonstrates how closely the mechanical approach approximates the Australian Bureau of Statistics (ABS) method in the case of the market sector. Section 3.2 presents summary results from the application of the uniform rules in each industry. The differences between industries are examined further in section 3.3.

3.1 MFP growth cycles for the market sector

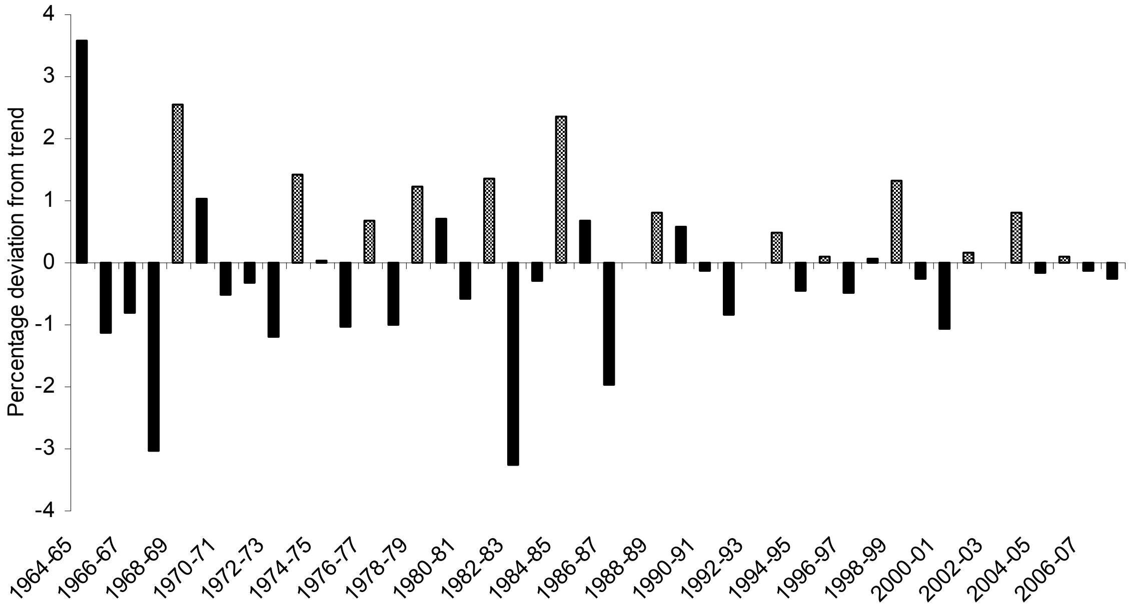
The ABS method for selecting market sector MFP growth cycles was presented in chapter 2. Here the uniform mechanical rules developed for cycle identification for industries (outlined in chapter 2) are used to select market sector peaks in order to compare the outcomes under the mechanical rules with the ABS declared peaks. This is helpful in a qualitative assessment of the practical similarity between these mechanical rules and the ABS approach. The longer MFP series under an earlier industrial classification (ANZSIC93) gives more opportunity to evaluate the method and therefore it is used in this section for demonstration purposes.[1] Following this short section the analysis returns to the current industrial classification (ANZSIC06).

Figure 3.1 shows the percentage deviations from trend generated by the 11-term Henderson, H(11), filter (corresponding to those shown in figure 2.1 of chapter 2), with the grey-shaded bars indicating positive local maxima. It is not possible to determine whether the first year, 1964-65, is a positive local maximum because there are no earlier observations.

[1] The declared peaks in the ANZSIC93 (*Australian and New Zealand Standard Industrial Classification 1993 edition*) series correspond to those in the ANZSIC06 (*Australian and New Zealand Standard Industrial Classification 2006 edition*) series in all but one case. The exception is 2007-08, which does not appear as a peak in the ANZSIC93 but does in the ANZSIC06 series with the benefit of an additional observation. This reflects the effect of revisions on the filtered trend, particularly at the end of the series (see appendix A).

Figure 3.1 **Market sector[a] MFP, percentage deviations from trend under H(11) filter**

Grey-shaded bars indicate positive local maxima

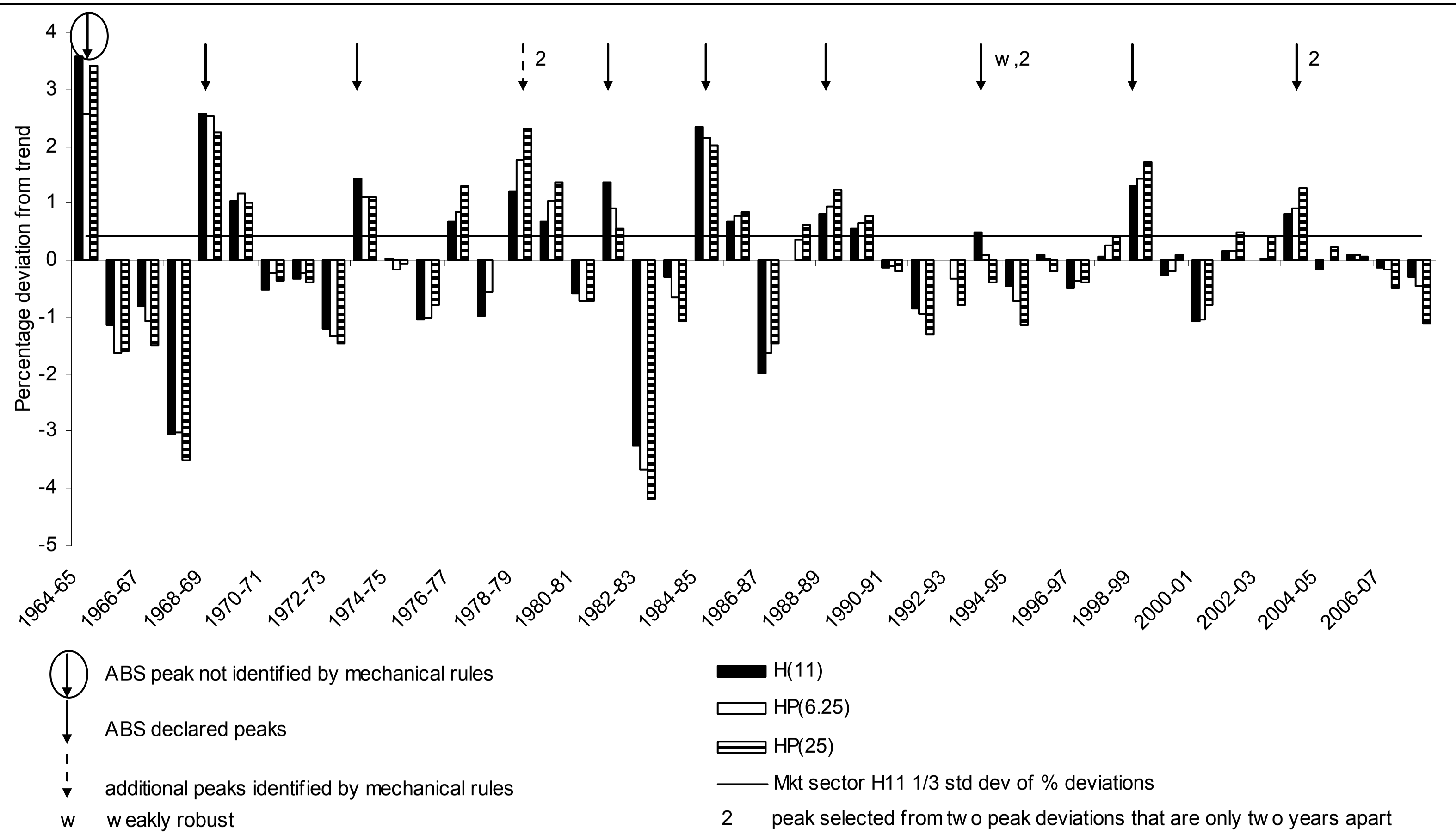


a ANZSIC93 industry classification. The market sector includes: Agriculture, forestry & fishing; Mining; Manufacturing; Electricity, gas & water; Construction; Wholesale trade; Retail trade; Accommodation, cafes & restaurants; Transport & storage; Communication services; Finance & insurance; and Cultural & recreation services.

Data source: Author's estimates based on application of H(11) filter to original series from ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2007-08,* Cat. no. 5260.0.55.002).

In order to apply the uniform mechanical rules outlined in chapter 2, including checking the robustness of the H(11) results to other filters, the local maximum percentage deviations from trend using the Hodrick-Prescott filters are also considered. The percentage deviations from the HP(6.25) and the HP(25) filters are added in figure 3.2. Selected peaks, with any flags arising from the rules, are indicated with arrows.

Figure 3.2 **MFP cycles for the market sector[a] under uniform mechanical rules**



a ANZSIC93 industry classification.

Data source: Author's estimates based on application of H(11), HP(6.25) and HP(25) filters to original series from ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2007-08,* Cat. no. 5260.0.55.002).

All the ABS declared peaks in the ANZSIC93 series are selected by the uniform rules used in this study, with the exception of the beginning of the series peak in 1964-65 (for which there are not enough data to apply the uniform rules). An additional peak in 1978-79 is also selected (indicated by a dotted arrow). All the peaks are robust to both HP filters with the exception of the 1993-94 peak, which is robust to only one of the HP filters. Three pairs of close together peaks required the application of the stage 2 rule that discards the smaller peak of the pair. All peaks are 'big', that is at least one third of a standard deviation of the series of percentage deviations from the trend estimated using the primary filter. Thus, the uniform mechanical rules selected the same peaks as the ABS declared peaks for the market sector, without the consideration of general economic conditions. However, this does not necessarily imply that the mechanical rules will always produce the same peaks as those declared by the ABS at the market sector level. Nor does it imply that in the industry context such rules will produce the same results as consideration of industry-specific conditions.

3.2 Industry MFP growth cycles identified

As discussed in chapter 2, the time series tests performed on the industry MFP index series[2] confirmed that, with the exception of Arts & recreation services, it is acceptable to apply the filters to the industry MFP level (index) series to estimate a trend. Arts & recreation services is not examined any further in this paper.

Table 3.1 reports, for each industry, which years are peak deviations (denoted by a tick) identified by applying stage 1 of the uniform rules outlined in chapter 2. These are positive local maxima of the series of percentage deviations from trend (identified using the H(11) filter) that are also robust to at least one of the HP filters.

The table also shows the flags from the first stage of the rules — 's' indicates a small deviation from the H(11) trend (less than one-third of the standard deviation of the series of percentage deviations from trend); and 'w' indicates a weakly robust peak deviation (an H(11) positive local maximum that is robust to only one, not both, of the HP filters). A square around the tick highlights the peak deviations that are only two years apart and therefore need to be considered in stage 2 of the rules. The shaded columns indicate those years that the ABS declared as peaks for the market sector as a whole. Clearly, there is considerable variation across industries in those years identified as peak deviations.

2 For the remainder of this paper, all analysis is conducted using ANZSIC06.

Table 3.2 shows the final set of peak deviations, after applying stage 2 of the rules, that have been chosen to form the MFP growth cycles. Any flags that remain after stage 2 are also shown, including a '2' where the peak deviation has been selected from a pair of peak deviations that were two years apart (as highlighted in table 3.1). Again, the shaded columns indicate the years that form the MFP growth cycles declared by the ABS for the market sector.

Table 3.1 **Robust peak deviations and associated flags — identified under stage 1 of the uniform rules**

Columns indicate financial year ending

Industry[a]	*86*[b]	*87*	*88*	*89*	*90*	*91*	*92*	*93*	*94*	*95*	*96*	*97*	*98*	*99*	*00*	*01*	*02*	*03*	*04*	*05*	*06*	*07*	*08*	*09*[b]
AFF						✓			✓			✓				✓					✓			
MIN			✓				✓				✓					✓				☑		☑		
MAN				☑		☑s			☑		☑ws			✓w			☑w		☑				✓	
EGWW						✓w							✓			☑s		☑s				✓		
CON			✓						✓					✓				✓			☑s		☑	
WT				✓						✓w			✓					✓s			☑		☑	
RT							☑w		☑			✓					☑		☑					
AFS					✓				✓					✓				✓s				✓		
TPW				✓					✓s			✓						✓				✓		
IMT			☑ws		☑w			☑		☑				✓					✓				✓	
FIS			✓						✓						✓				✓w				✓	

✓ indicates a peak that does not need to be tested by a further stage of the process. ☑ indicates peaks that are only two periods apart and should be considered in stage 2 of the process. Flagged peaks may also be considered in stage 2 of process: 'w' indicates weakly robust; 's' indicates the percentage deviation from the H(11) trend is less than ⅓ of the standard deviation of the series of percentage deviations from trend. [a] For industry names see table 3.3. [b] There is insufficient data to identify peaks in the first and last year of a time series.

Source: Author's estimates.

Table 3.2 **Final peaks (and remaining flags) — identified under stage 2 of the uniform rules**

Columns indicate financial year ending

Industry[a]	*86*	*87*	*88*	*89*	*90*	*91*	*92*	*93*	*94*	*95*	*96*	*97*	*98*	*99*	*00*	*01*	*02*	*03*	*04*	*05*	*06*	*07*	*08*	*09*
AFF						✓			✓			✓				✓					✓			
MIN			✓				✓				✓					✓						✓2		
MAN				✓2					✓2					✓w					✓2				✓	
EGWW						✓w							✓					✓s2				✓		
CON			✓						✓					✓				✓					✓2	
WT				✓						✓w			✓					✓s			✓2			
RT							✓w2					✓							✓2					
AFS					✓				✓					✓				✓s				✓		
TPW				✓					✓s			✓						✓				✓		
IMT					✓w2			✓2						✓					✓				✓	
FIS			✓						✓						✓				✓w				✓	
Number of peaks	**b**	0	3	3	2	2	2	1	6	1	1	3	2	4	1	2	0	5	4	0	2	4	4	**b**

✓ indicates a peak that did not need to be tested by a further stage of the process. Flags indicate that further consideration of the peak may be warranted, where industry-specific information is available: **w** indicates weakly robust; **s** indicates the percentage deviation from the H(11) trend is less than ⅓ of the standard deviation of the series of percentage deviations from trend; and **2** indicates a peak that was selected from two peak deviations that were only two periods apart (with the other robust peak deviation shown in table 3.1 being rejected). **a** For industry names see table 3.3. **b** There is insufficient data to identify peaks in the first and last year of a time series.

Source: Author's estimates.

Among the 11 industries for which cycles were examined, there are a total of 52 peaks identified by the application of the uniform rules (table 3.3). Of these, 21 (less than half) occur at declared peak years for the market sector. The differences are not uniform across industries. They range from no market sector peaks coinciding with industry peaks in Mining and Electricity, gas, water & waste services to all market sector peaks coinciding with industry peaks in Manufacturing.

Table 3.3 **Comparison of market sector and industry peaks**

Industry	*Number of industry-specific peaks*	*Number that coincide with market sector peaks*
Agriculture, forestry & fishing (AFF)	5	1
Mining (MIN)	5	0
Manufacturing (MAN)	5	5
Electricity, gas, water & waste services (EGWW)	4	0
Construction (CON)	5	3
Wholesale trade (WT)	5	1
Retail trade (RT)	3	1
Accommodation & food services (AFS)	5	2
Transport, postal & warehousing (TPW)	5	2
Information, media & telecommunications (IMT)	5	3
Financial & insurance services (FIS)	5	3
Total	52	21

Source: Author's estimates.

There are cases where using the market sector peaks would lead to peak-to-trough comparisons or vice versa, which demonstrates the dangers of simply examining average industry MFP growth over market sector cycles. The proposed industry-specific cycles avoid such pitfalls, as is discussed further in chapter 4.

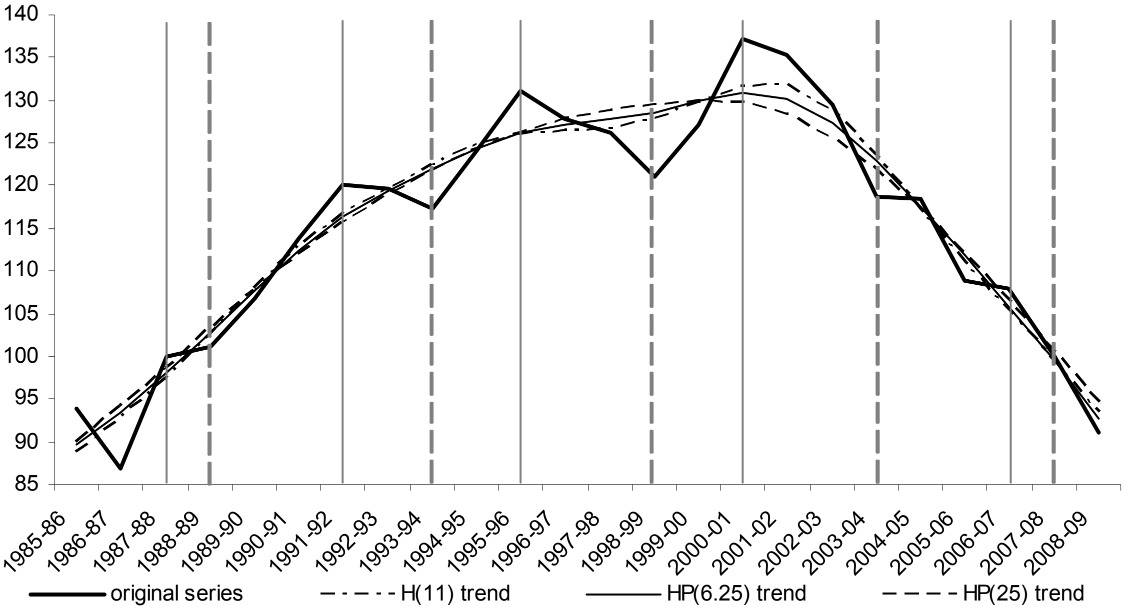
3.3 A closer look at industry MFP growth cycles

As noted above, the industry-specific cycles differ considerably across industries. The following figures — which show the original time series, estimated trends and cycles in each industry — further illustrate this. In each figure, the solid vertical lines indicate the peak years that form the industry MFP growth cycles and, for comparison, dotted vertical lines indicate market sector peak years identified by the ABS. Where both lines appear for a single year the market sector peak and industry peak coincide.

The MFP time series for both Mining (figure 3.3) and Electricity, gas, water & waste services (EGWW) (figure 3.4) display an inverted U-shape.

Figure 3.3 **Mining MFP index, original series and estimated trends**

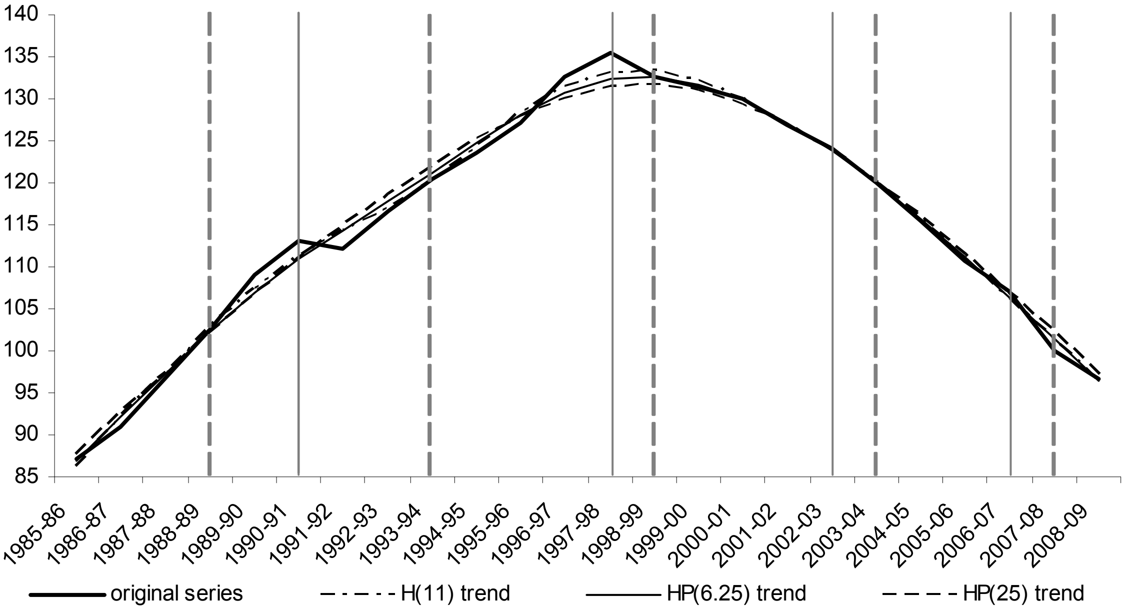
Index 2007-08 = 100. Vertical lines show peak years (solid for MIN and dotted for market sector)



Data source: Original series from ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002); trends are author's estimates.

Figure 3.4 **Electricity, gas, water & waste services MFP index, original series and estimated trends**

Index 2007-08 = 100. Vertical lines show peak years (solid for EGWW and dotted for market sector)



Data source: Original series from ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09*, Cat. no. 5260.0.55.002); trends are author's estimates.

While the MFP series for these two industries may appear similar in some ways, the cycle identification in the two is different. Peaks coincide in only one year (2006-07), and none of the peaks of either industry coincide with market sector peaks. Thus, it appears that the factors that affect the cyclical nature of MFP in the two industries are different and are not highly correlated with the market sector cycles. However, the reasons for such differences are not examined in this study — individual industry studies are better suited to that purpose.

The Mining MFP series is quite volatile and several market sector peak years are industry trough years. While EGWW MFP is less volatile than Mining MFP, there is still sufficient volatility for the choice of comparison period to materially alter average annual MFP growth (as will be discussed further in chapter 4).

