The Productivity Performance of Victorian Gas Distribution Businesses

Report prepared for
AusNet Services
Australian Gas Networks Limited, and
Multinet Gas

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EXECUTIVE SUMMARY

Economic Insights has been requested to examine the total factor productivity (TFP) and partial factor productivity (PFP) performance of the three Victorian gas distribution businesses – AusNet Services ('AusNet'), Australian Gas Networks' Victorian operations ('AGN Vic') and Multinet Gas ('Multinet'). As well as examining the TFP and PFP growth rates of the Victorian GDBs, Economic Insights has been requested to compare their productivity levels with those of New South Wales' largest GDB, Jemena Gas Networks (JGN), and AGN's gas distribution businesses in South Australia ('AGN SA') and Queensland ('AGN Qld'). This study updates Economic Insights (2012c).

The primary data source for this study is information supplied by the three Victorian GDBs. The data was provided in response to common detailed data surveys, covering key output and input value, price and quantity information for the calendar years 1998 to 2015. Similar data was provided in previous years by Australian Gas Networks Limited in relation to its South Australian and Queensland gas networks (see Economic Insights 2015b), and by Jemena Gas Networks (JGN) in relation to its New South Wales (NSW) gas distribution network (see Economic Insights 2014). Those surveys cover the financial years 1998–99 to 2014–15 in the case of AGN-SA; and 1998–99 to 2013–14 in the case of JGN and AGN Qld. No forecast data are used for any of the included GDBs.

The TFP measure used includes three outputs (throughput, customer numbers and system capacity) and 8 inputs (opex, lengths of transmission pipelines, high pressure pipelines, medium pressure pipelines, low pressure pipelines and services, meters, and other capital). For productivity level comparisons transmission pipelines are excluded to allow more like–with–like comparisons.

The time–series TFP results for the three Victorian GDBs are as follows:

- AGN Vic has had a reasonably consistent upward trend in TFP. On average TFP increased by 2.7 per cent per year from 1999 to 2008 and by approximately 1.0 per cent per year in the period from 2008 to 2015, reflecting reduced TFP growth over the last several years. Over the whole period from 1999 to 2015, AGN Vic's TFP index increased at a relatively strong average annual rate of 1.9 per cent.
- Except for the period 2011 to 2013, AusNet has had a reasonably consistent upward trend in TFP. On average TFP increased by 2.7 per cent per year from 1999 to 2008 and by 0.2 per cent per year in the period from 2008 to 2015. TFP has grown over the last two years. Over the whole period from 1999 to 2015, AusNet's TFP index increased at a relatively strong average annual rate of 1.6 per cent.
- Prior to 2011, Multinet had a reasonably consistent upward trend in TFP, however, there was a downturn in TFP in 2012 with only partial recovery since then, and this has had an important influence on its average TFP trend since 2008. On average Multinet's TFP increased by 2.0 per cent per year from 1999 to 2008 and decreased at an average rate of approximately 0.4 per cent per year in the period from 2008 to 2015. TFP has grown over the last three years. Over the whole period from 1999 to 2015, the TFP index increased at an average annual rate of 1.0 per cent.

AGN Vic has experienced a relatively high rate of output index growth throughout the period 1999 to 2015, averaging 2.3 per cent per year. AusNet experienced a relatively high rate of output index throughout the period 1999 to 2015 of 2.2 per cent per year, which is very similar to that of AGN Vic. The distribution regions of these two GDBs include Melbourne's major growth corridors. The characteristics of Multinet's more established distribution region are such that its output increased much more slowly than that of the other two GDBs. Multinet's output index increased at an average rate of only 0.9 per cent per year over the period 1999 to 2015. It is reasonable to expect that this factor would explain much of the difference between the TFP growth results of Multinet and the other two Victorian GDBs.

Another important element of the productivity story is, of course, the trends in input use. Over the period from 1999 to 2015, AGN Vic's input index increased at an average annual rate of 0.4 per cent. AusNet's input index increased at an average annual rate of 0.6 per cent, while Multinet's input index decreased at a rate of 0.1 per cent per year over the same period.

The input index is effectively a weighted average of the capital and non-capital ("opex") input indexes. For each of the three Victorian GDBs the capital index has grown fairly steadily and at a very similar rate to the growth rate of the output index. The opex input index has therefore played a key role in determining TFP trends.

- For AGN Vic, the opex inputs index decreased at an average annual rate of 3.8 per cent in the period 1999 to 2008, and from 2008 to 2015 it decreased on average by 0.5 per cent per year. Over the whole period from 1999 to 2015, the average annual growth rate of opex inputs was −2.4 per cent per year, which represents a relatively strong decline.
- AusNet's opex inputs usage decreased at an average annual rate of 4.9 per cent over the period 1999 to 2008, and increased on average by 0.5 per cent per year from 2008 to 2015. Over the whole period from 1999 to 2015, the average annual growth rate of opex inputs was –2.6 per cent per year, which represents a relatively strong decline.
- Multinet's opex inputs usage decreased at an average annual rate of 3.7 per cent over the period 1999 to 2008. From 2008 to 2015, opex inputs use increased on average by 1.2 per cent per year. During this period there was a sharp upwards spike in opex input usage in 2012, which had an important influence on Multinet's TFP results. Over the whole period from 1999 to 2015, the average annual growth rate of opex inputs was –1.6 per cent per year, which represents a relatively substantial decline.

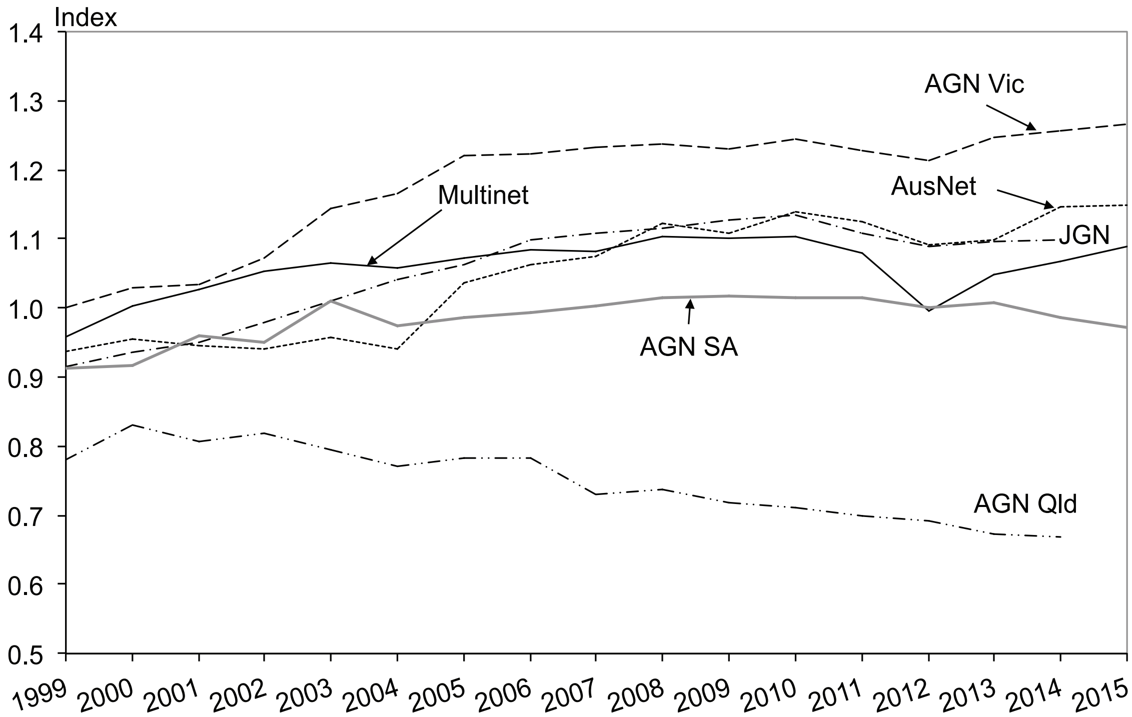
Partial factor productivity (PFP) indexes assist in understanding movements in the TFP index. The Opex PFP index measures output produced per unit of non-capital inputs, and the Capital PFP index measures output per unit of capital inputs. Capital PFP was relatively flat for most of the GDBs over the whole period from 1999 to 2015. The Opex PFP trends are of most interest:

- AGN Vic's opex PFP increased strongly between 1999 and 2008 at an average rate of 6.7 per cent, and increased at 2.5 per cent annually, on average, from 2008 to 2015. The annual rate of opex partial productivity growth over the whole period from 1999 to 2015 was 4.8 per cent.

- AusNet's opex PFP increased strongly between 1999 and 2008 at an average rate of 7.6 per cent, and increased at 1.6 per cent annually, on average, from 2008 to 2015. The annual rate of opex partial productivity growth over the whole period from 1999 to 2015 was 4.9 per cent, which is quite similar to that of AGN Vic.
- Multinet's opex PFP increased strongly between 1999 and 2008 at an average rate of 5.1 per cent, and increased at 0.7 per cent annually, on average, from 2008 to 2015. The annual rate of opex partial productivity growth over the whole period from 1999 to 2015 was 2.5 per cent, which is lower than those of AGN Vic and AusNet and which again reflects Multinet's lower output growth rate in its more established supply region.

Comparative productivity *levels*, as measured by the multilateral TFP (MTFP) index, are shown in Figure A. The MTFP results indicate that in the latest years available, AGN Vic had the highest productivity level—approximately 10% higher than that of AusNet. The latter's total factor productivity level in 2014 was similar to JGN's and Multinet's. AGN SA's MTFP index level in 2015 was lower than those of the three larger Victorian GDBs, and AGN Qld's MTFP in 2014 was significantly lower again, reflecting its much smaller scale and the lack of spacing heating required in its subtropical service area.

Figure A: **GDB multilateral TFP indexes, 1999–2015**



Source: Economic Insights GDB database

1 INTRODUCTION

1.1 Terms of reference

Three Australian gas distribution businesses (GDBs), AusNet Services ('AusNet'), Australian Gas Networks Limited ('AGN') and Multinet Gas ('Multinet') have commissioned Economic Insights Pty Ltd ('Economic Insights') to provide advice on productivity measurement and benchmarking of their Victorian gas distribution network operations. The advice provided in this report details analysis of total factor productivity (TFP) and partial factor productivity (PFP) trends of the Victorian gas distribution businesses over time. This report also provides a comparative analysis of the relative productivity levels and productivity growth rates of the Victorian GDB's using multilateral TFP.

This study entails updating and extending analysis that Economic Insights undertook for the three Victorian GDBs in 2012 on the productivity performance of their Victorian gas distribution systems (Economic Insights 2012a; c) and recent studies carried out for AGN in relation to its South Australian gas network business (Economic Insights 2015a; b).

1.2 Approach to this Study

The study concentrates on performance of Victorian gas networks in the period from 1999 to 2015. The primary data source for this study is information supplied by AGN in relation to its Victorian gas distribution business ('AGN Vic'), and by Multinet and AusNet in relation to their Victorian gas distribution networks. The data was provided in response to common detailed data surveys, covering key output and input value, price and quantity information for calendar years 1998 to 2015. Similar data was provided in previous years by Australian Gas Networks Limited in relation to its South Australian and Queensland gas networks ('AGN SA' and 'AGN Qld'), and by Jemena Gas Networks (JGN) in relation to its New South Wales (NSW) gas distribution network. Those surveys cover the financial years 1998–99 to 2014–15 in the case of AGN SA; and 1998–99 to 2013–14 in the case of JGN and AGN Qld. No forecast data are used for any of the included GDBs.

Measures of TFP and PFP are formed in this report using time series and multilateral indexes. These are used to compare the productivity growth rates and productivity levels of the Victorian GDBs with each other, and with the GDBs in NSW, South Australia and Queensland. The time series TFP analysis involves forming indexes of outputs and inputs using the Fisher index method. The analysis includes three outputs (throughput, customer numbers and system capacity) and eight inputs (opex, lengths of transmission pipelines, high pressure pipelines, medium pressure pipelines, low pressure pipelines, and services, meters and other capital). This specification is broadly consistent with the analogous preferred electricity distribution output and input specification presented in AER (2013). The time series TFP indexes use 1999 as the base–year for each individual GDB, and the analysis provides estimates of TFP growth over the period 1999 to 2015 as well as PFP growth for the GDBs. This analysis is presented in section 3.

Multilateral TFP analysis is used in this study for productivity level comparisons. Multilateral TFP is a method of measuring the TFP levels of all of the GDBs in the sample using a common base, so their TFP levels can be compared. In this part of the analysis, transmission pipelines are excluded to allow like–with–like comparisons across GDBs. This analysis is presented in section 4.

1.3 Relevant Previous Studies

There have been several studies undertaken previously of gas pipeline efficiency performance in Australasia.

The earlier studies tended to benchmark selected Australian gas utilities against a sample of overseas gas utilities. These included Bureau of Industry Economics (BIE 1994), Independent Pricing and Regulatory Tribunal (IPART 1999), and Pacific Economics Group (PEG 2001a; 2001b; c). The BIE and IPART studies used data envelopment analysis (DEA) although IPART also tested other methodologies. The IPART study concluded that the Australian GDBs were behind international best practice. The PEG study was an econometric analysis of opex costs. It concluded that the Victorian GDBs had lower opex than predicted given their scale and operating environment conditions, implying that their opex efficiency was better than the included US comparators.

In 2004 Denis Lawrence undertook a comparative benchmarking study of Australian and New Zealand gas transmission and distribution pipeline businesses, and a trend analysis of New Zealand gas businesses' TFP, for the New Zealand Commerce Commission using data sourced from New Zealand and Australian regulatory decisions (Lawrence 2004a; b). The benchmarking study used the multilateral TFP index method. It found New Zealand GDBs to be around 21 per cent behind the productivity of the Australian GDBs. The three Victorian GDBs were among the most efficient performers after allowing for operating environment differences.

In 2007 Lawrence undertook a study of the TFP performance of the Victorian gas distribution industry on behalf of the three Victorian GDBs (Lawrence 2007). The study contained a number of advances for gas distribution TFP measurement. In conjunction with the GDBs' engineers Lawrence developed a measure of system capacity to supplement the standard output measures of throughput and customer numbers. He also included 7 capital input components and presented a range of sensitivity analyses of alternative output and input specifications to assess the influence of specification changes on the results. Subsequently, Pacific Economic Group (2008) carried out a study of TFP trends for Victoria's GDBs on behalf of the Essential Service Commission.

Economic Insights has since carried out a number of productivity studies on behalf of gas distribution businesses, including for Jemena Gas Networks (JGN) (Economic Insights 2009; 2014), for Envestra South Australian and Queensland (Economic Insights 2010), for the three Victorian GDBs (Economic Insights 2012a; c), and AGN South Australia (Economic Insights 2015a; b).

Economic Insights has also produced, for the Victorian gas distribution businesses and for JGN, econometric models of gas distribution opex cost functions and used them to make projections of gas network business operating costs (Economic Insights 2012b; 2014).

1.4 Outline of the Report

Chapter 2 briefly explains productivity measurement and its applications in the context of the economic regulation of natural monopolies. This chapter also discusses measurement issues, data sources and the definitions of outputs and inputs used in the study. The comparator gas distribution businesses included in the analysis are introduced.

Chapter 3 presents an analysis of TFP and PFP *trends* for AusNet, AGN Vic and Multinet over the period 1999 to 2015, and provides comparative information for other GDBs.

Chapter 4 presents a comparative analysis of the TFP *levels* of the Victorian GDBs and three major GDBs in other states, using multilateral TFP analysis. The multilateral TFP method is explained and the results of the analysis of multilateral TFP are reported.

Finally, chapter 5 summarises all of the main conclusions of this study.

1.5 Economic Insights' experience and consultants' qualifications

Economic Insights has been operating in Australia for over 20 years as an economic consulting firm specialising in infrastructure regulation. Economic Insights provides strategic policy advice and rigorous quantitative research to industry and government. Economic Insights' experience and expertise covers a wide range of economic and industry analysis topics including:

- infrastructure regulation;
- productivity measurement;
- benchmarking of firm and industry performance;
- infrastructure pricing issues; and
- analysis of competitive neutrality issues.

This report was prepared by Michael Cunningham, who is an Associate of Economic Insights. His summary CV is presented in Attachment A. Michael Cunningham has read the Federal Court Guidelines for Expert Witnesses and this report has been prepared in accordance with the Guidelines. A declaration to this effect is presented in Attachment B to the report.

2 METHODOLOGIES

This chapter briefly outlines the basics of TFP and why it is of interest to regulators. It then discusses a number of key measurement issues affecting outputs, inputs and describes the data used in the study and the definitions of outputs and inputs. Finally, it provides some descriptive information relating to the comparator gas distribution businesses included in the analysis.

2.1 Productivity Measurement and Benchmarking

Productivity is a measure of the physical output produced from the use of a given quantity of inputs. All enterprises use a range of inputs including labour, capital, land, fuel, materials and services. If the enterprise is not using its inputs as efficiently as possible then there is scope to lower costs through productivity improvements and, hence, lower the prices charged to consumers. This may come about through the use of better quality inputs including a better trained workforce, adoption of technological advances, removal of restrictive work practices and other forms of waste, and better management through a more efficient organisational and institutional structure. When there is scope to improve productivity, this implies there is technical inefficiency. This is not the only source of economic inefficiency. For example, when a different mix of inputs can produce the same output more cheaply, given the prevailing set of inputs prices, there is allocative inefficiency.

