Attachment 4.1

The Productivity Performance of Australian Gas Networks' South Australian Gas Distribution System

A report by Economic Insights

2016/17 to 2020/21 Access Arrangement Information

Australian Gas Networks

The Productivity Performance of Australian Gas Networks' South Australian Gas Distribution System

Report prepared for
Australian Gas Networks Limited

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EXECUTIVE SUMMARY

Australian Gas Networks Limited (AGN) has commissioned Economic Insights to examine the total factor productivity (TFP) and partial factor productivity (PFP) performance of its South Australian gas distribution system (‘AGN SA’). As well as examining the TFP and PFP growth of AGN SA, Economic Insights has been requested to compare the levels of AGN SA’s productivity with those of other gas distribution businesses (GDBs), including the three Victorian gas distribution businesses — AGN Victoria, Multinet and AusNet Services — New South Wales’ largest GDB, Jemena Gas Networks (JGN), and AGN’s gas distribution business in Queensland (‘AGN Qld’).

The primary data source for this study is information supplied by AGN for AGN SA and AGN Qld, and similar information previously presented by JGN and the three Victorian GDBs in response to common detailed data surveys by Economic Insights. The surveys cover key output and input value, price and quantity information for the historic period 1999 to 2014 in the case of AGN SA, AGN Qld and JGN; and 1999 to 2011 for the three Victorian 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.

AGN SA’s changes in output and input quantities have led to TFP growth averaging 0.9 per cent annually over the last 15 years. This performance has been driven largely by significant reductions in non-capital inputs (“opex”) in the earlier part of this period. Its partial productivity of opex grew strongly at the high annual rate of 4.6 per cent between 1999 and 2008, and TFP growth averaged 1.6 per cent annually over the same period. AGN SA’s TFP and opex partial productivity were relatively flat over the period 2008 to 2014, averaging −0.1 and 0.2 per cent per year, respectively.

Over the period since 1999, AGN SA’s average productivity growth rate of 0.9 per cent annually is consistent with that of JGN, greater than AGN Qld (−0.5 per cent) and lower than the Victorian GDBs (1.9 per cent). Since productivity growth is generally weaker among the GDBs in the post-2008 period, when the TFP of the Victorian GDBs is extrapolated over the period to 2014 (using their TFP growth rate from 2008 to 2011) it is likely to be around 1.5 per cent annually over the whole period 1999 to 2014. This is a more appropriate basis of comparison with the other GDBs.

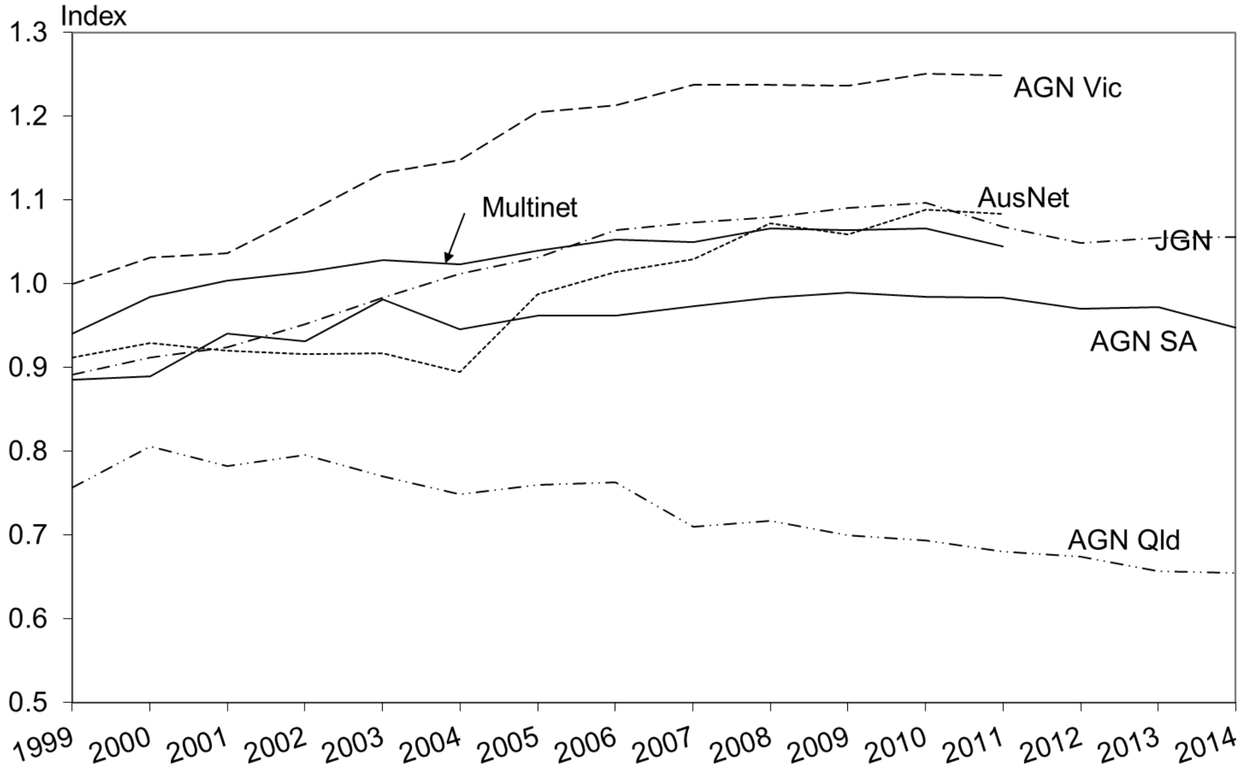
The pattern of strong productivity growth during the period 1999 to 2008 and relatively flat TFP growth after 2008 for AGN SA is common also to the Victorian GDBs and JGN. The annual average TFP growth rate of AGN SA between 2008 and 2014 of −0.1 per cent can be compared to −0.3 per cent for JGN over the same period, and +0.2 per cent for the Victorian GDBs over the period 2008 to 2011.

The MTFP results indicate that AGN SA is close to JGN’s and Multinet’s productivity levels (see figure A). For example in 2011, which is the latest year for which Multinet data is available, there was approximately a 7 per cent difference between the productivity levels of AGN SA and these two businesses. There has also been reasonable comparability with AusNet over most of the sample period. On the other hand, AGN Victoria had a higher level of productivity than the other comparator GDBs, and AGN Qld a lower level of productivity.

This comparison is favourable for AGN SA given that the operating environment conditions differ between GDBs. The three Victorian GDBs have higher domestic customer density and energy density per kilometre of main when compared to JGN and AGN SA. Furthermore, AGN SA is relatively small compared to JGN and the three Victorian GDBs. In terms of throughput it is less than half the size of each of the three Victorian GDBs and just over a quarter the size of JGN and in terms of customer numbers is around two thirds the size of the Victorian GDBs and less than 40 per cent the size of JGN.

The MTFP comparisons do not control for differences in scale or fully adjust for different operating environment conditions. While its scale and operating environment conditions could be expected to place AGN SA at a disadvantage in comparisons of productivity levels, it performs relatively well by almost matching the performance of some of the larger included GDBs. Taking the differences in network density and size into account, the results of this study indicate that AGN SA is most likely to be an efficient performer.

Figure A: **GDB multilateral TFP indexes, 1999–2014**



Source: Economic Insights GDB database

1 INTRODUCTION

1.1 Terms of reference

Australian Gas Networks Limited (AGN) (formerly Envestra Pty Ltd) has commissioned Economic Insights Pty Ltd (‘Economic Insights’) to provide advice on productivity measurement and benchmarking in relation to its South Australian gas distribution business. The advice provided in this report details analysis of AGN South Australia’s gas distribution total factor productivity (TFP) and partial factor productivity (PFP) trends over time. This report also provides a comparative analysis of AGN SA’s relative productivity levels and relative productivity growth rates using multilateral TFP.

This study entails updating and extending the analysis that Economic Insights undertook for Envestra in 2010 on the productivity performance of Envestra’s South Australian and Queensland gas distribution systems (Economic Insights 2010).

A copy of the letter of engagement for the study is presented in Attachment A.

1.2 Approach to this Study

The study concentrates on performance of AGN’s South Australian (SA) gas distribution networks in the period from 1999 to 2014. The primary data source for this study is information supplied by AGN in relation to its SA networks, and similar data provided in previous years by JGN and the three Victorian GDBs in response to common detailed data surveys. The surveys covered key output and input value, price and quantity information for the historic period 1999 to 2014 in the case of AGN SA; 1999 to 2013 in the case of JGN; 1999 to 2011 for the three Victorian GDBs. No forecast data are used for any of the included GDBs.

