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Productivity in Electricity, Gas and Water: Measurement and Interpretation

Productivity Commission Staff Working Paper

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Preface

This staff working paper examines productivity trends in the Australian utilities industry and highlights some significant issues relating to the measurement and interpretation of changes in measured productivity over time.

Valuable comments and assistance were provided by various organisations and utility companies, especially from the: Australian Energy Market Operator, Australian Energy Regulator, Energy Networks Association, Energy Supply Association of Australia, Melbourne Water, Sydney Water, and Water Supply Association of Australia.

The Australian Bureau of Statistics (ABS) provided vital assistance through the provision of data, and advice on data issues and productivity measurement. Ben Loughton (ABS) deserves special mention for his assistance.

Don Brunker (formerly of the Productivity Commission) provided substantial assistance and advice during the course of the project. Helpful comments on the draft paper were also received from Glenn Otto (UNSW).

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

Abbreviations

ABS	Australian Bureau of Statistics
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
AGA	Australian Gas Association
ANCOLD	Australian National Committee on Large Dams Incorporated
ANZSIC	Australian and New Zealand Standard Industrial Classification
ANZSIC93	Australian and New Zealand Standard Industrial Classification, 1993 edition
ANZSIC06	Australian and New Zealand Standard Industrial Classification, 2006 edition
BIE	Bureau of Industry Economics
CVM	chain volume measure
COAG	Council of Australian Governments
CCGT	combined cycle gas turbine
EGW	Electricity, gas and water
EGWW	Electricity, gas, water and waste services
esaa	Energy Supply Association of Australia
ES	Electricity supply
GDP	gross domestic product
GFCF	gross fixed capital formation
GL	Gigalitres (equal to one thousand megalitres)
GS	Gas supply
GVA	gross value added
GW	Gigawatts (equal to one thousand megawatts)
IAC	Industry Assistance Commission
IC	Industry Commission
LP	labour productivity

kL	Kilolitres (equal to one thousand litres)
kV	Kilovolt (equal to one thousand volts)
MDB	Murray Darling Basin
DAB	Murray Darling Basin Authority
MFP	multifactor productivity
ML	Megalitres (equal to one thousand kilolitres)
MRET	Mandatory Renewable Energy Target scheme
MVa	Mega Volt Ampere
MW	Megawatt (equal to one thousand kilowatts)
MWh	Megawatt hours
NEM	National Energy Market
NDC	non-dwelling construction
NWC	National Water Commission
OECD	Organisation of Economic Cooperation and Development
PC	Productivity Commission
PIM	perpetual inventory method
PJ	Petajoule
PKS	productive capital stock
RET	Renewable Energy Target scheme
R&D	research and development
SCNPMGTE	Steering Committee on National Performance Monitoring of Government Trading Enterprises
SEQ	south east Queensland
TFP	total factor productivity
WS	Water supply
WSAA	Water Supply Association of Australia
WSSD	Water supply, sewerage and drainage services

OVERVIEW

Key points

- Multifactor productivity (MFP) growth in Australia's market sector has been considerably below average since 2003-04. Utilities (Electricity, Gas, Water and Waste services), have played a significant role in this, with MFP growth being strongly negative between 1997-98 and 2009-10 (MFP falling, on average, by 3.2 per cent per year).
- To better understand why, this study examined MFP at the subdivision level, with a particular focus on the two largest subdivisions — Electricity supply (ES), and Water supply, sewerage and drainage services (WSSD). MFP growth between 1997-98 and 2009-10 was negative for both ES (on average, -2.7 per cent per year) and WSSD (-4.3 per cent per year).
- Around half of the MFP decline in ES was due to an increase in the ratio of peak to average electricity demand, which lowered average rates of capacity utilisation. This was largely attributable to rapid growth in household use of airconditioners.
  - Three other contributors were: cyclical investment in lumpy capital assets, which temporarily increased inputs ahead of growth in output; a shift to greater undergrounding of electricity cabling, which raised costs and the quality of output, but not the volume of measured output; and policy induced shifts away from coal-fired power to higher-cost, but less polluting, sources of new supply.
- In WSSD, two developments contributed around 80 per cent of the decline in MFP after 1997-98. First, restrictions on water demand in response to widespread drought conditions led to lower measured output. Second, stricter sewage treatment standards increased industry costs, but there was no adjustment to measured output to account for the quality improvement.
  - Two other contributing factors were cyclical investment patterns, and a shift to higher-cost sources of new water supplies, particularly desalination plants, to improve water security.
- The negative influence on utilities MFP growth of two of these influences — the cyclical surge in new investment and the 2000s drought — is expected to be largely temporary. However, the remaining factors are structural, permanently raising input requirements in the industry (though in some cases bringing an increase in the quality of outputs).
- This study highlights some of the challenges involved in measuring and interpreting estimates of MFP growth in utilities.
  - A particular concern is the influence of changes in capacity utilisation arising from either cyclical investment patterns, or changes in the structure of electricity demand.
  - Also, government policies, regulatory settings and external shocks (especially the weather) can impact on the quantity or quality of measured output, and on the choice of production technology, thereby influencing estimates of MFP.

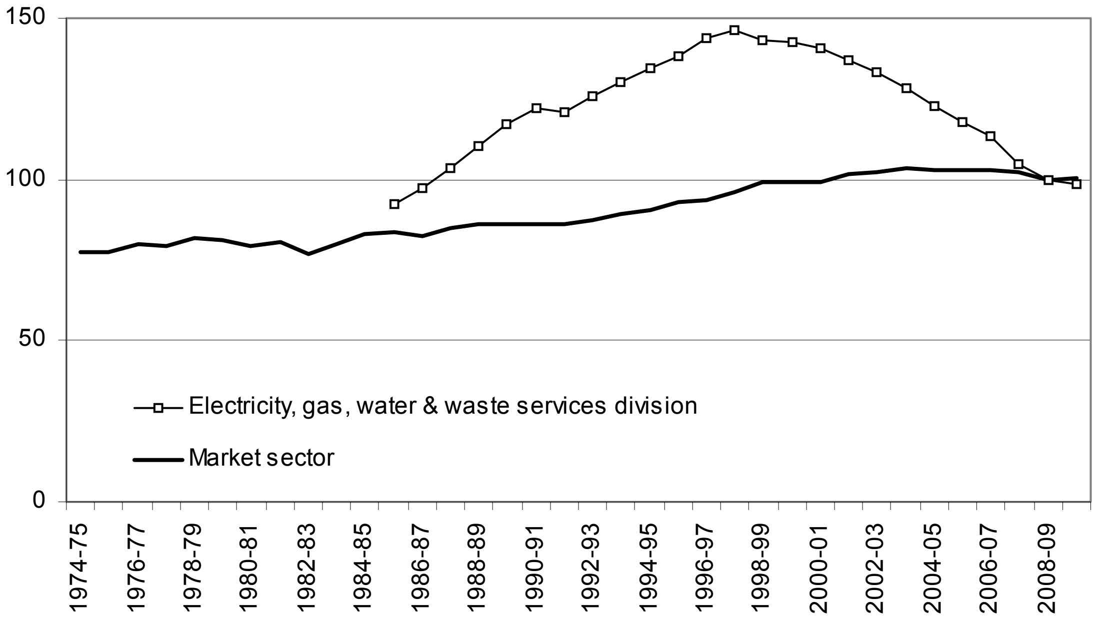
Overview

According to the Australian Bureau of Statistics (ABS), multifactor productivity (MFP) growth in Australia's market (non-government) sector has been well below average since the mid 2000s. This has led to a desire to better understand the driving forces behind the productivity changes, with a consequent focus on individual industries that have contributed significantly to the slowdown.

Although many industries within the market sector have recorded comparatively poor MFP growth at times during the past decade or so, the utilities industry (Electricity, gas, water and waste services) stands out due to the extent and duration of its productivity decline (figure 1).

Figure 1 **Multifactor productivity in the Market sector and in Electricity, gas, water and waste services (utilities), 1974-75 to 2009-10**

Index 2008-09 = 100



In the decade prior to 1997-98 MFP growth in the utilities industry was strongly positive, compared with the subsequent strongly negative MFP growth. The aim of this paper is to identify and, where possible quantify, the driving forces behind the observed trends in utilities MFP. This should assist further analysis and interpretation of movements in official productivity statistics, and inform the ongoing public debate and discussion on productivity outcomes and objectives.

Inputs, output and multifactor productivity

The ABS defines MFP as the ratio of output (value added) to the combined inputs of labour and capital, with output and inputs being measured in volume or quantity terms. It is a measure of a producer's ability to convert inputs into output.

MFP *growth* is defined as the difference in the growth of output and inputs. In theory, this reflects the rate at which new technologies and other innovations enable more output to be produced from the same quantity of inputs or equivalently the same output from less inputs.

However, interpretation of MFP growth statistics is not straightforward. At the economy and industry level, measured MFP growth may be influenced by a wide range of factors. Examples include the impact of structural changes in response to relative price shifts, regulatory change, responses to competitive pressures, and the entry and exit of businesses. Imperfection in the measurement of outputs and inputs can also distort the picture. Variation in capacity utilisation, unmeasured changes in the quality of inputs and outputs, as well as random measurement errors may creep into the MFP growth estimates.

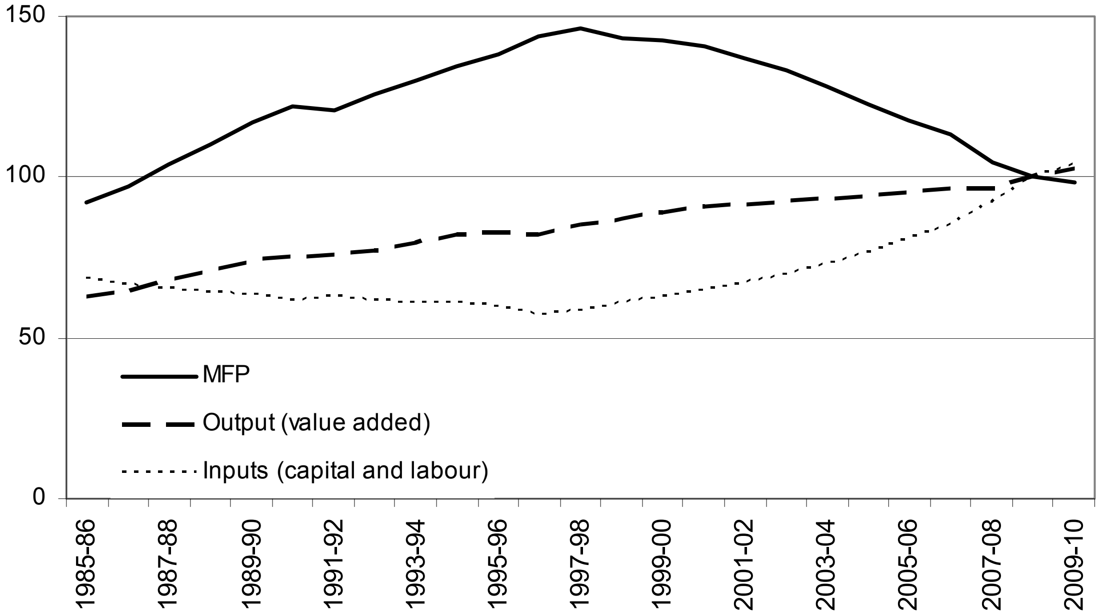
Impacts of these economic and measurement issues manifest themselves in different ways in the MFP statistics for different industries. Through examining the impact of these factors, this paper assists users of the statistics to better interpret and analyse the measured MFP growth in the utilities industry.

Trends in utilities MFP

The period of strong positive MFP growth in utilities from the mid-1980s to the late 1990s was characterised by comparatively strong growth in output alongside a reduction in inputs (figure 2). In the subsequent period from 1997-98 to 2009-10, output growth continued but at a more subdued rate, while inputs grew strongly. Hence MFP growth was negative during this period.

Figure 2 **Electricity, gas, water and waste services: Inputs, output and multifactor productivity, 1985-86 to 2009-10**

Index 2008-09 = 100



A key piece of the MFP puzzle in utilities, therefore, is to analyse the individual factors contributing to changes over time in input (and, less so, output) growth rates. To explore this issue, estimates were made of inputs, outputs and MFP within three of the four utilities subdivisions. The subdivision MFP estimates were derived using data and a methodology that was as consistent as possible with the approach used by the ABS to generate estimates of MFP in utilities as a whole.

Subdivision MFP estimates

The three subdivisions for which MFP growth was estimated were:

- Electricity supply (ES)
- Water supply, sewerage and drainage services (WSSD)
- Gas supply (GS).

Due to a lack of data, MFP estimates were not able to be produced for the fourth subdivision — Waste services. However, ABS data shows that the Waste services subdivision had only a small impact on the underlying developments and trends in utilities MFP.

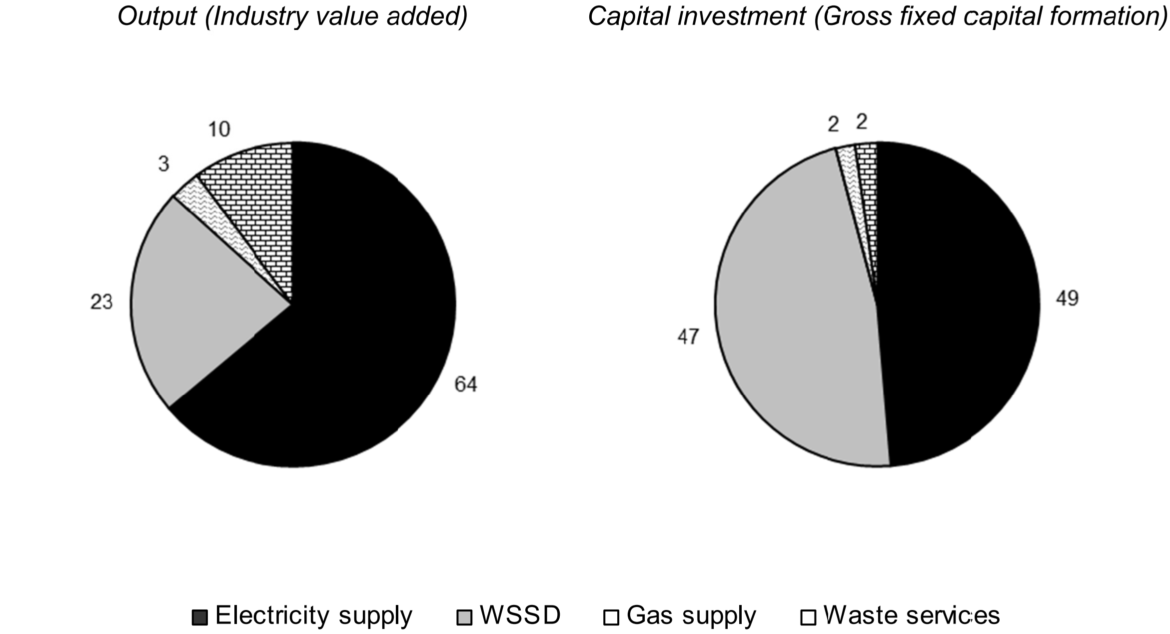
The subdivision MFP estimates were generated over a longer time frame (1974-75 to 2009-10) than the ABS estimates for the division as a whole (only available from

1985-86 onwards). This allowed for a more detailed assessment of the influences at work.

Two subdivisions — ES and WSSD — account for the vast majority of output and capital investment in utilities, and are most influential in the growth of utilities MFP (figure 3). Hence they are the focus of this study.

Figure 3 **Electricity, gas, water and waste services: output and capital investment shares in 2009-10**

Percentage share



While estimates of MFP in GS were also produced, they have not been analysed in as much detail for two reasons. First, GS represents only a small part of utilities, and hence has little impact on MFP results for the division as a whole. But more importantly, data and measurement issues are of significantly greater concern for GS, and cause uncertainty in the interpretation of measured MFP. For example, the industry classification system used by the ABS to define GS only covers gas distribution and retail activities, and excludes gas production and transmission activities. More information regarding the difficulties in measuring and interpreting MFP in this subdivision is contained in chapter 6.

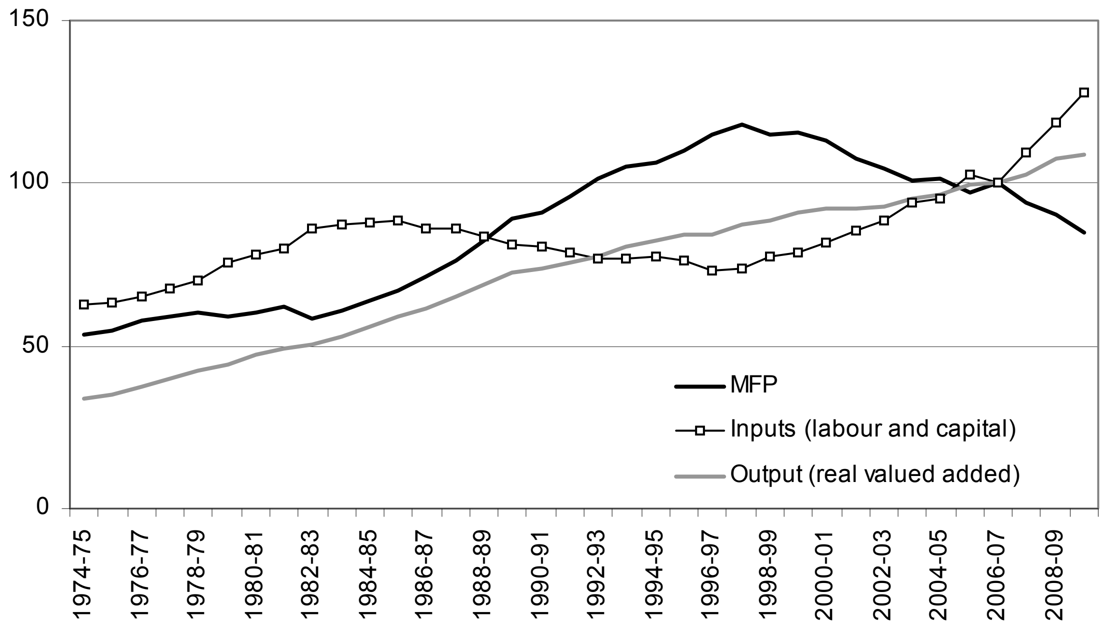
MFP in the Electricity subdivision

The MFP estimates for ES represent the combined productivity performance across the four sub-groups:

- electricity generation
- electricity transmission
- electricity distribution
- on selling electricity and electricity market operation.

Between 1974-75 and 2009-10, MFP growth in ES averaged around 1.2 per cent per year, but there were three distinct phases: an early period of moderate MFP growth; a middle period of strong positive MFP growth; and a period of strong negative MFP growth since 1998 (figure 4). Given the relative size of ES, this was the major reason for the decline in productivity in the utilities division as a whole from 1997-98 onwards.

Figure 4 **Electricity supply: inputs, output and multifactor productivity, 1974-75 to 2009-10**
Index 2006-07 = 100



The middle period of strong positive MFP growth in ES was mainly due to two factors. First, structural reforms allowed ES to use existing labour more efficiently and reduce labour inputs.

Second, unmeasured increases in capital utilisation meant that output grew with only minimal additions to new supply capacity. In essence, an overhang of generation and network capacity at the beginning of the period, which was due to excessive investment in supply capacity in the previous period, allowed an increase in the average rate of utilisation of capital capacity, and this contributed to strong, positive MFP growth.

Negative MFP growth in ES after 1997-98 was a result of a number of factors, including: growing relative peak demand for electricity during summer which led to further capacity investment but which lowered average capacity utilisation; a shift to higher cost underground electricity cabling; and a move away from large coal-fired power stations towards generally higher cost gas-fired power and renewable energy sources. In more recent years, a cyclical pattern of investment associated with replacing ageing network infrastructure assets may have added further (albeit temporary) downward pressure.

In the past decade, the more widespread use of residential air-conditioning in summer required substantial investment in generation and network infrastructure to meet the peak demand. As peak (maximum) daily electricity consumption grew more rapidly than average daily electricity consumption, this drove down average rates of capital utilisation, and put downward pressure on MFP. Although difficult to estimate with precision, these factors explained around one-half of the decline in the level of MFP in ES between 1997-98 and 2009-10.

There has also been a shift to higher cost underground electricity cabling since the late 1990s. This was largely driven by policy changes aimed at reducing some of the perceived disadvantages of overhead power lines. Although there were benefits from greater use of undergrounding that flowed to both electricity distributers and the broader community, the effect has been to lower measured MFP growth of the subdivision. This is because the quality benefits of undergrounding are not reflected in the ABS estimates of subdivision output, while the additional costs of undergrounding are included in inputs. Similarly, improvements in the reliability of electricity supply — particularly those in response to changes in regulatory standards and operating conditions — generally required more inputs to achieve, but did not show up as an increase in the volume of output.

In relation to changes in the technology of supply, a move away from coal-fired power during the period towards higher cost gas-fired power and renewable energy sources contributed to lower MFP in ES, albeit with the expectation that future economic losses (due to climate change) will be mitigated.

A final factor was the augmentation and renewal of electricity supply infrastructure. While some of the recent augmentation was due to the effects of growing relative peak demand, some also appears to reflect cyclical patterns of investment, in which periods of slow investment growth are followed by periods of rapid growth to replace ageing assets. An increase in the rate of investment in lumpy capital assets put temporary downward pressure on MFP in recent years.

However, whether all of the new investments were economically efficient is a more complex issue. Some commentators have claimed that growth in peak demand could have been better addressed through demand management, and that a significant amount of the new investment in recent years was premature or unnecessary. Were that true, the recorded MFP decline would largely represent genuine inefficiency. This has been strongly debated by regulators, users and suppliers. Any judgment on the matter is outside the scope of this study, though it is being considered as part of a Productivity Commission inquiry into benchmarking of electricity networks (due to report in April 2013).

Collectively, these four factors have increased input requirements per unit of measured output in utilities since the late 1990s, driving down MFP.

Operating in the opposite direction was the introduction of the National Energy Market (NEM). Interregional trade in electricity is now a feature of the eastern Australian electricity market, and has assisted the industry to respond to the challenges of growing peak demand and the consequences of reduced hydro-electricity production due to drought. In essence, the NEM should have boosted productivity levels in electricity supply by allowing more efficient use of generation and network capacity.

MFP growth in the Water supply, sewerage and drainage services subdivision

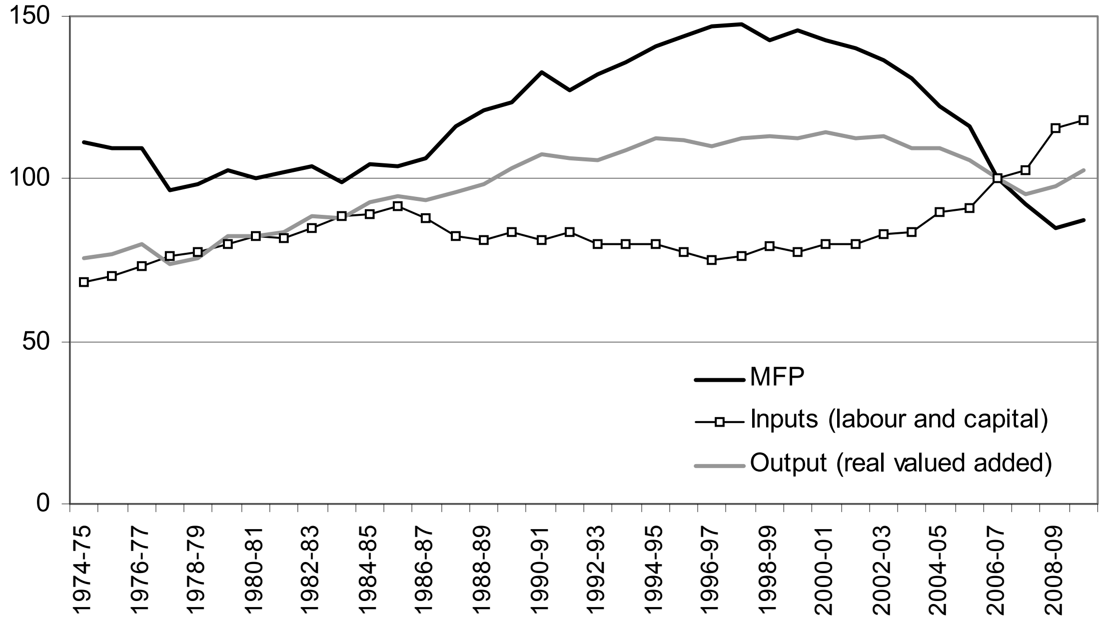
The major activities in the Water supply, sewerage and drainage (WSSD) subdivision are:

- urban water storage, treatment and distribution
- the collection, treatment and disposal of waste through sewer systems and sewage treatment facilities.

Multifactor productivity growth in WSSD was estimated to have been low on average, and variable over the longer term. There was a period of strong positive growth from the mid-1980s to the late 1990s (figure 5). Since then, however, annual productivity growth in the subdivision has generally been negative.

Figure 5 **Water supply, sewerage and drainage services: inputs, output and multifactor productivity, 1974-75 to 2009-10**

Index 2006-07 = 100



Like ES, MFP growth in WSSD from the mid 1970s onwards was characterised by three reasonably distinct phases: an early period of comparatively flat MFP growth; a middle period of strong positive MFP growth; and a more recent period of mostly negative MFP growth. Closer examination of movements in inputs and outputs in figure 5 indicates that the difference between the first two MFP phases was largely due to a marked reduction in inputs, while there was ongoing growth in outputs. In contrast, the recent period of negative MFP growth in WSSD was a consequence of both a rapid growth of inputs, and low or negative measured output growth.

Supply capacity built in the first phase (that is, during the period from the mid-1970s to the mid-1980s) caused measured inputs to rise at a rate that was broadly commensurate with growth in outputs. Hence MFP growth was comparatively weak. From the mid-1980s to the late-1990s, investment in new capital assets fell sharply, and labour inputs were cut as water utilities responded to structural and competition reforms. Output was able to continue growing during this phase on the back of pre-existing supply capacity. With positive output growth and negative input growth, measured productivity growth during the phase was particularly strong.

The negative MFP phase in WSSD that began in the late 1990s was due to some influences that are likely to be largely temporary in nature, but also to influences that are likely to have permanently reduced the level of productivity in the subdivision.

Two factors may ultimately prove to have only a temporary effect. First, measured output in WSSD (which is partly determined by the quantities of urban and irrigation water consumed each year) was negatively affected by drought during much of the early 2000s. This tended to result in lower measured MFP. If aggregate urban and rural water consumption responds to increased water availability over the next few years (due to both improved rainfall and dam inflows combined with newly established supply capacity), measured output could rise quite quickly relative to measured inputs. This would tend to boost future measured MFP growth. However, future water consumption may not revert to historical levels quickly even after the supply constraints have been resolved, reflecting the impact of water saving initiatives on people's attitudes to water use. Should this be the case, the recovery in MFP may take longer.

Second, an industry-wide surge in new urban water supply capacity underway from the mid-2000s until 2009-10 had a significant impact on measured inputs, but little impact on output as the majority of new supply projects (and their related network infrastructure) were not completed during the period. The surge in new investment temporarily drove down measured productivity. However, with new supply capacity now largely in place and expected to be more than adequate to meet demand growth into the medium term, measured input growth in the subdivision is likely to decline. Slower input growth will (all else equal) tend to result in faster MFP growth.

Whether WSSD can regain all of the productivity losses recorded since the late 1990s is a separate question. One of the factors that is likely to have permanently reduced the level of productivity in the subdivision has been a fundamental technology shift away from rain-fed dams towards the use of desalination and water recycling as the primary sources of new urban water supplies. In general, the latter two are high cost sources of supply compared to existing rain-fed dams. In this respect, a recent Productivity Commission inquiry into the urban water sector found that there were cheaper ways to augment water supplies than desalination plants. The implication is that MFP growth in WSSD was lower than it might have been, had the least cost supply augmentation options been chosen first.

Stricter environmental standards and regulations in relation to the treatment and disposal of sewage and waste water also resulted in a significant increase in capital and labour inputs. However, the benefits of the improved standards were not reflected in measured output — in effect, the quality of output was improved, but not the measured quantity — and the net effect on measured MFP of this development was negative. This is an area where an improvement in the measurement of output is desirable.

Explaining trends in utilities MFP

The broad trends in MFP illustrated in figure 1 largely reflect MFP trends in ES, the largest subdivision. Coincidentally, MFP trends in the next largest subdivision, WSSD, have been very similar to those in ES over the longer term. In this sense, the MFP results for both ES and WSSD are mutually reinforcing when it comes to explaining MFP changes in utilities as a whole, and the strongly negative growth in MFP since the late 1990s in particular. Measured MFP growth in GS had little impact on utilities MFP overall.

The factors identified in this study as impacting on MFP estimates in both ES and WSSD can be broadly summarised into the following four categories:

1. Cyclical investment
2. Output measurement
3. Shifts to higher cost technologies
4. Unmeasured quality improvements.

In general, strong cyclical investment patterns are common in utilities, and unmeasured changes in the utilisation of lumpy capital assets can show up as changes in measured MFP. While this factor has the potential to influence the variability of MFP estimates in utilities from time to time, its net effect over the longer term would ordinarily be minimal. However, to the extent that some investments are not efficient, then the impact on MFP may be more enduring.

Empirical challenges associated with measuring the volume of output in both major subdivisions also partly explain lower measured productivity in this industry since the late 1990s. In the case of WSSD, the adverse effect on MFP resulting from the way output is measured (using the quantity of water supplied during periods of drought, particularly when water restrictions are in place) is, however, likely to be only temporary. In contrast, the on-going impact on utilities MFP of the output measurement issue identified in ES (measuring changes in average, rather than peak, power consumption) is much harder to predict. For example, a further increase in relative peak demand cannot be ruled out, and to the extent this happens, there would be additional downward pressure on measured MFP growth in the division. Alternatively, if the ratio of peak to average demand could be reduced by, for example, the wider use of demand management, this would tend to have a positive impact on measured MFP growth.

Technological changes in response to environmental factors and policy requirements altered the production landscapes in both ES and WSSD from the late 1990s. The changes led to the introduction of higher cost sources of new supply in utilities, although they are expected to generate improved environmental outcomes. The adverse effects on measured productivity represent permanent increases in input requirements per unit of output. Looking ahead, continued shifts away from coal-fired power and rain-fed dams would tend to reduce further the measured level of MFP in utilities relative to what it might otherwise be.

Finally, unmeasured quality improvements in utilities output during the past 10 to 15 years increased average costs of production without any adjustment to measured output to reflect the quality change. The negative effects on measured productivity of the quality improvements again reflect structural changes to operating environments in utilities, and represent real increases in the quantity of inputs required to produce output. Further tightening or strengthening of standards and regulations that increase production costs will continue to show up as reductions in measured MFP as long as associated quality changes are not reflected in measured output.

While some of the empirical and conceptual issues surrounding the measurement of productivity in utilities have been explored in detail in this study, there is scope for further investigation. In particular, more effort is required on the issues of capital utilisation and output measurement in utilities.

More broadly, this study has highlighted the need for caution when trying to interpret the causes of MFP change at the industry level. Detailed studies of industry productivity can help to better understand the nature and significance of the forces behind changes in official MFP statistics.

1 Introduction

There has been a widely reported slowdown in market sector multifactor productivity (MFP) growth in the 2000s compared with the 1990s.[1] Although a number of industries contributed to the slowdown — particularly manufacturing, agriculture and mining — the utilities division stands out because of its unusually poor MFP performance over a sustained period of time.[2]

The Australian Bureau of Statistics (ABS) estimates of MFP growth in the Electricity, gas, water and waste services division (commonly referred to as *utilities*) were negative between 1997-98 and 2009-10. This contrasts with generally positive and strong MFP growth for utilities in the decade or so leading up to that year (figure 1.1).

While the ABS has been publishing estimates of MFP for the market sector for over twenty five years, it has only been publishing MFP estimates at the industry level since 2007, and still refers to the latter as *experimental.*[3] Nevertheless, the industry MFP estimates published by the ABS are a key component of the aggregate productivity story in Australia, and this is likely to remain the case in the future. For this reason, it is important that effort and attention are given to better understanding and explaining how industry MFP estimates are derived by the ABS, and why they change the way they do over time.

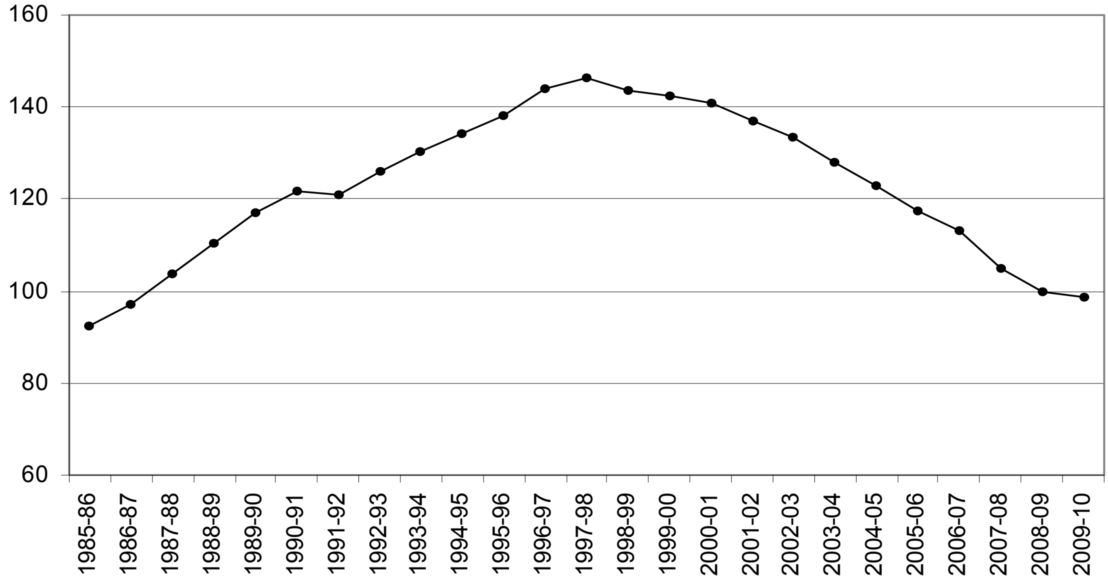
1 The *market sector* is defined by the ABS and includes those industries or divisions of the economy where prices are generally used in the exchange of goods and services. It excludes hard to measure sectors of the economy such as government administration, defence, education and health (see ABS 2010 and 2011) for more information.

2 Productivity Commission (PC 2008a and 2010) reviewed in detail aggregate productivity growth developments in Australia in the 2000s.

3 ABS (2007) outlined the development of division-level MFP estimates for Australia.

Figure 1.1 **Multifactor productivity[a] in the Electricity, gas, water and waste services division, 1985-86 to 2009-10**

Index 2008-09 = 100



a Multifactor productivity (MFP) is measured by the ABS as a ratio of output (gross value added measured in real or volume terms) to a composite index of the volume of labour and capital inputs. Changes over time in MFP therefore reflect changes in the ratio of output to inputs, where both output and inputs are measured in volume or quantity terms. The concept of MFP is discussed in more detail in chapters 4 to 6 and in appendix A.

Data source: ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2009-10,* Cat. no. 5260.0.55.002).

1.1 Project aims and outcomes

The aim of this paper is to identify and, where possible quantify, the driving forces behind the observed trends in utilities MFP. A better understanding of the driving forces should assist further analysis and interpretation of movements in official productivity statistics, and inform the ongoing public debate and discussion on productivity outcomes and objectives.

More broadly, this project is part of a program of research at the Productivity Commission aimed at better understanding productivity trends and developments across a number of key divisions or sectors of the economy.[4] The identification of possible improvements to the way official productivity statistics are estimated and

4 For example, an earlier Productivity Commission study investigated productivity trends and developments in Australia’s Mining division, and highlighted a number of important issues that influence the ABS estimates of productivity growth in this industry (Topp et al. 2008).

interpreted for individual divisions or subdivisions of the market sector is a related goal.

1.2 Project methodology and approach

The ABS define MFP as the ratio of output (value added) to the combined inputs of labour and capital, with output and inputs measured in volume or quantity terms. It is a measure of a producer's ability to convert inputs into output.

MFP *growth* is defined as the difference in the growth of output and combined inputs. In theory, this reflects the rate at which new technologies and other innovations enable more output to be produced from the same quantity of inputs or equivalently the same output from less inputs.

However, interpretation of MFP growth statistics is not straightforward. At both the economy and industry levels, measured MFP growth may be influenced by a wide range of factors which include, for example, the impact of changes in the business operating environment, regulatory change, economies of scale, business cycles and the entry and exit of businesses. Imperfection in the measurement of outputs and inputs can also distort the picture. Variation in capacity utilisation, capital/input lags, unmeasured changes in the quality of inputs and outputs, as well as random measurement errors may creep into the MFP growth estimates.

Impacts of these economic and measurement issues manifest themselves in different ways in the MFP statistics for different industries. Given this, the approach taken in this paper involves two major steps. First, to review the way the ABS generates estimates of inputs and outputs when deriving utilities MFP. Second, to identify the key factors and forces — including policy changes and other external events impacting on businesses operating within utilities — that might explain why the ratio of output to inputs has changed over time.

A key feature of this work is the disaggregation of the division into its major subdivisions, and the measurement and analysis of MFP separately for each. The subdivision productivity estimates presented in this paper provide deeper insights into the nature and significance of MFP changes occurring at the aggregate utilities level. Moreover, measurement issues and the underlying factors determining MFP growth are likely to vary across subdivisions, and hence are best reviewed separately.

1.3 Organisation of this study

Chapter 2 assesses the decline in MFP within utilities over the past decade or so, including its contribution to the decline in MFP in the market sector overall. Also included are basic explanations and definitions of key terms and data sources for the official MFP statistics. Chapter 3 presents estimates of MFP growth for three subdivisions of utilities — Electricity supply (ES), Gas supply (GS), and Water supply, sewerage and drainage services (WSSD).

In chapters 4 to 6 the subdivision MFP estimates are explained and examined in more detail. Important factors influencing the observed changes in inputs and outputs are discussed, and in some cases quantified. Chapter 7 ties together the results from the subdivision analyses to provide a synthesis of productivity developments at the aggregate level. Implications regarding the measurement and interpretation of the ABS estimates of MFP in utilities are discussed.

1.4 Related Productivity Commission research

While this study is focussed on measuring and interpreting productivity trends in the utilities sector, two recent Productivity Commission inquiries — one into the electricity network sector, and one into the urban water sector — also examine some of the issues raised.

An inquiry into the electricity network sector (which was announced in late 2011 and is due to report in April 2013) will review, amongst other things, the use of benchmarking as a means of achieving the efficient delivery of network services and electricity infrastructure.

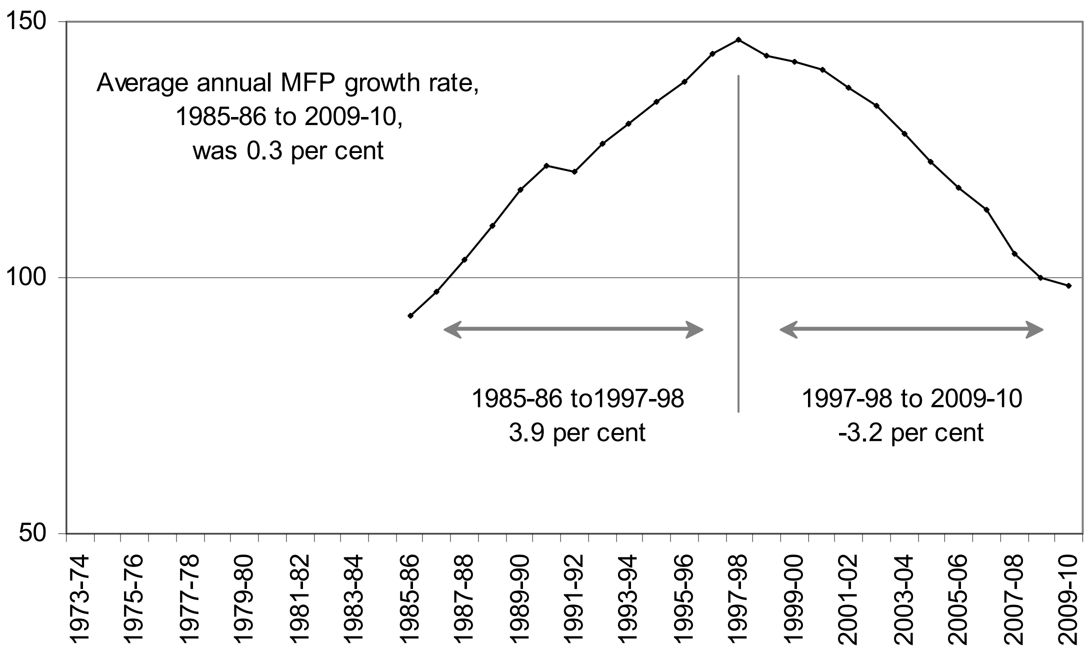
In relation to the water sector, the final report of the Commission's inquiry into urban water was released last year, and considered a broad range of issues including the case for microeconomic reform in the urban water sector, and possible pathways to achieving improved resource allocation and efficiency (PC 2011b).

2 Declining MFP in the utilities division

ABS estimates of MFP in the utilities division between 1985-86 and 2009-10 tell a story of two halves. During the first half of this period MFP growth in utilities was positive and strong, while after 1997-98 measured MFP growth was strongly negative (figure 2.1).

Figure 2.1 **MFP in Electricity, gas, water and waste services, 1985-86 to 2009-10**

Index 2008-09 = 100



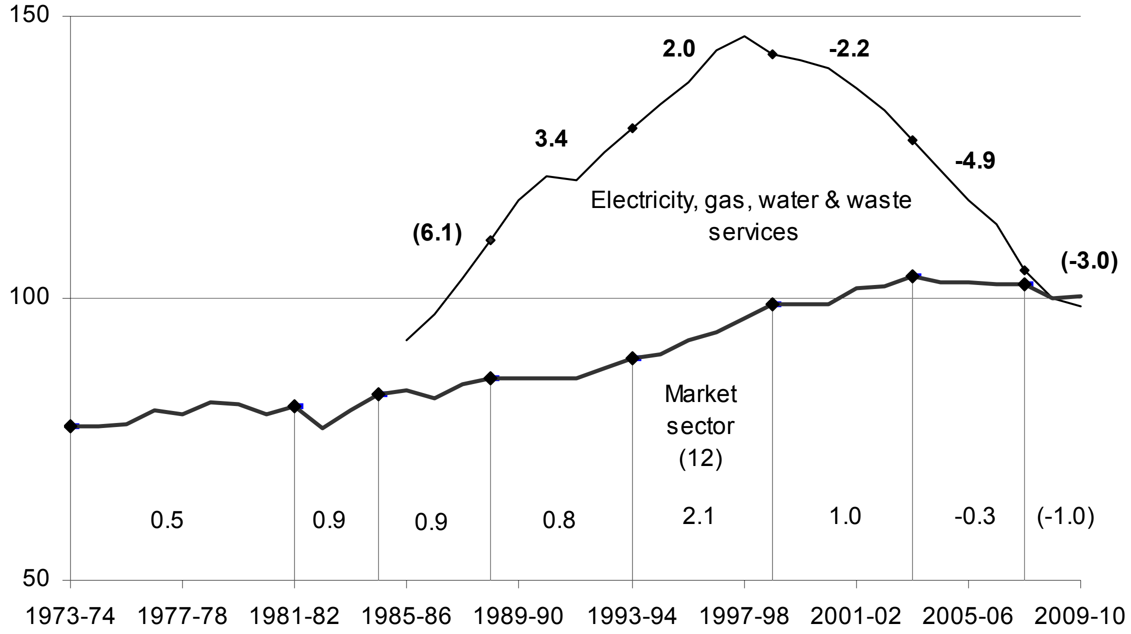
Data source: ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2009-10,* Cat. no. 5260.0.55.002).

2.1 Impact on the market sector

The decline in utilities MFP after 1997-98 contributed to the broader slowdown in market sector MFP growth in the 2000s (figure 2.2).

Figure 2.2 **Market sector[a] and utilities division MFP indexes and growth rates across market sector productivity cycles,[b] 1973-74 to 2009-10**

Index 2008-2009 = 100 and per cent per year



a The market sector consists of 12 selected industries (ANZSIC06 Divisions A to K and R). **b** Market sector productivity cycles as defined by the ABS. Numbers on the chart are average annual growth rates within each designated cycle. Figures in parenthesis indicate that the average value refers to an incomplete cycle. ABS estimates of MFP in utilities (EGWW) are only available from 1985-86 onwards. In the market sector MFP cycle from 1984-85 to 1988-89, the average growth rate of MFP in EGWW covers the period from 1985-86 to 1988-89 only.

Data source: ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2009-10,* Cat. no. 5260.0.55.002).

During the most recently completed market sector productivity cycle (2003-04 to 2007-08),[1] average MFP growth in utilities was -4.9 per cent — the largest decline in percentage terms among the 12 market sector industries (table 2.1). For the same period, average annual MFP growth for the whole of the market sector was -0.3 per cent — well below its longer term average (1973-74 to 2009-10) of 0.7 per cent.

Utilities is the only division to have made a negative contribution to market sector MFP in each of the two most recently completed cycles — that is, 1998-99 to 2003-04 and 2003-04 to 2007-08 (table 2.1). And while the division is comparatively small — it accounted for just 3.4 per cent of market sector output in

1 Trends and developments in market sector productivity are usually assessed in relation to formal productivity *cycles*, as defined by the ABS. The cycles — which vary in length but are typically around 4 to 5 years in duration — are an attempt to smooth out the effects of unusual year-on-year changes such as those caused by recessions or droughts. For more information see ABS (2010) and PC (2010, pp. 55-74).

2009-10 and 2.3 per cent of total hours worked (see table 2.2) — the decline in utilities MFP during the last two productivity cycles was a major drag on market sector MFP growth.[2]

Table 2.1 Average annual MFP growth, by division and market sector cycles

Per cent per year

	ABS market sector productivity cycles				
Industry	*1985-86 to 1988-89*	*1988-89 to 1993-94*	*1993-94 to 1998-99*	*1998-99 to 2003-04*	*2003-04 to 2007-08*
Agriculture, forestry & fishing	0.7	4.1	4.0	3.4	-1.5
Mining	2.6	2.7	0.7	0.0	-4.2
Manufacturing	2.0	-0.2	0.7	1.5	-1.3
Electricity, gas, water & waste services	**6.1**	**3.4**	**2.0**	**-2.2**	**-4.9**
Construction	-2.4	-0.6	2.5	1.1	0.7
Wholesale trade	1.3	-2.2	5.4	1.4	0.1
Retail trade	-2.3	1.7	2.1	1.2	0.3
Accommodation & food services	-1.9	-0.8	1.7	0.7	0.4
Transport, postal & warehousing	1.5	1.2	2.1	1.7	0.4
Information, media & telecommunications	3.9	5.8	2.9	-0.7	0.2
Financial & insurance services	3.7	4.6	1.1	0.8	3.1
Arts & recreation services	-2.3	-1.6	-1.9	1.3	-1.3
Market sector[a]	**0.9**	**0.8**	**2.1**	**1.0**	**-0.3**

[a] The market sector consists of the 12 selected industries (ANZSIC06 Divisions A to K and R).