Productivity is measured by expressing output as a ratio of inputs used. There are two types of productivity measures: total factor productivity (TFP) and partial factor productivity (PFP). TFP measures total output relative to an index of all inputs used. Output can be increased by using more inputs, making better use of the current level of inputs and by exploiting economies of scale. The TFP index measures the impact of all the factors affecting growth in output other than changes in input levels. PFP measures one or more outputs relative to one particular input (eg labour productivity is the ratio of output to labour input).

Total factor productivity is measured by the ratio of an index of all outputs (Q) to an index of all inputs (I):

(1) $$TFP = Q/I$$

The rate of change in TFP between two periods is measured by

(2) $$\dot{TFP} = \dot{Q} - \dot{I}$$

where a dot above a variable represents the rate of change of the variable.[1] In this study the partial productivity of factor *i* is defined as:

(3) $$PFP_i = Q/I_i$$

[1] This measure of the change in TFP in terms of the difference between the growth rates of outputs and inputs is known as the Hicks-Moorsteen approach. Alternative methods are based on changes in profitability with adjustment for changes in input and output prices, or on changes in measures of technical efficiency (see: Coelli et al 2005, pp. 64-65).

where I_i is the quantity used of factor i. The PFP can be measured with respect to *any* single factor type. It is not a holistic measure, like TFP, but PFP measures can be useful for gaining a better understating of the trends observed in TFP.

TFP indexes have a number of advantages including:

- indexing procedures are simple and robust;
- they can be implemented when there are only a small number of observations;
- the results are readily reproducible;
- they have a rigorous grounding in economic theory;
- the procedure imposes good disciplines regarding data consistency; and
- they maximise transparency in the early stages of analysis by making data errors and inconsistencies easier to spot than using some of the alternative econometric techniques.

As noted in Lawrence (1992), by providing a means of comparing efficiency levels, TFP measurement is an ideal tool for promoting so–called 'yardstick competition' in non–competitive industries. It provides managers with useful information on how their business is performing overall and on how it is performing relative to its peers. TFP measurement, thus, provides a ready means of 'benchmarking' the business's overall performance relative to other businesses supplying similar outputs.

Forecast future productivity growth rates can play a key role in setting the annual revenue requirement used in building blocks regulation. Productivity studies provide a means of benchmarking GDB performance to assist the regulator in determining whether the GDB in question is operating at efficient cost levels. They also assist the regulator in determining possible future rates of productivity growth to build into annual revenue requirement forecasts.

2.2 Measurement Issues

To measure productivity performance we require data on the price and quantity of each output and input, and data on key operating environment conditions. We require quantity data because productivity is essentially a weighted average of the change in output quantities divided by a weighted average of the change in input quantities. Although the weights are complex and vary depending on the technique used, for outputs they are derived from the share of each output in total revenue or, alternatively, from output cost shares and for inputs from the share of each input in total costs. To derive the revenue and cost shares we require information on the value of each output and input, ie its price times its quantity. Hence, we require either the price and quantity of each output and input or, alternatively, their values and quantities, or their values and prices. To derive output cost shares we require additional information on how cost drivers link to output components. This is usually derived from estimation of econometric cost functions.

In a sense the quantity data are the primary drivers of productivity results while the value or price data are secondary drivers in that they are used to determine the weights for aggregation. Quantity information can be obtained either directly or indirectly. Direct quantity data are physical measures of a particular output or input, eg terajoules of throughput or full–time equivalent employees. Indirect quantity data are obtained by deflating the revenue or cost of a particular output or input by an average price or a price index. There are arguments in favour of both methods. Some argue that the indirect method allows greater differences in the quality of outputs or inputs to be captured and for a greater range of items to be captured within the one measure (eg a greater extent of automation reflected in a higher capital value). However, the indirect method places more onus on having both the value and the price data completely accurate. Since price data are generally harder to match to the specific circumstances of a particular firm, there is more scope for error with the indirect method. Hence, it is a good policy to rely on direct quantity data wherever possible and to only use indirect quantity data in those cases where the category is too diverse to be accurately represented by a single quantity (eg materials and services inputs).

In common with other network infrastructure industries, measuring the performance of gas pipelines presents a number of challenges. In the following section we examine a number of difficult measurement issues including how to define GDB outputs and inputs and the likely impact of operating environment conditions.

2.2.1 Measuring GDB outputs

Early energy supply productivity studies simply measured output by system throughput. However, this simple measure ignores important aspects of what pipelines really do. To capture the multiple dimensions of electricity DB output, Lawrence (2003a) measured distribution output using three outputs: throughput, system line capacity and connection numbers. A similar output specification is appropriate for gas distribution given their functional similarity to electricity networks. Lawrence (2007) developed a capacity output measure for the three Victorian GDBs using detailed data on lengths, diameters and pressures of different mains types for each GDB.

To aggregate the outputs into a total output index using indexing procedures, we have to allocate a weight to each output. It is long established that the use of revenue share weights in the output index will only be consistent with measuring production efficiency growth if prices are proportionate to marginal costs, a condition of cost minimization (Denny et al. 1981; Fuss & Waverman 2002). Economic Insights (2009b) has shown that when the increasing returns to scale nature of energy networks and the role of sunk cost assets are taken into account, allocative efficiency requires that all functional outputs (of which billable outputs will be a subset) be included and the deviation of market prices from marginal costs be allowed for. One way of doing this using econometrics is to use the relative shares of cost elasticities derived from an econometric cost function. This approach is often used in industries not subject to high levels of competition because the cost elasticity shares reflect the marginal cost of providing an output and this is the approach we adopt in this study.

2.2.2 Measuring GDB inputs

Previous studies of pipeline productivity have typically used two or three input categories. For instance, BIE (1994) used labour numbers, kilometres of distribution main and kilometres of transmission main. No allowance was made for materials and services inputs due to lack of data at that time. IPART (1999) used operating expenditure and kilometres of main as its two inputs. Differences in the levels of contracting out between utilities made obtaining labour data problematic either due to its unavailability or lack of comparability. PEG (2001) used a three input specification with labour, other operating expenditure and capital inputs. As labour data is not available for most Australian GDBs and the extent of contracting out makes such a measure problematic, in this study labour inputs are subsumed within operating expenditure.

There are a number of different approaches to measuring both the quantity and cost of capital inputs. The quantity of capital inputs can be measured either directly in quantity terms (eg using pipeline length measures) or indirectly using a constant dollar measure of the value of assets. Similarly, the annual cost of using capital inputs can be measured either directly by applying the sum of an estimated depreciation rate and a rate reflecting the opportunity cost of capital to the regulatory asset base (RAB) or indirectly as the residual of revenue less operating costs.

Some analysts have argued that measuring the quantity of capital by the deflated asset value method provides a better estimate of total input as it better reflects the quality of capital and can include all capital items, not just pipelines. There are two potential problems with this approach. Firstly, it is better suited to more mature systems where the asset valuations are very consistent over time and across organisations. In Victoria and NSW there has been only one full asset valuation done in each state. In the case of Victoria, these asset values were further 'adjusted' before privatisation for political considerations and so, while the adjusted values form the basis of the current regulatory asset base, they are inappropriate for comparing capital input quantities.

The second problem with basing capital quantities on constant price asset value measures is that they usually incorporate some variant of the straight line approach to measuring depreciation. Gas pipeline assets tend to be long lived and produce a relatively constant flow of services over their lifetime. Consequently, their true depreciation profile is more likely to reflect the 'one hoss shay' or 'light bulb' assumption than that of a straight line approach. That is, they produce the same service each year of their life and until the end of their specified life rather than producing a given amount less service every year. In these circumstances it may be better to proxy the quantity of capital input by the physical quantity of the principal assets. This approach is also invariant to different depreciation profiles that may have been used by different pipeline businesses.

The direct approach to measuring capital costs involves explicitly calculating the return of and return on capital to reflect depreciation and the opportunity cost of capital. The indirect approach of allocating a residual or ex post cost to capital of the difference between revenue and operating costs has been favoured by some regulatory agencies such as the US Federal Communications Commission (1997) and is the approach used in PEG (2006). Given that the implicit rates of return in the Economic Insights GDB database are relatively stable and broadly similar in magnitude, and the focus of this study is on productivity performance, we use the indirect approach here for simplicity. We note this differs from the amortisation approach when the effect of sunk costs and financial capital maintenance are fully allowed for as in Economic Insights (2009b) but it will provide a close approximation in this case.

2.2.3 Normalisation for operating environment conditions

Operating environment conditions can have a significant impact on distribution costs and productivity and in many cases are beyond the control of managers. Consequently, to ensure reasonably like–with–like comparisons it is desirable to 'normalise' for at least the most important operating environment differences. Likely candidates for normalisation include energy density (energy delivered per customer), customer density (customers per kilometre of main), customer mix, the proportion of cast iron pipes and climatic and geographic conditions.

Energy density and customer density are generally found to be the two most important operating environment variables in energy distribution normalisation studies (see Lawrence 2003a). Being able to deliver more energy to each customer means that a GDB will usually require less inputs to deliver a given volume of gas, or deliver a greater volume for the same investment in pipelines. A GDB with lower customer density will require more pipeline length to reach its customers than will a GDB with higher customer density, making the lower density distributor appear less efficient unless the differing densities are allowed for.

Most energy distribution studies incorporate density variables by ensuring that the three main output components – throughput, system capacity and customers – are all explicitly included. This means that distribution businesses that have low customer density, for instance, receive credit for their longer line lengths whereas this would not be the case if output was measured by only one output such as throughput.

2.3 Data used

The primary data source for this study is information supplied by AGN Vic, Multinet and AusNet in relation to each of their Victorian gas distribution networks in response to common detailed data surveys, covering key output and input value, price and quantity information for calendar years 1998 to 2015. Similar data was provided in previous years by AGN in relation to its South Australian and Queensland gas networks, and by JGN in relation to its NSW gas distribution network. Those surveys cover the financial years 1998–99 to 2014–15 in the case of AGN SA; and 1998–99 to 2013–14 in the case of JGN and AGN Qld. No forecast data are used for any of the included GDBs.

2.3.1 Output quantities and weights

The outputs produced by GDBs are defined in this study as:

1) **Throughput**: The quantity of the GDB's throughput is measured by the number of terajoules of gas supplied. It is the sum of energy supplied to all customer segments: residential, commercial and large industrial customers.

2) **Customers**: Connection dependent and customer service activities are proxied by the GDB's number of customers.

3) **System capacity**: Gas distribution networks have three primary functions: delivery of gas from supply point to demand point; the interim storage of gas to make available sufficient gas during peak periods; and, the performance of these functions safely and

efficiently. We include a measure of system capacity to capture the GDB's functional responsibility of making capacity available to meet the needs of customers. The measure we require is somewhat analogous to the MVA–kilometre system capacity measure used in electricity DB TFP studies (see, for example, Lawrence 2003a) but, in this case, it needs to also capture the interim storage function of pipelines.

The system capacity measure used in this study is that developed in Lawrence (2007) which is the volume of gas held within a gas network converted to standard cubic meters using a pressure correction factor based on the average operating pressure. The volume of the distribution network is calculated based on pipeline length data for high, medium and low distribution pipelines and estimates of the average diameter of each of these pipeline types, which differ between networks. The quantity of gas contained in the system is a function of operating pressure. Thus, a conversion to an equivalent measure using a pressure correction factor is necessary to allow for networks' different operating pressures. These conversion factors also differ between networks.

From historical observations GDB engineers have forecast the approximate load on the system per month during periods of peak flow and as a result have approximated the mean pressure in the network for the twelve month period. Average network pressure is a better representation of service to the majority of customers than is fringe pressure—the minimum pressure at the fringe of the network—because it needs to be sufficient to ensure periods of peak demand can be accommodated while still meeting the minimum pressure requirement.

The system capacity measure is the addition of the individual high, medium and low pressure network capacities. As noted above, pipelines owned by GDBs operating at very high pressures (above 1050 kPa) with characteristics normally associated with transmission or sub–transmission are excluded from the calculation.

To aggregate a diverse range of outputs into an aggregate output index using indexing procedures, we have to allocate a weight to each of the three outputs. In this case we use the estimated output cost shares derived from the econometric cost function outlined in appendix A, as used in Lawrence (2007) on data for the three Victorian GDBs for the period 1998 to 2006. The weights used in this study are the same as those used in previous Economic Insights studies, with the aim of ensuring the studies reflect actual changes in year–to–year operations. A weighted average of the output cost shares was formed using the share of each observation's estimated costs in the total estimated costs for all GDBs and all time periods following Lawrence (2003a). This produced an output cost share for throughput of 13 per cent, for customers of 49 per cent and for system capacity of 38 per cent.

The total revenue of each GDB is the sum of revenue from all customer segments: residential, commercial and large industrial customers.

2.3.2 Input quantities and weights

The inputs used by GDBs are defined in this study as:

1) **Opex**: The quantity of the GDB's opex is derived by deflating the value of opex by the opex price deflator originally developed by PEG (2006). As noted above, the opex values

supplied by the GDBs were consistent with the GDBs' Regulatory Accounts but the focus has been on ensuring data reflects actual year–to–year operations. A number of accounting adjustments such as allowance for provisions have been excluded as they do not reflect the actual inputs used by the businesses in a particular year which is what we need for TFP purposes. To ensure consistency in functional coverage throughout the period, for those years prior to the introduction of full retail contestability (FRC) each GDB's constant price opex is increased by the amount of expenses incurred in the early years of FRC. In these early years FRC was expected to have only affected opex (and not capital) requirements.

To ensure consistency with previous studies, including Economic Insights (2010, 2014), a number of adjustments have been made to the functional coverage of opex to ensure more like–with–like comparisons between GDBs. Government levies and unaccounted for gas are excluded from opex for all GDBs. Carbon costs are excluded where separately identified.[2]

The PEG (2006) opex price deflator was developed for electricity DBs. It is made up of a 62 per cent weighting on the Electricity, gas and water sector Wages price index with the balance of the weight being spread across five Producer price indexes covering business, computing, secretarial, legal and accounting, and advertising services. Since the functions of electricity and gas distribution are broadly analogous, the PEG (2006) deflator is considered the best currently available for GDB opex as well.[3]

2) **Transmission network**: The quantity of transmission network for AGN SA and the Victorian GDBs is proxied by their transmission pipeline length and for JGN is similarly proxied by the sum of its 'trunk' and 'primary' mains length.

3) **High pressure network**: The quantity of each GDB's high pressure network is proxied by its high pressure pipeline length.

4) **Medium pressure network**: The quantity of each GDB's medium pressure network is proxied by its medium pressure pipeline length.

5) **Low pressure network**: The quantity of each GDB's low pressure network is proxied by its low pressure pipeline length.

6) **Services network**: The quantity of each GDB's services network is proxied by its estimated services pipeline length.

7) **Meters**: The quantity of each GDB's meter stock is proxied by its total number of meters.

[2] In the case of JGN, other items of opex have been excluded to put it on a comparable functional basis, including opex associated with trunk and primary mains, marketing and retail incentives, market operations expenses and meter reading. Network marketing expenses are also excluded for AGN Qld given its low penetration.

[3] The Australian Bureau of Statistics discontinued some of the Producer Price Indexes used in the PEG (2006) opex price deflator with its move to the latest industrial classification so it has been necessary to splice the series with the nearest proxies under the new classification.

8) **Other assets**: The quantity of other capital inputs is proxied by their deflated asset value. Other capital comprises city gate stations, cathodic protection, supply regulators and valve stations, SCADA and other remote control, other IT and other non–IT.

The starting point for our Victorian GDB asset values are the 1997 valuations of the regulatory asset base (RAB) for 12 asset categories for each of the three GDBs. Asset life and remaining asset life estimates are also provided for each of the 12 asset categories, as reported by the GDBs.

We form disaggregated constant price depreciated capital stock estimates by rolling forward the opening asset values by taking away straight line depreciation based on remaining asset life of the opening capital stock and adding in yearly constant price capital expenditure and subtracting yearly constant price depreciation on capital expenditure for 1998 and subsequent years calculated using straight line depreciation based on asset–specific asset lives.

A similar approach was adopted for JGN, where the 1998 IPART RAB is used as the starting point, and for AGN SA where the 1998 RAB is used. In each case the roll forward is done on the same basis with the Victorian GDB data to maintain comparability. A similar approach was also adopted for AGN Qld using 1999 asset values.

Following PEG (2006) we use the endogenous rate of return method for forming estimates of the user cost of capital. Using this approach the value of total costs equals total revenue by definition. As noted in Lawrence (2007), the implicit gross rate of return for the three Victorian GDBs was relatively stable over the period up to 2006 and also across the three GDBs so there would be little difference in TFP estimates formed using this approach and the exogenous user cost method. The JGN and AGN SA implicit gross rates of return are also relatively stable. The input weight given to opex is simply the ratio of opex to total revenue. The aggregate capital input weight is simply given by one minus the opex share. It is then necessary to divide this overall capital share among the 7 capital asset inputs. This is done using the share of each of the 7 asset categories' asset values in the total asset value for that year.

2.4 Key characteristics of the included GDBs

The key characteristics of the six GDBs included in this study are presented in table 2.1 for 2014, the latest year for which data are available in the database for all of these GDBs. JGN is the largest of the GDBs in terms of throughput (91 PJ), customer numbers (1.2 million), and distribution mains length (25 thousand km). The Victorian GDBs are similar to each other in size and much smaller than JGN. In terms of throughput they are on average less than two–thirds of the size of JGN, ranging from 51 (AGN Vic) to 65 PJ (AusNet). In terms of the number of customers they are on average about half of the size of JGN, ranging from 0.60 (AGN Vic) to 0.69 million (Multinet). In terms of distribution network length they are on average about 40 per cent of the size of JGN, ranging from 9.9 (Multinet) to 10.7 thousand km (AusNet).