Measures of TFP and PFP are developed in this report using time series and multilateral indexes, and these are used to compare AGN SA’s productivity growth rates and productivity levels with the Victorian and NSW GDBs. The time series TFP analysis involves developing 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 analysis provides estimates of AGN SA’s TFP growth over the period 1999 to 2014 and compares this to TFP growth for other 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 U.S. 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), Envestra South Australian and Queensland (Economic Insights 2010), and the three Victorian GDBs (Economic Insights 2012a; b), among others.

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 indexes for AGN SA over the period 1999 to 2014, and provides comparative information for other GDBs.

Chapter 4 presents a comparative analysis of the TFP levels of AGN SA and other major GDBs 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 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 has been prepared by Michael Cunningham who is an Associate of Economic Insights. A summary CV for Michael is presented in Attachment B. 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 C 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) $$T\dot{F}P = \dot{Q} - \dot{I}$$

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) $$TFP = Q/I_i$$

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[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 SA, AGN Qld, JGN and the three Victorian GDBs in response to common detailed data surveys. The surveys covered key output and input value, price and quantity information for the historic period 1999 to 2014 for AGN SA; for 1999 to 2014 in the case of JGN; and for 1999 to 2011 in the case of the Victorian GDBs. 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. 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.

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 Labour cost 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.[2]

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.

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 done by GHD (reported in SKM 1998). These valuations present DORC valuations for 12 asset categories

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[2] 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.

for each of the three GDBs. Asset life and remaining asset life estimates are also provided for each of the 12 asset categories. As distribution pipelines are presented as one category in the GHD valuations, we distribute this value between high, medium and low pressure pipelines using a common formula across the three GDBs based on their specific line lengths by pressure type and estimates of relative construction costs for each of the three pressure types.

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.

AGN SA's 1998 asset values were used as the starting point for the asset roll forward. A similar approach was adopted for JGN, where the 1999 IPART RAB is used as the starting point, and 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 AGN SA, AGN Qld, JGN and the three Victorian GDBs are presented in table 2.1 for 2011, the latest year for which actual Victorian data are available in the database. In terms of throughput AGN SA is less than half the size of each of the three Victorian GDBs and just over a quarter the size of JGN. In terms of customer numbers AGN SA is less than three quarters the size of each of the three Victorian GDBs and around 40 per cent the size of JGN. To the extent that economies of size are important in gas distribution, AGN SA will be at a disadvantage relative to both JGN and the three Victorian GDBs.

As noted in section 3.3, the two key operating environment characteristics which influence energy distribution business productivity levels are energy density (throughput per customer) and customer density (customers per kilometre of mains). Together these determine the energy throughput per kilometre of distribution mains. In terms of energy density AGN SA has significantly lower density than the three Victorian GDBs and around 30 per cent lower density than JGN.

Table 2.1: **Included GDBs' key characteristics, 2011**

GDB	Throughput *TJ*	Customers *No*	System capacity *Sm³*	Distribution mains length *kms*	Energy density *GJ/cust.*	Customer density *Cust./km*	Energy per unit mains *TJ/km*
AGN SA	25,651	403,446	91,600	7,210	64	56	3.6
AGN Qld	5,520	84,975	27,258	2,436	65	35	2.3
JGN	100,169	1,110,566	370,698	24,416	90	45	4.1
AGN Vic	56,568	566,001	142,526	10,622	100	53	5.3
Multinet	55,896	673,154	122,169	9,728	83	69	5.7
AusNet	67,480	593,197	127,308	15,763	114	38	4.3

Source: Economic Insights GDB database

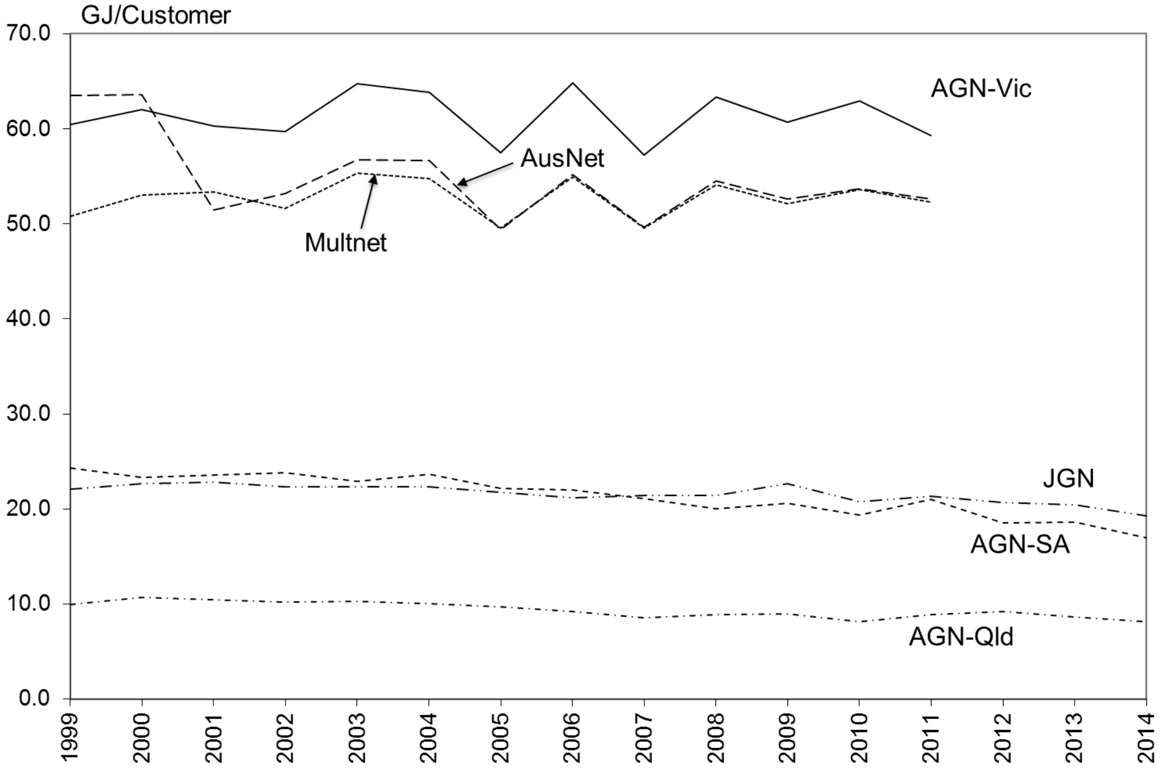
However, these energy densities are overall figures across domestic, commercial and industrial customers and a key cost driver for GDBs is domestic energy density. GDBs operating in a temperate climate will be at an obvious disadvantage relative to GDBs operating in cold climates where there is a much 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. These densities are less than 40 per cent those of the three Victorian GDBs. 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. This is further highlighted by the share of domestic energy throughput in total throughput across the GDBs. In 2011 domestic throughput accounted for 45 per cent of AusNet's throughput, 50 per cent of AGN Victoria's throughput and 70 per cent of Multinet's throughput. By contrast it accounted for 23 per cent of JGN's throughput and 32 per cent of AGN SA'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.