Source: ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2009-10,* Cat. no. 5260.0.55.002).

2 Note that the pattern of MFP growth in utilities does not always equate or coincide with the market sector productivity cycles defined by the ABS. While some care should be taken when comparing or considering average growth rates in utilities MFP based on the market sector cycles, the central issue at hand — negative MFP growth in utilities since the late 1990s contributing to a slowdown in market sector MFP growth — is unambiguous. A recent PC research report (Barnes 2011) examined the issue of productivity cycles at the industry level in detail.

Table 2.2 **Division shares of market sector output, hours worked, and capital investment, 2009-2010**

Per cent

Industry	*Industry gross value added*[b]	*Hours worked*	*Gross fixed capital formation*[b]
Agriculture, forestry & fishing	3.7	6.8	6.4
Mining	13.6	3.4	25.6
Manufacturing	15.2	16.6	12.2
Electricity, gas, water & waste services	**3.4**	**2.3**	**13.0**
Construction	12.8	17.0	4.6
Wholesale trade	7.9	7.2	3.7
Retail trade	7.2	15.4	3.3
Accommodation & food services	3.7	9.3	1.8
Transport, postal & warehousing	8.4	9.6	17.6
Information, media & telecommunications	5.3	3.4	6.0
Financial & insurance services	17.3	6.5	3.8
Arts & recreation services	1.3	2.5	2.1
Market sector[a]	**100.0**	**100.0**	**100.0**

[a] The market sector consists of the 12 selected industries (ANZSIC06 Divisions A to K and R). [b] Current prices.

Sources: ABS (*Australian System of National Accounts, 2009-10*, Cat. no. 5204.0) on dXtime (database); ABS (*Labour Force Statistics*) on dXtime (database).

2.2 The rise and fall of utilities MFP

Two questions arise from the above: first, why did productivity in utilities grow so strongly between 1985-86 and 1997-98; and second, why did it fall so dramatically after 1997-98?

To answer these questions (and the first question in particular) it would be advantageous if productivity estimates for utilities were available *prior* to the mid-1980s, not just from the mid-1980s onwards. In essence, a longer time series could potentially provide more insight into the driving forces behind the period of strong positive growth as well as the more recent period of negative MFP growth.

Current ABS estimates of utilities MFP go back only as far as 1985-86 (ABS 2011). The Productivity Commission has previously extended an older ABS series of utilities MFP back to 1974-75. This longer-running series is, however, based on a superseded definition of the utilities division that included just three subdivisions — *Electricity supply*, *Gas supply*, and *Water supply, sewerage and drainage services (EGW)* — rather than the more recent definition of utilities that adds a forth subdivision, *Waste services*.[3]

A comparison of the two MFP series shows that their main features — the steep rise and subsequent fall in MFP — are essentially the same (see figure 2.3). In essence, the addition of *waste services* to the division did not substantially change the broad trends and developments in utilities MFP over time. On this basis, the Commission has used the longer-running EGW MFP series to help explain longer term trends and developments in productivity in the division.[4] In particular, it allows an examination of productivity developments in utilities prior to the mid-1980s. An added advantage of using data and definitions based on the older ANZSIC93 industry classification scheme is that longer time series can also be estimated for the individual subdivisions — the subject of chapters 3 to 6.[5]

Using the *EGW* series in figure 2.3, the long-run average rate of MFP growth in utilities is 1.2 per cent per annum. This is above the current long-term average figure for the market sector as a whole (0.7 per cent). The path by which the utilities division achieves this outcome remains a substantive issue however, particularly in relation to negative MFP growth after 1997-98.

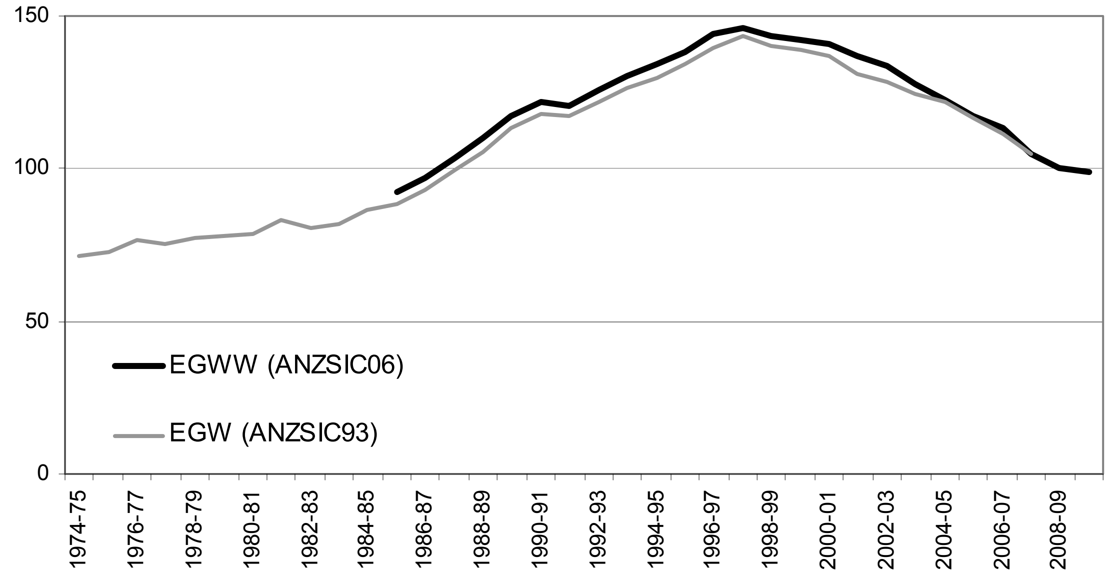
3 Primary activities in the newly constructed *Waste collection, treatment and disposal services* subdivision include: garbage disposal; operating landfills and rubbish dumps; and cleaning up contaminated building and mine sites. Note also that the new *Waste* subdivision did not exist prior to the introduction of the latest industry classification scheme (*Australia and New Zealand Industry Classification Scheme 2006*) — rather, its constituent parts were classified to divisions other than EGW under ANZSIC93. For more information regarding the industry classification changes embodied in the move to the new ANZSIC06 classification scheme see ABS *Australian and New Zealand Standard Industrial Classification 2006 ANZSIC*, Cat. no. 1292.0.

4 Strictly speaking, the longer-running *Electricity, gas and water* (*EGW)* MFP series shown in figure 2.3 comprises PC estimates of utilities MFP for the period from 1974-75 to 1985-86, which have effectively been spliced onto previously published ABS estimates of MFP in EGW covering the period from 1985-86 to 2007-08. The latter are available from ABS *Experimental Estimates of Industry Multifactor Productivity*, Cat. no. 5260.0.55.002.

5 This is because the ABS provides longer time series data for some key variables (at the subdivision level) using the superceded industry classification scheme (that is, ANZSIC93).

Figure 2.3 **Multifactor productivity in the utilities division, effect of ANZSIC changes, 1974-75 to 2009-2010**

Index 2008-09 = 100



[a] EGW stands for Electricity, gas and water division (based on the ANZSIC93 industry classification), while EGWW stands for Electricity, gas, water and waste services, and is based on ANZSIC06.

Data sources: ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates,* Cat. no. 5260.0.55.002, various years); Commission estimates.

2.3 Three phases of MFP growth in the utilities division

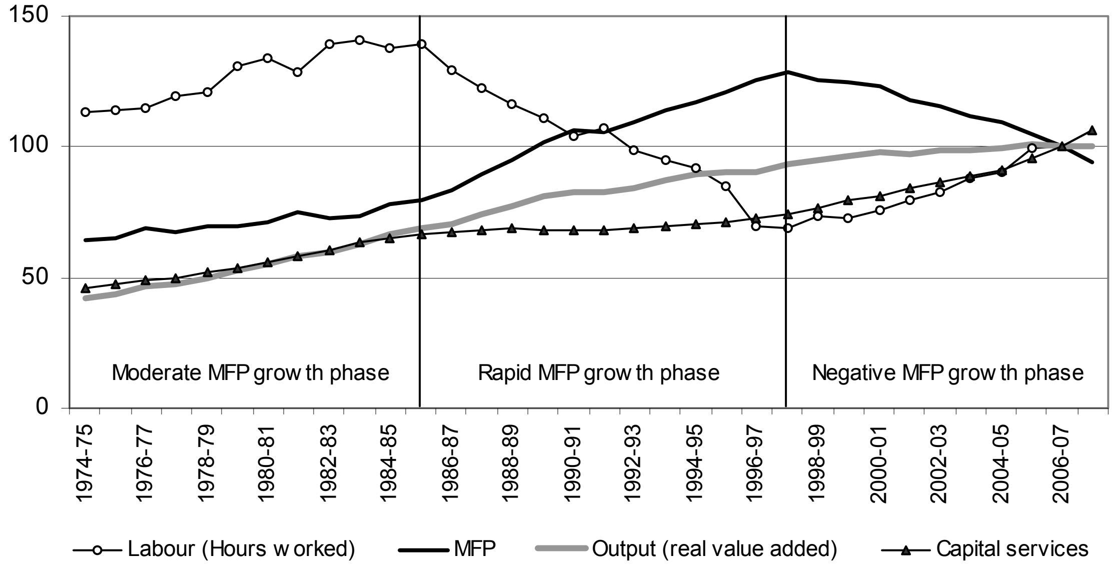
Based on the MFP series for EGW and EGWW shown in figure 2.3, productivity growth in utilities can be characterised as having three reasonably distinct phases:

1. A moderate positive growth phase from 1974-75 to the mid-1980s
2. A rapid positive growth phase from the mid-1980s to the late 1990s
3. A strong negative growth phase from the late 1990s to the present.

To understand the source of MFP growth in the three phases it is useful to disaggregate the MFP series for EGW into its component parts — labour and capital inputs, and output. This shows that the early, *moderate MFP growth* phase was characterised by strong growth in output that outweighed slightly weaker (but still positive) growth in inputs (figure 2.4 and table 2.3). In contrast, the *rapid MFP growth* phase comes on the back of markedly declining labour inputs, slower growth in capital inputs, with only a minor reduction in the rate of output growth. In the final *negative MFP growth* phase, output growth slowed further, while growth rates of labour turned strongly positive and capital input growth accelerated. Hence MFP growth in the period is negative.

Figure 2.4 **Inputs, output and MFP in EGW,[a] 1974-75 to 2007-08**

Index 2006-07 = 100



a Electricity, gas and water division. The vertical lines represent cut-off points for dividing the overall time period covered into three distinct MFP phases. MFP estimates using the EGW classification are only available up to 2007-08.

Data sources: ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates,* Cat. no. 5260.0.55.002, various years); Commission estimates.

Table 2.3 **Utilities division,[a] average annual growth rates in, MFP, output and inputs, by MFP growth phase,[b] 1974-75 to 2007-08**

Annual average growth rates in each phase, per cent

	Moderate MFP growth phase (1974-75 to 1985-86)	*Rapid MFP growth phase (1985-86 to 1997-98)*	*Negative MFP growth phase (1997-98 to 2007-08)*	*Full period (1974-75 to 2007-08)*
MFP	**2.0**	**4.1**	**-3.1**	**1.2**
Output	4.6	2.6	0.7	2.7
Labour	1.9	-5.7	4.4	-0.2
Capital	3.5	0.9	3.7	2.6

a Electricity, gas and water division. **b** The turning point chosen for the first to second phase is essentially arbitrary, although moving it slightly does not change the substantive results.

Sources: ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates,* Cat. no. 5260.0.55.002, various years); Commission estimates.

The need for disaggregation

The proximate analysis of MFP described above allows the key questions to be reframed. First, in regard to the *rapid MFP growth* phase, how is it that output can continue to grow while labour inputs are falling rapidly and capital inputs are comparatively stagnant? Similarly, in relation to the negative MFP growth phase, how is it that output growth can be so slow while labour and capital inputs are growing at record or near record pace? To begin answering these questions, EGW is first disaggregated into its three subdivisions, with MFP measured separately for each.

3 MFP by subdivision

3.1 Subdivision MFP

This chapter presents estimates of MFP for three subdivisions within utilities:

1. Electricity supply (ES)
2. Gas supply (GS)
3. Water supply, sewerage and drainage services (WSSD).

The subdivision MFP estimates have been derived to approximate as closely as possible the methodology and data sources used by the ABS when producing division-level estimates. However, they are nevertheless *authors' estimates*, and are not official productivity statistics. This approach was taken as this study seeks to examine reasons for the ongoing decline in MFP at the division level, as reflected in the published ABS estimates.

Industry classification changes

As noted in chapter 2, recent changes to the industry classification scheme used by the ABS to divide the economy into its component parts mean that the utilities division now includes a fourth subdivision — *Waste collection, treatment and disposal services* — and on the surface this is a potentially significant change. The waste subdivision is smaller than the electricity and water subdivisions, but larger than the gas subdivision, at least on the basis of key metrics — see table 3.1.

Unfortunately the time-series information required to develop MFP estimates for the new subdivision — *Waste collection, treatment and disposal service*s — is not available. It is also the case that the addition of the new subdivision did not fundamentally change the MFP story for the utilities division. That is, comparing MFP trends in both EGW and EGWW shows no major differences over time. In particular, measured productivity growth in utilities is negative for the last decade or so, and this is having a significant adverse effect on productivity in the market sector overall.

Table 3.1 Subdivision shares of utilities division output and employment under old and new ANZSIC classifications[a]

Per cent

ANZSIC93			*ANZSIC06*		
Subdivisions	*Industry value added share 2005-06*	*Employment share 2005-06*	*Subdivisions*	*Industry value added share 2008-09*	*Employment share 2008-09*
Electricity supply	70	63	Electricity supply	64	47
Gas supply	6	3	Gas supply	3	2
Water supply, sewerage & drainage services	24	34	Water supply, sewerage & drainage services	23	25
			Waste collection, treatment & disposal services	10	26
Total Electricity, gas & water (EGW)	100	100	Total Electricity, gas, water & waste (EGWW)	100	100

[a] Output (industry value added) is measured in current price terms, while employment is measured in terms of numbers.

Sources: ABS (*Australian Industry, 2008-09*, tables 81550DO002_200809. Cat. no. 8155.0); ABS (*Electricity, Gas, Water and Sewerage Operations, Australia, 2005-06*, tables 82260DO001. Cat. no. 8226.0).

In this case it seems reasonable to conclude that if the MFP story within the three original subdivisions can be explained satisfactorily, this will go a long way to explaining developments in the utilities division overall — whatever definition of utilities is used. Also, the data collected and reported by the ABS using the older ANZSIC classification system allows the production of longer time-series estimates of MFP for each the three original subdivisions. This allows for a more detailed assessment of the key issues at work.

Developing MFP estimates at the subdivision level is challenging, however, irrespective of the choice of industry classification. In particular, there are the usual difficulties associated with obtaining accurate and consistent time-series data on individual inputs and outputs, and the other variables required to estimate MFP. While every effort has been made to derive the best possible estimates, compromises have been made due to gaps in data and/or inconsistencies in collection methodologies and variable definitions.[1] In light of this, the estimates should be seen as representing a *first step* in developing a consistent set of subdivision productivity estimates for the utilities division, and further refinement of the estimates is desirable should additional data become available. Particular problems with the quality of the MFP estimates for Gas supply are discussed in chapter 6.

3.2 Relative importance of the different subdivisions

ABS industry survey data show that the most important subdivision within utilities is Electricity supply. Under the previous ANZSIC93 classification system, Electricity supply accounted for around 70 per cent of division output (value added), and 63 per cent of employment (table 3.1). Water supply accounted for 24 per cent of output, and Gas supply was 6 per cent of output. In general therefore, explaining productivity developments in two subdivisions — Electricity supply and Water supply — will go a long way to explaining MFP developments in the utilities division as a whole.

One reason for the comparatively small size of GS is that the scope of activities within the ANZSIC classification scheme is more limited for GS compared with ES and WSSD.[2] Specifically, under the ANZSIC classification system, ES covers a broad range of activities including electricity generation, transmission, distribution, and retailing. Similarly, WSSD covers urban and irrigation water supply (which encompasses the operation of dams, desalination and recycling plants, drinking water treatment facilities, and water distribution networks), as well as the collection, treatment and disposal of sewerage and wastewater (table 3.2). In contrast, GS includes only gas distribution and gas retailing activities — it does not include gas production (which is in the Mining division) or gas transmission (which is in the Transport division). Hence, GS represents a comparatively small share of both the total gas industry and overall utilities division output.

1 During the course of this project a number of meetings were held with the ABS to discuss the methodology and data used to derive the subdivision productivity estimates. While valuable input was received and the feedback regarding the productivity estimates was generally favourable, they do not have the imprimatur of the ABS and the authors take sole responsibility for the quality and accuracy of the final results.

2 This is the same under either ANZSIC93 or ANZSIC06. For the three original subdivisions of EGWW, the change from ANZSIC93 to ANZSIC06 had no substantive impact on activities covered.

Table 3.2 **ANZSIC93: Division, subdivision, group codes and titles**

D: Electricity, gas, & water				
26	**Electricity supply**			
	261	Electricity generation		
	262	Electricity transmission		
	263	Electricity distribution		
	264	On selling electricity & electricity market operation		
27	**Gas supply**			
	270	Gas supply		
			2700	Gas supply
28	**Water supply, sewerage & drainage services**			
	281	Water supply, sewerage & drainage services		
			2811	Water supply
			2812	Sewerage & drainage services

Source: ABS (*Australian and New Zealand Standard Industrial Classification 2006 ANZSIC*. Cat. no. 1292.0).

In essence, GS in the national accounts is effectively a margin business (like wholesale or retail trade), as opposed to both ES and WSSD which embody production characteristics like manufacturing, transport characteristics like those associated with road and rail transport (to transmit and distribute electricity across space, or to deliver water to homes and businesses), as well as the margin characteristics of wholesale or retail trade businesses.

3.3 Other productivity studies

To the best of our knowledge this paper represents the first attempt to produce an integrated set of time-series MFP estimates for the subdivisions of the ABS utilities division. More work has been done in the past on productivity in different sub-groups within the main subdivisions, particularly within electricity supply. An early example was Industries Assistance Commission (IAC) (1989) which contained time series estimates of total factor productivity (TFP) in electricity supply for selected states, covering the period from 1955 to 1988.[3]

Swan Consultants (1991) produced TFP estimates for Australian electricity supply covering the period from 1975-76 to 1989-90, and these were extended by the BIE/PC to 1993-94 (BIE/PC 1996). More recently, Abbott (2006) produced TFP estimates for Australian electricity supply covering the period from 1968-69 to 1998-99.

Time series analyses of productivity trends in Australian water supply and Australia gas supply are comparatively rare. In the case of urban water supply, Coelli and Walding (2005) attempted to fill the gap by producing aggregate productivity estimates for the period from 1995 to 2003.

In late 2011, the Independent Pricing and Regulatory Tribunal (IPART) released a report that reviewed the productivity performance of state owned corporations in New South Wales (IPART 2010). This included the major electricity and water utilities in that state. The report estimated productivity growth rates for individual utilities, and provided detailed explanations of driving forces behind observed changes over time. The period covered is generally the first decade of the 2000s.

More will be said about these and other studies in chapters 4 to 6.

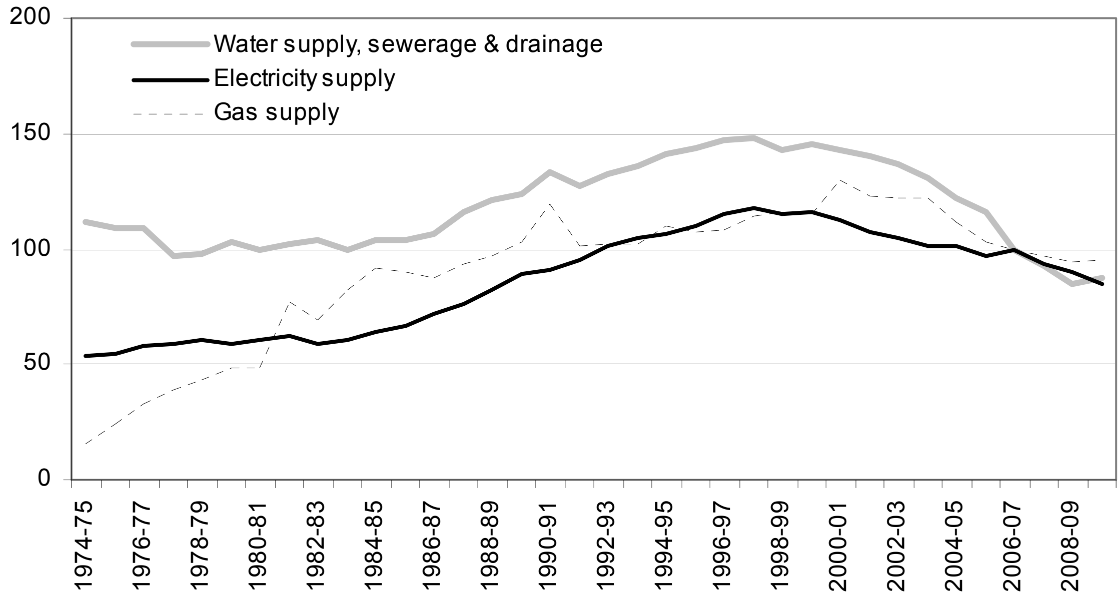
3.4 Subdivision MFP results

The MFP results show major differences between the subdivisions in terms of long term MFP growth rates, and in patterns of productivity growth over time (figure 3.1). In particular, MFP growth in Gas supply was estimated to have been very high, on average, over the longer term, although this result was primarily due to exceptionally rapid growth very early in the period. MFP growth in Water supply has been poor, on average, over the longer term, and has been strongly negative over the past ten years or so.

3 TFP typically uses real gross output as the volume or quantity measure of output, and adds intermediate inputs explicitly to the inputs side of the equation (as opposed to MFP which uses real value added as output, with only labour and capital explicitly identified as inputs). Hence, TFP is usually defined as the ratio of gross output to combined inputs of labour, capital, and intermediate inputs. Under this definition, MFP and TFP are related, with the difference between the two measures determined by the relative importance of intermediate inputs (which is small at higher levels of aggregation, and larger at lower levels). However, the terms *MFP* and *TFP* are sometimes used interchangeably, so it is best to examine the definition used by different authors on a case by case basis. For more information on the functional relationship between MFP and TFP see Cobbold (2003) or OECD (2001, p. 30).

Figure 3.1 **Subdivision MFP results, 1974-75 to 2009-10**

Index 2006-07 = 100



Data source: Authors' estimates. Detailed information regarding the construction of subdivision MFP estimates is contained in chapters 4, 5 & 6 and appendix A of this report.

The average annual rate of MFP growth in Electricity supply has been positive over the longer term (averaging 1.2 per cent per annum compared with the market sector average of 0.7 per cent). However, the decline in MFP in Electricity supply from the late 1990s to 2009-10 was a major constraint on long term productivity growth.

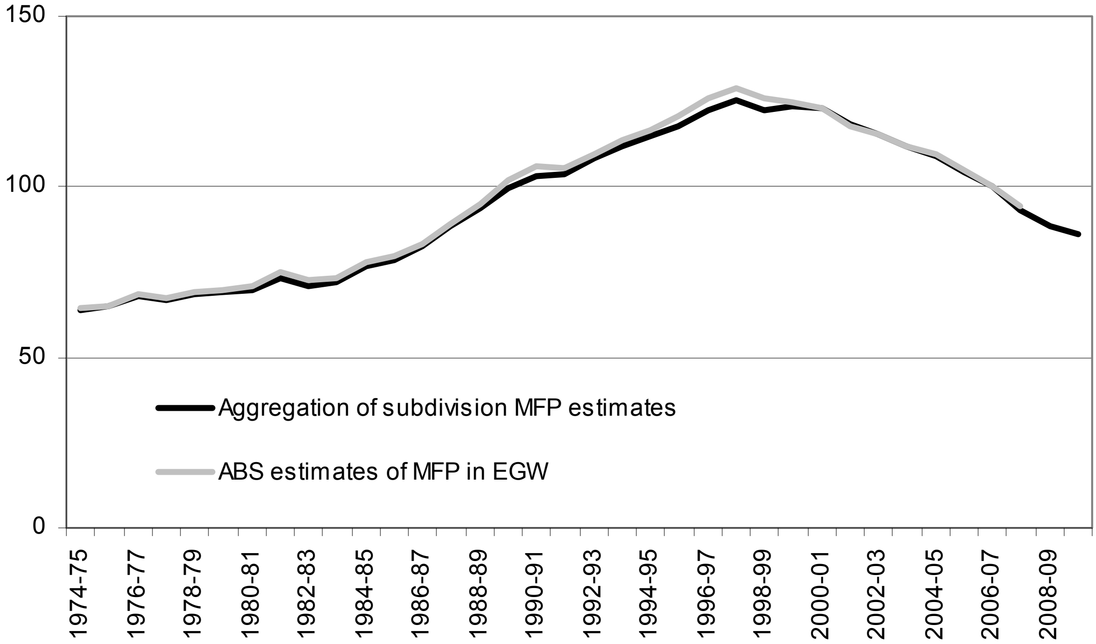
Consistency with ABS estimates of division-level MFP

The consistency of the subdivision MFP estimates with the ABS division result was checked by comparing an aggregate *utilities* MFP index derived from the three subdivision MFP series with the ABS estimate of utilities MFP. The closer the two series, the more likely it is that the subdivision MFP results are measured in accordance with the ABS methodology, and hence suitable for use in evaluating and commenting on MFP changes at the division level.

In general, the results indicate that the subdivision MFP estimates are consistent with the ABS estimates of utilities MFP, at least in an aggregate sense (figure 3.2).

Figure 3.2 **Utilities MFP: ABS estimates and aggregation of subdivision results,[a] 1974-75 to 2009-10**

Index 2006-07 = 100



[a] The series labelled *ABS estimates of MFP in EGW* is the *EGW (ANZSIC93)* MFP series shown in figure 2.3.

Data sources: ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2007-08,* Cat. no. 5260.0.55.002); authors' estimates; Commission estimates.

This result is, however, partly predetermined, in the sense that some of the assumptions and data choices made in modelling subdivision MFP effectively *line-up* the subdivision results to the ABS's division-level MFP estimates.[4] These choices were made partly because of data limitations, and partly in order to ensure maximum consistency with the division level results. The compromise is that the subdivision results may be of lesser quality individually, even though they are consistent with the ABS division-level results in an aggregate sense.

4 For example, both MFP series shown in figure 3.2 use the same output variable (ABS gross value added in EGW) and the same labour input variable (total hours worked in the case of the ABS labour inputs, and the sum of subdivision hours worked in the case of the *PC estimates*). The differences between the two series are therefore primarily due to differences in estimates of capital services, and in the incomes shares assigned to capital and labour inputs. For the *aggregation of PC subdivision MFP estimates*, capital inputs are derived using a Perpetual Inventory Model that is based on the sum of capital investment across the three subdivisions. More information regarding the sources of data and other assumptions used to derive the subdivision MFP results is contained in appendix A.

Subdivision contributions to utilities MFP changes

Examination of the average rates of MFP growth recorded for each subdivision during the three *phases* identified for utilities as a whole in chapter 2 shows that the *moderate MFP growth* phase (that is, from 1974-75 to 1985-86) was the result of extremely high MFP growth in GS, average MFP growth in ES, and negative MFP growth in WSSD. All three subdivisions recorded strong positive growth during the *rapid MFP growth* phase, and all three recorded negative MFP growth during the *negative MFP growth* phase (table 3.3).

Table 3.3 **Annual average growth rates in utilities MFP, by subdivision and time period**[a]

Per cent

	Moderate MFP growth phase (1974-75 to 1985-86)	*Rapid MFP growth phase (1985-86 to 1997-98)*	*Negative MFP growth phase (1997-98 to 2009-10)*	***Full period (1974-75 to 2009-10)***
Electricity supply	2.0	4.9	-2.7	**1.3**
Gas supply	17.5	2.0	-1.5	**5.4**
Water supply, sewerage & drainage	-0.7	3.0	-4.3	**-0.7**

[a] Time periods represent the growth *phases* identified for the utilities division as a whole in chapter 2 (based on MFP in EGW as illustrated in figure 2.4) and over the full period for which subdivision MFP estimates have been constructed. Note that the subdivision MFP estimates in figure 3.1 and this table extend to 2009-10, whereas the PC/ABS estimates of MFP at the EGW level finish in 2007-08.

Source: Authors' estimates.

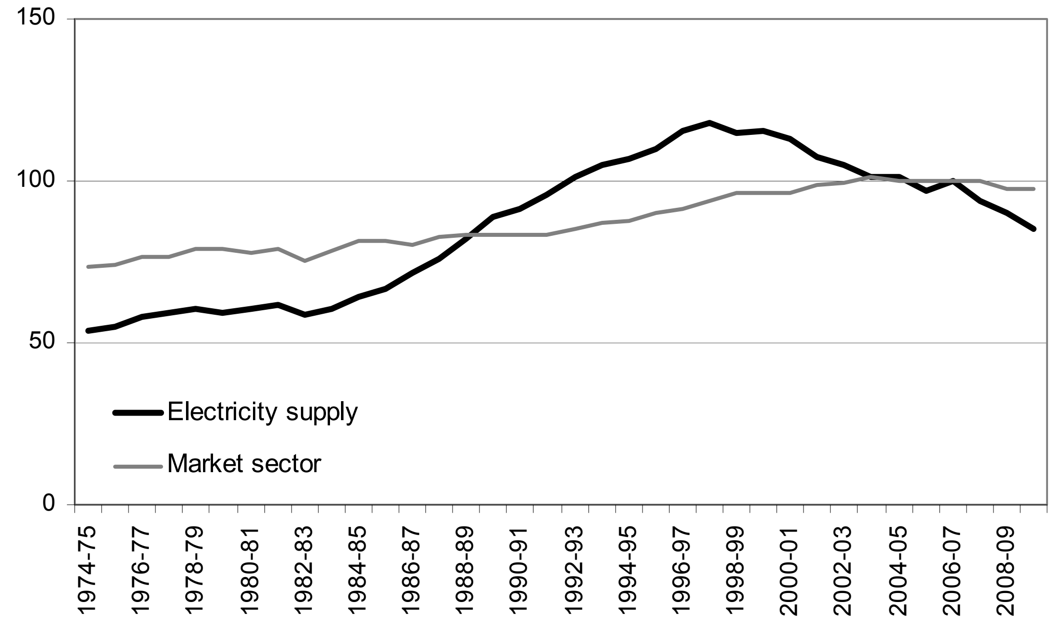
Given these results, it may be more appropriate to characterise MFP growth in two subdivisions — ES and WSSD — as having the following three phases: an early period of slow to moderate growth; a middle period of comparatively rapid growth; and a more recent period of negative growth. Noting, of course, that while the MFP estimates for ES and WSSD exhibit the same general trends over time (including, coincidentally, the timing of the turning points for the *phases* of MFP growth) the final outcome for WSSD in terms of long term average MFP growth is much worse than for ES (-0.7 per cent per year in WSSD, compared with 1.3 per cent per year in ES).

In the next three chapters, MFP trends in each subdivision are examined in more detail. The component input and output measures are presented and discussed, and the driving forces behind the observed changes in productivity are identified.

4 Productivity in Electricity supply

This chapter reviews the key drivers of measured productivity change in the Electricity supply subdivision of Australia's utilities division. As noted in chapter 3, multifactor productivity (MFP) in Electricity supply (ES) is estimated to have grown at a rate slightly faster than the market sector average over the longer term, although the growth path has been more variable (figure 4.1).

Figure 4.1 **Multifactor productivity in Electricity supply and in the market sector, 1974-75 to 2009-10**
Index 2006-07 = 100



Data source: Authors' estimates; ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2009-10,* Cat. no. 5260.0.55.002).

4.1 Structure of the Electricity supply subdivision

It was also noted in chapter 3 that the Electricity supply subdivision of the utilities division is comprised of four sub-groups:

1. electricity generation
2. electricity transmission

3. electricity distribution
4. on selling electricity and electricity market operation.

The MFP series shown in figure 4.1 is therefore an aggregation of the underlying trends in productivity growth within the various sub-groups of Electricity supply. While estimating MFP at the *sub-group* level is outside the scope of this project, understanding the activities of the different sub-groups and their relative importance to aggregate subdivision output and inputs is important in explaining developments at the subdivision level.

The main activities of businesses within the four sub-groups of Electricity supply are outlined in table 4.1.[1]

Table 4.1 **Main activities of businesses in Electricity supply sub-groups**

Sub-group	*Primary activities*
Electricity generation	Electricity production using fossil fuels, hydro-electric processes, or other sources including renewable
Electricity transmission	Transmission of high-voltage power from generators to low-voltage distributors
Electricity distribution	Low voltage distribution of electricity to final consumers
On selling electricity and electricity market operation	Retailing of electricity and electricity market operation

Relative importance of the different sub-groups

In relation to their shares of subdivision output and employment, the dominant sub-groups within the Electricity supply subdivision are *electricity distribution* and *electricity generation* (table 4.2). Some differences can arise, however, in relation to output shares and shares of other important variables such as capital investment. For example in 2006-07 the transmission sector accounted for just 11 per cent of subdivision output, but 18 per cent of new capital investment.

1 More information regarding the industry classification scheme used by the ABS to define the sub-groups can be found in ABS (2006). More information regarding the structure and operation of the various component parts of the electricity sector can be found in AER (2009).

Table 4.2 **Shares of Electricity supply output and employment: by ANZSIC group, 2006-07**

Per cent

	Share of output (industry value added)[a]	*Share of employment*[a]	*Share of net capital expenditure*
Electricity generation	35	22	30
Electricity transmission	11	6	18
Electricity distribution	47	62	48
On selling electricity and electricity market operation	7	11	4
Electricity supply subdivision	**100**	**100**	**100**

[a] Industry value added (gross output less intermediate inputs) and net capital expenditure are both measured in current price terms, while employment is measured in employee numbers.

Source: Derived from ABS (*Electricity, Gas, Water and Waste Services, Australia, 2006-07*, Cat. no. 8226.0).

Electricity supply is capital intensive, with capital accounting for around 74 per cent of total subdivision income, on average, over the past ten years. This compares with the average for the market sector as a whole of around 40 per cent.[2] Within the generation, transmission and distribution sub-sectors, many capital assets are also comparatively long-lived, and are often large and lumpy in nature.

In the generation sector, 44 power stations accounted for just over 70 per cent of Australia's total electricity generation capacity in 2008-09. Within the transmission and distribution sectors, a large share of capital assets are in the form of power lines, transformers, substations and switching equipment. These assets are generally long-lived, and are usually built with enough spare capacity to meet future demand growth, not just current demand, as it is generally not economic to make incremental increases to network capacity each year.

As will be discussed in more detail below, such investment can be a cause of temporal bias in productivity results if many such investments are made simultaneously.

2 Capital and labour shares of total income are indicators of the extent to which businesses and industries use more or less capital and labour in production. They are also used as weights to add together labour and capital inputs for the purpose of measuring MFP. ABS (2000, p. 369) contains a formal derivation of *total income*, and of the capital and labour shares of total income.

Business concentration

For most of the period covered by the productivity estimates in this report, the Electricity supply subdivision can be characterised as having a comparatively small number of businesses that accounted for the majority of output. This model is changing however, as reforms to the industry (discussed in more detail below) have allowed greater competition, particularly in the generation and retail sectors. Many new companies and businesses are being attracted to the electricity market, particularly those seeking to supply power using renewable sources of energy.

Distribution and transmission activities remain heavily dominated by a handful of companies in each state, and this situation is unlikely to change in the near future. As *network* activities account for a major share of subdivision output, operational decisions in a small number of electricity transmission and/or distribution businesses — particularly in relation to investment — can have a major impact on subdivision results.

4.2 The operating environment of Electricity supply

The operating environment of the Electricity supply subdivision has changed substantially during the period covered by the MFP estimates shown in figure 4.1. Prior to the 1990s state governments owned and operated vertically integrated electricity supply businesses that were, essentially, monopolies within each jurisdiction. Extensive reforms starting around 1990-91 resulted in some key changes, including the disaggregation of government owned businesses into separate generation, transmission, distribution and retail arms, and the privatisation (full in Victoria and South Australia, partial elsewhere) or corporatisation of these businesses. The intention of the reforms was to increase the efficiency and competitiveness of Australia's overall electricity sector.[3]

In regard to the individual sub-groups within Electricity supply, the reforms have had the following impacts:

1. Generation is now competitive, with individual businesses in the eastern states of Australia competing to supply electricity every five minutes in an auction system. Western Australia also has a competitive wholesale market. Around two thirds of generation capacity remains government owned or controlled.

3 BIE/PC (1996) and PC (2002) outline the reform process and its effects in detail, as does AER (2009), which also contains detailed historical and background information on the development of the electricity sector, and a description of the current regulatory environment.

2. Transmission networks remain state based monopolies, with revenues earned for services subject to regulation. They remain government owned in all states except Victoria and South Australia.
3. Distribution networks are regional monopolies, with revenues subject to regulation. They remain government-owned except in Victoria and South Australia, and in the Australian Capital Territory which has joint government and private ownership.[4]
4. Retail businesses operate in a contestable market, but retail price caps remain in place in all states except Victoria. Private sector ownership of retail businesses is significant and continues to grow, although governments still own retail businesses in some states (AER 2009, p. 194).

The National Energy Market

Another major operational change to electricity supply in Australia during the past decade and a half was the inter-connection and integration of electricity networks in the five eastern states — Queensland, New South Wales,[5] Victoria, South Australia and Tasmania — to form a *National Energy Market*. The National Energy Market (NEM) began in December 1998 following the interconnection of separate networks in New South Wales, Victoria and South Australia. In 2000-01 Queensland was physically connected to the network, while an undersea link connected Tasmania in 2006.[6] The NEM is one of the largest electricity networks in the world (in terms of distance covered), and the wholesale market for electricity within the NEM is one of the most active in the world (AER 2009 and 2010). Electricity networks in Western Australia and the Northern Territory remain independent of the NEM, largely due to geography and cost factors.

The introduction of the NEM was intended to improve the efficiency with which electricity services could be supplied in eastern Australia by allowing more rational location of generation and network capacity (AER 2009). For example, by interconnecting regions, more rational use of generating capacity was expected to result in peak demand being met at a lower average cost through interstate trade in

4 Note also that there is no separation of the transmission and distribution networks in south-west Western Australia — a single network business produces an integrated transmission/distribution service within this part of the state.

5 Including the electricity network within the Australian Capital Territory.

6 The NEM is a dynamic system, and there are ongoing discussions and decisions being made regarding the number, location, capacity and other characteristics of current and future interconnections.

power. More will be said about the impact of the NEM on productivity later in this chapter.

Renewable energy schemes

Finally, the period from the late 1990s onwards coincides with the development and introduction of a number of federal and state government policies mandating the production of electricity from renewable sources. A key policy development in this regard was the Australian Government's Mandatory Renewable Energy Target (MRET) scheme, which was introduced in 2001. The aim of the scheme was to encourage additional generation of electricity from renewable sources to reduce emissions of greenhouse gases (AGO 2003). In 2007 the Australian Government announced that the MRET would be expanded to meet a 45 000 GWh target by 2020.

The MRET remained in place until 2010, when the national Renewable Energy Target (RET) scheme was introduced. The national RET scheme aims to meet a renewable energy target of 20 per cent by 2020. Like its predecessor, the MRET, the national RET scheme requires electricity retailers to source a proportion of their electricity from renewable sources developed after 1997. (For more details see the Department of Climate Change and Energy Efficiency website, http://www.climatechange.gov.au/government/initiatives/renewable-target.aspx/)

The impact of the MRET on the share of renewable power sources in the mix of electricity generation capacity during the first few years of the 21th century was comparatively minor (see PC 2008b, p. 69). Growth in renewable sources of electricity supply did not increase sharply until towards the end of the decade, particularly with the development of wind farms. In 2009-10 wind farms supplied 6 175 GWh of electricity, which represented 2.7 per cent of total generation (esaa 2011, p. 22).

At the same time there was reduced new investment in what had traditionally been the lowest cost source of electricity supply in Australia — coal-fired power. The effect on measured productivity of this change in the preferred technology of supply is also examined in more detail later in this chapter.

4.3 Measurement of outputs and inputs in Electricity supply

Before presenting and discussing changes in the estimates of output and inputs that underlie the MFP results for Electricity supply as illustrated in figure 4.1, it is useful to consider briefly how they are defined.

Output

In this report the measure of output used to calculate MFP in Electricity supply is taken directly from published ABS data, and is value added in the subdivision, measured in real terms. In essence, real value added is simply nominal value added (nominal gross output less intermediate inputs) adjusted for the effects of price changes to outputs and intermediate inputs. It represents a *volume* measure of output (less intermediate inputs) in the subdivision, and is consistent with the ABS estimate of volume output for utilities as a whole. [7]

Prior to 1994-95 the ABS assumed that real value added in Electricity supply grew at the same rate as real gross output. This implies an assumption that, prior to 1994-95 at least, real gross output and real intermediate inputs had the same growth rate.

Real gross output was itself derived using a process that linked annual changes in real gross output to movements in annual electricity production, as published by the Energy Supply Association of Australia (esaa) (ABS 1990, p. 119). Hence, movements in annual real value added directly reflected movements in annual electricity production, at least up to 1994-95.

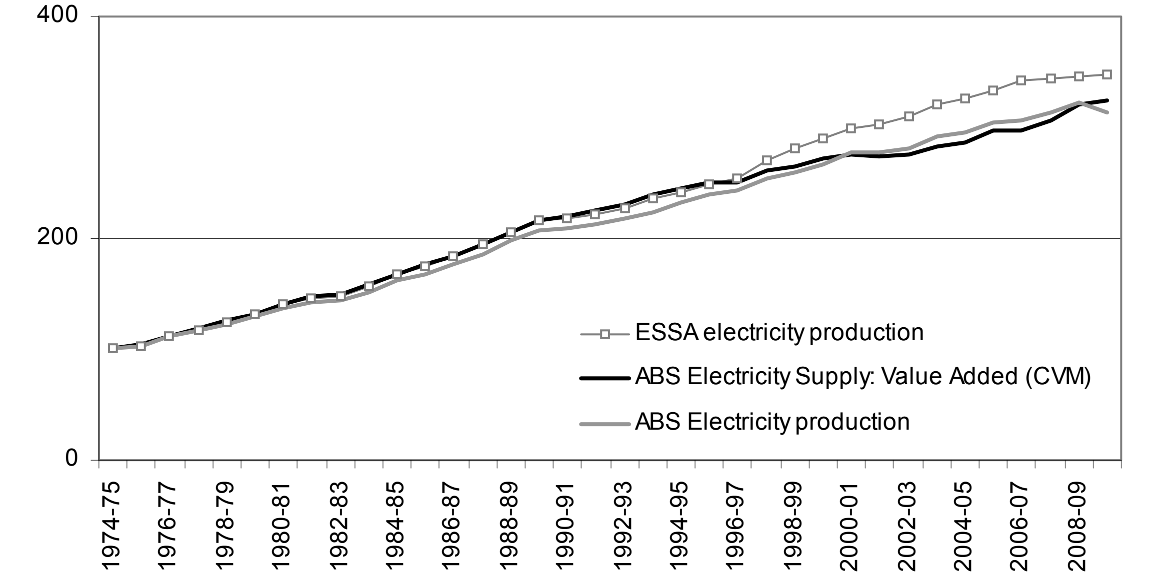
Post 1994-95, the ABS has derived its estimates of annual real value added in Electricity supply using a process of double deflation — that is, estimating real gross output and subtracting an estimate of real intermediate inputs. However, as the ABS does not publish time series estimates of real gross output and real intermediate inputs at the subdivision level, it is difficult to be certain about the basis for changes in the ABS real value added series after 1994-95.

Time series data confirms the link between ABS real value added in ES and the esaa estimate of electricity production up to 1994-95 (figure 4.2). After 1994-95 however, movements in real value added are more closely related to growth in the

[7] The full ABS description of output in ES, GS and WSSD is *Industry Gross Value Added, chain volume measures*, as reported in the ABS *National Accounts*, Cat. no. 5204.0. For more information on data and data sources see appendix A.

ABS estimate of aggregate electricity production, rather than the esaa estimate.[8] While real value added grows more slowly than the esaa estimate of electricity production after 1994-95, towards the end of the period covered the two series are beginning to converge.

Figure 4.2 **Output estimates in Electricity supply, 1974-75 to 2009-10**
Index 1974-75 = 100



Data sources: ABS National Accounts on dXtime (database); esaa, various years, *Electricity Gas Australia;* esaa's historical database.

There are some broader issues regarding the choice of a (volume) output measure for this subdivision that have the potential to create difficulties when measuring and interpreting productivity results. For example, unmeasured changes to the reliability of electricity supply (positive or negative) that impact on the costs of supplying electricity will also impact on MFP since these *quality* changes are hidden or not reflected by the standard output measure — the quantity of electricity produced.

Similarly, changes in diurnal demand for electricity (such as increases in the demand for power to run air-conditioners on hot summer afternoons that lead to maximum electricity production each year rising faster than average daily electricity production) could impact on MFP. The latter issue is explored in greater detail later in this chapter.

In general, measuring the volume of output in electricity supply for the purpose of estimating MFP can be complex, and data limitations tend to favour the use of simple measures like aggregate electricity production. Swan Consulting (1991, p. 4)

8 The discrepancies between esaa and ABS estimates of aggregate electricity production were not able to be adequately explained.

touches on this issue, while Lawrence and Diewert (2006, p. 214-216) contains a more detailed discussion of output measurement challenges in the electricity network (transmission and distribution) sector. Box 4.1 briefly discusses some of the other productivity studies of the Australian electricity industry.

Inputs (labour and capital)

In regard to the quantity of labour inputs, the measure used in this study is an estimate of the total number of hours worked in the subdivision each year. As noted in Appendix A, there are data quality issues associated with the accuracy of measured labour inputs at the subdivision level, so some care must be taken in interpreting changes in labour inputs over time. As noted earlier, electricity supply is a comparatively capital-intensive sector, so changes in labour inputs will tend to have less impact on MFP than equal proportionate changes in capital inputs.