Agriculture, forestry & fishing (AFF) and Retail trade (RT) both show an upward trend in MFP (figures 3.5 and 3.6, respectively), but again the identified cycles in the two industries are very different.[3] AFF exhibits a pattern of big drops during droughts, followed by corrections in the following one or two years.[4] Only one peak coincides with a market sector peak year (1993-94). The use of market sector cycles for analysis of AFF could be misleading, notwithstanding that movements in AFF MFP have recently had an important part to play in explaining short-term outcomes for market sector MFP. In RT, it is also the case that only one industry peak coincides with a market sector peak (2003-04). However, the relative absence of volatility in the RT MFP series, after the trough in 1987-88 and up to the start of the 2000s, means that the identification of industry-specific peaks is less likely to materially alter average annual MFP growth. Over the last decade, on the other hand, there is some volatility and the use of market sector cycles is potentially more misleading.[5]

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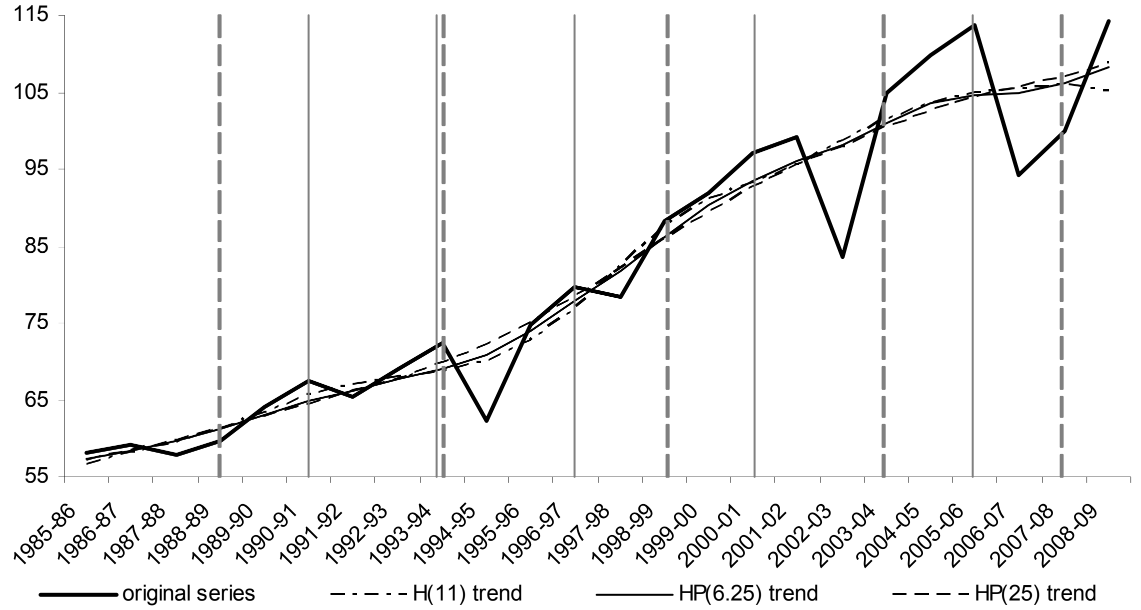
3 The alternative of applying the HP(100) filter to the AFF series was also examined. This alternative approach identified exactly the same peaks as under the uniform approach. If the HP(100) filter was used as the primary filter, rather than the H(11), the 1993-94 and 1996-97 peaks would be flagged as small.

4 In the period under consideration, there are three severe drought years — 1994-95, 2002-03 and 2006-07 (ABS 2010b).

5 As noted in chapter 2, the reliability of the tests of the properties of the RT MFP data series is reduced by the small number of observations. There are few RT peaks identified and this may be because the series has a deterministic trend. However, there are insufficient observations to confirm this.

Figure 3.5 **Agriculture, forestry & fishing MFP index, original series and estimated trends**

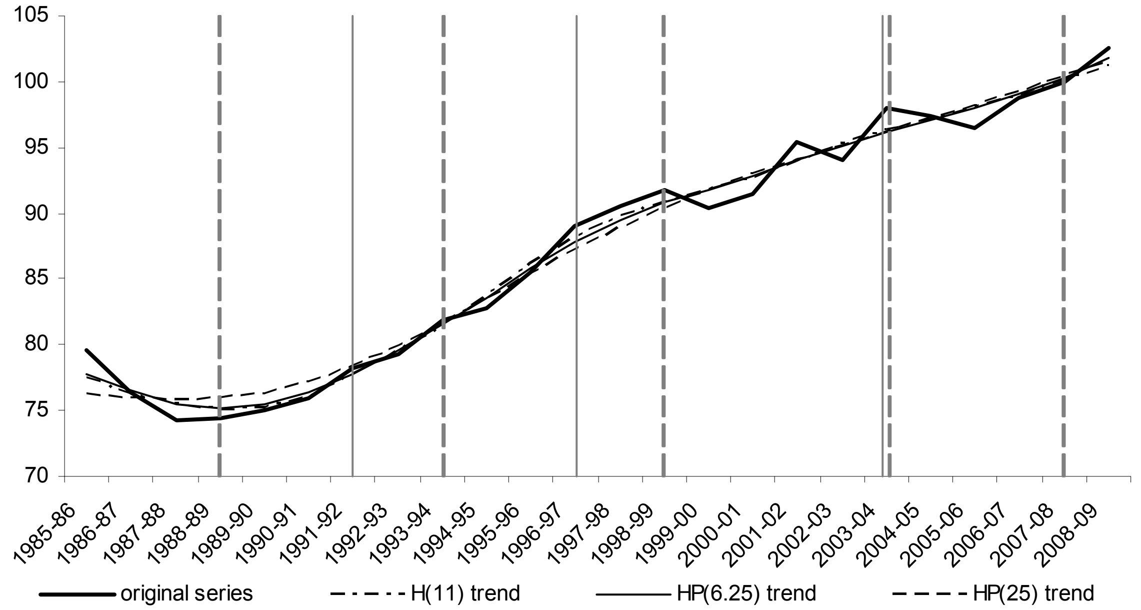
Index 2007-08 = 100. Vertical lines show peak years (solid for AFF and dotted for market sector)



Data source: Original series from ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002); trends are author's estimates.

Figure 3.6 **Retail trade MFP index, original series and estimated trends**

Index 2007-08 = 100. Vertical lines show peak years (solid for RT and dotted for market sector)

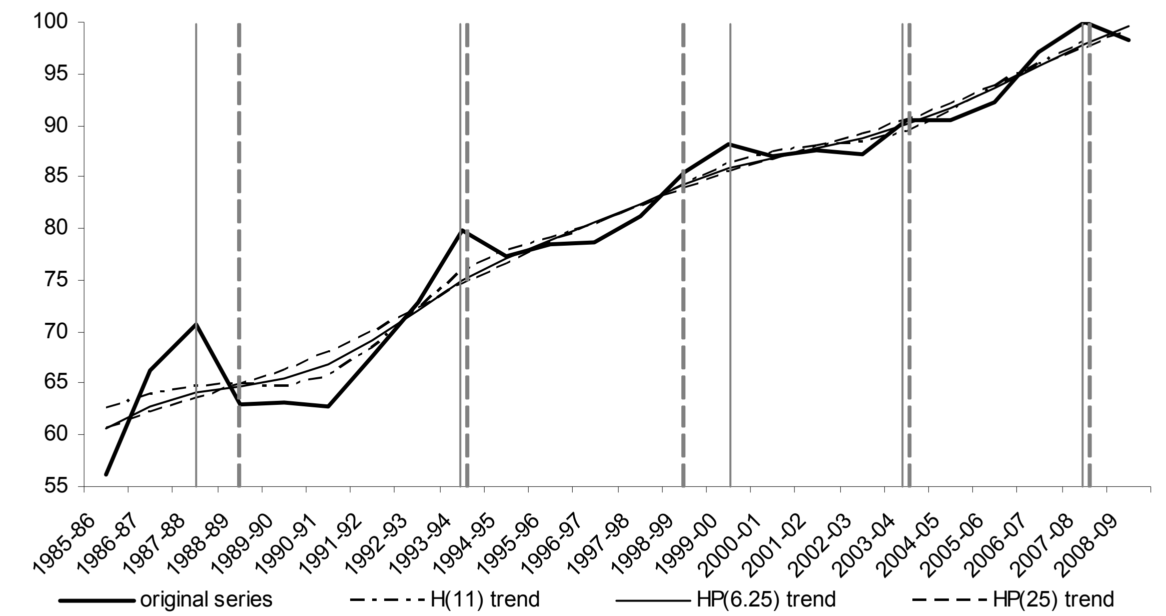


Data source: Original series from ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002); trends are author's estimates.

Financial & insurance services (FIS), like AFF and RT, shows an upward MFP trend (figure 3.7). However, unlike RT, FIS shows more volatility at the beginning of the period under consideration than in the latter part. Local spikes in the FIS MFP series are more pronounced than in RT, and therefore identified peaks are quite robust. Three of the identified peaks in FIS are also market sector peaks. The other two industry peaks are adjacent to market sector peaks.[6] But, as figure 3.7 shows, in the case of 1987-88 compared with the market sector peak year of 1988-89, the difference in FIS MFP is substantial with a marked drop between the two years. Using the market sector cycle of 1988-89 and 1993-94 would lead to average MFP for FIS being calculated from below trend to peak.

Figure 3.7 **Financial & insurance services MFP index, original series and estimated trends**

Index 2007-08 = 100. Vertical lines show peak years (solid for FIS and dotted for market sector)



Data source: Original series from ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002); trends are author's estimates.

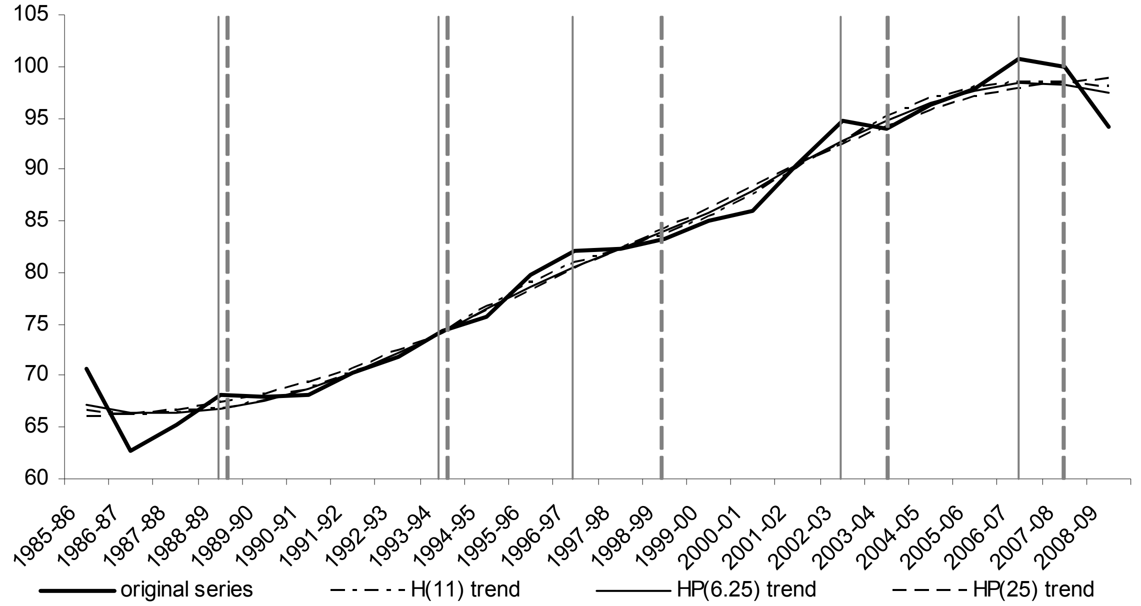
MFP for Transport, postal & warehousing (TPW) also shows an upward trend, except at the beginning and end of the series (figure 3.8). However, MFP for TPW is not as volatile as that for FIS. For TPW, the first two peaks coincide with market sector peaks and the last two are in adjacent, immediately preceding years. Because the series is not very volatile, in most cases the resulting average growth rates over

6 The alternative of applying the HP(100) filter to the FIS series was also examined. This alternative approach identified all but one of the same peaks as under the uniform approach, with the exception being that 2003-04 would not be a peak under the HP(100) filter.

the industry cycles are not very different from those calculated over market sector cycles (see chapter 4).[7] Of course, in future years this may not be the case.

Figure 3.8 **Transport, postal & warehousing MFP index, original series and estimated trends**

Index 2007-08 = 100. Vertical lines show peak years (solid for TPW and dotted for market sector)



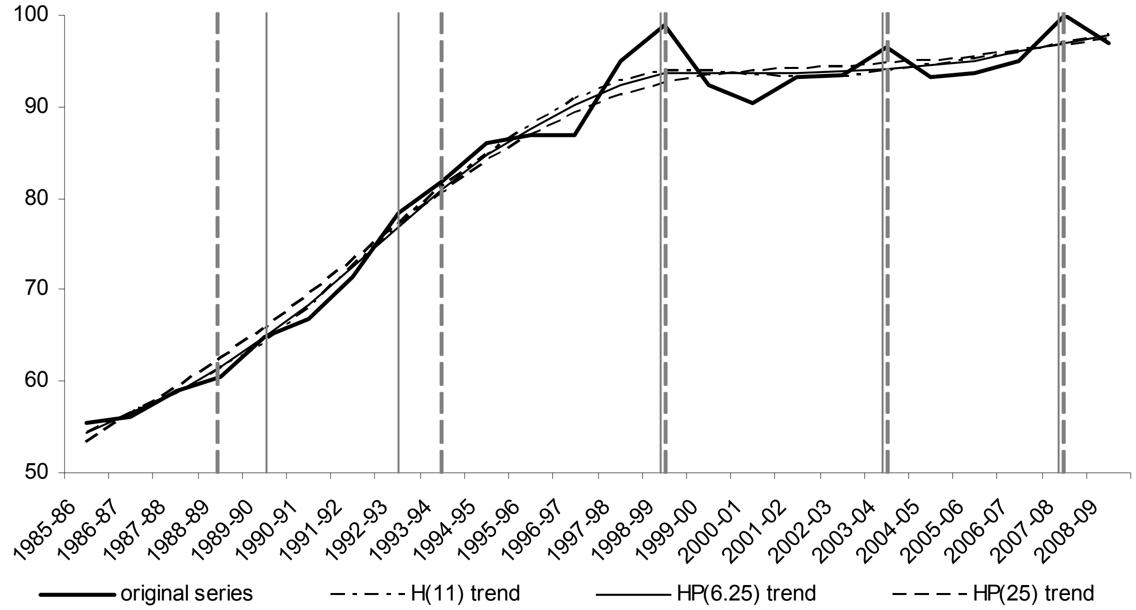
Data source: Original series from ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002); trends are author's estimates.

Information, media & telecommunications (IMT), along with FIS and Construction, has the second highest number of peaks coinciding with market sector peaks (figure 3.9). Like FIS, IMT peaks in the latter part of the period coincide with market sector peaks. The other two are in adjacent periods, but, unlike FIS, there is relatively little volatility in the IMT MFP series over this period. This means that moving from the use of market sector cycles to the use of industry-specific cycles will have less effect on average growth rates (see chapter 4). Again, this conclusion is specific to the period examined here and may differ in future years.

7 As noted in chapter 2, the reliability of the tests of the properties of the TPW MFP data series is reduced by the small number of observations. The alternative of applying the HP(100) filter to the TPW series was also examined. This alternative approach identified all but one of the same peaks as under the uniform approach, with the exception being that 1993-94 would not be a peak under the HP(100) filter. Also, if the HP(100) filter was used as the primary filter, rather than the H(11), the 1988-89 peak would be flagged as small.

Figure 3.9 Information, media & telecommunications MFP index, original series and estimated trends

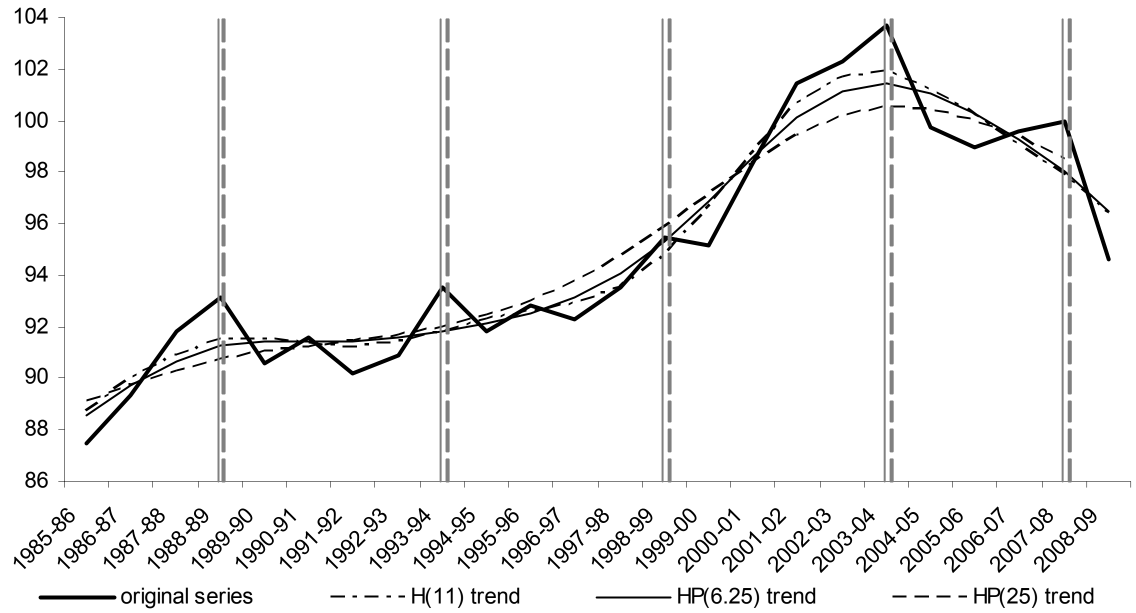
Index 2007-08 = 100. Vertical lines show peak years (solid for IMT and dotted for market sector)



Data source: Original series from ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09*, Cat. no. 5260.0.55.002); trends are author's estimates.

Figure 3.10 Manufacturing MFP index, original series and estimated trends

Index 2007-08 = 100. Vertical lines show peak years (solid for MAN and dotted for market sector)



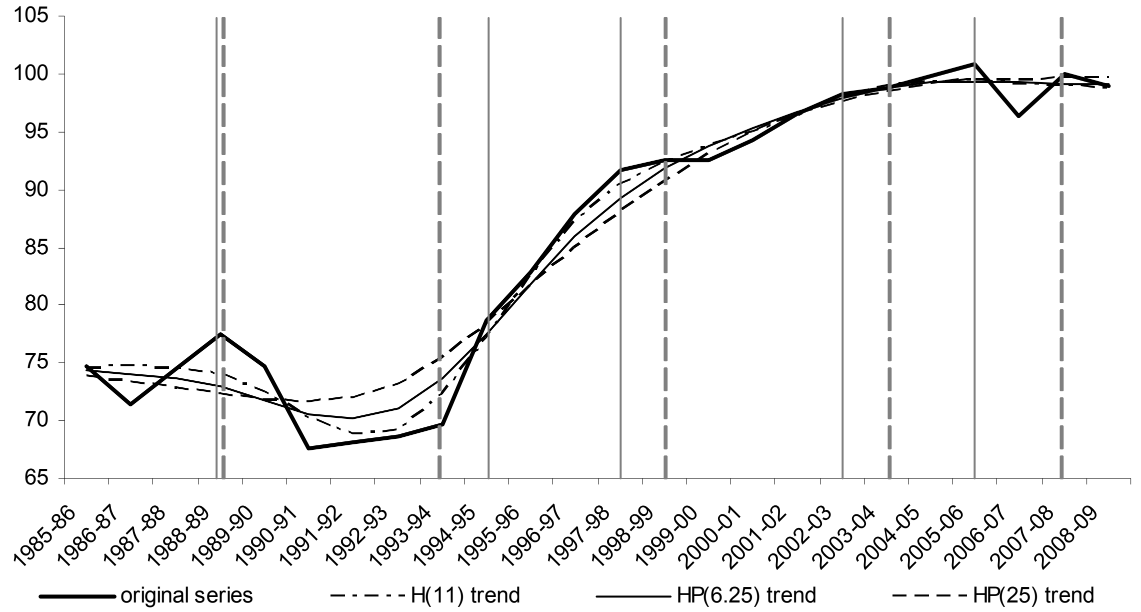
Data source: Original series from ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002); trends are author's estimates.

For Manufacturing, the industry-specific cycles are exactly the same as the market sector cycles (figure 3.10). There are some similarities between the MFP series for Manufacturing and the market sector as a whole over the period examined, with a decline in recent years.

Wholesale trade (WT) also shows a slowdown in MFP growth in the most recent period. This followed a period of rapid growth, which in turn followed a period of volatility. Only one peak, 1988-89, coincides with a market sector peak (figure 3.11).

Figure 3.11 **Wholesale trade MFP index, original series and estimated trends**

Index 2007-08 = 100. Vertical lines show peak years (solid for WT and dotted for market sector)

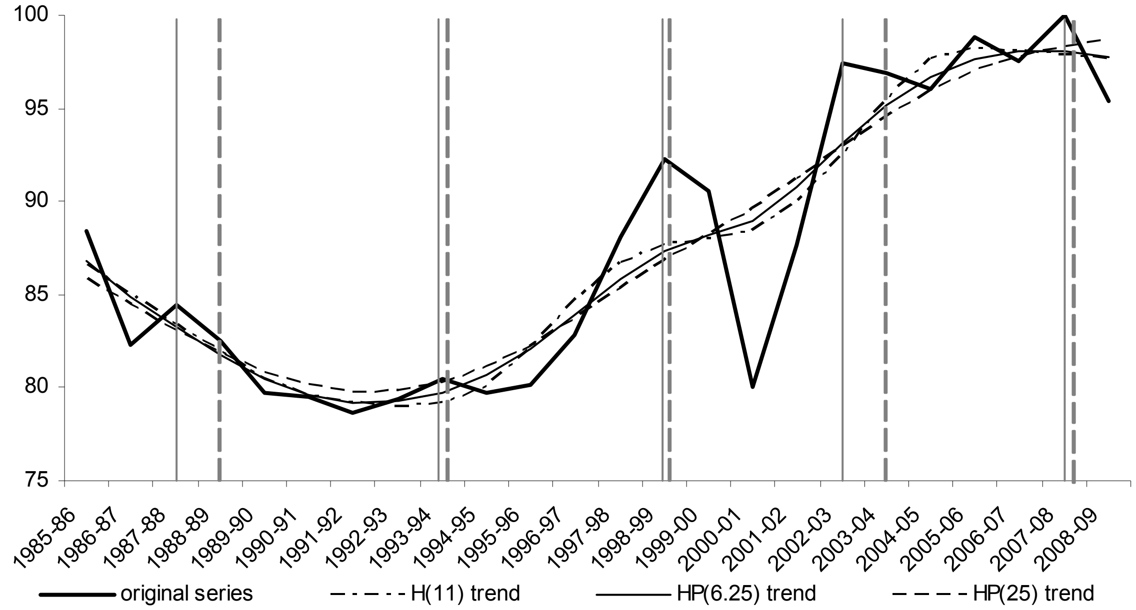


Data source: Original series from ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002); trends are author's estimates.

Both Construction (CON) and Accommodation & food services (AFS) show evidence of a U-shaped time series (figures 3.12 and 3.13, respectively). In both cases, some industry peak years coincide with those for the market sector and some are in adjacent years. However, where the MFP series for an industry is volatile the value of the MFP index in adjacent years can be quite different. For example, the AFS MFP index for 2007-08 (the market sector peak year) is more than 4 percentage points lower than for 2006-07 (the industry-specific peak year) (figure 3.13). This leads to a quite different average annual growth rate over the industry cycle compared with the market sector cycle (see chapter 4). Again this demonstrates the danger of simply using market sector cycles to examine industry MFP growth.