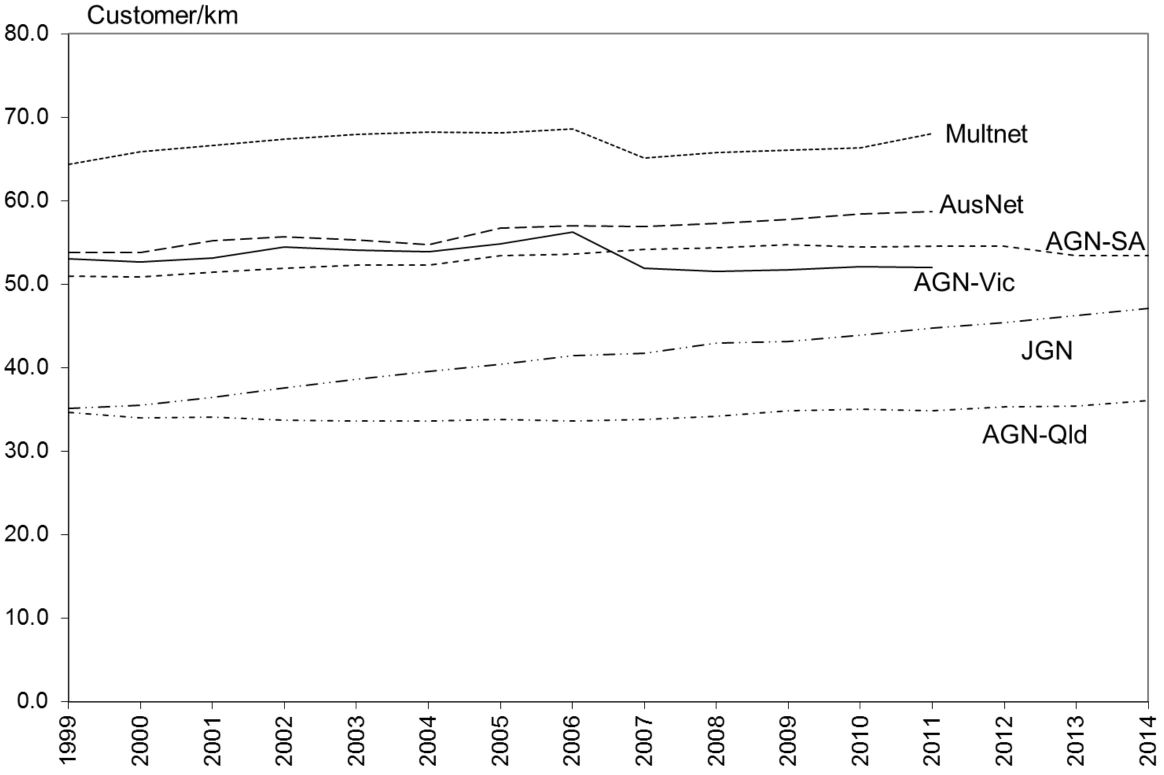
Multinet has the highest customer density of the included GDBs reflecting its coverage of Melbourne's densely populated inner southeast. AGN Victoria and AusNet have the next highest customer densities followed closely by AGN SA, all of which have relatively compact, meshed distribution systems despite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

Figure 2.1: **Included GDBs' domestic energy densities, 1999–2014**



Source: Economic Insights GDB database

Figure 2.2: **Included GDBs' customer densities, 1999–2014**

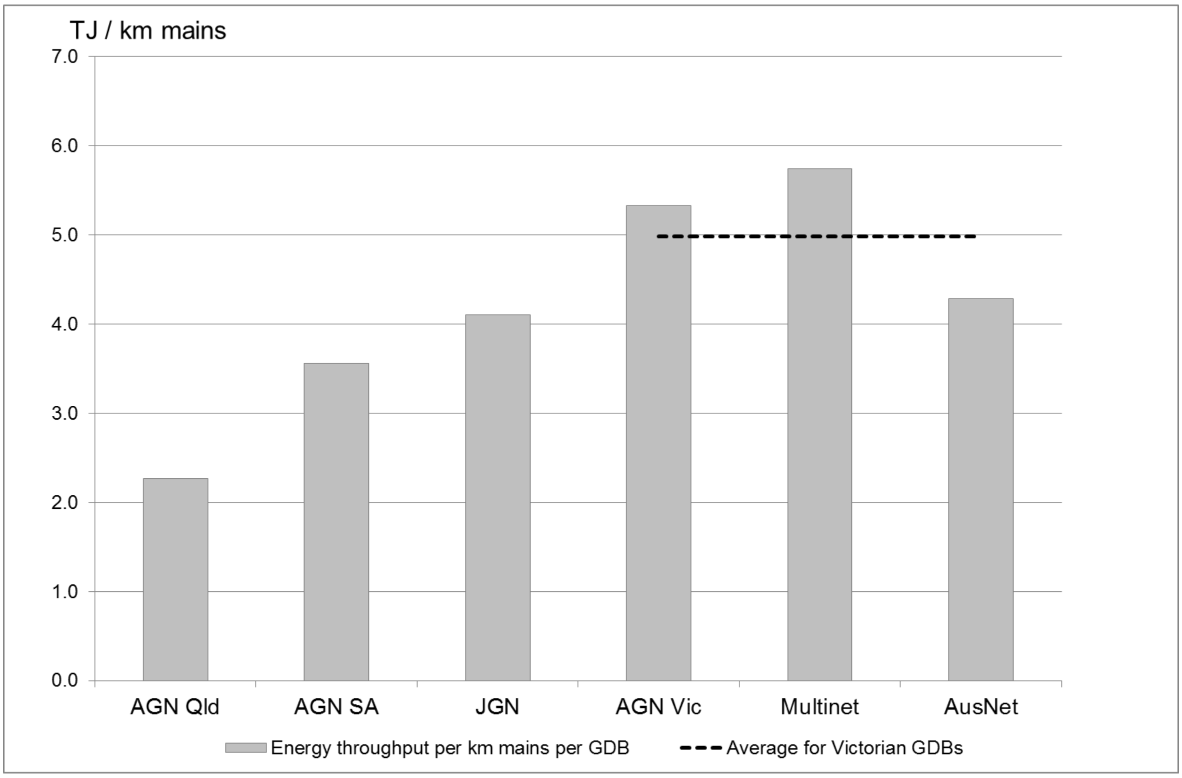


Source: Economic Insights GDB database

The AGN SA, JGN and AGN Qld systems have lower energy throughput per km of distribution main compared to the Victorian systems due to either lower energy density per customer or lower customer penetration. In each case, these differences are influenced by differences in climate. Figure 2.3 summarises the differences between the GDBs in terms of energy throughput per km. Since the three Victorian GDBs are combined when presenting productivity results in the remainder of the report, Figure 2.3 also shows the overall energy throughput per km for the three Victorian GDBs.

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 AGN SA and AGN Qld. AGN SA has a size disadvantage and relatively low domestic energy density and overall energy density, as well as customer density below those of the Victorian GDBs. In consequence, it has a significantly lower energy throughput per km of distribution mains. This would be expected to place AGN SA at a disadvantage in comparisons of productivity levels compared to most of the GDBs in the sample.

Figure 2.3: **Included GDBs' energy throughput per km main, 2011**



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.[3] Diewert found that only the Fisher ideal index passed all of the axiomatic tests.[4] 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:

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

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;

---

[3] 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.

[4] 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 *i*th output for observation *t*;

P_i^t is the price of the *i*th output for observation *t*; and

Y_j^B is the quantity of the *j*th output for the base observation.

Similarly, the Fisher ideal input index is given by:

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

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

W_i^B is the price of the *i*th input for the base observation;

X_i^t is the quantity of the *i*th input for observation *t*;

W_i^t is the price of the *i*th input for observation *t*; and

X_j^B is the quantity of the *j*th input for the base observation.

The Fisher ideal TFP index is then given by:

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

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:

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

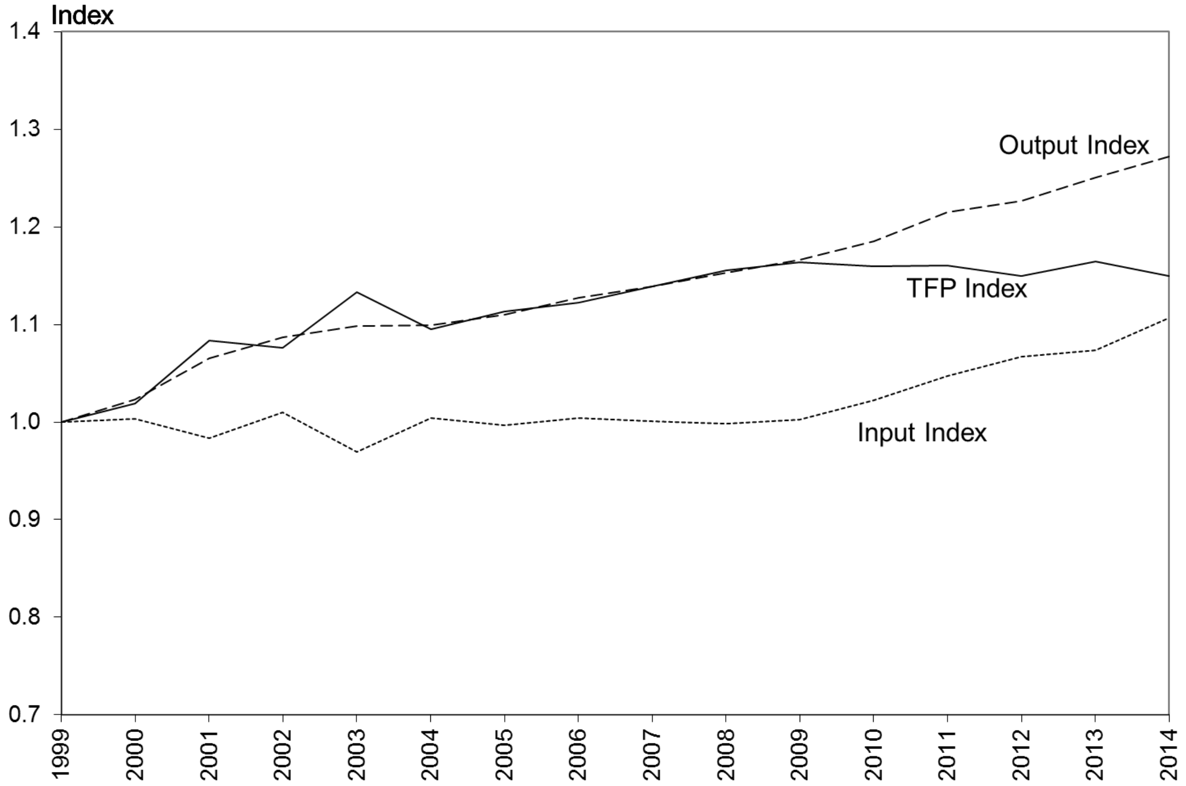
In this section the chained Fisher ideal index number method is used to calculate output and input indexes, TFP and partial productivity measures.

3.2 AGN SA productivity growth results, 1999 to 2014

In this section we present the key productivity results for the Australian Gas Networks SA gas distribution business for the 15 year period to 2014. 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).

The output, input and TFP indexes for the AGN SA gas distribution system are presented in figure 3.1 and table 3.1.

Figure 3.1: **AGN SA output, input and TFP indexes, 1999–2014**



Source: Economic Insights GDB database

The increase in the output quantity index over the last 15 years has been relatively steady with an average annual growth rate of 1.6 per cent, with essentially the same growth rate in the two sub-periods from 1999 to 2008 and from 2008 to 2014.

The total quantity of inputs used stayed relatively constant between 1999 and 2008 — with an annual growth rate over this period of zero per cent. Over the period from 2008 to 2014, the growth rate of inputs was 1.7 per cent on average per year. Over the whole 15 year period, the average annual growth rate of inputs was 0.7 per cent.

The change in the trend in input use between the two sub-periods largely reflects a change in the growth rate of non-capital (or "opex") inputs. In the period 1999 to 2008, opex inputs usage decreased at an average annual rate of 2.9 per cent, while over the period 2008 to 2014 opex inputs use increased on average at 1.5 per cent per year. The average annual growth rate of opex inputs over the whole period from 1999 to 2014 was –1.2 per cent per year. Capital inputs usage increased at an average rate of 1.8 per cent per year over the period from 1999 to 2014, and increased at a similar rate in each of the two sub-periods. The trends in the indexes of capital and non-capital inputs are depicted in figure 3.2.

Table 3.1: **AGN SA productivity indexes, 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	1.023	1.004	0.964	1.032	1.061	0.991	1.019
2001	1.066	0.983	0.893	1.047	1.193	1.018	1.084
2002	1.087	1.010	0.939	1.061	1.158	1.024	1.076
2003	1.099	0.970	0.817	1.076	1.345	1.021	1.133
2004	1.100	1.004	0.870	1.097	1.264	1.002	1.095
2005	1.110	0.997	0.842	1.106	1.318	1.004	1.114
2006	1.127	1.004	0.828	1.129	1.362	0.999	1.122
2007	1.139	1.001	0.799	1.144	1.426	0.996	1.139
2008	1.153	0.998	0.770	1.163	1.497	0.992	1.155
2009	1.167	1.002	0.764	1.175	1.528	0.993	1.164
2010	1.186	1.022	0.780	1.198	1.520	0.990	1.160
2011	1.215	1.047	0.812	1.216	1.496	0.999	1.161
2012	1.227	1.067	0.835	1.235	1.470	0.994	1.150
2013	1.250	1.073	0.796	1.270	1.571	0.985	1.165
2014	1.272	1.107	0.840	1.298	1.514	0.979	1.149
Average Annual Change							
1999–2008	1.59%	-0.02%	-2.86%	1.69%	4.58%	-0.09%	1.62%
2008–2014	1.65%	1.74%	1.46%	1.86%	0.19%	-0.21%	-0.08%
1999–2014	1.62%	0.68%	-1.16%	1.76%	2.80%	-0.14%	0.93%

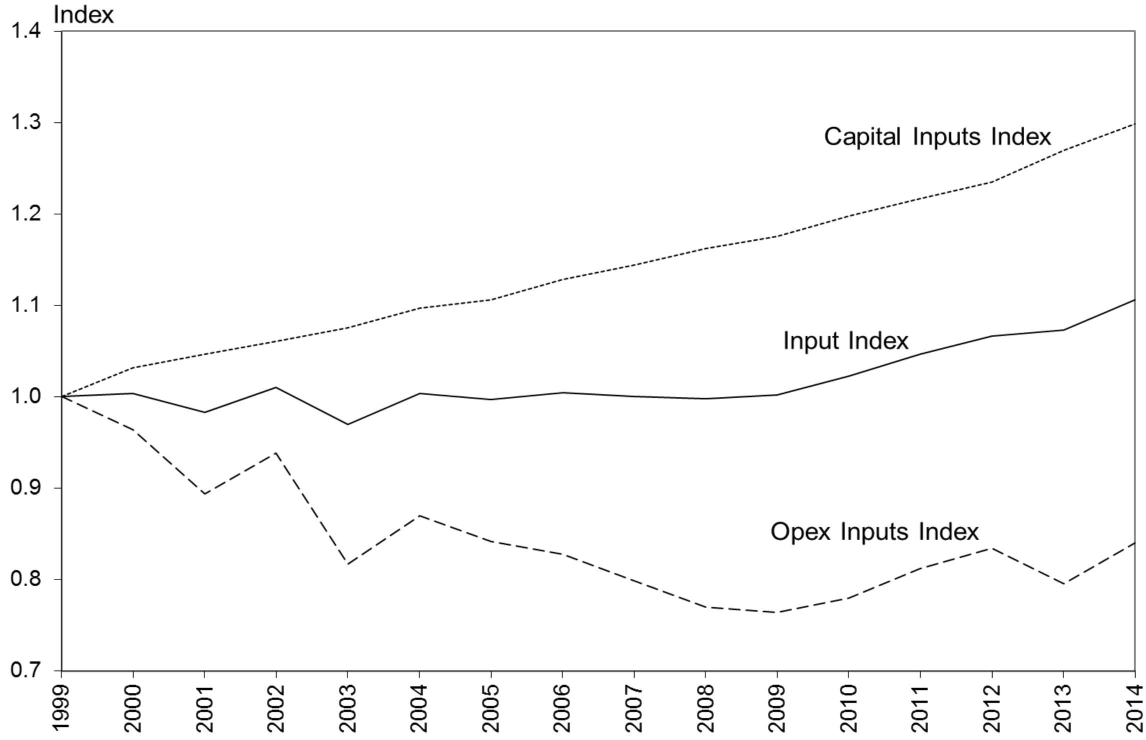
Source: Calculations using Economic Insights GDB database

The changes in output and input quantities shown in figure 3.1 and table 3.1 have led to a relatively strong productivity performance over the last 15 years, driven largely by significant reductions in opex. Between 1999 and 2014, the average rate of growth of TFP was 0.9 per cent per year.

The TFP index is effectively a weighted average of the partial productivity indexes shown in figure 3.3. The opex partial productivity index measures output produced per unit of non-capital inputs, and the capital partial productivity index measures output per unit of capital inputs. Figure 3.3 and table 3.1 show that the partial productivity of opex increased strongly between 1999 and 2008, at an average rate of 4.6 per cent, but has increased more modestly since then at 0.2 per cent annually. The annual rate of O&M partial productivity growth was 2.8 per cent over the whole 15 year period. Annual growth in the partial productivity of capital has been relatively flat over the whole period from 1999 to 2014, with an average annual growth rate of –0.1 per cent.