Inputs of capital services are potentially the most difficult to explain conceptually and to get right empirically. Estimation of MFP requires a measure of the quantity or volume of capital services consumed during production each year. In this report the volume measure of capital inputs — *capital services* — is estimated using the same broad procedure adopted by the ABS to produce estimates of capital inputs for the utilities division as a whole (see ABS 2000).

The volume of capital services consumed during production each year is assumed to be a fixed proportion of the annual productive capital stock of the subdivision, where the latter is defined as a volume measure of the total available stock of capital assets. The productive capital stock is derived using the perpetual inventory model (PIM) approach, whereby the size of the productive capital stock each year is determined by adding new investment (in real terms) to an estimate of the existing capital stock, and then adjusting for both the expected retirement of some assets, and the decline in productive services of remaining capital goods due to ageing. Appendix B contains more information on the estimation of capital services in this report, while ABS (2000) and OECD (2001) provide detailed descriptions of the theory and practice involved in measuring capital services.

Critically, new investment (converted into volume terms) is generally added to the productive capital stock as the investment expenditure occurs, irrespective of whether or not the assets being invested in are complete and operational, or whether they are being utilised to their maximum or expected full capacity. Similarly, existing capital assets are assumed to be fully utilised at all times, and this can be problematic in industries like utilities which have many large, indivisible capital assets, and which are prone to cyclical investment patterns.[9] An alternative to the capital services approach is to use physical measures of capital assets — kilometres of power lines for example, or MW of power generation capacity — however this does not resolve the utilisation issue.

In relation to the estimates of capital services in Electricity supply presented below the most important factor influencing trends and changes over time is the rate of (real) capital investment. When the rate of investment in new capital equipment increases, growth in capital services tends to increase, and vice versa. If there are large cycles in investment behaviour at the subdivision level, this will cause the measured growth rate of capital inputs to speed up or slow down, depending on where the subdivision is located in the investment cycle.

4.4 Proximate drivers of MFP in Electricity supply

The proximate factors behind the longer term trends in MFP shown in figure 4.1 are reviewed below using the same basic framework used to evaluate MFP trends in the utilities division as a whole in chapter two. That is, results have been divided into three time-periods — a *moderate MFP growth* phase, a *rapid MFP growth* phase, and a *negative MFP growth* phase — with trends and developments in each phase then examined in more detail. For simplicity, the same terminology and time periods have been chosen as those used in the assessment of MFP trends within EGW as a whole in chapter 2. As noted in that chapter, a case can be made for using slightly different cut-off years for the MFP phases in ES, although the fundamental productivity growth trends in the subdivision do not change as a result. To keep comparisons simpler, the same phases have been used in this chapter and in the discussion of MFP in WSSD in the next chapter.

During the *moderate MFP growth* phase, MFP growth in Electricity supply is estimated to have been reasonably strong (2.0 per cent per year), and is the result of strong growth in output (5.3 per cent per year) that exceeded growth in combined inputs of capital and labour (figure 4.3 and table 4.3). Note though that capital input growth is itself comparatively strong during this phase.

During the *rapid MFP growth* phase, very high MFP growth is associated with declining (negative) inputs of labour, a marked slowdown in capital input growth as new capital investment in the period slows considerably, and continuing positive growth in output (albeit slower compared with output growth in the previous phase).

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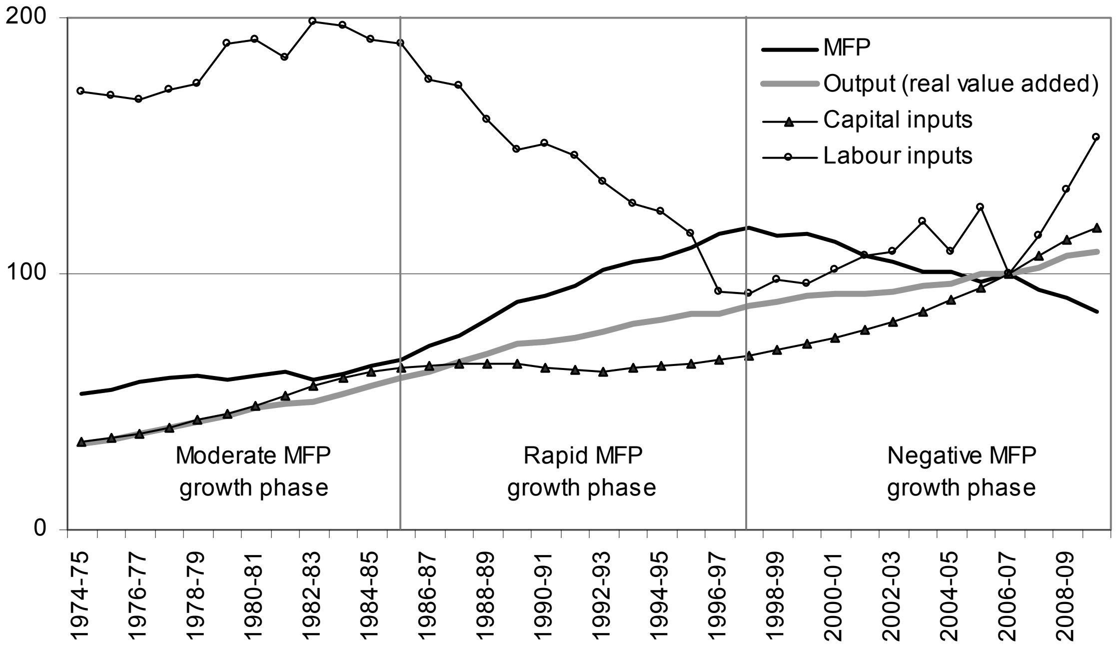
9 The ABS nominate the issue of capital utilisation as a possible cause of bias in capital services estimates in EGWW (see ABS 2007, p. 44).

From the late 1990s however, output growth slows further, while strong capital input growth resumes and there is a sharp turn-around in labour inputs from a strong decline to sustained growth. With inputs now growing much faster than measured output, MFP in Electricity supply declines.

Figure 4.3 **Electricity supply: MFP, output and inputs, 1974-75 to 2009-10[a]**
Index 2006-07 = 100



[a] Vertical lines represent the cut-off years for the three MFP growth *phases* identified for the utilities division as a whole in chapter 2. For ease of comparison, the same terminology is used to describe the phases throughout the paper (see section 2.3 and table 2.3).

Data source: Authors' estimates.

Table 4.3 **Changes in MFP, output and inputs in Electricity supply, by growth phase[a]**
Annual average growth rates in each phase, per cent

	Moderate MFP growth phase (1974-75 to 1985-86)	*Rapid MFP growth phase (1985-86 to 1997-98)*	*Negative MFP growth phase (1997-98 to 2009-10)*	*Full period (1974-75 to 2009-10)*
MFP	**2.0**	**4.9**	**-2.7**	**1.3**
Output	5.3	3.3	1.8	3.4
Labour	1.0	-5.8	4.3	-0.3
Capital	5.8	0.6	4.7	3.6

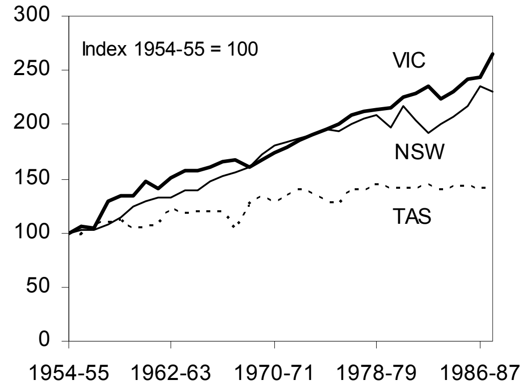
[a] For simplicity, the cut-off years for the growth phases used in this table are the same as those identified for the EGW division as a whole — that is, 1985-86 and 1997-98, which were reported in chapter 2 (see table 2.3).

Source: Authors' estimates.

Box 4.1 **Productivity studies into the Australian electricity industry**

Over the years there have been numerous studies into the productivity performance of the Australian electricity industry. Early productivity studies often focused on the state electricity authorities. For example, the IAC (1989) estimated total factor productivity (TFP) for three states for the period 1954-55 to 1987-88, with the estimates being based on data and methodology from Swan (1988).

Total factor productivity, New South Wales, Victoria and Tasmania, 1954-55 to 1987-88



Source: IAC (1989, p. 14 and pp. 80-82)

Over the 34 year period, the annual productivity growth in New South Wales and Victoria was estimated to be slightly above 2.5 per cent. However, productivity growth declined noticeably in New South Wales and Tasmania and less so in Victoria in the early 1970s.

	1954-55 to 1970-71	*1971-72 to 1987-88*
NSW	3.69%	1.13%
VIC	3.27%	2.04%
TAS	1.44%	0.40%

BIE/PC (1996) contains TFP estimates for Australian electricity supply based on earlier work by Lawrence, Swan and Zeitsch (1991). The results, which cover the period from 1975-76 to 1992-93, are broadly consistent with the results in this paper — that is, they show little productivity growth in electricity supply from the mid-1970s to the mid-1980s, but strong positive growth from the mid-1980s to the mid-1990s (see below).

Murtough et al. (2001) also reviewed the various index number studies that were conducted during the late 1980s to 1990s in response to the ongoing debate at that time regarding the impact of electricity reforms. The overall view was that from the mid-1970s to the mid-1980s there was negligible productivity growth in the Australian electricity supply industry but during the mid-1980s to the early 1990s there was a marked increase (Murtough et al. 2001, p. 10). Again, many of these studies focussed on the states and some focussed exclusively on electricity generation or distribution.

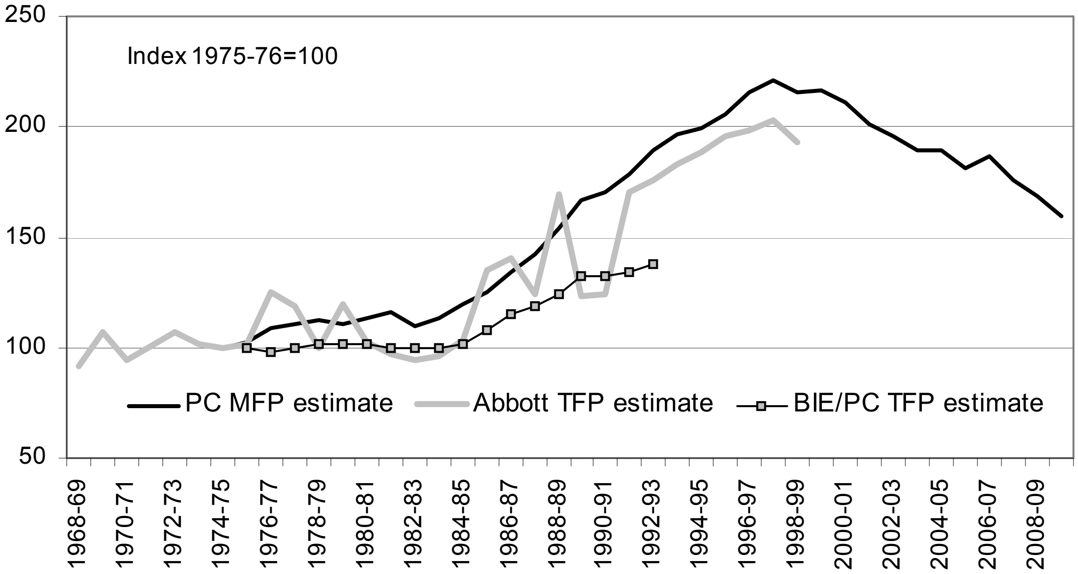
In addition, Murtough et al. (2001) identified a number of production frontier studies that benchmarked individual electricity firms against an estimated best practice frontier, along with studies that have employed data envelopment analysis (DEA) or stochastic frontier analysis (SFA).

(continued on next page)

Box 4.1 **(continued)**

More recently, Abbott (2006) produced TFP estimates for Australian electricity supply covering the 30 year period from 1968-69 to 1998-99. Again the broad trends in productivity measured by Abbott are consistent with the MFP results for electricity supply presented in this paper, despite some differences in the definition and measurement of capital, labour and other inputs.

Productivity growth in Australian electricity supply, 1968-69 to 2009-10



Data sources: Abbott (2006); authors' estimates; BIE/PC (1996).

Studies of productivity within electricity distribution (as opposed to electricity supply overall) include ESC and PEG (2006), PEG (2008b) and Lawrence (2009a).

IPART (2010) estimated TFP for state owned electricity generators, distributors, and the single transmission business in New South Wales. Estimates generally cover the last ten to fifteen years, and the report included detailed assessments of the driving forces behind the observed productivity trends. TFP growth was found to be around zero among generators, and negative in transmission and distribution businesses.

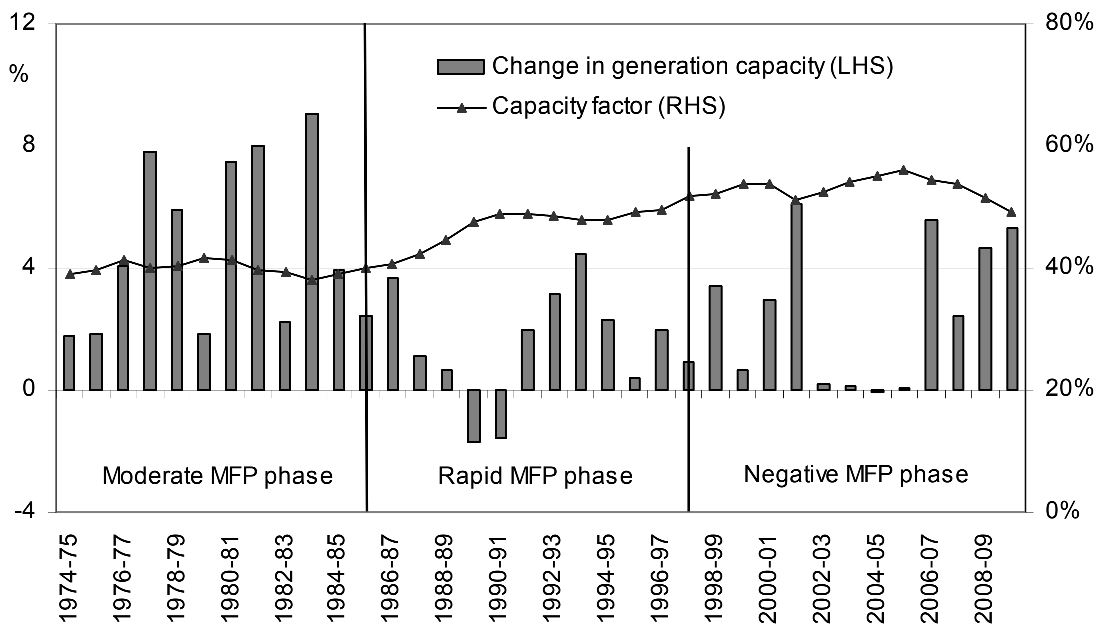
Interest in the industry's productivity performance remains strong. For instance, the Australian Energy Market Commission (AEMC) is reviewing the possible use of a total factor productivity methodology in determining regulated prices and revenues for electricity and gas network service providers — see AEMC (2010) and Lawrence and Kain (2010).

4.5 Explaining the moderate MFP growth phase (1974-75 to 1985-86)

Annual output growth was positive and strong during this phase, and exceeded total input growth. Hence MFP growth was also positive. However the average rate of growth in capital inputs during the period was particularly high, and exceeded growth in output (see figure 4.3 and table 4.3). Industry data relating to changes in the amount of physical supply capacity in operation — that is, physical measures of electricity generation capacity and transmission and distribution infrastructure — indicate a significant increase in supply capacity at the time (figures 4.4 and 4.5). In percentage terms, the annual rates of increase in physical supply capacity that were occurring in the late 1970s and early 1980s have never been exceeded, and contrast sharply with annual rates of growth in new supply capacity in subsequent decades, particularly in relation to generation capacity.

Figure 4.4 **Annual change in electricity generation capacity[a] and average annual capacity factor,[b] 1974-75 to 2009-10**

Per cent

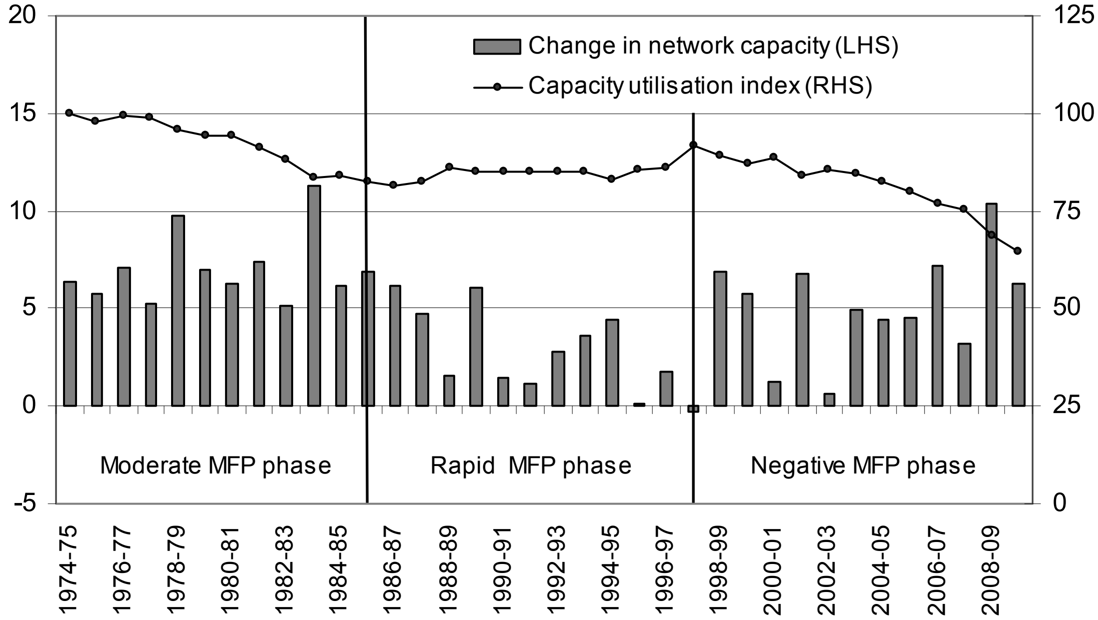


[a] Generation plant installed includes all principal generation plant identified by the Energy Supply Association of Australia (esaa) in its various *Electricity Gas Australia* reports. [b] Capacity factor is a measure of the extent to which electricity generation capacity is being utilised. It is calculated as the ratio of total power produced each year to the maximum possible quantity of power that could have been produced had all generation plant been run for 24 hours each day of the year. The capacity factor shown above is the average annual capacity factor across all generation types — coal, hydro, gas, wind etc.

Data sources: Authors' estimates based on esaa, various years, *Electricity Gas Australia;* esaa's historical database.

Figure 4.5 **Annual change in physical network (transmission and distribution) capacity and capacity utilisation,[a] 1974-75 to 2009-10**

Per cent and index 1974-75 = 100



[a] *Network capacity* is measured by the product of total installed transformer capacity (measured in MVa) and the aggregate length of transmission and distribution lines (in circuit kilometres). It is a physical measure of network supply capacity. A proxy for capacity utilisation in the network sector is estimated using the ratio of total electricity supplied to network capacity. In this graph the ratio is expressed as an index with 1974-75 = 100.

Data sources: Derived from esaa, various years, *Electricity Gas Australia;* esaa's historical database.

Some key examples of the new generation capacity that became operational during this period include the Eraring and Bayswater power stations in New South Wales, major parts of the Yallourn and Loy Yang power stations in Victoria, the Gladstone and Tarong stations in Queensland, and the Muja power station in Western Australia. Also constructed during this phase was a significant amount of network capacity (transmission and distribution infrastructure), required to connect the new generators to demand centres.

Despite the comparatively rapid growth in electricity production (output) during the *moderate MFP growth* phase, the extent of the augmentations to the physical supply system meant that average rates of capacity utilisation during the phase were kept low (figures 4.4 and 4.5). In essence, lumpy capital investments put temporary downward pressure on MFP during the phase because the investments added to inputs of capital services as they were made, even though the supply capacity embodied in the new assets was underutilised at the time.[10] The excess supply capacity constructed during the phase did, however, provide a platform for future output growth.

4.6 Explaining the rapid MFP growth phase (1985-86 to 1997-98)

The lead up to the *rapid MFP growth* phase was characterised by a significant excess of supply capacity. An Industry Commission inquiry into the electricity generation and distribution sector in 1991 found that '... poor investment decisions (led) to excess capacity and gross overstaffing during the 1980s' (IC 1991). Industry reports from the time also refer to significant over-capacity in the sector, along with an expectation that the capacity overhang was expected to continue into the 2000s (see Electricity Supply Association of Australia 1993, pp. 16-17).

During this second phase annual output continued to grow steadily although the rate of growth was slower, on average, than it was during the preceding phase. With a marked slowdown in the rate of supply augmentation however, the average rate of capacity utilisation increased significantly (figures 4.4 and 4.5), and this helped to bolster MFP growth. That is, the high rate of MFP growth during this phase was partly the result of more efficient use of the previously built infrastructure.

The slowdown in input growth during this phase was quite strong in the case of labour, which was strongly negative at the time. Industry and other reports identify improved labour practices and significant shedding of labour in the sector during the period, particularly during the early to mid-1990s. Reforms to the structure and governance of the sector that made electricity businesses more competitive were nominated as a primary driver of these changes (see IC 1991 for example).

Where labour shedding was due to decisions by electricity businesses to outsource certain activities, a positive effect on MFP would have been expected if the outsourced services were subsequently provided more efficiently than in-house provision. In cases where the labour that was shed was surplus to actual needs, this would have had a direct positive effect on MFP. Both effects would tend to permanently improve the *level* of productivity in Electricity supply, and hence the average rate of productivity growth over this phase.

[10] Abbott (2006, p. 453) also finds comparatively slow productivity growth in electricity supply during this period, which he attributes to an excessive build-up in capital stock in advance of demand.

In summary, strong MFP growth in Electricity supply from the mid-1980s to the late 1990s appears to be the result of two main factors: structural reforms that allowed the sector to use labour more efficiently; and the availability of significant amounts of excess supply capacity — both generation and network capital — arising from high rates of investment in lumpy supply capacity in the previous phase. The latter allowed output to grow comparatively strongly throughout the period despite the significant winding back of capital expenditure programs.

4.7 Explaining the negative MFP growth phase (1997-98 to 2009-10)

As noted earlier, negative MFP growth in Electricity supply from the late 1990s to 2009-10 is associated with rapid growth in inputs of capital and a turn-around from labour shedding to net hiring, with both substantially exceeding growth in output (table 4.3). In the remainder of this chapter various issues and factors that might explain how this combination of inputs and outputs has come to characterise ES over an extended period of time are examined.

Rising capital services inputs

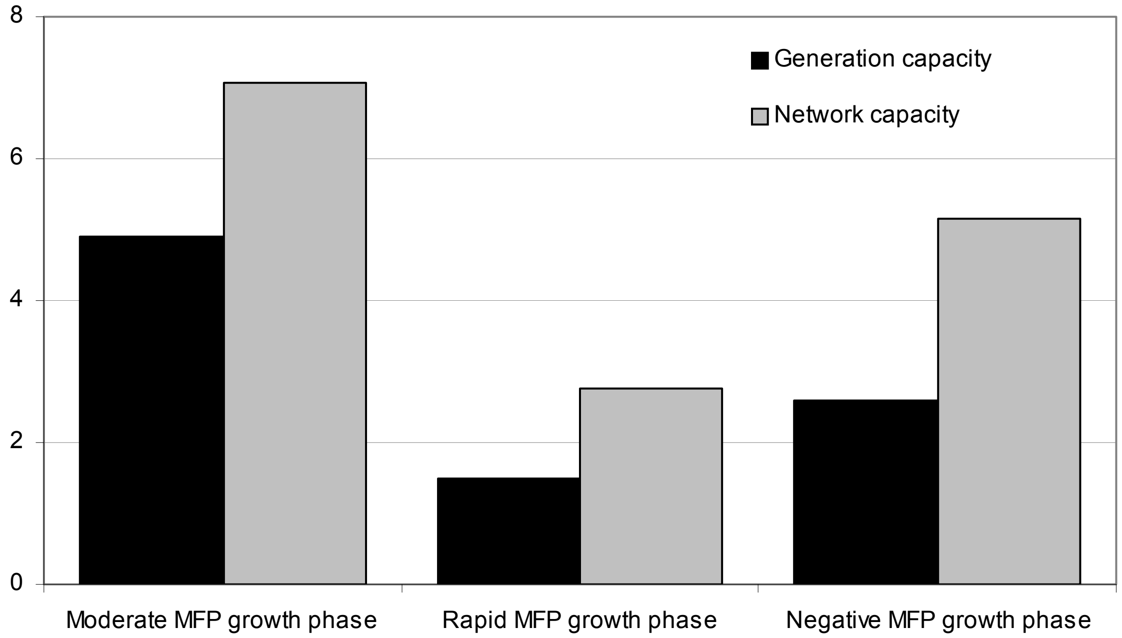
The estimates of growth in capital services in Electricity supply developed in this study are broadly consistent with industry estimates of growth in physical measures of capital infrastructure, such as electricity generation capacity and network capacity. Further, cyclical or industry-wide trends over time in the amount of physical supply capacity in-situ, along with associated changes in the efficiency with which that capacity is utilised, are clearly influential in explaining broader movements in MFP.

Data from esaa show that augmentation of both generation and network capacity was particularly strong during the *negative MFP growth* phase relative to the rapid MFP growth phase, though modest relative to the earlier *moderate MFP growth* phase (figure 4.6).

Increased capital expenditure in the subdivision in recent years has been attributed to a number of factors, including the need to: meet growing *peak* demand for electricity; deliver rising standards of supply; respond to the electricity needs of a growing population; and replace ageing infrastructure that is reaching the end of its economic life (see AER 2009, IPART 2010, and Sims 2010).

Figure 4.6 **Average annual change in generation and network capacity,[a] by MFP growth phase**

Per cent



[a] See footnote to figure 4.5 for definitions of generation and network capacity. MFP growth phases are as per table 4.3.

Data sources: Authors' estimates based on esaa, various years, *Electricity Gas Australia;* esaa's historical database.

Peak demand

In relation to the *peak demand* issue, electricity demand varies throughout the day, and the maximum or *peak* amount of power being demanded at some point each day is usually much higher than the average amount of electricity demanded throughout the day as a whole. For example, electricity demand tends to rise during the morning around breakfast time, and then drop away during the course of the day before rising again in the late afternoon/early evening. It is important to note that peak demand on any one day might last for just a short period of time.

While daily peak demand is influenced by factors such as the day of the week, seasonal changes and climatic conditions, some general rules apply. Within the week, peak daily demand is nearly always higher on weekdays than on weekends. Within the year, peak daily demand is generally higher in summer (cooling) and winter (heating) compared with spring and autumn. But even within summer and winter, peak demand can vary from day to day depending on the severity of temperature and other climatic conditions. For example, absolute peak summer demand in most regions occurs in the late afternoon or early evening period of a very hot working day, primarily due to cooling requirements. However, on mild summer days, peak demand can occur at breakfast time rather than later in the day, and may be no more than the highest peak daily demand recorded during spring or autumn.

The challenge for the electricity industry is to ensure that enough supply capacity (generation and network) is available to meet the expected peak demand whenever it might occur, not just the average amount of electricity demanded[11]. Hence, growth in peak demand over time determines required supply capacity, not growth in average demand.

If peak demand is not met, customers will be faced with outages (including blackouts) until supply and demand can be rebalanced. Operators of the electricity system therefore face a continuous daily process of anticipating likely peak demand, and ensuring that enough supply capacity is in place to satisfy it. This is irrespective of how long demand is at absolute peak levels each year. For example, electricity distribution business ENERGEX claims that 13 per cent of their network capacity is only used for a few *hours* a few times a year.[12]

This complicates productivity measurement. While input requirements in ES are largely determined by changes over time in peak demand, the ABS measure of output in ES is based on growth in aggregate annual electricity production. The latter is effectively a measure of growth in *average* daily demand, not peak demand.

If peak demand grows at a different rate to average demand, this will tend to show up as changes to measured productivity (ceteris paribus) due to unmeasured changes in the average rate of capital utilisation. For example, if peak demand is growing faster than average demand, this will tend to lower the average rate of capacity utilisation in the sector, and thereby depress measured productivity. This issue is explored below.

Summer versus winter peaking

The cost to generators and network service providers (particularly in relation to capital costs) of meeting a given quantity of peak demand is generally higher in summer than in winter. This is because high ambient temperatures reduce the capacity of electricity networks to deliver a specific load or quantity of power

[11] Once produced, electricity cannot be easily stored — exceptions being in relation to battery banks and pumped storage systems.

[12] Direct quote from ENERGEX website, http://www.energex.com.au/network/peak_demand/peak_demand.html (accessed 11 April 2011).

(PB Associates 2006). As a result, transmission and distribution businesses must invest in network capacity on the basis of *when* absolute peak demand occurs during the year (summer versus winter), as well as the magnitude of peak demand.

If absolute peak demand shifts from winter to summer, this tends to require additional supply capacity, thereby lowering measured productivity growth (and vice versa).

Changing peak demand in Australia

The nature of peak electricity demand has changed in most states during the past 10 to 15 years. ENERGEX (2009a, p. 46) reports that prior to the early 2000s peak electricity demand in south east Queensland typically occurred in winter, but is now occurring in summer (figure 4.7). This is confirmed by esaa data (table 4.4) which also shows that peak demand in New South Wales has shifted from regularly occurring in winter to occasionally peaking in summer.[13] In Victoria, peak demand prior to the mid-1990s also consistently occurred in winter but now occurs in summer (Energy Efficient Strategies 2004).

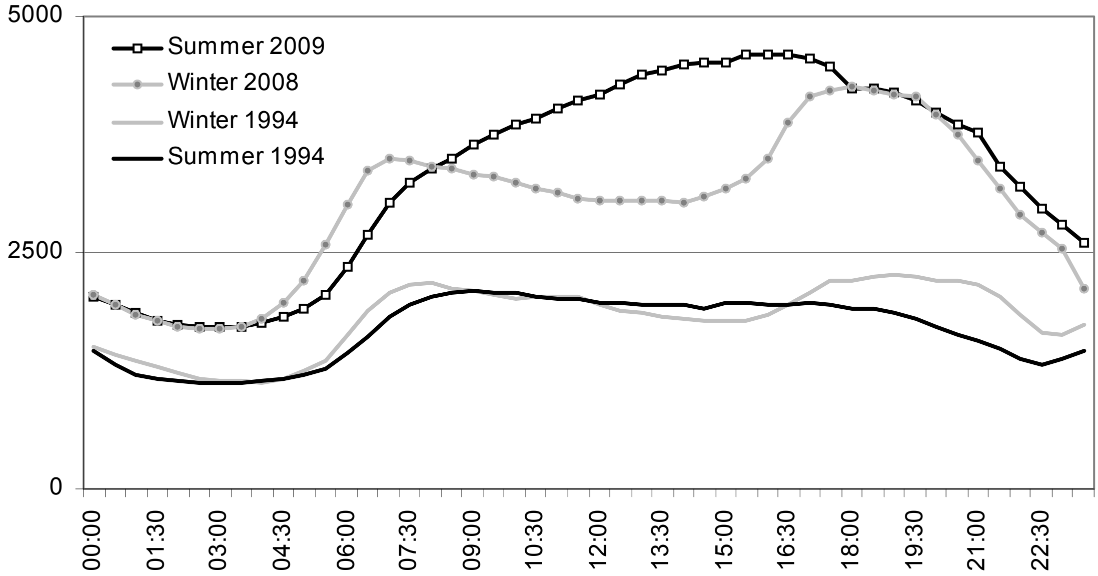
In south-west Western Australia (which accounts for 80 to 85 per cent of that state's electricity consumption) peak demand switched from winter to summer in 1993-94 and has remained summer dominant since (Raphael Ozsvath, Western Power, pers. comm., 19 May 2011). In contrast, Tasmania is still winter-peaking, primarily due to cold winters and comparatively mild summers.

As noted earlier, summer peaks are more costly to meet than equivalent-sized winter peaks, so the shift to summer peaking in Western Australia, Queensland, New South Wales and Victoria will have put downward pressure on MFP levels during the late 1990s and 2000s.

13 Smith (2005, p. 8) states that: '... prior to 2003 in NSW, summer peak demand had never exceeded the previous winter peak demand. However, in the summer of 2002-03, fuelled by extreme temperatures, peak demand of 12,456 MW exceeded the preceding winter peak for the first time.' esaa data indicate that the summer peak in the combined NSW/ACT region in 2000-01 was also above the winter peak, but is otherwise consistent with the winter peaking to occasionally summer peaking assessment.

Figure 4.7 **Changes in seasonal and diurnal electricity demand in south-east Queensland**

MW



Data source: ENERGEX (2009b, p. 4).

Table 4.4 **Season of peak electricity demand, by state, 1996-97 to 2009-10**

	New South Wales & ACT	*Victoria*	*Queensland*	*South Australia*	*Western Australia*	*Tasmania*
1996-97	Winter	Summer	Winter	Summer	Summer	Winter
1997-98	Winter	Summer	Summer	Summer	Summer	Winter
1998-99	Winter	Summer	Summer	Summer	Summer	Winter
1999-00	Winter	Summer	Winter	Summer	Summer	Winter
2000-01	Summer	Summer	Summer	Summer	Summer	Winter
2001-02	Winter	Summer	Summer	Summer	Summer	Winter
2002-03	Summer	Summer	Summer	Summer	Summer	Winter
2003-04	Winter	Summer	Summer	Summer	Summer	Winter
2004-05	Winter	Summer	Summer	Summer	Summer	Winter
2005-06	Summer	Summer	Summer	Summer	Summer	Winter
2006-07	Winter	Summer	Summer	Summer	Summer	Winter
2007-08	Winter	Summer	Summer	Summer	Summer	Winter
2008-09	Summer	Summer	Summer	Summer	Summer	Winter
2009-10	Summer	Summer	Summer	Summer	Summer	Winter

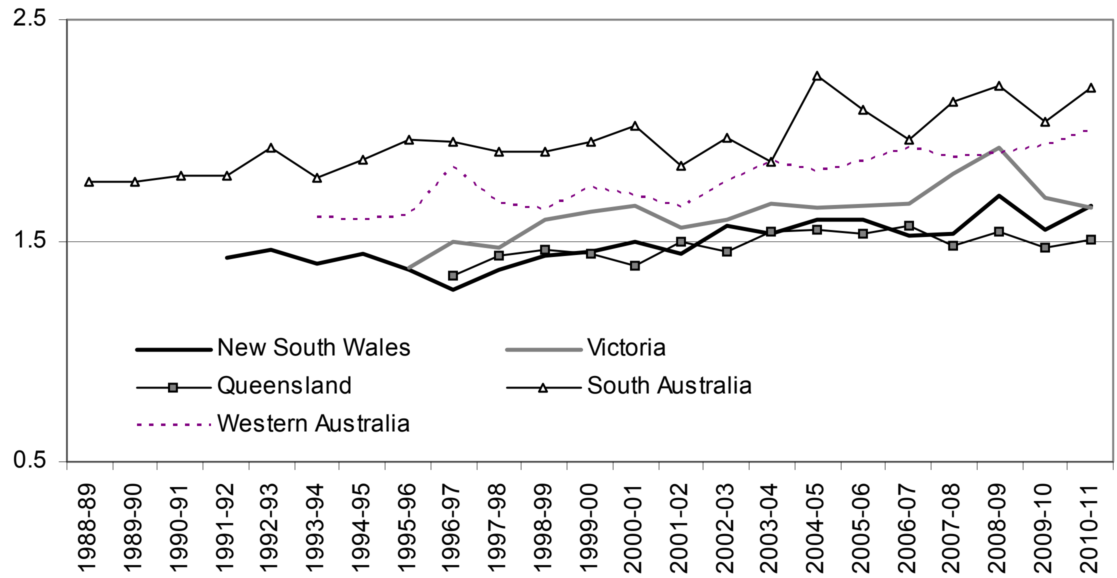
Source: Authors' estimates derived from data in esaa, various years, *Electricity Gas Australia;* esaa's historical database.

Extent of summer peak demand

Apart from the general shift of peak demand from winter to summer, the next key question is to what extent has peak demand risen over time relative to average demand?

In most states, the ratio of peak summer demand to average annual demand has been trending upwards over the past ten to fifteen years, with quite substantial increases in some states over the period for which data are available (figure 4.8). The summer peak demand problem is particularly acute in South Australia and has been a long-standing challenge for the electricity supply sector in that state (Government of South Australia 2003).

Figure 4.8 **Peak summer to average annual demand ratio,[a] 1989 to 2011**
Ratio



a Peak summer demand information is not available for all states prior to 1996-97. Peak demand and average annual demand are measured in megawatt hours (MWh).

Data sources: Authors' estimates from data in esaa, various years, *Electricity Gas Australia;* esaa's historical database.

Similarly, the rise of relative peak summer demand in Victoria during the 2000s has been particularly rapid, with the ratio of peak to average demand growing from 1.5 in 1996-97 to just under 2.0 during the very hot summer of 2008-09. That is, peak electricity demand in Victoria during summer in early 2009 was almost double the average daily demand for electricity in Victoria during 2008-09 as a whole.[14]

A graphical illustration of the problem of peak demand

While not directly related to the time period covered by the analysis of productivity in this report, a comparison of daily peak electricity demand within the NEM in 2009-10 versus 2010-11 (see figure 4.9) highlights the effect that peak demand can have on capital requirements, and the efficiency with which the generation and network capacity is used. This figure also illustrates a number of features of peak daily demand mentioned earlier, including that peak daily demand is typically lower on weekends compared with weekdays, and is typically lower during the milder seasons (spring and autumn) compared with the more extreme seasons (winter and summer).

The summer of 2009-10 was comparatively hot, and maximum daily demand for electricity within the NEM (largely driven by air-conditioner use) rose above 30 GW on 27 occasions (figure 4.9). In contrast, summer in 2010-11 in Australia was comparatively cool, and maximum daily demand exceeded 30 GW on just 7 occasions.[15] For the remainder of summer 2010-11, maximum daily demand was comparatively low.

However, when a spell of hotter weather did eventually occur in south-east Australia in late January/early February 2011, maximum daily demand increased dramatically, reaching a final peak for the summer of 34.888 GW, which was well above the absolute summer peak of the previous year (33.667 GW).

So while average and daily maximum summer demands were generally higher in 2009-10, ultimately more generation and network capacity was needed to meet the one short period of extremely high demand for electricity within the NEM (that finally peaked on 2 February 2011), than at any time during the longer, hotter summer of the previous year. In fact, total electricity supplied in summer 2010-11 was around 5 per cent lower than the previous summer, despite the fact that peak demand in 2010-11, when it finally occurred, was around 4 per cent higher.

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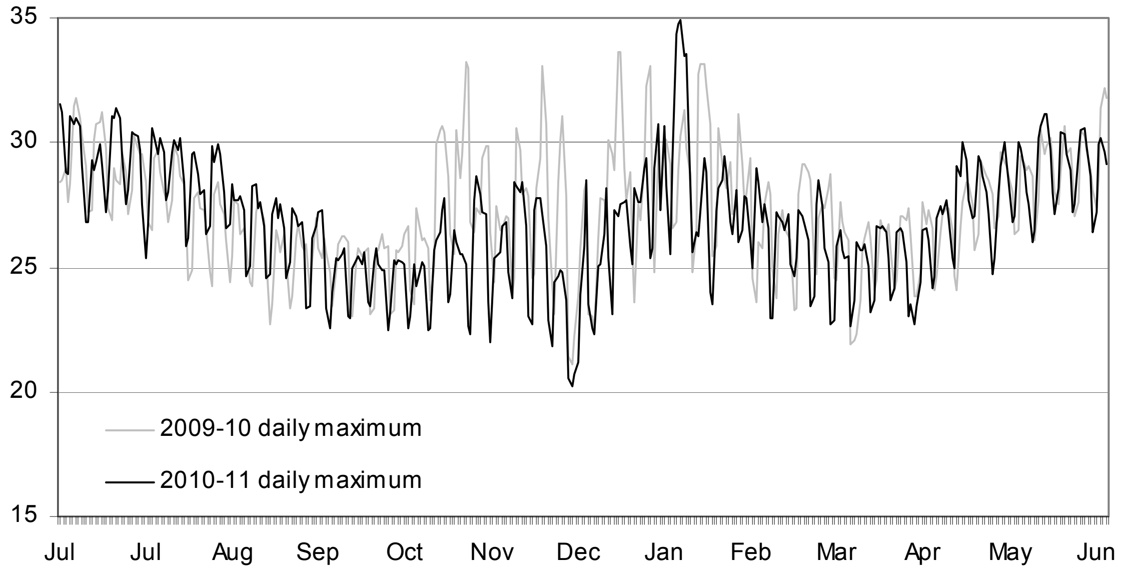
14 Growing peak to average electricity demand is not peculiar to Australia. A report by the Electric Power Research Institute (EPRI) showed that summer peak demand in the United States grew at 2.1 per cent per year from 1996 to 2006, while average demand grew by 1.7 per cent (EPRI 2009).

15 For the purpose of this analysis, summer is defined to be the period from 1 November to 28 February.

Figure 4.9 **Peak (maximum) daily electricity demand in the NEM, 2010-11 versus 2009-10[a]**

GW



[a] Peak daily demand is defined as the maximum of the 48 half-hourly electricity demand estimates published each day by the Australian Energy Market Operator (AEMO) across the National Electricity Market.

Data source: Derived from AEMO aggregated monthly price and demand data sets, http://www.aemo.com.au/data/price_demand.html.

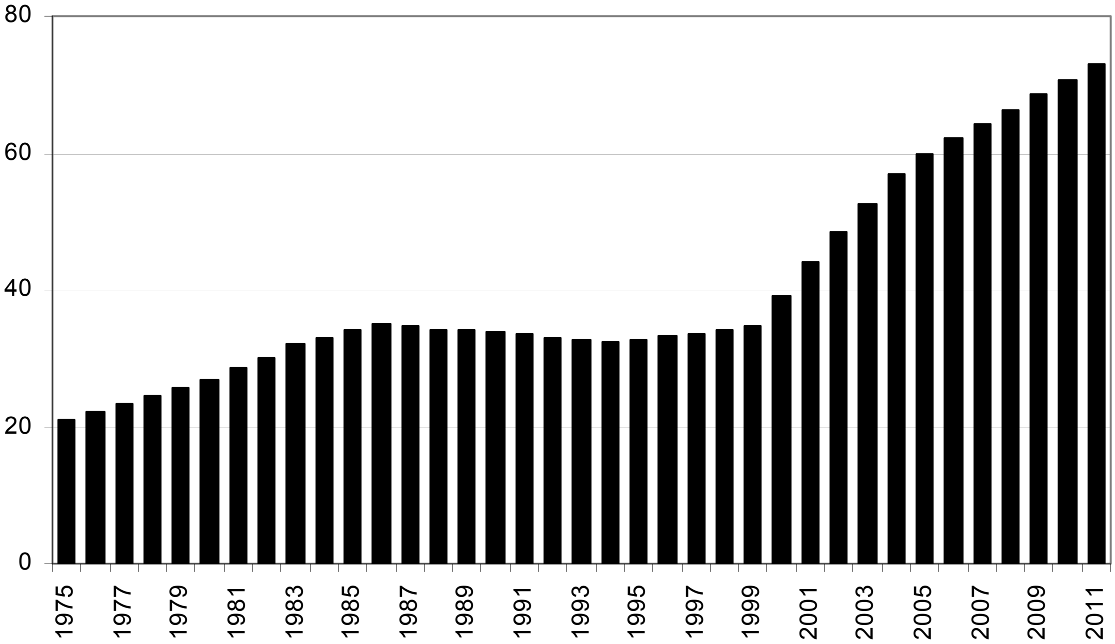
Drivers of growth in peak demand

The increase in the peakiness of electricity demand is generally attributed to growing penetration and ownership of air-conditioners, particularly in the residential sector (see PC 2005; AER 2010; Energy Efficient Strategies 2006; Office of Energy, Government of Western Australia 2004 and IPART 2010).

The proportion of homes in Australia with a cooler/air-conditioner has risen significantly over the past decade and a half (figure 4.10). The growth in cooler penetration rates[16] was strong across most states, but less rapid in the Northern Territory where penetration rates were already quite high, even in the mid 1990s (figure 4.11).

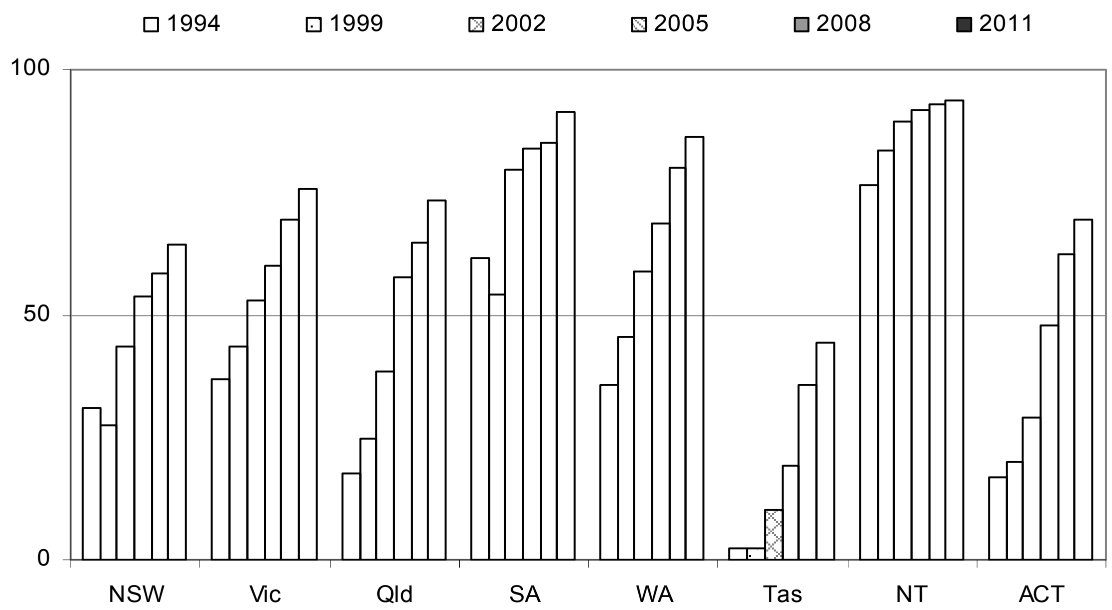
[16] Penetration refers to the proportion of homes that have a cooler, whereas ownership refers to the total number of coolers owned divided by the total number of households.

Figure 4.10 **Australian homes with an air-conditioner or evaporative cooler, 1974-75 to 2010-11**
Per cent



Data source: Authors' estimates derived from ABS (*Environmental Issues: Energy Use and Conservation*, Cat. no. 4602.0.55.001, March 2011) and Energy Efficient Strategies (2006).