The remaining two GDBs included in the study are smaller. In terms of throughput, AGN SA is about 40 per cent of the average for the Victorian GDBs, and about one quarter the size of JGN. In terms of customer numbers, AGN SA is about two–thirds of the average for the

Victorian GDBs and about one–third of the size of JGN. AGN Qld is smaller again, being about one–quarter of the size of AGN SA.

As noted in section 3.3, the two key operating environment characteristics that influence energy distribution productivity levels are energy density (throughput per customer) and customer density (customers per kilometre of mains). Together these determine the energy throughput per kilometre (km) of distribution mains. The three Victorian GDBs have relatively high energy density, ranging from 77 (Multinet) to 101 GJ per customer (AusNet). The energy densities of the other GDBs range from 55 (AGN SA) to 75 GJ per customer (JGN). The customer densities of the Victorian GDBs are also relatively high ranging from 59 (AGN Vic) to 69 customers per km of main (Multinet). The customer densities of the other GDBs range from 36 (AGN Qld) to 55 customers per km (AGN SA). The combined effect of these two factors is that the Victorian GDBs have relatively high energy throughput per km of mains, ranging from 5.0 (AGN Vic) to 6.0 TJ per km (AusNet). For the other GDBs, energy throughput per km of mains ranges from 2.1 (AGN Qld) to 3.6 TJ per km (JGN).

Table 2.1: **Included GDBs' key characteristics, 2014**

GDB	Throughput	Customers	System capacity	Distribution mains length	Energy density	Customer density	Energy per unit mains
	TJ	*No*	*Sm^3*	*kms*	*GJ/cust.*	*Cust./km*	*TJ/km*
AGN Vic	51,404	600,386	138,431	10,217	86	59	5.0
Multinet	52,979	685,082	122,907	9,918	77	69	5.3
AusNet	64,577	637,535	139,403	10,703	101	60	6.0
AGN SA	23,168	423,437	100,645	7,741	55	55	3.0
AGN Qld	5,356	91,783	27,725	2,542	58	36	2.1
JGN	90,622	1,211,793	384,007	25,277	75	48	3.6

Source: Economic Insights GDB database

These energy densities are overall figures across domestic, commercial and industrial customers, whereas a key cost driver for GDBs is domestic energy density. GDBs operating in a temperate climate will be at an obvious disadvantage relative to GDBs operating in cold climates where there is a much higher demand for gas for space heating. The domestic demand for gas for GDBs operating in temperate climates is likely to be more focused on cooking and hot water heating.

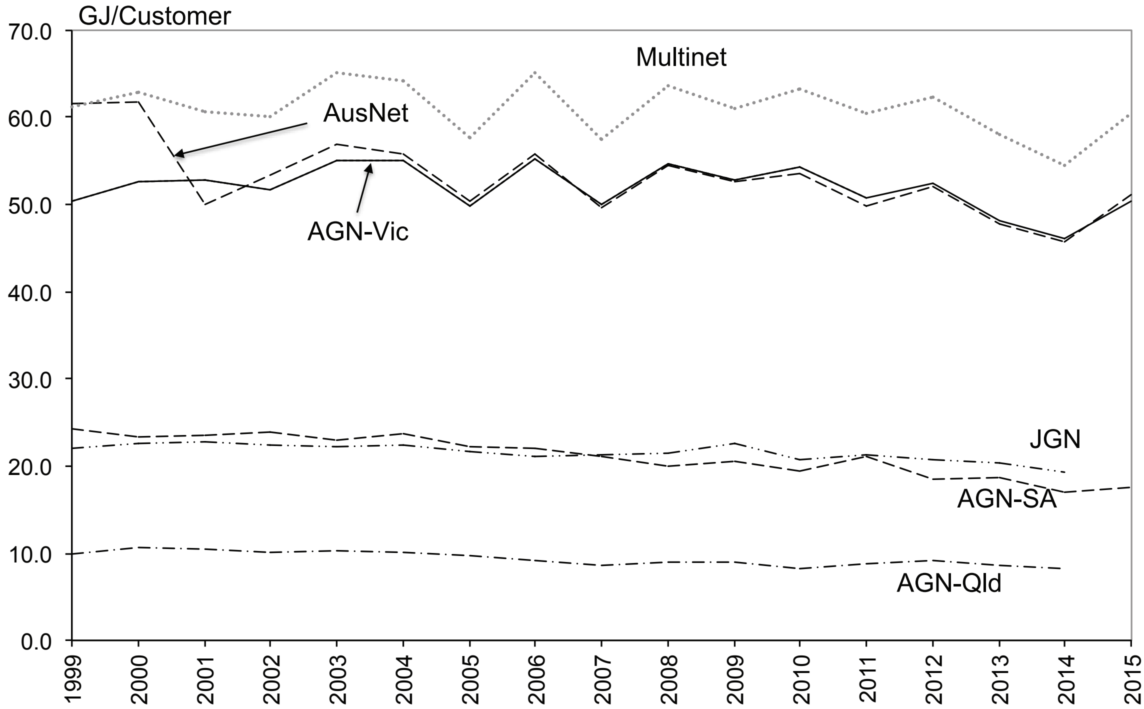
The domestic energy densities of the six included GDBs are plotted in figure 2.1. From this figure we can see that the three Victorian GDBs have considerably higher domestic energy densities than the three non–Victorian GDBs. AGN SA and JGN have similar domestic energy densities reflecting their broadly similar climatic conditions. The relatively higher proportion of domestic space heating demand is reflected in the greater variability of the Victorian densities, as demand will be less in mild winters. The significant differences in domestic energy densities highlight the different operating conditions faced by GDBs.

Such differences are further highlighted by differences in the share of domestic energy out of total energy throughput between GDBs. In 2014 domestic throughput accounted for 44 per cent of AusNet's throughput, 52 per cent of AGN Vic's throughput and 69 per cent of

Multinet's throughput. By contrast it accounted for 25 per cent of JGN's throughput; 30 per cent of AGN SA's throughput; and 13 per cent of AGN Qld's throughput.

Climatic conditions can also be expected to have a significant impact on a GDB's customer density, as will the geographic characteristics of the area served. Domestic customer penetration rates are likely to be much lower for GDBs operating in milder climates, meaning that those GDBs have to lay relatively more length of pipeline to reach each domestic customer. Customer densities will also be lower for those GDBs whose geography dictates a relatively 'dendritic' system rather than a more compact, meshed system. A dendritic system will arise where a number of spread out pockets of consumption have to be served. Customer densities for the included GDBs are plotted in figure 2.2.

Figure 2.1: **Included GDB domestic energy densities, 1999–2015**

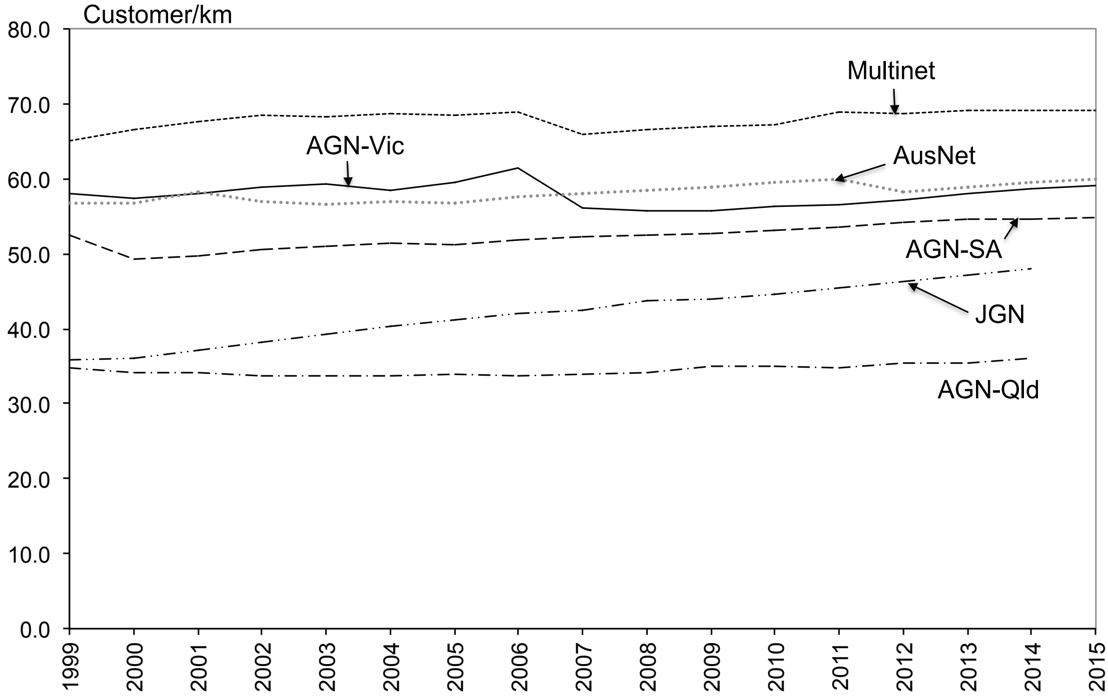


Source: Economic Insights GDB database

Multinet has the highest customer density of the included GDBs reflecting its coverage of Melbourne's densely populated inner southeast. AGN Victoria and AusNet have the next highest customer densities followed closely by AGN SA, all of which have relatively compact, meshed distribution systems despite some differences in climatic conditions. JGN's customer density is approximately 80 per cent of that of AusNet and AGN Vic, and increasing more strongly.

The Victorian GDBs have higher energy throughput per km of distribution main compared to the other networks due to a combination of higher energy density per customer and higher customer density on average. These differences are influenced by differences in climate. Figure 2.3 summarises the differences between the GDBs in terms of energy throughput per km. An important feature of the energy densities per km main is that they have been steadily declining for most of the six GDBs shown, for most of the period, especially since around 2004. Over the period 1999 to 2004, the (simple) average energy throughput per km main for the three Victorian GDBs was 7.4 TJ per km. The average energy throughput per km subsequently declined by more than 20 per cent to 5.8 TJ per km in 2015. For the other three GDBs, there was a similar decline in average energy throughput per km.

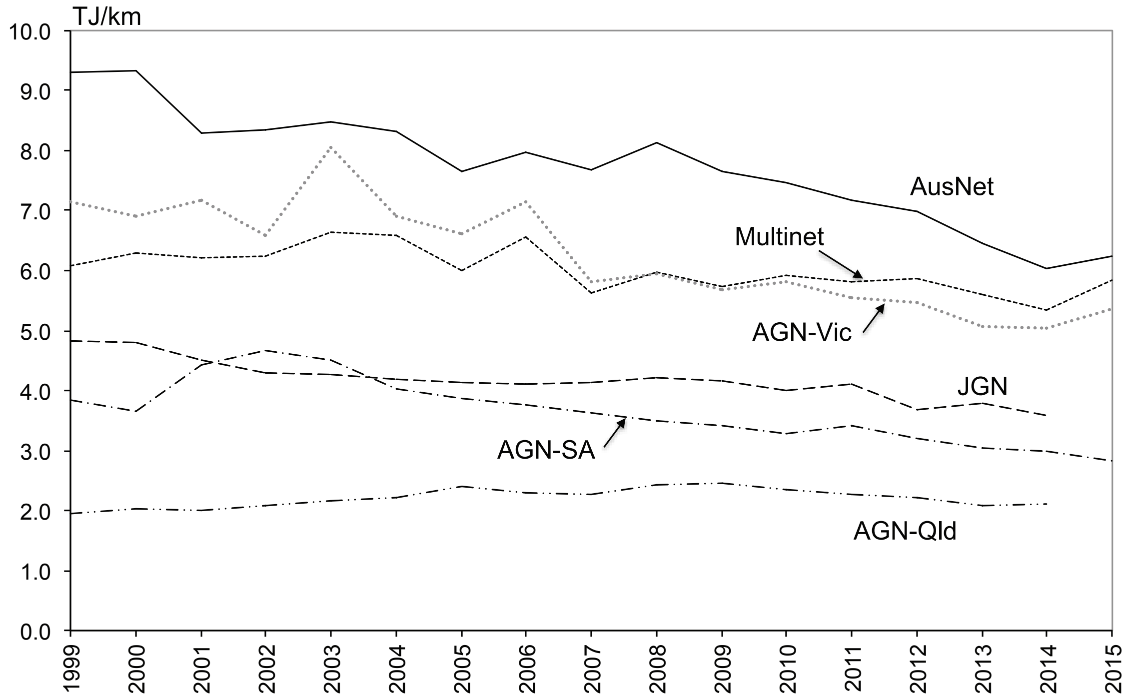
Figure 2.2: **Included GDB customer densities, 1999–2015**



Source: Economic Insights GDB database

To summarise, the review of operating environment conditions has shown that the three Victorian GDBs have relatively high overall energy densities, the highest domestic energy densities, the highest customer densities of the included GDBs and the highest overall energy throughput per km of distribution mains. Together with their medium sizes, this could be expected to give them an advantage when comparing productivity levels. JGN on the other hand is much larger than the other included GDBs and has relatively good overall energy density but it has lower domestic energy density and relatively low customer density. Its overall energy throughput per km of distribution mains is comparatively close to that of the Victorian GDBs, and with its greater scale, this can be expected to give it a productivity advantage over smaller GDBs such as AGN SA and AGN Qld.

Figure 2.3: **Included GDB energy throughput per km main, 1999–2015**



Source: Economic Insights GDB database

3 PRODUCTIVITY GROWTH RESULTS

3.1 TFP indexes

Index numbers are a quantitative method developed in economics for aggregating prices or quantities of products that may be measured in different units, and hence cannot be aggregated by summation or simple averages. Index numbers normally measure relativities, such as changes from one period to another or comparisons between other situations, such as comparisons between localities or groups of consumers.

To operationalise TFP measurement we need to combine changes in diverse outputs and inputs into measures of changes in total outputs and total inputs. That is, it is necessary to develop an index for all the outputs produced by a business and another for all the inputs used by the business. The four most popular index formulations are:

- the Laspeyres base period weight index;
- the Paasche current period weight index;
- the Fisher ideal index which is the square root of the product of the Paasche and Laspeyres index; and
- the Törnqvist index which has been used extensively in previous TFP studies.

Diewert (1993) reviewed alternate index number formulations to determine which index was best suited to TFP calculations. Indexing methods were tested for consistency with a number of axioms which an ideal index number should always satisfy.[4] Diewert found that only the Fisher ideal index passed all of the axiomatic tests.[5] On the basis of his analysis, Diewert recommended the Fisher ideal index be used for TFP work although he indicated that the Törnqvist index could also be used as it closely approximates Fisher's ideal index. For this study the Fisher ideal index was therefore chosen as the preferred index formulation for the TFP time series analysis. It is also increasingly the index of choice of leading national statistical agencies.

Mathematically, the Fisher ideal output index is given by:

(4) $$Q_F^t = [(\sum_{i=1}^m P_i^B Y_i^t / \sum_{j=1}^m P_j^B Y_j^B)(\sum_{i=1}^m P_i^t Y_i^t / \sum_{j=1}^m P_j^t Y_j^B)]^{0.5}$$

where: Q_F^t is the Fisher ideal output index for observation *t*;

P_i^B is the price of the *i*th output for the base observation;

[4] These tests were: (a) the constant quantities test: if quantities are the same in two periods, then the output index should be the same in both periods irrespective of the price of the goods in both periods; (b) the constant basket test: this states that if prices are constant over two periods, then the level of output in period 1 compared to period 0 is equal to the value of output in period 1 divided by the value of output in period 0; (c) the proportional increase in outputs test: this states that if all outputs in period t are multiplied by a common factor, λ, then the output index in period t compared to period 0 should increase by λ also; and (d) the time reversal test: this states that if the prices and quantities in period 0 and t are interchanged, then the resulting output index should be the reciprocal of the original index.

[5] The Laspeyres and Paasche index fail the time reversal test while the Törnqvist index fails the constant basket test.

Y_i^t is the quantity of the ith output for observation t;

P_i^t is the price of the ith output for observation t; and

Y_j^B is the quantity of the jth output for the base observation.

Similarly, the Fisher ideal input index is given by:

(5) $I_F^t = [(\sum_{i=1}^n W_i^B X_i^t / \sum_{j=1}^n W_j^B X_j^B)(\sum_{i=1}^n W_i^t X_i^t / \sum_{j=1}^n W_j^t X_j^B)]^{0.5}$

where: I_F^t is the Fisher ideal input index for observation t;

W_i^B is the price of the ith input for the base observation;

X_i^t is the quantity of the ith input for observation t;

W_i^t is the price of the ith input for observation t; and

X_j^B is the quantity of the jth input for the base observation.

The Fisher ideal TFP index is then given by:

(6) $TFP_F^t = Q_F^t / I_F^t$.

The Fisher index can be used in either the unchained form denoted above or in the chained form used in this study where weights are more closely matched to pair–wise comparisons of observations. Denoting the Fisher output index between observations i and j by $Q_F^{i,j}$, the chained Fisher index between observations 1 and t is given by:

(7) $Q_F^{1,t} = 1 \times Q_F^{1,2} \times Q_F^{2,3} \times .... \times Q_F^{t-1,t}$.

In this section the chained Fisher ideal index number method is used to calculate output and input indexes, TFP and partial productivity measures.

3.2 Victorian GDB productivity growth results, 1999 to 2015

In this section we present the key productivity results for each of the three Victorian gas distribution businesses for the 16–year period to 2015. Results are presented using the specification outlined in section 2 of three outputs (throughput, customer numbers and system capacity) and 8 inputs (opex, lengths of transmission pipelines, high pressure pipelines, medium pressure pipelines, low pressure pipelines and services, meters, and other capital).