Figure 3.12 **Construction MFP index, original series and estimated trends**

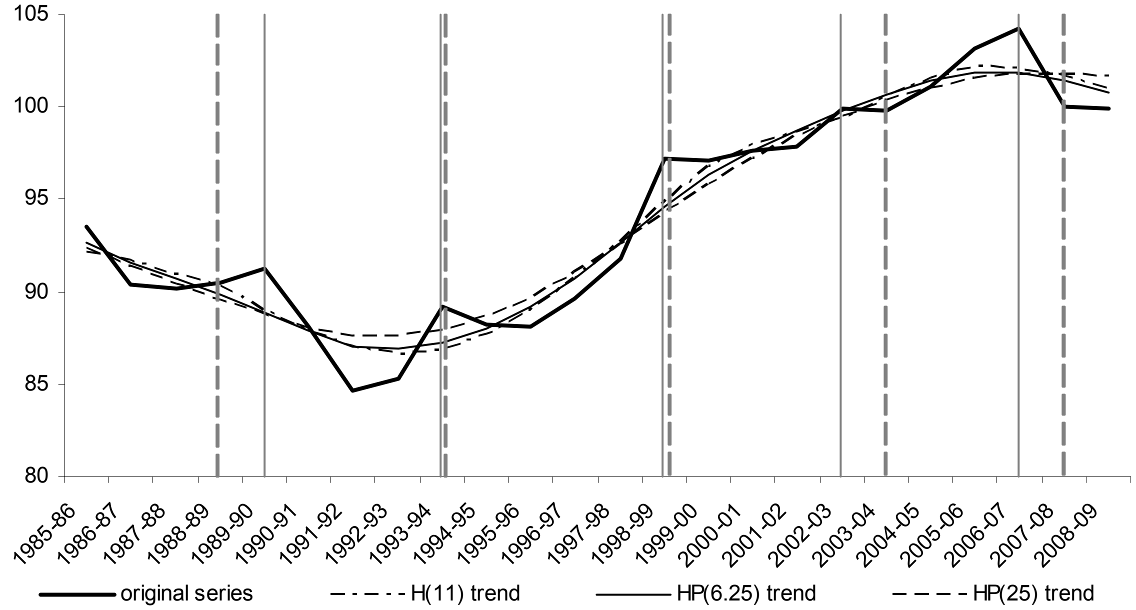
Index 2007-08 = 100. Vertical lines show peak years (solid for Construction and dotted for market sector)



Data source: Original series from ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002); trends are author's estimates.

Figure 3.13 **Accommodation & food services MFP index, original series and estimated trends**

Index 2007-08 = 100. Vertical lines show peak years (solid for AFS and dotted for market sector)



Data source: Original series from ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002); trends are author's estimates.

The Construction MFP series is very volatile around the turn of the century. In the late 1990s there was a sharp increase in MFP followed by a large slump in 2000-01, and again a sharp increase in the following year. The anticipation of the introduction of the GST, its introduction and the rise in construction before the Sydney 2000 Olympics almost certainly were influential in the surge and subsequent slump in Construction MFP (see Parham 2005 and ABS 2000b).[8] However, both the industry cycle and the market sector cycle avoid this trough, although the subsequent peak year differs.

Overall, there are many differences between the MFP growth cycles for the market sector and those identified for specific industries. The extent to which looking at MFP growth over industry-specific cycles, rather than market sector cycles, alters the picture of productivity change in individual industries is discussed further in chapter 4.

8 It is possible there is a break in the Construction MFP index series but the statistical properties of this time series are hard to establish with the given number of observations. The peaks identified in this study should be used with caution — if there is a break in the series this may have affected the results of the mechanical approach to MFP growth cycle identification.

4 Implications for analysis of industry MFP growth

Looking at an industry's average growth in multifactor productivity (MFP) over industry-specific cycles, rather than market sector cycles, can alter the picture of the development of productivity over time. This chapter examines the extent to which this is the case for MFP for industries within the Australian market sector. It also discusses the implications of the possible refinement of industry productivity cycles that include flagged peaks. Some conclusions are drawn in the final section.

4.1 Comparison of average annual growth in industry MFP over industry cycles and market sector cycles

As noted in chapter 3, in many cases the industry-specific MFP peaks identified do not coincide with the peaks identified by the Australian Bureau of Statistics (ABS) for the market sector as a whole. With consecutive matching peaks needed for peak-to-peak industry-specific cycles to match market sector cycles, only 10 of the 41 industry-specific cycles coincide with those of the market sector (as shown in boxes in table 4.1). Manufacturing exactly matches the market sector cycles. Five industries have no industry-specific cycles that coincide with market sector cycles, whereas two industries have no peaks that coincide with market sector peaks.

Many peak years for the market sector are below trend years for MFP in individual industries (shown as underlined years in table 4.1). In some cases, indeed, the below trend year is a 'trough', that is a negative local minimum (shown with thick underlining in the table). For example, Agriculture examined over the period 2003-04 (an above trend year) to 2007-08 (a below trend year) has negative average MFP growth but over the closest industry cycle, 2000-01 to 2005-06, average MFP growth is positive.

Table 4.1 Comparison of average annual growth rates using industry-specific cycles[a] and market sector cycles, selected industries

Per cent per year

	Industry cycle[b]	*Av. annual growth rate*	*Market sector cycle*[c]	*Av. annual growth rate*
Agriculture, forestry & fishing[d]	1990-91 to 1993-94	2.4	1988-89 to 1993-94	4.0
	1993-94 to 1996-97	3.2	1993-94 to 1998-99	4.0
	1996-97 to 2000-01	5.0	1998-99 to 2003-04	3.5
	2000-01 to 2005-06	3.2	2003-04 to 2007-08	-1.2
	1985-86 to 2008-09	3.0	1985-86 to 2008-09	3.0
Mining	1987-88 to 1991-92	4.7	1988-89 to 1993-94	3.0
	1991-92 to 1995-96	2.2	1993-94 to 1998-99	0.6
	1995-96 to 2000-01	0.9	1998-99 to 2003-04	-0.4
	2000-01 to 2006-07[2]	-3.9	2003-04 to 2007-08	-4.2
	1985-86 to 2008-09	-0.1	1985-86 to 2008-09	-0.1
Manufacturing[e]	1988-89[2] to 1993-94[2]	0.1	1988-89 to 1993-94	0.1
	1993-94[2] to 1998-99[W]	0.4	1993-94 to 1998-99	0.4
	1998-99[W] to 2003-04[2]	1.7	1998-99 to 2003-04	1.7
	2003-04[2] to 2007-08	-0.9	2003-04 to 2007-08	-0.9
	1985-86 to 2008-09	0.3	1985-86 to 2008-09	0.3
Electricity, gas, water & waste services	1990-91[W] to 1997-98	2.6	1988-89 to 1993-94	3.2
			1993-94 to 1998-99	1.9
	1997-98 to 2002-03[S2]	-1.7	1998-99 to 2003-04	-2.0
	2002-03[S2] to 2006-07	-3.6	2003-04 to 2007-08	-4.4
	1985-86 to 2008-09	0.5	1985-86 to 2008-09	0.5
Construction	1987-88 to 1993-94	-0.8	1988-89 to 1993-94	-0.5
	1993-94 to 1998-99	2.8	1993-94 to 1998-99	2.8
	1998-99 to 2002-03	1.4	1998-99 to 2003-04	1.0
	2002-03 to 2007-08[2]	0.5	2003-04 to 2007-08	0.8
	1985-86 to 2008-09	0.3	1985-86 to 2008-09	0.3
Wholesale trade	1988-89 to 1994-95[W]	0.2	1988-89 to 1993-94	-2.1
	1994-95[W] to 1997-98	5.2	1993-94 to 1998-99	5.8
	1997-98 to 2002-03[S]	1.4	1998-99 to 2003-04	1.3
	2002-03[S] to 2005-06[2]	0.9	2003-04 to 2007-08	0.3
	1985-86 to 2008-09	1.2	1985-86 to 2008-09	1.2

(continued on next page)

Table 4.1 **(continued)**

	Industry cycle[c]	*Av. annual growth rate*	*Market sector cycle*[e]	*Av. annual growth rate*
Retail trade			1988-89 to 1993-94	2.0
	1991-92[W2] to 1996-97	2.6	1993-94 to 1998-99	2.3
	1996-97 to 2003-04[2]	1.4	1998-99 to 2003-04	1.3
			2003-04 to 2007-08	0.5
	1985-86 to 2008-09	1.1	1985-86 to 2008-09	1.1
Accommodation & food services	1989-90 to 1993-94	-0.5	1988-89 to 1993-94	-0.3
	1993-94 to 1998-99	1.7	1993-94 to 1998-99	1.7
	1998-99 to 2002-03[S]	0.7	1998-99 to 2003-04	0.5
	2002-03[S] to 2006-07	1.1	2003-04 to 2007-08	0.1
	1985-86 to 2008-09	0.3	1985-86 to 2008-09	0.3
Transport, postal & warehousing	1988-89 to 1993-94[S]	1.7	1988-89 to 1993-94	1.7
	1993-94[S] to 1996-97	3.4	1993-94 to 1998-99	2.3
	1996-97 to 2002-03	2.4	1998-99 to 2003-04	2.4
	2002-03 to 2006-07	1.5	2003-04 to 2007-08	1.6
	1985-86 to 2008-09	1.3	1985-86 to 2008-09	1.3
Information, media & telecommunications	1989-90[W2] to 1992-93[2]	6.6	1988-89 to 1993-94	6.3
	1992-93[2] to 1998-99	3.9	1993-94 to 1998-99	3.8
	1998-99 to 2003-04	-0.5	1998-99 to 2003-04	-0.5
	2003-04 to 2007-08	0.9	2003-04 to 2007-08	0.9
	1985-86 to 2008-09	2.4	1985-86 to 2008-09	2.4
Financial & insurance services	1987-88 to 1993-94	2.1	1988-89 to 1993-94	4.9
	1993-94 to 1999-00	1.6	1993-94 to 1998-99	1.3
	1999-00 to 2003-04[W]	0.7	1998-99 to 2003-04	1.2
	2003-04[W] to 2007-08	2.5	2003-04 to 2007-08	2.5
	1985-86 to 2008-09	2.5	1985-86 to 2008-09	2.5

a As discussed in chapter 3, 'small' peaks are marked with an 's' and peaks that are less robust to filter choice with a 'w', and the peak chosen from two close together robust peak deviations are marked with a '2'. **b** The industry cycles do not cover the full period for which data are available as it is not possible to identify peaks in the first (last) year of the time series because the data before (after) that year are not available to show whether that year is a peak deviation or not. **c** While the ABS has the data to determine that there is a market sector peak in 1984-85, the industry time series do not start until 1985-86 so it is not possible to calculate average annual growth over the complete market sector cycle 1984-85 to 1988-89. **d** PC (2005) using an ANZSIC93 Agriculture time series from 1974-75 to 2003-04 identified some cycles that were similar and some that were different during the period that time series overlaps with the ANZSIC06 series used in this paper — 1983-84 to 1990-91, 1990-91 to 1993-94, 1993-94 to 2001-02, and 2001-02 to 2003-04. **e** PC (2003) using an ANZSIC93 Manufacturing time series from 1954-55 to 2001-02 identified similar but slightly different cycles during the period that time series overlaps with the ANZSIC06 series used in this paper — 1988-89 to 1993-94, 1993-94 to 1996-97; and 1996-97 to 2001-02.

Source: Author's estimates based on ABS national accounts data and ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09*, Cat. no. 5260.0.55.002).

Those peaks flagged in chapter 3 are also identified in table 4.1. It should be noted that any average annual growth rate estimates based on periods including flagged peaks may be revised in light of additional industry-specific information.[1]

Given the differences between market sector and industry-specific cycles that exist for all industries except Manufacturing, it is not surprising that the patterns of average MFP growth differ considerably depending on which set of cycles is used. The nature and extent of these differences is further illustrated in the following figures.

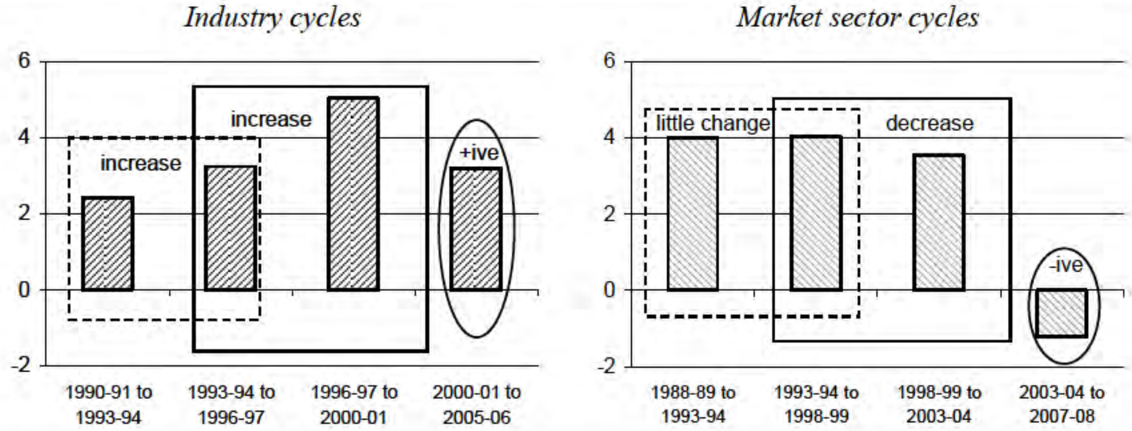
For Agriculture, forestry & fishing (AFF), the most notable difference from looking at average MFP growth over industry cycles, rather than market sector cycles, is in the last cycle. For that cycle, MFP growth is 3.2 per cent a year over the industry cycle rather than -1.2 per cent a year over the nearest market sector cycle (as circled in figure 4.1). There is typically a strong ‘bounce back’ in output following particularly poor rainfall years. But where the timing of this event does not coincide with the market sector cycle, average MFP growth in AFF calculated over the market sector cycle is more likely to be negative. In this case 2007-08, which is outside the last complete *industry* cycle but inside the last complete *market* cycle (see figure 3.5), is the year after the severe drought year of 2006-07 and only a partial recovery in output had occurred.[2] Figure 4.2 further illustrates that in the last market sector cycle, the fall in output attributable to the drought underlies the negative MFP growth rate. The last industry cycle, which ends before the drought year of 2006-07, shows positive growth in output and MFP.

More generally, the use of industry cycles changes the pattern of growth across the cycles, in terms of an increase or decrease in MFP growth between cycles (as shown by the boxed pairs of cycles in figure 4.1). Based on the market sector cycles it might be concluded that there was a steep downward trend in AFF MFP growth in the 2000s, but that conclusion would not be drawn from analysis over the industry-specific cycles. Rather, it might be concluded that the 1996-97 to 2000-01 industry cycle was an exceptionally strong period for MFP growth in AFF.

1 Revisions by the ABS to its official industry MFP time series, as well as additional years of data, may also lead to revisions to the industry cycles identified and average annual growth rates over these cycles.

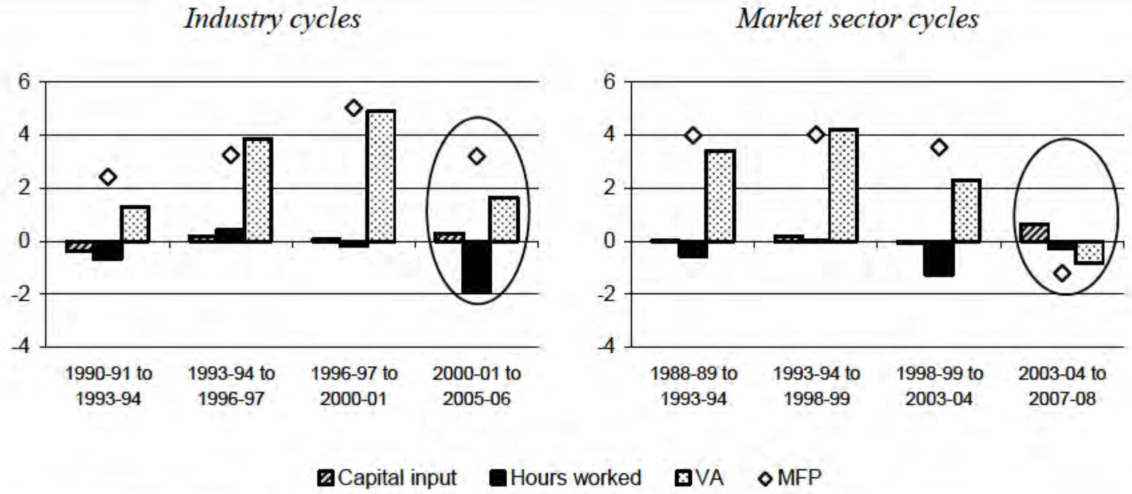
2 When additional years are eventually added to the AFF time series and the next complete industry-specific cycle can be identified it will also partly overlap with the last market sector cycle in figure 4.1.

Figure 4.1 **Average annual growth in Agriculture, forestry & fishing MFP**
Per cent per year



Data source: Author's estimates based on ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002).

Figure 4.2 **Value added, capital and labour input components[a] of MFP growth in Agriculture, forestry & fishing**
Per cent per year



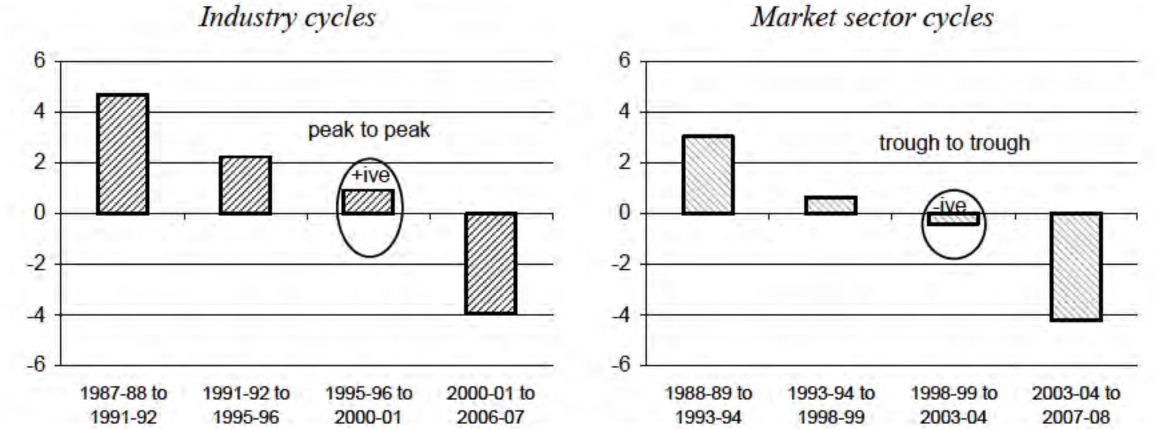
[a] Capital and labour inputs are weighted by their relative income shares.

Data source: Author's estimates based on ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002).

For Mining, both sets of cycles provide a similar pattern of change in MFP growth between periods (in terms of direction), but quite different magnitudes of average growth in the early cycles. Also, using market sector cycles leads to negative growth in MFP in the last two cycles, whereas using industry cycles there is positive growth in the penultimate cycle (as circled in figure 4.3). Half of the market sector cycles happen to coincide with 'trough' to 'trough' periods for Mining — analysis over these periods is potentially less misleading than comparing a peak to trough period with a trough to peak period. Figure 4.4 illustrates that looking at the components of MFP growth over the Mining industry cycles does show a clearer pattern of increasing growth in capital and decreasing growth in value added. This accords with the findings of the detailed study of Mining by Topp et al. (2008). It attributed a substantial part of the decline in Mining MFP between 2000-01 and 2006-07 to yield declines and production lags associated with the surge in new capital investment.

Figure 4.3 **Average annual growth in Mining MFP**

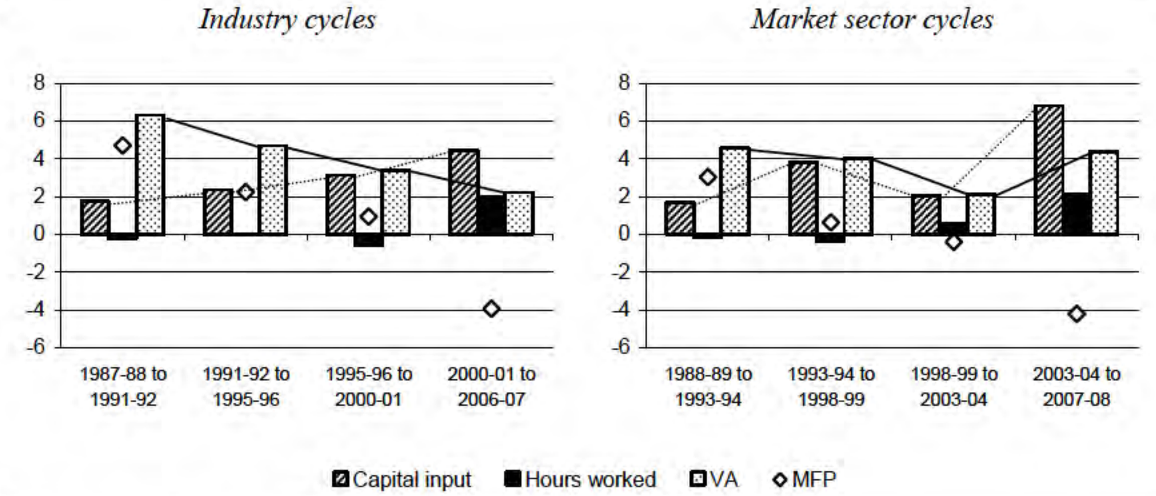
Per cent per year



Data source: Author's estimates based on ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002).

