Jemena Gas Networks (NSW) Ltd

2015-20 Access Arrangement

Response to the AER's draft decision and revised proposal

Updated appendix 5.2 – Economic Insights – updated productivity assessment

Public

27 March 2015

Relative Opex Efficiency and Forecast Opex Productivity Growth of Jemena Gas Networks

Report prepared for
Jemena Gas Networks

25 March 2015

Michael Cunningham

Economic Insights Pty Ltd
10 By Street, Eden, NSW 2551, Australia, AUSTRALIA
Ph +61 02 6496 4005
WEB www.economicinsights.com.au
ABN 52 060 723 631

CONTENTS

EXECUTIVE SUMMARY

Jemena Gas Networks (NSW) Ltd ('JGN') has commissioned Economic Insights to carry out an analysis of the total factor productivity (TFP) and partial productivity (PFP) performance of JGN's New South Wales gas distribution system. Economic Insights has been requested to compare JGN's productivity levels with the Victorian, South Australian and Queensland gas distribution businesses for which similar analysis has previously been undertaken. The report is also required to include an estimated opex cost function, and using that model, provide a forecast of JGN's opex partial productivity growth rate. The opex cost function is also used to compare JGN's opex cost efficiency with that of other Gas Distribution Businesses (GDBs).

The time series TFP index analysis provides estimates of the changes in JGN's TFP over the period 1999 to 2014, and these changes are compared to the changes in TFP for other GDBs. This analysis finds that JGN's TFP grew at an average annual rate of 1.2 per cent between 1999 and 2011, but taken over the period to 2014, the average was 0.9 per cent due to small productivity reductions in the period 2011 to 2014. JGN's TFP growth over the period 1999 to 2011 was at a similar rate to those of Multinet Gas ("Multinet") and Australian Gas Networks' (AGN)[1] South Australian gas distribution business (AGN SA), although AGN's Victorian business ("AGN Vic") and AusNet Services ("AusNet")[2] both achieved average TFP growth rates of over 2 per cent over the same period. The main source of TFP growth for most GDBs over this period was strong growth in opex partial productivity in the period from 1999 to 2006. JGN had the equal highest growth rate of opex partial productivity over this period. For most GDBs, this source of productivity gain was considerably more modest in the period from 2006 to 2011.

Multilateral TFP analysis is used for measuring the TFP levels of all GDBs in the sample using a common base, so that TFP levels can be compared. This analysis finds that JGN has had similar multilateral TFP levels to AusNet and Multinet since around 2005. AGN Vic has had consistently higher multilateral TFP levels than these three GDBs but they have had higher multilateral TFP levels than AGN SA and AGN Queensland.

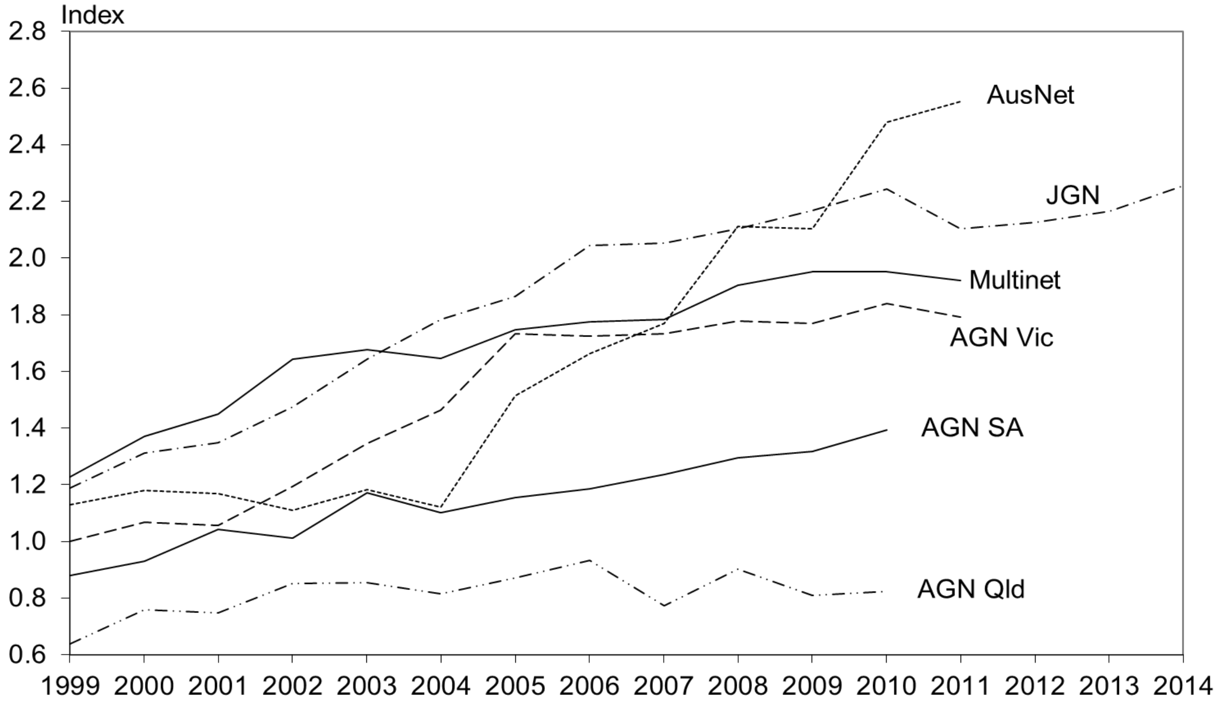
In terms of multilateral opex partial productivity, JGN had the highest or second highest opex partial productivity level for the last 15 years, exceeded only by AusNet in 2010 and 2011 (see Figure A). JGN's opex partial productivity increased by over 80 per cent during the same 15 year period. JGN has had similar levels of multilateral capital partial productivity to Multinet and AusNet over the last decade but lower than those of AGN Vic and AGN SA. Overall, the index number productivity analysis shows JGN to have been a good performer in terms of both opex partial productivity levels and growth rates. And it has had similar TFP levels to two of the three Victorian GDBs for the last decade.