3.2.1 AGN Vic

The output, input and TFP indexes for the AGN Vic gas distribution system are presented in table 3.1. The input index is an aggregate of separate opex and capital input indexes, which are also shown in table 3.1 together with capital partial factor productivity (PFP) and non–capital ("Opex") PFP indexes.

Table 3.1: **AGN Vic productivity indexes, 1999–2015**

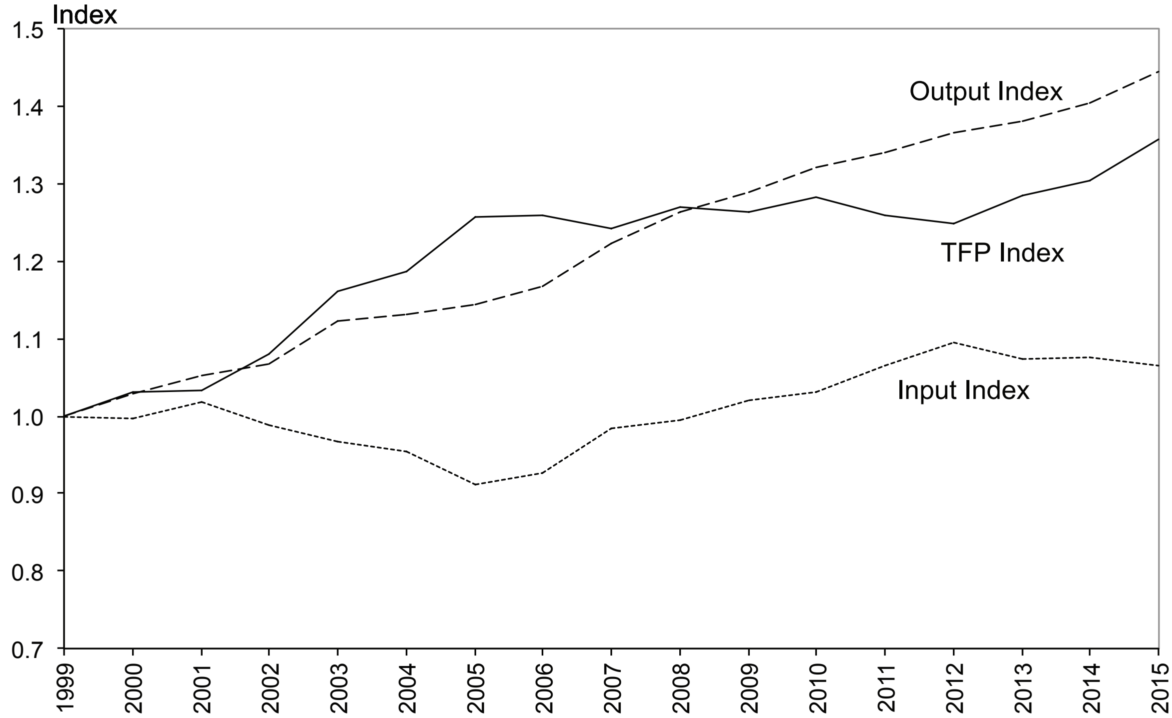
Year	Output	Input	Opex	Capital	PP Opex	PP Capital	TFP
1999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2000	1.029	0.997	0.963	1.030	1.068	0.999	1.031
2001	1.053	1.019	0.994	1.043	1.059	1.009	1.033
2002	1.068	0.987	0.897	1.070	1.190	0.998	1.081
2003	1.123	0.968	0.831	1.092	1.352	1.028	1.161
2004	1.132	0.954	0.772	1.118	1.465	1.012	1.186
2005	1.144	0.911	0.660	1.134	1.734	1.009	1.256
2006	1.168	0.927	0.681	1.146	1.716	1.019	1.260
2007	1.222	0.984	0.721	1.218	1.696	1.003	1.242
2008	1.263	0.995	0.707	1.253	1.786	1.008	1.269
2009	1.288	1.019	0.725	1.283	1.777	1.004	1.263
2010	1.321	1.030	0.715	1.312	1.848	1.007	1.282
2011	1.341	1.065	0.759	1.338	1.765	1.002	1.259
2012	1.365	1.094	0.778	1.377	1.755	0.992	1.248
2013	1.380	1.073	0.716	1.395	1.927	0.989	1.285
2014	1.403	1.076	0.721	1.395	1.946	1.006	1.304
2015	1.444	1.065	0.681	1.407	2.122	1.026	1.357
Average Annual Change							
1999–2008	2.63%	–0.06%	–3.78%	2.54%	6.66%	0.09%	2.69%
2008–2015	1.93%	0.97%	–0.54%	1.67%	2.49%	0.26%	0.95%
1999–2015	2.32%	0.39%	–2.38%	2.16%	4.81%	0.16%	1.92%

Source: Calculations using Economic Insights GDB database

Figure 3.1 plots AGN Vic's TFP index, together with the output and input indexes. The latter assist to interpret movements in the TFP index, which is the ratio of the output and input indexes. AGN Vic has had a reasonably consistent upward trend in TFP. On average TFP increased by 2.7 per cent per year from 1999 to 2008 and by approximately 1.0 per cent per year in the period from 2008 to 2015 reflecting the impact of reduced TFP growth over the last several years has. Over the whole period from 1999 to 2015, AGN Vic's TFP index increased at a relatively strong average annual rate of 1.9 per cent.

AGN Vic has experienced a relatively high rate of output index growth throughout the period 1999 to 2015, with slightly higher growth in the first half of the period (ie to 2008) and slightly lower growth in the second half. The total quantity of inputs was relatively constant between 1999 and 2008, decreasing up to 2005 with an offsetting increase thereafter. Over the period from 2008 to 2015, the growth rate of inputs was 1.0 per cent on average per year, with an increase up to 2012 partially offset by decreases from 2012 to 2015. Over the whole period from 1999 to 2015, AGN Vic's input index increased at an average annual rate of 0.4 per cent.

Figure 3.1: **AGN Vic output, input and TFP indexes, 1999–2015**



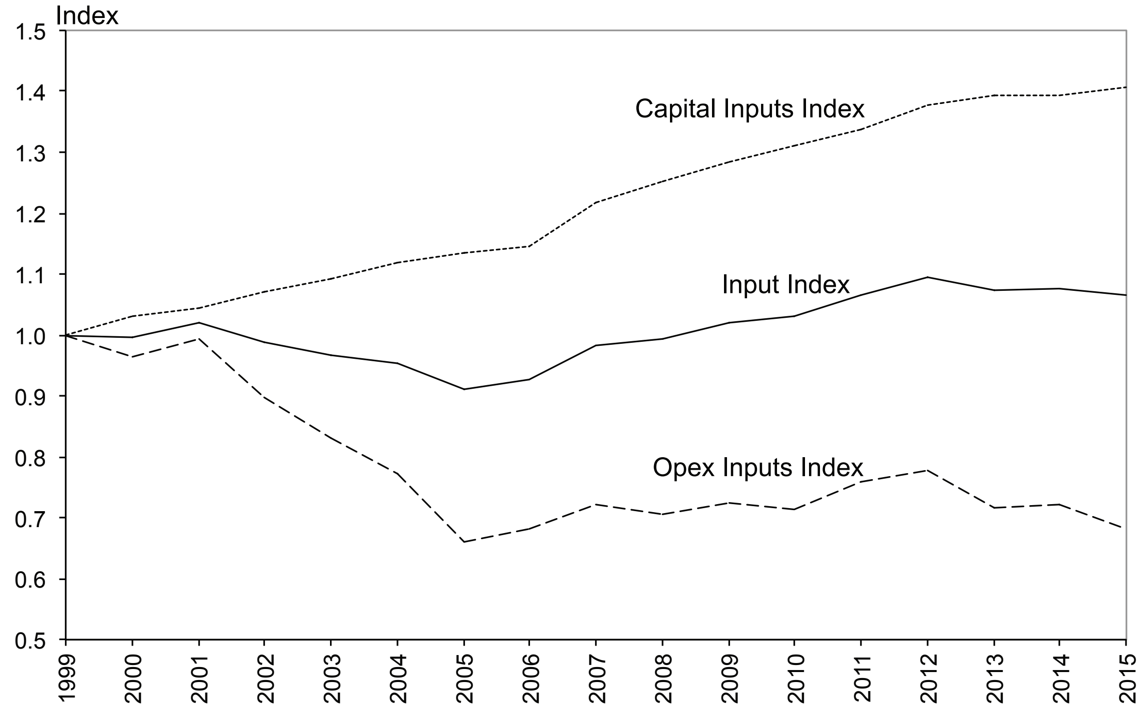
Source: Economic Insights GDB database

Figure 3.2 shows the capital and opex input indexes for AGN Vic. The capital input index has increased fairly steadily over the period 1999 to 2015, with an average rate of increase of 2.2 per cent per year, which is very similar to the growth rate of the output index of 2.3 per cent.

In the period 1999 to 2008, opex inputs usage decreased at an average annual rate of 3.8 per cent, which primarily reflected a strong decline in the period 2001 to 2005. From 2008 to 2015, opex inputs use decreased on average by 0.5 per cent per year. Over the whole period from 1999 to 2015, the average annual growth rate of opex inputs was –2.4 per cent per year, which represents a relatively strong decline.

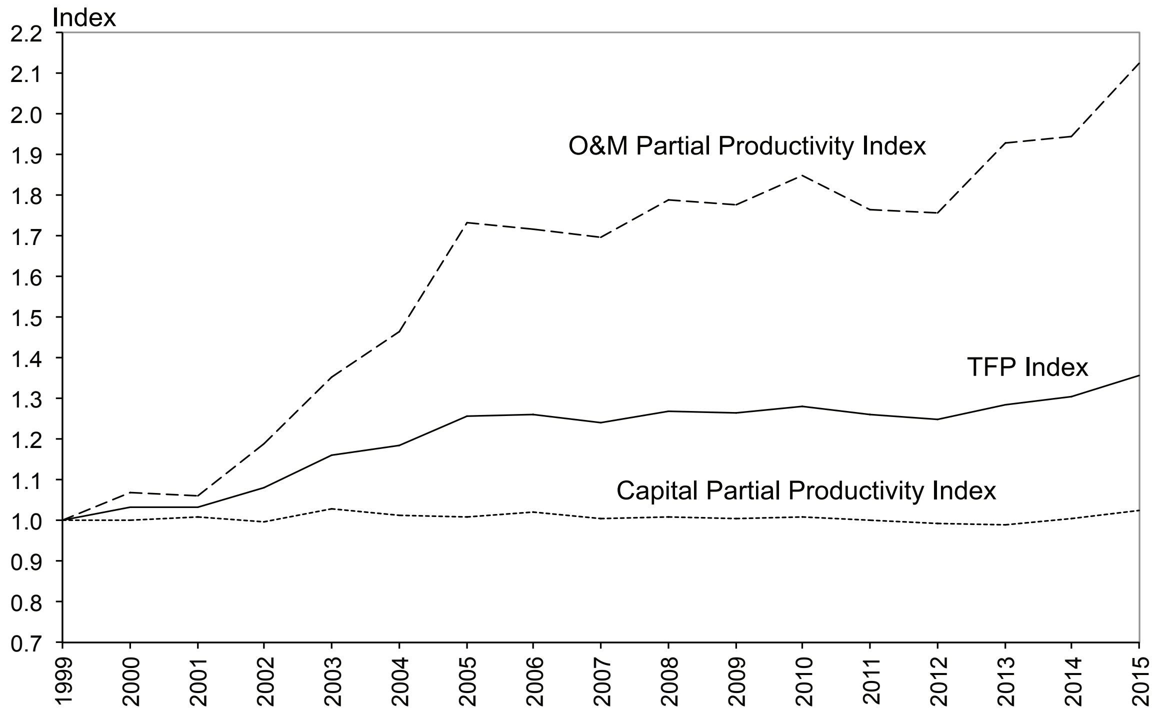
Figure 3.3 shows the partial factor productivity (PFP) indexes for AGN Vic. The TFP index is effectively a weighted average of the partial productivity indexes shown in figure 3.3. The opex PFP index measures output produced per unit of non–capital inputs, and the capital PFP index measures output per unit of capital inputs. Capital PFP increased only marginally between 1999 and 2015, averaging 0.2 per cent per year. Relatively flat capital PFP is common to most of the GDBs. AGN Vic's opex PFP increased strongly between 1999 and 2008 at an average rate of 6.7 per cent, and increased at 2.5 per cent annually, on average, from 2008 to 2015. The annual rate of opex partial productivity growth over the whole period from 1999 to 2015 was 4.8 per cent.

Figure 3.2: **AGN Vic inputs indexes, 1999–2015**



Source: Economic Insights GDB database

Figure 3.3: **AGN Vic partial productivity indexes, 1999–2015**



Source: Economic Insights GDB database

3.2.2 AusNet

The output, input and TFP indexes for the AusNet gas distribution business are presented in table 3.2. The input index is an aggregate of separate opex and capital input indexes, which are also shown in table 3.2 together with capital partial factor productivity (PFP) and non–capital ("Opex") PFP indexes.

Figure 3.4 plots AusNet's TFP index, together with the output and input indexes. The latter assist to interpret movements in the TFP index, which is the ratio of the output and input indexes. Except for the period 2011 to 2013, AusNet has had a reasonably consistent upward trend in TFP. On average TFP increased by 2.7 per cent per year from 1999 to 2008 and by 0.2 per cent per year in the period from 2008 to 2015. TFP has grown over the last two years. Over the whole period from 1999 to 2015, AusNet's TFP index increased at a relatively strong average annual rate of 1.6 per cent.

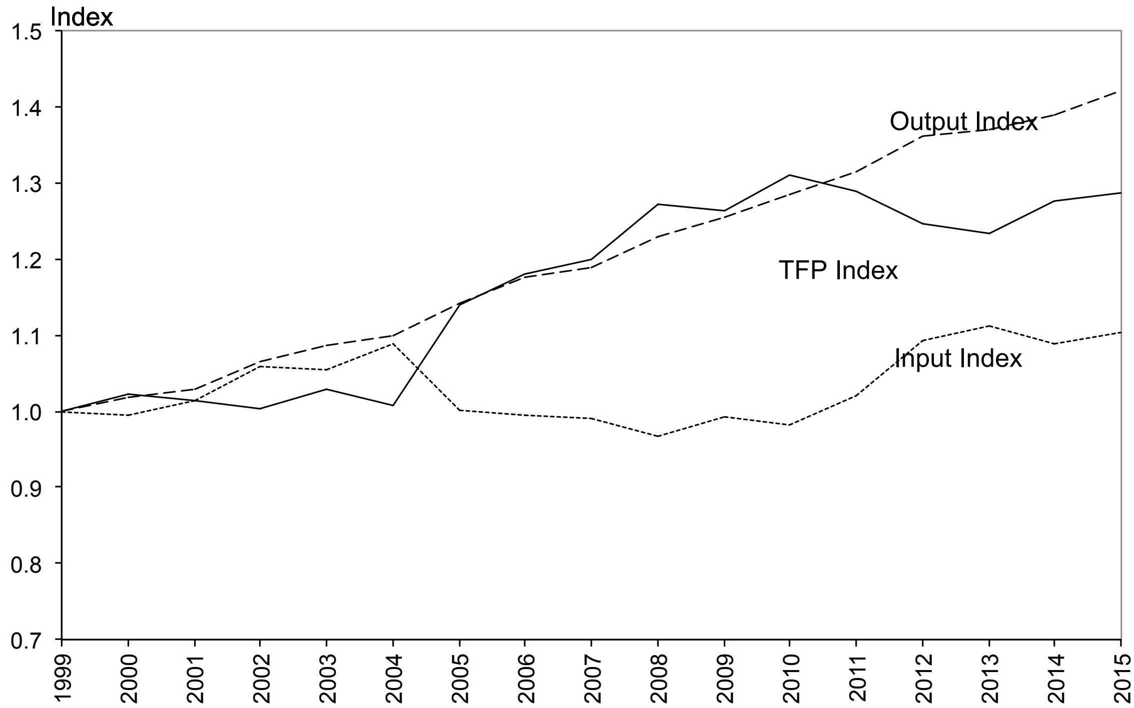
AusNet experienced a relatively high rate of output index throughout the period 1999 to 2015 of 2.2 per cent per year, which is very similar to that of AGN Vic. The distribution regions of those two GDBs include Melbourne's major growth corridors. The total quantity of inputs declined slightly between 1999 and 2008 at a rate of 0.4 per cent per year. Over the period from 2008 to 2015, the growth rate of inputs was 1.9 per cent on average per year, which is close to the rate of output growth over the same period, and the reason for the relatively flat TFP growth in that period. Over the whole period from 1999 to 2015, AusNet's input index increased at an average annual rate of 0.6 per cent.