Figure 4.11 **Dwellings with a cooler,[a] June 1994 to March 2011, by jurisdiction**
Per cent



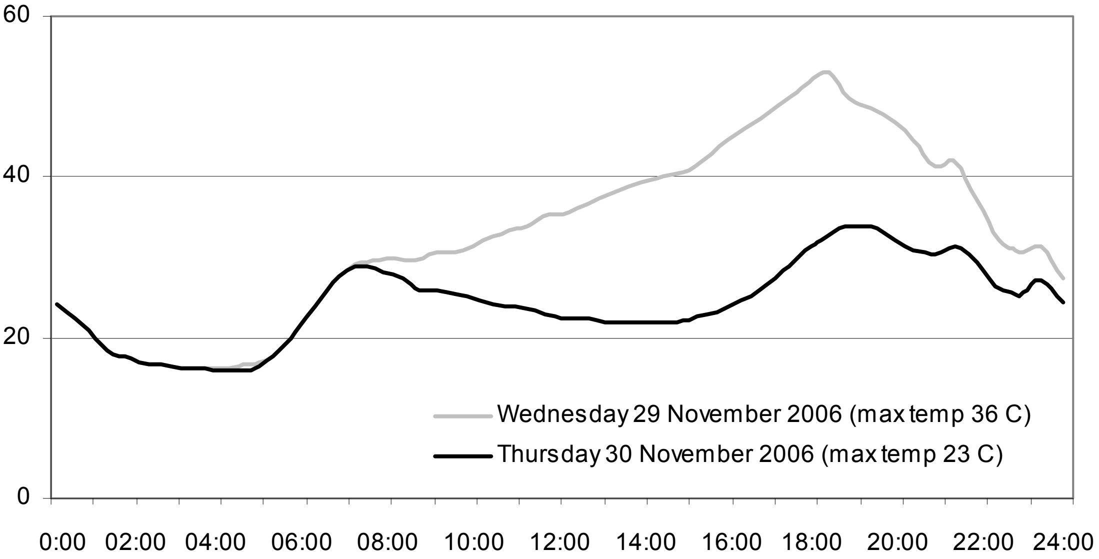
[a] A cooler refers to an air-conditioner or evaporative cooler.

Data source: ABS (*Environmental Issues: Energy Use and Conservation*, Cat. no. 4602.0.55.001, March 2011).

The relationship between temperature change and air-conditioner use (and hence power demand) on hot summer days is illustrated in figure 4.12, which compares diurnal power demand in a power supply region in Brisbane on two consecutive days — one very hot (max 35.6 degrees centigrade), and the other comparatively mild (max of 23.3 degrees centigrade). Power consumption on the hot day peaked at a level 65 per cent higher than peak consumption the following day.[17]

Figure 4.12 **Impact of temperature on diurnal power demand in a region of Brisbane[a]**

Mega Volt Ampere



[a] Albany Creek/Arana Hills region. Peak demand on consecutive days in November 2006.

Data source: Reproduction of data from ENERGEX (2009a, p. 46).

Apart from air-conditioning, growing penetration and ownership rates of other residential appliances, such as dishwashers, televisions and refrigerators, may also be contributing to growing relative peak demand. For example, dishwasher penetration increased from 25 per cent of households in 1995 to 45 per cent of households in 2008, while the number of households with a second refrigerator rose from 22 per cent to 30 per cent over the same period (ABS 2008). According to ENERGEX (2010), penetration and ownership rates of certain electrical appliances have increased significantly in south east Queensland during the past decade, and these changes are contributing to the challenge of meeting peak demand in that state (table 4.5).

[17] For detailed information regarding energy appliance usage patterns (including air-conditioner use) and typical summer and winter peak demand load patterns in the residential and commercial sectors, see EMET Consultants Pty Limited (2004).

However, the rise in ownership and use of these appliances could only be contributing to the increase in relative peak demand if they were being used proportionately more often during the late afternoon/early evening peak period, rather than being used more evenly throughout the day.

Table 4.5 **The changing south east Queensland (SEQ) home[a]**

Appliances	*1999*	*2009*
SEQ homes with air-conditioning	23 per cent	72 per cent (34 per cent with 2 or more)
Homes with at least one personal computer	48 per cent	98 per cent
Number of televisions in average SEQ family	1	3 (25 per cent are high-energy use)
SEQ homes with a dishwasher	31 per cent	50 per cent
Microwave ovens (less than 30 per cent in 1989)	72 per cent	97 per cent

[a] Reproduction of data contained in a slide presentation given by ENERGEX in 2010.

Source: ENERGEX 2010.

Growth in physical capital to accommodate growing *peak* demand

Peak electricity demand in Australia is generally supplied by gas turbine *peaking plants*. These plants are specifically designed to meet peak-load demand, and while expensive to run, they are quick to start up and shut down. They can be called on to operate at short notice, such as when supply from baseload and/or intermediate stations[18] is unexpectedly unavailable. Primarily however, gas turbine plants are referred to as *peaking* plants on the basis that they typically supply power during periods when electricity demand is in excess of the total available capacity of baseload and intermediate generators (see AER 2009, p. 53).

Data from esaa show that there was a significant increase in the proportion of gas turbine plants in the aggregate generation mix late in the first decade of the 2000s,

18 'The classifications of *base*, *intermediate* and *peak* are based on typical hours of running or capacity factors, and mode and cost of operation. Generation classified as *base* has a long term capacity factor (proportion of capacity in use) close to one, and low operating costs, but can take many hours to start. *Peak* generation has a long term capacity factor closer to zero, and higher operating costs, but can start rapidly. *Intermediate* generation falls in between.' AER (2007, p. 65)

which is consistent with the strong growth in the ratio of peak to average demand during the period (figures 4.13 and 4.14).[19]

Amount of additional peaking capacity?

While difficult to quantify with precision, the increase in peak to average demand between 1997 and 2010 is estimated to have required an additional 6 300 MW of (peak) generation capacity, compared with what would otherwise have been the case. This estimate is made by holding fixed the ratio of peaking to non-peaking capacity from 1996-97 forward. The additional peaking capacity represents around 13 per cent of current generation capacity, and while it is critical in terms of meeting peak summer demand during extremely hot periods, it sits idle for the majority of the year. (It represents an investment of around $6.2 billion, which is around 6 per cent of total capital investment in Electricity supply over the period.)

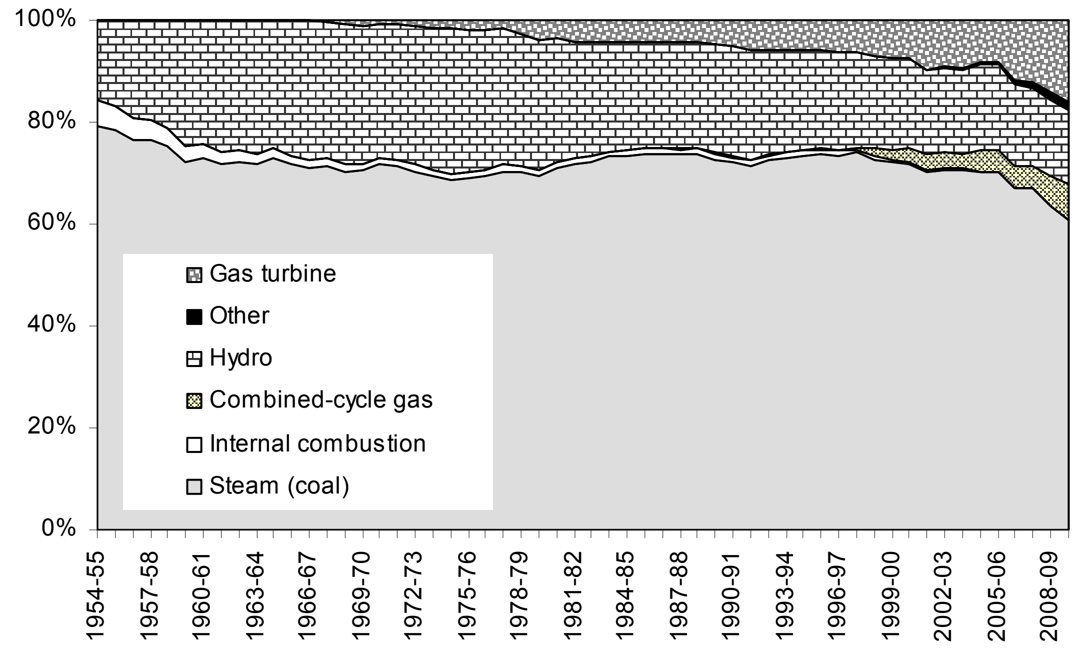
Impact on capacity factors?

Assuming there was no pre-existing surplus of supply capacity, persistent growth in the ratio of peak to average demand since the late 1990s should have shown up as a decline in the (average) rate of capacity utilisation. Data from esaa (shown earlier in figure 4.4) indicate a slight decline in average capital utilisation in the generation sector over the first decade of the 2000s as a whole, with a sharper drop in the final few years of the decade.

In relation to network capacity, the utilisation ratio has fallen significantly since 1997-98, consistent with the view that growth in relative peak demand has resulted in a reduction in network system efficiency (figure 4.5).

[19] Figure 4.13 also shows the growth in combined-cycle gas plants, a comparatively new source of baseload and intermediate capacity that is taking over from coal-fired power stations as the latter lose favour due to their carbon intensity. This issue is discussed in more detail later in this chapter.

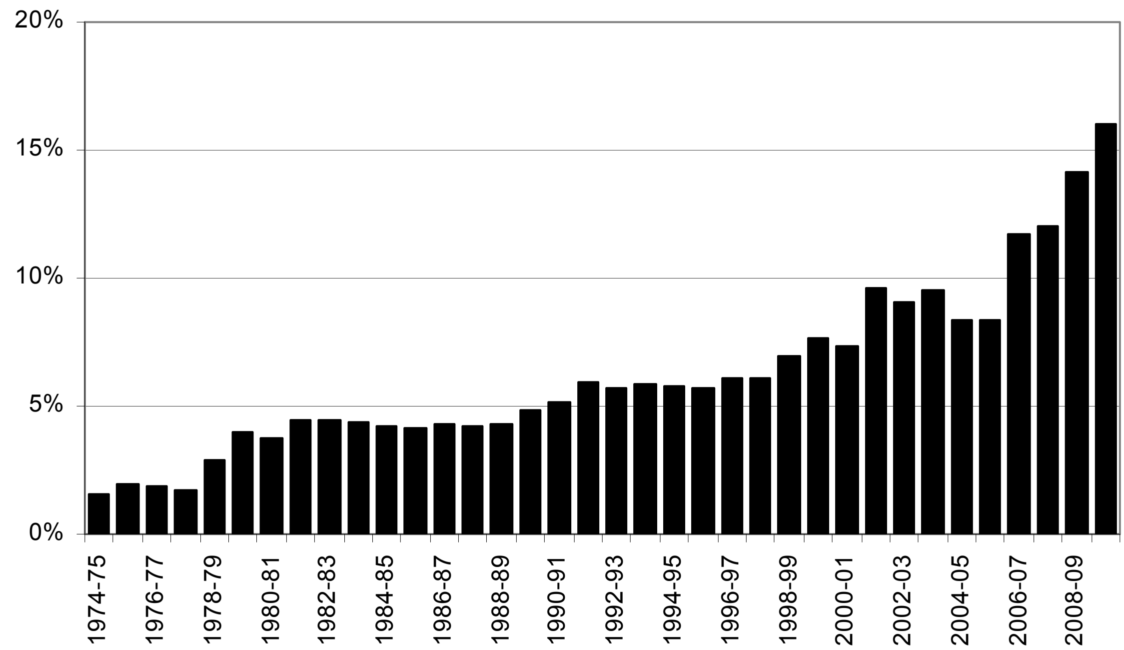
Figure 4.13 **Shares of electricity generation capacity, 1954-55 to 2009-10**
Per cent



[a] Refers to principal generation capacity as reported by esaa.

Data sources: esaa, various years, *Electricity Gas Australia;* esaa's historical database.

Figure 4.14 **Gas turbine share of total generation capacity,[a] 1975 to 2009**
Per cent



[a] Based on principal generating capacity as reported by esaa.

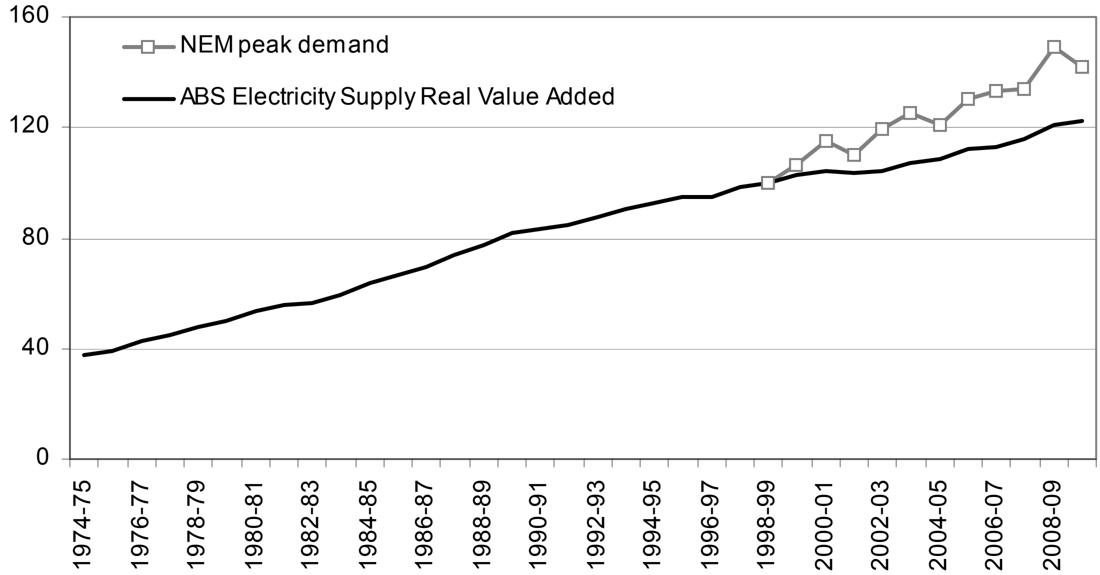
Data sources: esaa, various years, *Electricity Gas Australia;* esaa's historical database.

Quantifying the impact of peak demand on MFP

An estimate of the extent to which growing relative peak demand has impacted on MFP has been made using an index of peak summer demand each year as the measure of output for the subdivision rather than the ABS estimate of real value added. As noted earlier, the latter largely reflects changes in aggregate electricity production, and this has grown more slowly than an index of peak demand since the late 1990s (figure 4.15). Peak or maximum demand is more variable from year to year than real value added, reflecting the fact that it is inherently more variable than average annual electricity demand.

Figure 4.15 **Electricity supply: Real value added and peak summer demand,[a] 1974-75 to 2009-10**

Index 1997-98 = 100



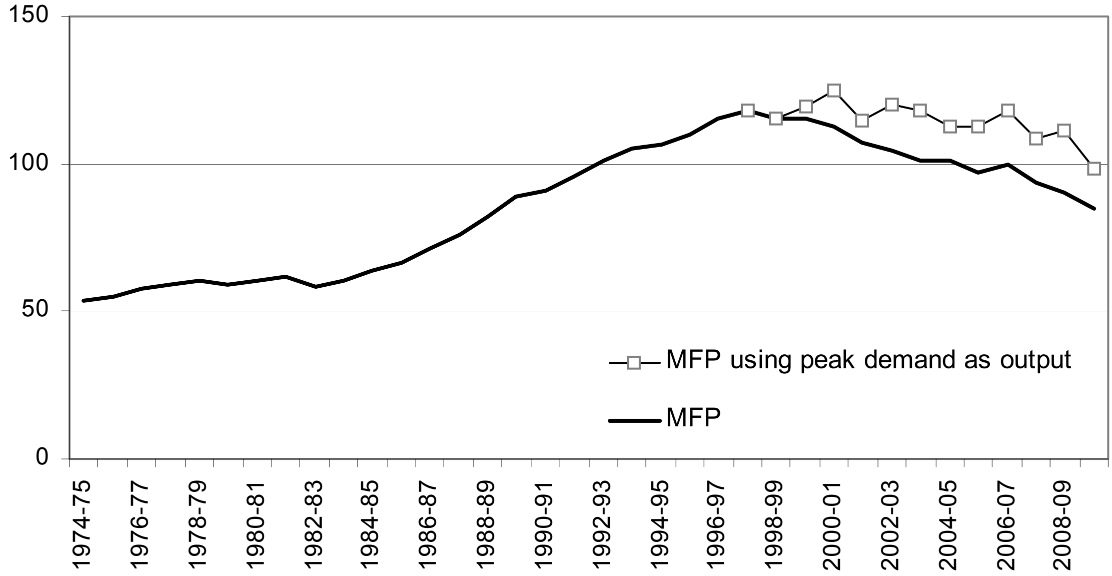
a Index of annual concurrent peak demand in the NEM from 1989-90 onward.

Data sources: ABS National Accounts on dXtime (database); AEMO, http://www.aemo.com.au.

Substituting the index of peak demand for the standard measure of output (from 1988-89 onwards) and re-estimating MFP on that basis provides an indication of the extent to which the change in relative peak demand has contributed to the observed decline in productivity since the late 1990s (figure 4.16). On this basis, around one half of the decline in the level of MFP between 1997-98 and 2009-10 is potentially the result of an increase in the ratio of peak to average demand.

Figure 4.16 **Electricity supply: Impact on MFP of increasing relative peak demand[a]**

Index 2006-07 = 100



a There is only limited information available regarding (relative) peak summer demand prior to 1998-99. The analysis in this figure shows only the impact on MFP of changes to relative peak summer demand since 1998-99. Also, the analysis uses changes in coincident peak summer demand in the NEM as a proxy for national peak demand.

Data source: Authors' estimates.

Implications of the peak demand 'problem' for MFP analysis and interpretation

While growth in relative peak demand was largely accommodated by building new supply infrastructure, some have claimed that it could have been better addressed through demand management. Were that true, some part of the decline in MFP due to growing peak demand should be seen as representing genuine inefficiency. The issue of the efficient level of investment in ES is, however, contentious (see, Garnault 2011; Mountain and Littlechild 2009 and IPART 2010). Any judgment on the matter is outside the scope of this study, though it is being considered as part of a Productivity Commission inquiry into benchmarking of electricity networks (due to report in April 2013).

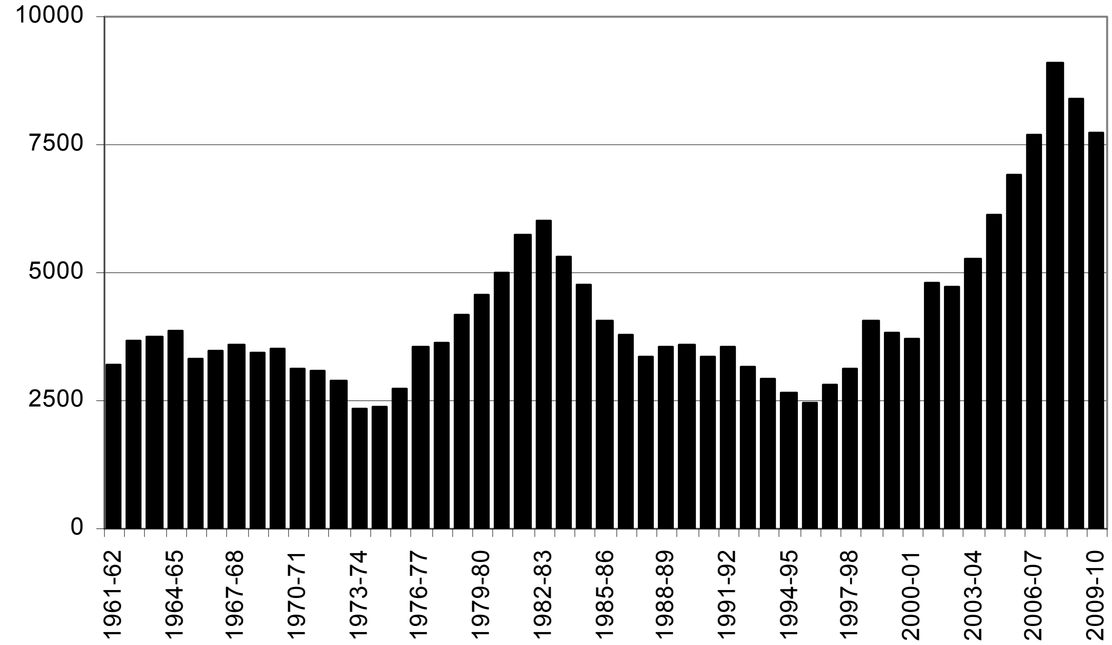
Looking ahead, any further growth in the ownership and use of air-conditioners in Australia may put further downward pressure on measured productivity in the sector if relative peak demand increases. However, if policy or other changes are introduced that lead to a reduction in the *peakiness* of electricity demand (such as greater use of demand management), this will tend to have an ameliorating effect on measured productivity in ES.

Ageing infrastructure and cyclical investment behaviour

The second reason identified as a cause of negative productivity growth in ES since the late 1990s is that of lumpy capital investments, and associated lags in the time taken before new supply capacity is fully utilised.

Electricity supply is characterised by periodic surges and declines in the rate of growth of generation and network capacity. The strong growth in capital and labour inputs in ES from the late 1990s to 2009-10 is the most recent of a number of investment surges in ES that have occurred over time (see figure 4.17). It is consistent with the observation that much of the growth in capital and labour inputs during the period has been associated with a major program of infrastructure renewal or replacement (see AER 2010; Sims 2010; Industry and Investment NSW 2010 and IPART 2010, pp. 8, 38, 45).

Figure 4.17 **Electricity supply: Real capital investment, 1961-62 to 2009-10[a]**
$ million, constant 2006-07 dollars



[a] From 1974-75 to 2009-10, real capital investment is the sum of investment in two types of capital goods: non-dwelling construction; and plant, machinery and equipment. Estimates prior to 1974-75 were derived by splicing on an index of (total) capital investment in the Electricity supply subdivision that was itself derived from unpublished ABS data on (current price) gross fixed capital formation in the subdivision. The latter was deflated using a capital goods price index also provided by the ABS. Further details available in Appendix A.

Data sources: Authors' estimates based on ABS (Cat. nos: 8208.0, 8226.0, 8155.0 and 5204.0); ABS unpublished data.

Infrastructure assets built in the mid-to-late 1960s that had a lifespan of 30 to 40 years would likely have been up for replacement or refurbishment from the mid-to-late 1990s onwards. Similarly many of the assets built in the investment boom of the late 1970s/early 1980s would also have been at or near retirement or renewal age from the early 2000s onwards. Refurbishment and replacement of these assets would also be contributing to the surge in investment since the late 1990s, and particularly in the past five years or so.

While estimated input growth in ES has slowed in recent years, it is probably too early to say whether the subdivision is about to enter a phase of significantly slower growth in measured inputs. For example, further growth in relative peak demand and/or the early closure of coal-fired power stations for environmental reasons would maintain pressure on current rates of investment in the sector. However, the historical record indicates that the rapid growth in inputs during the past five to ten years is unlikely to be maintained indefinitely.

Given the periodic or cyclical component to capital infrastructure investment in ES, some part of the recent build up in capital capacity (particularly in the network) is likely to be in the form of lumpy capital assets that are designed to underpin growth in demand well into the future, not just to meet current demand. The consequences for MFP are twofold: first, MFP growth in recent years will have been lower than would otherwise have been the case. An increase in investment in long-lived capital assets that will not be fully utilised until sometime in the future will have put (temporary) downward pressure on MFP. Second, once the current investment cycle is completed, output is likely to grow while labour and capital input growth is likely to moderate. These developments will have positive effects on measured MFP. Underlying growth in MFP will not be clear until these developments play out.

Hidden quality changes — the case of underground versus overhead distribution of electricity

Another issue raised during industry and stakeholder consultations for this project was that a mandated shift towards underground electricity cabling may also have contributed to lower measured productivity because the former has a higher capital cost (per circuit kilometre) than the latter.[20]

The capital costs of installing underground cables are greater than those for equally rated overhead lines, with the ratio rising as the voltage of the line increases. Cost ratios can range from about 2:1 at 11 kV to 20:1 or more at 400 kV, but the cost for each individual line is highly location specific, depending on many local factors, including the ground conditions (Energy Networks Association 2006). An inquiry

20 In most states undergrounding of electricity cabling is now required or mandatory for all new developments, while there are also policies and programs aimed at undergrounding existing cabling in some circumstances (IPART 2002, p. 36).

into electricity distribution in Queensland estimated the cost of undergrounding all electricity cabling in that state to be in the order of $50-60 billion, around ten times the current value of these assets (Department of Natural Resources, Mines and Energy 2004).

Although there are benefits to underground cabling as well as costs, some of the benefits — such as improved amenity values, reduced risk of vehicular accidents and reduced bushfire risk[21] — do not always accrue to the electricity sector, and hence are not reflected in the subdivision's productivity statistics. (In fact, these benefits are not systematically accounted for as an increase in the output of any sector.)

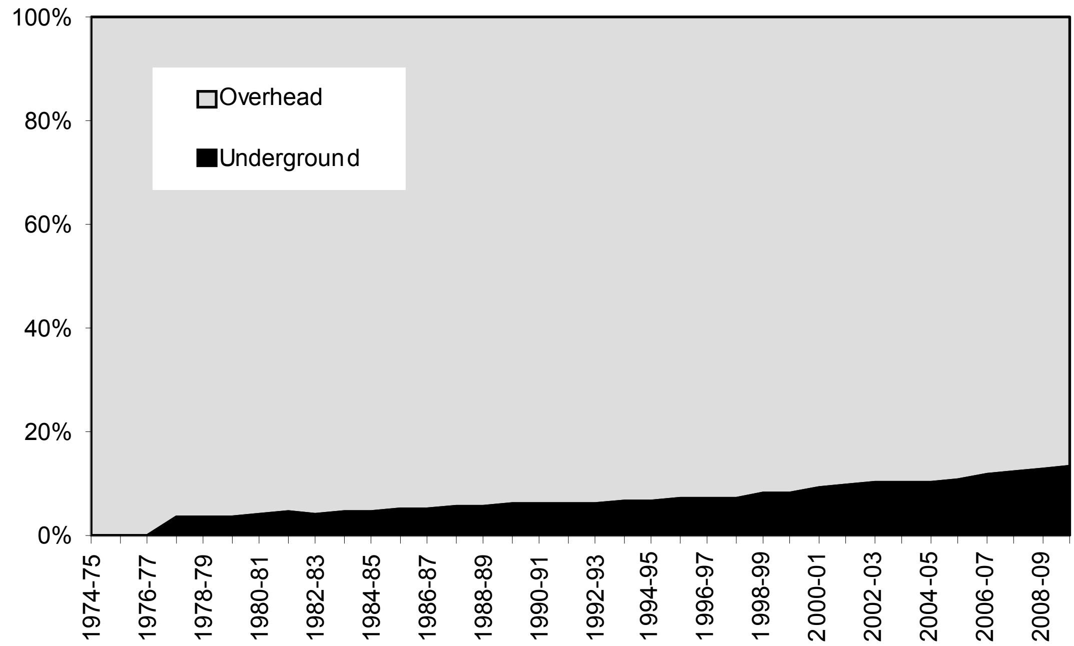
Data from esaa show that, while the aggregate quantity of underground cabling in place remains small relative to overhead cabling, the installation of underground cabling has been growing much faster than overhead lines, and grew particularly quickly during the recent *negative* phase of MFP (figures 4.18 and 4.19). In fact, the majority of new transmission and distribution cabling laid during the negative MFP growth phase was underground (56 411 circuit kilometres out of a total 88 046). This is in marked contrast to earlier periods when the vast majority of new electricity lines were installed above ground.

It has not been possible to measure the extent to which the switch to underground cabling has contributed to the observed decline in ES MFP in the *negative MFP growth* phase. However, electricity distribution represents a significant share of subdivision costs, and the majority of all new distribution cabling is now underground rather than overhead.

The switch to underground cabling identified above is a cause of negative MFP growth in ES, and represents an increase in costs to electricity businesses. What is not established in this assessment is whether or not the costs of the policy change (including those represented by a loss in measured productivity) exceed the benefits. Comparison of these costs and benefits is beyond the scope of this paper.

21 The 2009 Victorian Bushfires Royal Commission (2010), recommended: '... the progressive replacement of all SWER (single-wire earth return) power lines in Victoria with aerialbundled cable, underground cabling or other technology that delivers greatly reduced bushfire risk.' http://www.royalcommission.vic.gov.au/Assets/VBRC-Final-Report-Recommendations.pdf, (Recommendation 27).

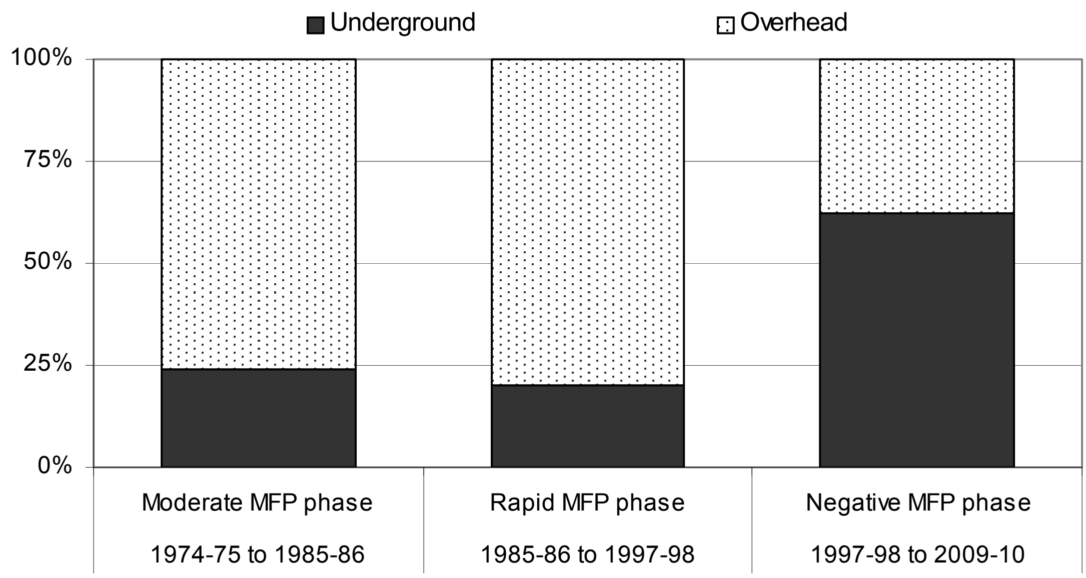
Figure 4.18 **Shares of electricity lines,[a] 1974-75 to 2009-10**
Per cent of total



[a] Overhead cabling excludes 500 kV lines as there is no underground equivalent to overhead lines of this type in Australia.

Data sources: esaa, various years, *Electricity Gas Australia;* esaa's historical database.

Figure 4.19 **Electricity cabling installed, by type, 1974-75 to 2009-10**
Circuit kilometres, per cent



Data sources: esaa, various years, *Electricity Gas Australia;* esaa's historical database.

Other hidden quality issues

Apart from undergrounding of electricity cabling, measured productivity in ES during the past decade or so may also have been adversely affected by regulatory and other changes that were targeted at improving the reliability of electricity supply.

There is some evidence of higher reliability standards being required in ES and that additional expenditures were needed to meet these standards (see New South Wales Minister for Energy 2007; Endeavour Energy 2011, p. 19 and IPART 2010, p. 64). Additional data and research are required to quantify the extent to which this factor contributed to the decline in measured productivity in the subdivision after 1997-98.

Changes to the source of electricity generation due to climate change policy

While the debate regarding climate change and the appropriate public policy response has been particularly prominent in Australia during the past few years, the issue has influenced investment decisions in the electricity sector for considerably longer.

The 1997 esaa annual report describes a looming challenge to coal as the dominant electricity fuel source in Australia because of two main factors. First, a more competitive market was expected to make gas more attractive to investors, as gas-fired power plants could be made smaller and modular, and had shorter lead times for construction and expansion, thereby making them less risky compared with the large investments needed to achieve economies of scale with coal-fired power stations. Second, greenhouse gas abatement policies would work against coal, and in favour of gas and renewables (esaa 1997, p. 4).

The Managing Director of esaa at the time of the report cited above, Keith Orchison, has recently written that:

> ... in a world managed by power engineers, ground would long since have been broken at Macquarie Generation’s Bayswater B site to construct two more 1000 MW coal-burning units to sustain the state’s baseload supply well beyond 2020 and to underpin some large-scale, energy-intensive industrial development with low-priced fuel. (Business Spectator, 13 January 2011).

As noted earlier, coal-fired power’s share of total generation capacity fell quite considerably during the 2000s (although its share of total energy production has not fallen by as much) as new generation capacity shifted towards combined-cycle gas plants (figure 4.13). Government policies have supported rapid growth in non-hydro renewable generation capacity (especially wind power), although they supply only a small share of total output (2.8 per cent of principal electricity generation in 2009-10).

Examination of the size, type and decade of first operation of Australia's current mix of generating capacity also provides insights into the effects of actual and anticipated energy policy changes on the generation sector over time, and the effects of uncertainty regarding the future profitability of higher-emission sources of supply such as coal (figure 4.20). In this figure, generating capacity in place in 2009-10 is grouped according to the decade it was commissioned and by the type of plant (coal, gas, hydro etc). A separate line indicates how many of the current stock of generation plants were commissioned in each decade. For example, of the 264 power stations operating in 2009-10, 101 were first commissioned in the 2000s, 49 were commissioned in the 1990s, and 21 were commissioned prior to 1959.[22]

The information in figure 4.20 indicates that:

1. A large share of Australia's current generation capacity is accounted for by a comparative small number of large coal-fired power stations that were built in the 1970s and 1980s. The prevailing philosophy at the time was that Australia should consolidate its energy future by focussing on its core comparative advantage — cheap and plentiful supplies of coal.
2. Comparatively little of our current generation capacity was built in the 1990s, which is consistent with the marked decline in new investment in the sector in that decade.[23]
3. Since 2000, just under one half of new baseload and intermediate power needs have been met by combined-cycle gas plants.

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[22] Figure 4.20 includes principal and non-principal power stations, as defined by esaa (2011). Power stations that provide their output to the retail electricity market and have their output subject to the control of electricity market operators are categorized as *principal power stations*. They accounted for 91 per cent of total power generating capacity in 2009-10. Non-principal power stations accounted for the other 9 per cent of capacity, and are typically much smaller in size, on average, than principal power stations. The output of non-principal power stations is not generally subject to the control of the electricity market operators. Non-principal power stations often provide electricity to a single end-user, rather than to the retail market. Many wind farms are classified as non-principal power stations on this basis, as their output is often tied to a particular production facility, such as a factory or a desalination plant. For more information see esaa (*Electricity Gas Australia 2011*, Appendix 6a).

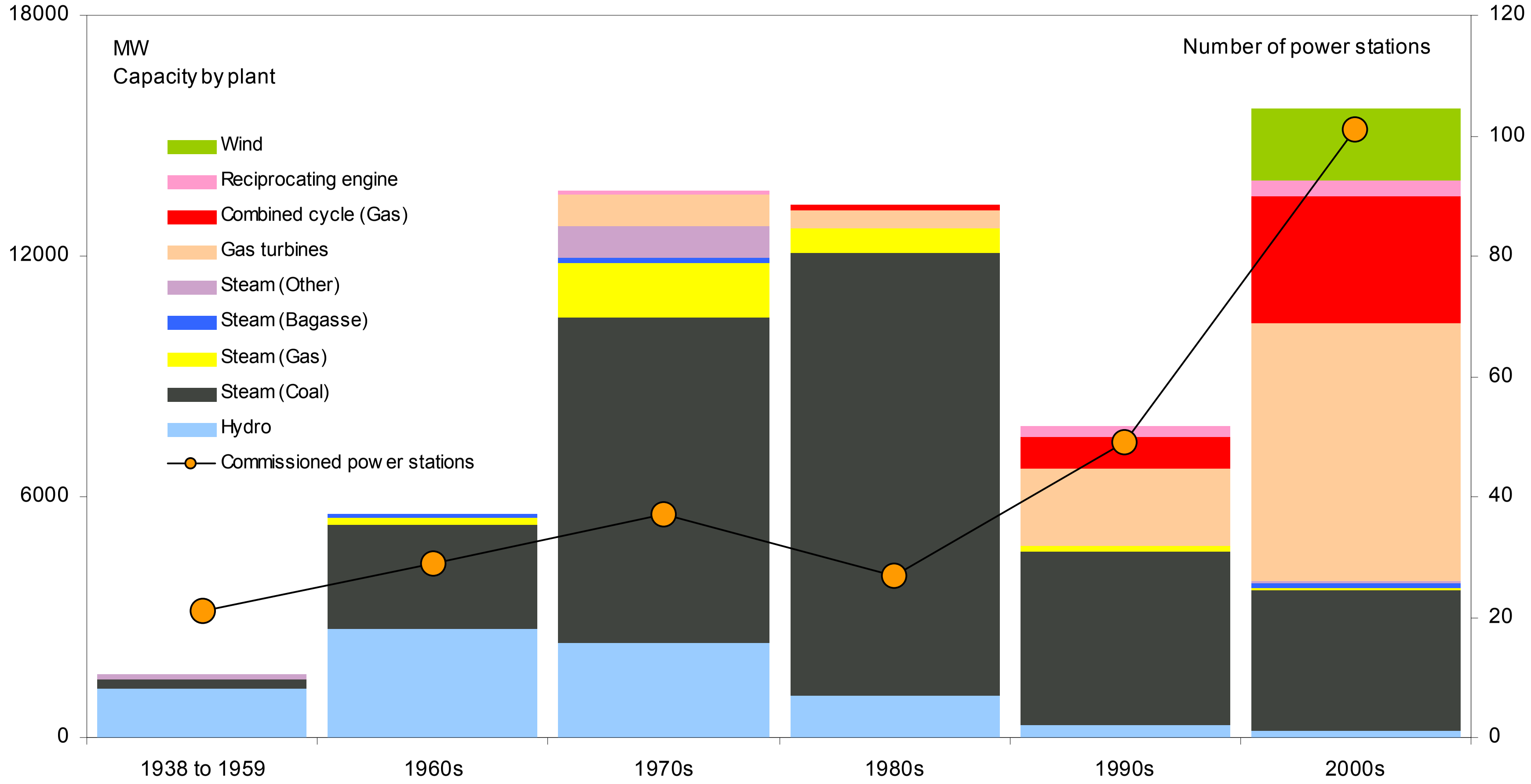
[23] If a disproportionate amount of new plant added in the 1990s was de-commissioned prior to 2009-10, this would partly invalidate this result. However, examination of esaa historical data shows that this is not the case.

4. 38 per cent (101 out of a total of 264) of the power stations in operation in 2009-10 were constructed after 2000. However, these plants only account for 27 per cent of aggregate generation capacity.
5. The average size (in terms of maximum generation capacity) of the power stations that were built in the 1990s and 2000s is substantially smaller than that of those stations built in previous periods. Stations operating in 2009-10 that were commissioned in the 1990s and the first decade of the 2000s average 140 MW each, versus 367 MW for stations originally built in the 1970s and 537 MW for those built in the 1980s.
6. Most of Australia's currently operating hydro power stations are comparatively old.
7. Wind power continues to grow in response to government initiatives, but remains only a small contributor.

In essence, from the late 1990s onwards Australia began to shift away from coal as the primary source of new baseload and intermediate generation capacity. These needs were largely being supplied by combined cycle gas turbine (CCGT) power stations and, to a much lesser extent, renewable energy plants.

In comparison, the increased importance of open-cycle gas turbine plants was, as noted earlier, largely a response to growing peak demand for electricity. Arguably, this development would have occurred irrespective of climate-change considerations.

Figure 4.20 **Generation capacity in 2009-10, by size, age (based on decade of first operation), and type of plant**[a]



a Plants commissioned between 1938 and 1959 have been aggregated into a single group. Includes principal and non-principal power generators (see esaa 2011, p. 126). 23 power producers (representing 770 MW of capacity) are excluded because no year of commission is available.

Data source: Based on esaa 2011, *Electricity Gas Australia 2011*, June, esaa, Melbourne.

Evidence on costs

Although coal-fired power has traditionally been the cheapest way to produce baseload power in Australia (see box 4.2), improvements in the technology and efficiency of CCGT plants have narrowed the gap (AER 2009, p. 52; ACIL Tasman 2009, p. 83).[24] Nevertheless, the cost disadvantage of combined-cycle gas relative to coal-fired power will have contributed to the loss in measured productivity in electricity supply during the last 10 to 15 years.

Box 4.2 **The costs of electricity sources**

The levelised cost of electricity (LCOE) is a widely-used measure of the cost of different electricity generation technologies. Estimates of the LCOE are sensitive to assumptions about factors such as capital costs, the useful life of assets and the technical efficiency of generation technologies. As such, they should be treated as an indicative guide to the relative costs of various technologies.

The Electric Power Research Institute (EPRI 2010) reported estimates of the LCOE of various sources of electricity in Australia, including:

- coal-fired electricity (without carbon capture and storage) — A$78–91/MWh
- combined-cycle gas turbines (without carbon capture and storage) — A$97/MWh
- wind — A$150–214/MWh
- medium-sized (five megawatt) solar photovoltaic systems — A$400–473/MWh.

Smaller domestic photovoltaic systems are likely to have higher costs again. The high LCOE for solar photovoltaic is one of the reasons that policies that subsidise solar photovoltaic have high implicit abatement subsidies.

Sources: PC (2011c, p. 81); EPRI (2010).

Continued investment in CCGT plants in preference to coal-fired plants (to meet new baseload demand growth) will tend to put further downward pressure on measured productivity growth in the sector (ceteris paribus). However the productivity losses may be reduced if CCGT plants improve their efficiency. Early closure of otherwise productive coal-fired power stations would also contribute to downward pressure on measured productivity in ES.

The size of the negative effect on measured MFP due to the growth in renewable power sources is likely to have been small, but will have been increasing over time. Moreover it will continue to grow into the future as more renewables (particularly

24 This is putting to one side the issue of environmental or external costs associated with fossil fuel based power sources. For a detailed discussion of the external costs associated with different power generation sources see ATSE (2009).

wind power) are brought into the system under the RET scheme. More broadly, given these cost differentials, until the energy sector completes its ongoing process of structural adjustment in response to climate change policies (current and future), further downward pressure on measured productivity in the sector can be anticipated. On the other hand, there will be gains in the form of emissions reductions. In addition, there may be scope for greater relative efficiency of renewable generation technology in the future.

In summary, four key factors — growing relative peak demand, cyclical investment, unmeasured quality improvements to output, and a shift to higher cost supply sources in response to climate change — have been identified in this research as possible explanations for the negative MFP growth measured in ES since the late 1990s.

While the recent surge in new investment in ES may be having only a temporary effect on MFP in ES, the other three factors are structural, and reflect more permanent increases in the quantity of inputs required to produce each unit of measured output in the sector.

Other issues

Impact of the NEM on productivity

The motivation behind the introduction of the NEM was a desire to raise the efficiency and productivity of electricity supply in eastern Australia by taking advantage of potential cost savings arising from a system of interconnected state networks.

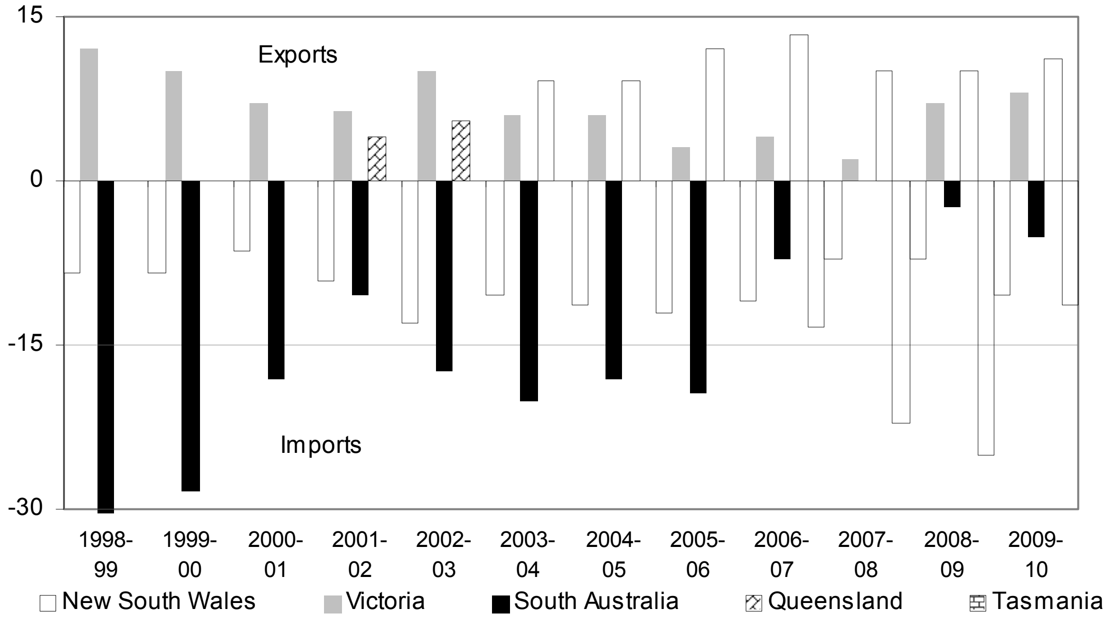
In practice, interregional flows of electricity since the start of the NEM indicate the benefits from having an interconnected system (figure 4.21).

The interregional trade data indicate the following:

1. New South Wales is a net importer of electricity. It relies on local baseload generation, but has limited peaking capacity at times of high demand.
2. Victoria has substantial low cost baseload capacity, making it a net exporter of electricity.
3. Queensland's installed capacity exceeds the region's peak demand for electricity, making Queensland a significant net exporter.

4. South Australia imported over 25 per cent of its energy requirements in the early years of the NEM. New investment in generation — mostly in wind capacity — has reduced this dependence since 2005-06.
5. Tasmania has been a net importer since its interconnection with the NEM in 2006, partly because drought has constrained its ability to generate hydroelectricity (AER 2010, p. 27). A return to average rainfall could see it switch from being a net importer to being a net exporter, as was initially expected when Tasmania joined the NEM.

Figure 4.21 **Interregional trade as a percentage of regional electricity consumption, 1998-99 to 2009-10**
Per cent



Data sources: AEMO, http://www.aemo.com.au; AER (2009).

More broadly, competitive pressures within the NEM are believed to have increased the utilisation and performance of generation assets and lowered operating costs, thereby driving real efficiency gains through the NEM-wide dispatch of generation (ERIG 2007, p. 3). Such gains would have had positive effects on MFP in Electricity supply.