Figure 4.4 **Value added, capital and labour input components[a] of MFP growth in Mining**

Per cent per year



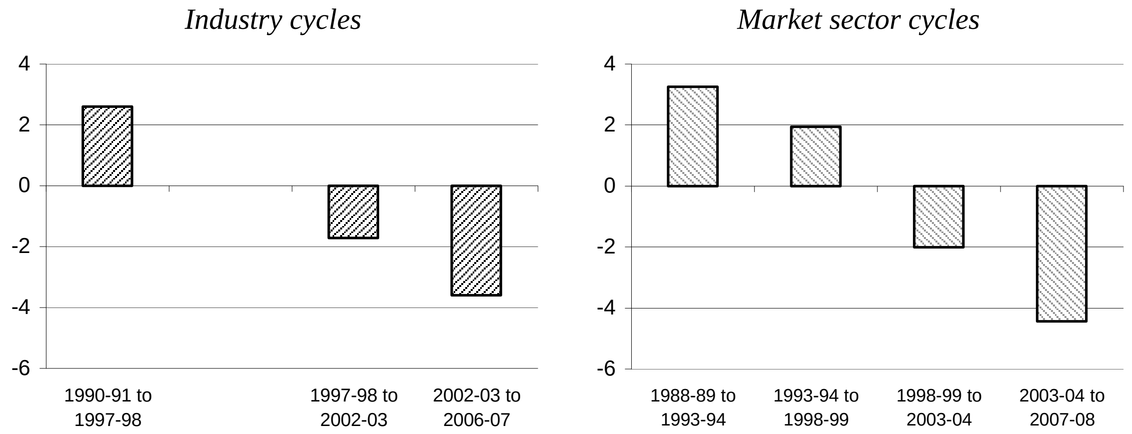
[a] Capital and labour inputs are weighted by their relative income shares.

Data source: Author's estimates based on ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002).

For Electricity, gas, water & waste services (EGWW), there is one fewer industry cycle than market sector cycle (figure 4.5). However, whether industry cycles or market sector cycles are used, the pattern of average MFP growth is much the same. While the magnitudes of the MFP growth rates differ, whether average MFP growth increases or decreases relative to the previous cycle is unchanged. This is because there is not much year-to-year volatility in the EGWW MFP data, although there is a strong inverted-U shape to the actual MFP index over the full time period. The influences behind this trend are currently being examined by the Commission in an industry-specific study of EGWW.

Figure 4.5 **Average annual growth in Electricity, gas, water & waste services MFP**

Per cent per year

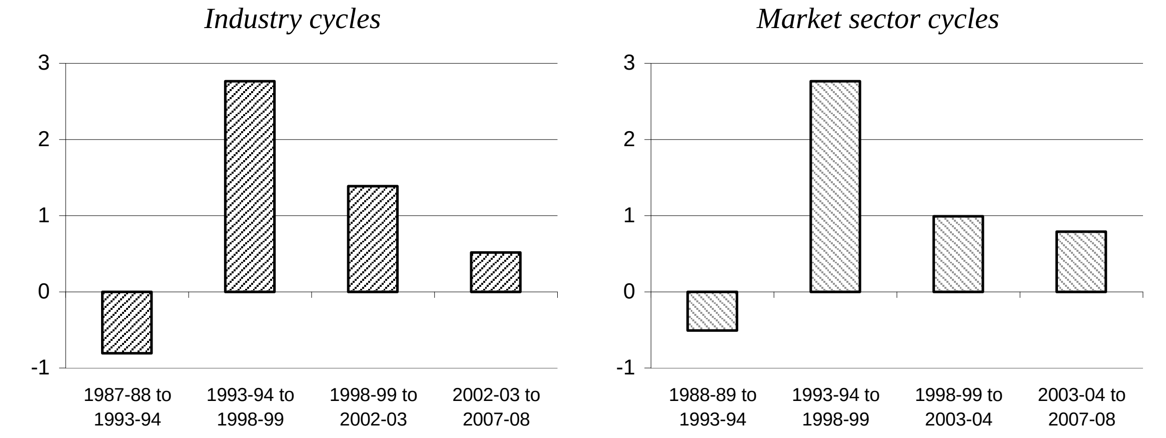


Data source: Author's estimates based on ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates*, *2008-09,* Cat. no. 5260.0.55.002).

For Construction, there is one industry cycle that coincides with a market sector cycle (1993-94 to 1998-99). While the use of industry-specific cycles rather than market sector cycles changes the magnitude of the average annual MFP growth rates, it does not change the pattern of MFP growth between cycles (figure 4.6).

Figure 4.6 **Average annual growth in Construction MFP**

Per cent per year

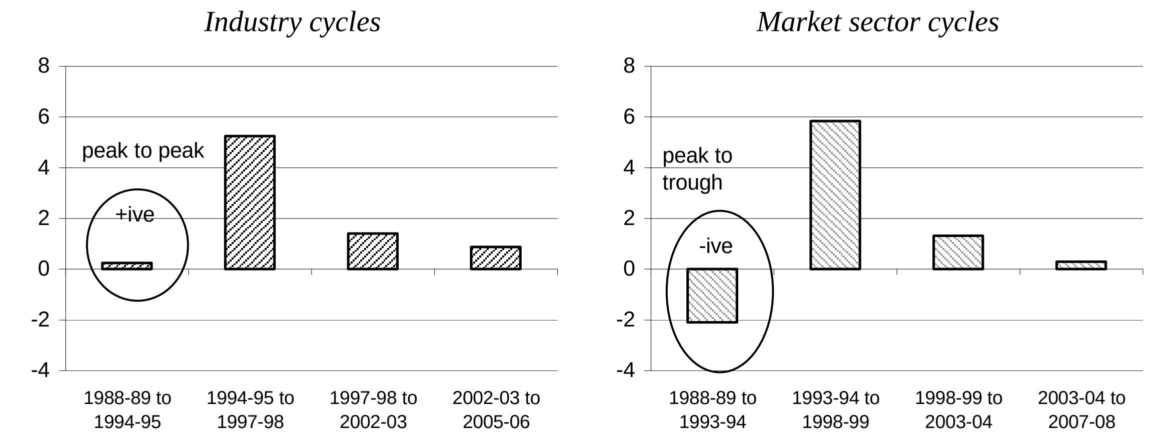


Data source: Author's estimates based on ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates*, *2008-09,* Cat. no. 5260.0.55.002).

For Wholesale trade, over the late 1980s to mid-90s the industry-specific cycle and the market sector cycle differ by only one year — 1988-89 to 1994-95 rather than 1988-89 to 1993-94. However, average annual growth calculated over the market sector cycle suggests a large negative rate of average MFP growth, while the industry-specific cycle suggests a small positive rate of MFP growth (as circled in figure 4.7). This is because the market sector cycle compares a peak year with a trough year.

Figure 4.7 **Average annual growth in Wholesale trade MFP**

Per cent per year

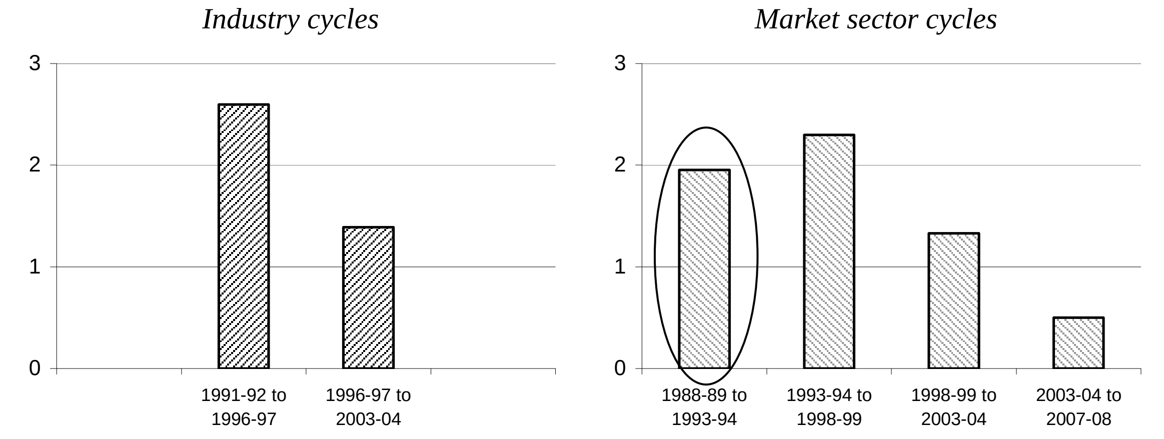


Data source: Author's estimates based on ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates*, *2008-09,* Cat. no. 5260.0.55.002).

For Retail trade (RT), there are two fewer industry-specific cycles than market sector cycles. Prior to the industry-specific peak in 1991-92 and after the peak in 2003-04 the only positive deviations from trend in the RT MFP series are 1985-86 and 2008-09. However, it is not possible to identify these years as industry-specific peaks because there are no earlier/later observations to confirm these years as peaks. The first market sector cycle starts in 1988-89, which is actually a below trend year for RT, leading to a large positive growth rate when compared with the above trend year of 1993-94 (as circled in figure 4.8). A similar but opposite problem occurs for 2007-08, a market sector peak but a below trend year for RT. Above trend years and below trend years are less likely to represent comparable periods, and hence these average growth rates are potentially distorted.

Figure 4.8 **Average annual growth in Retail trade MFP**

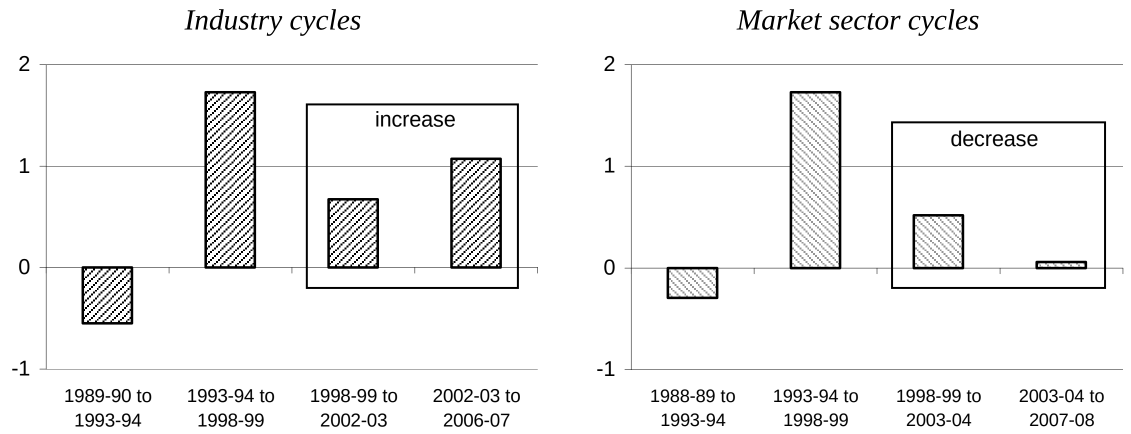
Per cent per year



Data source: Author's estimates based on ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates*, *2008-09,* Cat. no. 5260.0.55.002).

Accommodation & food services (AFS) has one industry cycle in common with the market sector (1993-94 to 1998-99). The pattern of MFP growth between the last two cycles changes if industry cycles are used instead of market sector cycles (as boxed in figure 4.9). This is because 2003-04 and 2007-08 are trough years for AFS. The industry peaks are both one year earlier (2002-03 and 2006-07). A decrease in MFP growth between the last two cycles observed using market sector cycles actually becomes an increase in MFP growth on an industry cycle basis. The average growth in AFS MFP over the last industry cycle is considerably larger than that over the last market sector cycle.

Figure 4.9 **Average annual growth in Accommodation & food services MFP**
Per cent per year

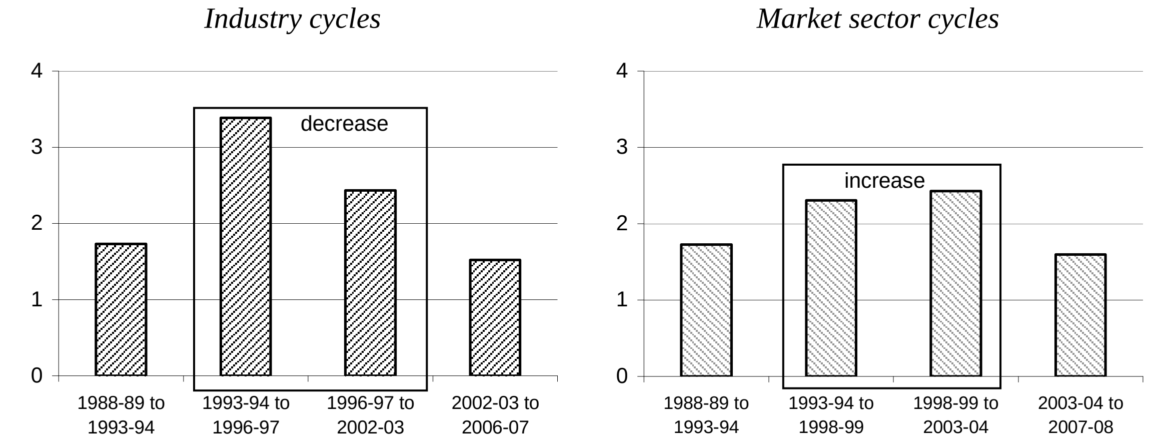


Data source: Author's estimates based on ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates*, *2008-09,* Cat. no. 5260.0.55.002).

For Transport, postal & warehousing (TPW), the first industry cycle coincides with a market sector cycle. There is a similar pattern of increase or decrease in MFP growth between most cycles whether industry or market sector cycles are used. The exception is the change between the second and third cycles (boxed in figure 4.10). Market sector cycles would suggest that average MFP growth was higher in the 1998-99 to 2003-04 cycle than in the 1993-94 to 1998-99 cycle. But using industry cycles there is a decline in MFP growth between the 1993-94 to 1996-97 cycle and the 1996-97 to 2002-03 cycle. For TPW, the market sector peak years of 1998-99 and 2003-04 are both below trend years, and the average growth rate is little changed when the industry peak to peak period of 1996-97 to 2002-03 is used instead. However, for the previous cycle, the market sector cycle of 1993-94 to 1998-99 is for TPW a period that starts with a peak year (1993-94) and finishes with a below trend year (1998-99). This leads to a lower average growth rate than over the peak-to-peak industry cycle of 1993-94 to 1996-97.

Figure 4.10 **Average annual growth in Transport, postal & warehousing MFP**

Per cent per year

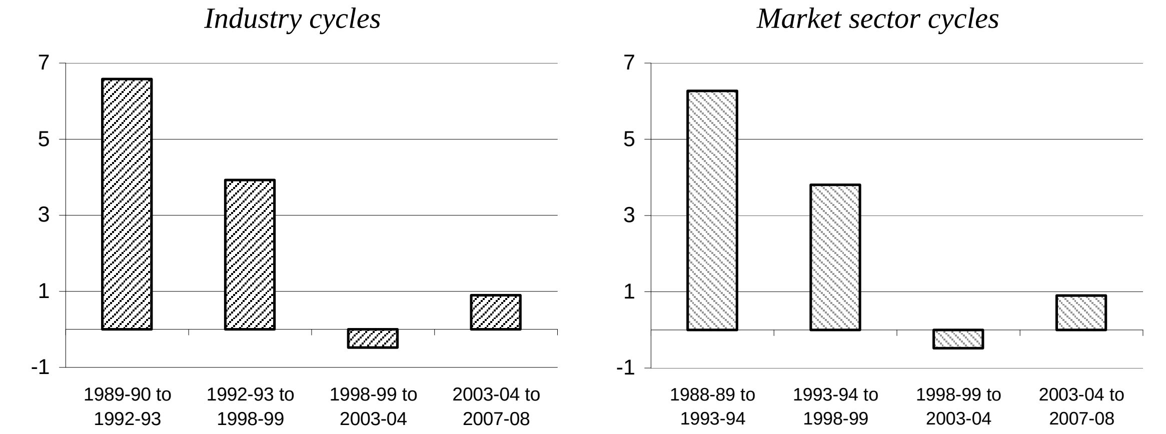


Data source: Author's estimates based on ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates*, *2008-09,* Cat. no. 5260.0.55.002).

For Information, media & telecommunications (IMT), the last two industry cycles coincide with market sector cycles (figure 4.11). Looking at the beginning of the time series, the first market sector cycle peak, 1988-89, is a below trend year for IMT. But even though the market sector cycle compares an IMT below trend year with an above trend year, the growth rate is nearly the same as over the industry cycle. This is because there is not much volatility in the actual MFP series over this period.

Figure 4.11 **Average annual growth in Information, media & telecommunications MFP**

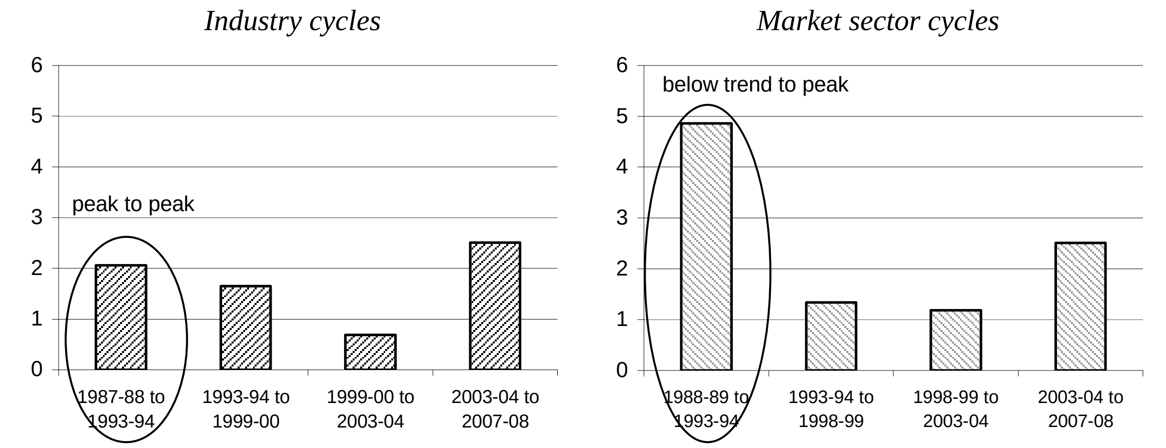
Per cent per year



Data source: Author's estimates based on ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates*, *2008-09,* Cat. no. 5260.0.55.002).

For Financial & insurance services (FIS), the last industry cycle coincides with the market sector cycle. The pattern of growth across the other cycles is largely unaffected by whether industry or market sector cycles are used. The biggest variation in the size of average MFP growth is for the first cycle (as circled in figure 4.12). This is because the market sector cycle compares a below trend year with a peak year for FIS during a period of considerable volatility, which leads to a misleadingly large average MFP growth rate.

Figure 4.12 **Average annual growth in Financial & insurance services MFP**
Per cent per year



Data source: Author's estimates based on ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates*, *2008-09,* Cat. no. 5260.0.55.002).

Implications of flagged peaks

As already noted, detailed industry studies may provide information that would allow further refinement of industry-specific cycles, particularly in the case of the peaks flagged in the analysis above.

The peaks, as identified, appear to be more robust in some industries than others. AFF has more robust peaks with none of them flagged (table 4.1). In contrast, the results for Manufacturing and Wholesale trade are less robust, with each having at least one flagged peak in each growth cycle identified. In the case of Retail trade, for which only two cycles are identified (both with flagged peaks), the industry-specific cycles provide only a limited basis on which to examine the pattern of MFP growth over the full time series.

However, a flag does not necessarily mean that an alternative decision made about that peak would have a notable effect on the pattern of average annual MFP growth over the industry-specific cycles. For example, for the peaks flagged as having been selected from a pair of close together peak deviations, the use of the other peak deviation in the growth cycle generally does not change the *pattern* of MFP growth (in terms of an increase or decrease in growth from cycle to cycle) — although the magnitude of the growth rate does change by a considerable amount in some cases. The notable differences in the picture of industry MFP growth over industry-specific rather than market sector cycles, as highlighted in the previous section, are not in periods affected by these alternative peaks. And the industry-specific cycle periods remain quite different across industries and from those for the market sector. Indeed, using the alternative peaks, four fewer industry-specific cycles would coincide with those for the market sector.

In the case of peaks flagged as weakly robust or as small deviations, the alternative is to exclude them from the industry-specific MFP growth cycles. This would result in the identification of fewer and/or longer cycles. Whether or not there would be a notable change in the pattern of average annual MFP growth across these cycles, compared with the original industry-specific cycles, depends on the timing and extent of volatility in the MFP time series. While the change would be notable in some industries and not in others, the industry-specific cycles would still be quite different to cycles for the market sector. Regardless, any decision to discard these flagged peaks should be informed by industry-specific information, and such consideration is better suited to industry-specific studies. Such studies also provide a vehicle for exploring the extent to which MFP measures might be directly adjusted for changes in capacity utilisation. For example, Topp et al. (2008) in a study of Mining partially adjusted for capacity utilisation change by allowing for a lag in the full utilisation of new additions to the capital stock.

4.2 Conclusions

As discussed in chapter 1, closer analysis of industry productivity is key to understanding aggregate productivity performance and to providing policy-relevant insights into how to influence that performance. Looking at industry MFP growth over an ABS market sector cycle is appropriate if the aim is to simply identify industry contributions to market sector MFP growth. But analysis of MFP growth and its drivers within an individual industry over time requires a different approach given that cyclical influences and their timing can differ across industries.

The industry-specific cycles presented in this paper, and the methodology for identifying them, are tools that can assist in understanding industry productivity performance. This initial set of cycles, while not intended to be definitive, provides the basis for more refined examinations of productivity in individual industries. And the methodology outlined provides a generic approach to the identification of industry cycles, but also indicates the scope for further refinement of the cycles where more detailed industry-specific information is available.

How much difference do industry-specific cycles make?

Three quarters of the industry-specific cycles identified in this paper do not coincide with market sector cycles. But there is considerable variation across industries and time in the extent to which it is misleading to use market sector cycles to examine the pattern of MFP growth in an individual industry over time.

There are three main ways in which analysis based on industry-specific cycles may provide a more accurate view of industry productivity performance over time.

- The sign of average annual MFP growth may be reversed. For example, industry MFP growth may be positive examined over an industry-specific cycle but negative when examined over the closest market sector cycle.
- The magnitude of average annual MFP growth may be considerably higher or lower.
- The pattern of growth between consecutive cycles may be reversed. For example, an increase in the rate of average annual MFP growth between industry-specific cycles may appear to be a decrease between the closest market sector cycles.

Table 4.2 summarises the extent to which these different interpretations occur for particular industries over the period examined in this paper. For most industries, in at least one cycle, there is some difference in interpretation of industry productivity performance if industry-specific cycles are used instead of market sector cycles. AFF is the most affected, with all three types of differences in interpretation and every cycle affected. Most other industries are affected by at least one type of difference in interpretation for at least two cycles. Only for Manufacturing, EGWW, RT and IMT is there little difference in interpretation (although for EGWW and RT fewer industry cycles are also identified than for the market sector). This is because the industry and market sector cycles coincide or, where they do not, there is relatively little volatility in the series so the effect on average annual growth rates is small.