To assess JGN's opex efficiency levels and forecast its achievable opex productivity growth for the next regulatory period, we have used an operating cost function model similar to that reported in Economic Insights (2012a). The operating cost function model presented here contains several advances compared to our earlier study. In particular, two additional

[1] Envestra recently changed its name to Australian Gas Networks.
[2] SP AusNet recently changed its name to AusNet Services.

operating environment factors – network age and network fragmentation – are included and the larger number of observations now available has enabled us to directly estimate GDB opex efficiency levels using a stochastic frontier model.

Figure A: **Australian GDB Multilateral Opex PFP indexes, 1999–2014**



Source: Economic Insights GDB database

The main findings from the opex cost function econometric analysis are:

- JGN is among the more efficient of the GDBs in terms of opex cost efficiency, when the effects of scale, customer density, network age and network fragmentation are taken into account. Although JGN's opex efficiency is slightly lower and statistically different from the three most cost efficient GDBs in the sample, we do not believe that any clear inferences can be drawn from this. It is likely there are some differences in the scope of activities undertaken by businesses, since the sources of information are not uniform, and there are differences across regulatory jurisdictions and changes over time. It is our understanding that JGN carries out a wider range of activities compared to GDBs in most other jurisdictions, such as operating relatively more transmission-equivalent mains, undertaking more marketing due to the discretionary nature of gas consumption in NSW, and it incurs local government taxes which may not apply to other GDBs. The observed small differences in the cost efficiency of the more efficient GDBs in the sample may be due to differences of this kind.
- Based on JGN's latest forecasts of throughput, customer numbers, pipeline length and capital over the next regulatory period, JGN's forecast average annual opex partial productivity growth rate over the period 2015-16 to 2019-20 is 0.60 per cent when returns to scale, the impact of operating environment factors and technical change are allowed for.

1 INTRODUCTION

This report updates the report of the same title dated 10 September 2014, to take into account Jemena's most recent pipeline length forecasts. The September report updated and amended Economic Insights' report dated 14 April 2014.

1.1 Terms of reference

Jemena Gas Networks (NSW) Ltd ('JGN') has commissioned Economic Insights Pty Ltd ('Economic Insights') to provide advice on efficiency measurement and benchmarking in relation to its New South Wales (NSW) gas distribution business, which is the principal gas distribution business in that State.

The terms of reference provided to Economic Insights by JGN required the preparation of an expert report detailing:

a) an analysis of time series and multilateral total factor productivity (TFP) estimates and partial productivity estimates (PFP) estimates, where that analysis is to be suitable for comparing JGN's productivity level and productivity growth rate performance with the Victorian, South Australian and Queensland gas distribution businesses (GDBs) for which similar analysis has previously been undertaken; and

b) an estimate of the opex cost function and forecast opex partial productivity growth rate for JGN, in a form that is suitable for incorporation into the rate of change approach for forecasting opex in JGN's revised Access Arrangement proposal.

The first part of this study is similar in scope to previous studies by Economic Insights (2009, 2010, 2012c), which examined TFP and PFP trends for most of the major Australian gas distribution businesses (GDBs). This study updates Economic Insights (2012c) using similar analysis to maintain comparability and incorporates the latest data for JGN.

The second part of the study is broadly similar in scope to the Economic Insights (2012a) econometric study of GDB productivity using cost functions undertaken for the Victorian GDBs. While the earlier study estimated both the total cost and opex cost functions, the present study is confined to estimating the opex cost function. The purpose of this analysis is to forecast the opex partial productivity growth rate. An innovation included in the current study is the direct measurement of relative opex efficiency levels within the opex cost function.

The terms of reference require Economic Insights to have regard to:

- historical and forecast cost, input and output data provided by JGN;
- subject to the agreement of the relevant GDBs, the data set that informed the previous Economic Insights studies mentioned;
- relevant published research literature;
- relevant government decisions on energy policy and policy implementation;

- factors such as the scale, topography and configuration of the JGN network, that may contribute to or explain observed differences between the results obtained for JGN and for other GDBs in the data set on which the analysis is based;
- recent regulatory reviews for gas that have considered efficiency measures within the context of establishing cost forecasts; and
- any other information that Economic Insights considers should be taken into account to address the scope of work.

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

1.2 Discussion

The TFP performance of network industries is of considerable interest to both managers and regulators. As a comprehensive measure of overall economic performance, TFP can provide managers with important information on the overall performance of their business from one year to the next. It enables targets to be set for productivity growth and its progress to be monitored. This provides managers and owners of GDBs with a ready means of gauging the success of reform efforts. Measurement of industry level and firm-specific TFP performance is of interest to regulators seeking to determine price outcomes that are consistent with competitive market outcomes in an industry operating under natural monopoly conditions. Information from industry and firm-level TFP studies can be used when setting X factors in CPI–X regulation. It also provides the regulator with a means of assessing whether available efficiency improvements have been achieved during the past regulatory period and may provide insights into what further efficiency improvements are available in the forecast period.