The NEM continues to evolve in response to supply and demand developments, and in response to policy and regulatory changes. Problems and limitations in the operation and management of the NEM were identified in the ERIG (Energy Reform Implementation Group) review, particularly in relation to planning and investment decision making.

> An efficient national transmission system requires improved locational signals to generators, better efficiency incentives for Transmission Network Service Providers (TNSPs), and proper national planning, coordination and system integration for national, market-wide grid development. (ERIG 2007, p. 1).

The AEMC is currently undertaking a wide ranging Transmission Frameworks Review that is exploring many of these issues.[25]

Labour inputs

The strong growth in labour inputs in Electricity supply in the past five to ten years has contributed to the poor MFP outcome in the sector. The rise in labour inputs is confirmed by examination of company annual reports, particularly those of the major electricity distribution companies that collectively account for the majority of labour inputs in the sector. Labour inputs have been increased to upgrade and augment network infrastructure, to assist distribution businesses respond to ageing workforces, and to prepare for skills transfer as older workers retire. Apprenticeship and other training programs have also expanded in many electricity businesses. [26]

While the ABS accounts for the fact that some labour is used to produce *own-account* capital, there is a possibility that in periods where there is a marked change in the amount of this activity — such as has been occurring during the past five years — some adjustments will be missed.[27] If the result is an under-estimate of output (real value added) then there will be a downward bias to MFP estimates. This bias should be offset in the future, however, once the current period of capacity renewal and augmentation, and its associated workforce, concludes.

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[25] See: http://www.aemc.gov.au/Market-Reviews/Open/Transmission-Frameworks-Review.html.

[26] IPART (2010 pp. 5, 53) discusses the driving forces behind labour input growth in New South Wales electricity distributions businesses between 2001-02 and 2008-09.

[27] The ABS adds the value of new capital assets produced in-house for future use in-house (which is comparatively large in utilities, mining, and communications) to output, on the basis that these assets are produced using labour and capital inputs that could otherwise have been used to produce *final* goods and services. In essence, the adjustments are made to ensure that firms that contract out the construction of capital goods (or purchase completed capital goods) are treated the same as firms that choose to produce their own capital goods.

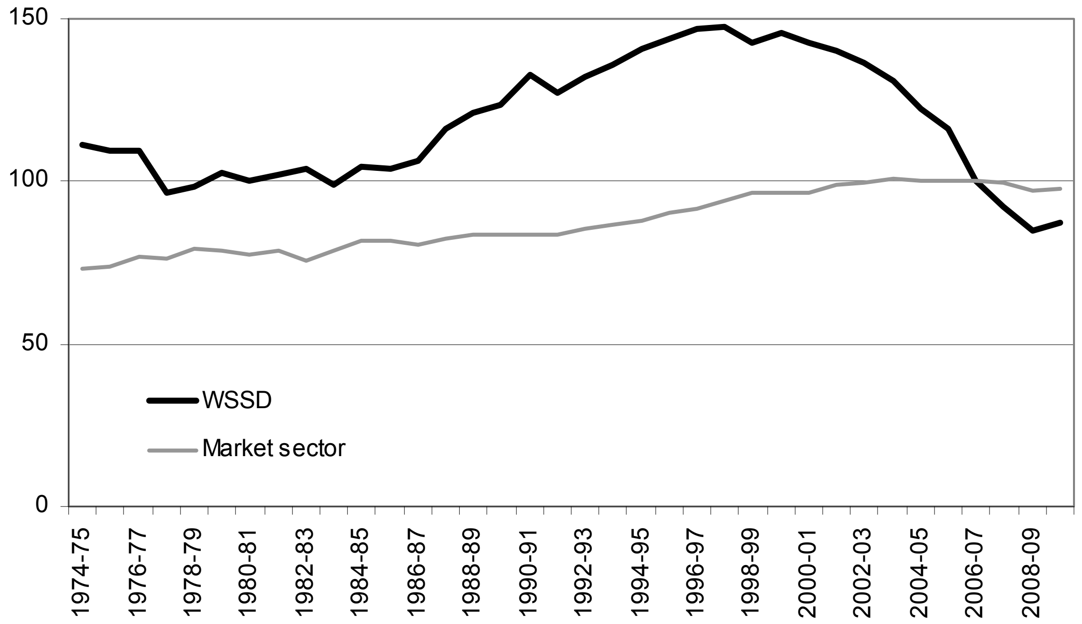
5 Productivity in Water supply, sewerage and drainage services

As noted in chapter 1, the primary purpose of this paper is to better understand the driving forces behind trends and developments in the ABS estimates of annual multifactor productivity (MFP) growth within the utilities division as a whole. Of particular concern is the substantial decline in MFP growth in utilities since 1997-98.

This chapter examines the drivers of productivity change in the Water supply, sewerage and drainage services (WSSD) subdivision of utilities. As noted in chapter 3, while growth in MFP in this subdivision is estimated to have been around zero over the longer term, there have been three very distinct and different MFP phases over the past three decades (figure 5.1).

Figure 5.1 **Multifactor productivity in the Water supply, sewerage and drainage services subdivision and the market sector, 1974-75 to 2009-10**

Index 2006-07 = 100



Data sources: Author's estimates; ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2009-10,* Cat. no. 5260.0.55.002).

The sustained period of negative MFP growth since the late 1990s is the primary issue at hand. However, the driving forces behind the period of strong positive MFP growth in the subdivision during the late 1980s and 1990s are also investigated, particularly as they contrast with the more stable period from the mid-1970s to the mid-1980s.

Background information on the subdivision helps to better understand and interpret the MFP estimates, and the likely forces impacting on growth rates in inputs and outputs.

5.1 Subdivision structure

The *Water supply, sewerage and drainage* subdivision includes the:

- storage, treatment and distribution of water through water supply systems
- collection, treatment and disposal of waste through sewer systems and sewage treatment facilities
- operation of stormwater and town drainage systems (ABS 2006).[1]

Businesses in this subdivision include the water utilities that provide potable drinking water and sewerage and drainage services to households and businesses in Australia's major cities and towns. The subdivision also includes the supply of water to farms for irrigation, such as occurs in a number of man-made irrigation districts and schemes around Australia. Businesses that supply irrigation water to farms using infrastructure such as dams, weirs, pumps, canals and pipes, are part of this subdivision.

Although only limited statistical information is available regarding the relative size of the different components of the subdivision, ABS data show that the majority of WSSD revenue comes from two main sources — sales of urban water, and the provision of urban sewerage and wastewater services. Revenue from sales of water to irrigators is quite small — representing around 4 per cent of total WSSD revenue in 2008-09 (table 5.1). This is despite the fact that the quantity of irrigation water supplied each year is much larger than the quantity of urban water supplied — around 20 000 GL of irrigation water compared with around 2000 GL of urban

[1] The MFP estimates for WSSD presented in this chapter are based on the ANZSIC93 industry classification system, not the more recent ANZSIC06 system. This allows a longer time series to be examined, and there were no major changes to the structure or activities of the subdivision as a result of the move to ANZSIC06. See ABS (2006) for more information regarding industry classification changes.

water. Urban potable water is, however, a very different product to irrigation water, and has a much higher unit value.

Table 5.1 **Revenue from water sales and services, 2008-09**

Water supply, sewerage and drainage subdivision (WSSD)	*$ million*	*Per cent*
Urban water	5 925	*52*
Urban sewerage, wastewater and drainage	5 032	*44*
Irrigation water	473	*4*
Total revenue earned	**11 430**	**100**

Source: ABS (*Water Account* 2008-09, Cat. no. 4610.0, table 3, p. 42).

Within the *urban* component of the subdivision (where urban means cities *and* towns), industry data show that two main activities — water supply and sewerage services — account for the majority of costs and revenues, and are roughly equal in terms of their shares of total revenue (NWC and WSAA 2009). Urban stormwater and drainage activities are a comparatively small part of overall subdivision output.[2]

WSSD is capital intensive, with the capital share of total subdivision income estimated to be around 70 per cent in 2008-09. Fixed costs are also high relative to variable costs, leading to annual industry costs that are not particularly sensitive to changes in key variables, such as the quantity of water delivered. Investment in some capital assets — dams, pipelines, sewage treatment plants etc — can be large and lumpy. As discussed later in this chapter, this presents considerable challenges when it comes to productivity measurement.

Within WSSD a comparatively small number of large urban water utilities account for a significant share of output. Based on data published by the National Water Commission (NWC) and Water Services Association of Australia (WSAA), 16 major urban water authorities account for nearly three quarters of total urban water and wastewater revenue. Given that irrigation water supply is only a small share of WSSD revenue (4 per cent), this implies that 16 urban water utilities could account for around 70 per cent of WSSD output. This concentration of subdivision output in the hands of a small number of businesses has the potential to lead to trends or cycles in subdivision use of inputs and output if just a few businesses choose similar courses of action at roughly the same time. A recent example is the contemporaneous decisions by most capital city water utilities in Australia to build

2 Abbott and Cohen (2010, pp. 53-58) provide a detailed description of the structure and activities of the major urban water utilities operating in Australia's state capitals, while NWC and WSAA (2011) contains detailed information on utility costs, revenues, service delivery and capital investment.

large desalination plants, partly to deal with the same external shock — reduced water supplies due to persistent drought and low dam inflows. The consequences of this for the measurement of MFP are discussed in more detail later in this chapter.

5.2 The operating environment of water supply

MFP estimates can be influenced by changes in policy or regulatory settings, so it is important to consider whether there have been any major changes over time.

Up until the 1990s, most urban water businesses were vertically-integrated monopolies that were owned and operated by state and local governments as regional monopolies. In the 1990s and 2000s most jurisdictions corporatised water utilities, and there was some vertical separation of activities. Water businesses remain largely government owned monopolies however, and state governments have a major impact on their operating environments (see PC 2011a for a detailed assessment of the changes).

A key change to the operating environment of WSSD was the introduction of consumption based pricing, initially by the Hunter Valley Water Board in New South Wales and then more generally as part of the Council of Australian Governments (COAG) national water reform framework in 1994. Historically, annual water and sewerage charges were based on property values, with no restrictions (apart from occasional constraints during droughts) on the quantity of water used (PC 2002, p. 86). While the primary objectives of pricing reforms were to put water utilities on a more commercial footing and make water charges more *cost-reflective*, another objective was to promote water conservation through improved demand management (PC 2002, p. XVI). Certainly the introduction of volumetric pricing gave many urban water customers an incentive to reduce consumption.

In 2004 COAG responded to growing concerns about water security by agreeing to *extend the (water) reform agenda to more fully realise the benefits intended by COAG in 1994* (COAG 2004, p. 1). Under the new National Water Initiative (NWI), further improvements were to be made in the area of water use efficiency, and in the provision of healthy, safe and reliable water supplies.

Water businesses are subject to regulations governing pricing, licensing, health, and environmental standards for both drinking water supply and waste-water treatment and disposal.[3] Changes to these (and other) regulations may impact on the costs of supplying water and sewerage services (and the quality features of the services), but do not necessarily affect quantity measures of output. The impact on MFP of stricter or more stringent regulations governing the activities of water businesses is discussed later in this chapter.

5.3 Measures of output and inputs (volume terms)

Output

The measure of (volume) output used to calculate the MFP estimates for WSSD shown in figure 5.1 is the ABS estimate of annual subdivision value added measured in real terms.[4]

Prior to 1994-95 the ABS made the operational assumption that annual real value added in WSSD grew at the same rate as real gross output. (This implies that estimates of real gross output and real intermediate inputs were assumed to have the same growth rate prior to 1994-95, but not necessarily thereafter.) Real gross output was derived by the ABS using a process that effectively linked annual changes (in real gross output) to changes in three quantity variables — the quantity of urban water sold to final customers; the number of sewerage connections; and the quantity of water supplied for irrigation (ABS 1990, p. 120). Information on these *quantity* variables was taken from reports by state and local government authorities, although the raw data used by the ABS is not published.

Post 1994-95, the ABS has derived its estimates of annual real value added through the process of double deflation — that is, estimating real gross output and subtracting an estimate of real intermediate inputs. In principle therefore, estimated growth in real value added after 1994-95 can now differ from growth in real gross output if there are changes in the relative size of intermediate inputs — say because of a change in the amount of outsourcing going on in the subdivision. However, if the relationship between intermediate inputs and gross output remains comparatively stable, real value added will continue to trace the path set by changes in real gross output — as was the case prior to 1994-95.

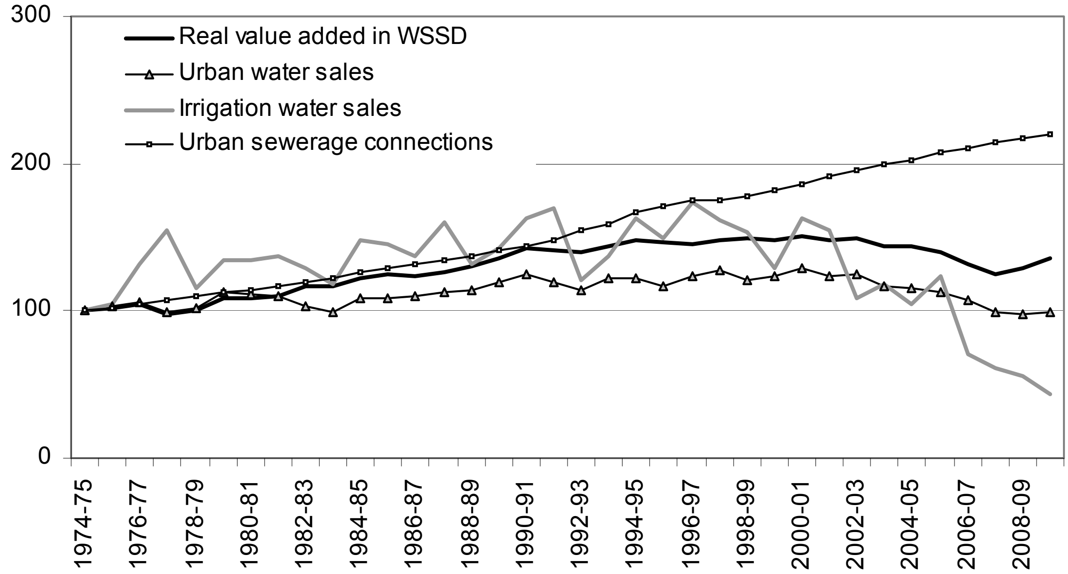
3 These and other aspects of urban water businesses have been investigated in detail by the Productivity Commission (PC 2011a).

4 In current price terms, value added is defined as gross output less intermediate inputs.

For the purpose of the analysis of output presented in the following discussion, independent estimates of the three *quantity* variables mentioned above have been derived from industry and other sources and compared with the ABS estimate of real value added in WSSD (figure 5.2). At face value, the three quantity variables appear to be likely proxies for the actual data used by the ABS to estimate real value added during the period.

Figure 5.2 **Real valued added in WSSD and quantity output measures, 1974-75 to 2009-10**

Index 1974-75 = 100



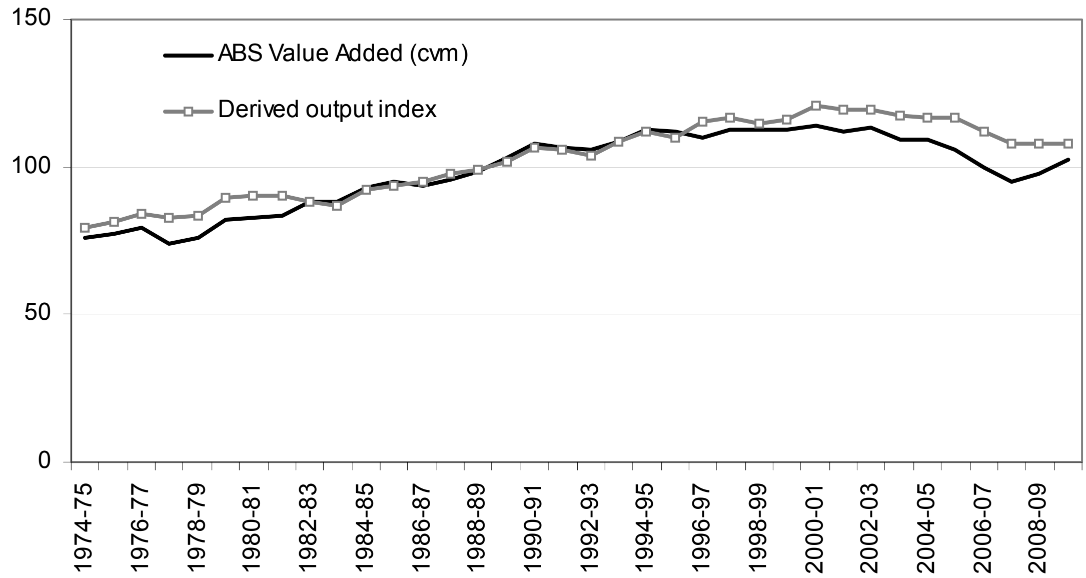
Data sources: Authors' estimates derived from ABS National Accounts on dXtime (database); NWC and WSAA (various years); SCNPMGTE (various years); WSAA (various years).

A key development in the subdivision over the past ten to fifteen years has been the continued growth in the number of new homes and businesses being provided with sewage and wastewater services, while growth in the aggregate quantities of water supplied — both urban water and irrigation water — slowed before becoming negative. The latter reflected the impact of drought on water availability, and the associated use of demand management initiatives designed to permanently improve water use efficiency (for example, the promotion of dual flush toilets and low-flow shower heads). These issues — and their implications for measured productivity — are discussed in more detail later in this chapter.

An *independent* output index for WSSD was derived in this paper by weighting together the three quantity components shown in figure 5.2 to form a single index (figure 5.3). The weights used are based on the revenue shares shown earlier in table 5.1 for the year 2008-09 — that is, 52 per cent for urban water sales, 44 per cent for waste water connections, and 4 per cent for irrigation water.[5]

Figure 5.3 **Output in WSSD: ABS output (real value added) versus derived output,[a] 1989-90 to 2009-10**

Index 1989-90 = 100



[a] The *Derived output index* is an index formed from three quantity indexes: the quantity of urban water sales, the number of urban properties connected to wastewater services, and the quantity of water diverted to irrigators in the Murray Darling basin. The weights used (which are held constant across the entire period) are: quantity of urban water supplied (52 per cent), number of urban sewage connections (44 per cent), and quantity of irrigation water supplied (4 per cent).

Data sources: Authors' estimates derived from ABS National Accounts on dXtime (database); MDBA (special data request); NWC and WSAA (various years); SCNPMGTE (various years); WSAA (various years).

In general, the derived output index is a good proxy for ABS real value added over the period from 1974-75 to 1994-95. A discrepancy in 1982-83 may have been the result of adjustments made to value added by the ABS in response to the major drought in Australia that year (which reduced water availability in some cities). Outside of that year, the derived output index is very close to the ABS estimate of real value added, confirming the significance of the three indicator variables as the source of annual changes in measured subdivision output.

5 An ordinary least squares regression of real value added against the three *quantity* variables over the period from 1974-75 to 1994-95 (with the intercept suppressed) gives slightly less weight to irrigation water sales as an explanator of changes in real value added in WSSD, but confirms the size and significance of urban water sales and the number of urban sewage connections.

After 1994-95 the revised methodology used by the ABS to measure real value added (based on the concept of double deflation) has generated estimates for WSSD that have grown slightly more slowly than the derived output index to which it was formerly closely related (figure 5.3). In general however, movements in the real value added series for WSSD post 1994-95 still appear to be fundamentally driven by the weighted impact of changes in three quantity variables: the quantity of urban water supplied, the number of urban sewage connections, and the quantity of irrigation water supplied.

More broadly, the choice of a volume or quantity measure of output in WSSD (for the purpose of measuring productivity) is not straightforward, as previous researchers have identified. For example, in an early study of MFP growth in a major Australian water utility, the authors highlight the limitations of using output measures based on quantities of water supplied or quantities of waste water treated, such as failing to account for changes to water quality or service delivery standards over time, and being influenced by climatic conditions from year to year (Manning and Molyneux, 1993). However, they also concede the advantage of simplicity, and while ultimately choosing to construct an output index from multiple indicators — throughput, number of properties served, and indicators of quality and reliability — the majority of weight is given to throughput and numbers of properties served estimates. (Box 5.1 contains other references to water productivity research.)

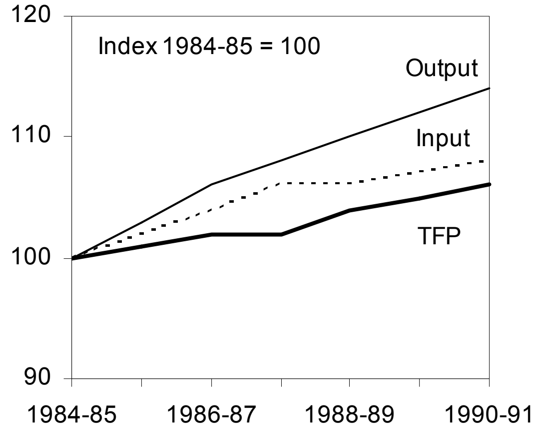
Unmeasured quality changes and other aspects of output measurement and their implications for estimating MFP in WSSD are discussed later in this chapter.

Box 5.1 **Productivity studies into the Australian water industry**

There have been only a limited number of studies examining changes in productivity over time for the Australian water industry as a whole, or even at the state level.

Early productivity studies — The case of Melbourne Water

One attempt at measuring productivity performance within the industry was a study undertaken by SCNPMGTE (1992, pp. 66-75) into Melbourne Water. Using a methodology developed by the Industry Commission (1990), Melbourne Water's total factor productivity (TFP) was estimated for the period 1984-85 to 1990-91. SCNPMGTE found that TFP increased at a trend annual growth rate of 0.9 per cent, with output growth of 2.2 per cent and input growth of 1.3 per cent.



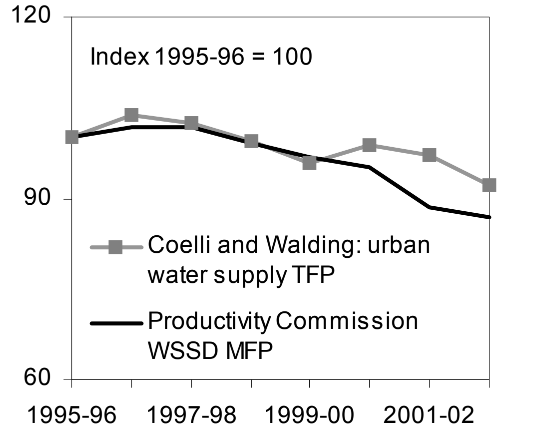
Data source: SCNPMGTE (1992, p. 71).

National level studies

The limited number of time-series analyses of productivity growth at the national level was also noted by Coelli and Walding (2005).

In their study, the authors used data envelope analysis (DEA) to produce estimates of urban water TFP covering the period from 1996 to 2003.

Although the methodology and data used are different to those used in this report, the Coelli and Walding results are broadly similar to the WSSD MFP estimates presented in this chapter.



Data source: Authors' estimates; Coelli and Walding (2005).

(continued on next page)

Box 5.1 (continued)

A more recent study of productivity growth in Melbourne Water produced total factor productivity (TFP) estimates covering the period from 1971 to 2008 (Abbott, Wang and Cohen, 2011).

Their results show TFP growth in Melbourne Water rising during the 1990s, but then slowing and eventually becoming negative during the 2000s. The authors use an output measure based on connected properties rather than throughput (water deliveries) because of the adverse effects on the later caused by drought during the period.

Byrnes, Crase, Dollery and Villano (2007) contains aggregate TFP estimates for a group of urban water utilities in Victoria and New South Wales covering the period from 2001 to 2004. They found a 10 per cent decline in productivity over the period.

Other recent water productivity studies

The Productivity Commission's inquiry into urban water also contains a review of some of the more recent studies into the productivity performance of the water industry (PC 2011a, p. 44).

Apart from the Coelli and Walding study mentioned above, the inquiry team identified three other studies that attempted to measure the overall relative productivity of the urban water industry — Woodbury and Dollery (2004), Byrnes et al. (2009) and Byrnes et al. (2010).

For the most part these studies focussed on the relative efficiency of different water utilities within specific jurisdictions, such as New South Wales and Victoria, and covered comparatively short time periods. The methodological approach used in all four studies was data envelopment analysis.

Another recent study was undertaken by IPART in New South Wales which reviewed productivity growth in the major water utilities in that state (IPART 2010). The study found negative productivity growth in the two major urban water utilities between 2003-04 and 2008-09.

Industry regulators have a keen interest in the productivity performance of the water utilities because of the impact that productivity may have on prices. The regulators are also aware that the industry's productivity performance in years has been poor and that this needs to be comprehensively explored (sub. 72 to PC 2011a).

Inputs (labour and capital)

As with the Electricity supply subdivision, labour inputs in WSSD have been measured in this study using an estimate of the aggregate number of hours worked in the subdivision each year. Data quality is again an issue, not least because many businesses in the subdivision experienced significant changes to their ownership structures and activities during the period covered by the MFP estimates. Some caution regarding the interpretation of movements in labour inputs is therefore required.

The quantity of capital inputs used to derive MFP estimates in WSSD is derived using the same general approach used by the ABS to estimate capital services at the division level. That is, capital inputs are measured by *capital services*, which are assumed to be a fixed proportion of the *productive capital stock*. The latter is an estimate of the physical quantity of capital assets available to the subdivision each year for use in production. The *productive capital stock* is derived using a perpetual inventory model (PIM) approach, whereby the size of the productive capital stock each year is determined by adding new investment (in real terms) to an estimate of the existing capital stock, and then adjusting for both the expected retirement of some assets, and the decline in productive services of remaining capital goods due to ageing[6] (see OECD 2001, chapter 5 for a detailed description of the approach to measuring capital services). Critically, spending on new capital assets (converted into quantity terms) is generally added to the productive capital stock as the investment occurs, irrespective of whether or not the assets being invested in are complete and operational, or whether the new assets are being utilised to their maximum or expected full capacity. Similarly, existing capital assets are assumed to be fully utilised at all times.

As noted in appendix A and in chapter 4, there are various challenges and potential sources of bias or error associated with measuring the *quantity* of capital inputs each year. As with Electricity supply, a key problem in this regard is the possibility that there may be significant changes in average rates of capital utilisation over time. An obvious issue in WSSD is how to measure the *quantity* of capital inputs provided each year by extremely large and long-lived capital assets like dams, reservoirs, underground water pipes, and water and waste-water treatment plants. Assets such as these (which can last for many tens and possibly hundreds of years) are often built to a size and standard that will support future growth in consumption, implying maximum utilisation of capital assets at some point in the future rather than on initial construction or during the earlier years of the asset's life. In this case, the assumption of 100 per cent utilisation of all capital assets at all times will not always be appropriate.

6 Different types of capital (buildings versus machinery for example) are dealt with by aggregating estimates of the productive capital stock of each capital type using user costs or rental prices as weights. ABS (2007) describes the process used to estimate capital services for use in constructing MFP estimates.

Similarly, during periods of abnormally low rainfall and water availability, many capital assets in WSSD are effectively underutilised, in the sense that the quantity of water being stored, treated and delivered is well below the system's maximum or designated capacity. Again, the assumption of 100 per cent utilisation may be a problem when it comes to interpreting MFP changes.

While the issue of investment in lumpy assets is not generally a problem in industries where there are many businesses investing in many projects at different points in time, in a subdivision like WSSD where a small number of large water utilities account for the majority of output, cyclical or coincident behaviour in investment and capital utilisation rates may also impose significant temporary biases on MFP estimates.

5.4 Assessing productivity trends

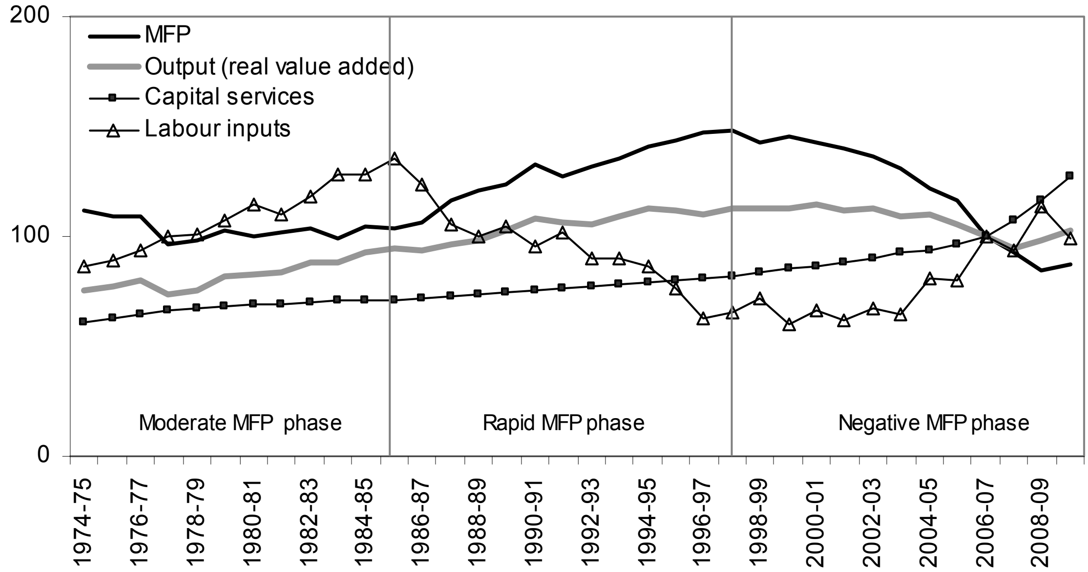
The assessment of MFP trends and developments in WSSD presented below uses the same basic framework as that used to analyse MFP growth in the utilities division as a whole. That is, the time period covered by the MFP estimates has been divided into three phases: an early period of stable MFP growth; a middle phase of rapid positive MFP growth; and a more recent period of strong negative MFP growth. Productivity developments within the key phases are then examined in more detail.

For ease of comparison, the same time periods and terminologies used to identify the phases that were applied to the utilities division as a whole (and to the electricity supply subdivision) have been applied to WSSD. As noted in relation to electricity supply, a more statistically rigorous approach to identifying productivity cycles (as per Barnes (2011) for example) for WSSD might result in the choice of (slightly) different cut-off years compared with those used at the division level. However, this is not likely to be a major limitation of the analysis.

With this in mind, it is noted that during the *moderate MFP growth phase* — which covers the period from 1974-75 to 1985-86 — average annual MFP growth in WSSD was negative (-0.7 per cent per year) (figure 5.4 and table 5.2). On average, output growth during this phase was quite strong (2.0 per cent per year) but growth in labour inputs was stronger still (4.2 per cent per year). Growth in capital inputs was weaker (1.4 per cent per year) but strong enough when combined with labour input growth to result in aggregate inputs increasing slightly faster than output.

Figure 5.4 **Output, inputs and MFP in WSSD, 1974-75 to 2009-10[a]**

Index 2006-07 = 100



[a] Vertical lines represent the cut-off years for the three MFP growth *phases* identified for the utilities division as a whole in chapter 2. For ease of comparison, the same terminology is used to describe the phases throughout the paper (see section 2.3 and table 2.4).

Data source: Authors' estimates.

Table 5.2 **Changes in MFP, output and inputs in WSSD, by growth phase[a]**

Annual average growth rates in each phase, per cent

	Moderate MFP growth phase (1974-75 to 1985-86)	*Rapid MFP growth phase (1985-86 to 1997-98)*	*Negative MFP growth phase (1997-98 to 2009-10)*	*Full period (1974-75 to 2009-10)*
MFP	**-0.7**	**3.0**	**-4.3**	***-0.7***
Output	2.0	1.4	-0.8	*0.9*
Labour	4.2	-5.9	3.6	*0.4*
Capital	1.4	1.2	3.7	*2.1*

[a] For ease of comparison, the growth phases (and the terminologies used to describe them) are the same as those identified for the EGW division as a whole, which were reported in chapter 2 (see section 2.3 and table 2.4).

Source: Authors' estimates.

During the *rapid MFP growth phase*, output growth had slowed but was still positive (1.4 per cent per year), while labour input growth turned negative (-5.9 per cent), and capital input growth slowed slightly to 1.2 per cent per year).

Finally, in the *negative MFP growth* phase, average output growth in WSSD was negative (-0.8 per cent), while growth in labour and capital inputs was positive and comparatively fast at 3.6 per cent and 3.7 per cent respectively.

As with electricity supply, the proximate forces driving the MFP results in each of the phases are somewhat unusual or counter-intuitive at times.

The *moderate MFP phase*

Although measured inputs of capital services did not grow particularly strongly during this phase (it averaged 1.4 per cent per year), physical estimates of a key class of capital assets in the subdivision — dams — show a significant increase in capital capacity during the period (figure 5.5). For example, the average annual growth rate in urban water dam storage capacity during this phase was around 5 per cent, and around 2 per cent per year for irrigation capacity.

Interestingly, there was little further growth in water storage capacity in Australia after the conclusion of this phase (that is, from the mid-1980s onwards), either in the urban sector or the irrigation sector. As argued below, the long term developments in water storage capacity illustrated in figure 5.5 (along with associated estimates of water supplied) are one of the central factors in explaining MFP trends in WSSD in all three phases.[7]

From 1950 until the mid-1980s there was considerable growth in the aggregate amount of both urban and irrigation water storage capacity in Australia. New or expanded dams were being added to the stock of dams on a regular basis, with the completion of particularly large dams prominent in the data. Examples include the Ord River Dam in 1972 in the irrigation sector, and the Warragamba (1960), Thomson (1983) and Wivenhoe (1985) dams in the urban dam sector.[8]

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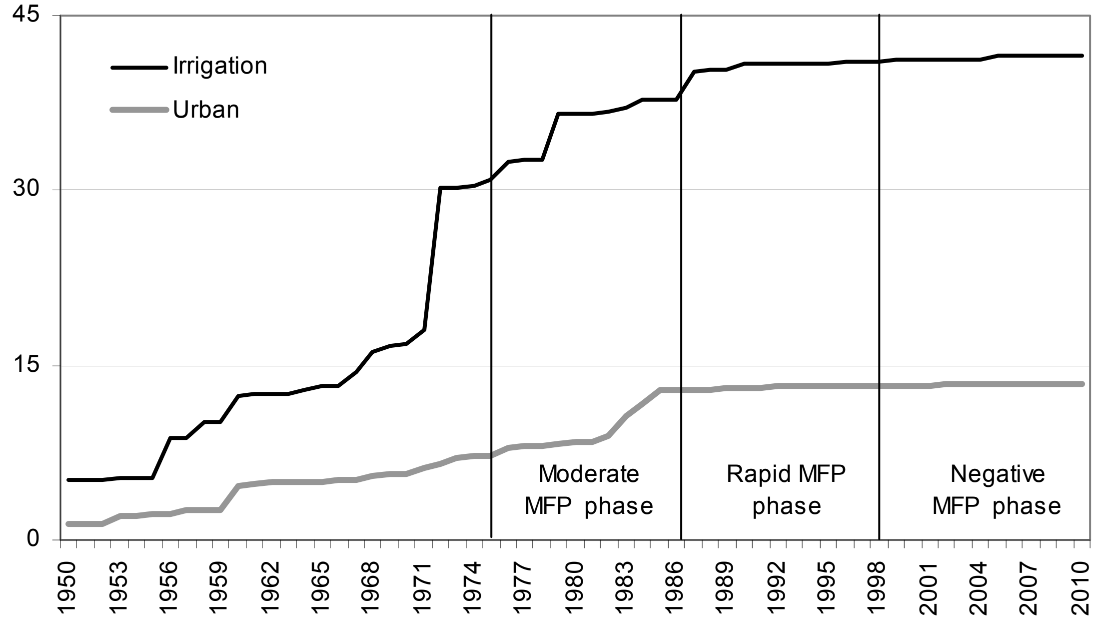
7 Note also that while irrigation water storage capacity dominates urban capacity in volume terms, the latter is the dominant sector of WSSD in relation to the value of output. On a per unit basis, potable water is much more valuable (and costly to produce) than irrigation water. In relation to changes in capacity over time however, both series have displayed broadly similar trends, particularly in relation to key changes since 1974-75 — the period for which we have MFP estimates.

8 During this period there was also strong growth in the aggregate capacity of dams that were primarily built to provide hydro-electricity power production. However, these dams are nominally part of the Electricity supply subdivision, not WSSD.

Figure 5.5 **Urban and irrigation dam storage capacity (millions ML), 1950 to 2010[a]**



a Vertical lines indicate the cut-off years for the three MFP phases.

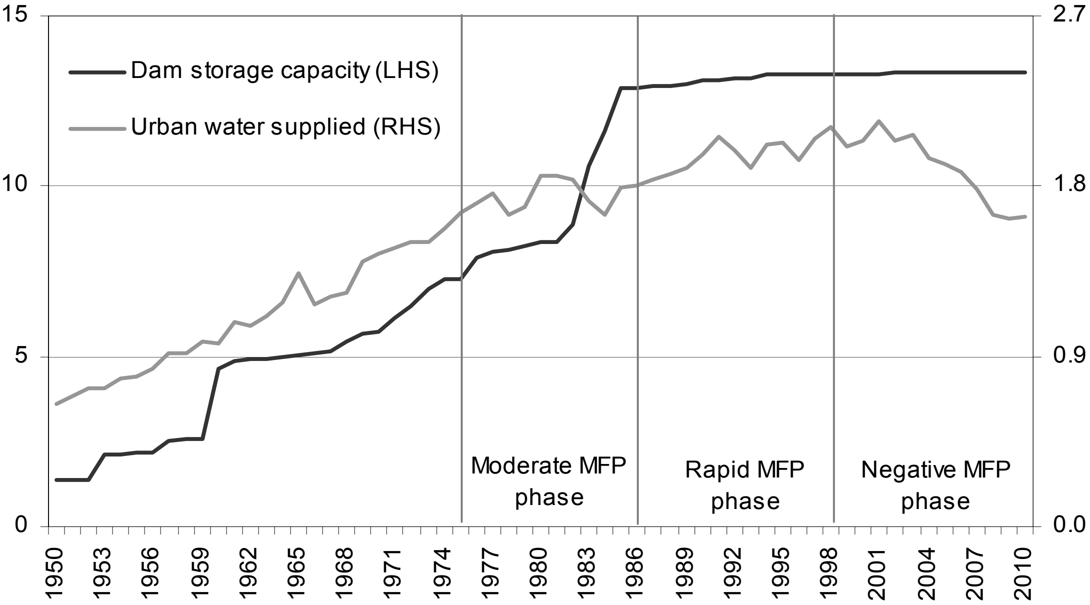
Data source: Authors' estimates using data from Australian National Committee on Large Dams Incorporated (ANCOLD) (*Register of Large Dams in Australia).*

At the same time, the quantities of both urban water and irrigation water supplied generally increased in line with the growth in storage capacity (figures 5.6 and 5.7). For example, the quantity of urban water supplied grew in line with the increases in urban dam capacity through to the mid-1980s, although a major drought in much of southern Australia in 1982-83 had a noticeable impact on water availability at the time. The impact of major droughts and recovery years on urban water deliveries can also be observed in the late 1960s and the late 1970s.

Similarly, diversions of water for irrigation in the Murray-Darling Basin (MDB) rose between 1950 and 1986 in line with additions to storage capacity and water availability.[9] Year to year variability was considerable however, and generally reflected the greater sensitivity of annual irrigation water demand to climatic conditions.

9 Note that the Ord River Dam, while adding a large amount of new capacity, was underutilised.

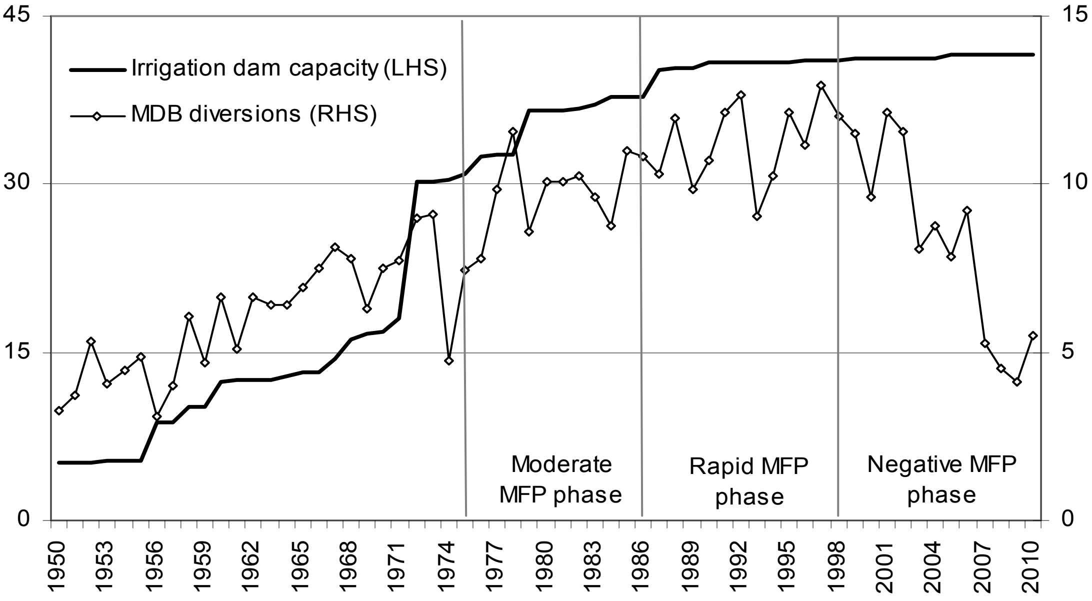
Figure 5.6 **Urban water dam storage capacity and urban water supplied (millions ML),[a] 1950 to 2010**



a From 1988 to 2009 the estimate of *Urban water supplied* is the sum of the quantities of urban water supplied in 16 water authorities. Values prior to 1988 are back cast using annual changes in the sum of urban water These four centres accounted for approximately 70 per cent of total urban water supplied in 1987-88.

Data sources: Authors' estimates using data from ANCOLD (*Register of Large Dams in Australia*); NWC and WSAA (various years); SCNPMGTE (various years); WSAA (various years).

Figure 5.7 **Irrigation water dam storage capacity and MDB diversions (millions ML),[a] 1950 to 2010**

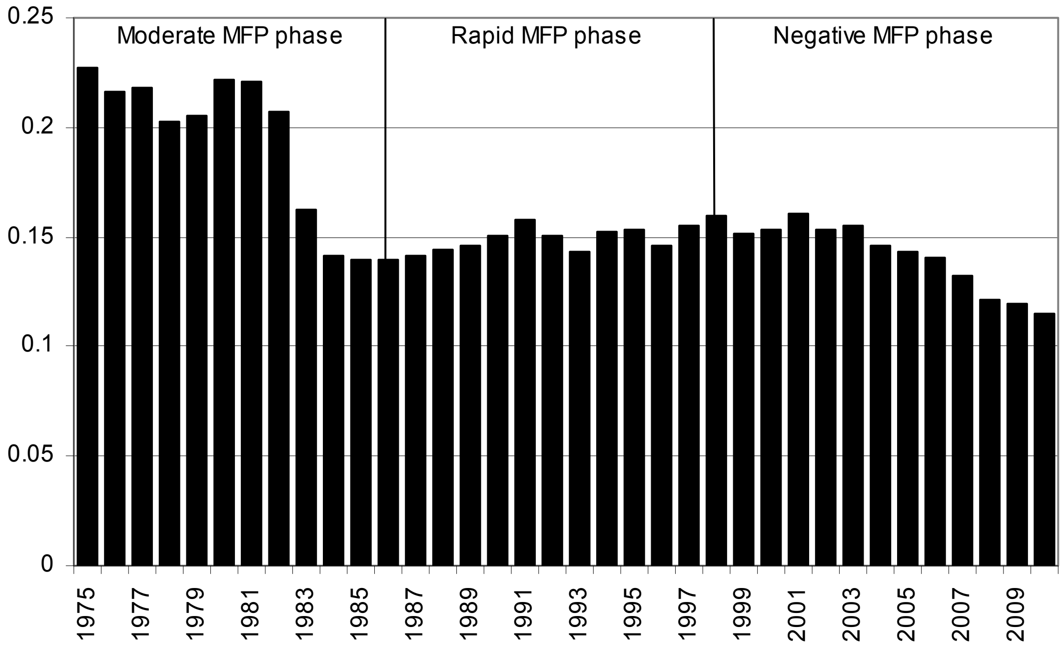


a By definition, *MDB diversions* do not account for irrigation water supplied from irrigation schemes outside of the MDB, such as the Ord River scheme in Western Australia and the Burdekin Dam scheme in Queensland. However, the vast majority of water from irrigation schemes is accounted for by suppliers in the MDB.

Data sources: Authors' estimates using data from ANCOLD (*Register of Large Dams in Australia*); MDBA (special data request).

The *moderate MFP phase* (1974-75 to 1985-86) was therefore characterised by a significant increase in total (urban plus irrigation) dam capacity — an average annual increase of around 2.6 per cent — although the average annual growth in estimated capital inputs during the phase is much less than that (1.4 per cent per annum).[10] Industry data show a decline in the average rate of capacity utilisation in urban water storage during the period, as dam capacity grew faster than output (figure 5.8).[11]

Figure 5.8 **Urban water supplied per unit of storage capacity (ML), 1975 to 2009**



a Urban dam storage capacity has been adjusted for the additional supply capacity inherent in the Kwinana desalination plant in Western Australia that was operational from late 2006. The conversion of desalination capacity into *dam equivalents* is explained in the footnote to figure 5.17. The vertical bars in this figure indicate the cut-off points for the three MFP growth *phases* shown in previous figures.

Data sources: Authors' estimates using data from ANCOLD (*Register of Large Dams in Australia, Dams Australia*); NWC and WSAA (various years); SCNPMGTE (various years); WSAA (various years).

[10] While urban and irrigation water dams are only one component of the total capital stock of this subdivision, they nevertheless account for a comparatively large share. There is little information available regarding changes in physical measures of sewage treatment capacity during the period.