Table 4.2 **The extent of differences in the interpretation of industry MFP growth over industry-specific cycles compared with market sector cycles**

	Number of times analysis over an industry-specific cycle, compared with market sector cycle, shows average annual MFP growth that has a:		
Industry	*Different sign*	*Considerably different magnitude*[a]	*Different pattern of change over consecutive cycles*
Agriculture, forestry & fishing	1	3	2
Mining	1	3	0
Manufacturing	0	0	0
Electricity, gas, water & waste serv.	0	0	0
Construction	0	2	0
Wholesale trade	1	2	0
Retail trade	0	0	0
Accommodation & food services	0	2	1
Transport, postal & warehousing	0	1	1
Info., media & telecommunications	0	0	0
Financial & insurance services	0	2	0

a Average annual MFP growth rate over market sector cycle is at least 30 per cent more or less than average annual MFP growth rate over closest industry-specific cycle.

Source: Author's estimates.

This is not to suggest that the extent of the differences or the industries affected will be the same for future MFP estimates. But it does demonstrate that the purpose of the analysis should guide the selection of periods over which to examine industry MFP. While market sector cycles are useful for examining aggregate performance and unpacking industry contributions to those cycles, industry-specific cycles are a better tool for examining industry productivity over time.

A Additional details about data, methodology and results

This appendix provides additional details about the data, methodology and results presented in this paper.

A.1 Components of a time series

The decomposition of economic time series is motivated by the idea that distinct forces account for long-term growth and short-term variations associated with, for example, the business cycle (Nelson 2008).

The assumption underlying the use of filters to estimate a trend in an annual time series is that the time series is made up of a number of components including trend, cycle and irregular components. A standard assumption in time series analysis is that observations can be linearly decomposed into three possible components:

$$y_t = trend + cycle + irregular$$

The trend component shows the longer-term movement of a time series. ABS (2003a) defines a cycle as a *regularly* repeating fluctuation in a time series, but adds that the term is also used for less regular fluctuations.

> Strictly speaking, the length of the cycle should be fixed, for example 1 year for the fundamental seasonal cycle. However the term is also used for less regular repetitions, for instance, the business cycle. (ABS 2003a, p. 133)

The irregular component of a time series is any random or irregular influences that correspond to noise in the data. Further details are provided in ABS (2003a, 2005a) and Enders (2010).

In this study, all deviations from trend are considered jointly. The purpose of the ABS MFP growth cycle identification exercise is to identify deviations from trend, not to separately identify the trend, cycle and noise components of the annual multifactor productivity (MFP) series. Nor is it to provide an MFP trend for forecasting purposes.

A.2 Technical description of filters

Filters are designed to estimate the trend component of a time series. This allows a time series to be 'detrended' to derive the non-trend component. These trend and non-trend components have different properties depending on the filter used, and different filters have different strengths and weaknesses. However, this appendix does not discuss the properties of the filtered trend and non-trend components, because they are not separately analysed but simply used to identify periods over which to calculate average annual growth in the original MFP series. (For a discussion of these properties, see ABS (2003a, 2005a) and Zhang and Conn (2007)).

The following sub-sections provide a brief description of the Henderson filter and the Hodrick-Prescott filters as implemented in this study.

Henderson 11-term filter

As noted in chapter 2, the ABS uses the Henderson 11-term filter, or H(11) filter, to estimate the long-term trend in market sector MFP. The Henderson filter belongs to the class of linear filters, which estimate a point on the trend of the series as a weighted average of observations in the series. Due to this averaging behaviour, linear filters are best described as smoothing the series.

The H(11) filter is a centred symmetric moving average. The trend estimate for a particular year is the weighted average of 11 observations — the observation for that year and the 5 observations either side of it. The weights are symmetric (that is, the same set of weights is applied on each side of the year being estimated) and time invariant (that is, the same weights are applied throughout the time series). However, at either end of the series (the first five and last five observations), the symmetric weights cannot be used because observations have not been collected or have not occurred. This is called the 'end point problem' and the ABS approach to dealing with it is to use a set of surrogate filters (one for each of the 5 end years).[1]

Table A.1 provides the symmetric weights of the H(11) filter and the asymmetric weights for the surrogate filters used in this study. The first row shows the symmetric weights, which are applied to estimate the trend for each year of the series except for the ends of the series (the first and last five years). These are centred around the year for which the trend is being estimated (that is, the weight N-5 is applied to observation for this year and the weights on either side applied to the five observations on either side). The remaining rows of table A.1 are the

[1] See ABS (2003a, p. 60) for further details.

asymmetric weights applied to estimate the trend for the fifth last, four last, third last, second last and last years, respectively. The zero weights reflect the missing observations. The column containing the weight applied to the observation for the year for which the trend is being estimated shifts to the right as the number of missing observations increases. For example, in estimating the trend for the fifth last year, the weight N-4 is applied to the observation for that year, with weights N-5 to N-9 applied to the preceding five years and weights N-3 to N applied to the following four years. For the first five years of the series, the weights within each asymmetric weight row are reversed.

Table A.1 **Henderson 11-term filter weights[a], symmetric and asymmetric[b]**

	N-10	*N-9*	*N-8*	*N-7*	*N-6*	*N-5*	*N-4*	*N-3*	*N-2*	*N-1*	*N*
symmetric	-0.028	-0.027	0.036	0.141	0.239	0.278	0.239	0.141	0.036	-0.027	-0.028
asymmetric5	–	-0.022	-0.023	0.038	0.141	0.237	0.274	0.233	0.134	0.026	-0.038
asymmetric4	–	–	-0.014	-0.018	0.040	0.140	0.233	0.267	0.223	0.120	0.010
asymmetric3	–	–	–	-0.016	-0.019	0.039	0.141	0.234	0.270	0.226	0.125
asymmetric2	–	–	–	–	-0.052	-0.037	0.039	0.159	0.270	0.323	0.298
asymmetric1	–	–	–	–	–	-0.150	-0.076	0.059	0.238	0.408	0.520

– indicates a weight of zero. **a** The inclusion of negative as well as positive weights allows the tracking of various curvatures. **b** The asymmetric weights are the same as those used by the ABS for the market sector MFP series. They are based on an end weight parameter (or I/C ratio) of 0.4.

Source: ABS (pers. comm., 3 August 2010).

Hodrick-Prescott filter

The Hodrick-Prescott (HP) filter is used extensively in the macroeconomics literature and was originally designed to examine US business cycles (Hodrick and Prescott 1997).

The HP filter attempts to maximise the fit of the trend to the series while minimising changes in the trend's slope (see Hodrick and Prescott (1997) for further details).

A smoothing parameter influences how much of the observed volatility of the original series is allocated to the estimated trend and how much to the cycle component. The larger the smoothing parameter the less volatility is allocated to the estimated trend. As the parameter approaches zero, the extracted trend approximates the original series. As the parameter approaches infinity, the extracted trend approaches linearity.

The choice of HP smoothing parameter is important. Hodrick and Prescott recommended a smoothing parameter of 1600 for quarterly data for US GDP and this has become the 'standard' parameter for quarterly data. Ravn and Uhlig (2001) have shown that a value of 1600 for quarterly data corresponds to a value of 6.25 for annual data. However, there is less consensus about this 'standard' value for annual data. For example, Backus and Kehoe (1992) use 100 for annual data, but Ravn and Uhlig (2001) note that some studies have used values up to 400. For MFP data, a parameter of 25 is preferred by Zhang and Conn (2007) for use with annual market sector MFP series[2], while Statistics New Zealand (2007) uses 6.25 for its annual measured sector MFP series.[3]

In this study, the HP(6.25) and HP(25) are both used in testing the robustness of the H(11) trend (as discussed in chapter 2). The HP(100) was also trialled for selected industries, where tests on the properties of the time series suggested a more linear trend may be appropriate (see chapter 3).[4] The HP filter was implemented in excel using code available from Annen (2005).

Use of multiple filters

Filters are only one way of estimating trends and, depending on the properties of the time series to which they are applied, the resulting trends may not be well identified. The trend identified by a filter may also be sensitive to the specific filter and both the H(11) and HP filters have strengths and weaknesses. For example, Zhang and Conn (2007) found that the H(11) filter is more likely to create spurious short duration cycles than the HP filter for the MFP series for the Australian market sector, but the HP filter generally produces relatively large revisions to the series.

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2 Zhang and Conn (2007, p. 15) note that this choice was based on their judgment and empirical evidence from their analysis of the signal-noise ratio and its variations over time.

3 SNZ (2007, p. 38) in its examination of New Zealand's measured sector MFP found that there was no appreciable difference between the HP(6.25) and HP(8) filters and that these choices yielded the most reasonable results when compared with known economic events.

4 It is common in the literature for smoothing parameters to be selected on the basis of the frequency of the data. Smoothing parameters of 6.25 and 100 are commonly used in studies based on annual data (which is the frequency of the data used in this paper). An alternative approach is to determine a specific smoothing parameter for each data series by means of additional statistical analysis of the data. As mentioned previously, Zhang and Conn (2007) undertook such analysis for Australian MFP (ANZSIC93) series. After considering the results of this statistical analysis and issues such as consistency over time and across industries, they recommended the use of a smoothing parameter of 25. Accordingly, the HP filter with smoothing parameters of 6.25, 25 and 100 are considered in this paper to ensure the results are robust.

The use of multiple filters in order to counterbalance any pitfalls of a particular filter is an approach that has been proposed by some researchers. For example, Canova and Ferroni (2011) examined a weighted average of sufficiently different filters and argued that in the absence of an ideal filter this performed better than any one filter. In practice, their approach would be very complicated to implement on the industry MFP data. Furthermore, it does not seem warranted in the limited exercise of identifying peak deviations from trend, and not other cycle properties.

Statistics New Zealand (SNZ) also uses multiple filters in determining MFP growth cycles. The Hodrick-Prescott filter is the primary filter used, but SNZ also considers the results of other filters (including the H(11) filter and the Baxter-King filter) in finalising its cycles (SNZ 2007). As discussed in chapter 2, a similar approach is followed in this paper, but with the H(11) filter as primary filter in order to be consistent with the ABS market sector methodology.

A.3 Testing of time series properties of the industry MFP series

This section provides some details about the industry MFP dataset before outlining the tests used to identify the properties of these series and the results of those tests.

Industry MFP time series

As noted in chapter 2, this study uses industry MFP index data from the ABS *Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09* (Cat. no. 5260.0.55.002). The industries examined are the 12 (core) industry divisions, as classified under the *Australian and New Zealand Standard Industrial Classification 2006* (ANZSIC06), that make up the market sector (see table A.2). Data for each of these 12 ANZSIC06 industries are available for a relatively short period — 1985-86 to 2008-09.[5]

5 Since new MFP data will only be generated under ANZSIC06, this is the primary dataset used in this study. It should be noted that the small number of observations (twenty-four) does limit the efficiency of the time series tests on the data.

Table A.2 **Market sector (core) industries under ANZSIC06**

Industry division	*Abbreviation used in this paper*
Agriculture, forestry & fishing	AFF
Mining	MIN
Manufacturing	MAN
Electricity, gas, water & waste services	EGWW
Construction	CON
Wholesale trade	WT
Retail trade	RT
Accommodation & food services	AFS
Transport, postal & warehousing	TPW
Information, media & telecommunications	IMT
Financial & insurance services	FIS
Arts & recreation services	ARS

Time series tests

Tests were conducted on the industry MFP time series to answer the following questions.

1. Is there a trend, and is it more appropriate to estimate the trend in the levels of MFP or in MFP growth?
2. What is the nature of the trend, specifically whether or not the trend includes a stochastic (or random) component?[6]

As discussed in chapter 2, a trend must be present for it to be appropriate to apply a filter to estimate the trend. Otherwise, the cycles identified by reference to deviations from the estimated trend are likely to be spurious.

The nature of the trend in each industry time series is important in the choice of smoothing parameter in the HP filter. If a trend is deterministic in nature, then a higher smoothing parameter that forces a more linear trend may be appropriate. However, if the trend is more stochastic in nature, then forcing a more linear trend is inappropriate and a smaller smoothing parameter should be used. For this reason, several different smoothing parameters are considered for the HP filter.

6 As noted in chapter 2, Stock and Watson (1988) define a stochastic trend as one which increases each period by a fixed amount on average but in any given period the change in the trend will deviate from its average by some unforecastable random amount. This is in contrast to a deterministic linear time trend which increases by a fixed amount each period.

Details of time series test results

A sequence of tests was carried out, the results of which jointly suggest the answers to the two questions posed above:

- tests for the presence of unit roots[7]
- tests for autocorrelation.

The first set of tests include two separate unit root tests — the Augmented Dickey-Fuller (ADF) and the Kwiatkowski, Phillip, Schmidt and Shin (KPSS) — to identify the order of integration of each series. The Ljung-Box test for autocorrelation is used as a double check on the results of the unit root tests.

If the MFP series is found to be trend stationary or if it is found to be integrated of order one, this indicates a trend in the *level* of the series and the filter should be applied to the MFP level series. If the MFP series is found to be integrated of order two, this indicates a trend in the *growth* of the series and the filter should be applied to the growth of MFP series. If the unit root tests do not indicate that the MFP series is trend stationary or that it has a unit root, it is concluded that there is insufficient evidence of a trend for the filter to be applied to the series.

If the MFP series is trend stationary (that is, has a deterministic linear time trend without a stochastic component), this is taken as indication that a higher smoothing parameter in the HP filter (which leads to a more linear trend) may be appropriate. If the MFP series is integrated of order one or two, this indicates the presence of a stochastic component to the trend. This is taken as an indication that a higher smoothing parameter in the HP filter is not appropriate.

Unit root tests

The MFP index series were tested for unit roots and model specification in order to indicate whether they had a deterministic trend and whether there was a stochastic component in the trend.

The null hypothesis for the ADF test is that there is a unit root. The ADF test determines the optimal autoregressive lag — the number of lags is chosen using the Schwarz Information Criterion (SIC).

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[7] A series that has a unit root is integrated of at least order one. The order of integration of a series indicates the number of times the series must be differenced before it becomes stationary. For example, if a series has an order of integration of one, I(1), the series becomes stationary after differencing once. A stationary series is one whose properties stay unchanged over time, in particular its mean and variance do not change.

The ADF test is used on the levels of the series to determine if there is a unit root. If the result of the test fails to reject the presence of a unit root, then another ADF test is performed on the first difference of the series and so on until the test rejects the presence of a unit root. A linear trend is included in some of these ADF tests if such a trend is found to be statistically significant.[8] A series is trend stationary if the ADF test rejects the presence of a unit root when a linear trend is included. Through this process, the order of integration in the MFP index for each industry is determined.

Unit root tests are reported on the levels of the MFP indexes (table A.3) and on the first differences of the MFP indexes (table A.4). The ADF tests could not reject the existence of a unit root (or the presence of a stochastic component to the trend) in the MFP levels for most industries. The exceptions are Agriculture, forestry & fishing (AFF), Transport, postal & warehousing (TPW), Financial & insurance services (FIS) and Arts and recreation services (ARS). The unit root tests on the first differences of the MFP indexes show that the unit root hypothesis can be rejected in all industries (that is, there is no stochastic trend in the *growth* of MFP series).

For all industries other than AFF, TPW, FIS and ARS, the ADF tests supported the hypothesis that the series are integrated of order one. That is, the unit root hypothesis was not rejected in the MFP levels and was rejected in the first differences. This indicates that it is appropriate to apply the filters to the level of the MFP indexes (rather than the growth in MFP). The ADF tests found no evidence that any series were integrated of order greater than one.

For AFF, TPW and FIS, the tests gave evidence to reject the presence of a unit root and indicated trend stationarity in the levels of the series (with the linear trend included in the ADF test found to be significant). This indicates the presence of a trend in the levels and the filter should be applied to the levels of the MFP index series. It also suggest that for these industries a higher smoothing parameter in the HP filter, which estimates a more linear trend, may be appropriate.

In the case of ARS, the ADF test result rejects the presence of a unit root and the appropriate exogenous variables included in the ADF regression do not include a linear trend. This suggests that it would be inappropriate to apply a filter to the ARS series to estimate a trend as there is little evidence to suggest the existence of a trend.

8 The unit root tests are sequentially tested including a linear trend and a drift and then a drift but no time trend to determine the appropriate model specification. The time trend was dropped if it was not statistically significant at the 10% level of significance.

The KPSS test of level stationarity or trend stationarity is used as a second unit root test on the levels of MFP series. The KPSS test has a null hypothesis of level stationarity, or trend stationarity when a linear trend is included.[9] Thus, if the null hypothesis for the KPSS test is rejected then the errors in the equation are non-stationary. The KPSS test is helpful in providing further support to the case where the ADF test suggests there is no stochastic component to the trend (that is, the null hypothesis of a unit root is rejected).

The KPSS tests on the industry MFP time series are consistent with those of the ADF tests for all industries except ARS (table A.3). For AFF, TPW and FIS, trend stationarity is not rejected at the 10% level of significance and this is consistent with the ADF test rejecting a unit root. The KPSS tests reject the hypothesis of trend stationarity or level stationarity for Mining (MIN), Manufacturing (MAN), Electricity, gas, water & waste services (EGWW), Construction (CON), Wholesale trade (WT), Retail trade (RT), Accommodation & food services (AFS), Information, media & telecommunications (IMT), and ARS. For all of these industries (except ARS), this reinforces the results of the ADF test in failing to reject a unit root. For ARS, the KPSS test is inconsistent with the ADF test, but overall there is insufficient evidence to support filtering the ARS series.

9 A linear trend component is included in the test if it was found to be statistically significant in the ADF test.

Table A.3 **Unit root tests on industry MFP indexes**

Augmented Dickey-Fuller test (using SIC)[a] and KPSS test[b]

Industry[c]	*Exogenous variables included regressions*	*Augmented Dickey-Fuller statistic — null hypothesis of unit root*	*KPSS statistic — null hypothesis of level or trend stationarity*
AFF	Linear trend and drift	-4.10** Unit root hypothesis rejected at 5% level of significance	0.10 Trend stationarity is not rejected at 10% level of significance
MIN	Linear trend and drift	0.04 Unit root hypothesis not rejected at 10% level of signif.	0.17** Trend stationarity is rejected at 5% level of significance
MAN	Drift	-1.81 Unit root hypothesis not rejected at 10% level of signif.	0.49** Level stationarity is rejected at 5% level of significance
EGWW	Linear trend and drift	0.31 Unit root hypothesis not rejected at 10% level of signif.	0.17** Trend stationarity is rejected at 5% level of significance
CON	Linear trend and drift	-2.74 Unit root hypothesis not rejected at 10% level of signif.	0.16** Trend stationarity is rejected at 5% level of significance
WT	Drift	-0.99 Unit root hypothesis not rejected at 10% level of signif.	0.52** Level stationarity is rejected at 5% level of significance
RT	Drift	0.53[d] Unit root hypothesis not rejected at 10% level of signif.	0.67** Level stationarity is rejected at 5% level of significance
AFS	Linear trend and drift	-2.48 Unit root hypothesis not rejected at 10% level of signif.	0.14* Trend stationarity is rejected at 10% level of significance
TPW	Linear trend and drift	-4.10**[e] Unit root hypothesis rejected at 5% level of significance	0.11 Trend stationarity is not rejected at 10% level of significance
IMT	Drift	-1.86 Unit root hypothesis not rejected at 10% level of signif.	0.53** Level stationarity is rejected at 5% level of significance
FIS	Linear trend and drift	-3.30* Unit root hypothesis rejected at 10% level of significance	0.06 Trend stationarity is not rejected at 10% level of significance
ARS	Drift	-2.97* Unit root hypothesis rejected at 10% level of significance	0.48** Level stationarity is rejected at the 5% level of significance

*** 1% level of significance ** 5% level of significance * 10% level of significance [a] ADF test with 0 lags except for CON and WT (1 lag). [b] KPSS test with 1 lag for TPW and FIS; 2 lags for CON; 3 lags for AFF, RT, AFS and ARS; and 4 lags for MIN, MAN, EGWW, WT and IMT. [c] Full industry names provided in table A.2. [d] Based on the modified SIC with 4 lags the trend is not significant. Under SIC, 8 lags are selected in the ADF regression and the trend is significant. However, the use of 8 lags reduces the degrees of freedom to the point where the ADF test is not reliable (less than 20 degrees of freedom). [e] Based on the modified SIC with 0 lags the trend is significant. Under SIC, 8 lags are selected in the ADF regression and the trend is not significant. However, the use of 8 lags reduces the degrees of freedom to the point where the ADF test is not reliable (less than 20 degrees of freedom).

Source: Author's estimates.

Table A.4 **Unit root tests on first differences of industry MFP indexes**
Augmented Dickey-Fuller test (using SIC)[a]

Industry[b]	*Exogenous variables included in ADF regressions*	*Augmented Dickey-Fuller statistic — null hypothesis of unit root*
AFF	Drift	-5.13*** Unit root hypothesis rejected at 1% level of significance
MIN	Linear trend and drift	-4.45** Unit root hypothesis rejected at 5% level of significance
MAN	Drift	-3.70** Unit root hypothesis rejected at 5% level of significance
EGWW	Linear trend and drift	-3.93** Unit root hypothesis rejected at 5% level of significance
CON	Drift	-4.52*** Unit root hypothesis rejected at 1% level of significance
WT	Drift	-3.72** Unit root hypothesis rejected at 5% level of significance
RT	Drift	-4.78***[c] Unit root hypothesis rejected at 1% level of significance
AFS	Drift	-3.99*** Unit root hypothesis rejected at 1% level of significance
TPW	Drift	-5.02*** Unit root hypothesis rejected at 1% level of significance
IMT	Linear trend and drift	-4.34** Unit root hypothesis rejected at 5% level of significance
FIS	Drift	-4.71*** Unit root hypothesis rejected at 1% level of significance
ARS	Drift	-7.59*** Unit root hypothesis rejected at 1% level of significance

*** 1% level of significance ** 5% level of significance * 10% level of significance [a] ADF test with 0 lags, except for 1 lag for CON and IMT and 2 lags for AFF and MIN. [b] Full industry names provided in table A.2. [c] This is based on the SIC with 0 lags and no trend. In the ADF regression including a trend, the SIC selected 3 lags and the trend was not significant. However, the use of 3 lags reduces the degrees of freedom to the point where the ADF test is not reliable (less than 20 degrees of freedom).

Source: Author's estimates.

Autocorrelation tests

The time series were tested for autocorrelation using correlograms and the Ljung-Box test. The autocorrelation function (ACF) and partial autocorrelation function (PACF) of the industry MFP indexes were plotted as correlograms and examined. All correlograms for the industry MFP indexes showed evidence of persistence consistent with an autoregressive process. For most industries, persistence was eliminated in the first differences. For EGWW there was strong evidence of persistence in the first differences.