This study addresses the issues of whether JGN's past performance was efficient relative to its peers, and whether it has improved its efficiency over time, both matters that the Australian Energy Regulator (AER) has regard to in its access arrangement approval processes (AER 2013a, p. 8).

Part B of this report presents an index analysis of TFP and PFP performance of the major Australian GDBs. The analysis concentrates on performance in the period from 1999 to 2014, and is similar in scope to several previous studies by Lawrence (2007a) and Economic Insights (2009, 2010, 2012c) which have compared the productivity growth rates and levels of Australian GDBs. The GDBs included in this part of the study, in addition to JGN, are the three Victorian GDBs, namely AGN's Victorian network (AGN Vic), Multinet and Ausnet, as well as AGN's South Australian network (AGN SA) and AGN's Queensland network (AGN Qld).

The primary data source for the index analysis is survey-based data gathered by Economic Insights from six major Australian GDBs. For JGN, the survey data covers the period from 1999 to 2014, while data for the other GDBs generally extends only to 2010 or 2011. This survey-based data provides a detailed decomposition of capital assets into categories, which permits improved measurement of capital inputs. It also enables the estimation of system capacity, which can be included in the analysis as an output of GDBs.

In Part C of this report, we develop forecasts of JGN's opex partial productivity growth rate by forming econometric estimates of the variable cost function (or operating cost function) for GDBs. The estimated parameters of this model are then used to predict opex productivity for JGN given the forecasts of a number of explanatory variables, such as market demand and capex. The forecast of future opex partial productivity growth is an important component of the 'rate of change' formula for rolling forward opex allowances frequently used in the application of building blocks regulation.

The analysis in Part C extends similar work by Lawrence, Fallon and Kain (2007), Lawrence (2007b) and Economic Insights (2012a). The AER has previously said of that study:

> *SP AusNet's proposed approach to opex partial factor productivity forecasts is reasonable and represents the best methodology available in the circumstances. As such, the AER has applied SP AusNet's proposed methodology to the AER's adjusted base year forecast. (AER 2012c, p. 229)*

To ensure comparability with earlier studies and to ensure that the sample is as large and broad as possible, the econometric study uses a different database to the TFP and PFP index analysis (part (a)). The data used in this part of the study includes 9 Australian and two New Zealand gas distribution businesses. It has been sourced from documents in the public domain to the maximum extent possible. The sample periods differ between utilities, but in most cases includes historical data for the period from 1999 to 2012 or to 2014. For most Australian DBs other than JGN, forecast data from final regulatory determinations are also included to maximise the number of observations available. The data includes revenue, throughput, customer numbers, distribution pipeline length, opex, capex and regulatory asset value. In some cases missing observations were estimated based on growth rates for the variable or a related variable before and after the missing year. The database used for part (b) of this study includes a total of 171 observations.

1.3 Outline of the Report

Chapter 2 of this report briefly discusses the purposes and applications of productivity benchmarking within the context of the economic regulation of natural monopolies.

Chapter 3 presents an analysis of TFP and PFP indexes for the purpose of estimating the rates of growth in each GDB's TFP growth over the study period from 1999 to 2014. JGN's TFP growth is compared to the TFP growth of other GDBs.

Chapter 4 presents a comparative analysis of the TFP levels of the major GDPs using multilateral TFP analysis. The multilateral TFP method is explained and the results of the analysis of multilateral TFP and PFP are reported.

Chapter 5 presents the analysis of the operating cost function of Australasian GDBs. The econometric methodology used in the analysis is explained, and the econometric results are presented. The model is used for assessing JGN's opex efficiency, and together with JGN's forecasts of key explanatory variables, it is used to develop a forecast of opex partial productivity growth for JGN.

Finally, chapter 6 summarises all of the main conclusions of this study.

1.4 Economic Insights' experience and consultants' qualifications

Economic Insights has been operating in Australia for 20 years as an infrastructure consulting firm. 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 PRODUCTIVITY MEASUREMENT AND BENCHMARKING

This chapter provides a brief discussion of the role of productivity benchmarking in the economic regulation of natural monopolies.

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: TFP and 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 effecting growth in output other than changes in input levels. PFP measures one or more outputs relative to one particular input (e.g. labour productivity is the ratio of output to labour input).

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 likely future rates of productivity growth to build into annual revenue requirement forecasts.

Government agencies and inquiries have given increasing attention to the role of productivity benchmarking in the economic regulation of natural monopolies. The Expert Panel on Energy Access Pricing (2006) advocated consideration of ‘productivity based’ approaches to regulation whereby X factors are set using information on industry productivity trends. The Australian Energy Market Commission (AEMC) emphasised the crucial role of benchmarking in assessing the efficiency of network service providers and informing the public about their performance (2012):

> “The Commission considers that benchmarking is a critical exercise in assessing the efficiency of a NSP and approving its capital expenditure and operating expenditure allowances. Benchmarking should take into account differences in the environments of

the different NSPs, being those factors that are outside the control of the NSP" (AEMC Nov 2012, p.vii).