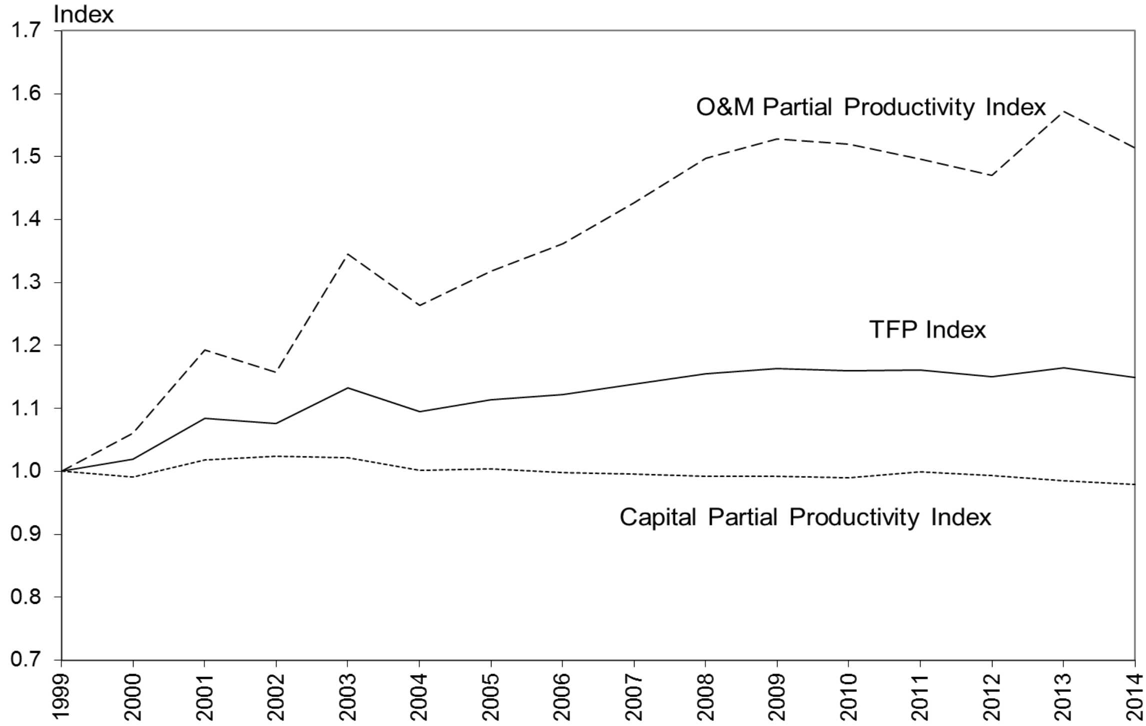
AGN SA's changes in output and input quantities have led to TFP growth averaging 0.9 per cent annually over the last 15 years. The growth of TFP differed between the two sub-periods due to the changing rates of growth of input use previously discussed. In the period 1999 to 2008, TFP increased at an annual rate of 1.6 per cent. On the other hand, over the period from 2008 to 2014, TFP was relatively flat — the average annual growth rate of TFP in this period was –0.1 per cent.

Figure 3.2: **AGN SA inputs indexes, 1999–2014**



Source: Economic Insights GDB database

Figure 3.3: **AGN SA partial productivity indexes, 1999–2014**



Source: Economic Insights GDB database

3.3 Comparison with Victorian GDB and JGN productivity growth

This section compares AGN SA's productivity growth with that of the three Victorian GDBs (combined for the comparison), AGN Qld, and for JGN in NSW which was reported in Economic Insights (2014). A summary of the combined output, input and productivity indexes and growth rates for the three Victorian GDBs, AGN Victoria, Multinet and AusNet Services ('AusNet') are presented in table 3.2.[5] Comparable information for JGN is presented in table 3.3 and for AGN Qld in table 3.4. Although the data for JGN and AGN Qld covers the period to 2014, the Victorian data only extends to 2011, so that some of the growth rates are calculated over shorter periods.

AGN SA's TFP performance is plotted against those of the Victorian distribution industry, as well as JGN and AGN Qld, in figure 3.4. AGN SA's TFP growth over the period 1999 to 2008 was somewhat behind that of the Victorian GDBs and was similar to that of JGN. AGN SA had an average annual TFP growth rate of 0.9 per cent over the period 1999-2014, and JGN's also averaged 1.0 per cent over the same period, whilst AGN Qld's TFP growth rate averaged −0.5 per cent per year over that period. The average annual TFP growth rate of the Victorian GDBs was 1.9 per cent over the period 1999 to 2011. However, this comparison is likely to overstate the differences between the Victorian GDBs and the other GDBs because of the different periods of data available, noting that the Victorian GDBs and JGN, like AGN SA, have had little or no TFP growth over the period since 2008.

Table 3.2: **Gas distribution productivity indexes for Victoria, 1999–2011**

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	1.021	0.985	0.949	1.013	1.076	1.007	1.036
2001	1.033	0.992	0.951	1.023	1.091	1.010	1.042
2002	1.054	0.991	0.915	1.047	1.172	1.007	1.066
2003	1.084	0.982	0.878	1.063	1.253	1.021	1.108
2004	1.094	0.998	0.889	1.085	1.265	1.010	1.104
2005	1.112	0.944	0.751	1.100	1.498	1.013	1.180
2006	1.138	0.945	0.739	1.110	1.547	1.028	1.205
2007	1.165	0.972	0.737	1.156	1.583	1.008	1.198
2008	1.195	0.963	0.691	1.173	1.733	1.020	1.240
2009	1.213	0.978	0.697	1.193	1.741	1.017	1.239
2010	1.238	0.980	0.667	1.215	1.874	1.019	1.261
2011	1.251	1.002	0.678	1.244	1.873	1.005	1.246
Average Annual Change							
1999-2008	2.00%	-0.41%	-4.02%	1.79%	6.30%	0.22%	2.42%
2008-2011	1.53%	1.33%	-0.66%	1.98%	2.61%	-0.47%	0.17%
1999-2011	1.88%	0.02%	-3.19%	1.84%	5.37%	0.04%	1.85%

Source: Economic Insights GDB database

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[5] The indexes presented in table 3.2 are averages for the three Victorian GDBs.