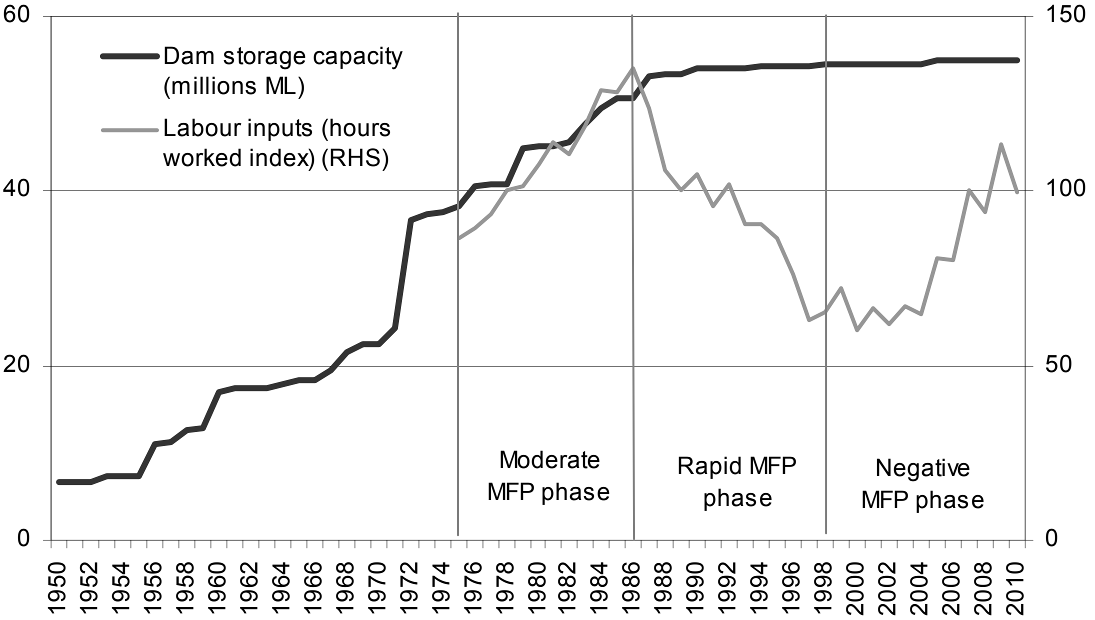
[11] Note however, that part of the reason for the decline in the ratio of urban water supplied to storage capacity in the early 1980s was reduced water availability in 1982-83 due to drought, and generally lower water demand in the high rainfall year that followed.

Many of the construction costs associated with the dams that became operational during this phase were actually incurred prior to 1974-75, rather than during the phase. This partly explains why measured capital services growth was comparatively slow during the period. In real terms, annual capital *investment* was declining through the phase, albeit from historically high levels in the early 1970s.

Labour inputs grew very strongly during this phase, and this was a key reason for the sluggish rate of MFP growth. While data quality issues may be a factor, ABS data indicate strong growth in labour inputs at the division level. Labour's share of total subdivision costs was also much higher in this phase, particularly when compared with its cost share today.

What is clear from the data, however, is that labour inputs in WSSD dropped suddenly and significantly at the end of this phase (figure 5.9). This coincides with the cessation in the construction of (major) new urban and irrigation water dams in Australia, and the onset of a major period of structural adjustment and reform in water utilities.

Figure 5.9 **Water storage capacity (urban + irrigation) and WSSD labour inputs, 1950 to 2010**



Data sources: Authors' estimates using data from ANCOLD (*Register of Large Dams in Australia*); NWC and WSAA (various years); SCNPMGTE (various years); WSAA (various years).

The evidence suggests that the strong growth in labour inputs during the moderate MFP growth phase was linked to the extensive amount of dam building and related construction activity occurring in the subdivision at the time.[12] Once the supply augmentation process slowed however (and structural reform began), labour began to be shed from the subdivision. (While the marked increase in labour inputs during the *negative* MFP growth phase does not have an associated increase in dam capacity — which is unchanged — it does align with a significant increase in non-dam construction activity, both in supply and sewage treatment. This issue is discussed later in the chapter.)

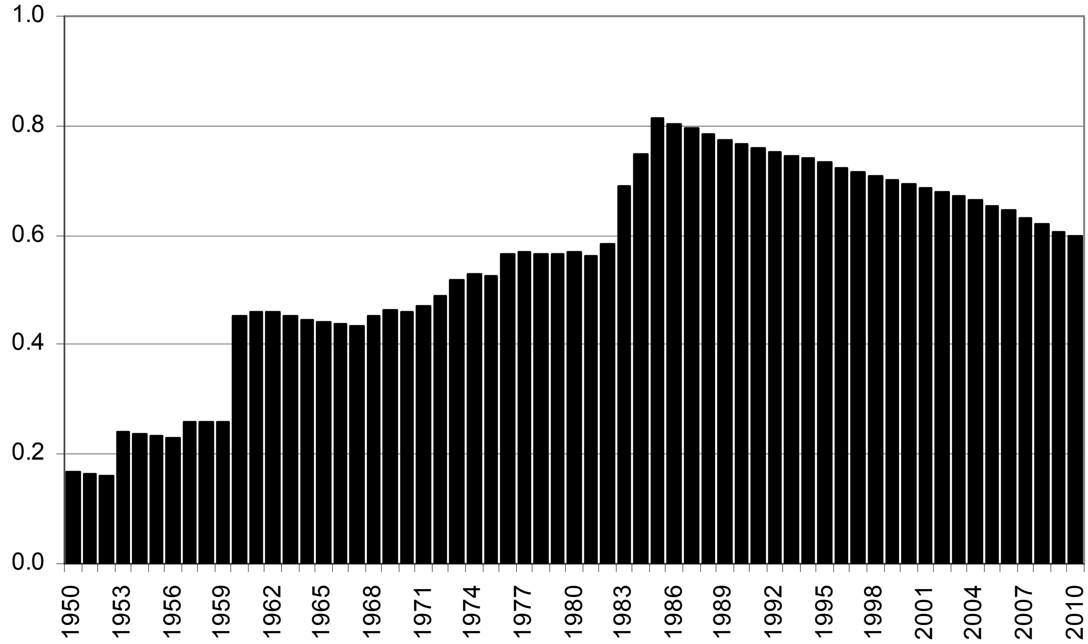
The *rapid MFP phase*

At the onset of the *rapid MFP phase*, WSSD was characterised by a significant *excess* of water storage capacity, with capacity utilisation at historically low levels (figures 5.6, 5.7 and 5.8). On a per capita basis, urban dam storage capacity in Australia peaked in 1985, although it fell progressively from then on as Australia's population grew faster that new dam capacity (figure 5.10).

On the output side, urban and irrigation water sales continued to grow during the phase in response to population growth and an expansion in the area of irrigated land, along with the general increase in the availability of water permitted by the previous additions to storage capacity.

12 As noted earlier, the ABS measure of output in WSSD during this period (real value added) did not include any adjustments for changes in the amount of capital work done by water businesses using their own labour and intermediate inputs. As a result, an increase in the amount of own-account capital construction in WSSD would have had a direct negative impact on measured MFP.

Figure 5.10 **Urban dam storage capacity per capita[a] (ML), 1950 to 2010**



[a] Total Australian population has been used to measure this ratio, rather than the total *urban* population. To the extent that there has been increasing urbanisation of the population over the period, the decline in urban storage per capita would tend to show an even more rapid decline from the mid-1980s onwards.

Data sources: Authors' estimates based on ABS (*Australian Historical Population Statistics, 2008*, Cat. no. 3105.0.65.001); ANCOLD (*Register of Large Dams in Australia*).

However, urban water output growth during this phase was also affected by growing community concern about the long term sustainability of Australia's water resources. As noted earlier, COAG reforms beginning in 1994 saw the introduction of volumetric pricing for urban water supplies, and this is believed to have slowed urban water consumption during the 1990s. For example, WSAA *facts* (WSAA 2001) estimate that per-capita urban water consumption fell by 17 per cent between 1990 and 2000 as a result of the move to volumetric water pricing. The Productivity Commission (PC 2002, p. 90) also cite community education programs and the use of water saving devices as possible causes of the reduction in per capita urban water consumption during the period. Accordingly, policy measures that were explicitly aimed at reducing per capita urban water consumption lead to lower measured output growth.[13]

On the inputs side, with sufficient dam storage capacity in place and no immediate need for additional capacity, capital investment in the subdivision slowed

13 Coelli and Walding (2005) also identified demand management measures as a cause of slow output growth (as measured by water deliveries) in major urban water utilities between 1996-97 and 2002-03.

considerably during the phase, and this slowed growth in capital inputs. Growth in labour inputs was negative during the period, partly in response to the decline in dam building and associated activities (construction of water treatment plants and distribution infrastructure etc) and partly in response to structural reforms associated with commercialising and corporatising water businesses. The latter was more relevant to the second half of the phase when the majority of water utilities were corporatised and made more accountable for financial and operational performance (PC 2002, p. 87).

A key outcome of structural reforms in the late 1980s and 1990s was that many water businesses began to contract out a greater proportion of non-core activities. This contributed to a decline in subdivision inputs (labour and capital) during the period, and an increase in the relative size of intermediate inputs (which is where the cost of purchased services is recorded by the ABS).[14]

From an MFP measurement point of view, an increase in intermediate input costs associated with an increase in outsourcing would normally lead to lower real value added (gross output less intermediate input costs), and this would tend to offset the positive effect on MFP of reduced labour and capital inputs. Assuming that increased outsourcing of non-core services was made for sound economic reasons, the net effect should nevertheless be productivity enhancing, with the size of the gain depending on the real cost savings. However, as noted earlier in this chapter, until 1994-95 the ABS estimate of real value added in WSSD was derived in a way that effectively made it insensitive to substitutions between intermediate inputs and capital and labour inputs. As a result, the growth in outsourcing during the period led to a reduction in measured inputs of capital and labour inputs, but no corresponding downward adjustment to real value added to reflect the increase in (real) intermediate inputs. As a result, measured MFP growth in the subdivision would have been over-estimated.

In summary, three factors appear to have been key to the comparatively fast rate of MFP growth in WSSD during this phase: first, there was an (unmeasured) increase in the utilisation of water supply assets, particularly in the urban water sector. Lumpy investment in dam capacity prior to this phase permitted output to grow in the absence of major new investments in supply capacity. Second, labour inputs fell due to a slowdown in capital augmentation, and in response to structural and governance reforms that allowed water businesses to make more efficient use of

[14] Unpublished ABS data indicates that, when measured as a proportion of the value of gross output, expenditure on intermediate inputs (in nominal terms) was much higher during the rapid MFP growth phase compared with the preceding phase. Combined with the decline in labour and capital inputs observed at the time, this is consistent with there being a shift toward greater outsourcing of non-core services during the period.

labour resources. And finally, as a consequence of the methodology used by the ABS to measure the volume of output in WSSD (real value added), an increase in contracting out of non-core activities during the period led to an under-estimate of total inputs to production, and hence an over-estimate of MFP.

At the same time, State Governments and water authorities were also beginning to implement urban water demand management strategies, and to the extent urban water demand was lower as a result, this would have had a moderating impact on MFP growth. In the absence of the various demand management strategies that were implemented during the phase, average MFP growth during this phase might have been higher still.

The *negative MFP phase*

As noted earlier, the period of negative MFP growth in WSSD since the late 1990s is characterised by negative output growth, and strong positive growth in inputs. A number of factors that might explain how this combination of *proximate forces* could eventuate are examined below. They include:

- the effects of drought on urban and irrigation water supplies
- the shift to higher cost sources of water
- lumpy new capital assets and associated production lags
- stricter environmental and health standards for wastewater treatment and disposal, and potable (drinking) water.

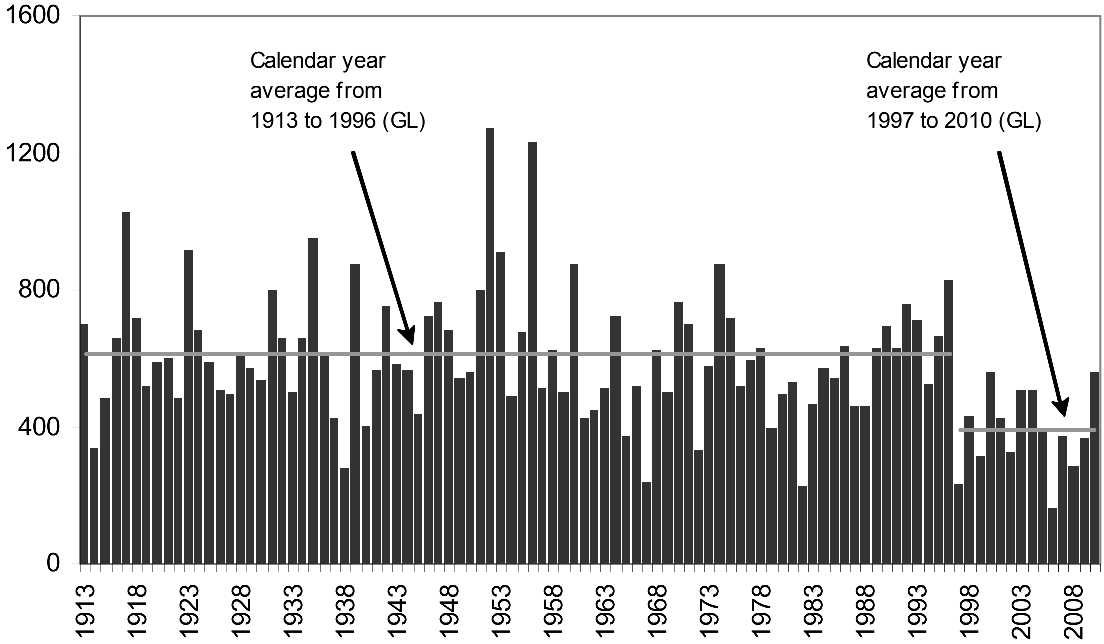
Apart from possible capital utilisation issues, these factors point to theoretical and practical considerations regarding how statisticians and productivity analysts measure the quantity of output in a subdivision like WSSD, particularly when conducting temporal analysis of productivity at an aggregate level.

The impact of the drought

The ability of urban and irrigation water businesses to deliver water to customers during the 2000s was frequently compromised by low water storage levels caused by widespread and persistent low rainfall and runoff. For example, figure 5.11 shows inflows into Melbourne's major reservoirs, while figure 5.12 displays rainfall trends within the Murray-Darling Basin — a key determinant of available water supplies for irrigators in the basin.[15]

[15] Appendix B in Productivity Commission (2011a) provides additional rainfall and storage-inflow information for other major urban centres, including Perth, Sydney, and south-east Queensland.

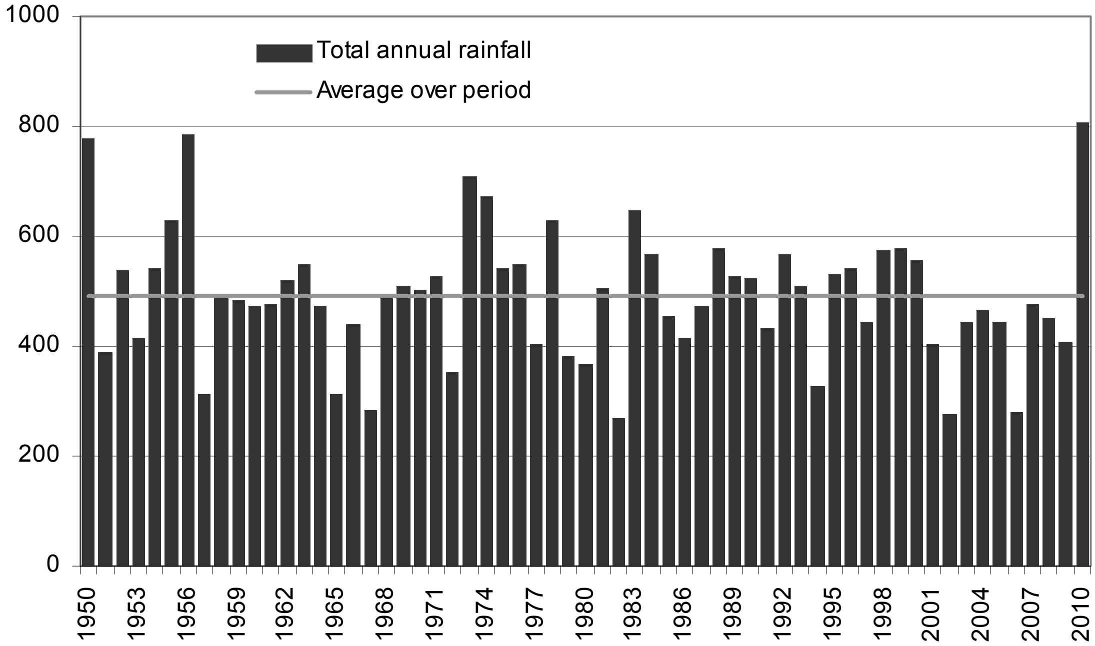
Figure 5.11 **Annual inflows at Melbourne's major harvesting reservoirs,[a] 1913 to 2010**



[a] Thompson, Upper Yarra, O'Shannassy and Maroondah Reservoirs.

Data source: PC (2011a).

Figure 5.12 **Annual rainfall in the Murray-Darling Basin (mm), 1950 to 2010**



Data source: Bureau of Meteorology, www.bom.gov.au.

In the urban water sector, the lack of any major new storage capacity built in the 1990s — when rainfall conditions were generally favourable — compounded the problem of low inflows due to drought. That is, if new urban dam storages had been built in the 1990s it is likely that more water would have been available, and hence the observed decline in the quantity of urban water supplied during the 2000s would not have been as severe. In contrast, there was much less scope in the irrigation water sector (and particularly within the MDB), to increase water availability by building new storages (as by the 1990s the MDB was effectively a fully utilised system, with water output limited only by rainfall and runoff rather than storage capacity), so little could be done to halt dwindling water availability in the 2000s as rainfall conditions worsened and inflows to dams fell.

In the face of limited water availability and growing demand due to an increasing population and hot, dry weather, governments and water businesses further intensified supply and demand side management initiatives during the 2000s. Demand side measures included education and suasion campaigns aimed at encouraging more efficient water use, subsidies and other inducements to save or reduce water use, and quantitative restrictions on water use outside the home.[16]

On the supply side, urban water businesses began to examine alternative sources of water supply, including water trading with the rural sector, water recycling, and desalination plants. In the irrigation sector, water allocations to farmers were cut in response to reduced water availability and growing concerns regarding the environmental health of river systems. Incentives and other programs were implemented to improve water use efficiency on farms, and to reduce system losses due to evaporation and waste. Fundamentally however, reduced water availability meant that both urban and irrigation water supplied fell considerably during the 2000s (figure 5.13).

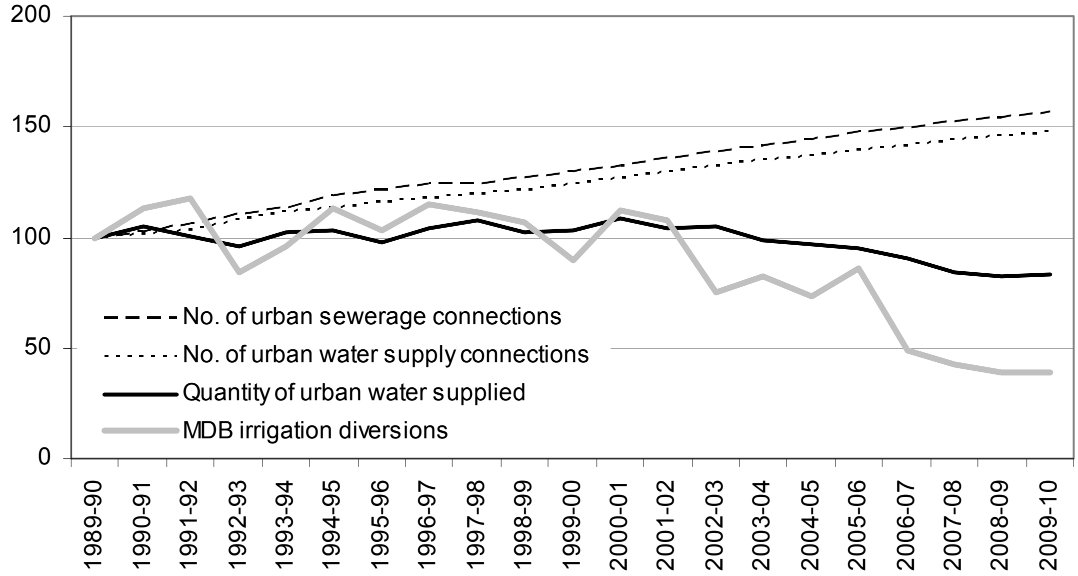
At the same time, urban water businesses in Australia continued to provide water (and waste-water) services to a growing number of homes and businesses. That is, while the aggregate quantity of water delivered to urban water customers declined during the 2000s, the aggregate number of individual homes and businesses being supplied with water and waste-water services was nevertheless growing strongly (figure 5.13). New connections required additional inputs of labour and capital, including new reservoirs, water and waste-water treatment plants, transmission and distribution infrastructure, and retail infrastructure. In the irrigation water sector, rural water businesses still incurred most of the normal costs of operation in

[16] For more detail regarding the various supply and demand initiatives introduced in the urban water component of WSSD (including estimates of the economic costs of implementing water restrictions) (see PC 2011a).

supplying farmers, even though they were restricted in the quantities of water that could be made available.

Figure 5.13 **Urban and rural water quantities supplied, and numbers of properties connected to urban water and waste-water systems, 1989-90 to 2009-10**

Index 1989-90 = 100



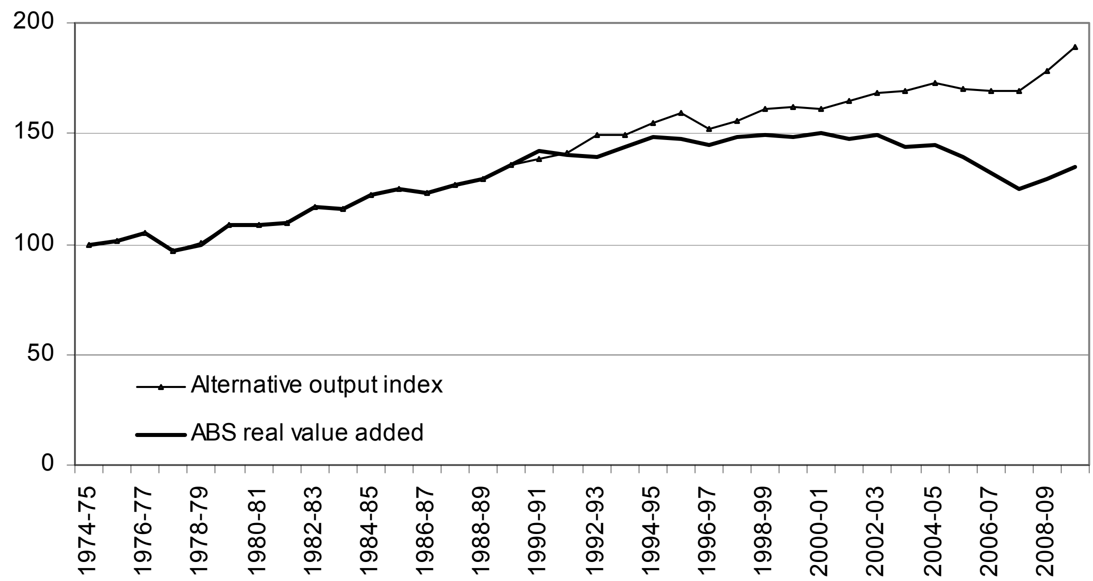
Data sources: MDBA (special data request); NWC and WSAA (various years); SCNPMGTE (various years); WSAA (various years).

The divergence between the aggregate number of customers serviced and the aggregate quantity of water supplied since 1989-90 highlights the difficulty of finding a suitable measure of the volume of output for this industry during sustained periods of *abnormal* water availability, or when demand management initiatives are being applied for policy or other reasons, such as achieving environmental objectives. As noted earlier, the ABS estimate of real value added in WSSD is partly determined by changes in the quantity of urban water supplied over time, and has shown negative growth, on average, since the late 1990s. Water utilities have been actively pursuing demand reduction strategies throughout this period, including imposing physical restrictions on water use (largely on uses outside the home). The consequence for measured MFP is adverse — output growth is slower or negative, but input use is unchanged or higher, largely because most WSSD costs are fixed, but also because of continued strong growth in the aggregate number of connections to water supply networks.

An estimate of the extent to which the 2000s drought contributed to the recent decline in MFP in water supply is presented below, and is made by comparing the original estimate of MFP in the subdivision with one made using a different measure of output. The latter was constructed by adjusting the ABS estimate of subdivision output in two ways: first, the urban water component of WSSD output was adjusted so that it reflected annual changes in the number of properties connected (which increased over the period), rather than changes in the volume of water delivered (which fell over the period); and second, the irrigation water component of WSSD output was adjusted so that it reflected changes in the number of properties supplied with irrigation water over time (which is assumed to be unchanged in the absence of other information), rather than changes in the volume of water supplied (which declined sharply over the period, as shown in figure 5.13). No change was made to the component of WSSD output representing urban sewage and wastewater treatment activities. The net effect of these changes was to produce an output index for WSSD that grew much faster than the ABS estimate of subdivision output (figure 5.14).

Figure 5.14 **Volume output in WSSD: ABS real value added versus alternative output index, 1974-75 to 2009-10**

Index 1974-75 = 100



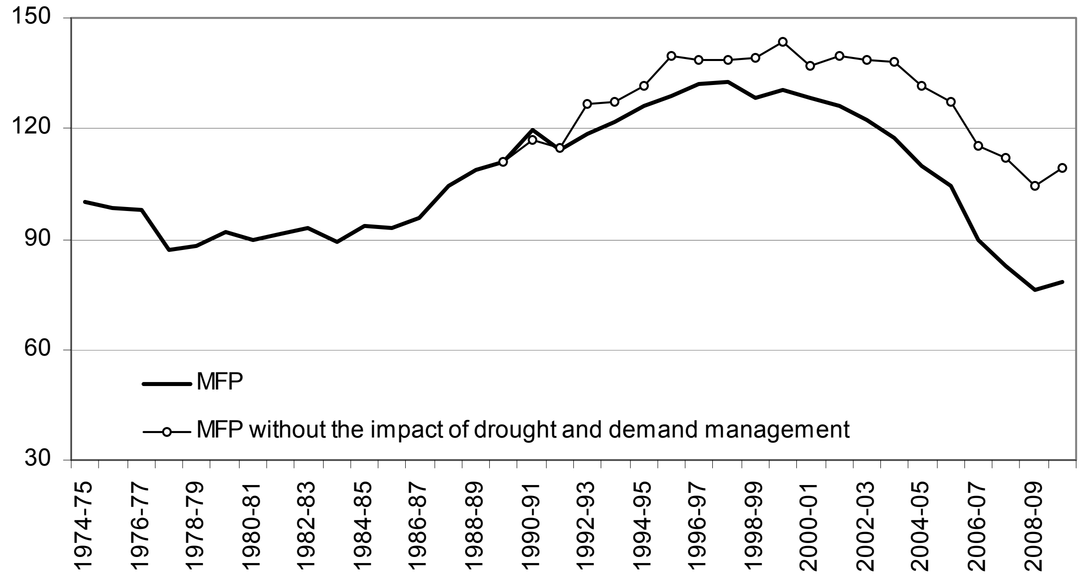
a The *Alternative output index* is made by adjusting the ABS output measure (real value added) from 1988-89 onwards so that it reflects changes in the number of urban water connections rather than changes in the quantity of urban water supplied (as per figure 5.13), and changes in the number of farms supplied with irrigation water (assumed to be constant from 1988-89 onward), rather than the quantity of irrigation water supplied. The difference between the two series is therefore an estimate of the extent to which the ABS estimate of volume output in WSSD has been impacted by drought and demand management initiatives since the mid -990s.

Data sources: ABS (*Australian System of National Accounts*, Cat. no. 5204.0); authors' estimates.

Using the alternative output measure shown in figure 5.14 to estimate MFP shows that in the absence of drought and associated demand reduction measures, MFP in WSSD would still have fallen after 1997-98, but by considerably less — about one half as much (figure 5.15). On this basis therefore, it can be estimated that the drought was responsible for around one half of the decline in measured productivity of WSSD since the late 1990s.

Figure 5.15 **Impact on MFP of demand management and drought,[a] 1974-75 to 2009-10**

Index 1974-75 = 100



[a] *MFP without the impact of drought and demand management* is a measure of MFP using the alternative output index shown in figure 5.14. No changes were made to the other variables and parameters used to estimate MFP. The difference between the two MFP series indicates the extent to which MFP in WSSD is sensitive to the choice of measure used to represent the volume of output in the water supply components (urban and irrigation) of the subdivision.

Data source: Authors' estimates.

It is also the case that MFP growth during the previous *rapid MFP growth* phase is estimated to be slightly faster when using *connections* as the measure of water supply output rather than the standard measure based on quantities delivered. This likely reflects the influence of demand-side measures introduced during the phase that were partly aimed at reducing underlying demand and deferring the need for new supply capacity.

During the *negative MFP growth* phase the primary reason for the decline in water use per connection was the effect of persistent rainfall deficits on dam storage levels (and hence water availability), and the consequent imposition of physical restrictions on water use. That is, if normal climatic conditions had prevailed during the phase, urban water supply would likely have been significantly higher.

The results in figure 5.15 highlight the potential limitations of using an output measure for WSSD that partly reflects changes in the quantities of water supplied, particularly during sustained periods of abnormal weather that lead to quantitative restrictions being placed on water use. Similarly, significant biases in MFP estimates may occur when governments and water authorities change or implement new policies designed to permanently attenuate water demand.

Implications for interpreting MFP changes

From an MFP *measurement* perspective, it is likely that the negative effect on MFP of drought in the first decade of the 2000s will be transitory or temporary to the extent that the decline in output was largely the result of abnormally low water availability, rather than permanently lower demand. Following the 2000s drought, output in WSSD is expected to increase (assuming the lifting or removal of any remaining restrictions on urban water use, and an increase in irrigation water supplies), and this would have a positive impact on measured MFP.

On the other hand, the various demand management programs that have been instituted over the past ten to fifteen years (including greater use of home tanks) will have caused some urban water customers to permanently reduce their demand for water relative to what it was prior to the 2000s. Similarly, if aggregate irrigation water use in the MDB does not ultimately return to the average levels recorded prior to the 2000s drought (because of efficiency improvements or other measures designed to reduce demand), this would tend to reduce the extent to which WSSD output grows in the short to medium term. As a result, it may take longer for aggregate water demand (urban plus irrigation) to recover to pre-drought levels, and this will tend to slow any rebound in measured productivity.

Investment in new sources of water

This section examines the second key feature of the negative MFP growth phase — a significant increase in the growth rate of inputs, particularly capital.

In the early to mid-2000s urban water businesses in southern and eastern Australia began to investigate alternatives to rain-fed dams as the source of future water supplies. This reflected a major change in thinking, as the industry had relied almost exclusively on rain-fed water storages to supply urban and irrigation water needs for most of its history (see WSAA 2007, p. 9).

Western Australia was the first state to address the issue, and in 2005 began the construction of a desalination plant to serve Perth's water needs. This was Australia's first large-scale seawater desalination plant, and began operation on 19 November 2006 (Water Corporation 2006).[17] During the remainder of the decade construction began on desalination projects to service urban populations in south-east Queensland, Sydney, Melbourne and Adelaide (table 5.3).

Table 5.3 **Desalination plants in Australia**

City/region	*Location*	*Maximum Capacity (GL/pa)*	*Maximum capacity with future upgrade (GL/pa)*	*Per cent of average annual urban water consumption in the 2000s*[b]	*Start of construction*	*Completion*
Sydney	Kurnell	90	(up to) 180	16 (potential 32)	2007	Completed
Melbourne	Wonthaggi	150	(up to) 200	35 (potential 47)	2009	June 2012
South East Queensland	Tugun	49	na	20	2006	Completed
Perth	Kwinana	45	na	19	2005	Completed
	Binningup[a]	100	na	42	2009	50 GL end 2011, 100 GL end 2012
Adelaide	Port Stanvac	100	na	62	2009	mid-2012
Total		**484**	(up to) **674**			

[a] Note that the Binningup plant had an initial maximum capacity of 50 GL with an option to expand capacity to 100 GL. The option to expand was exercised prior to the completion of the first stage of the project. [b] Based on annual water supplied information published by WSAA for the various capital city water authorities. The figure for South East Queensland is based on water supply information for Brisbane Water and Gold Coast Water. **na** Not applicable.

Source: WSAA 2009; updates by authors using water authority reports.

A number of large-scale water recycling projects were also commissioned during the 2000s, including the Western Corridor Recycled Water Project in South-East Queensland, and the industrial water recycling plant at Port Kembla in New South Wales. The former is one of the largest water recycling projects in the world, and had an estimated cost of around $2.6 billion (WSAA 2009). Other initiatives and

[17] Prior to the Kwinana plant there were around 240 desalination plants in Australia, most of them small-scale plants to desalinate seawater or brackish water to provide water needs in remote communities or industrial users (see Office of Water, Victoria, http://www.water.vic.gov.au/programs/desalination/desalination/desalination-in-australia).

projects to shore up urban water supplies included expanded groundwater developments, along with the construction of new pipelines, pumping stations and water treatment plants to provide greater interconnection of existing water sources and storages.

Fundamentally, the urban water industry embarked on a suite of major supply augmentation projects during the mid to late 2000s, many of which involved large, lumpy new capital investments that took (and are still taking in some cases) considerable time to build.

Although the contribution of desalination and water recycling plants to total urban water supply during the time period covered by this report was comparatively small, it has been growing quickly. According to WSAA (2009, p. 3), 172 GL of urban water was recycled in 2007-08, which was up 118 per cent on 2002. Based on the information in table 5.3, desalination plants could potentially be supplying 484 GL of urban water by 2012-13, which would be equivalent to approximately 35 per cent of total capital city water consumption in 2008-09. Moreover, as many of the new desalination plants also have scope for increased capacity, the share of urban water supplied via desalination will likely grow further over time. For example, if all of the additional supply capacity associated with existing plants was to be built, this would push total desalination capacity up to 674 GL per annum. Based on capital city water consumption in 2008-09, this represents approximately 49 per cent of supply. How much water is actually produced by desalination and water recycling plants over the next decade or so will ultimately be determined by developments in demand, changes in available stored water, demand management measures (including developments in water pricing) and contractual and other conditions regarding the operation of desalination and recycling plants.

From a productivity measurement perspective, three questions regarding the shift to alternative water sources are particularly important: first, are capital, labour, and intermediate input costs higher for the alternative water sources compared with existing sources; second, how long did construction of the new assets take; and third, how long is it expected to be before annual output from the new water assets reaches full capacity?

High cost of non-dam technologies

In general, water recycling and desalination are capital and energy intensive water production technologies. Apart from high capital costs, the operating costs (labour and intermediate inputs) of recycling and desalination plants are also particularly high (see box 5.2). In its recent inquiry into the urban water sector, the Productivity Commission was critical of decisions to invest in desalination plants during the

2000s, arguing that alternative augmentation options such as making greater use of aquifers or purchasing water from the rural sector could have secured additional water for urban users at lower cost (PC 2011a, p. XXIII).

Box 5.2 **Cost of desalination**

Operating costs

Desalination and dams

The Productivity Commission's urban water inquiry estimated that the operating costs of desalination plants in Australia are likely to vary from about $0.50 to $1.10 per kL (PC 2011a, p. 110). This compares with operating costs of 0.10 $/kL of water delivered from dams in Melbourne and Perth (PC 2011d, p. 28).

The Commission pointed out that:

> ...obtaining water from desalination involves relatively high per unit costs due to its intensive use of energy. There are also high fixed annual costs to maintain a desalination plant. (PC 2011d, p. 28).

Moreover:

> Based on case-study modelling of Melbourne and Perth undertaken by the Commission, the costs to consumers and the community of proceeding with desalination plants ahead of lower cost alternatives could be of the order of $1.8 billion to $2.5 billion for these two cities combined over a 10 year period and $3.1 billion to $4.2 billion over a 20 year period, depending on modelling assumptions. (PC 2011a, p. XXII)

Other large-scale non dam water supplies

The Commission's modelling paper also estimated the cost for a range of other water sources for Melbourne and Perth. For example, rural-urban trade had costs in a range from 0.25 to 1.00 $/kL, and recycling was 0.86 $/kL in Perth and 1.50 $/kL in Melbourne .

Further details about the characteristics of these water supplies can be found in PC (2011d, pp. 25-34).

Capital costs

The capital costs of large scale non-dam water supply technologies (primarily desalination, recycling, and pipelines) are likely to be considerably higher, on average, than the (average) capital cost of Australia's existing dam supplies.

The weighted average capital cost of the six large-scale urban water desalination plants in Australia is $21 per GL while the weighted average cost of the pipeline and recycling options is $11 and $25 per GL respectively. Non-dam technologies may also have shorter operational lives than dams, or at least require more frequent repairs and maintenance to stay in long term production. On the other hand, desalination and recycling schemes have the advantage of providing greater certainty of supply during extreme weather events.

(continued on next page)

Box 5.2 **(continued)**

In contrast, the capital costs of the two most recently completed large-scale urban water dams in Australia — the Wivenhoe in Queensland and the Thompson dam in Victoria, were estimated to be $8 and $3 per GL of potable water supply respectively (in 2008-09 dollars). In addition, for the Wivenhoe dam around one half of the storage capacity is earmarked for water supply, with the remainder being used to provide flood mitigation services. Hence at least some of its construction cost is not attributable to supplying potable water.

Capital costs of selected recent urban water supply projects

Plant	*Estimated capital cost ($ million)*	*Yield per year (GL)*	*Capital cost divided by annual yield ($ million per GL)*
Desalination			
Kurnell (NSW)	1 890	90	21.0
Wonthaggi (VIC)	3 500	150	23.3
Tugun (QLD)	1 200	49	24.5
Binningup (WA)	955	50	19.1
Port Stanvac (SA)	1 830	100	18.3
Pipeline			
Melbourne to Geelong (VIC)	138	16	8.6
Sugarloaf (VIC)	750	100	7.5
Northern interconnector, stage 2 (QLD)	440	6.5	67.7
Murrumbidgee to Googong (ACT)	155	12	12.9
Recycling			
St Mary’s replacement flows (NSW)	250	18	13.9
Rosehill-Camellia (NSW)	100	7	14.3
Wollongong water recycling (NSW)	25	7.3	3.4
West Werribee recycled water (VIC)	114	3	38.0
Western Corridor recycled water (QLD)	2 600	84.7	30.7
Glenelg to Adelaide park lands (SA)	76	5.5	13.8

Sources: Downie 2011; PC 2011a; NWC and WSAA 2011; authors’ estimates.

Impact on MFP levels

With the operating and capital costs of non-dam water supply technologies likely to be considerably higher (on average) compared with existing water supply sources, the ongoing shift towards the former is likely to put continued downward pressure on MFP in WSSD.

To the extent that provision of water via recycling and desalination entailed a greater quantities of capital, labour, and intermediate inputs compared with already established sources, the introduction of these technologies lowered the level of MFP in the subdivision (notwithstanding any positive effects such as greater water security). This will continue to be the case as long as or until the cost of resources used to produce a unit of water using non-dam technologies is no more than the cost of producing water using the existing mix of water supply capacity.

Quantifying the effect on MFP of the introduction of higher-cost supply technologies (particularly desalination but also water recycling) is challenging. For one thing, only one desalination plant was constructed and operational during the time-frame of the MFP estimates shown in figure 5.1, and it is unlikely that the effect of this plant alone on MFP could be identified in the data. Once all of the large-scale desalination plants are completed and operating at capacity, it may be possible to review the extent to which the introduction of non-dam sources of water supply has impacted on subdivision MFP. As noted below however, it may be some time before all of the new supply capacity in Australia is running at full capacity.

Apart from the *permanent* consequences for MFP of introducing higher-cost production technologies, the industry-wide surge in investment driven by the construction of desalination and recycled water plants is likely to have had adverse effects on MFP during the past decade. There are two reasons for this: first, it takes time to build these plants, and officially measured capital inputs rise as capital expenditures are made, which is sometimes well before plants become operational. This tends to result in officially measured MFP growing more slowly (temporarily) as measured inputs rise before there is a production response. Once construction is completed, measured input growth typically slows and, assuming output growth is positive, there is an offsetting boost to measured MFP. Second, even when new plants begin production, full system output (maximum supply from dams, desalination, and recycling) may not be required (or achieved) for some time if the new capital assets are lumpy, and have been designed to underwrite future demand growth.[18]

The impacts on measured MFP of these temporary effects — capital lags associated with comparatively long construction times, and economies-of-fill associated with lumpy additions to supply capacity — are considered below.

[18] Even if the desalination plants are initially run at full capacity for contractual reasons, it may be some time before aggregate water demand catches up to total system capacity (dam plus non-dam capacity). As noted earlier, unmeasured declines in capacity utilisation (as lumpy new supply capacity is added) temporarily lower MFP, while unmeasured increases in capacity utilisation (as greater use is made of existing supply capacity over time) add to MFP.

The impact of lengthy construction times for sources of new supply

Although only one capital city desalination plant was operational during the time-frame of the MFP estimates in this study (the Kwinana plant in Western Australia), capital costs associated with the construction of desalination plants in the eastern states were being added to measured subdivision inputs during the mid to late 2000s.[19] With few offsetting effects on output, the net result was (temporary) downward pressure on MFP. While lags associated with construction times are not generally an issue, if an industry-wide investment surge is large enough, the effect on MFP can be significant.[20]

Lumpy capacity and economies of fill

Once new water supply assets are operational, it may be many more years before aggregate supply capacity (existing supply capacity plus new capacity) is fully utilised. This is a consequence of the technology of supplying water and wastewater services, where incremental adjustments to supply capacity each year are neither technologically practical nor economically optimal. Dams cannot be raised slightly every year, nor pipes or wastewater treatment plants widened slightly each year in order to meet growing demand for water or wastewater treatment. Instead, capital assets are usually constructed with a view to meeting current and future demand. For example, the array of desalination and water recycling plants invested in by water utilities across the country in recent years are expected to underpin water demand growth for some time into the future, not just to meet immediate needs.[21]

To the extent that there is a surge in investment in lumpy new supply capacity, MFP is likely to be adversely affected at first if there is no adjustment made for changes in the average rate of capital utilisation (which is the case in relation to the ABS estimates of capital services inputs). Once lumpy new assets have been constructed however, capital investment and capital services estimates typically slow down, while output tends to increase in line with population growth and the available capital capacity.

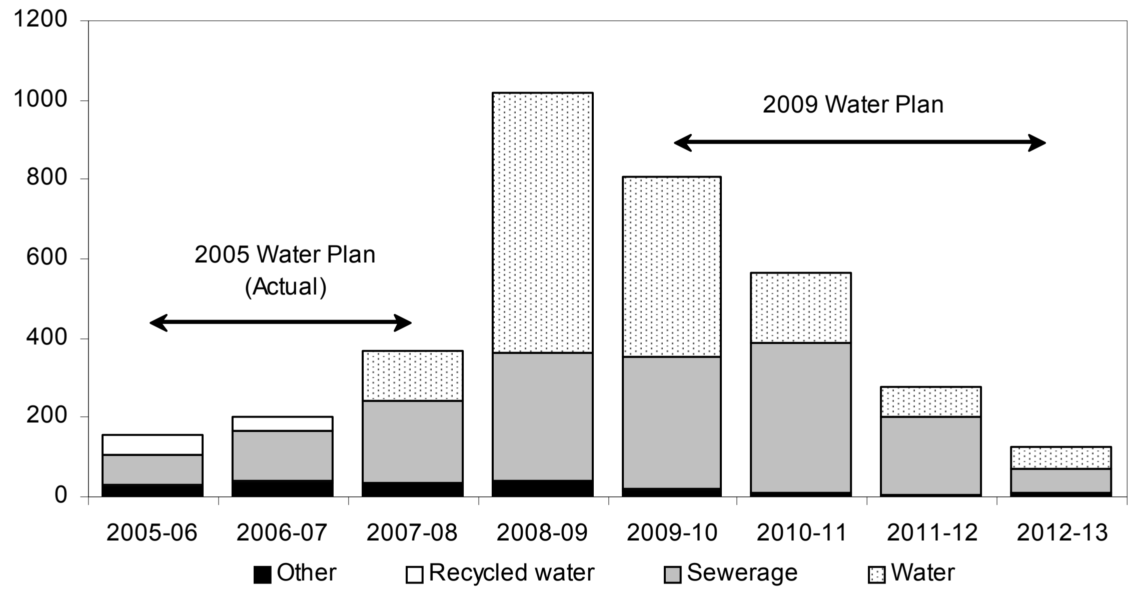
[19] The Tugun desalination plant in Queensland was operational in February 2009, and hence contributed to WSSD output in 2008-09. However, it was closed for five weeks in May-June 2009, so it's total contribution to subdivision output in 2008-09 would have been comparatively small. Sydney's desalination plant commenced water production in January 2010, and hence will impact on WSSD output from 2009-10 onwards.

[20] Topp et al. (2008) examined the impact of an industry-wide surge in new investment on MFP in the mining division and found a significant but temporary negative effect.

[21] This may be less the case in Western Australia, where changing climatic conditions have had an extremely adverse impact on the capacity of dams to supply water, and where desalination is expected to continue growing rapidly as a source of supply.

In the case of WSSD there is evidence that the industry-wide surge in new investment from the mid-2000s is coming to an end, with two of the largest water utilities in Australia — Sydney Water and Melbourne Water — expecting to significantly reduce their capital investment programs over the next few years (see figure 5.16 and Sydney Water 2009, p. 6).

Figure 5.16 **Melbourne Water capital expenditure, 2004-05 to 2012-13**
$ million, constant 2008-09 dollars

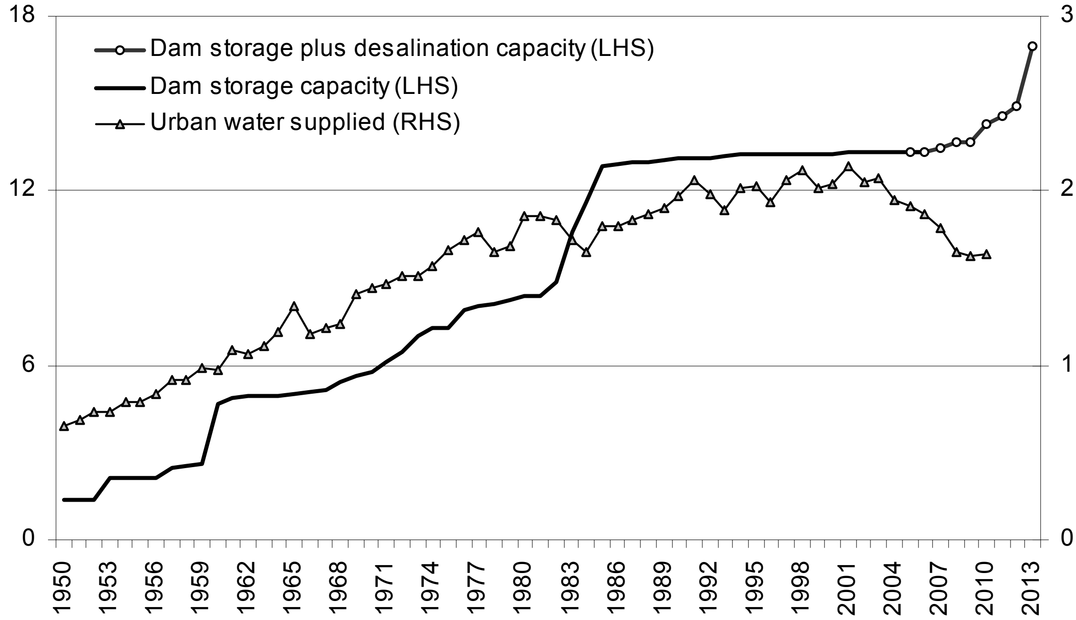


Data source: Melbourne Water (2008).