Potential constraints within the governing regulatory instruments were removed by the AEMC to facilitate greater use of benchmarking by the Australian Energy Regulator (AER) in regulatory processes. A requirement that AER produce an annual benchmarking report was also introduced into the national electricity rules. The AER (2013a) has indicated it will be making greater use of benchmarking for assessing the efficiency of network businesses.

The AER has highlighted two forms of benchmarking that it intends to use as an integral part of future energy infrastructure price reviews. The first involves benchmarking a network business' expenditure when disaggregated into cost categories, termed category analysis. The second is economic benchmarking of the efficiency of a network business' regulatory operations as a whole. The latter permits a comparison of the efficiency of peer network businesses and can be used for 'top down' forecasting of a network business' expenditure and productivity growth. The analysis in this report is an application of economic benchmarking in this sense.

The AER has commenced an information collection process for benchmarking purposes with electricity network service providers, following the release of its regulatory information notices (RINs) in November 2013. This process will provide eight years of historical data and, together with annual information collection, will support the AER's forthcoming annual benchmarking reports and its other benchmarking activities (AER 2013b). It will also enable interested parties to conduct their own analysis and modelling. This information collection process for electricity network service providers will later be extended to gas network service providers.

The benchmarking techniques the AER is likely to have particular regard to in its access arrangement reviews include multilateral TFP analysis, data envelopment analysis (DEA) and econometric modelling (AER, 2013c, p. 13). Two of these methods are used in the present study.

In regard to establishing the allowed opex for a regulated business in a future regulatory period, AER uses a 'base-step-trend' method, which for each forecast year involves applying the forecast opex growth rate to the preceding year's actual or forecast opex and making any applicable adjustments for step changes. This extrapolation normally commences from the opex in the penultimate year of the previous regulatory period, adjusted for any assessed inefficiency and for any adjustments associated with the Efficiency Benefit Sharing Scheme (EBSS). The forecast opex growth rate is equal to the forecast output growth rate, plus real input price inflation, less the rate of opex partial productivity growth.

The AER states that when assessing forecast productivity, it will consider:

- forecast output growth
- forecast changes in network service provider operating environment factors
- forecast technological change
- how close the network service provider is to the efficient frontier
- historical productivity performance

- any difference between industry average productivity change and the rate of productivity change at the efficient frontier.

The analysis carried out in this study is relevant to key matters that the AER considers when assessing forecast productivity and determining the opex growth rate.

PART B: PRODUCTIVITY INDEX ANALYSIS

This part of the report analyses JGN's partial factor productivity (PFP) and total factor productivity (TFP) using time series and multilateral indexes, and compares its productivity levels and growth rates with the Victorian, South Australian and Queensland gas distribution businesses (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 (2013a). The time series TFP analysis provides estimates of the changes in JGN's TFP over the period 1999 to 2014, and these changes are compared to those for other GDBs. This analysis is presented in section 3.

Multilateral TFP analysis is used 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 and associated opex are excluded to allow like–with–like comparisons across GDBs, but in other respects the same database and output and input definitions are used. This analysis is presented in section 4.

A number of adjustments have been made to the functional coverage of JGN's data to ensure more like–with–like comparisons. In particular, very few transmission pipelines are present within the Victorian GDBs' operations whereas JGN operates significant amounts of trunk and primary mains which operate at very high pressures (above 1050 kPa) with characteristics normally associated with transmission or sub-transmission. To ensure comparability, trunk and primary mains for JGN (and associated opex) are excluded for JGN and transmission mains are excluded for Victoria in the comparison of productivity levels (section 4). These items are, however, included where productivity growth comparisons are made (section 3). In all cases, marketing and retail incentives, market operations expenses, meter reading, government levies and unaccounted for gas are excluded from JGN's opex to put it on a comparable functional basis with data for the Victorian GDBs.

3 PRODUCTIVITY GROWTH

3.1 TFP indexing methods

Productivity is a measure of the quantities of outputs produced in proportion to the quantities of inputs used in the production process, and changes in productivity are measured by changes in the ratio of outputs to inputs between two time periods. Since firms usually use several inputs, and may produce several different outputs, the levels of outputs and inputs are measured by indexes. Index numbers are perhaps the most commonly used means of measuring economic variables (Coelli et al. 2005, p. 85).[3] An index number measures a set of related variables relative to a base period. Growth rates for individual outputs and inputs are weighted together using revenue or output cost shares and input cost shares, respectively. In other words, the TFP index is essentially a weighted average of changes in output quantities relative to a weighted average of changes in input quantities.

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

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

Since indexes are defined relative to a base period, the TFP index measures the *proportionate* change in productivity level relative to the base period. The *rate* of change in TFP between two periods is measured by:

(3.2) $$T\dot{F}P = \dot{Q} - \dot{I}$$

where a dot above a variable represents the rate of change of the variable.[4] 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.

To operationalise TFP measurement we need to combine changes in diverse outputs and inputs into measures of change in total outputs and total inputs. There are alternative index number methods that calculate the weighted average change in outputs or inputs in different ways. The four most popular index formulations are:

[3] An index number is defined as a real number that measures a set of related variables.
[4] 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).