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%

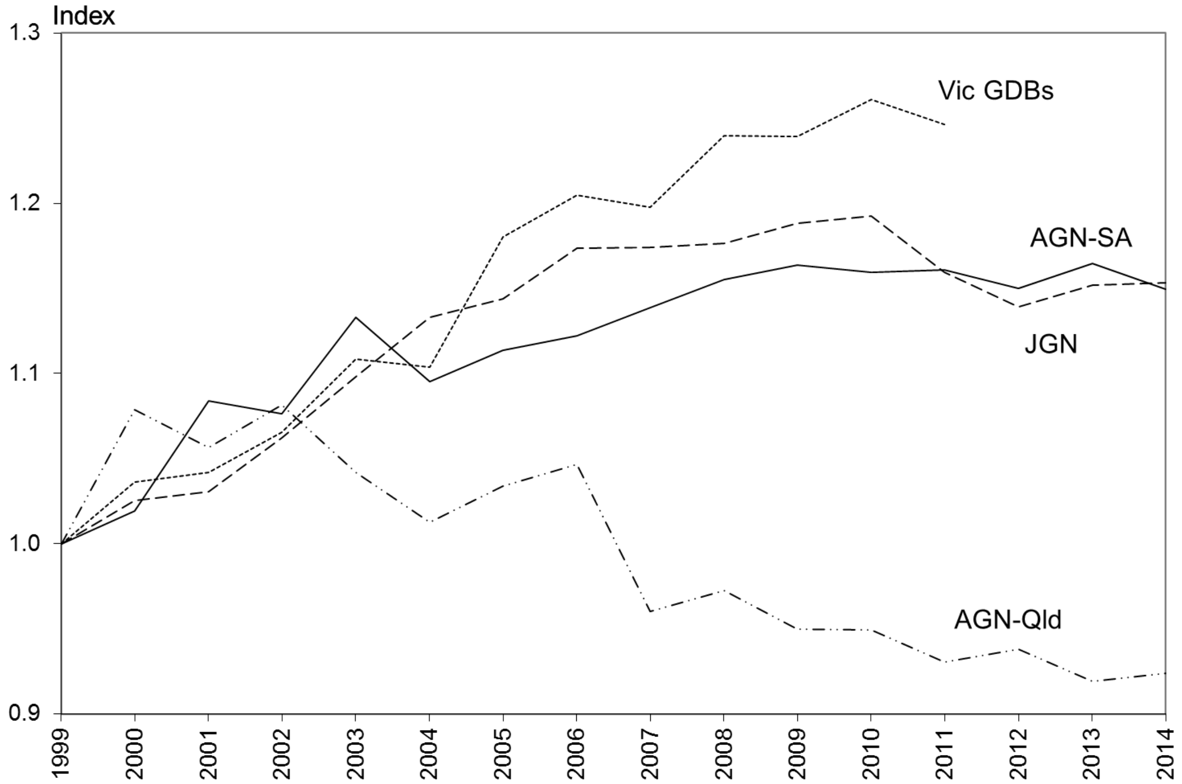
Source: Economic Insights GDB database

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	1.033	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	1.100	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	1.160	1.255	0.937	1.047
2007	1.105	1.151	1.041	1.228	1.062	0.900	0.960
2008	1.130	1.163	1.026	1.260	1.102	0.897	0.972
2009	1.153	1.214	1.110	1.288	1.039	0.895	0.950
2010	1.167	1.230	1.106	1.317	1.056	0.886	0.949
2011	1.172	1.260	1.132	1.351	1.035	0.868	0.930
2012	1.188	1.266	1.114	1.372	1.066	0.866	0.938
2013	1.190	1.295	1.122	1.412	1.060	0.842	0.919
2014	1.220	1.322	1.113	1.458	1.096	0.837	0.923
Average Annual Change							
1999-2008	1.37%	1.69%	0.28%	2.61%	1.08%	-1.20%	-0.31%
2008-2014	1.28%	2.16%	1.37%	2.46%	-0.09%	-1.15%	-0.86%
1999-2014	1.34%	1.88%	0.72%	2.55%	0.61%	-1.18%	-0.53%

Source: Economic Insights GDB database

Figure 3.4: **AGN SA, JGN and Victorian GDB TFP indexes, 1999–2014**



Source: Economic Insights GDB database

A better comparison between the TFP growth rates of the Victorian GDBs and the other GDBs— AGN SA, JGN and AGN Qld—is perhaps gained by having regard to the flat TFP growth in the more recent sub-period and considering what a comparison over comparable periods might more likely look like. If the relatively flat TFP growth for the Victorian GDB's in the period 2009 to 2011 is assumed to have persisted over the subsequent three years, then their average TFP growth over the 15 year period between 1999 and 2014 would be around 1.5 per cent.

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:

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

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 are presented in table 4.1 and figure 4.1. The indexes are calculated relative to AGN Victoria in 1999 having a value of one.

Table 4.1: **GDB multilateral TFP indexes, 1999–2014**

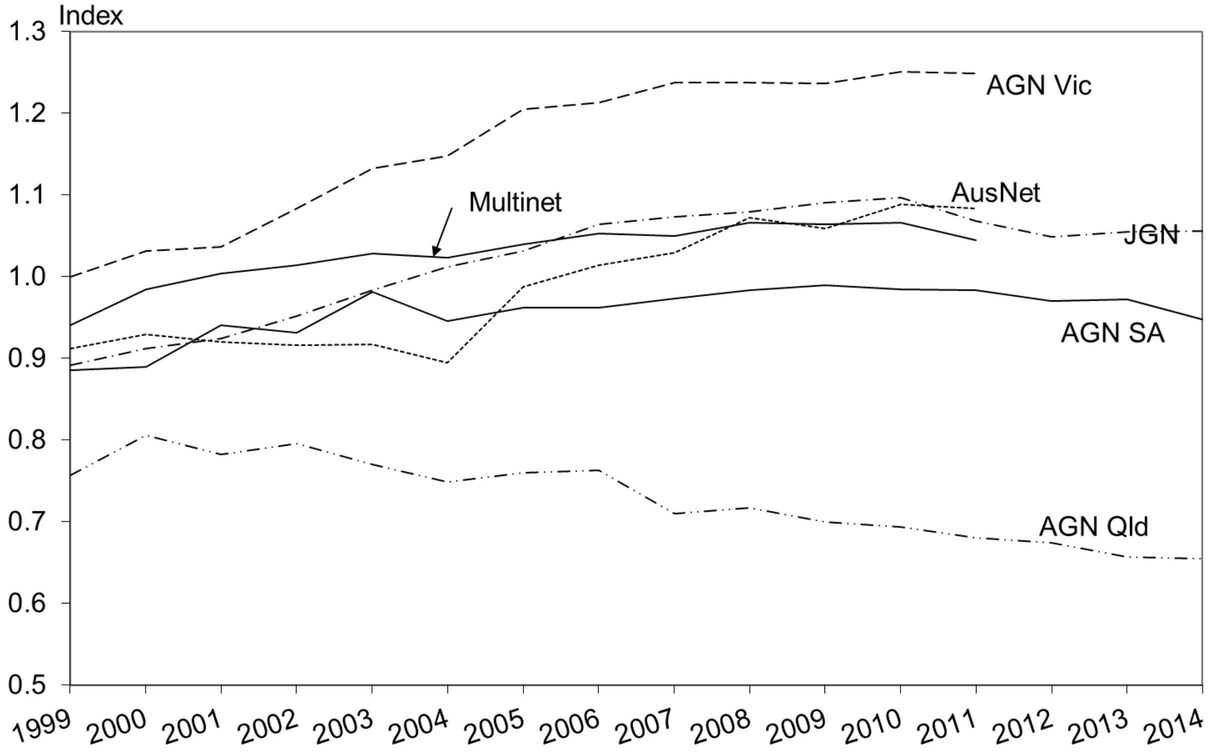
	AGN SA	AGN-Qld	JGN	AGN Vic	Multinet	AusNet
1999	0.886	0.756	0.892	1.000	0.940	0.912
2000	0.889	0.805	0.912	1.031	0.984	0.929
2001	0.941	0.782	0.924	1.036	1.004	0.920
2002	0.931	0.796	0.952	1.084	1.014	0.916
2003	0.982	0.770	0.983	1.132	1.029	0.917
2004	0.946	0.749	1.012	1.148	1.023	0.895
2005	0.962	0.760	1.031	1.205	1.039	0.988
2006	0.962	0.763	1.064	1.213	1.053	1.014
2007	0.973	0.710	1.073	1.237	1.049	1.030
2008	0.984	0.717	1.079	1.238	1.066	1.073
2009	0.989	0.700	1.091	1.236	1.064	1.059
2010	0.985	0.694	1.096	1.251	1.066	1.089
2011	0.983	0.680	1.069	1.249	1.045	1.083
2012	0.970	0.674	1.049			
2013	0.972	0.656	1.055			
2014	0.948	0.654	1.056			

Source: Calculations using Economic Insights GDB database

The MTFP results indicate that AGN SA has come reasonably close to matching the productivity levels of JGN and Multinet. For example in 2011, which is the latest year for which Multinet data is available, there was approximately a 7 per cent difference between the productivity levels of AGN SA and these two businesses. There has also been reasonable comparability with AusNet over most of the sample period. On the other hand, AGN Victoria had a significantly higher level of productivity than the other comparator GDBs, and AGN Qld has had a significantly lower level of productivity.

This comparison is favourable for AGN SA given the relative differences in operating environment conditions between GDBs. The three Victorian GDBs have higher customer density and energy density per kilometre of main when compared to JGN and AGN SA. Furthermore, AGN SA is relatively small compared to JGN and the three Victorian GDBs. In terms of throughput it is less than half the size of each of the three Victorian GDBs and just over a quarter the size of JGN and in terms of customer numbers it is around two thirds the size of the Victorian GDBs and less than 40 per cent the size of JGN. The MTFP comparisons do not directly control for differences in scale between GDBs (ie, economies of scale), nor do they *fully* adjust for different operating environment conditions.