Table 3.2: **AusNet productivity indexes, 1999–2015**

Year	Output	Input	Opex	Capital	PP Opex	PP Capital	TFP
1999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2000	1.018	0.996	0.974	1.014	1.045	1.004	1.022
2001	1.028	1.014	0.994	1.031	1.035	0.998	1.014
2002	1.064	1.060	1.081	1.044	0.984	1.019	1.004
2003	1.086	1.055	1.037	1.071	1.047	1.014	1.029
2004	1.098	1.090	1.073	1.103	1.024	0.995	1.008
2005	1.142	1.002	0.826	1.147	1.382	0.996	1.140
2006	1.175	0.995	0.773	1.174	1.520	1.001	1.181
2007	1.188	0.991	0.735	1.194	1.617	0.995	1.199
2008	1.230	0.966	0.637	1.216	1.930	1.011	1.273
2009	1.254	0.993	0.652	1.251	1.923	1.003	1.264
2010	1.285	0.981	0.568	1.282	2.264	1.002	1.309
2011	1.314	1.020	0.614	1.318	2.140	0.998	1.289
2012	1.361	1.093	0.720	1.373	1.891	0.991	1.245
2013	1.371	1.112	0.729	1.399	1.879	0.980	1.233
2014	1.390	1.089	0.652	1.425	2.132	0.976	1.276
2015	1.421	1.104	0.660	1.444	2.153	0.984	1.287
Average Annual Change							
1999–2008	2.32%	–0.38%	–4.88%	2.20%	7.58%	0.12%	2.72%
2008–2015	2.09%	1.92%	0.50%	2.48%	1.58%	–0.38%	0.16%
1999–2015	2.22%	0.62%	–2.56%	2.32%	4.91%	–0.10%	1.59%

Source: Calculations using Economic Insights GDB database

Figure 3.4: **AusNet output, input and TFP indexes, 1999–2015**



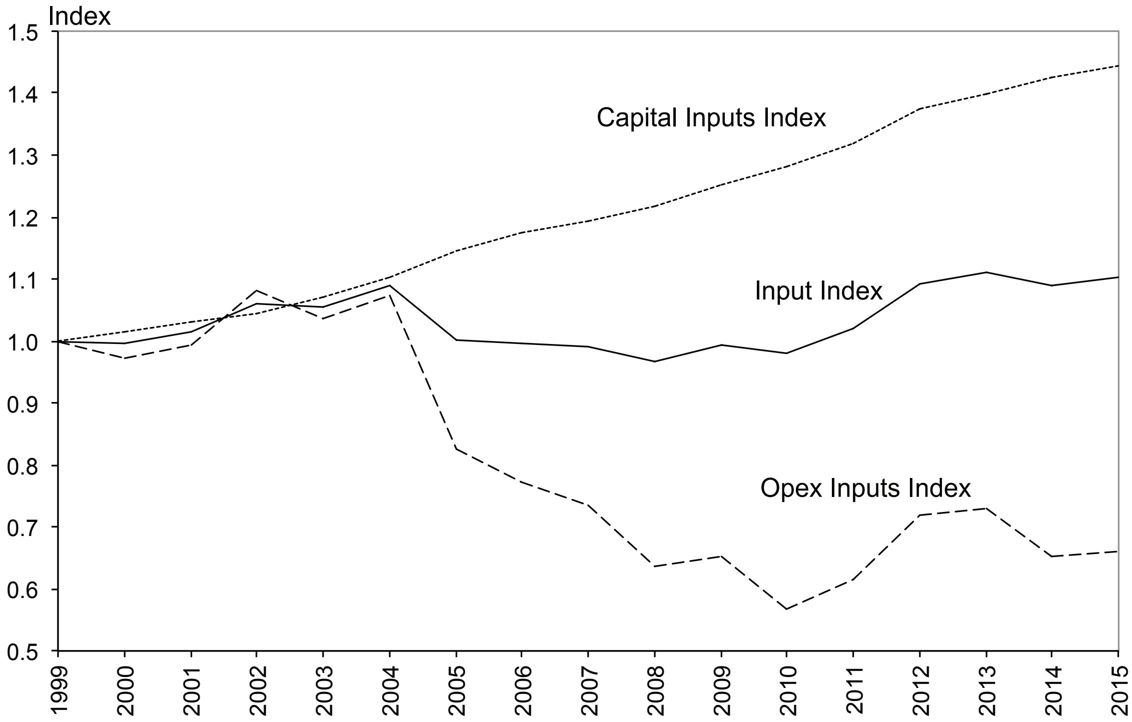
Source: Economic Insights GDB database

Figure 3.5 shows the capital and opex input indexes for AusNet. The capital input index has increased fairly steadily over the period 1999 to 2015, with an average rate of increase of 2.3 per cent per year, which is very similar to the growth rate of the output index of 2.2 per cent.

In the period 1999 to 2008, opex inputs usage decreased at an average annual rate of 4.9 per cent, which primarily reflected a strong decline in the period 2004 to 2008. From 2008 to 2015, opex inputs use increased on average by 0.5 per cent per year. Over the whole period from 1999 to 2015, the average annual growth rate of opex inputs was –2.6 per cent per year, which represents a relatively strong decline.

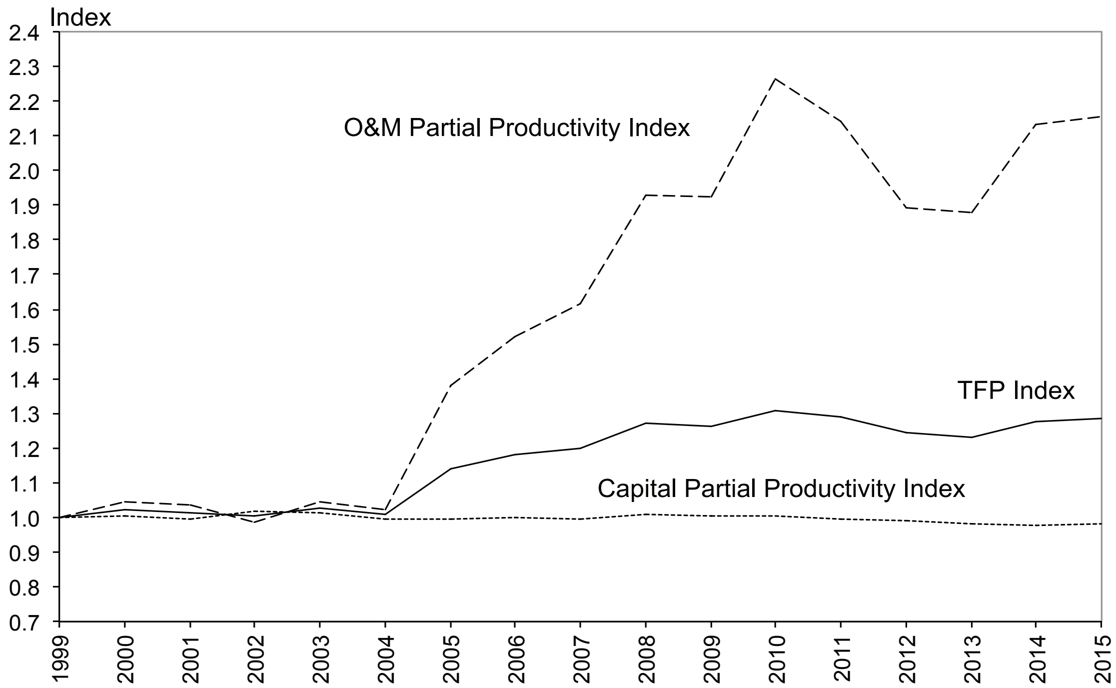
Figure 3.6 shows the partial factor productivity (PFP) indexes for AusNet. The TFP index is effectively a weighted average of the partial productivity indexes shown in figure 3.6. The opex PFP index measures output produced per unit of non–capital inputs, and the capital PFP index measures output per unit of capital inputs. Capital PFP decreased only marginally between 1999 and 2015, averaging –0.1 per cent per year. Relatively flat capital PFP is common to most of the GDBs. AusNet's opex PFP increased strongly between 1999 and 2008 at an average rate of 7.6 per cent, and increased at 1.6 per cent annually, on average, from 2008 to 2015. The annual rate of opex partial productivity growth over the whole period from 1999 to 2015 was 4.9 per cent. This overall average opex PFP growth rate is quite similar to that of AGN Vic.

Figure 3.5: **AusNet inputs indexes, 1999–2015**



Source: Economic Insights GDB database

Figure 3.6: **AusNet partial productivity indexes, 1999–2015**



Source: Economic Insights GDB database

3.2.3 Multinet Gas

The output, input and TFP indexes for Multinet's gas distribution business are presented in table 3.3. The input index is an aggregate of separate opex and capital input indexes, which are also shown in table 3.3 together with capital partial factor productivity (PFP) and non–capital ("Opex") PFP indexes.

Figure 3.7 plots Multinet's TFP index, together with the output and input indexes. The latter indexes assist to interpret movements in the TFP index, which is the ratio of the output and input indexes. Prior to 2011, Multinet had a reasonably consistent upward trend in TFP, however, there was a large downturn in TFP in 2012 with only partial recovery since then, and this has had an important influence on its average TFP trend since 2008. On average Multinet's TFP increased by 2.0 per cent per year from 1999 to 2008 and decreased at an average rate of approximately 0.4 per cent per year in the period from 2008 to 2015. TFP has grown over the last three years. Over the whole period from 1999 to 2015, the TFP index increased at an average annual rate of 1.0 per cent.

Table 3.3: **Multinet productivity indexes, 1999–2015**

Year	Output	Input	Opex	Capital	PP Opex	PP Capital	TFP
1999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2000	1.016	0.965	0.910	1.002	1.116	1.014	1.052
2001	1.022	0.949	0.864	1.005	1.183	1.018	1.077
2002	1.029	0.921	0.767	1.021	1.342	1.008	1.118
2003	1.052	0.896	0.768	0.981	1.370	1.072	1.173
2004	1.059	0.909	0.787	0.990	1.346	1.070	1.165
2005	1.058	0.891	0.740	0.990	1.431	1.069	1.187
2006	1.079	0.897	0.742	0.997	1.454	1.082	1.203
2007	1.096	0.941	0.749	1.064	1.463	1.030	1.166
2008	1.110	0.926	0.709	1.066	1.564	1.041	1.199
2009	1.111	0.923	0.693	1.071	1.604	1.038	1.204
2010	1.124	0.932	0.701	1.081	1.603	1.039	1.206
2011	1.116	0.954	0.735	1.095	1.517	1.019	1.170
2012	1.130	1.072	0.979	1.125	1.154	1.005	1.054
2013	1.127	1.005	0.802	1.145	1.405	0.984	1.121
2014	1.131	0.992	0.783	1.139	1.445	0.993	1.140
2015	1.152	0.985	0.773	1.134	1.491	1.016	1.170
Average Annual Change							
1999–2008	1.16%	–0.86%	–3.74%	0.71%	5.10%	0.45%	2.04%
2008–2015	0.54%	0.89%	1.23%	0.89%	–0.69%	–0.34%	–0.35%
1999–2015	0.89%	–0.10%	–1.60%	0.79%	2.53%	0.10%	0.99%

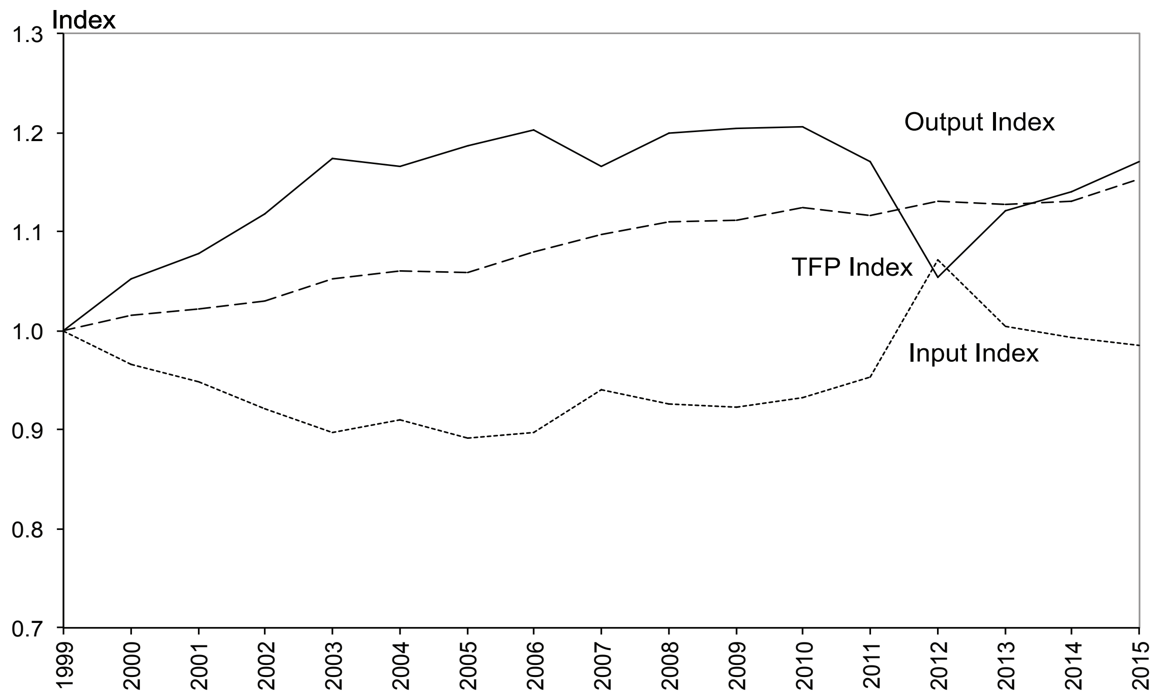
Source: Calculations using Economic Insights GDB database

Multinet experienced an average rate of output index of 0.9 per cent per year over the period 1999 to 2015, a much slower rate than those of AGN Vic and AusNet. This difference probably reflects the nature of its distribution region, which does not include any major residential growth corridors. Further, the growth rate of outputs slowed in the latter half of the period. It averaged 1.2 per cent per year between 1999 and 2008, decreasing to 0.5 per cent per year from 2008 to 2015.

Multinet's input index declined substantially between 1999 and 2008, at an average rate of 0.9 per cent per year. Over the period from 2008 to 2015, the input index increased by 0.9 per cent on average per year, which exceeded the rate of output growth over the same period. Over the whole period from 1999 to 2015, Multinet's input index decreased at an average annual rate of 0.1 per cent. The slight decline in Multinet's inputs from 1999 to 2015 compares favourably to AGN Vic's average input increase of 0.4 per cent and AusNet's average input increase of 0.6 per cent per year over the same period. These comparisons suggest that although Multinet's inputs have been slightly more contained than those of AGN Vic and AusNet, the much slower growth of its outputs has resulted in a lower average rate of TFP growth than those two businesses.

The methodology of measuring productivity using output and input indexes does not enable an exact assessment of the counterfactual situation in which Multinet's output index increased at a similar rate to those of AGN Vic and AusNet. If we calculate an average output index for AGN Vic and AusNet and divide this by Multinet's input index we would obtain indicative counterfactual TFP growth estimates for Multinet of 3.4 per cent for the period 1999 to 2008; 1.1 per cent for the period 2008 to 2015; and 2.4 per cent for the period 1999 to 2015. That is, TFP results comparable to those of AGN Vic and AusNet. However, while this comparison might be suggestive, it should be noted that the input and output indexes are not unrelated variables, since input requirements are driven by outputs, and if Multinet's outputs were different then its inputs would also be different.

Figure 3.7: **Multinet output, input and TFP indexes, 1999–2015**



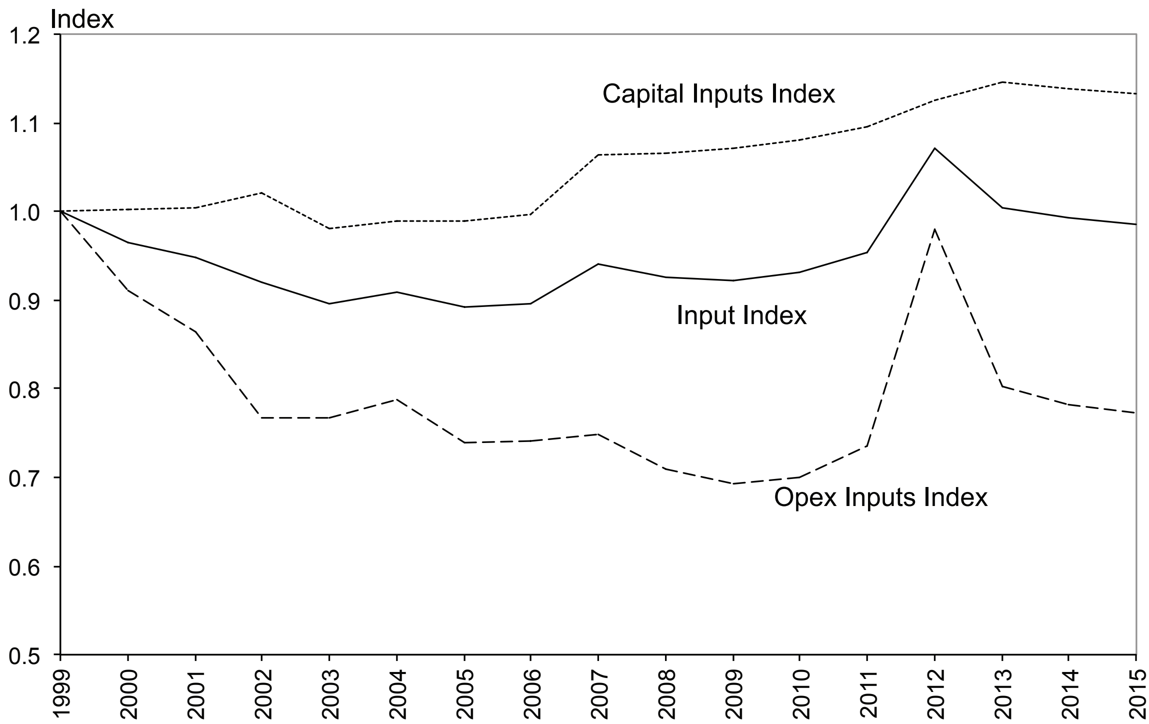
Source: Economic Insights GDB database

Figure 3.8 shows the capital and opex input indexes for Multinet. The capital input index has increased fairly steadily over the period 1999 to 2015, with an average rate of increase of 0.8 per cent per year, which is similar to the growth rate of the output index of 0.9 per cent.