- the Laspeyres base period weight index (Laspeyres, 1871);
- the Paasche current period weight index (Paasche, 1874);
- the Fisher ideal index (Fisher, 1922) which is the square root of the product of the Paasche and Laspeyres index, and used in previous studies including Economic Insights (2012c); and
- the Törnqvist index (Tornqvist, 1936), which has also 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.[5] Diewert found that only the Fisher ideal index passed all of the axiomatic tests.[6] On the basis of his analysis, Diewert recommended that 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:

$$(3.3) \qquad Q_F^t = [(\sum_{i=1}^m P_i^B Y_i^t / \sum_{j=1}^m P_j^B Y_j^B)(\sum_{i=1}^m P_i^t Y_i^t / \sum_{j=1}^m P_j^t Y_j^B)]^{0.5}$$

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;

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:

$$(3.4) \qquad I_F^t = [(\sum_{i=1}^n W_i^B X_i^t / \sum_{j=1}^n W_j^B X_j^B)(\sum_{i=1}^n W_i^t X_i^t / \sum_{j=1}^n W_j^t X_j^B)]^{0.5}$$

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

[5] 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.

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

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:

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

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:

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

In this study we generally use the cost function method developed in Lawrence (2003) and applied to GDB data in Lawrence (2007a) to form output cost shares for the included output components and hence prices that are used in the index number application. This methodology is described in appendix B.

3.2 Data

The primary data source for this part of the study is information supplied by GDBs in response to common detailed data surveys, including by JGN in February 2014 (updated and corrected in January 2015), AGN Victoria, Multinet and AusNet in October 2011, and AGN SA and AGN Qld in 2010. This survey data is much more detailed than the dataset used in the econometric analysis in Part C, but covers fewer GDBs. The survey data has been subjected to detailed checking and, where necessary, clarification to ensure compatibility over time and between included GDBs.

The surveys covered key output and input value, price and quantity information for the periods 1999 to 2014 for JGN; 1999 to 2011 for the Victorian GDBs; and 1999 to 2010 for AGN SA and AGN Qld. The survey data is consistent with the GDBs' Regulatory Accounts, but the cost classifications used are intended to ensure the data reflects actual year–to–year operations. A number of accounting adjustments such as allowance for provisions were 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. These adjustments ensure more like–with–like comparisons. Government levies and unaccounted for gas are excluded from opex for all GDBs to establish a comparable functional basis across the included businesses. Full retail contestability (FRC) costs are included. For the period prior to the introduction of FRC in each jurisdiction, an 'FRC equivalent' amount is added to opex based on the share of FRC costs in opex in the first full year of FRC operation to ensure comparability of coverage over time. In 2012 to 2014 (which are only available for JGN) carbon costs are excluded.

3.3 Outputs, inputs & weights

To measure productivity growth using index analysis we require data on the price and quantity of each output and input. Quantity data is needed 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 output cost shares and for inputs from the share of each input in total costs. 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.[7] To derive the cost shares for inputs we require information on the cost of each input (i.e. its price times its quantity). 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, e.g. terajoules of throughput or number of 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 (e.g. 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 generic 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 (e.g. materials and services inputs).

3.2.1 Output quantities

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 domestic and non–domestic 'tariff' or 'volumetric' customers, and to large 'demand' or 'contract' customers.

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

[7] Economic Insights (2012c) also examined an alternative approach to output weights using revenue shares for each output. This method confines the outputs that can be used in the analysis to billed outputs, and given prevailing tariff structures, implies that most weight is given to gas throughput. The study compared the billed output approach to the method used here, based on functional outputs. It found that the TFP index based on billed outputs had a similar underlying trend as the TFP index based on functional outputs, but was considerably more volatile. This volatility was due to the high weight given to throughput, which is sensitive to the impact of climatic differences (and corresponding differences in the consumption of gas for heating) across years. Over longer time periods starting and ending in years with relatively average climatic conditions, the average annual growth rates of the billed and functional TFP indexes were relatively similar. However, there was a more significant difference in average growth rates for periods starting or ending in years with abnormal climatic conditions. The billed output approach is considered suitable to TFP-based price cap regulation, whereas the functional approach used in this study is considered more appropriate for use in building block regulation.

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 (see, for example, Lawrence 2003) 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 (2007a) 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 for each GDB.[8] 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.

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. Victorian gas networks are designed to deliver a regulated minimum operating pressure (1.4 kiloPascals (kPa) for low pressure, 15 kPa for medium pressure and 140 kPa for high pressure) as per the Gas Distribution Code. To maintain at least this minimum pressure at the fringe of the network and to ensure periods of peak demand can be accommodated while still meeting the minimum pressure requirement, average system pressures have to be considerably higher than these minimums. Average network pressure is, thus, a better representation of service to the majority of customers. The inlet pressure to each of the networks varies throughout the day and season, with a maximum of 450 kPa for high pressure, 70 kPa for medium pressure and 2.8 kPa for low pressure in Victoria and a maximum of 823 kPa for high pressure, 103 kPa for medium pressure and 3.5 kPa for low pressure for JGN. The average system pressure has been calculated to be 300 kPa for high pressure, 32 kPa for medium pressure and 2.2 kPa for low pressure pipelines for the Victorian GDBs and 525 kPa for high pressure, 70 kPa for medium pressure and 3.5 kPa for low pressure pipelines for JGN.[9]

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.

3.2.2 Output weights

To aggregate a diverse range of outputs into an aggregate output index using indexing procedures, a weight must be attributed to each output. We have used the estimated output cost shares derived from the econometric cost function outlined in appendix B used in

[8] These estimates were provided by each GDB's engineers.
[9] See note 6.

Lawrence (2007a) on data for the three Victorian GDBs for the period 1998 to 2006. 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 (2003). 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.