Figure 4.1: **GDB multilateral TFP indexes, 1999–2014**



Source: Economic Insights GDB database

5 CONCLUSIONS

AGN SA's changes in output and input quantities have led to a robust productivity performance over the last 15 years, averaging 0.9 per cent annually, driven largely by significant reductions in opex. Its partial productivity of opex has grown strongly at the high annual rate of 4.6 per cent between 1999 and 2008, but has grown more modestly since, averaging 0.2 per cent growth annually between 2008 and 2014. Similarly, TFP growth was relatively strong in the period 1999 to 2008, averaging 1.6 per cent per year, but been relatively flat, averaging –0.1 per cent annually, in the period 2008 to 2014.

AGN SA's TFP performance over the period from 1999 to 2014 was very similar to that of JGN. On the other hand, the average TFP of the Victorian GDBs over the period 1999 to 2011 was considerably higher at 1.9 per cent annually. However, the Victorian data extends only to 2011, so that TFP growth rates since 2008 are calculated over shorter periods. Given the common pattern of flat TFP growth after 2008, this comparison is likely to overstate the differences in productivity performance because of the different periods of data available. Extrapolating the productivity growth of the Victorian GDBs suggests that over a comparable period (using their average TFP growth rate from 2008 to 2011) their average annual TFP growth is likely to be around 1.5 per cent. This remains somewhat higher than the TFP growth rates of AGN SA and JGN.

The pattern of strong productivity growth during the period 1999 to 2008 and relatively flat TFP growth after 2008 for AGN SA is common also to the Victorian GDBs and JGN. The annual average TFP growth rate of AGN SA between 2008 and 2014 of −0.1 per cent can be compared to −0.3 per cent for JGN over the same period, and +0.2 per cent for the Victorian GDBs over the period 2008 to 2011.

In terms of overall productivity levels, AGN SA is close to JGN and some of the Victorian GDBs, such as Multinet. This is despite AGN SA having the lowest overall energy density and its relatively small size compared to JGN and the three Victorian GDBs. In terms of throughput it is less than half the size of each of the three Victorian GDBs and just over a quarter the size of JGN and in terms of customer numbers it is approximately two thirds the size of the three Victorian GDBs and less than 40 per cent the size of JGN. While its scale and operating environment conditions could be expected to place AGN SA at a disadvantage in comparisons of productivity levels, it performs relatively well by almost matching the performance of some of the larger included GDBs. Taking the differences in network density and size into account, the results of this study indicate that AGN SA is most likely to be an efficient performer.

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:

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

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:

$$\text{(A2)} \qquad x_i^t = \sum\nolimits_{j=1}^{N} (a_{ij})^2 \, y_j^t \, (1+b_i t)$$

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.

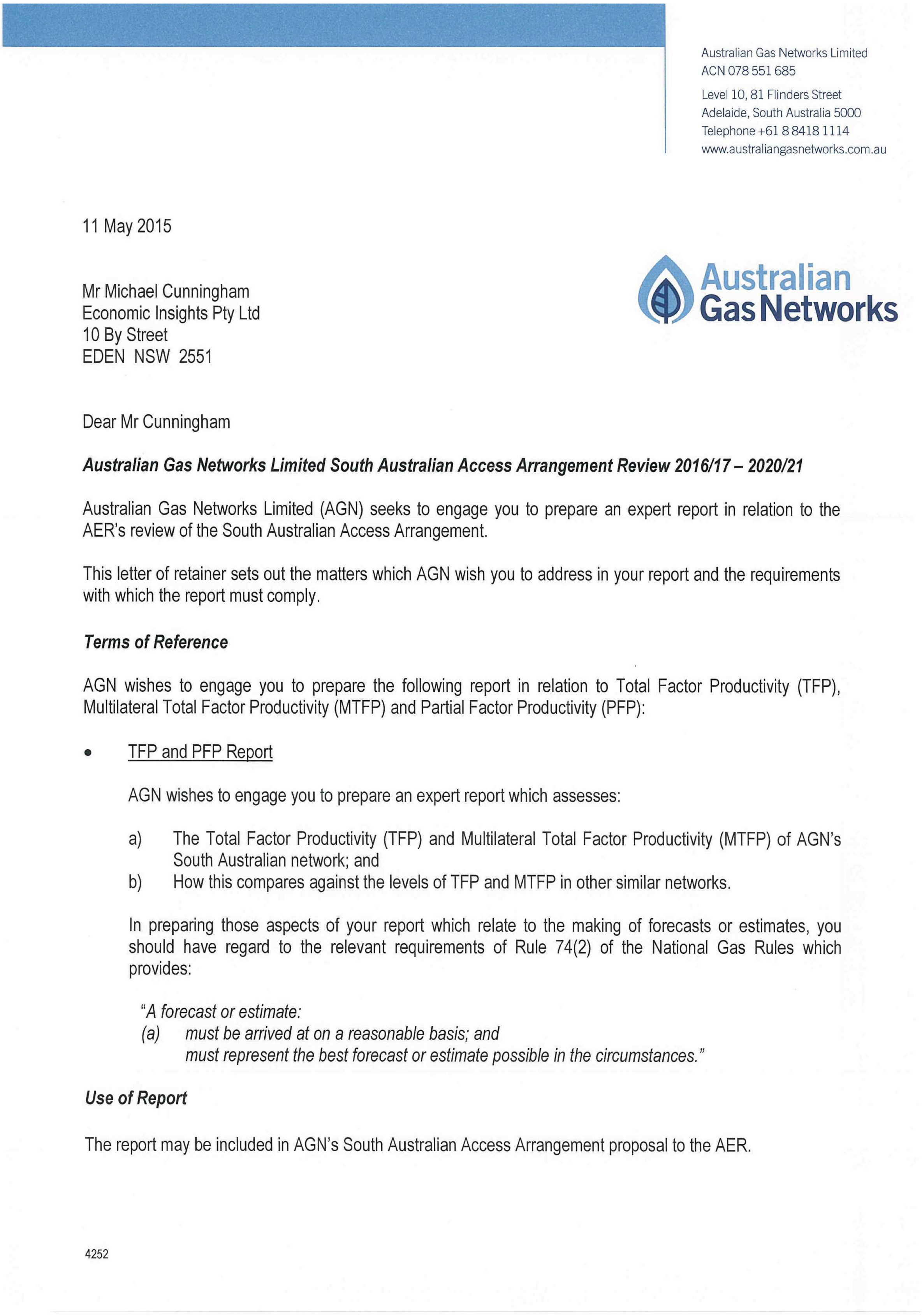
Lawrence (2007) then derived the output cost shares for each output and each observation as follows:

$$\text{(A3)} \qquad h_j^t = \{\sum\nolimits_{i=1}^{M} w_i^t \, [(a_{ij})^2 \, y_j^t \, (1+b_i t)]\} / \{\sum\nolimits_{i=1}^{M} w_i^t \, [\sum\nolimits_{j=1}^{N} (a_{ij})^2 \, y_j^t \, (1+b_i t)]\} .$$

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:

$$\text{(A4)} \qquad s_b^t = C(b, y_b^t, w_b^t, t) / \sum\nolimits_{b,t} C(b, y_b^t, w_b^t, t) .$$

ATTACHMENT A: LETTER OF ENGAGEMENT



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11 May 2015

Mr Michael Cunningham
Economic Insights Pty Ltd
10 By Street
EDEN NSW 2551

Dear Mr Cunningham

Australian Gas Networks Limited South Australian Access Arrangement Review 2016/17 – 2020/21

Australian Gas Networks Limited (AGN) seeks to engage you to prepare an expert report in relation to the AER's review of the South Australian Access Arrangement.

This letter of retainer sets out the matters which AGN wish you to address in your report and the requirements with which the report must comply.

Terms of Reference

AGN wishes to engage you to prepare the following report in relation to Total Factor Productivity (TFP), Multilateral Total Factor Productivity (MTFP) and Partial Factor Productivity (PFP):

- TFP and PFP Report

  AGN wishes to engage you to prepare an expert report which assesses:

  a) The Total Factor Productivity (TFP) and Multilateral Total Factor Productivity (MTFP) of AGN's South Australian network; and
  b) How this compares against the levels of TFP and MTFP in other similar networks.

  In preparing those aspects of your report which relate to the making of forecasts or estimates, you should have regard to the relevant requirements of Rule 74(2) of the National Gas Rules which provides:

  > *"A forecast or estimate:*
  > *(a) must be arrived at on a reasonable basis; and*
  > *must represent the best forecast or estimate possible in the circumstances."*

Use of Report

The report may be included in AGN's South Australian Access Arrangement proposal to the AER.