In the period 1999 to 2008, opex inputs usage decreased at an average annual rate of 3.7 per cent. From 2008 to 2015, opex inputs use increased on average by 1.2 per cent per year. During this period there was a sharp spike in opex inputs in 2012, which has an important influence over the TFP results previously discussed. Over the whole period from 1999 to 2015, the average annual growth rate of opex inputs was –1.6 per cent per year, which represents a relatively substantial decline.

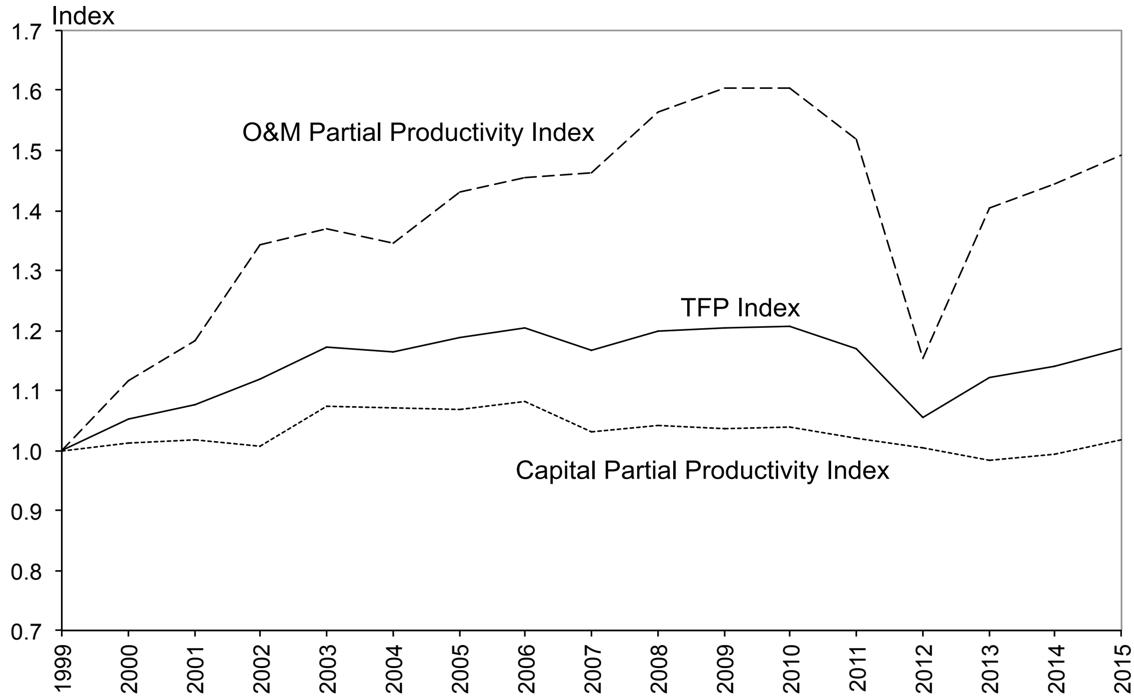
Figure 3.9 shows the partial factor productivity (PFP) indexes for Multinet. The TFP index is effectively a weighted average of the partial productivity indexes shown in figure 3.9. The opex PFP index measures output produced per unit of non–capital inputs, and the capital PFP index measures output per unit of capital inputs. Capital PFP increased only marginally between 1999 and 2015, averaging 0.1 per cent per year. Relatively flat capital PFP is common to most of the GDBs. Multinet's opex PFP increased strongly between 1999 and 2008 at an average rate of 5.1 per cent, but increased at 0.7 per cent annually, on average, from 2008 to 2015. The annual rate of opex partial productivity growth over the whole period from 1999 to 2015 was 2.5 per cent. This overall average opex PFP growth rate is lower than those of AGN Vic and AusNet, again reflecting Multinet's lower output growth rate in its more established supply region.

Figure 3.8: **Multinet inputs indexes, 1999–2015**



Source: Economic Insights GDB database

Figure 3.9: **Multinet partial productivity indexes, 1999–2015**



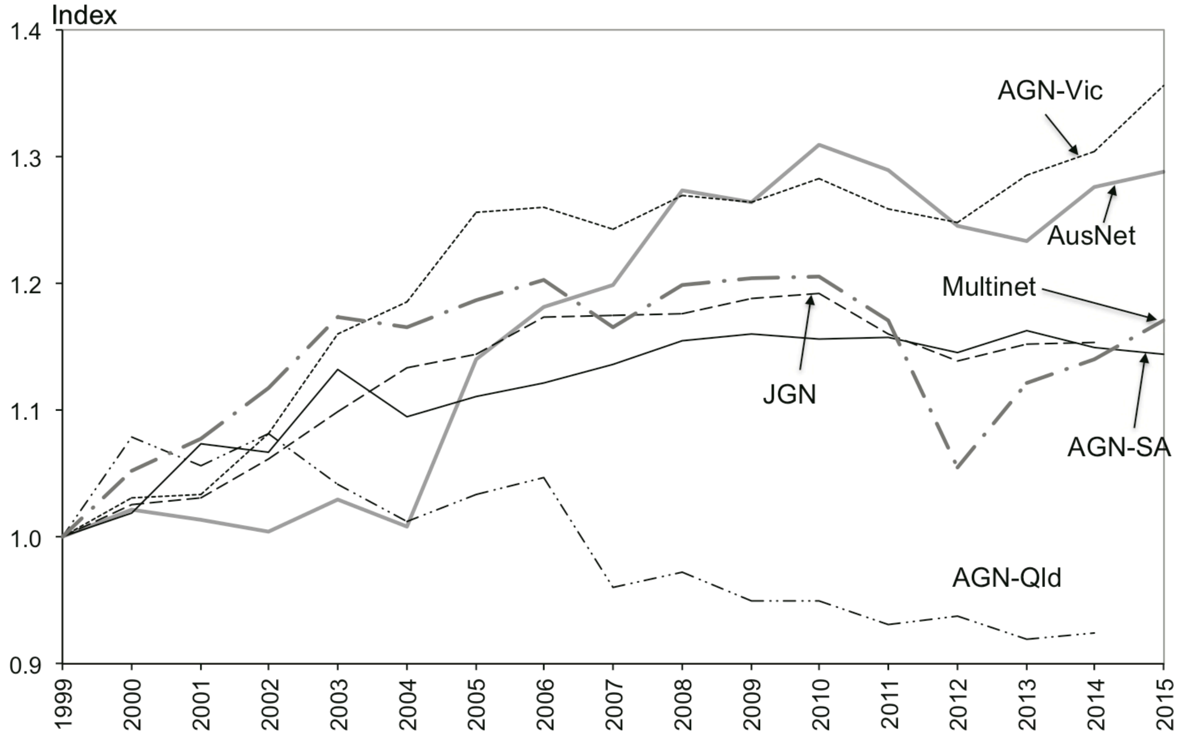
Source: Economic Insights GDB database

3.3 Comparison with interstate GDB productivity growth

This section makes summary observations about the productivity growth of the three Victorian GDBs and compares them with selected interstate GDBs, namely: AGN SA, AGN Qld and JGN in NSW. Output, input and productivity indexes and growth rates for JGN, AGN Qld and AGN SA are presented in tables 3.4, 3.5 and 3.6, at the end of this section.

The TFP performance of the three Victorian GDBs and three interstate GDBs is plotted in figure 3.10. Whereas the Victorian GDBs had similar TFP growth rates from 1999 to 2008, all more than 2 per cent per year, after 2008 there was greater divergence of TFP growth rates, and TFP growth rates were typically lower. AGN Vic, and to a lesser extent AusNet, appear to have maintained an upward TFP trend in the period since 2008. Multinet, JGN and AGN SA all appear to have had relatively flatter TFP over the period since 2008. For Multinet, there was a downturn in TFP in 2012 which had an important influence on its TFP trend, as discussed. AGN Qld is much smaller than the other GDBs and has a less favourable climate (for gas consumption), and its TFP has declined over most of the period since 1999.

Figure 3.10: **Comparative TFP indexes 1999 – 2015**



Source: Economic Insights GDB database

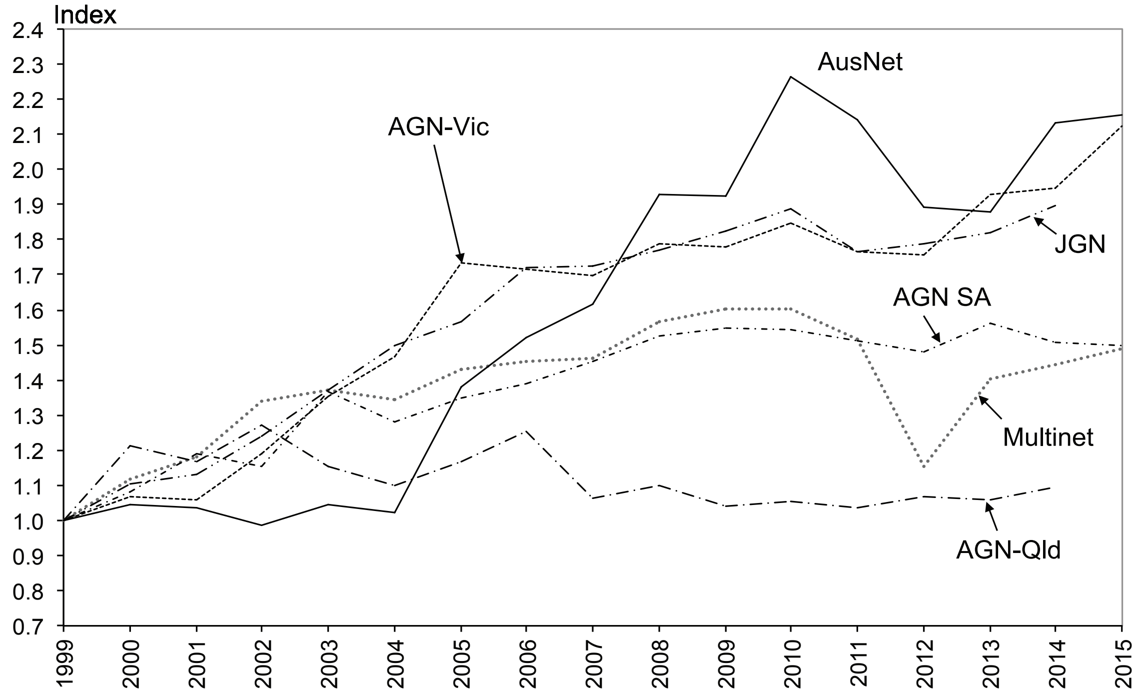
Figures 3.11 and 3.12 plot the Opex PFP indexes and the Capital PFP indexes respectively. Generally speaking, the capital partial productivity indexes have been comparatively flat and consequently most of the movement in the TFP indexes has been driven by changes in the Opex partial productivity indexes. Figure 3.11 shows that the Opex PFP trends for JGN and AGN Vic were broadly similar and, together with AusNet, had the highest growth over the period from 1999 to 2015. Opex PFP trends for AGN SA and Multinet were broadly similar, and grew somewhat less over the same period.

Movements in Opex PFP are a function of movements in the output index and movements in the Opex input index, since Opex PFP is the ratio between the output index and the Opex inputs index. To provide some insight into the Opex PFP trends, figure 3.13 shows the output indexes and figure 3.14 shows the indexes of real opex, which together determine the Opex PFP measure.

The most obvious point to note in figure 3.13 is that the growth rate of output has been much stronger for AGN Vic and AusNet than for the interstate GDBs, and considerably lower for Multinet than for most of the other GDBs. The NSW and SA GDBs have had relatively similar output index growth.

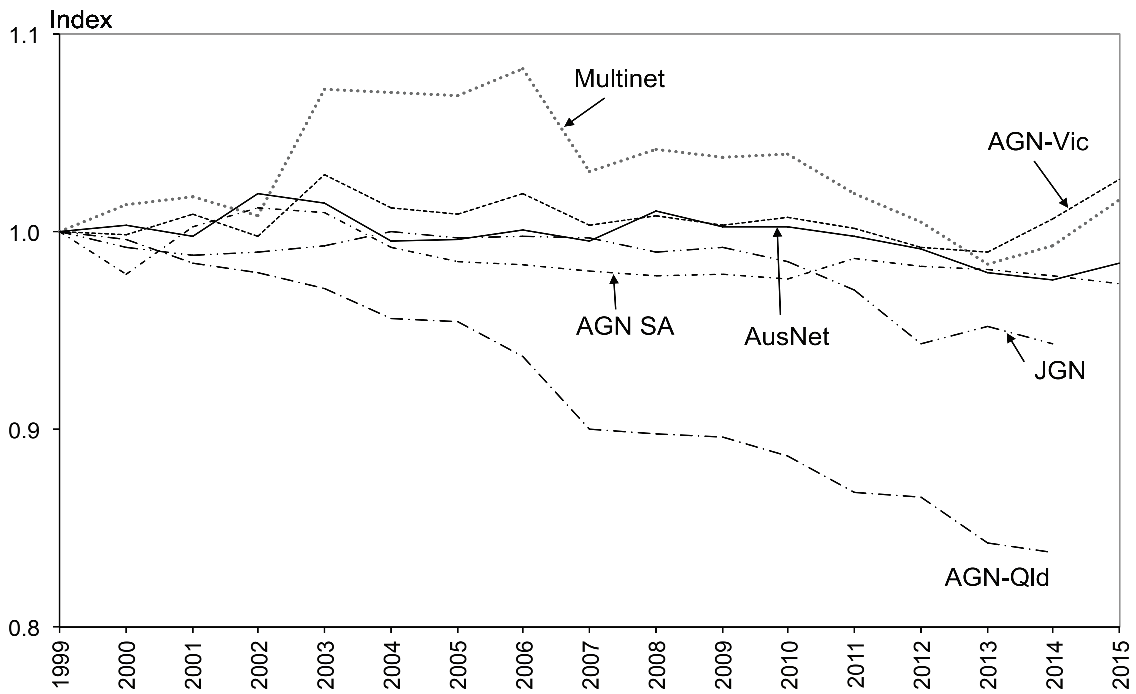
With regard to trends in the real Opex indexes, figure 3.14 suggests there were similar for the Victorian GDPs and for JGN, although in the case of Multinet there was an increase in the opex index particularly in 2012 and to a lesser extent thereafter, which reversed some part of the opex gains in previous periods.