3.2.3 Input quantities

Opex: The quantity of the GDB's opex is derived by deflating the value of opex by an update of the opex price deflator developed by PEG (2006).[10] 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. JGN's carbon costs in 2012 to 2014 were excluded. To ensure consistency in functional coverage throughout the period, for those years prior to the introduction of FRC each GDB's 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.

Transmission network: The quantity of transmission network for JGN is proxied by the sum of its trunk and primary mains length while that for the Victorian GDBs, AGN SA and AGN Qld is proxied by their transmission pipeline length. Transmission and sub-transmission mains are included when measuring and comparing productivity growth in this section of the report, to ensure TFP growth estimates reflect the whole of the GDB regulated business. However, they are excluded in the analysis of comparative productivity levels (section 4), in order to ensure comparability between GDBs.[11] The effect of including transmission pipelines on the results presented in this section can be seen by comparing the stand-alone TFP index for JGN shown in table 3.2 with the multilateral TFP index for JGN presented in table 4.1. JGN's stand-alone TFP index increased at an average annual rate of 0.88 per cent between 1999 and 2014, while over the same period the multilateral index (which excludes transmission pipelines) increased at an average annual rate of 0.97 per cent.

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

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

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

---

[10] 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.

[11] The Victorian GDBs, Envestra SA and Envestra Qld have few transmission pipelines whereas JGN has a significant amount of trunk and primary mains which operate at very high pressures (above 1050 kPa) with characteristics normally associated with transmission or sub-transmission.

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

Meters: The quantity of each GDB's meter stock is proxied by its total number of meter installations.

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.

3.2.4 Input weights

For the update of earlier work and cross–State comparisons, we follow PEG (2006) in using 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 previous studies (Lawrence 2007a; Economic Insights 2012b), the implicit gross rate-of-return for the six GDBs included in this analysis was relatively stable over the period studied, so there is likely be little difference in TFP estimates formed using this approach and the alternative exogenous user cost method.

Under the endogenous rate-of-return approach, the input weight given to opex is simply the ratio of opex to total revenue. The aggregate capital input weight is 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.

3.4 Key characteristics of the included GDBs

The key characteristics of JGN, the three Victorian GDBs, AGN SA and AGN Qld are presented in table 3.1 for 2010, the latest year of common coverage in the database. Further information about these businesses is provided in Appendix 1.

JGN is the largest of the GDBs in the sample. In terms of customer numbers, AGN Victoria, Multinet and AusNet are just over half the size of JGN. However, AusNet has a comparatively high energy density per customer, so its throughput is three-quarters of JGN's. AGN SA is about one-quarter the size of JGN on the basis of both customer numbers and throughput, while AGN Queensland is less than 10 per cent of JGN's size by either measure.

Table 3.1 includes information on two key operating environment characteristics which influence the productivity of energy distribution businesses: energy density (throughput per customer) and customer density (customers per kilometre of mains). AGN Queensland and JGN both have below average customer density, but while AGN Queensland's energy density is also below average, JGN's is around the average level for the included GDBs. AGN SA and Vic both have approximately average levels of customer density, however, AGN SA has below-average energy density while AGN Vic has above-average energy density.

Table 3.1: **Included GDBs' key characteristics, 2010**

GDB	Throughput	Customers	System capacity	Distribution mains length	Energy density	Customer density
	TJ	No	Sm3	kms	GJ/cust	Cust's/km
AGN Vic	56,442	551,925	138,429	10,341	102	53
Multinet	58,686	668,373	124,137	9,910	88	67
AusNet	72,325	576,987	123,982	9,679	125	60
JGN	96,994	1,080,102	369,628	24,196	90	45
AGN SA	24,313	396,084	89,635	7,065	61	56
AGN Qld	5,796	84,057	27,178	2,378	69	35

Source: Economic Insights GDB database

Multinet and AusNet both have above-average customer density, but while Multinet's energy density is approximately average, AusNet's is well above average and the highest in the sample. Since AGN Queensland, JGN and AGN SA are each in some respects below average in regard to these measures, this can be expected to represent a disadvantage when comparing productivity levels against the other businesses (and especially AusNet), which are all in some respects above average in terms of the density measures. On the other hand, JGN's greater size can be expected to represent an advantage over other businesses if there are economies of scale.