Table A.5 presents the Q-statistic from the Ljung-Box test for the first differences of the industry MFP series. The Ljung-Box test is used to test the hypothesis that a series is white noise, and thus not autocorrelated. If the Q statistic indicates that the level of the series is autocorrelated but the first difference is white noise, then this is consistent with a series that is integrated of order one. If the ADF test indicates a series is integrated of order one, but there is a high level of autocorrelation in the first differences, then this may be evidence to suggest that the series is of a higher order of integration.

For all industries, except EGWW, the null hypothesis that the first difference of the series is white noise cannot be rejected at the 10% level of significance. The Ljung-Box test results were therefore consistent with the ADF tests for all industries found to be integrated of order one, except for EGWW. For EGWW the correlograms and the Ljung-Box test of the first differences find autocorrelation, suggesting that the series may possibly be of a higher order of integration. However, further analysis of the EGWW series found that even if the series was integrated of order two and the filter was applied to MFP growth rather than levels, the cycles identified would be virtually the same.[10]

[10] If the filters are applied to the log, rather than the level, of the EGWW MFP series, 1989-90 instead of 1990-91 is identified as a peak. However, there is little volatility in MFP over this period, and the use of 1989-90 as a peak would make little difference to the average growth rates calculated over the cycles.

Table A.5 **Correlations in first differences of industry MFP indexes**

Q-statistic with ten lags[a]

Industry[b]	*Q-statistic — null hypothesis of white noise*
AFF	9.54
	White noise hypothesis not rejected at 10% level of significance
MIN	6.74
	White noise hypothesis not rejected at 10% level of significance
MAN	2.87
	White noise hypothesis not rejected at 10% level of significance
EGWW	46.16***
	White noise hypothesis rejected at 1% level of significance
CON	7.45
	White noise hypothesis not rejected at 10% level of significance
WT	5.59
	White noise hypothesis not rejected at 10% level of significance
RT	9.61
	White noise hypothesis not rejected at 10% level of significance
AFS	10.03
	White noise hypothesis not rejected at 10% level of significance
TPW	2.56
	White noise hypothesis not rejected at 10% level of significance
IMT	12.12
	White noise hypothesis not rejected at 10% level of significance
FIS	14.43
	White noise hypothesis not rejected at 10% level of significance
ARS	8.39
	White noise hypothesis not rejected at 10% level of significance

*** 1% level of significance ** 5% level of significance * 10% level of significance [a] The Q-statistic reported is the Ljung-Box version and under the null hypothesis of no autocorrelation (up to the specified number of lags) it is asymptotically distributed as χ^2 distribution with degrees of freedom equal to the number of lags. Thus for ten lags the critical values at 1%, 5% and 10% confidence are 23.2, 18.3 and 16.0, respectively (see Hamilton 1994, table B.2). [b] Full industry names provided in table A.2.

Source: Author's estimates.

Conclusions about the industry MFP series

Table A.6 summarises the implications of the tests for the approach taken in this paper.

Table A.6 **Implications of time series testing of industry MFP series**

Industry	*Estimate trend in MFP in:*	*Smaller smoothing parameters indicated for HP filter*
Agriculture, forestry & fishing	levels	no
Mining	levels	yes
Manufacturing	levels	yes
Electricity, gas, water & waste services	levels	yes
Construction	levels	yes
Wholesale trade	levels	yes
Retail trade	levels	yes
Accommodation & food services	levels	yes
Transport, postal & warehousing	levels	no
Information, media & telecommunications	levels	yes
Financial & insurance services	levels	no
Arts & recreation services	do not estimate trend	filter not applied

Source: Author's estimates.

Overall, the results of the testing suggest that for most industries it is appropriate to apply the filters to the level of MFP and to use small smoothing parameters for the HP filter. The exceptions are:

- Arts & recreation services, for which there is insufficient evidence of the presence of a trend, so this industry is not examined further
- Agriculture, forestry & fishing, Transport, postal & warehousing, and Financial & insurance services, for which the tests suggest that a more linear trend may be appropriate, indicating the use of a larger smoothing parameter in the HP filter.

The results of varying the uniform approach to the application of the filter to these industries are reported in chapter 3.

A.4 Robustness testing and flagged peaks under the uniform approach to identifying peaks

As outlined in chapter 2, the identification of peaks in industry MFP involves a number of steps. Chapter 3 summarised the results of this process at the end of stage one (identification of robust peak deviations) and stage two (the choice of which close together robust peak deviations to use to form the growth cycles). This section provides additional details of the results at intermediate stages of this process in stage 1:

- the identification of positive local maxima in the series of percentage deviations from the trend estimated using the primary filter, the H(11)
- the flagging of small deviations from the H(11) trend
- the testing of robustness to secondary filters, the HP(6.25) and HP(25).

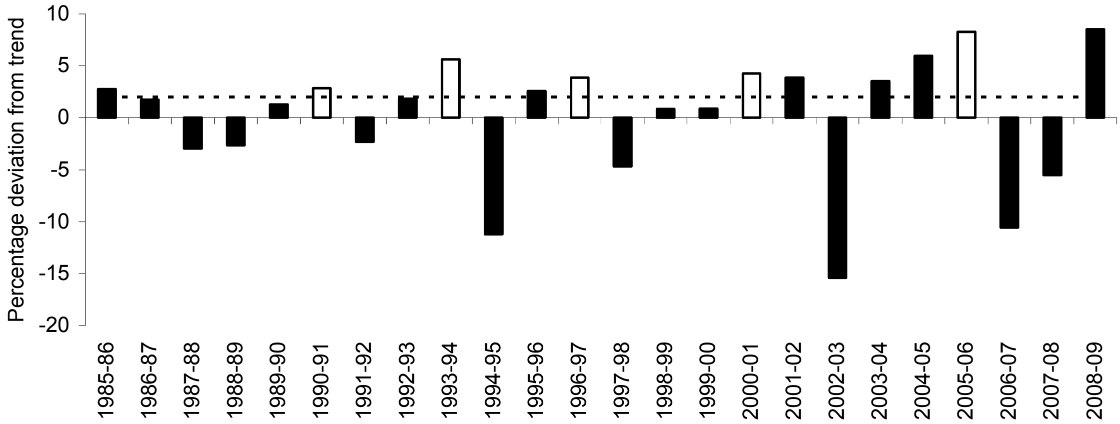
Positive local maxima under the H(11) trend and the flagging of small deviations

The following set of charts (figure A.1) shows, for each industry, the series of percentage deviations of the original MFP series from the MFP trend estimated using the H(11) filter. The white bars are the positive local maxima of this series. (These charts are equivalent to middle panel of chart 2.1 in chapter 2, which illustrated this for the market sector). Each chart also shows a horizontal line which indicates ⅓ of a standard deviation of this series of deviations from trend. This is the threshold for declaring a peak deviation from trend 'small'. These small peak deviations are flagged with an 's'. There are 11 small peak deviations across 7 industries. Some of these small deviations are eliminated in subsequent stages of the peak identification process because they are not robust to alternative filters or are the smaller of two close together peaks (see below).[11]

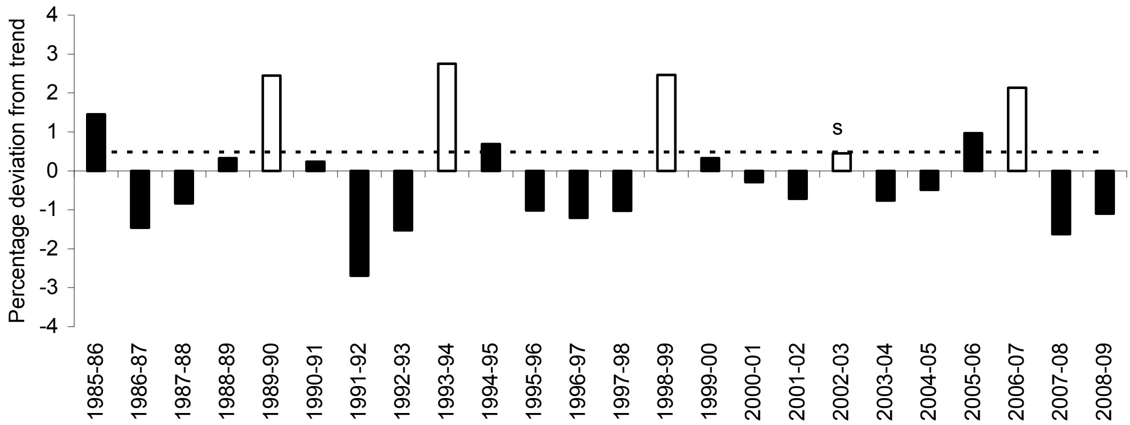
[11] Seven small peak deviations across 5 industries are eliminated at subsequent stages of the process.

Figure A.1 **Percentage deviations of industry MFP from H(11) trend and size threshold, by industry**

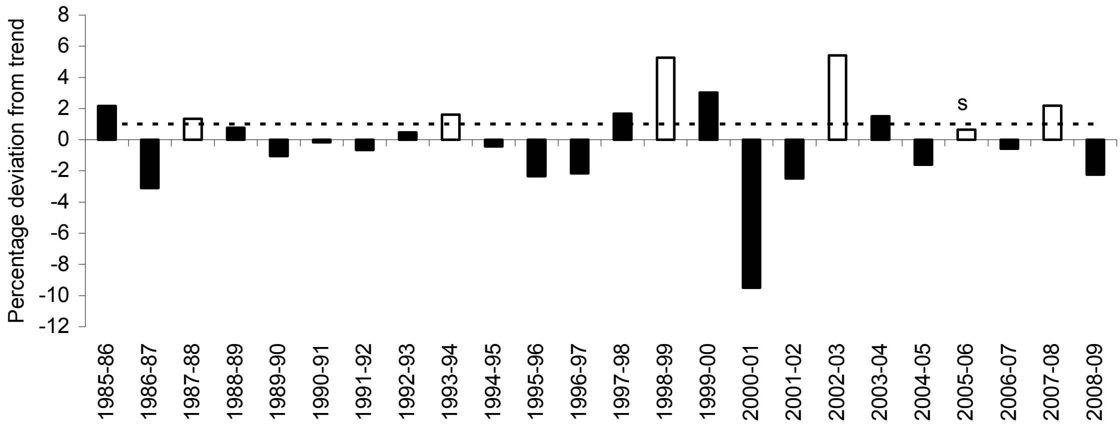
Agriculture, forestry & fishing



Accommodation & food services



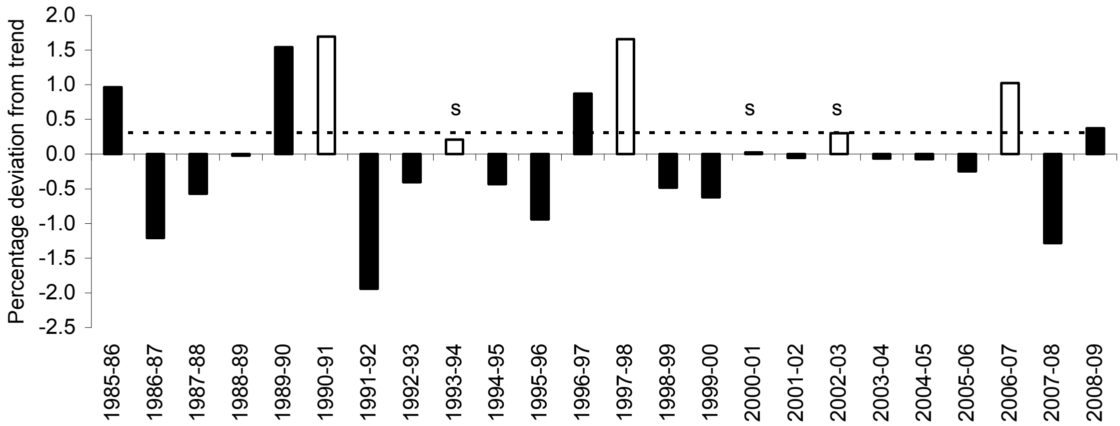
Construction



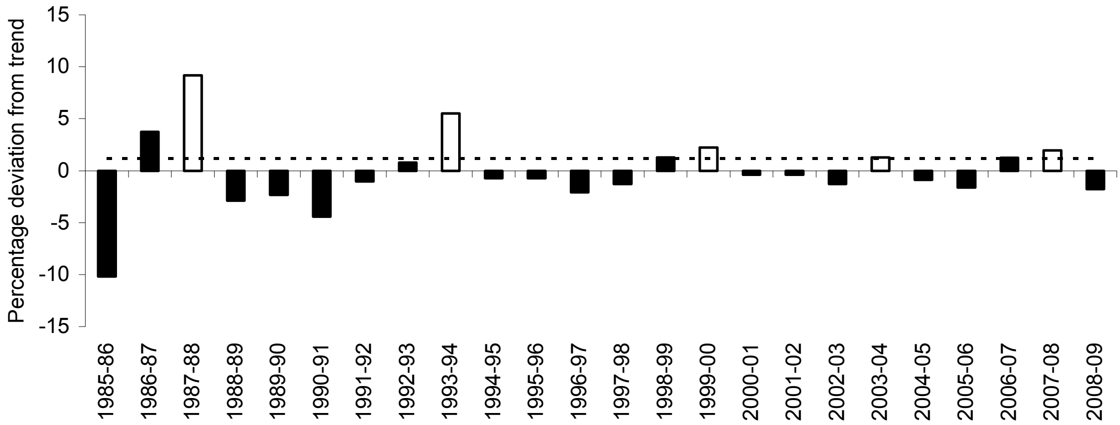
(continued on next page)

Figure A.1 **(continued)**

Electricity, gas, water & waste services



Financial & insurance services



Information, media & telecommunications

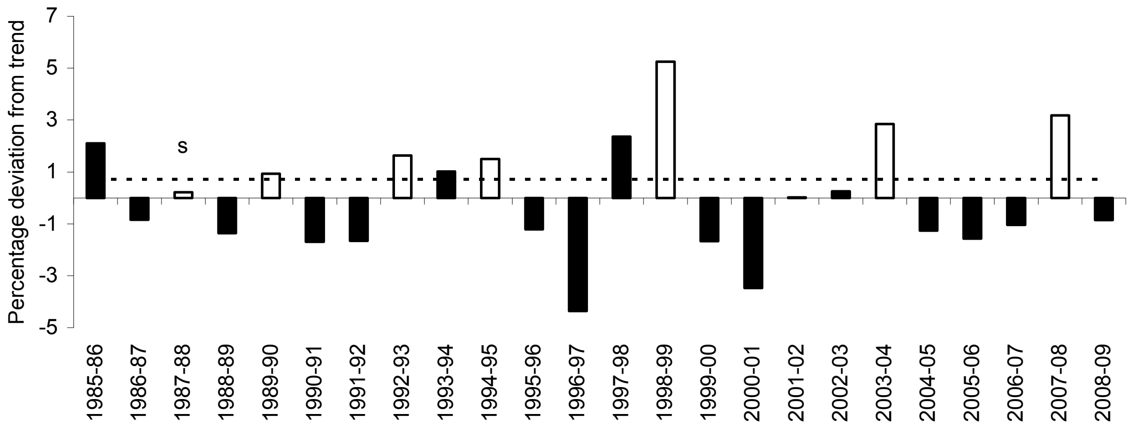


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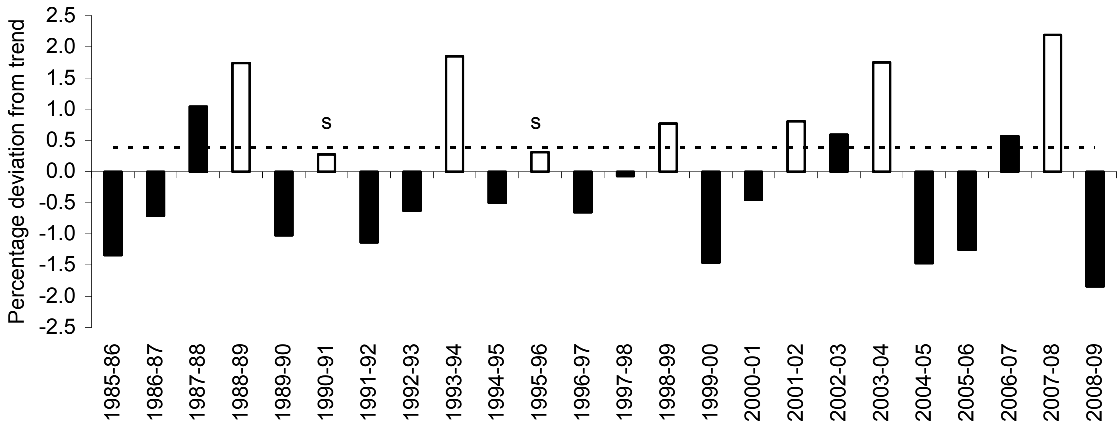
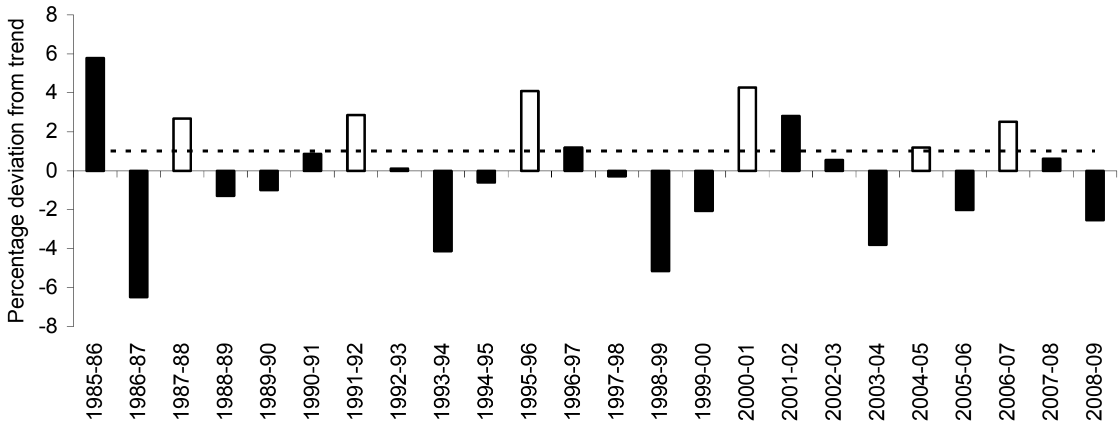
Figure A.1 (continued)

Manufacturing



Mining



Retail trade

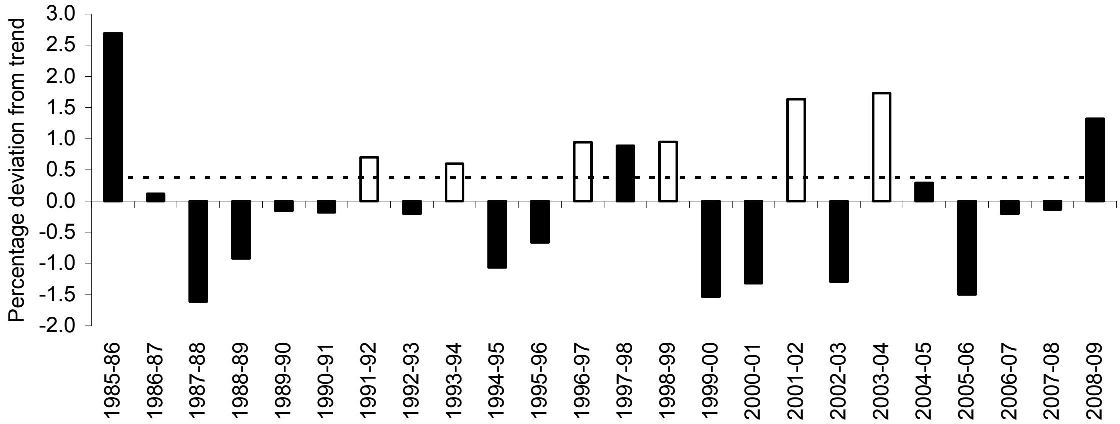


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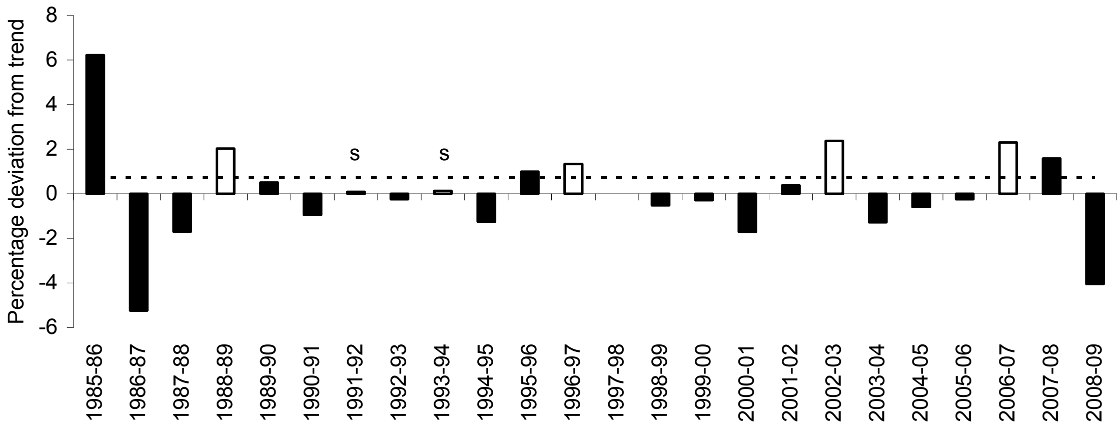
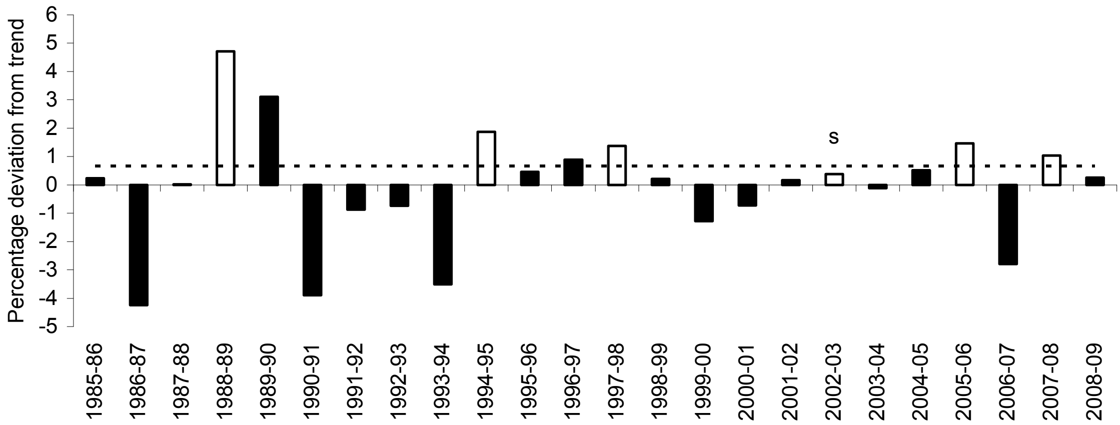
Figure A.1 **(continued)**

Transport, postal & warehousing



Wholesale trade



Data source: Author's estimates based on application of H(11) filter to original series from ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002).