Figure 3.11: **Comparative Opex PFP indexes, 1999 – 2015**



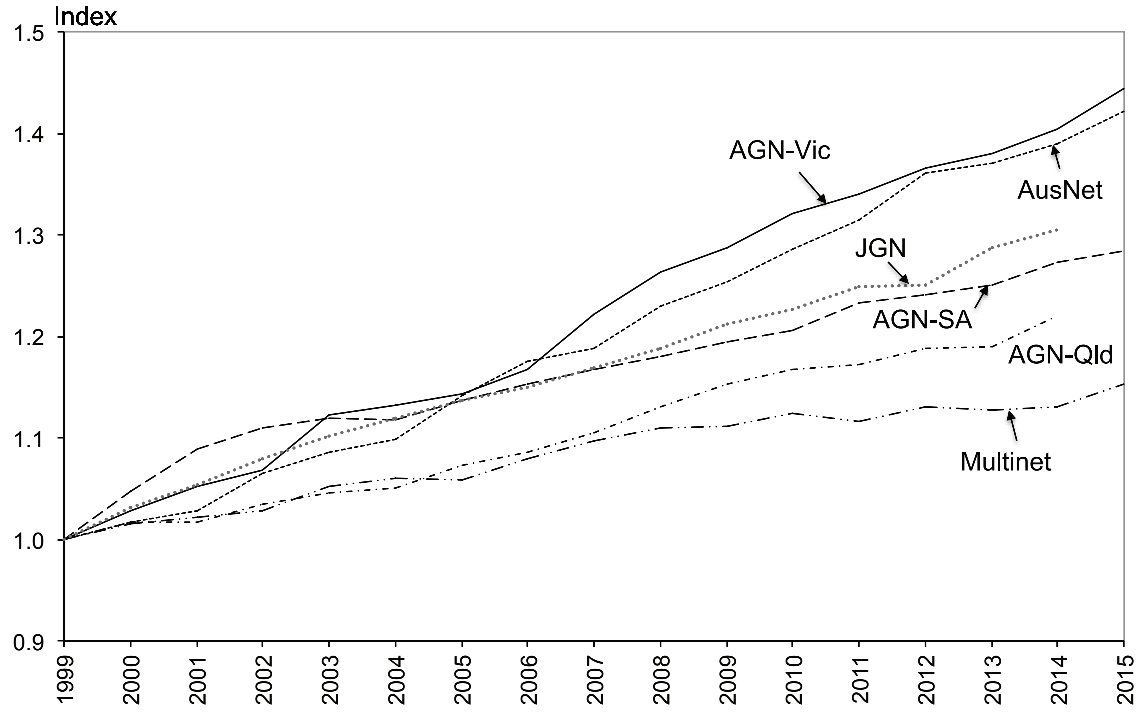
Source: Economic Insights GDB database

Figure 3.12: **Comparative Capital PFP indexes, 1999–2015**



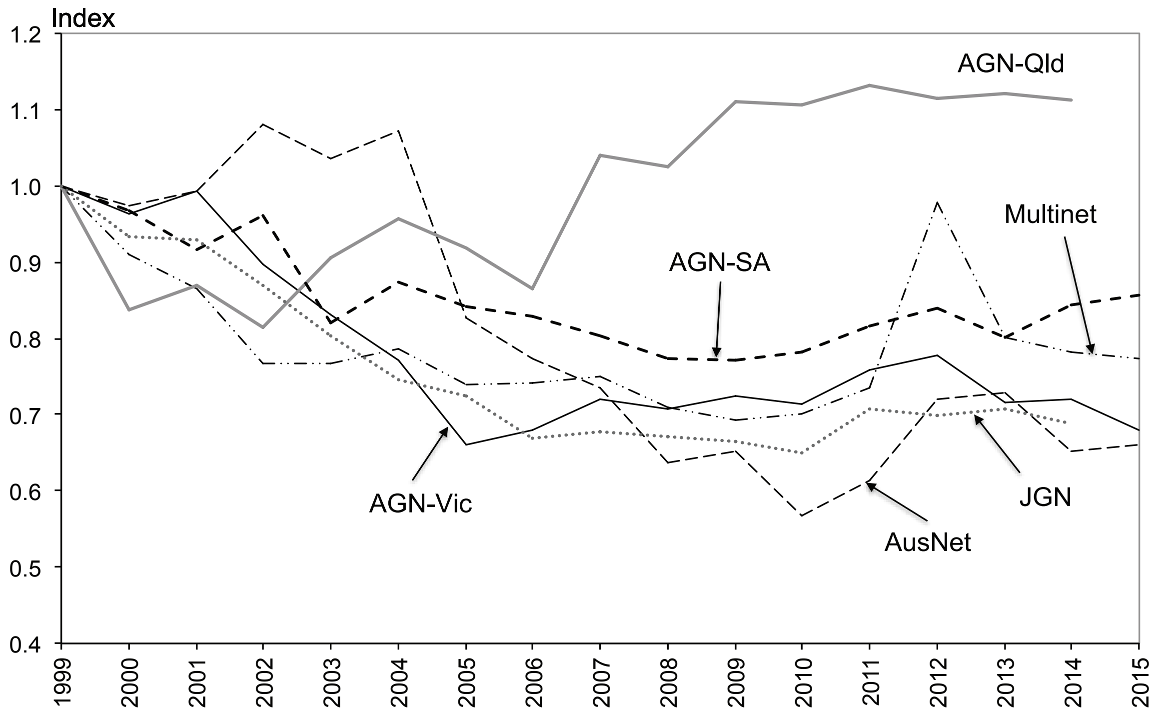
Source: Economic Insights GDB database

Figure 3.13: **Comparative Output indexes, 1999 – 2015**



Source: Economic Insights GDB database

Figure 3.14: **Comparative Opex indexes, 1999–2015**



Source: Economic Insights GDB database

Table 3.4: **Gas distribution productivity indexes for JGN, 1999–2014**

Year	Output	Input	Opex	Capital	PP Opex	PP Capital	TFP
1999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2000	1.032	1.006	0.934	1.040	1.104	0.992	1.025
2001	1.054	1.022	0.930	1.067	1.133	0.988	1.031
2002	1.079	1.016	0.870	1.090	1.240	0.990	1.062
2003	1.101	1.003	0.802	1.109	1.372	0.993	1.098
2004	1.120	0.988	0.746	1.119	1.500	1.000	1.133
2005	1.136	0.993	0.725	1.139	1.567	0.997	1.144
2006	1.150	0.979	0.669	1.152	1.719	0.998	1.174
2007	1.169	0.995	0.677	1.172	1.726	0.997	1.174
2008	1.188	1.010	0.672	1.200	1.768	0.990	1.176
2009	1.212	1.020	0.665	1.221	1.824	0.992	1.188
2010	1.226	1.028	0.650	1.245	1.887	0.985	1.193
2011	1.249	1.077	0.707	1.288	1.768	0.970	1.160
2012	1.251	1.098	0.699	1.326	1.788	0.944	1.139
2013	1.288	1.118	0.707	1.353	1.822	0.952	1.152
2014	1.304	1.131	0.688	1.383	1.895	0.943	1.154
Average Annual Change							
1999–2008	1.93%	0.11%	–4.32%	2.05%	6.54%	–0.11%	1.82%
2008–2014	1.57%	1.90%	0.40%	2.39%	1.16%	–0.81%	–0.33%
1999–2014	1.79%	0.82%	–2.46%	2.19%	4.35%	–0.39%	0.96%

Source: Economic Insights GDB database

Table 3.5: **Gas distribution productivity indexes for AGN Qld, 1999–2014**

Year	Output	Input	Opex	Capital	PP Opex	PP Capital	TFP
1999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2000	1.016	0.942	0.838	1.020	1.213	0.996	1.079
2001	1.016	0.962	0.870	1.032	1.169	0.984	1.056
2002	1.034	0.956	0.814	1.056	1.270	0.979	1.082
2003	1.046	1.004	0.905	1.077	1.156	0.971	1.042
2004	1.051	1.038	0.957	1.099	1.098	0.956	1.013
2005	1.073	1.038	0.919	1.125	1.168	0.954	1.034
2006	1.086	1.038	0.866	1.159	1.255	0.937	1.047
2007	1.105	1.150	1.041	1.228	1.062	0.900	0.960
2008	1.130	1.162	1.026	1.260	1.102	0.897	0.973
2009	1.153	1.214	1.110	1.287	1.039	0.896	0.950
2010	1.167	1.229	1.106	1.317	1.056	0.886	0.949
2011	1.172	1.260	1.132	1.350	1.035	0.868	0.930
2012	1.188	1.266	1.114	1.371	1.066	0.866	0.938
2013	1.190	1.294	1.122	1.412	1.060	0.843	0.919
2014	1.220	1.321	1.113	1.457	1.096	0.837	0.924
Average Annual Change							
1999–2008	1.37%	1.68%	0.28%	2.60%	1.08%	–1.20%	–0.31%
2008–2014	1.28%	2.16%	1.37%	2.45%	–0.09%	–1.14%	–0.86%
1999–2014	1.34%	1.87%	0.72%	2.54%	0.61%	–1.18%	–0.53%

Source: Economic Insights GDB database

Table 3.6: **AGN SA productivity indexes, 1999–2015**

Year	Output	Input	Opex	Capital	PP Opex	PP Capital	TFP
1999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2000	1.047	1.027	0.967	1.070	1.082	0.978	1.020
2001	1.089	1.015	0.915	1.086	1.190	1.003	1.073
2002	1.109	1.039	0.962	1.097	1.153	1.012	1.067
2003	1.120	0.989	0.819	1.110	1.367	1.009	1.133
2004	1.118	1.021	0.873	1.127	1.281	0.992	1.094
2005	1.137	1.024	0.842	1.155	1.350	0.985	1.110
2006	1.153	1.029	0.830	1.173	1.390	0.984	1.121
2007	1.167	1.027	0.803	1.190	1.452	0.980	1.136
2008	1.181	1.023	0.773	1.207	1.527	0.978	1.155
2009	1.194	1.029	0.771	1.221	1.550	0.978	1.161
2010	1.206	1.043	0.782	1.236	1.541	0.976	1.157
2011	1.234	1.066	0.816	1.250	1.511	0.987	1.157
2012	1.240	1.082	0.839	1.262	1.479	0.982	1.146
2013	1.251	1.076	0.801	1.275	1.562	0.981	1.163
2014	1.273	1.107	0.844	1.302	1.507	0.978	1.150
2015	1.284	1.122	0.856	1.319	1.500	0.973	1.145
Average Annual Change							
1999–2008	1.86%	0.25%	–2.82%	2.11%	4.82%	–0.25%	1.61%
2008–2015	1.21%	1.33%	1.46%	1.28%	–0.25%	–0.07%	–0.12%
1999–2015	1.57%	0.72%	–0.97%	1.75%	2.57%	–0.17%	0.85%

Source: Calculations using Economic Insights GDB database

4 PRODUCTIVITY LEVEL RESULTS

4.1 Multilateral TFP indexes

Traditional measures of TFP such as those discussed in section 3 have enabled comparisons to be made of rates of change of productivity between GDBs but have not enabled comparisons to be made of differences in the absolute levels of productivity in combined time series, cross section GDB data. This is due to the failure of conventional TFP measures to satisfy the important technical property of transitivity. This property states that direct comparisons between observations *m* and *n* should be the same as indirect comparisons of *m* and *n* via any intermediate observation *k*.

Caves, Christensen and Diewert (1982) developed the multilateral translog TFP (MTFP) index measure to allow comparisons of the absolute levels as well as growth rates of productivity. It satisfies the technical properties of transitivity and characteristicity which are required to accurately compare TFP levels within panel data. Lawrence, Swan and Zeitsch (1991) and the Bureau of Industry Economics (BIE 1996) have used this index to compare the productivity levels and growth rates of the five major Australian state electricity systems and the United States investor–owned system. Lawrence (2003) and Pacific Economics Group (PEG 2004) also used this index to compare electricity DB TFP levels and Lawrence (2007) used it to compare TFP levels across the three Victorian GDBs. Economic Insights (2009, 2010, 2012b,2014) have used this method in a number of GDB studies.

The multilateral translog index is given by:

(8)
$$\log (TFP_m/TFP_n) = \Sigma_i (R_{im}+R_i^*) (\log Y_{im} - \log Y_i^*)/2 - \Sigma_i (R_{in}+R_i^*) (\log Y_{in} - \log Y_i^*)/2 - \Sigma_j (S_{jm}+S_j^*) (\log X_{jm} - \log X_j^*)/2 + \Sigma_j (S_{jn}+S_j^*) (\log X_{jn} - \log X_j^*)/2$$

Where R_i^* (S_j^*) is the revenue (cost) share averaged over all utilities and time periods and $\log Y_i^*$ ($\log X_j^*$) is the average of the log of output *i* (input *j*). In the main application reported in the following section we have three outputs (throughput, customers and system capacity) and, hence, *i* runs from 1 to 3. In the MTFP analysis, transmission assets are not included, and consequently there are 7 inputs (opex, high pressure pipelines, medium pressure pipelines, low pressure pipelines, services pipelines, meters, and other capital) and, hence, *j* runs from 1 to 7. The Y_i and X_j terms are the output and input quantities, respectively. The R_i and S_j terms are the output and input weights, respectively.

The formula in (8) gives the proportional change in MTFP between two adjacent observations (denoted *m* and *n*). An index is formed by setting some observation (usually the first in the database) equal to one and then multiplying through by the proportional changes between all subsequent observations in the database to form a full set of indexes. The index for any observation then expresses its productivity level relative to the observation that was set equal to one. However, this is merely an expositional convenience as, given the invariant nature of the comparisons, the result of a comparison between any two observations will be independent of which observation in the database was set equal to one.

This means that when using equation (8), comparisons between any two observations *m* and *n* will be both base–distributor and base–year independent. Transitivity is satisfied since comparisons between the two GDBs for 1999 will be the same regardless of whether they are compared directly or via, say, one of the GDBs in 2002. An alternative interpretation of this index is that it compares each observation to a hypothetical average distributor with output vector $\log Y_i^*$, input vector $\log X_j^*$, revenue shares R_i^* and cost shares S_j^*.

As noted, transmission assets are excluded in the MTFP analysis in order to facilitate like–for–like comparisons between GDBs, as they tend to have differing amounts of transmission mains depending on the characteristics of the territory they serve and on past decisions relating to vertical separation.

4.2 Productivity levels comparisons

The multilateral TFP indexes for six GDBs are presented in table 4.1 and figure 4.1. The indexes are calculated relative to AGN Vic in 1999 having a value of one. These indexes can, of course, be influenced by a number of factors, such as economies of scale, which are mostly not controlled for in this comparison.

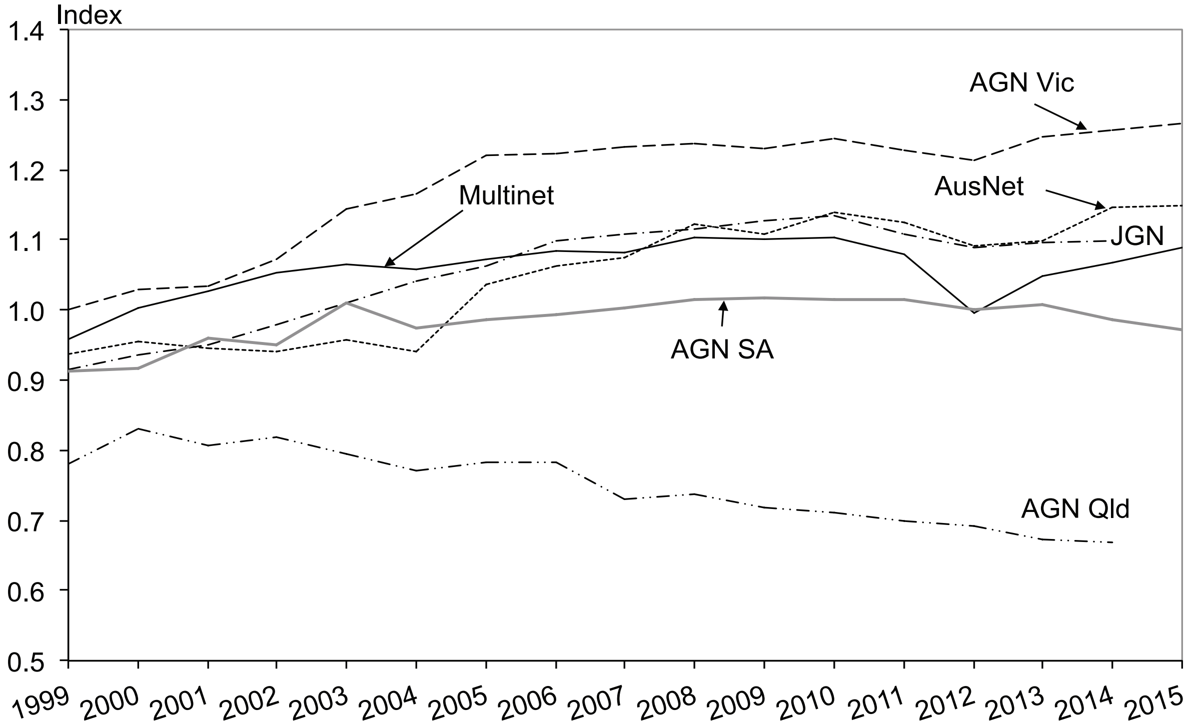
Table 4.1: **GDB multilateral TFP indexes, 1999–2015**

	AGN Vic	Multinet	AusNet	JGN	AGN SA	AGN Qld
1999	1.000	0.958	0.937	0.915	0.913	0.781
2000	1.029	1.004	0.955	0.936	0.917	0.831
2001	1.033	1.028	0.947	0.950	0.961	0.807
2002	1.073	1.053	0.941	0.979	0.952	0.820
2003	1.145	1.066	0.958	1.011	1.011	0.794
2004	1.165	1.058	0.940	1.041	0.974	0.771
2005	1.221	1.073	1.037	1.063	0.987	0.782
2006	1.223	1.085	1.063	1.098	0.993	0.784
2007	1.232	1.083	1.076	1.108	1.004	0.731
2008	1.237	1.103	1.121	1.115	1.015	0.738
2009	1.230	1.101	1.108	1.128	1.018	0.719
2010	1.244	1.104	1.140	1.134	1.015	0.712
2011	1.228	1.080	1.126	1.108	1.015	0.698
2012	1.213	0.995	1.092	1.089	1.000	0.691
2013	1.246	1.048	1.099	1.096	1.007	0.672
2014	1.258	1.068	1.146	1.099	0.986	0.669
2015	1.265	1.090	1.149	.	0.973	.

Source: Calculations using Economic Insights GDB database

The MTFP results indicate that in the latest years available, AGN Vic is found to have the highest TFP level—an MTFP index of 1.27 in 2015—approximately 10% higher than the next highest (AusNet) TFP level. AusNet's MTFP index in 2015 of 1.15 is only slightly higher than those of JGN (1.10) and Multinet (1.09). AGN SA's MTFP index level in 2015 (0.97) is approximately 11–16 per cent lower than these three GDBs.

Figure 4.1: **GDB multilateral TFP indexes, 1999–2015**

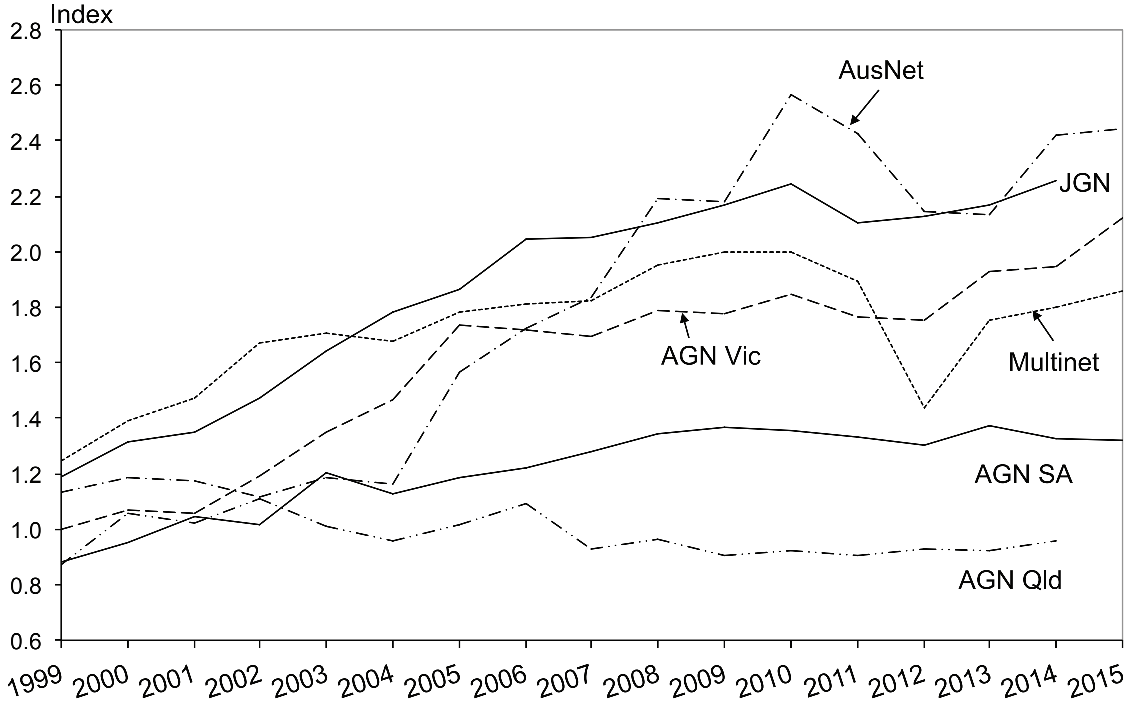


Source: Economic Insights GDB database

Figure 4.2 compares the *levels* of Opex PFP using multilateral Opex PFP indexes for the six GDBs, and figure 4.3 compares Capital PFP levels using multilateral Capital PFP indexes. These indexes are also presented in tables 4.2 and 4.3 respectively.