3.5 JGN's productivity growth, 1999 to 2014

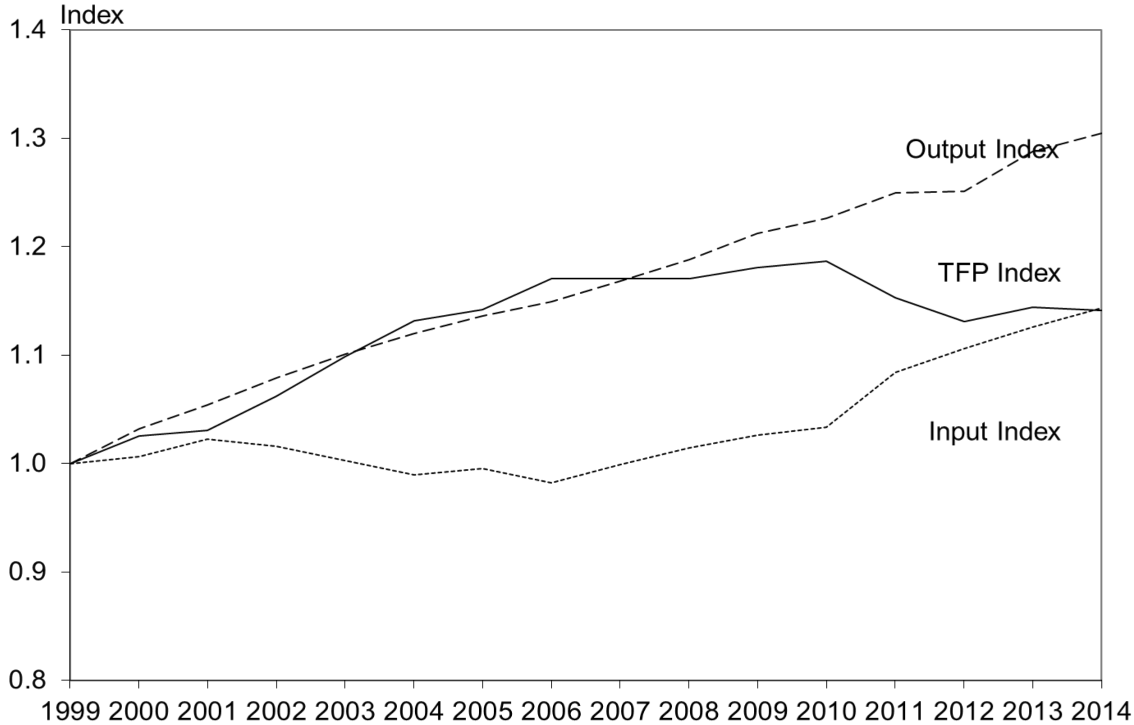
In this section we report JGN's TFP and PFP performance over the 16 year period 1999 to 2014. In the following section (3.6) these are compared with the productivity growth rates of the other GDBs included in the detailed productivity database. To maintain comparability with data available for the other included GDBs we use the same specification as used in Economic Insights (2009c, 2010a, 2012b).

The output quantity, input quantity and TFP indexes for JGN are presented in figure 3.1 and its partial productivity indexes for opex and capital are presented in figure 3.2. All of these indexes are also presented in table 3.2.

The increase in the output quantity index over the 15 years after 1999 has been relatively steady with an average annual growth rate of 1.8 per cent over the period as a whole; 2.0 per cent over the 7 years to 2006; and 1.6 per cent over the 8 years to 2014. The total quantity of inputs followed two distinct trends during the first and second halves of this 15 year period. From 1999 to 2006 inputs decreased at an average annual rate of 0.3 per cent. Over the second part of the period, inputs increased at an annual average rate of 1.9 per cent. Over the whole 15 year period, inputs increased at an average rate of 0.9 per cent per year.

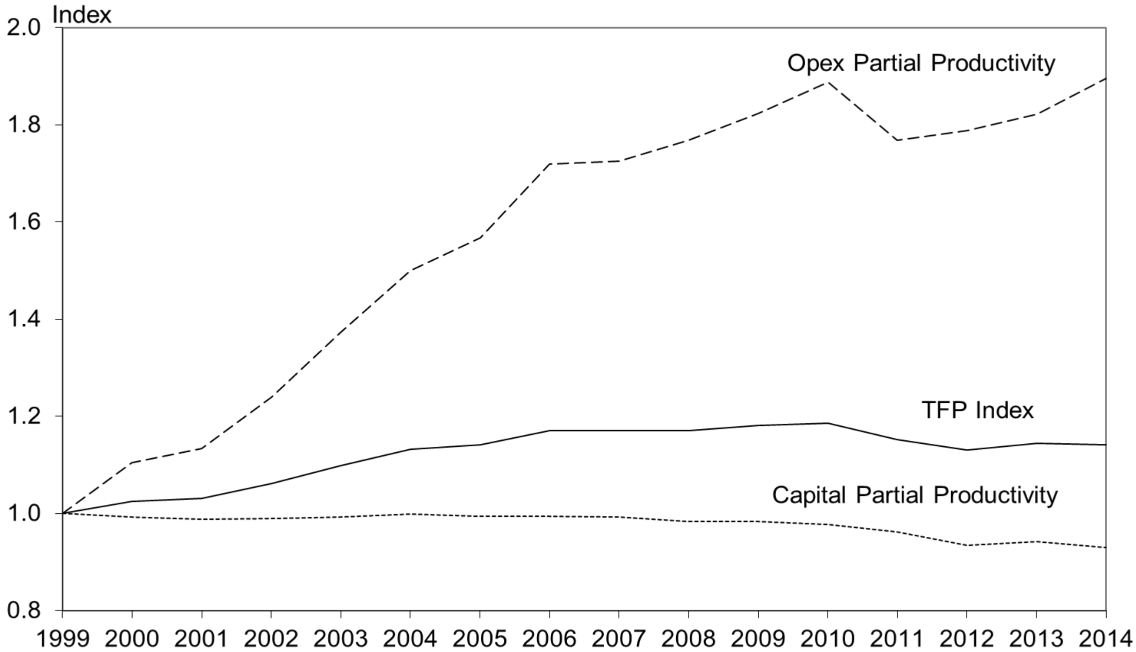
The pattern of input quantity growth has differed markedly between opex and capital. Capital inputs have increased at a relatively steady rate, averaging 2.3 per cent per year over the period from 1999 to 2014. Opex quantity fell markedly between 1999 and 2006 at an average rate of 5.6 per cent per year. In the period from 2006 to 2014, opex usage increased at 0.4 per cent per year on average. Over the 1999 to 2014 period, opex inputs decreased at an average annual rate of 2.5 per cent.