Robustness to secondary filters

As discussed above, robustness of the peak deviations from the trend estimated using the primary filter, the H(11), are tested using secondary filters — two versions of the Hodrick-Prescott filter with different smoothing parameters, HP(6.25) and HP(25).

Table 3.1 in chapter 3 shows the robust peak deviations, including those flagged as being weakly robust (that is, robust to only one not both HP filters). Table A.7 provides further details of the peak deviations (positive local maxima) under each of the three filters — the Henderson 11-term filter (H), the Hodrick-Prescott filter with a smoothing parameter of 6.25 (HP1), and the Hodrick-Prescott filter with a smoothing parameter of 25 (HP2).

There are three peak deviations from the H(11) trend that are not included as robust peak deviations in chapter 3 because they are not robust to either HP filter. This occurs for Electricity, gas, water & waste services in 1993-94, Retail trade in 1998-99 and Transport, postal & warehousing in 1991-92. These peak deviations (marked with a bolded H) are rejected for use as MFP growth cycle start/end points.

On nine occasions, a peak deviation from the H(11) trend is only weakly robust — these years have only H and HP1 listed against them (in italics in table A.7). These years correspond to the weakly robust flagged peaks (marked with 'w') in table 3.1. Three weakly robust peaks are subsequently not selected for use in MFP growth cycles after consideration of close together peaks.

Table A.7 **Positive local maxima under H(11) and HP filters**

Columns indicate financial year ending

Industry[a]	*86*	*87*	*88*	*89*	*90*	*91*	*92*	*93*	*94*	*95*	*96*	*97*	*98*	*99*	*00*	*01*	*02*	*03*	*04*	*05*	*06*	*07*	*08*	*09*
AFF						H HP1 HP2			H HP1 HP2			H HP1 HP2				H HP1 HP2					H HP1 HP2			
MIN			H HP1 HP2				H HP1 HP2				H HP1 HP2					H HP1 HP2				H HP1 HP2		H HP1 HP2		
MAN				H HP1 HP2		H HP1 HP2			H HP1 HP2		*H HP1*			*H HP1*			*H HP1*		H HP1 HP2				H HP1 HP2	
EGWW					**HP2**	*H HP1*			**H**				H HP1 HP2			H HP1 HP2		H HP1 HP2				H HP1 HP2		
CON			H HP1 HP2						H HP1 HP2					H HP1 HP2				H HP1 HP2			H HP1 HP2		H HP1 HP2	
WT				H HP1 HP2						*H HP1*			H HP1 HP2					H HP1 HP2			H HP1 HP2		H HP1 HP2	
RT							*H HP1*		H HP1 HP2			H HP1 HP2		**H**			H HP1 HP2		H HP1 HP2					
AFS					H HP1 HP2				H HP1 HP2					H HP1 HP2				H HP1 HP2				H HP1 HP2		
TPW				H HP1 HP2			**H**		H HP1 HP2			H HP1 HP2						H HP1 HP2				H HP1 HP2		
IMT			*H HP1*		*H HP1*			H HP1 HP2		H HP1 HP2				H HP1 HP2					H HP1 HP2				H HP1 HP2	
FIS			H HP1 HP2						H HP1 HP2						H HP1 HP2				*H HP1*				H HP1 HP2	

H is the Henderson 11-term filter; HP1 is the Hodrick-Prescott filter with a smoothing parameter of 6.25; HP2 is the Hodrick-Prescott filter with a smoothing parameter of 25. [a] Industry labels: AFF is Agriculture, forestry & fishing; MIN is Mining; MAN is Manufacturing; EGWW is Electricity, gas, water & waste services; CON is Construction; WT is Wholesale trade; RT is Retail trade; AFS is Accommodation & food services; TPW is Transport, postal & warehousing; IMT is Information, media & telecommunications; FIS is Financial & insurance services.

Source: Author's estimates.

Rejected positive local maxima under the H(11) trend

Table A.8 summarises the positive local maxima under the H(11) filter that are not included in MFP growth cycles after all stages of the selection process. This highlights the difference between the selection process outlined in chapter 2 and simply using peak deviations from the H(11) trend to identify MFP growth cycles. The final set of peaks selected to form MFP growth cycles (including remaining flags discussed in previous sub-sections) are shown in table 3.2 in chapter 3.

Table A.8 **Positive local maxima of the series of percentage deviations from H(11) trend in industry MFP that are not included in MFP growth cycles**

Industry	*Year*	*Reason eliminated*
Construction	2005-06	Small peak eliminated as smaller of close together peaks
Electricity, gas, water & waste services	1993-94	Small peak not robust to either HP filter
	2000-01	Small peak eliminated as smaller of close together peaks
Information, media & telecommunications	1987-88	Small, weakly robust peak eliminated as smaller of close together peaks
	1994-95	Smaller of close together peaks
Manufacturing	1990-91	Small peak eliminated as smaller of close together peaks
	1995-96	Small, weakly robust peak eliminated as smaller of close together peaks
	2001-02	Weakly robust peak eliminated as smaller of close together peaks
Mining	2004-05	Smaller of close together peaks
Retail trade	1993-94	Smaller of close together peaks
	1998-99	Not robust to either HP filter
	2001-02	Smaller of close together peaks
Transport, postal & warehousing	1991-92	Small peak not robust to either HP filter
Wholesale trade	2007-08	Smaller of close together peaks

Source: Author's estimates.

A.5 Components of industry MFP over industry-specific cycles

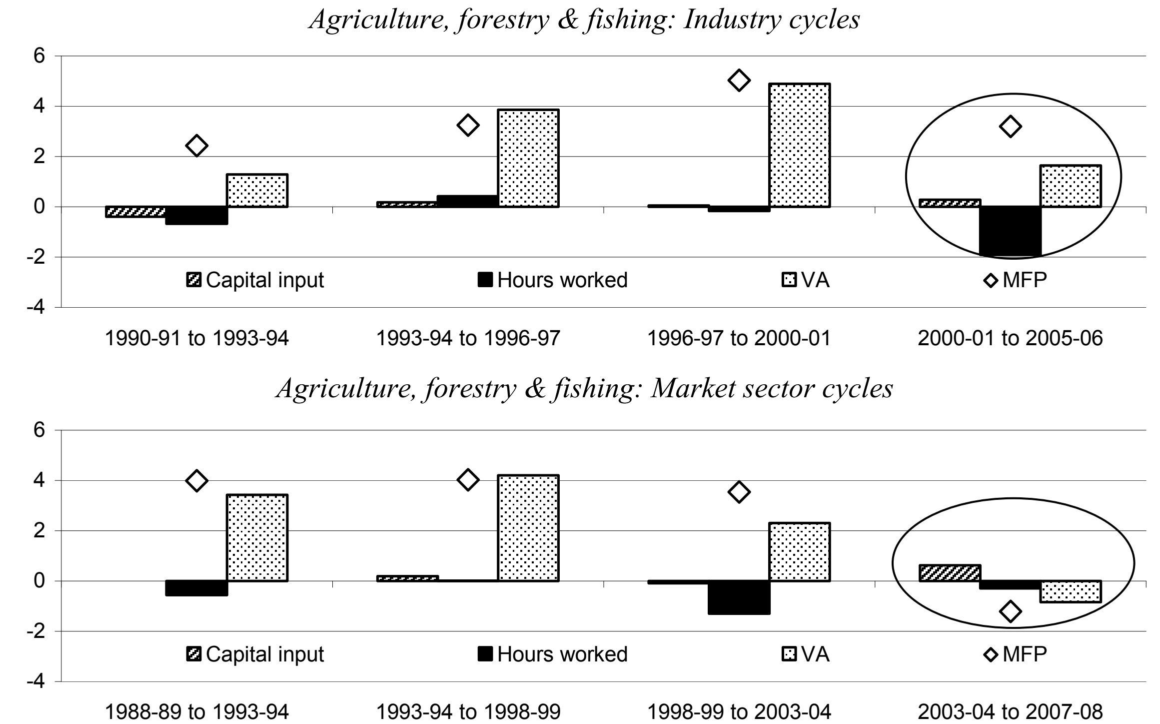
Once industry MFP growth cycles have been identified useful additional information can be gleaned from examining average annual growth rates of value added, and capital and labour inputs over these cycles. Figures A.2 to A.12 illustrate this for each industry. The notable differences in the patterns of growth over industry-specific cycles compared with growth over market sector cycles are discussed below.

In this set of figures, the dotted bars represent average annual growth in valued added (VA) and the black and hashed bars represent the weighted average annual growth rates in the contribution of labour and capital, respectively. The capital and labour contributions are weighted by their respective shares of income. The diamonds represent average annual MFP growth rates — approximately equal to the difference between VA growth (the dotted bar) and input growth (the sum of the hashed and black bars).

As discussed in chapter 4, where drought years coincide with some market sector MFP peaks, average MFP growth measured over the market sector cycles can be misleading. Based on the market sector cycles it might be concluded that there was a steep downward trend in AFF MFP growth in the 2000s, but that conclusion would not be drawn from analysis over the industry-specific cycles. Rather, it might be concluded that the 1996-97 to 2000-01 industry cycle was an exceptionally strong period for MFP growth in AFF. In the last cycle (as circled in figure A.2), the growth in the components of MFP growth are also quite different depending on which set of cycles is used. Over the market sector cycle, the fall in VA attributable to the drought underlies the negative MFP growth rate. The industry cycle shows positive growth in VA and MFP.

Figure A.2 **Components of MFP growth in Agriculture, forestry & fishing, industry cycles and market sector cycles**

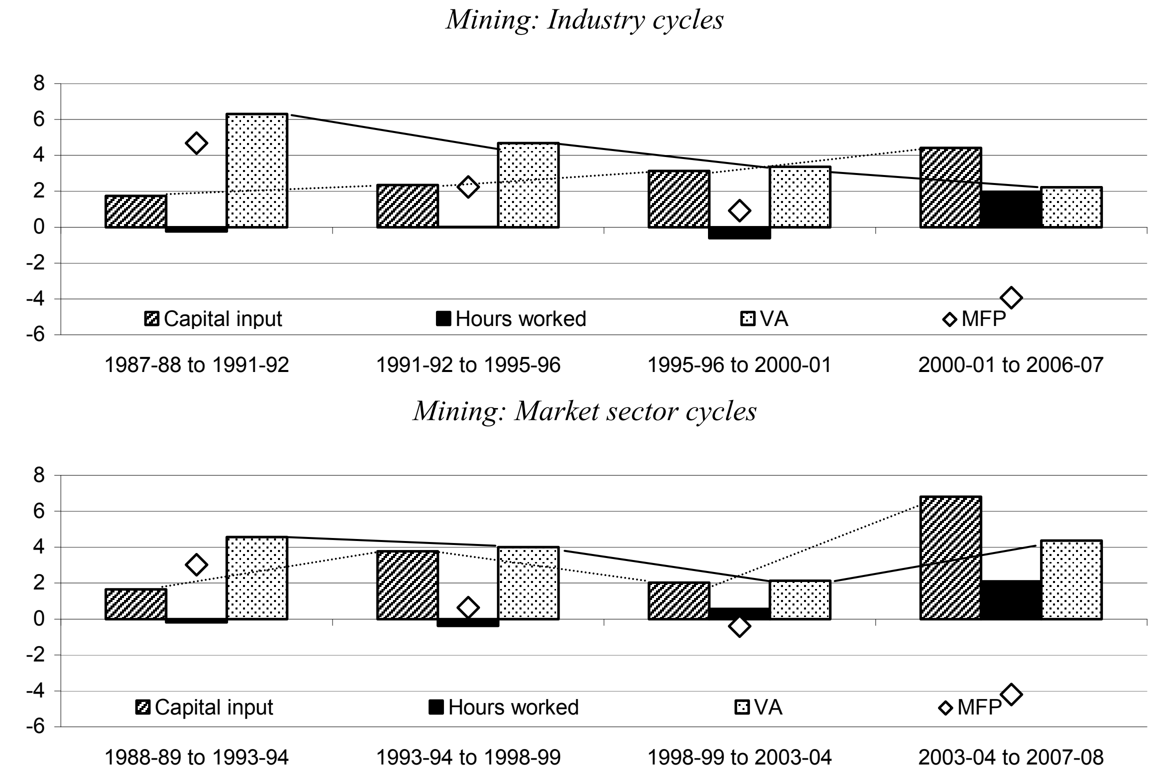
Per cent per year



Data source: Author's estimates based on ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002).

Also discussed in chapter 4, for Mining both sets of cycles provide a similar pattern of change in MFP growth between cycles (in terms of direction), but quite different magnitudes of average growth in the early cycles. However, the pattern of change in the VA, capital and hours worked is quite different when the industry-specific cycles are used instead of the market sector cycles. Looking at the components of MFP growth over the industry cycles shows a clearer pattern of increasing growth in capital and decreasing growth in VA (as shown in figure A.3).

Figure A.3 **Components of MFP growth in Mining, industry cycles and market sector cycles**
Per cent per year



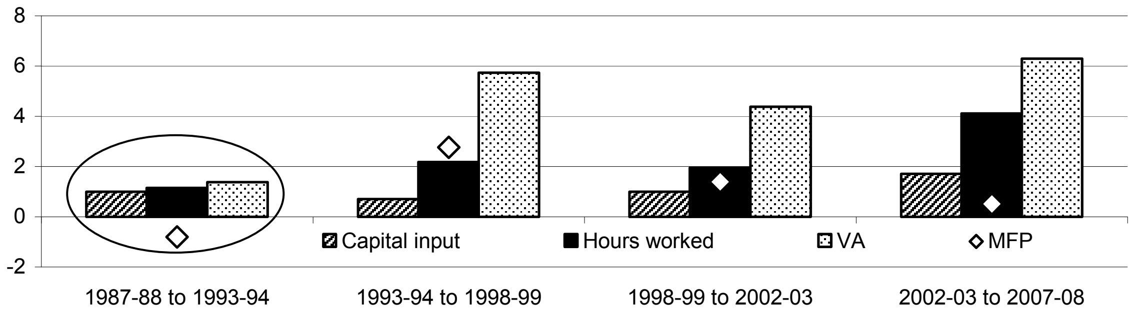
Data source: Author's estimates based on ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002).

For Construction, the last three cycles are the same or close to those for the market sector. The mid-80s to mid-90s cycle shows the most difference in the components of MFP when the industry-specific cycle is used, even though average MFP growth is negative in both cases (as circled in figure A.4). Over the market sector cycle, growth in hours worked and VA are negative but over the industry cycle both are positive. For that cycle, the industry cycle picture is one of an industry that is growing but input growth is outstripping VA growth. The market sector cycle picture is of an industry that is contracting slightly, with capital growing but hours worked declining.

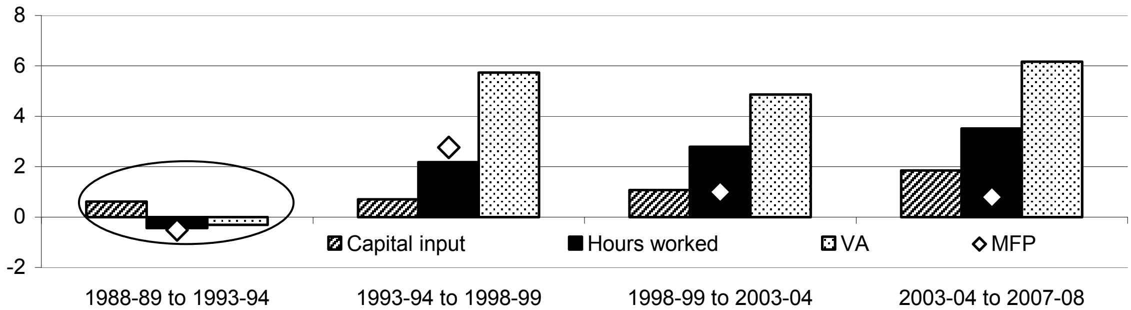
Figure A.4 **Components of MFP growth in Construction, industry cycles and market sector cycles**

Per cent per year

Construction: Industry cycles



Construction: Market sector cycles

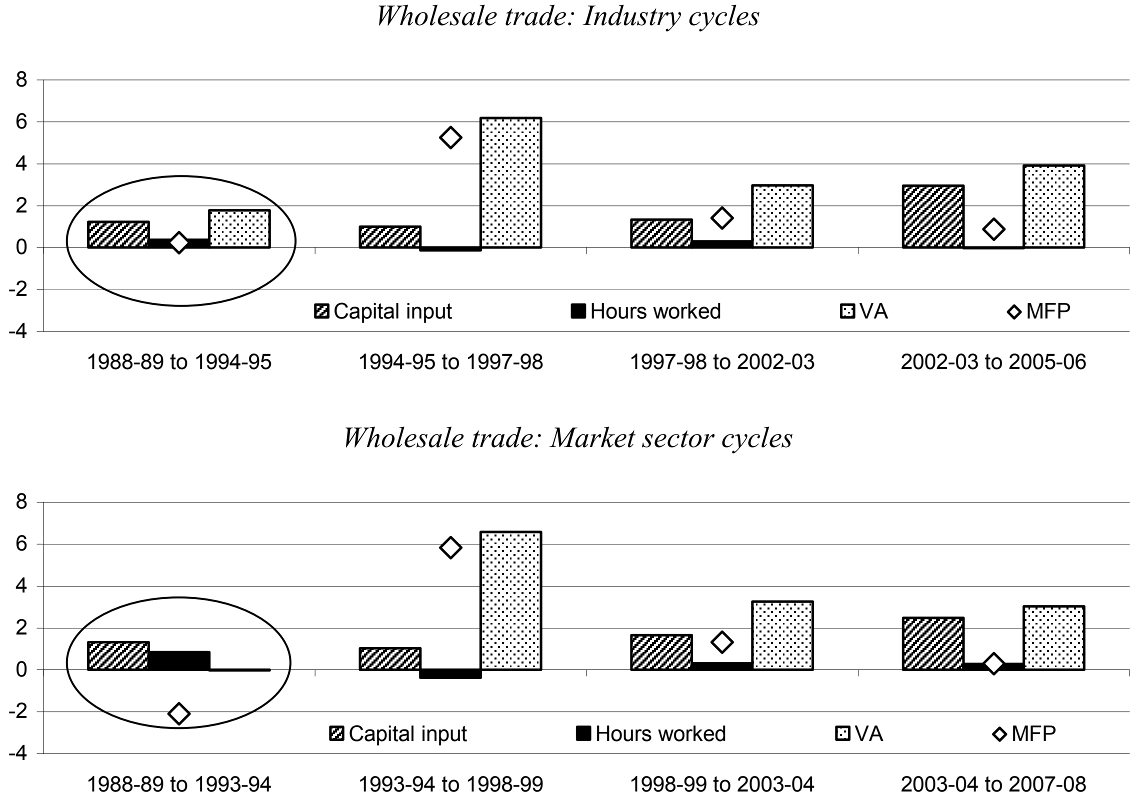


Data source: Author's estimates based on ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002).

For Wholesale trade, from the mid-80s to mid-90s, average annual growth in MFP and VA is higher over the industry cycles than the market sector cycles (as circled in figure A.5). Average growth calculated over the first market sector cycle suggests there is no VA growth and some input growth, leading to negative MFP growth. However, the first industry cycle, using years that are more likely to be comparable, shows positive VA growth that outweighs input growth and therefore MFP growth is positive.

Figure A.5 **Components of MFP growth in Wholesale trade, industry cycles and market sector cycles**

Per cent per year

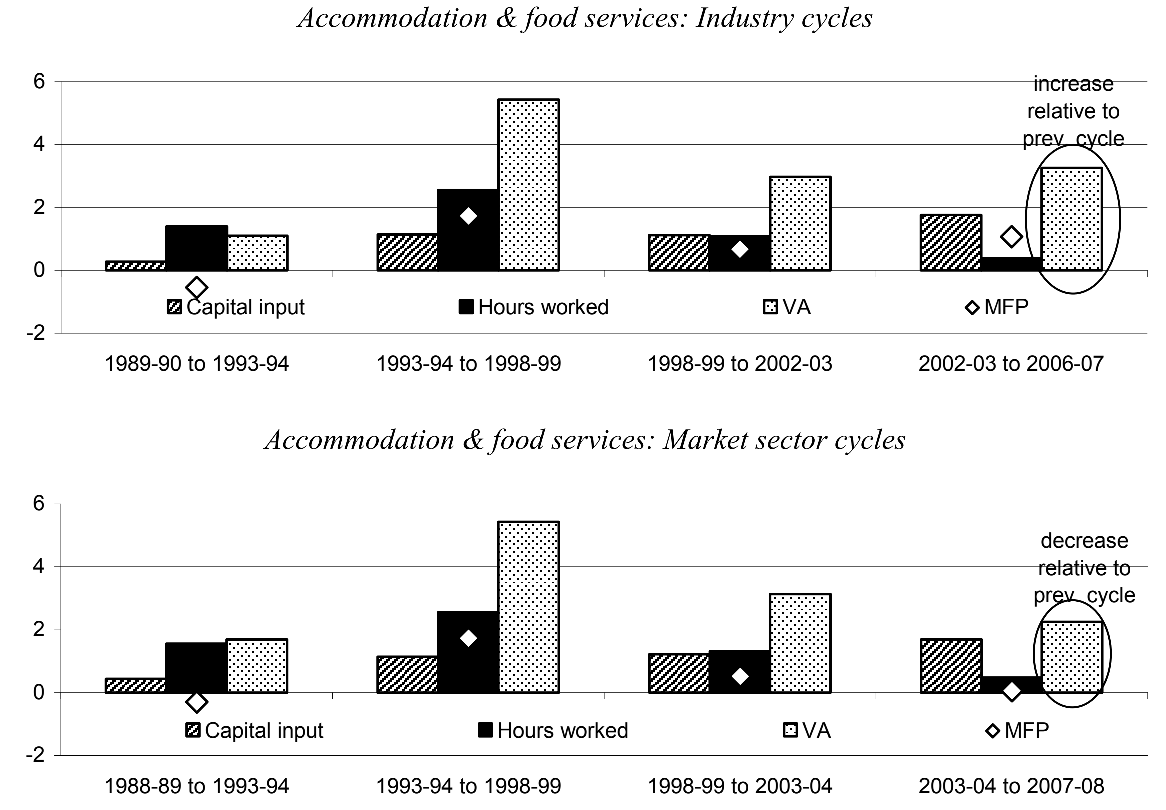


Data source: Author's estimates based on ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002).