The cyclical investment pattern in WSSD has been a key factor influencing periodic swings or phases in MFP. As noted earlier, the period of rapid MFP growth in WSSD from the mid-1980s to the late 1990s was partly attributable to the substantial overhang of urban water storage capacity at the beginning of the period that followed an industry-wide surge in lumpy capital investments in the previous phase. In the *negative MFP phase* the opposite situation occurred — large new urban water supply projects were under construction, although there was little in the way of additional output (in fact, urban water supply continued to fall) as many of the projects were incomplete.

An indication of the extent to which urban water supply capacity is now running ahead of demand is shown in figure 5.17, which contains an estimate of aggregate urban water supply capacity based on existing dams and desalination plants. In essence, the desalination plants that were operational by mid-2011 along with those expected to be completed over the next couple of years will add substantially to water supply capacity. Even if climatic conditions for water catchments do not improve compared with the first decade of the 2000s, WSSD now has significantly greater capacity to meet current and future water demand growth. Importantly, the capacity associated with desalination plants also has a higher probability of being able to deliver sustained water supply when it is most needed compared with traditional water sources.

Figure 5.17 **Urban water storage capacity, desalination plant capacity, and urban water supplied (millions ML), 1950 to 2011 and projections to 2012[a]**



a Desalination capacity is measured in *dam equivalents* and is calculated by dividing desalination plant capacity (in GL) by 0.15, which is the average quantity of water supplied (in GL) per unit of dam storage capacity (in GL). Hence 1 GL of desalination plant capacity is assumed to be equivalent to 6.7 GL of dam storage capacity. Projections of storage capacity to 2012 are based on expected completion dates for the three desalination plants currently under construction, and assuming that there is no change to the aggregate quantity of dam storage.

Data sources: Authors' estimates using data from ANCOLD (*Register of Large Dams in Australia*); NWC and WSAA (various years); SCNPMGTE (various years); WSAA (various years).

More broadly, if rainfall and runoff levels improve over the short to medium term, WSSD has the capacity to substantially increase both urban and irrigation water supplies without requiring any major increase in inputs. To the extent output growth recovers, this will tend to lift growth in measured MFP.

Unmeasured changes in the quality of WSSD outputs

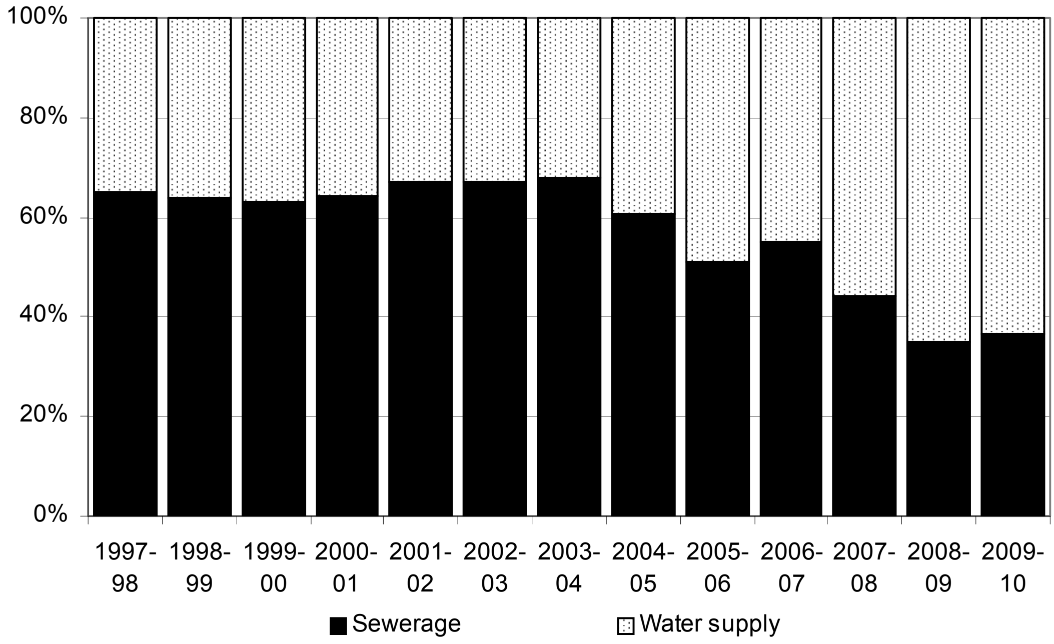
Another potential contributing factor to the decline in MFP in WSSD since the late 1990s is unmeasured improvements in the *quality* of outputs of the subdivision, particularly in relation to sewage treatment standards. As the ABS measure of real value added in WSSD does not reflect changes in the quality of subdivision output, there may be adverse consequences for the measurement of MFP if the costs of improvements in output quality are substantial.

The issue of increasing costs of sewage water treatment was noted in an early study of productivity growth in Melbourne Water (Manning and Molyneux, 1993, p. 51), in which the authors argued that improved standards of sewage treatment would be required over time in order to '... remain within the absorptive capacity of the local environment ...', and that this would require increasing capital inputs per unit of output.

In relation to the *negative MFP phase* therefore, two key questions arise. First, is there evidence of a substantial improvement (relative to the previous phases) in the average standard to which sewage was treated and disposed of to the environment? And second, if there was such an improvement, is there evidence that the real costs of achieving it were significant in relation to total subdivision costs?

Before discussing these questions directly, it is useful to recall that the collection, treatment and disposal of sewage and wastewater is a significant activity within WSSD. Moreover, for much of the *negative MFP phase*, expenditure on sewage treatment and disposal capital was substantially higher than that on water supply capital (figure 5.18).

Figure 5.18 **Capital expenditure shares, 1997-98 to 2009-10**
Per cent



[a] Allocation based on capital expenditure on the two types of capital reported by WSAA for the 16 major urban water businesses in Australia.

Data sources: Authors' estimates using data from NWC and WSAA (various years); SCNPMGTE (various years); WSAA (various years).

Evidence of improved standards of sewage treatment

Industry data provide direct evidence of an improvement in average sewage treatment standards in Australia over the period from 1997-98 to 2009-10 (see box 5.3 and figure 5.19). For example, from 1997-98 to 2009-10, the proportion of sewage treated to tertiary standard rose from around 20 per cent to just over 60 per cent (box 5.3 and figure 5.19). Most of the improvement came from a switch from secondary to tertiary treatment, although the proportion of sewerage treated to primary standard also fell slightly during the phase (from 35 per cent to 29 per cent).

Box 5.3 **Wastewater treatment standards**

Below are some terms and definitions used in describing the treatment of wastewater. They are taken from the 1997 *Australian Guidelines for Sewerage Systems, Effluent Management.*

Pre treatment

This process involves the removal of gross solids, coarse suspended and floating matter.

Primary treatment

Wastewater treatment which involves sedimentation (sometimes this is preceded by screening and grit removal) followed by sludge digestion or other means of sludge disposal.

Secondary treatment

A level of treatment that can remove 85 per cent of Biochemical Oxygen Demand (BOD) and suspended solids.

Tertiary treatment

Processes that can further improve secondary effluent quality prior to discharge or reuse. These processes can include sand filtration, oxidation pond retention, disinfection and the use of wetland filters.

Advanced wastewater treatment

The application of multiple unit processes beyond secondary treatment (tertiary or above).

Biochemical Oxygen Demand (BOD)

This is a measure of the amount of oxygen used in the biochemical oxidation of organic matter, over a given time and at a given temperature. It is determined entirely by the availability of the material as a biological food and by the amount of oxygen used by the micro-organisms during oxidation.

Wastewater

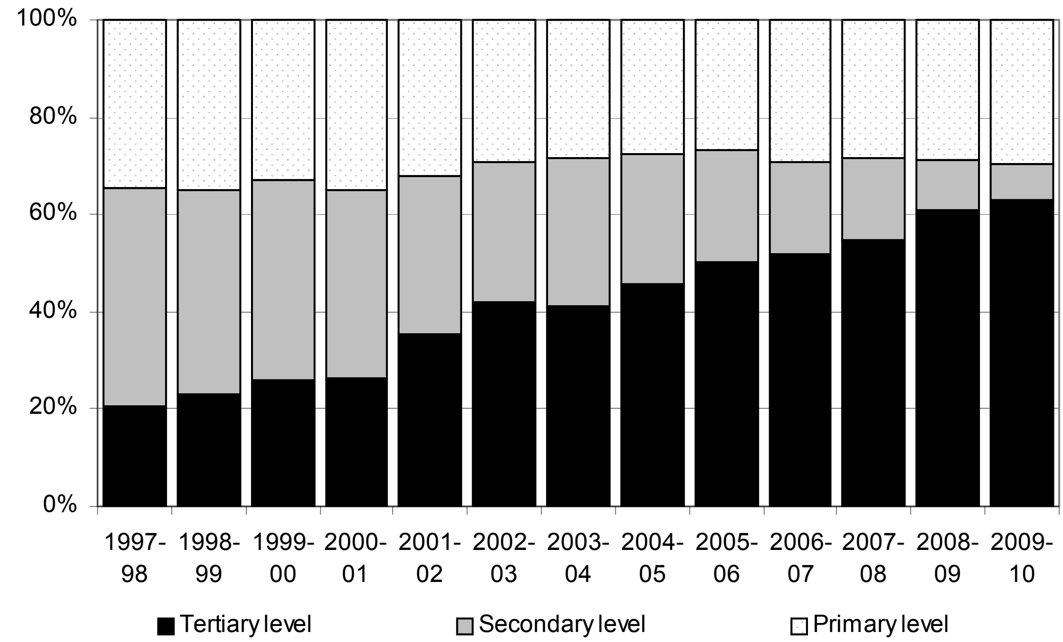
Water which has been used, at least once, and has thereby been rendered unsuitable for reuse for that purpose without treatment and which is collected and transported through sewers. Wastewater normally includes water from both domestic and industrial sources.

Some additional details about the *elements of the water cycle* can be found in Productivity Commission (PC 2011a, box 2.1, pp. 12-13).

Source: Agriculture and Resource Management Council of Australia & New Zealand and Australian & New Zealand Environment and Conservation Council (1997) Australian Guidelines for Sewerage Systems — Effluent Management, Canberra. http://www.environment.gov.au/water/publications/quality/pubs/sewerage-systems-effluent-man-paper11.pdf

Figure 5.19 **Sewage treatment by type: shares of total treatment,[a] 1997-98 to 2009-2010**

Per cent



[a] Shares are weighted averages across the 16 major urban water businesses in Australia, where the weights used are based on quantities of sewerage water treated.

Data source: Authors' estimates using data from NWC and WSAA (various years); SCNPMGTE (various years); WSAA (various years).

Impact on costs

The next question is whether the improvement in sewage treatment quality shown in figure 5.19 came at a significant cost.

WSAA facts 1997 makes reference to urban water businesses facing an expected increase in capital expenditure on sewage treatment in order to meet higher environmental discharge standards (WSAA 1997, p. 70). Increasingly sophisticated sewage treatment plants and facilities also require more labour, including more highly skilled labour.[22]

In relation to water utilities in New South Wales, an IPART paper (Cox and Seery 2010, p. 14) states:

> In our reviews, we identified increased water quality and sewerage discharge standards as the main drivers of capital expenditure, with large expenditure more recently on the desalination plant.

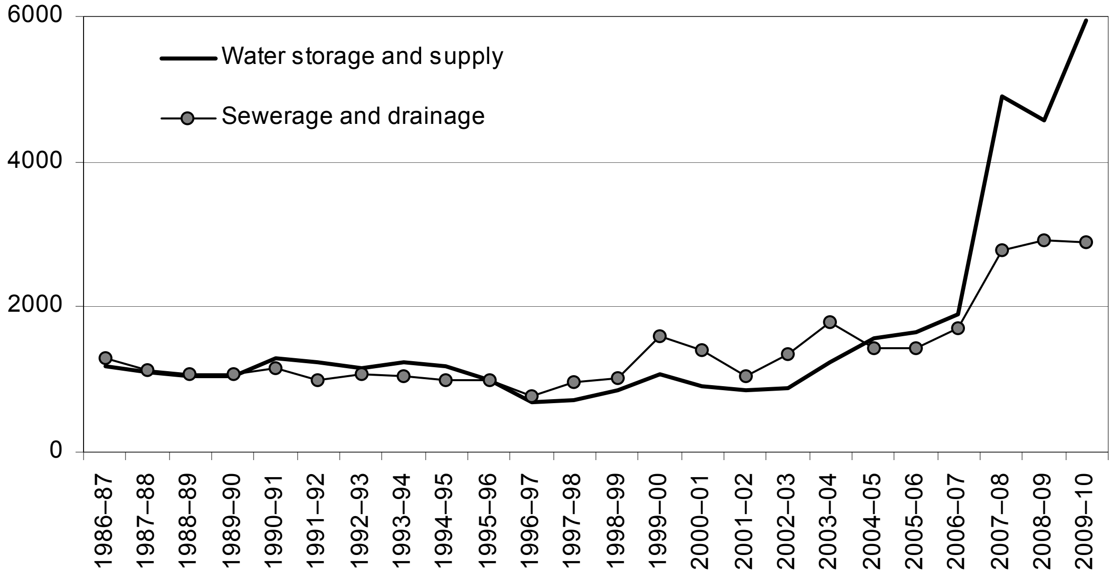
22 Skill shortages were identified in the Productivity Commission urban water inquiry as hindering the operations of water utilities, particularly in regional areas (see PC 2011a, pp. 383-387).

The change in capital productivity has had a big impact on overall productivity. This seems to be driven by government decisions and licensing requirements imposed by the environmental and other regulators.

At the aggregate level, ABS data indicates that investment in sewerage and drainage works increased in real terms from the late 1990s onwards (figure 5.20). Annual capital expenditure in the 2000s on sewage treatment was clearly well above levels recorded in the preceding decade.

Figure 5.20 **Capital investment by urban water authorities, by type, 1986-87 to 2009-10**

$ million, 2008-09 dollars chain volume measure



Data source: ABS (*Engineering Construction Survey*, Cat. no. 8762.0).

Treatment costs by type of treatment

Data on the costs of sewage treatment by type (that is, primary versus secondary versus tertiary) is limited, although there is evidence that some costs escalate comparatively quickly according to the level or standard of treatment. For example, energy costs per unit of sewage treated double between primary and secondary treatment, and double again between secondary and tertiary treatment (Kenway et al. 2008, p. 12).

WSAA (1997, p. 38) provides indicative total cost ratios of 1 : 3 : 6 for primary, secondary and tertiary sewage treatment. That is, secondary treatment costs three times that of primary treatment, while tertiary treatment costs twice that of secondary treatment. WSAA noted that these cost ratios are only a rough guide to actual cost differences.

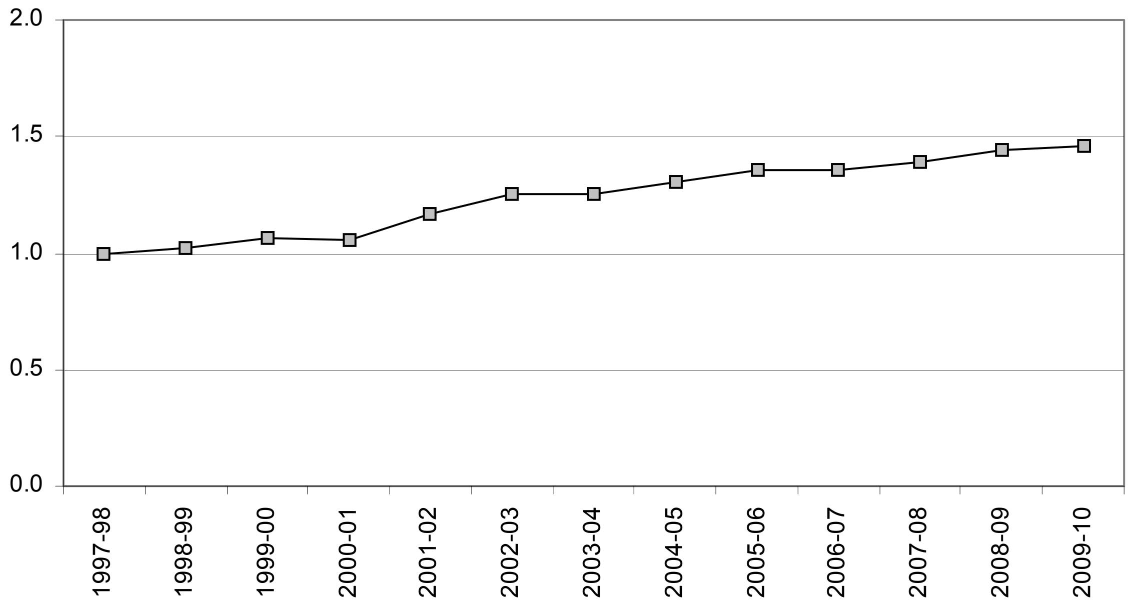
On balance, the substantial improvement in the standard of sewage treatment in Australia between 1997-98 and 2009-10 is likely to have come at considerable additional cost, and would have had a major adverse effect on measured productivity.

Quantifying the impact on MFP

An estimate of the size of the adverse effect on MFP is made below by converting the sewage treatment shares in figure 5.8 into an index of sewage treatment quality, and using this index to *quality adjust* WSSD output, and re-estimate MFP.

The sewage treatment quality index was derived by weighting the changes in annual sewage treatment by type according to the cost ratio 1 : 3: 6, as noted above. The index increases over time reflecting the general shift towards tertiary-level treatment over the period (figure 5.21). It indicates that the quality of urban sewage treatment has increased by around 41 per cent since the late 1990s.

Figure 5.21 **Index of sewage treatment quality,[a] 1997-98 to 2009-10**
Index 1997-98 = 1

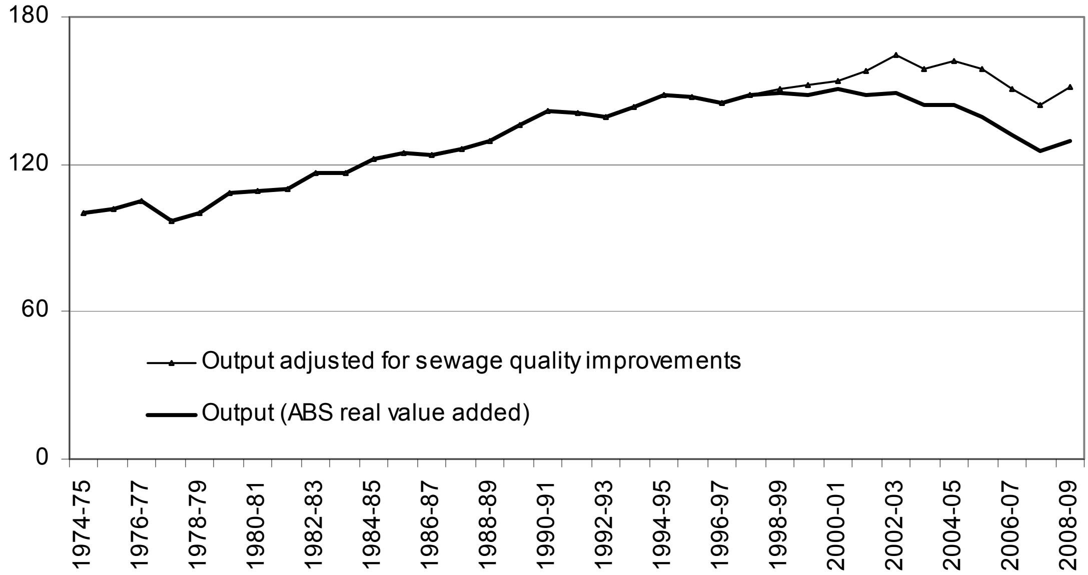


[a] The index in this figure is derived from the *sewage treatment by type* results in figure 5.8 and using weights for each treatment type given by the ratio 1:3:6 — that is, secondary treatment receives twice the weight of primary treatment, and tertiary treatment receives twice the weight of secondary treatment.

Data sources: Authors' estimates derived from NWC and WSAA (various years); SCNPMGTE (various years); WSAA (various years).

This *quality* improvement to output in WSSD — which can be viewed alternatively as an improvement in human and environmental health relative to what would otherwise have been the case — is then incorporated as an output *volume* change in WSSD by adjusting the wastewater treatment component of total subdivision output by the estimated change in treatment quality. The adjustment indicates a faster rate of output growth in WSSD (figure 5.22).

Figure 5.22 **Output (real valued added) and output adjusted for estimated sewage treatment quality improvements, 1974-75 to 2008-09**
Index 1974-75 = 100



[a] The adjustment to total WSSD output is made by adjusting the annual growth in the sewage treatment component of total output by the annual change in sewage treatment quality (as shown in figure 5.21), and assuming that the output components — urban and irrigation water supplies — are unchanged. As noted earlier, wastewater and sewage treatment is assumed to represent 44 per cent of total WSSD output, and hence adjusted WSSD output grows by less than the percentage increase in sewage treatment quality.

Data sources: ABS National Accounts on dXtime (database); authors' estimates.

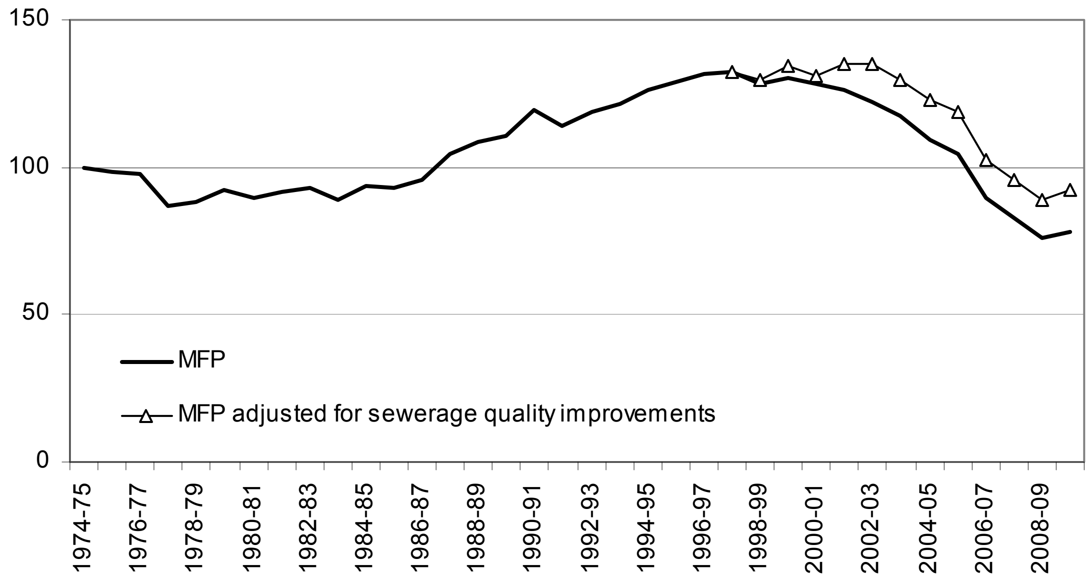
The adjusted output index from figure 5.22 is then used to re-estimate subdivision MFP.

The result suggests that around 10 percentage points of the 41 per cent decline in the level of MFP in WSSD between 1997-98 and 2009-10 (or around one quarter of the decline) could have been the consequence of policy and regulatory changes that led to a considerable improvement in the (average) standard of sewage treatment in Australia over the period (figure 5.23).

While further research and additional data are required to provide greater confidence regarding the true size or extent of this effect, it is nevertheless likely to remain an important factor influencing the measured productivity performance of the utilities division over the past decade or so.

Figure 5.23 **Impact on MFP in WSSD of improved sewage treatment standards,[a] 1974-75 to 2009-10**

Index 1974-75 = 100



[a] The *adjusted* MFP series in this figure is estimated using the alternative output index shown in figure 5.22.

Data source: Authors' estimates.

Higher drinking water standards

Similar considerations regarding stricter drinking water standards would also tend to lower measured productivity in WSSD (to the extent that they have occurred over the time frame covered in this report). For example, IPART (2010, p.27) identified higher drinking water standards as a factor behind significantly increased inputs in major New South Wales water utilities in the 2000s.[23] However, a lack of data means that it has not been possible to identify the size or timing of any such effects in this study.

The Productivity Commission inquiry into the urban water sector noted the potential impact that different standards can have on utility costs, although it is less clear whether standards have increased significantly over time (PC 2011a, p. 318). The

23 Coelli and Walding (2005, p. 24) also identified cost increases associated with quality improvement strategies as a possible cause of negative productivity growth in the Australia urban water supply sector during the period from 1996 to 2003.

Commission report does, however, identify problems that some rural water businesses are having in meeting existing drinking water standards.

In general, to the extent that growth in capital and labour inputs over the time period was, in fact, due to the imposition of stricter drinking water standards, this would also have contributed to the comparatively poor rate of productivity growth in the subdivision observed over the longer term.

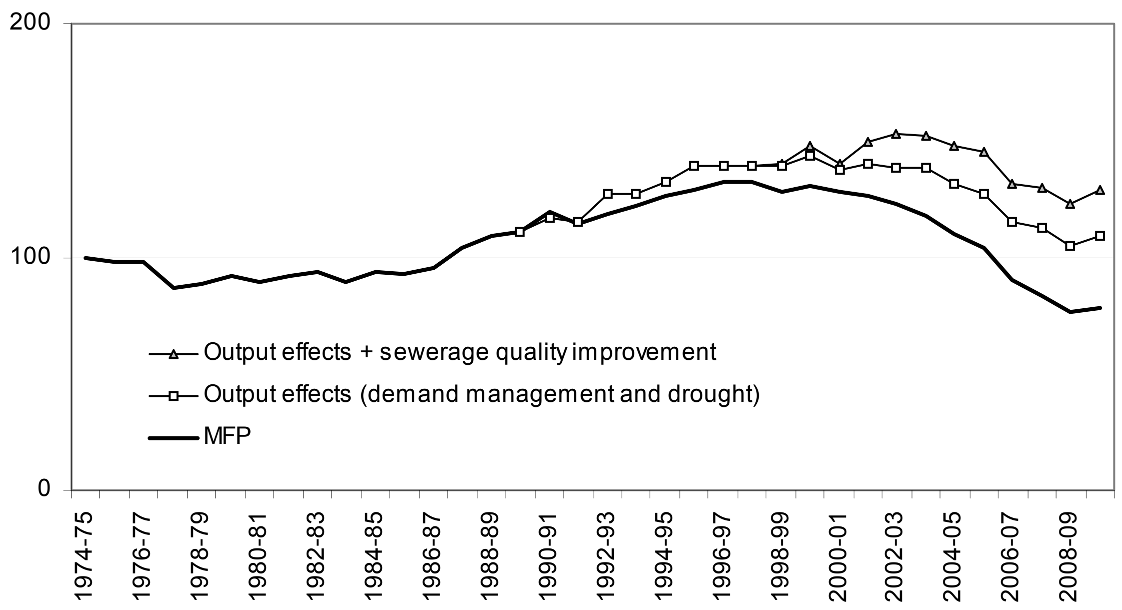
Looking ahead, if (average) sewage treatment or drinking water standards continue to rise over time, this will put further downward pressure on measured MFP in the subdivision (assuming that quality changes in output are not taken into account when measuring productivity).

5.5 Summarising the quantitative impacts on MFP

Two factors — the impact of drought and improvements in sewage water quality — are estimated to potentially explain around 80 per cent of the decline in the level of MFP in the subdivision since 1997-98 (figure 5.24). Other factors explain the remainder of the decline.

Figure 5.24 **Cumulative impact on MFP of selected factors,[a] 1974-75 to 2009-10**

Index 1974-75 = 100



[a] In estimating MFP impacts it is assumed that urban water supplied represents 47.5 per cent of WSSD output, sewage treatment represents 47.5 per cent of WSSD output, and irrigation diversions represent 5 per cent of WSSD output.

Data source: Authors' estimates.

What is not measured in figure 5.24

Two important factors are not measured in figure 5.24. First, the effects of unmeasured changes in average rates of capacity utilisation associated with industry-wide cycles in investment in lumpy capital assets have not been quantified. As noted earlier, changes in average rates of capacity utilisation are likely to have had a significant impact on broader MFP trends in the subdivision since 1974-75, and contributed to the decline in measured MFP in WSSD after 1997-98, and particularly during the period from the mid-2000s to 2009-10. Future MFP growth in the subdivision should occur, however, as the current crop of desalination and recycled water projects gradually increase their operating capacity.

On the other hand, the technological shift towards desalination and recycled water projects is likely to be fundamentally negative for conventionally measured productivity. Non-dam technologies such as desalination and recycling are typically higher cost sources of supply, and to the extent that they are introduced to the supply mix they will tend to lower the level of productivity in the subdivision. Although a quantification of this effect has not been possible, its impact on the average level of productivity in the subdivision is likely to be significant given the scale of the change. By the end of 2012 as much as 30 per cent of urban water needs could be being met by desalination plants, with further additions beyond that level also a possibility.[24]

24 Some of the major new desalination plants in Australia also have scope for additional capacity to be added in the future, should it be required (see table 5.3). On the other hand, a dramatic improvement in rainfall and run-off could limit the immediate requirement for desalinated and/or recycled water, in which case it may be some time before all of the capacity embodied in the new non-dam technologies is fully utilised.

6 Productivity in Gas supply

This chapter presents estimates of multifactor productivity (MFP) within the Gas supply (GS) subdivision, the third and final subdivision of utilities examined in this paper.[1]

While the MFP estimates for Gas supply have been derived in exactly the same way as the estimates for Electricity supply (ES) and Water supply (WSSD), for reasons explained below the Gas supply MFP estimates may be less reliable.

The consequences for the broader analysis of utilities MFP being conducted in this paper are, however, less significant. As noted in chapter 3, the Gas supply subdivision is only a small component of utilities, and hence developments within it have only a small impact on MFP changes at the utilities level. With respect to the latter, developments in ES and WSSD are much more significant.

On the other hand, it was hoped at the outset of this project that the MFP results for Gas supply would provide useful information for analysts and others interested specifically in the gas sector. While this goal may not have been fully achieved due to data limitations, the MFP estimates for GS nevertheless help to complete the picture for utilities. The results for GS should, however, be treated with caution.

6.1 The Gas supply subdivision

The main reason that the ABS Gas supply subdivision is only a comparatively small part of utilities — in 2008-09 it accounted for only 3 per cent of division output (industry value added) and 2 per cent of employment — is that under the industry classification scheme used by the ABS, only gas distribution activities are included.

[1] As noted in chapter 2, the newly added *Waste services* subdivision was not considered for two main reasons. First, very little time series information on the subdivision was available to construct MFP estimates. Second, a comparison of ABS estimates of MFP in EGW and EGWW shows almost no difference, indicating that the main sources of change in MFP have been occurring in the three original subdivisions — ES, WSSD and GS.

That is, according to the ABS, ANZSIC06 classification system:

> Gas supply includes the distribution of gas, such as natural gas or liquefied petroleum gas, through mains systems. (ABS 2006, p. 200)

Information regarding the definition of *gas* is contained in box 6.1.

Box 6.1 **What is gas?**

The generic term *gas* covers a range of hydrocarbon-based products that can occur naturally or as a by-product of oil refining. This includes conventional natural gas, coal seam gas and liquefied petroleum gas (LPG). There is also biogas which comes from sources such as sewage and landfill.

The Australian Energy Regulator (AER) in its *State of the Energy Market* (2010, p. 69) pointed out that in Australia there are two main types of *natural gas — conventional natural gas* and *coal seam gas.*

Natural gas and coal seam gas are naturally occurring and consist mainly of methane. For domestic use natural gas is usually piped to homes and businesses. Natural gas for export is processed into liquefied natural gas (LNG).

Liquefied petroleum gas (LPG) is a by-product of oil refining and is supplied in cylinders or is piped to homes and businesses. LPG is a mix of propane and butane with the ratios adjusted for specific uses such as automotive LPG.

Sources: AER (2010, p. 69); NSW Department of Trade and Investment, Regional Infrastructure and Services (Trade and Investment), http://www.dtiris.nsw.gov.au/energy/gas.

Important elements of the wider gas industry *do not* fall within the ABS definition of Gas supply. The production of gas — the extraction and processing of raw gas from wells to produce a saleable product — is accounted for within the Mining division. Similarly, the bulk transmission of gas via high-pressure pipelines from sources of production to the various mains (distribution) systems (see figure 6.1) is part of the Transport, postal and warehousing division. Table 6.1 provides the full description of the primary activities and detailed list of exclusions for the Gas supply subdivision.

Table 6.1 **Description of Gas supply (Class 2700), ABS ANZSIC 2006 classification**

Primary activities

- Coal gas distribution through mains system
- Fuel gas distribution through mains system
- Liquefied petroleum gas distribution through mains system
- Liquefied petroleum gas reforming for distribution through mains system
- Natural gas distribution through mains system

Exclusions

Units mainly engaged in:

- treating natural gas to produce purified natural gas or liquefied hydrocarbon gases, or operating natural gas absorption or separation plants, are included in Class 0700 Oil and Gas Extraction
- manufacturing liquefied petroleum gas in conjunction with petroleum refining are included in Class 1701 Petroleum Refining and Petroleum Fuel Manufacturing
- construction repair or maintenance of gas mains are included in Class 9429 Other Machinery and Equipment Repair and Maintenance
- wholesaling or retailing liquefied petroleum gas in bottles or bulk (except through a mains system) are included in Class 3321 Petroleum Product Wholesaling; and operating pipelines for the transportation of gas are included in Class 5021 Pipeline Transport.

Source: ABS (*Australian and New Zealand Standard Industrial Classification, 2006*, Cat. no. 1292.0, p. 203).

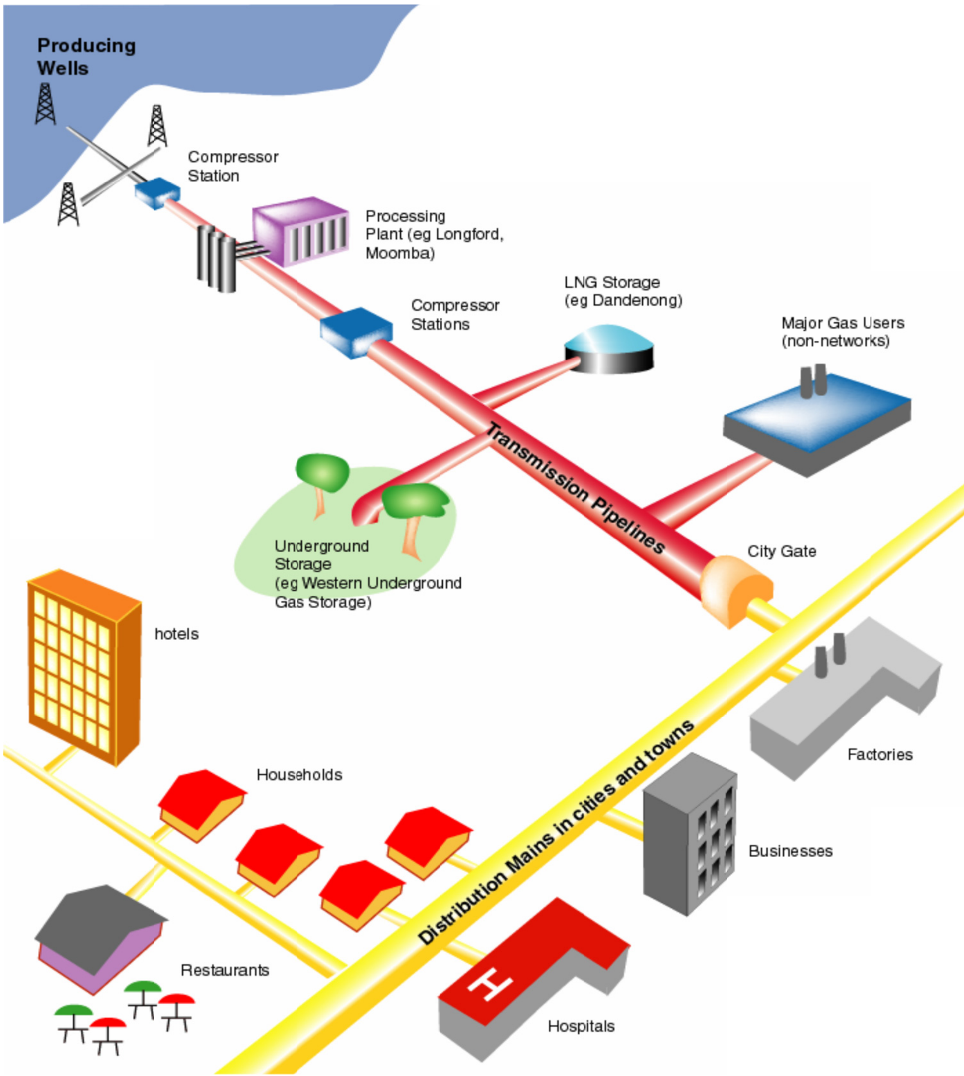
In contrast, the scope of activities covered in both ES and WSSD (as discussed in chapters 4 and 5) is significantly broader. ES includes electricity generation (power stations), long-distance electricity transmission, electricity distribution and retailing. Similarly, activities in WSSD include potable water production (dams and treatment plants, and desalination and recycling plants) as well as water transmission, water distribution and retailing, the collection, treatment and disposal of waste water, and stormwater management.

The ABS GS subdivision is therefore confined to gas distribution and retail activities only. This means that any MFP results derived using ABS Gas supply data, as is the case in this paper, will only reflect changes in inputs (labour and capital) used to distribute and retail gas. Changes over time in the quantities of labour and capital used to produce gas or to pipeline gas to the various mains networks around the country are not accounted for within GS, and hence do not contribute to these MFP estimates.

In practical terms, this is a significant omission. Growth in gas distribution networks can typically only occur if new transmission infrastructure is also available. Hence, transmission activity is essential to the delivery of the final product — sales of gas.

It is tempting to think that the MFP estimates might nevertheless be suitable indicators of productivity growth within the gas *distribution* component of the total gas supply chain shown in figure 6.1. However, the measure of (volume) output in GS used by the ABS is quantitatively linked to changes in gas production, and this is problematic when it comes to measuring productivity in gas distribution.

Figure 6.1 **Gas supply chain**



Source: PC (2004, p. 6).

First, studies of productivity within the gas distribution sector (or of productivity within individual gas distribution businesses) typically use more comprehensive measures of output, where gas production or throughput is only one of a number of output components (see Lawrence 2010, for example). The number of connected properties is generally considered an important indicator of output in gas distribution businesses, and may be given considerably more weight in measuring the volume of output than gas throughput. Indicators of supply reliability (an output quality dimension) are also sometimes incorporated in volume output measures for gas distribution businesses (see box 6.2 for information on studies of productivity within gas distribution businesses).

Second, the ABS estimate of gas production is defined as the *amount of gas available for issue through mains* (ABS 1999, p. 32). However, the latter appears to include significant quantities of gas that are not ultimately supplied through distribution mains networks, but are supplied directly to transmission customers. To the extent that this is true, there may be an inconsistency between the scope of the GS output measure (which is based on total gas production, rather than actual sales through the various distribution networks) and the scope of the GS input measure (which covers inputs used in gas distribution alone). In the context of figure 6.1 this is equivalent to saying that, on the inputs side of the equation, only the capital and labour used beyond the *City gate* point in the chain is counted by the ABS as inputs in the Gas supply subdivision, whereas on the output side of the equation, the ABS also includes gas sold prior to city gate to *Major gas users (non-network)*.

Data published by the Energy Supply Association of Australia (esaa) indicates that significant quantities of gas used in electricity production and in manufacturing are delivered directly from the transmission network, not via the distribution mains networks (esaa 2011, p. 68). For example, in 2009-10, esaa report that only 386 PJ of gas was delivered through mains networks out of total consumption of 1049 PJ, with the majority of gas supplied directly to transmission customers (mainly large industry and electricity generators). In contrast, the ABS estimate of gas production in 2009-10 was 903 PJ (ABS Cat. no. 8301.0, on dXtime database).

Perhaps more importantly, the esaa data combined with older data published by the Australian Gas Association (AGA) indicates that the growth rate in the quantity of gas supplied through the gas distribution sector between 1984-85 and 2009-10 was much slower than the growth rate in the quantity of gas supplied directly to transmission customers. In which case, the volume output measure in GS over this period may have been overstated.

Box 6.2 Productivity studies in the Australian gas sector

There have been a number of studies of productivity within various parts of the Australian gas sector. In some studies, the scope, definitions and methodology used have been notably different than those used in this paper, while other productivity studies have focused on the performance of specific businesses or specific elements of the gas industry such as distribution.

Previous productivity studies

- Lawrence (2010) estimated total factor productivity (TFP) and partial factor productivity in six individual gas distribution businesses over the period from the late 1990s to the late 2000s. He found that productivity among the businesses varied — some displayed steady positive growth while others experienced a more variable performance. For example, Envestra SA recorded strong annual average TFP growth of 1.5 per cent a year for the period 1999 to 2010, largely as a result of significant reductions in operating expenses. In contrast, over the same period, the TFP performance of Envestra Queensland was an average annual growth rate of –0.2 per cent.
- Rushdi (1994) focused on total factor productivity for the Gas and Fuel Corporation of Victoria (GFCV) for the period 1971 to 1989. The author found TFP growth for the GFCV was 8.5 per cent per year, with output growth at 12.4 per cent and input growth at 3.6 per cent.
- The Australian Gas Association (AGA 2000) in its annual *Gas statistics*, viewed benchmarking and performance monitoring as important information, and provided a range of partial factor productivity measures for the Australian gas distribution industry for a number of years.
- Carrington et al. (2002) attempted to measure the efficiency of the Australian gas distributors relative to each other and to distributors in the United States. A number of techniques were employed, including partial productivity measures and data envelopment analysis (DEA).

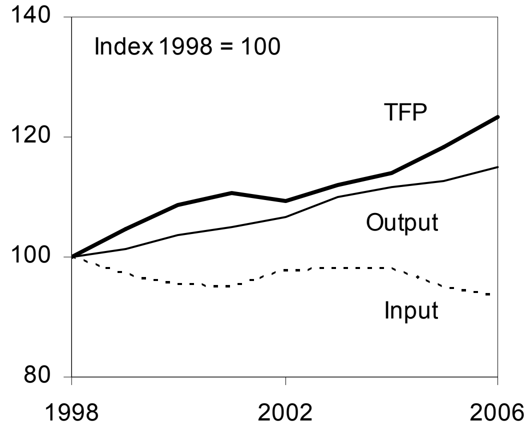
The Lawrence (2010, pp. 6-10) paper identified eight previous studies of *gas pipeline efficiency performance*. These studies included a range of productivity measures. The papers included international benchmarking studies undertaken by the BIE (1994) and IPART (1999), and reports by Meyrick and Associates (2007) and Pacific Economics Group (PEG) (2008a) that estimated TFP growth within the Victorian gas distribution industry. Lawrence (2009b), examined TFP for the New South Wales gas distribution system.

(continued on next page)

Box 6.2 **(continued)**

Productivity for Victorian gas distribution — some long term trends

The TFP results for gas distributors in Victoria that were estimated by Meyrick and Associates (2007, p. 27-29) focused on the post privatisation period (1998 to 2006). This period was characterised by strong TFP growth of 2.7 per cent per year, with output growth of 1.8 per cent, and a decline in input growth of 0.9 per cent a year. The explanation was that the high TFP growth rate was achieved in part by reducing operating and maintenance expenditure (OPEX), which declined by 4.3 per cent a year.

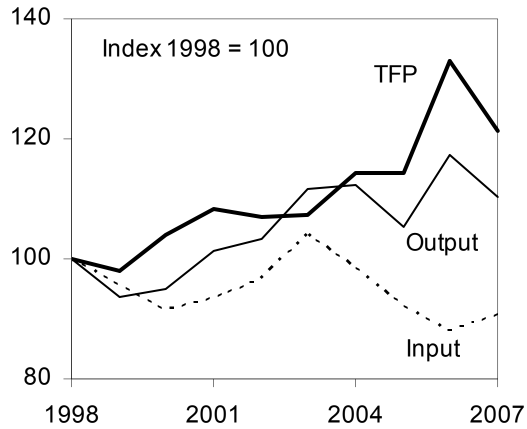


Data source: Meyrick and Associates (2007, p. 28).

Another study which estimated TFP for the Victorian gas distribution industry for the years 1998 to 2007 was undertaken by PEG (2008a).

The TFP growth rate was estimated at an average annual rate of 2.9 per cent, with output growth estimated at 1.1 per cent, and input growth falling by 1.8 per cent.

While the average annual growth rates for output and input may be notably different between the two studies, it is important to note that over the long term, outputs exceeded inputs and therefore productivity rose.



Data source: PEG (2008a, p. 22).

The productivity performance of the gas industry has been of interest to both the industry regulators and businesses for many years, especially the use of productivity estimates for productivity-based regulation in gas distribution. For example, the use of productivity-based regulation was discussed in detail by the Productivity Commission' s inquiry into the Gas Access Regime (PC 2004, pp. 275-280), and more recently by PC (2009, pp. 193-4), the AEMC (2010) and Lawrence (2010, pp. 3-6), which explored in detail the reasons why productivity continues to be of interest to regulators.

For both reasons — that is, a possible bias in MFP due to using gas throughput as the sole indicator of the volume of gas distribution output, along with the possibility that the ABS volume output measure for GS is itself inconsistently defined relative to the inputs covered — the output measure used in this study is less than ideal for measuring productivity in what is essentially just the gas distribution sector.

In summary, the MFP estimates for GS presented below are derived in a way that is consistent with the results for ES and WSSD presented in chapters 4 and 5, and that is consistent with the data and methodology used by the ABS to derive division level MFP estimates. However, the results for GS are based on inputs used in gas distribution only, and hence reflect the outcome of only a limited part of the complex interrelationships that determine the amount of mains gas used in Australia each year, and the real resources (labour and capital) used to produce it. Also, there is a potential inconsistency in the way volume output in the subdivision is measured. To the extent that this is true, the results presented below also have limitations as measures of productivity change within gas distribution.