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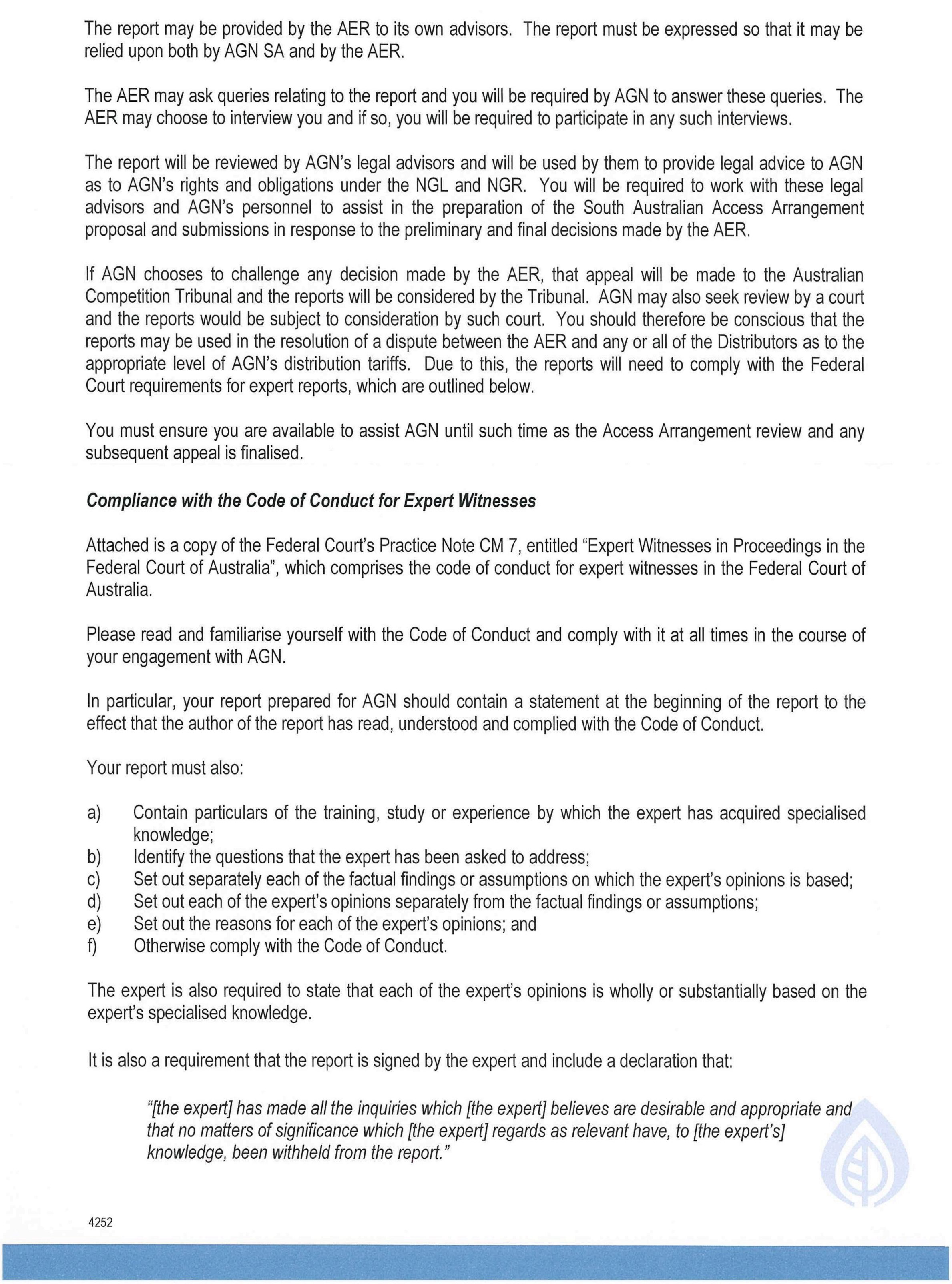

The report may be provided by the AER to its own advisors. The report must be expressed so that it may be relied upon both by AGN SA and by the AER.

The AER may ask queries relating to the report and you will be required by AGN to answer these queries. The AER may choose to interview you and if so, you will be required to participate in any such interviews.

The report will be reviewed by AGN's legal advisors and will be used by them to provide legal advice to AGN as to AGN's rights and obligations under the NGL and NGR. You will be required to work with these legal advisors and AGN's personnel to assist in the preparation of the South Australian Access Arrangement proposal and submissions in response to the preliminary and final decisions made by the AER.

If AGN chooses to challenge any decision made by the AER, that appeal will be made to the Australian Competition Tribunal and the reports will be considered by the Tribunal. AGN may also seek review by a court and the reports would be subject to consideration by such court. You should therefore be conscious that the reports may be used in the resolution of a dispute between the AER and any or all of the Distributors as to the appropriate level of AGN's distribution tariffs. Due to this, the reports will need to comply with the Federal Court requirements for expert reports, which are outlined below.

You must ensure you are available to assist AGN until such time as the Access Arrangement review and any subsequent appeal is finalised.

Compliance with the Code of Conduct for Expert Witnesses

Attached is a copy of the Federal Court's Practice Note CM 7, entitled "Expert Witnesses in Proceedings in the Federal Court of Australia", which comprises the code of conduct for expert witnesses in the Federal Court of Australia.

Please read and familiarise yourself with the Code of Conduct and comply with it at all times in the course of your engagement with AGN.

In particular, your report prepared for AGN should contain a statement at the beginning of the report to the effect that the author of the report has read, understood and complied with the Code of Conduct.

Your report must also:

a) Contain particulars of the training, study or experience by which the expert has acquired specialised knowledge;
b) Identify the questions that the expert has been asked to address;
c) Set out separately each of the factual findings or assumptions on which the expert's opinions is based;
d) Set out each of the expert's opinions separately from the factual findings or assumptions;
e) Set out the reasons for each of the expert's opinions; and
f) Otherwise comply with the Code of Conduct.

The expert is also required to state that each of the expert's opinions is wholly or substantially based on the expert's specialised knowledge.

It is also a requirement that the report is signed by the expert and include a declaration that:

> *"[the expert] has made all the inquiries which [the expert] believes are desirable and appropriate and that no matters of significance which [the expert] regards as relevant have, to [the expert's] knowledge, been withheld from the report."*

AGN may request the principal author of the report to sign a statutory declaration to the effect that the Code of Conduct has been complied with. This is to ensure that the report carries maximum weight and probative value and will be suitable to rely upon in any subsequent court proceedings.

Please also attach a copy of these terms of reference to the report.

Terms of Engagement

Your contract for the provision of the report will be directly with AGN. You should forward to AGN any terms you propose govern that contract as well as your fee proposal.

Please sign a counterpart of this letter and forward it to AGN to confirm your acceptance of the engagement by AGN.

Kind regards,

Peter Bucki
Manager Regulatory Strategy

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ATTACHMENT B: CURRICULUM VITAE

Michael Cunningham

Position	Associate
Business address:	28 Albert St, Brunswick East, VIC 3057
Business telephone number:	+61 3 9380 4700
Mobile:	0412 255 131
Email address	michael@economicinsights.com.au

Qualifications

Master of Commercial Law, Melbourne University

Master of Commerce (Hons), Melbourne University

Bachelor of Economics, Monash University

Key Skills and Experience

Michael Cunningham has recently become an Associate of Economic Insights 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 recently 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).

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).

Relevant Projects

- For the Essential Services Commission Victoria, developed options for feed-in tariffs for small renewable electricity generators in Victoria to apply in 2015 (2014).

- On behalf of Jemena Gas Networks, carried out productivity analysis, benchmarking and forecasting partial productivity to support its current access arrangement review (2014).
- For the Commonwealth Department of Environment, carried out (with Denis Lawrence) an economic benchmarking study of the Murray Darling Basin Authority's River Murray Operations joint venture against similar Australian rural water businesses using data envelopment analysis (2014).
- For the Essential Services Commission Victoria, carried out an econometric benchmarking study of Victorian urban water businesses against urban water businesses throughout Australia (2014).
- Assisted in preparing advice to the New Zealand Commerce Commission on international practices regarding setting regulated rates of return within a range of best estimates (2014).

ATTACHMENT C: 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. The opinions expressed in this report are wholly or substantially based on my specialised knowledge.

M. Cunningham

Michael Bradbury Cunningham

20 May 2015

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