For Accommodation & food services, average VA growth in the last cycle is lower over the market sector than the industry cycle (figure A.6). The influence of 2003-04 and 2007-08, both trough years, is to lower average growth in VA and MFP in the last market sector cycle. The end of this market sector cycle, 2007-08, falls outside the last complete industry cycle. The pattern of VA growth between the last two cycles is also reversed over the industry cycles compared with the market sector cycles (as circled in figure A.6).

Figure A.6 **Components of MFP growth in Accommodation & food services, industry cycles and market sector cycles**

Per cent per year



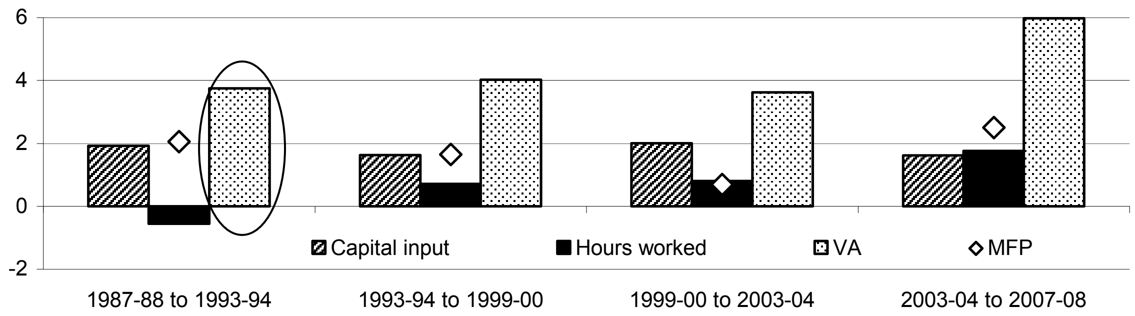
Data source: Author's estimates based on ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002).

For Financial & insurance services, the first market sector cycle (1988-89 to 1993-94) shows much larger growth in MFP than the first industry cycle, with much higher VA growth underlying this result (as circled in figure A.7). The market sector cycle compares a below trend year (1988-89) with a peak year (1993-94) for Financial & insurance services MFP.

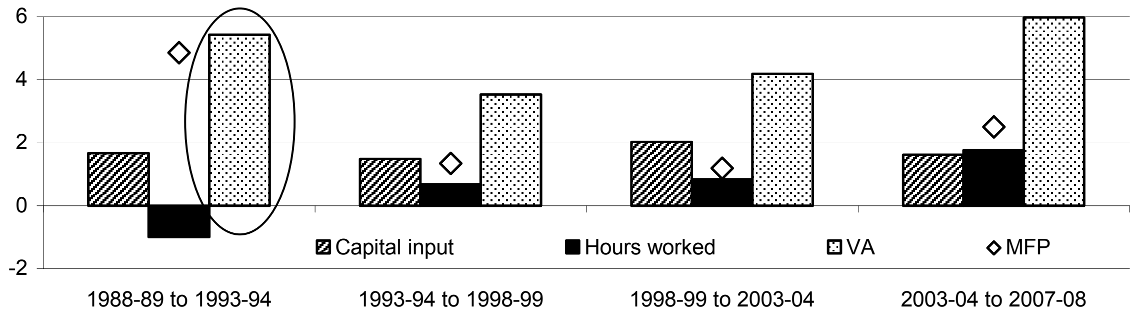
Figure A.7 **Components of MFP growth in Financial & insurance services, industry cycles and market sector cycles**

Per cent per year

Financial & insurance services: Industry cycles



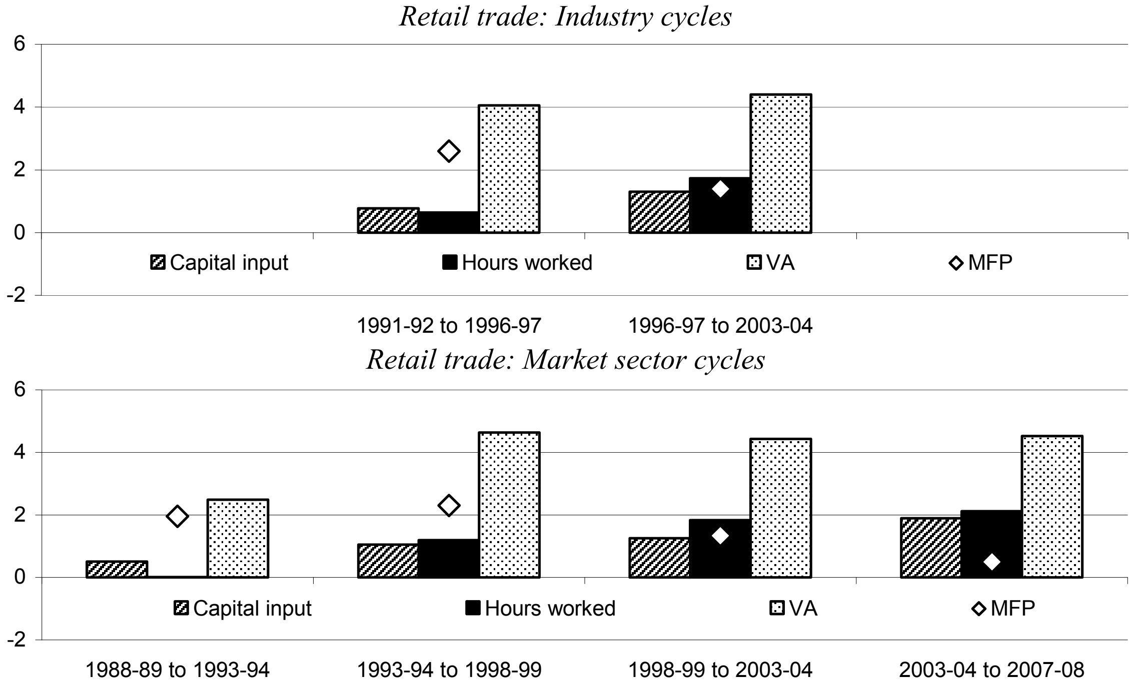
Financial & insurance services: Market sector cycles



Data source: Author's estimates based on ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002).

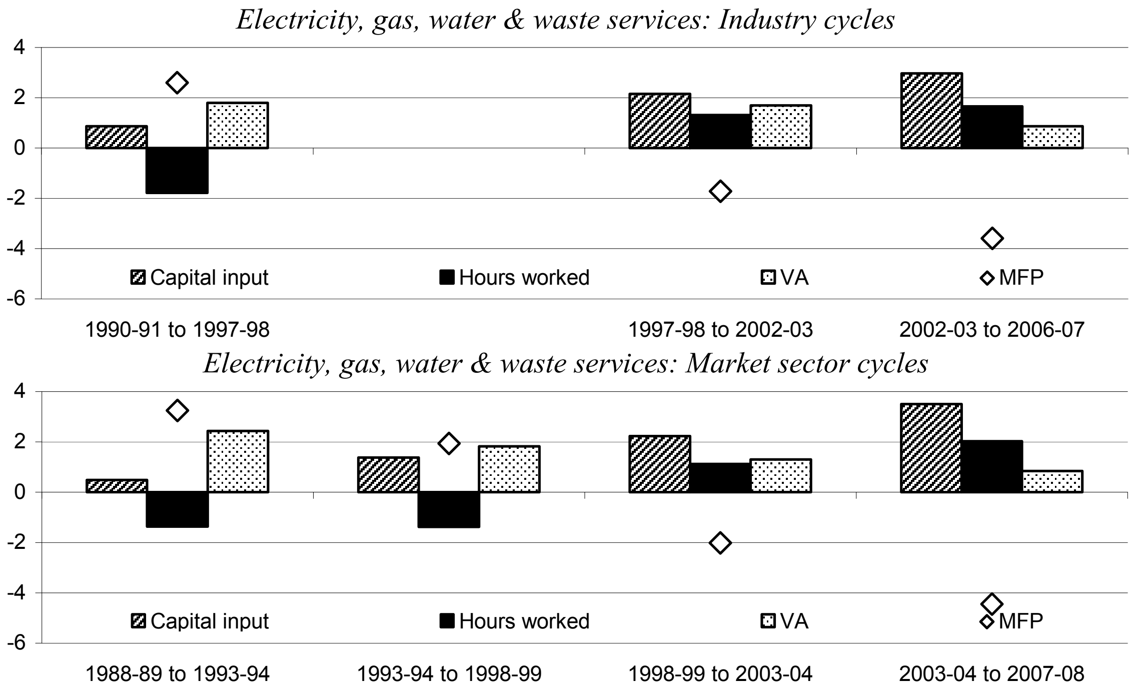
For the remaining industries in the market sector the choice of cycle affects the magnitude of average annual growth in the components of MFP but does not have a notable effect on the pattern of growth in these components between cycles. The figures for these industries are included below for completeness — Retail trade (figure A.8), Electricity, gas, water & waste services (figure A.9), Transport, postal & warehousing (figure A.10), Information, media & telecommunications (figure A.11), and Manufacturing (figure A.12). For Manufacturing only one figure is included because the industry and market sector cycles are identical.

Figure A.8 **Components of MFP growth in Retail trade, industry cycles and market sector cycles**
Per cent per year



Data source: Author's estimates based on ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002).

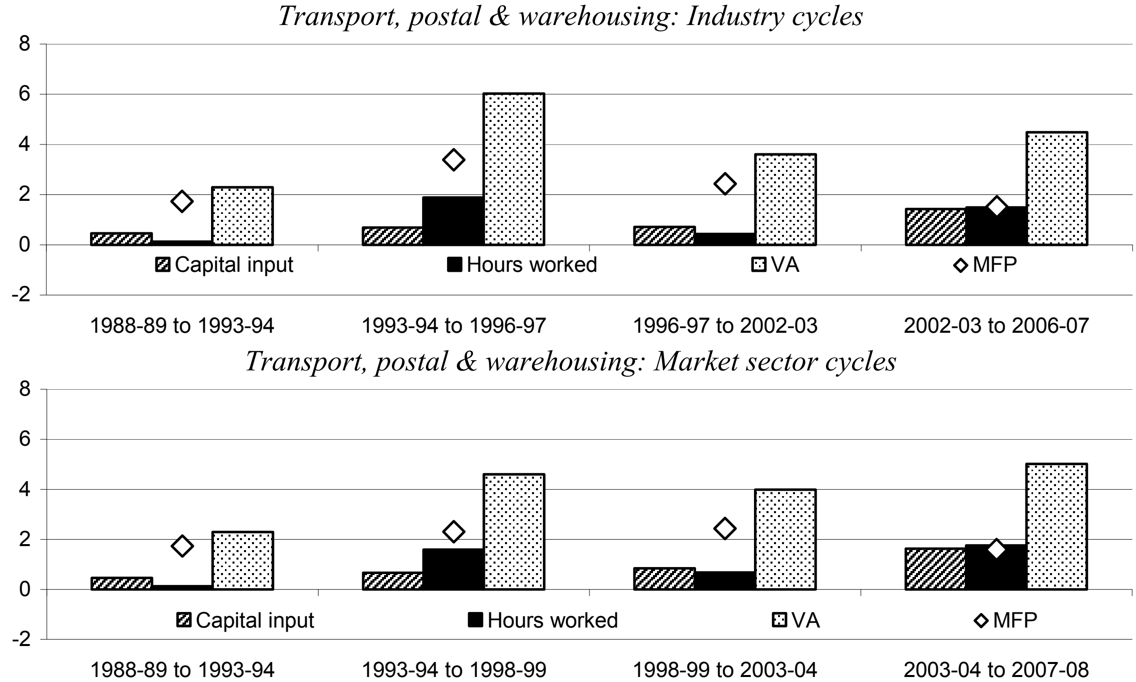
Figure A.9 **Components of MFP growth in Electricity, gas, water & waste services, industry cycles and market sector cycles**
Per cent per year



Data source: Author's estimates based on ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002).

Figure A.10 **Components of MFP growth in Transport, postal & warehousing, industry cycles and market sector cycles**

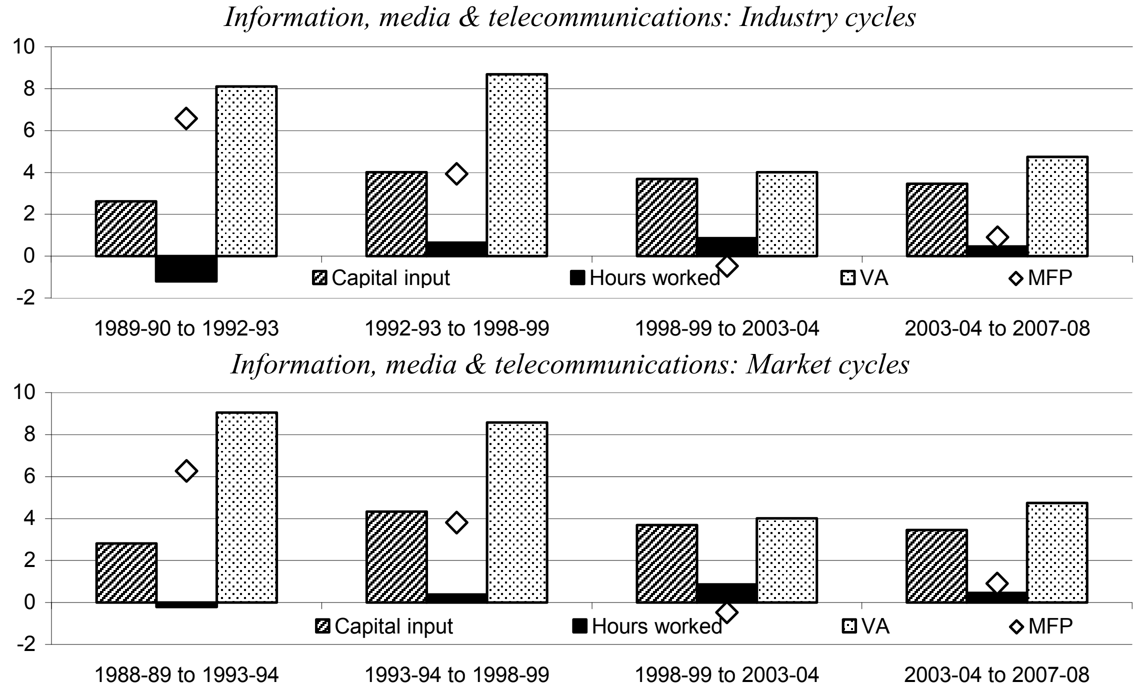
Per cent per year



Data source: Author's estimates based on ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002).

Figure A.11 **Components of MFP growth in Information, media & telecommunications, industry cycles and market sector cycles**

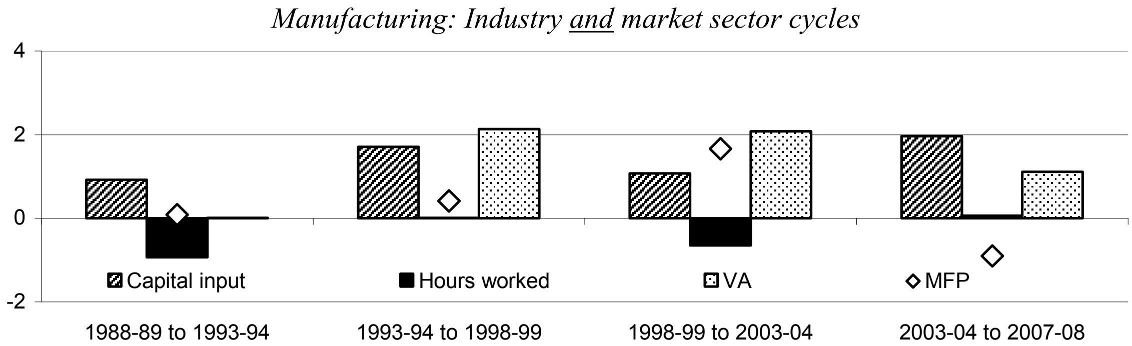
Per cent per year



Data source: Author's estimates based on ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002).

Figure A.12 **Components of MFP growth in Manufacturing, industry cycles and market sector cycles**

Per cent per year



Data source: Author's estimates based on ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2008-09,* Cat. no. 5260.0.55.002).

References

ABS (Australian Bureau of Statistics) 1996, *Australian National Accounts, Multifactor Productivity, 1994-95*, Cat. no. 5234.0, ABS, Canberra.

—— 1997, *Australian National Accounts, Multifactor Productivity, 1995-96*, Cat. no. 5234.0, ABS, Canberra.

—— 2000a, *Australian System of National Accounts: Sources, Concepts and Methods*, Cat. no. 5216.0, ABS, Canberra.

—— 2000b, 'Special article: The Sydney Olympic Games', *Australian Economic Indicators*, Cat. no. 1350.0, ABS, Canberra, August.

—— 2003a, *A Guide to Interpreting Time Series — Monitoring Trends*, Information Paper, Cat. no. 1349.0, ABS, Canberra.

—— 2003b, *Australian System of National Accounts, 2002-03*, Cat. no. 5204.0, ABS, Canberra.

—— 2005a, *An Introductory Course on Time Series — Electronic Delivery*, Information Paper, Cat. no. 1346.0.55.001, ABS, Canberra.

—— 2005b, 'Feature article — Estimates of productivity in the Australian National Accounts', *Australian System of National Accounts: National Income, Expenditure and Product, September, 2005*, Cat. no. 5206.0, http://www.abs.gov.au/ausstats/abs@.nsf/mf/5206.0 (accessed 6 August 2009).

—— 2006a, *Australian and New Zealand Standard Industrial Classification, 2006*, Cat. no. 1292.0, ABS, Canberra.

—— 2006b, *Australian and New Zealand Standard Industrial Classification, 2006 – Class Change Tables, 2006*, Cat. no. 1292.0.55.003, ABS, Canberra.

—— 2008, *Australian System of National Accounts, 2007-08*, Cat. no. 5204.0, ABS, Canberra.

—— 2010a, *Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2009-10*, Cat. no. 5260.0.55.002, ABS, Canberra.

—— 2010b, *Year Book Australia, 2009-10*, Cat. no. 1301.0, ABS, Canberra.

Annen, K. 2005, Hodrick-Prescott filter excel add-in, http://www.web-reg.de (accessed 9 August 2010).

Backus, D.K. and Kehoe, P.J. 1992, 'International evidence on the historical properties of business cycles', *American Economic Review*, vol. 82, no. 4, pp. 864–88.

Basu, S. and Fernald, J. 2000, *Why is Productivity Procyclical? Why Do We Care?*, Working Paper 2000-11, Federal Reserve Bank of Chicago, Chicago.

Bergen, D. van den, Rooijen-Horsten, M. van, Haan, M. de and Balk, B. 2008, *Productivity Measurement at Statistics Netherlands*, Statistics Netherlands Working Paper, The Hague.

Bureau of Labor Statistics (US) 1997, *Handbook of Methods*, Bureau of Labor Statistics, Washington DC.

Canova, F. 1999, 'Does detrending matter for the determination of the reference cycles and the selection of turning points?', *Economic Journal*, vol. 129, January, pp. 126–50.

—— and Ferroni, F. 2011, 'Multiple filtering devices for the estimation of cyclical DSGE models', *Quantitative Economics*, vol. 2, no. 1, pp. 73–98.

Enders, W. 2010, *Applied Econometric Time Series*, 3rd edition, Wiley, New Jersey.

Hamilton, J.D. 1994, *Time Series Analysis*, Princeton University Press, Princeton.

Harding, D. and Pagan, A. 2002, 'Dissecting the cycle: a methodological investigation', *Journal of Monetary Economics*, vol. 49, pp. 365–81.

—— and —— 2005, 'A suggested framework for classifying the modes of cycle research', *Journal of Applied Econometrics*, vol. 20, pp. 151–9.

Hodrick, R.J. and Prescott, E.C. 1997, 'Postwar U.S. business cycles: An empirical investigation', *Journal of Money, Credit and Banking*, vol. 29, no. 1, pp. 1–16.

Nelson, C.R. 2008, 'Trend/cycle decomposition', in Durlauf, S.N. and Blume, L.E. (eds), *The New Palgrave Dictionary of Economics*, 2nd edition, Palgrave Macmillan, http://www.dictionaryofeconomics.com/article?id=pde2008_T000221 (accessed 6 August 2010).

OECD (Organisation for Economic Cooperation and Development) 2001, *Measuring Productivity: OECD Manual*, OECD, Paris.

Parham, D. 2005, 'Is Australia's productivity surge over?', *Agenda*, vol. 12, no. 3, pp. 253–66.

PC (Productivity Commission) 2003, *Trends in Australian Manufacturing*, Commission Research Paper, Productivity Commission, Canberra.

—— 2005, *Trends in Australian Agriculture*, Productivity Commission Research Paper, Canberra.

—— 2009, *Submission to the House of Representatives Standing Committee on Economics: Inquiry into Raising the Level of Productivity Growth in Australia*, Canberra, September.

—— 2010, *Annual Report 2009-10*, Productivity Commission, Canberra.

—— 2011, Issues in measurement of industry productivity, http://www.pc.gov.au/research/productivity/estimates-trends/issues (accessed 28 February 2011).

Quiggin, J. 2001, 'The Australian productivity miracle: A sceptical view', *Agenda*, vol. 8, no. 4, pp. 801–17.

Ravn, M.O, and Uhlig, H. 2001, *On Adjusting the HP-Filter for the Frequency of Observations*, CESifo Working Paper No. 479, Center for Economic Studies & Ifo Institute for Economic Research, Munich.

SNZ (Statistics New Zealand) 2007, *Extracting Growth Cycles from Productivity Indexes*, Statistics New Zealand, Wellington.

—— 2010a, *Industry Productivity Statistics 1978–2008*, Statistics New Zealand, Wellington.

—— 2010b, *Productivity Statistics: Sources and Methods*, Sixth edition, Statistics New Zealand, Wellington.

Statistics Canada 2001, *Productivity Growth in Canada, Appendix 1 The Statistics Canada Productivity Program: Concepts and Methods*, Cat. no 15-204, Statistics Canada, Ottawa.

Statistics Netherlands 2010, *The Dutch Growth Accounts 2009*, Statistics Netherlands, The Hague.

Stock, J.H. and Watson, M.W. 1988, 'Variable trends in economic time series', *Journal of Economic Perspectives*, vol. 2, no. 3, pp. 147–74.

Topp, V., Soames, L., Parham, D. and Bloch, H. 2008, *Productivity in the Mining Industry: Measurement and Interpretation*, Productivity Commission Staff Working Paper, Canberra.

Zhang, X. and Conn, L. 2007, *Estimating the Cyclical Component from Annual Time Series*, ABS Research Paper, Cat. no. 1352.0.55.085, ABS, Canberra.