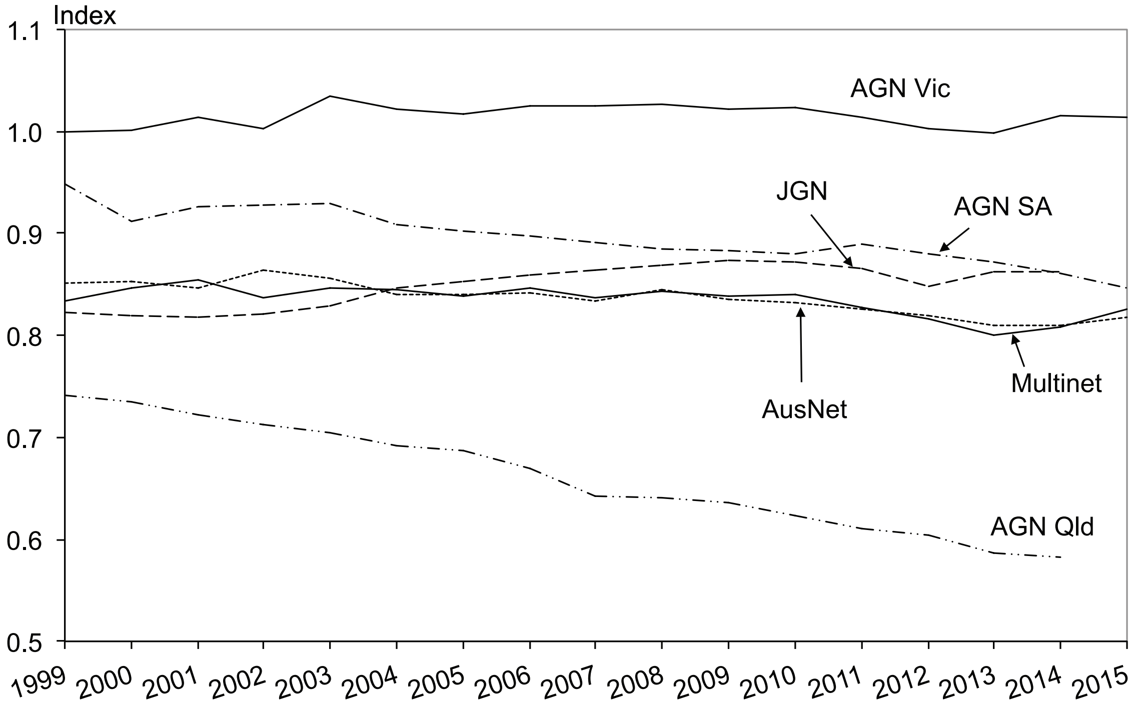
Figure 4.2 shows that AusNet has the highest Opex PFP level in the latest year available (2.44 in 2015). JGN is close to AusNet in terms of Opex PFP level (2.25 in 2014). JGN compares better against the Victorian gas networks in terms of Opex PFP levels than it does for TFP levels. AGN Vic's and Multinet's Opex PFP levels are below those of AusNet (2.12 and 1.86 respectively in 2015), but much higher than AGN SA (1.32 in 2015) and AGN Qld (0.96 in 2014), which have Opex PFP levels well below those of the other GDBs.

Figure 4.2: **GDB multilateral Opex PFP indexes, 1999–2015**



Source: Economic Insights GDB database

Figure 4.3: **GDB multilateral Capital PFP indexes, 1999–2015**



Source: Economic Insights GDB database

Table 4.2: **GDB multilateral Opex PFP indexes, 1999–2015**

	AGN Vic	Multinet	AusNet	JGN	AGN SA	AGN Qld
1999	1.000	1.247	1.135	1.189	0.881	0.873
2000	1.068	1.391	1.186	1.313	0.954	1.059
2001	1.059	1.475	1.174	1.348	1.048	1.020
2002	1.190	1.673	1.117	1.474	1.016	1.108
2003	1.352	1.708	1.188	1.643	1.204	1.009
2004	1.465	1.678	1.162	1.785	1.128	0.958
2005	1.734	1.784	1.568	1.864	1.189	1.020
2006	1.716	1.813	1.724	2.044	1.224	1.095
2007	1.696	1.825	1.835	2.052	1.279	0.927
2008	1.786	1.950	2.189	2.103	1.345	0.962
2009	1.777	2.000	2.182	2.169	1.365	0.907
2010	1.848	1.999	2.569	2.244	1.358	0.922
2011	1.765	1.892	2.428	2.102	1.331	0.904
2012	1.754	1.439	2.145	2.127	1.303	0.930
2013	1.927	1.752	2.132	2.166	1.376	0.926
2014	1.946	1.801	2.419	2.254	1.328	0.957
2015	2.122	1.859	2.443	.	1.321	.

Source: Calculations using Economic Insights GDB database

Table 4.3: **GDB multilateral Capital PFP indexes, 1999–2015**

	AGN Vic	Multinet	AusNet	JGN	AGN SA	AGN Qld
1999	1.000	0.834	0.851	0.823	0.948	0.742
2000	1.002	0.847	0.853	0.819	0.912	0.736
2001	1.014	0.854	0.847	0.818	0.926	0.722
2002	1.003	0.837	0.864	0.821	0.929	0.713
2003	1.035	0.847	0.857	0.829	0.929	0.705
2004	1.022	0.845	0.840	0.846	0.909	0.693
2005	1.017	0.838	0.839	0.854	0.903	0.687
2006	1.025	0.847	0.842	0.859	0.898	0.669
2007	1.024	0.837	0.834	0.864	0.892	0.643
2008	1.026	0.844	0.844	0.868	0.885	0.641
2009	1.022	0.839	0.836	0.874	0.883	0.635
2010	1.023	0.840	0.833	0.871	0.881	0.623
2011	1.014	0.828	0.825	0.865	0.890	0.610
2012	1.002	0.816	0.820	0.849	0.880	0.604
2013	0.998	0.800	0.810	0.862	0.872	0.587
2014	1.015	0.808	0.810	0.862	0.861	0.583
2015	1.014	0.826	0.818	.	0.846	.

Source: Calculations using Economic Insights GDB database

5 CONCLUSIONS

The time series TFP results for the three Victorian GDBs are as follows:

- AGN Vic has had a reasonably consistent upward trend in TFP. On average TFP increased by 2.7 per cent per year from 1999 to 2008 and by approximately 1.0 per cent per year in the period from 2008 to 2015, reflecting reduced TFP growth over the last several years. Over the whole period from 1999 to 2015, AGN Vic's TFP index increased at a relatively strong average annual rate of 1.9 per cent.
- Except for the period 2011 to 2013, AusNet has had a reasonably consistent upward trend in TFP. On average TFP increased by 2.7 per cent per year from 1999 to 2008 and by 0.2 per cent per year in the period from 2008 to 2015. TFP has grown over the last two years. Over the whole period from 1999 to 2015, AusNet's TFP index increased at a relatively strong average annual rate of 1.6 per cent.
- Prior to 2011, Multinet had a reasonably consistent upward trend in TFP, however, there was a downturn in TFP in 2012 with only partial recovery since then, and this has had an important influence on its average TFP trend since 2008. On average Multinet's TFP increased by 2.0 per cent per year from 1999 to 2008 and decreased at an average rate of approximately 0.4 per cent per year in the period from 2008 to 2015. TFP has grown over the last three years. Over the whole period from 1999 to 2015, the TFP index increased at an average annual rate of 1.0 per cent.

AGN Vic has experienced a relatively high rate of output index growth throughout the period 1999 to 2015, averaging 2.3 per cent per year. AusNet also experienced a relatively high rate of output index throughout the period 1999 to 2015 of 2.2 per cent per year, which is very similar to that of AGN Vic. The distribution regions of those two GDBs include Melbourne's major growth corridors. The characteristics of Multinet's more established distribution region are such that its output increased much more slowly than the other two GDBs. Multinet's output index increased at an average rate of 0.9 per cent per year over the period 1999 to 2015. It is reasonable to expect that this factor would explain much of the difference between the TFP growth results of Multinet and the other two Victorian GDBs.

Another important element of the productivity story is, of course, the trends in input use. Over the period from 1999 to 2015, AGN Vic's input index increased at an average annual rate of 0.4 per cent. AusNet's input index increased at an average annual rate of 0.6 per cent, while Multinet's input index decreased at a rate of 0.1 per cent per year over the same period.

Partial factor productivity (PFP) indexes assist to understand the movements in the TFP index. The Opex PFP index measures output produced per unit of non–capital inputs, and the Capital PFP index measures output per unit of capital inputs. Capital PFP was relatively flat for most of the GDBs over the whole period from 1999 to 2015, and the Opex PFP trends are of most interest:

- AGN Vic's opex PFP increased strongly between 1999 and 2008 at an average rate of 6.7 per cent, and increased at 2.5 per cent annually, on average, from 2008 to 2015. The annual rate of opex partial productivity growth over the whole period from 1999 to 2015 was 4.8 per cent.

- AusNet's opex PFP increased strongly between 1999 and 2008 at an average rate of 7.6 per cent, and increased at 1.6 per cent annually, on average, from 2008 to 2015. The annual rate of opex partial productivity growth over the whole period from 1999 to 2015 was 4.9 per cent, which is quite similar to that of AGN Vic.
- Multinet's opex PFP increased strongly between 1999 and 2008 at an average rate of 5.1 per cent, and increased at 0.7 per cent annually, on average, from 2008 to 2015. The annual rate of opex partial productivity growth over the whole period from 1999 to 2015 was 2.5 per cent, which is lower than those of AGN Vic and AusNet, and which again reflects Multinet's lower output growth rate in its more established supply region.

The multilateral total factor productivity (MTFP) index is used to measure comparative productivity *levels*. The MTFP results indicate that in the latest years available, AGN Vic had the highest productivity level—approximately 10% higher than that of AusNet. The latter's total factor productivity level in 2014 was similar to JGN's and Multinet's. AGN SA's MTFP index level in 2015 was lower than those of the three larger Victorian GDBs, and AGN Qld's MTFP in 2014 was significantly lower again, reflecting its much smaller scale and the lack of spacing heating required in its subtropical service area

APPENDIX A: DERIVING OUTPUT COST SHARE WEIGHTS

This study uses multi–output Leontief cost function method applied in Lawrence (2007) to derive output cost share weights. These weights are then used as the revenue shares in forming the multilateral output index outlined in appendix A. This multi–output Leontief functional form essentially assumes that GDBs use inputs in fixed proportions for each output and is given by:

(A1) $$C(y^t, w^t, t) = \sum_{i=1}^{M} w_i^t \left[\sum_{j=1}^{N} (a_{ij})^2 y_j^t (1+b_i t)\right]$$

where there are M inputs and N outputs, w_i is an input price, y_j is an output and t is a time trend representing technological change. The input/output coefficients a_{ij} are squared to ensure the non–negativity requirement is satisfied, ie increasing the quantity of any output cannot be achieved by reducing an input quantity. This requires the use of non–linear regression methods. To conserve degrees of freedom a common rate of technological change for each input across the three outputs was imposed but this can be either positive or negative.

The estimating equations were the M input demand equations:

(A2) $$x_i^t = \sum_{j=1}^{N} (a_{ij})^2 y_j^t (1+b_i t)$$

where the i's represent the M inputs, the j's the N outputs and t is a time trend representing the nine years, 1998 to 2006.

The input demand equations were estimated separately for each of the three GDBs using the non–linear regression facility in Shazam (White 1997) and data for the years 1998 to 2006. Given the limited number of observations and the absence of cross equation restrictions, each input demand equation is estimated separately.

Lawrence (2007) then derived the output cost shares for each output and each observation as follows:

(A3) $$h_j^t = \left\{\sum_{i=1}^{M} w_i^t [(a_{ij})^2 y_j^t (1+b_i t)]\right\} / \left\{\sum_{i=1}^{M} w_i^t \left[\sum_{j=1}^{N} (a_{ij})^2 y_j^t (1+b_i t)\right]\right\}.$$

Lawrence (2007) then formed a weighted average of the estimated output cost shares for each observation to form an overall estimated output cost share where the weight for each observation, b, is given by:

(A4) $$s_b^t = C(b, y_b^t, w_b^t, t) / \sum_{b,t} C(b, y_b^t, w_b^t, t).$$

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ATTACHMENT A: CURRICULUM VITAE

Michael Cunningham

Position	Associate
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Qualifications

Master of Commercial Law, Melbourne University

Master of Commerce (Hons), Melbourne University

Bachelor of Economics, Monash University

Key Skills and Experience

Michael Cunningham became an Associate of Economic Insights in late 2013 following more than a decade as a senior regulatory manager with the Essential Services Commission of Victoria. Michael has extensive experience in the regulation of energy, water and transport networks and in detailed productivity analysis.

Michael developed Victoria's minimum feed-in tariffs for 2014, and conducted research into Victoria's energy retail market, including methods for estimating retailer margins, and research into emerging regulatory issues such as household electricity control products. He produced the ESC's analysis of the productivity of the Victorian water industry in 2012, and on secondment to the Victorian Competition and Efficiency Commission in 2011, for the Inquiry into a State-Based Reform Agenda, he was lead author of its Productivity Information Paper (Dec 2011).

In August 2011, Michael produced a substantial ESC internal research report on "Returns to Businesses in Regulatory Decision Making: What is best practice?" which examined in detail the broad range of issues relating to regulated rates of return.

Michael has led many key ESC reviews, including:

- Review of the Rail Access Regime 2009-10
- Reviews of Victorian Ports Regulation 2009 & 2004
- Reviews of Grain Handling Access Regime 2009, 2006 & 2002
- Taxi Fare Review 2007-08
- Review of Port Planning 2007

- Implementing the Victorian rail access regime 2005 & rail access arrangement approvals 2006 & 2009
- Review of the Supply of Bottled LPG in Victoria 2002.

Prior to joining the ESC, Michael was a commercial advisor at Gascor Pty Ltd for the re-determination of the natural gas price under Victoria's (then) principal gas supply contract for Gippsland gas. From 1997 to 1999, he was an Associate Analyst at Credit Suisse First Boston Australian Equities, carrying out financial analysis of Australia listed infrastructure businesses and utilities. For more than 10 years Michael was employed by Gas & Fuel Corporation Victoria (GFCV) and was responsible for developing forecasting models, operations research, project evaluation, developing management performance reporting systems and tariff design.

As Manager, Resource Strategy, he participated in contract negotiations, and carried out key analysis, relating to the supply of LNG (for the Dandenong storage facility), and participated in the development of gas transmission prices. From 1994 to 1997, he was seconded to the Gas Industry Reform Unit (GIRU) in Victoria's Treasury department and assisted with the negotiation and settlement of the Resource Rent Tax dispute between GFCV and Esso-BHP (approximately $1 billion in claims). He was a member of the negotiating team that settled a new 13-year gas supply agreement to supply 95% of Victoria's natural gas. In addition to being a member of the negotiating team, he was responsible for carrying out all of the forecasting and risk analysis of key contractual terms such as take-or-pay, maximum day quantity, quantity renomination options etc.

Recent Publications

- Journal article: 'Productivity Benchmarking the Australian Water Utilities' *Economic Papers* (June 2013)
- Conference paper: Cunningham M B & Harb, D 'Multifactor productivity at the sub-national level in Australia', 41st Australian Conference of Economists 2012
- Submissions:
  - 'Submission to MCE consultation on the separation of electricity transmission and distribution' (Nov 2011)
  - 'Submission to AEMC consultation on AER rule change request' (Dec 2011)
  - 'Submission to PC Consultation on Electricity Network Regulation' (Apr 2012)
  - 'Processes for stakeholder negotiation for electricity regulation', submission to PC (Nov 2012)
  - 'Submission to Productivity Commission Review of the National Access Regime' (Feb 2013).
  - 'Options to Strengthen the Law Prohibiting Misuse of Market Power' submission to C'th Treasury (Feb 2016).

ATTACHMENT B: DECLARATION

I, Michael Bradbury Cunningham, Associate of Economic Insights Pty Ltd, declare that I have read the Federal Court Guidelines for Expert Witnesses and that I have made all inquiries I believe are desirable and appropriate and that no matters of significance which I regard as relevant have, to the best of my knowledge, been withheld.

Michael Bradbury Cunningham

15 June 2016