6.2 Inputs, output and MFP in Gas supply

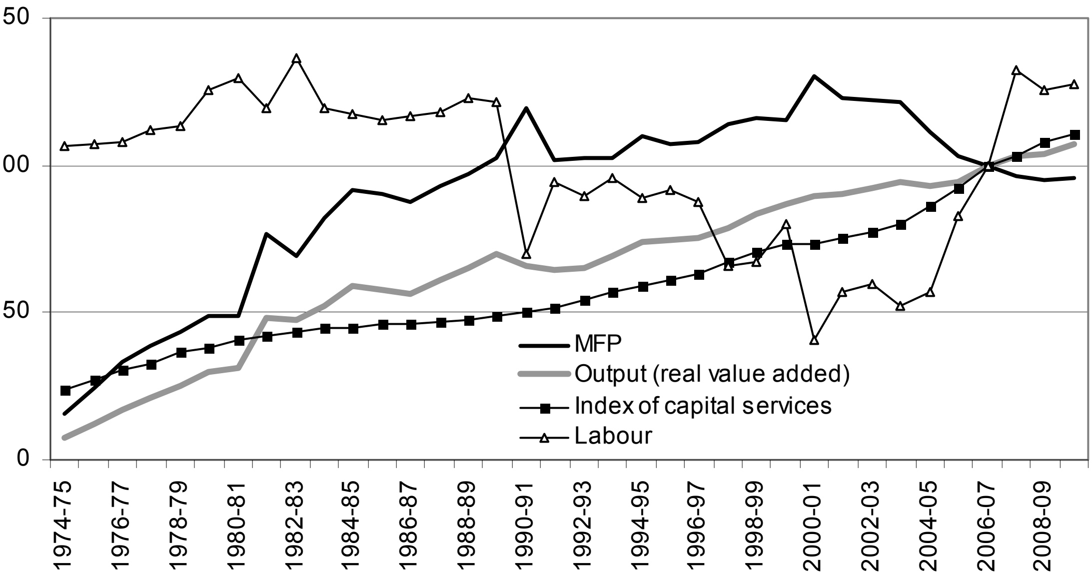
With the above qualifiers in mind, figure 6.2 shows the estimate of GS MFP derived in this study, along with the component parts.

As with ES and WSSD, labour inputs in GS have been measured by the number of hours worked each year. (See appendix A for information on data sources.) However, ABS estimates of hours worked in GS can be volatile, with results for 1990-91, 1999-2000 and 2000-01 being particularly noteworthy. Some of this volatility may reflect data limitations rather than actual changes in the amount of labour used to distribute and retail gas each year (ABS 2004, p. 34, discusses problems with data reliability for Gas supply during the early 2000s).

Industry data relating to the number of employees in gas supply businesses generally shows much less volatility over time, but matches the broad trends in ABS estimates of hours worked (at least over the time period for which the industry data are available). In particular, a dramatic reduction in the number of employees in gas supply businesses during the 1990s supports the broad changes in ABS estimates of aggregate hours worked during the period (figure 6.3).

Figure 6.2 **Gas supply: Inputs, output and MFP, 1974-75 to 2009-10**

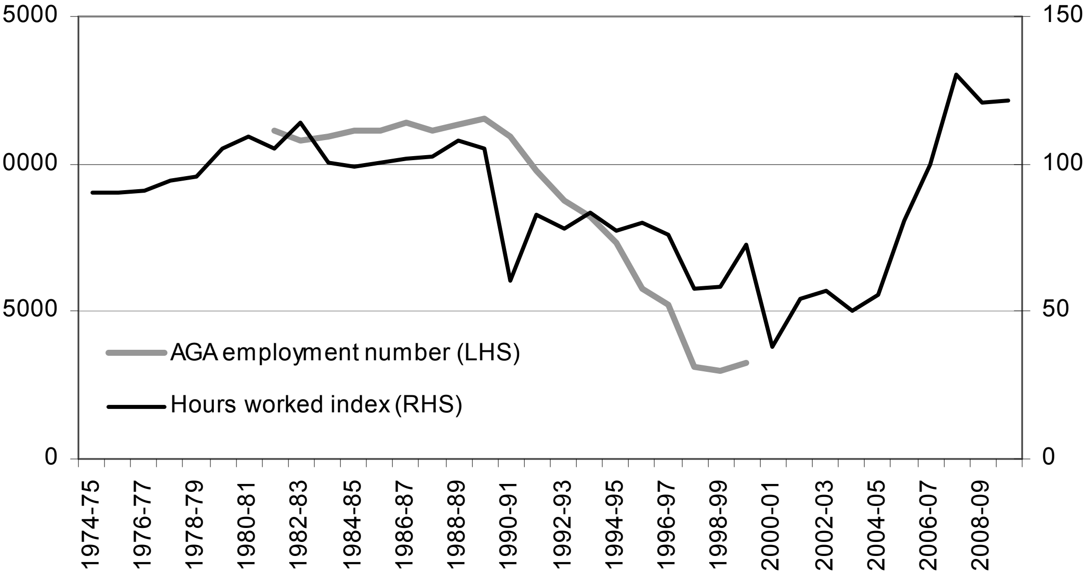
Index 2006-07 = 100



Data source: Author's estimates.

Figure 6.3 **Hours worked in Gas supply and industry estimate of employment numbers, 1974-75 to 2009-10**

Number of persons, index 2006-07 = 100



Data sources: ABS (unpublished data); Australian Gas Association (AGA) (various years); author's estimates (see appendix A).

On the other hand, the volatility of the ABS estimates of hours worked is not reflected in industry employment numbers, which is consistent with the view that there are, in fact, data reliability issues in the hours worked numbers, as noted by the ABS. An unfortunate consequence of the volatility in the hours worked estimates is that the effects tend to flow directly through to MFP, increasing its volatility.

It has also not been possible to validate or confirm the dramatic increase in the number of hours worked in GS after 2004-05. While there is some evidence that employment in GS has increased over this period, the extremely rapid growth in hours worked may again reflect data measurement problems.

As with ES and WSSD, the volume measure of capital inputs in GS — *capital services* — is estimated using the same broad procedure adopted by the ABS to produce estimates of capital inputs for the utilities division as a whole, and which is described in more detail in chapters 4 and 5 of this report as well as appendix A. An additional qualifier is that the only capital assets contributing to the capital services index are those belonging to gas distribution businesses.

Finally, as discussed earlier, the volume output measure for Gas supply shown in figure 6.2 is real value added, which is the ABS measure of the volume of output in the subdivision. In practice, real value added in GS is strongly correlated with changes in the *amount of gas available for issue through main*, as published by the ABS (figure 6.4). That is, real value added is quantity rebased from nominal value added, with the *quantity* being the ABS estimate of gas production.[2]

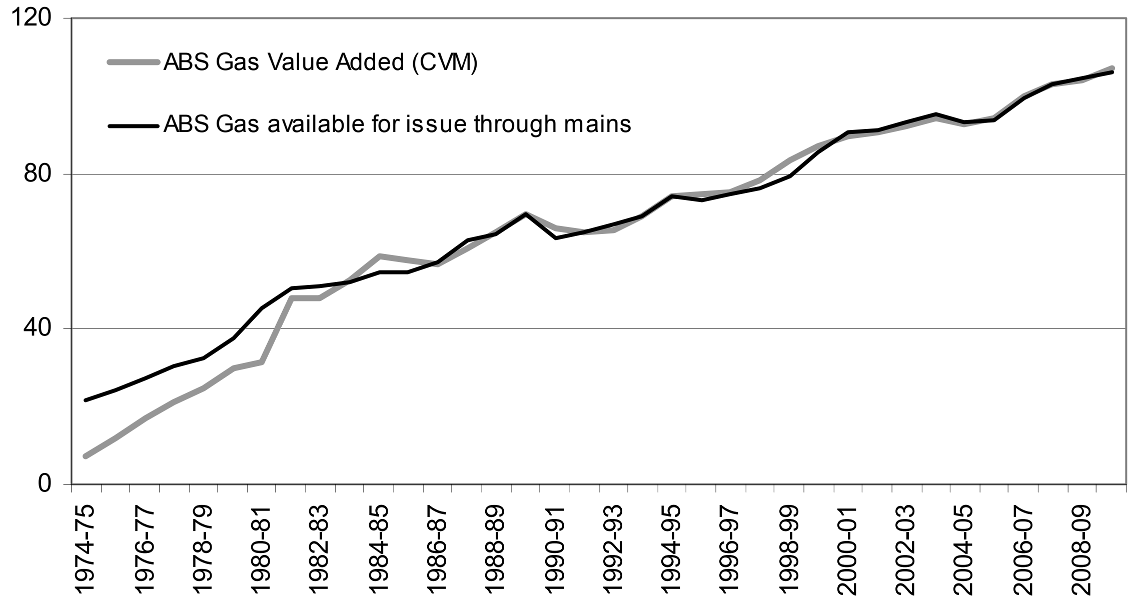
MFP

Absenting the volatility in observed MFP growth caused by the volatility in hours worked, the MFP series for GS indicates comparatively strong productivity growth from the beginning of the period until the mid 2000s. After this point MFP growth became negative, although there is slight positive growth in the final year of the period, 2009-10.

2 Note that during the early years of the period shown in figure 6.4 the ABS real value added series for GS grew considerably faster than the ABS estimate of gas production. This indicates that output components other than gas production also contributed to changes in real value added at that time. However from the early 1980s onwards, real value added in GS was very closely linked to changes in gas production, indicating that the latter was the dominant driver of annual changes.

Figure 6.4 **Output estimates in Gas supply, 1974-75 to 2009-10**

Index, 2006-07=100



Data sources: ABS (*Australian System of National Accounts*, Cat. no. 5204.0); ABS (Cat. no. 8301.0) on dXtime (database).

Although the impact of developments in GS on overall utilities productivity is small, the period of negative MFP growth in GS during the 2000s would nevertheless have contributed to negative MFP in utilities during this period. Based on the changes in inputs and outputs shown in figure 6.2, the period of negative MFP growth in GS during the mid to late 2000s was associated with rapid input growth (of both labour and capital) that exceeded output growth. As with ES and WSSD, one possible reason for the surge in inputs (relative to output) during this period could be lumpy capital investment. For example, the rollout and upgrading of network infrastructure during this period (which requires additional labour as well as capital) may have preceded expected output growth. But as measured inputs rose as soon as construction of the new infrastructure began, measured MFP may have been temporarily lower. With new capacity now in place however, input growth may slow. Assuming output grows and the utilisation of slack capacity is taken up, measured productivity could improve.

It should be noted that uncertainty regarding the accuracy and validity of the volume output measure used to derive the MFP results makes any interpretation of output related changes problematic.

6.3 Implications

The estimates of MFP in Gas supply presented in this chapter complete the trio of subdivision estimates that collectively underlie the changes in MFP reported by the ABS at the division (EGWW) level. However the MFP results for Gas supply are subject to significant data issues, and should be treated with caution.

Because of the way the subdivision is defined, Gas supply only includes gas distribution and retail activities. Hence the MFP results only reflect changes in the inputs of gas distribution and retail businesses. At the same time, the Gas supply output variable — aggregate gas production — is potentially a biased or inaccurate indicator of output for gas distribution businesses. That said, the MFP estimates for GS reflect a similar pattern since the late 1990s as exhibited in both ES and WSSD. This raises questions of the common factors — both in measurement and in underlying fundamentals — that might be affecting all the utilities. The next chapter brings the information together to answer these questions.

To improve the quality of Gas supply MFP estimates, further consideration could be given to incorporating gas transmission activities into the subdivision. A more comprehensive output indicator variable that accounted for the number of gas connections (as well as quality attributes such as reliability of supply) could also improve the quality and meaningfulness of MFP estimates for this subdivision. Both of these improvements would, however, require significant additional data to that currently available. These improvements are beyond the scope of this study.

7 Explaining negative MFP growth in utilities

The analyses of utilities subdivision MFP changes contained in chapters 4 to 6 identified a number of factors and issues that are important in explaining longer term trends and developments. This chapter synthesises the subdivision results to draw broader conclusions regarding trends and developments in ABS estimates of MFP in the utilities sector as a whole, particularly in regard to the recent period of strongly negative MFP growth.

The array of issues discussed in chapters 4 to 6 can be categorised into four broad themes:

1. Cyclical investment
2. Output measurement
3. Shifts to higher cost technologies
4. Unmeasured quality improvements.

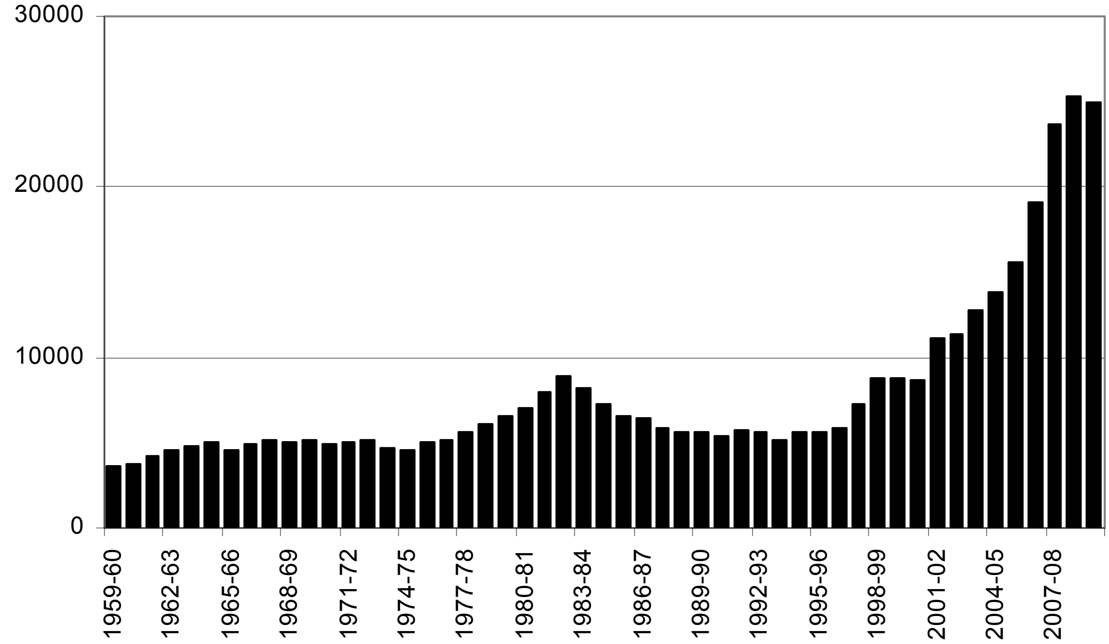
This categorisation is also useful when it comes to interpreting the nature and significance of MFP changes due to specific factors. For example, themes 1 and 2 include factors that primarily reflect empirical challenges associated with measuring the quantity of inputs and outputs when compiling MFP estimates. Perhaps more importantly, they also represent factors that are arguably temporal in nature, in the sense that they may not ultimately affect long term average MFP growth rates in utilities, even though they can have significant and sustained effects on measured MFP — either positive or negative — from time to time.

On the other hand, the changes in MFP that are associated with themes 3 and 4 represent factors that are structural or more permanent in nature, and reflect fundamental increases in the quantity of inputs used to produce output in utilities. To the extent that changes in output quality are able to be quantified in future measurements of utilities output, the theme 4 influences on measured MFP would become less problematic.

7.1 Cyclical investment

Cyclical investment patterns affect all subdivisions of utilities, and particularly electricity supply and water supply. They reflect the nature of many capital assets used in the division (large and lumpy or indivisible capital assets like dams, water treatment plants, power stations, high-voltage transmission lines, and gas distribution networks) along with historic investment patterns (figure 7.1). As measured output is typically less variable than capital inputs (which change significantly during surges and contractions in augmentation and renewal of supply capacity), unmeasured changes in the rate of utilisation of large and lumpy capital assets, along with measured changes in labour inputs, flow directly through to measured MFP.[1]

Figure 7.1 **Gross fixed capital formation in EGWW, 1959-60 to 2009-10**
$ million, 2008-09 dollars, chain volume measure



Data source: ABS (*Australian System of National Accounts, 2009-10*, Cat. no. 5204.0) on dXtime (database).

1 ABS estimates of capital inputs assume that all new investment expenditure is immediately and fully utilised in production. For large infrastructure assets that take many years to build and many years before they are fully utilised, this assumption has the ability to adversely affect measured MFP (see ABS 2007, p. viii).

An overhang of supply capacity resulting from excessive investment in the 1970s and early 1980s, together with structural reforms that allowed utilities businesses to shed excess labour, meant that utilities output grew strongly from the mid-1980s to the late 1990s on the back of negative (measured) input growth. This was a primary driving force behind the very rapid growth in measured productivity in the division during that period.

From the late 1990s, however, supply constraints started to be reached, and rates of investment in capital and labour inputs began to rise once again. By the mid-to-late 2000s the annual growth in inputs was at historically high levels as three key subdivisions — ES, WSSD and GS — were engaged in major programs of capacity augmentation and renewal. To some extent, the additional capacity put in place during the first decade of the 2000s was expected to underpin output growth into the medium term, not just to meet short term needs. A consequence, however, was a temporary downward pressure on measured MFP.

This assessment does not address the question of whether MFP growth since 1998 could have been higher if some of the new investment had been delayed, or whether there has been any excessive or unnecessary investment in new infrastructure (as measured in benefit-cost terms). If excessive investment has occurred, some part of the decline in measured MFP in utilities reflects a real decline in efficiency, rather than being a temporary phenomena associated with lumpy capital investments. A detailed examination of the economic merit of all new capital investments in utilities is beyond the scope of this paper.

Notwithstanding these issues, empirical data and other evidence indicate that the investment boom in utilities that began around the middle of the first decade of the 2000s may ease somewhat in coming years. Assuming that output growth is positive, a reduction in measured input growth is expected to have a positive effect on measured MFP in the division. The possible early closure of a number of large coal-fired power stations would, however, result in another round of major new investment in the sector, and this would tend to add further temporary downward pressure to MFP. Also, if the replacement supply capacity is fundamentally higher cost (in terms of labour and capital inputs) compared with the coal-fired power it replaces, the technology change will tend to permanently lower the level of measured MFP in the division (changes in emissions notwithstanding).

7.2 Output measurement

Measuring the volume of output for an industry is not easy, and the choice of output indicator variables can lead to unexpected or unanticipated changes in measured output and, hence, MFP.

In the case of utilities, the ABS volume output measures used for each subdivision generally reflect movements over time in key production variables: aggregate electricity production in the case of ES; aggregate gas production in the case of GS; and a composite of three quantity variables in the case of WSSD — the quantity of urban water supplied, the quantity of irrigation water supplied, and the number of properties connected to urban sewage treatment services.

For the most part, these assumptions by the ABS are reasonable, but reflect an inevitable trade-off between accuracy and comprehensiveness and the costs of obtaining more detailed information.

In the case of electricity supply, the volume output measure used by the ABS is aggregate electricity production, which has generally trended upward over time in line with population and business growth. However, during the past ten to fifteen years there has been a shift in diurnal (within the day) power use, such that maximum or peak daily demand has been rising faster than growth in average daily electricity demand. The rise in *relative* peak demand was largely due to strong growth in demand for air-conditioning during a succession of hot and atypically dry summers.

An increase in the ratio of peak to average demand lowers system efficiency — particularly transmission and distribution efficiency — since a greater proportion of supply capacity sits idle each year. With inputs rising faster than measured output (which, as noted earlier, is assumed by the ABS to reflect changes in average electricity demand over time, not peak demand), this development contributed to the negative growth in measured MFP in utilities from the late 1990s onward.

In future, it is possible that the ratio of peak to average demand might increase beyond current levels, and this would tend to further reduce measured productivity in the subdivision. On the other hand, measures to flatten out the profile of daily electricity demand — including more widespread use of time-of-day electricity prices — would tend to improve capacity utilisation in the subdivision, and this would have a positive effect on measured MFP.

Output measurement issue in WSSD

In WSSD the ABS measures the quantity of output in the urban water supply sub-sector (which is around one half of the subdivision) as the aggregate quantity of water supplied. Although the latter had grown steadily in the past in line with population growth, from the mid-1990s onwards growth in the quantity of urban water consumption first slowed and then became negative. This was due to two factors: more intensive use of demand management initiatives to encourage urban water customers to use less water; and widespread and persistent drought conditions during the first decade of the 2000s that dramatically reduced water availability and led to restrictions on water availability.

At the same time, the number of new connections to urban water networks were growing rapidly. Because this *output* of the subdivision was not reflected in the ABS output measure, some aspect of the decline in measured MFP in WSSD was a consequence of the choice of output indicator variable, rather than being due to a fundamental reduction in the efficiency with which urban water services were supplied.

In general, if the ABS had used the number of properties connected to urban water services as the output measure for this activity (rather than the quantity of water supplied), the reduction in measured MFP would not have been as severe.

Looking ahead, as aggregate urban water consumption responds to improved water availability (largely reflecting the new water supplies available from desalination and recycling plants, but also assuming that there is a sustained improvement in rainfall and dam storage levels), measured MFP is likely to recover many of the losses associated with the 2000s drought. However, it is also possible that the community will continue to practice a more parsimonious approach to water use. In this event it may take longer before *aggregate* urban water consumption returns to pre-drought levels, and this would limit the speed and extent of any recovery in measured productivity.

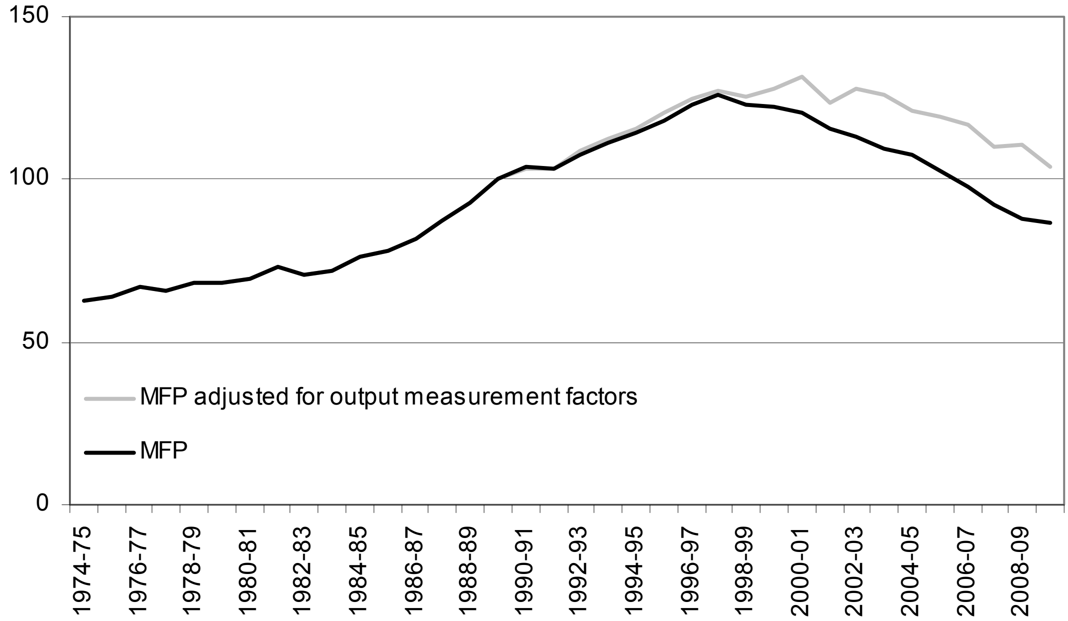
Quantifying the impact on MFP

In aggregate, the two output measurement issues described above are estimated to explain around 40 per cent of the decline the utilities MFP between 1997-98 and 2009-10 (see figure 7.2).

However, the information in figure 7.2 also indicates that the temporary or potentially reversible factors that acted as a brake on MFP growth in utilities since 1997-98 may ultimately only explain around one half of the overall decline. Other factors must explain not just why MFP growth in utilities has been negative since 1997-98, but why there has been no positive growth.

Figure 7.2 **MFP in utilities: impact of output measurement issues,[a] 1974-75 to 2009-10**

Index 1989-90 = 100



[a] The series, *MFP adjusted for output measurement factors* combines the effect of peak demand growth on output measurement in ES shown in figure 4.15, and the effect of drought on output measurement in WSSD shown in figure 5.15. More information can be found in the footnotes to the figures.

Data source: ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2009-10,* Cat. no. 5260.0.55.002); author's estimates.

7.3 Shifts to higher cost technologies

Negative MFP growth in utilities since the late 1990s is also a reflection of fundamental changes to production technology that have occurred in two key subdivisions in response to climate-related issues.

In the case of electricity supply there was a major shift in industry structure and the preferred technology of power generation in the late 20th century. This involved a move away from relying on a comparatively small number of large coal-fired power stations to meet energy needs, towards building a larger number of lower capacity gas-fired power stations and renewable energy sources. The shift to these higher cost sources of power has reduced measured productivity in electricity supply, although it has led to lower greenhouse gas emissions per unit of output than would otherwise have been the case.

The water supply subdivision also experienced a major technology shift during the late 20th century. In this case the technology shift was in response to widespread drought, and involved a move away from relying on rain-fed dams as the source of new urban water supplies and towards non-dam alternatives such as desalination and water recycling plants. The latter are higher cost sources of supply, and hence the effect on MFP has been negative. The trade-off is an urban water supply sector that is potentially less susceptible to the vagaries of climate, and which avoids the costs — social and environmental — of building new dams.

However, this is not to say that the trade-off is necessarily optimal in benefit-cost terms. A recent Productivity Commission inquiry into the urban water supply sector found that in metropolitan cities there were lower cost supply augmentation options that could have been pursued ahead of desalination and water recycling (PC 2011a). The implication of this for measured productivity in utilities is that the decline due to the shift away from dams was exacerbated by some of the non-dam augmentation options chosen.

Looking ahead, continued shifts away from coal-fired power and rain-fed dams will tend to further reduce the level of MFP in utilities (relative to what it might otherwise have been), at least until some period of comparative stability in the mix of supply sources is established. That is, as non-coal and non-dam technologies become the dominant sources of supply in their respective subdivisions, future MFP growth in utilities will tend to be driven by underlying changes in the efficiency of the new technologies. Until that time, the dominant issue will be the *level-reducing* effect on MFP of substituting higher-cost technologies for lower-cost technologies.

7.4 Unmeasured quality improvements

Finally, changes to the standards or regulations governing utilities outputs have increased production costs without any concomitant change in the measured volume of output. The consequence is that part of the observed reduction in MFP reflects unmeasured or hidden changes in the quality of industry outputs, rather than reflecting a decline in the efficiency with which outputs are produced.

In electricity supply, a significant hidden quality improvement is associated with the move to mandate the undergrounding of the distribution network in many regions. Undergrounding of electricity cabling is costly, but because the benefits do not appear as in increase in output (in fact, the benefits of this quality improvement are not measured directly anywhere in the economy), the outcome is lower measured productivity in utilities.

In the water sector, changing standards relating to sewage treatment and disposal have significantly improved the quality of this activity, but the quality change is not fully accounted for in the ABS measure of output. As the cost of meeting higher sewage and wastewater treatment standards has been substantial, the effect on measured MFP has been negative.

Other unmeasured improvements to the quality of outputs in utilities over recent years — such as improved electricity supply standards and higher potable water standards — will also have contributed to the observed decline in MFP since the late 1990s. These examples highlight the improved understanding of actual changes to MFP in the utilities division that would arise from quality adjusted measures of output.[2]

7.5 Lessons and implications

The broad trends in utilities MFP largely reflect MFP trends in Electricity supply, the largest subdivision. Coincidentally however, MFP trends in the next largest subdivision, WSSD, have been very similar to those in ES over the longer term. In this sense, the MFP results for both ES and WSSD are mutually reinforcing when it comes to explaining MFP changes in utilities as a whole. In particular, the decline in utilities MFP since the late 1990s is caused by strongly negative MFP growth in both major subdivisions.

Temporary or potentially temporary factors explain some of the MFP decline in utilities since the late 1990s. However, even after accounting for temporary factors, the underlying MFP story in utilities since 1997-98 is likely to be negative. In general, a greater quantity of inputs is now required to produce each unit of output in the division, and this has directly lowered the level of measured productivity. The increase in input use in utilities has contributed to higher average costs of production, with consequent pressures on many businesses in the division to seek regulatory approval to increase retail prices and revenues. That said, it is beyond the scope of this study to assess whether the observed increases in real resource use in utilities reflect the least-cost ways of dealing with the challenges the industry and its regulators faced.

2 Unmeasured changes in the quality of inputs and outputs are one of a number of theoretical and empirical challenges involved in estimating MFP. The Productivity Commission is currently participating in an Australian Research Council sponsored project examining some of these measurement issues.

Overall, the results of this project highlight the need for caution when trying to interpret MFP growth at the industry level. Detailed studies of industry productivity can help to better understand the nature and significance of the driving forces behind changes in official aggregate MFP statistics.

While some of the empirical and conceptual issues surrounding the measurement of productivity in utilities have been explored in detail in this study, there is scope for further analysis. In particular, more effort could be focussed on the issues of capital utilisation and output measurement in utilities.

A Methodology and data sources

A.1 Introduction

The primary motivation for developing multifactor productivity (MFP) estimates at the subdivision level within utilities was to better understand productivity trends and developments in Australian Bureau of Statistics (ABS) estimates of division MFP. To this end, the methodology and data used in this study have been chosen to match as closely as possible that used by the ABS to derive MFP for the utilities division as a whole.

While the methodology used to derive subdivision MFP is largely consistent with that used by the ABS at the division level, it has not been possible to perfectly match the data. In general, the ABS does not publish sufficient raw data at the subdivision level to allow completely consistent estimates of subdivision MFP to be estimated. As a result, some simplifying assumptions and choices have been made regarding the data used to estimate subdivision MFP. In making these choices and assumptions the overriding objective has been to ensure (as far as practicable) consistency between the *aggregate* of the subdivision MFP estimates and the official ABS division estimates for utilities. The outcome is a set of subdivision MFP estimates that are *collectively* consistent with the ABS utilities results. The trade-off is that the subdivision estimates may be individually of lesser quality, although the extent to which this may be the case is difficult to measure in the absence of more detailed information.

A.2 The basic model

The basic methodology used by the ABS to estimate MFP is set out in Aspen (1990). Over the years there have been refinements to align the concepts and definitions more closely with international standards, such as the United Nations *System of National Accounts 1993* (SNA). For more information see ABS (2000). For more information on the development of industry-level MFP estimates at the ABS see Zheng (2005) and ABS (2007).

As of 2011, ABS productivity estimates are based on the *System of National Accounts 2008* (SNA08) and the industry classifications set out in *Australian and*

New Zealand Standard Industrial Classification 2006 (ANZSIC06). Prior to this, the industry classification scheme used by the ABS was *Australian and New Zealand Standard Industrial Classification 1993* (ANZSIC93).

Definitions

Multifactor productivity is defined as the ratio of output to combined inputs of labour and capital:

- where output is defined as industry gross value added, and is measured as a chain volume index
- labour inputs are defined as hours worked
- capital is measured as capital services (see the ABS 1997-98 edition of *Australian System of National Accounts,* Cat. no. 5204.0), which has a feature article on the measurement of capital services).

Output and inputs are therefore measured in volume or quantity terms.

Multifactor productivity in period t (MFP_t) is the ratio of output in period t (Y_t) and a combined input index (I_t). That is:

$$MFP_t = \frac{Y_t}{I_t} \qquad \text{A1}$$

The index I_t is computed as a Tornqvist index, and is calculated recursively from the geometric mean of the growth rates of the labour input (L_t) and the capital input (K_t).

$$\frac{I_t}{I_{t-1}} = \left[\frac{K_t}{K_{t-1}}\right]^{W_t^k} \left[\frac{L_t}{L_{t-1}}\right]^{W_t^l} \qquad \text{A2}$$

Where W_t^k and W_t^l are respectively the average revenue shares of capital (S^k) and labour (S^l) in periods t and t-1. That is:

$$W_t^k = \left(S_t^k + S_{t-1}^k\right)/2 \qquad \text{A3}$$

and

$$W_t^l = \left(S_t^l + S_{t-1}^l\right)/2 \qquad \text{A4}$$

In implementing these equations, it is implicitly assumed that constant returns to scale are present and factors are rewarded according to their marginal products.

A.3 Data sources

The information needed to estimate MFP (as outlined above) in the various subdivisions of the utilities division is not available from a single source. Moreover, changes over time in ABS data collections and survey methods make it difficult to generate time-series data that are perfectly consistent with the inputs, outputs and MFP estimates for the utilities division as a whole. This problem has been compounded by the decision during the course of this study to estimate subdivision MFP over a comparative long period (1974-75 to 2009-10) in order to better understand some of the longer-term issues that impact on MFP trends and developments in the utilities division. (As noted in chapter 2, current ABS estimates of MFP at the division level only go back as far as 1985-86).

Much of the data that have been used to derive the subdivision MFP estimates contained in this report have been taken from ABS publications Cat. nos. 8208.0, 8226.0, 8140.0 and 8155.0, along with input-output table data provided to the Commission by the ABS for an earlier project, and some unpublished ABS data. Other important sources of data used to construct and validate the subdivision productivity estimates are the Energy Supply Association of Australia (esaa) and the Water Services Association of Australia (WSAA).

The key variables and parameters used in the construction of the MFP series for each subdivision or class are as follows:

Output

The volume output estimate used for each subdivision — that is, the ***Y*** variable in equation **A1** above — is the ABS estimate of *industry gross value added* in real (chain volume) terms, and is taken from the ABS *National Accounts* (Cat. no. 5204.0, 2007-08 edition, Table 5, Gross Value Added (GVA) by Industry — series identifiers A2420933J, A2420934K, and A2420935L). These estimates are based on the ANZSIC93 industry classification scheme, and cover the period from 1974-75 to 2007-08. Estimates for 2008-09 and 2009-10 are extrapolated using ABS estimates of *industry gross value added* in each subdivision based on the more recent ANZSIC06 industry classification scheme, which were taken from the ABS *National Accounts* (Cat. no. 5204.0, 2009-10 edition), Table 5, Gross Value Added (GVA) by Industry — series identifiers A3348083R, A3348084T and A3348085V).

In principle therefore, the subdivision output estimates used in this study are consistent with the output estimates used by the ABS to derive MFP at the division (EGWW) level.

Inputs

Labour inputs

As noted above, the ABS use an estimate of the aggregate number of hours worked in utilities to represent labour inputs in their MFP formula (the ***L*** term in equation **A2**). Subdivision estimates of hours worked for the period from 1985-86 to 2005-06 (based on the ANZSIC93 industry classification) were provided by the ABS. These estimates were indexed forward to 2009-10 using percentage changes in subdivision hours worked reported by the ABS under the new ANZSIC06 industry classification. (Note that the shift from ANZSIC 1993 to 2006 had very little effect on the structure and activities of ES, GS and WSSD. A comparison of ANZSIC06 results with ANZSIC93 results — during the period where overlapping estimates are available — indicates little difference attributable to the ANZSIC changes.

From 1974-75 to 1985-86, estimates of subdivision hours worked were backcast from values in 1985-86 by prorating estimates of hours worked at the aggregate (that is, EGW) level. The prorating of hours worked at the division (EGW) level was made using subdivision shares of division labour costs.

An implicit assumption, therefore, is that the during the period from 1974-75 to 1985-86 the ratio of labour costs to hours worked is constant across each subdivision. This may not always have been true. Subdivision labour cost information (*compensation of employees*) was taken from input-output table data provided to the Commission by the ABS.

Capital

The measure of capital inputs used by the ABS to estimate MFP (that is, the ***K*** term in equation **A2**) is *capital services*, which reflect the amount of *service* provided by capital assets during a period.

For each asset, the ABS assumes that the capital services provided in a period are directly proportional to the productive capital value of those assets, where the latter is assumed to decline over time as the asset ages. For example, the amount of capital services provided by a one year old truck is assumed to be greater than that provided by a two year old truck etc.

The ABS measures the *productive capital stock* of each asset type using the *perpetual inventory method* (PIM). This involves compiling a rolling inventory of capital stocks, with investment in new assets each year added to stocks, retired assets deducted, and the value of remaining assets adjusted according to ageing.

The total productive capital stock is estimated by weighting together chain volume measures of the productive capital stock of different asset types using estimates of their rental prices. Rental prices can be regarded as the *wages* of capital, or the compensation required to hire or rent a unit of capital.

In this report, subdivision-level estimates of ***Capital capacity*** have also been estimated using a PIM. One difference between the ABS approach and that used in this paper is in relation to the scope of assets covered. The ABS includes the full coverage of gross fixed capital formation when estimating capital services. This means that the ABS estimates of capital capacity are based on six categories or types of capital:

1. machinery and equipment
2. non-dwelling construction
3. livestock
4. intangible fixed asses
5. inventories
6. land (see ABS 2007 p.100).

In contrast, the subdivision results in this paper are based on two types of capital assets only: machinery and equipment, and non-dwelling construction. Since the latter are the dominant components of total capital assets for utilities, this difference is expected to have only a minor effect on the growth rate in capital services over time.

Important parameters and assumptions used to estimate subdivision capital stocks are generally consistent with those used by the ABS. For example, the assumed age-efficiency function is a hyperbolic function that uses the same efficiency reduction parameters as the ABS: 0.5 for machinery and equipment; and 0.75 for non-dwelling construction (see ABS 2000, p. 253). Average asset life assumptions for each capital type are equal to those specified by the ABS in tables 16.4 and 16.5 of their *Concepts, Sources and Methods* publication (ABS 2000, pp. 269 and 271). Note that the ABS assumes comparatively long asset lives for non-dwelling construction assets in the water sector (71 years), while the assumed average asset life for machinery and equipment assets in all three subdivisions is longer than that for most other industries.

Another difference between the methodology used by the ABS to measure capital services and the approach used in this paper is in relation to the assumption made regarding the profile of asset retirement around the mean asset life. The ABS uses a bell-shaped symmetric retirement curve that effectively means three quarters of assets are retired within 30 per cent of the mean asset life (see ABS 2000, p. 273). In contrast, the PIM used in this study to derive capital services at the subdivision level assumes simultaneous exit of assets. That is, all assets are retired at the same age. This is computationally simpler, and is likely to have only a small statistical effect on the results. (For a more detailed discussion of this issue see Gretton and Fisher, 1997, p. 65).

Capital expenditure estimates — nominal and constant price

It was not possible to construct consistent time-series estimates of (nominal) subdivision capital expenditure on the two capital types from standard ABS data sources. Instead, estimates of subdivision capital expenditure on the two capital types were derived by prorating division-level (that is, EGW) estimates of nominal expenditure on each type of capital using sub-division shares of *total* capital expenditure.

A limitation of this approach is that each subdivision is implicitly assumed to have the same ratio of the two capital types as the division average. While this is not likely to be a problem in relation to Electricity supply (because ES accounts for the majority of capital investment in the division), it may be more of problem in WSSD and GS if the ratio of investment in the two capital types has been systematically different to the ratio in ES.

Subdivision shares of total capital expenditure were derived from two sources. For the period from 1974-75 to 1988-89 the shares were derived from unpublished ABS data on gross fixed capital formation by public corporations within each subdivision. Since only a comparatively small share of activity in the division during this period was non-public (that is, *private*), this assumption seems reasonable. From 1989-90 to 2009-10, the shares were derived from subdivision information on net capital additions published in annual ABS industry publications Cat. nos. 8208.0, 8226.0 and 8155.0.

Nominal capital expenditure on the two types of capital within each subdivision was converted to constant prices using capital price indexes derived from published and unpublished ABS data. For the period from 1974-75 to 1988-89, the deflators were unpublished ABS capital price indexes (specific to EGW) for the two capital types. From 1988-89 to 2009-10, capital prices were linked to movements in implicit price deflators for the two capital types derived from ABS estimates of gross fixed capital formation in EGW (by type of capital) in nominal and chain volume terms. These estimates were taken from ABS publication Cat. no. 5204.0 (2007-08 edition, table 64), for the period from 1988-89 to 2007-08, and from Cat. no. 5204.0 (2009-10 edition, table 64) for the period from 2007-08 to 2009-10.

Starting capital stocks

The PIM, which has a starting year of 1974-75, also requires estimates of the opening stocks of the two capital types in each subdivision. Because of data limitations, subdivision estimates of opening capital stocks in 1974-75 were not directly available, and had to be derived from ABS division level data. The latter, closing net capital stocks in current price terms in 1973-74 for each of the two capital types, were sourced from ABS publication Cat. no. 5204.0, (2007-08 edition, table 63 — series identifiers A2423588K and A2423589L). Information previously provided to the Commission by the ABS on the WSSD *share* of EGW non-dwelling construction (NDC) capital stock in 1974-75 was used to prorate the EGW stock figure to directly estimate the stock of NDC capital in WSSD in the base year. As there was no information regarding how to allocate the remainder of the EGW NDC stock (that is, total EGW NDC stock less the derived WSSD component) among ES and GS, the allocation was based on ES and GS shares of total capital investment during the period from 1962 and 1975. That is, ES and GS shares of the non-WSSD component of NDC capital stock in 1974-75 were proxied by their respective shares of (total) capital investment in the period leading up to 1974-75.

Subdivision stocks of machinery and equipment (M&E) capital in 1974-75 were derived by prorating the division estimate using the subdivision proportions of NDC capital stock.

Adding the two capital types

Separate measures of capital capacity of M&E and NDC capital were estimated for each subdivision covering the period from 1974-75 to 2009-10. The two series were weighted together to form a composite measure of capital capacity for each subdivision using average user costs of capital (proxies for rental prices), where the user cost is defined, without time or subdivision subscripts, as:

$$p = q(r + \delta) - \dot{q} \qquad \text{A5}$$

where p is the user cost of capital, q is the expected price of a unit of capital, r is the nominal rate of return, δ is the rate of depreciation and $\dot{q}$ is the expected change in the price of the capital good over the period. In this framework, the expected user cost or rental price of a unit of capital for production in a period is equal to the depreciation in the value of the asset over the period due to its use in production, returns to management net of depreciation, less any revaluation of the nominal value of the asset due to inflation or other price changes.[1]

The expected value is first approximated by reference to actual flows in any one year (that is, the ex post user cost). To avoid negative average relative user cost weights due to large annual fluctuations in the fortunes of utilities industries, the user costs were averaged over the period 1974-75 to 2009-10. This longer term averaging in turn, avoids measuring capital as a negative input to production when period-specific user costs are negative.

As noted above, labour and capital input shares in each subdivision are used to weight labour and capital inputs together (in the form of a Tornqvist index) for the calculation of multifactor productivity.[2] Labour and capital input shares by subdivision are estimated as the share of wages, salaries and supplements, and gross operating surplus in gross value added, with all variables measured in nominal or current price terms (data sources are described in the next section). This estimation process is considerably simplified (and hence potentially less accurate) compared with the process used by the ABS to estimate factor shares at the division level. However, it is not expected that the differences in methodology will materially affect the results. A comparison of the average annual capital income share across the three subdivisions that were derived in this study with the EGW capital income share reported by the ABS (and used to derive the ABS estimate of MFP in EGW) shows comparatively small differences across time (figure A.1).

Other data sources

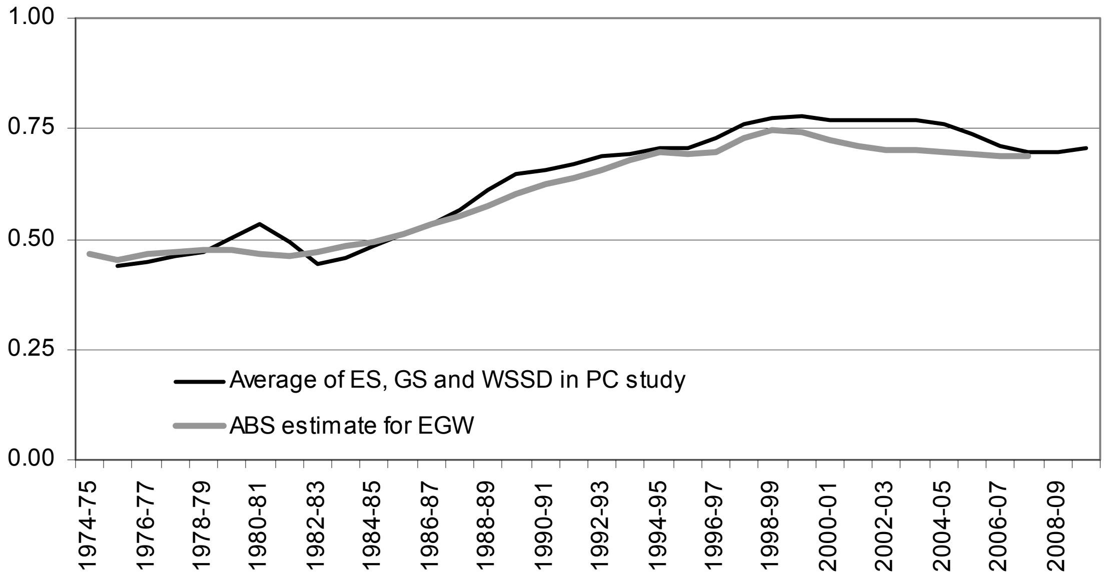
For the period from 1974-75 to 1989-90, nominal estimates of subdivision labour costs, gross output, intermediate inputs and industry value added (which are used in the derivation of labour and capital cost shares and capital rental prices) were available from subdivision input-output table data provided to the Commission by the ABS. The input-output table data were not available for all years during the period however, so values in some years were interpolated. (Note: input-output tables were available for the following years: 1974-75, 1977-78, 1978-79, 1979-80, 1980-81, 1981-82, 1982-83, 1983-84, 1986-87, 1989-90.)

[1] Note that this is a slightly simplified version of the ABS rental price calculation as it does not allow for any differences between the three subdivision in income tax rates (see ABS 2000, pp. 371-372).

[2] For more information regarding the calculation of Tornqvist indexes see ABS 2000, p. 371 or Gretton and Fisher 2007, p. D4.

Figure A.1 **Capital share of total EGW income, 1974-75 to 2009-10**

ABS estimate of EGW share compared with average of PC subdivision estimates



Data sources: ABS (*Experimental Estimates of Industry Multifactor Productivity, Australia: Detailed Productivity Estimates, 2007-08,* Cat. no. 5260.0.55.002); authors' estimates.

For ES and GS, estimates covering the period from 1989-90 to 2007-08 were obtained directly from ABS industry survey results, as reported in industry publications Cat. nos. 8208.0 and 8226.0. These results are based on ABS *management unit* data and reflect ANZSIC93 industry definitions. Values for 2008-09 and 2009-10 were obtained by indexing forward the 2007-08 values using subdivision data reported by the ABS in Cat. no. 8155.0 (2009-10 edition) which are based on ANZSIC06 industry definitions.

For WSSD, survey results do not appear in ABS industry publications until 1995-96. However, between 1989-90 and 1995-96 the ABS did publish nominal data for EGW as a whole (that is, for the sum of ES, GS and WSSD). Hence estimates for WSSD for this period were derived as the difference between EGW results and published estimates for ES and GS.

A spreadsheet containing all of the components parts required to derive the subdivision MFP estimates (as per equations A1 to A4 above) is available from the authors on request.

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