Figure 3.1: **JGN output quantity, input quantity and TFP indexes, 1999–2014**



Source: Economic Insights GDB database

Figure 3.2: **JGN partial productivity and TFP indexes, 1999–2014**



Source: Economic Insights GDB database

Table 3.2: **JGN output quantity, input quantity and productivity indexes, 1999–2014**

Year	Output quantity	Input quantity	Opex Input quantity	Capital Input quantity	Opex PP	Capital PP	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	0.989	0.746	1.121	1.500	0.999	1.132
2005	1.136	0.995	0.725	1.142	1.567	0.995	1.142
2006	1.150	0.982	0.669	1.156	1.719	0.994	1.171
2007	1.169	0.999	0.677	1.178	1.726	0.992	1.170
2008	1.188	1.015	0.672	1.208	1.768	0.983	1.171
2009	1.212	1.026	0.665	1.232	1.824	0.984	1.181
2010	1.226	1.033	0.650	1.254	1.887	0.977	1.186
2011	1.249	1.084	0.707	1.298	1.768	0.962	1.153
2012	1.251	1.106	0.699	1.339	1.788	0.934	1.131
2013	1.288	1.126	0.707	1.366	1.822	0.943	1.144
2014	1.304	1.143	0.688	1.404	1.895	0.929	1.141
Average Annual Change							
1999–2006	2.01%	-0.26%	-5.58%	2.10%	8.04%	-0.08%	2.28%
2006–2014	1.59%	1.92%	0.36%	2.45%	1.23%	-0.84%	-0.32%
1999-2014	1.79%	0.90%	-2.46%	2.29%	4.35%	-0.49%	0.88%

Source: Calculations using Economic Insights GDB database

These changes in output and input quantities have led to a relatively strong productivity performance over the first half of the period studied, driven largely by significant reductions in opex. But JGN's productivity performance in the latter half of the period has been flat or slightly declining, primarily due to capital inputs growth consistently outstripping output growth. From figure 3.2 we see that the partial productivity of opex grew strongly in the first half of the period, but continued to increase at a modest rate in the second half of the period. However, the partial productivity of capital has been slightly negative over the whole period from 1999 to 2014.

The TFP index (which is effectively a weighted average of the two partial productivity indexes) also followed two distinct trends over the 14-year period since 1999. Over the first 7 years to 2006 TFP increased at 2.3 per cent on average, but over the second 8 years to 2014 it declined by 0.3 per cent per annum on average.

3.6 Productivity growth of other GDBs, 1999 to 2011

This section compares JGN's productivity growth rate with the three Victorian GDBs and AGN SA.[12] The historical output, input and productivity indexes and growth rates for AGN Vic, Multinet, AusNet and AGN SA are presented in tables 3.3 to 3.6.

[12] Comparisons with Envestra Qld are not made as it faces very different operating environment conditions.

Table 3.3: **AGN Vic gas distribution productivity indexes, 1999–2011**

Year	Output quantity	Input quantity	Opex Input quantity	Capital Input quantity	Opex PP	Capital PP	TFP
1999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2000	1.028	0.994	0.963	1.024	1.068	1.005	1.034
2001	1.051	1.014	0.994	1.033	1.057	1.017	1.037
2002	1.071	0.981	0.897	1.057	1.193	1.013	1.091
2003	1.119	0.971	0.831	1.097	1.347	1.020	1.152
2004	1.131	0.962	0.772	1.131	1.464	1.000	1.176
2005	1.143	0.915	0.660	1.142	1.732	1.001	1.249
2006	1.167	0.926	0.677	1.148	1.724	1.016	1.260
2007	1.218	0.970	0.704	1.208	1.732	1.008	1.256
2008	1.257	0.987	0.707	1.236	1.779	1.017	1.275
2009	1.283	1.007	0.725	1.258	1.770	1.020	1.275
2010	1.315	1.016	0.715	1.284	1.840	1.024	1.295
2011	1.347	1.045	0.751	1.308	1.793	1.030	1.289
Average Annual Change							
1999–2011	2.51%	0.37%	-2.36%	2.26%	4.99%	0.25%	2.14%

Source: Economic Insights (2012b, p.26)

Table 3.4: **Multinet gas distribution productivity indexes, 1999–2011**

Year	Output quantity	Input quantity	Opex input quantity	Capital input quantity	Opex PP	Capital PP	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	1.020	0.949	0.864	1.005	1.180	1.015	1.074
2002	1.026	0.932	0.767	1.040	1.338	0.986	1.101
2003	1.048	0.906	0.768	0.996	1.365	1.052	1.157
2004	1.054	0.916	0.787	1.001	1.339	1.053	1.151
2005	1.052	0.896	0.740	0.997	1.422	1.055	1.174
2006	1.072	0.898	0.742	1.000	1.445	1.071	1.193
2007	1.087	0.941	0.749	1.066	1.451	1.019	1.155
2008	1.099	0.926	0.709	1.068	1.550	1.029	1.187
2009	1.101	0.924	0.693	1.074	1.590	1.026	1.192
2010	1.113	0.933	0.701	1.083	1.588	1.027	1.193
2011	1.103	0.949	0.705	1.107	1.564	0.996	1.163
Average Annual Change							
1999–2011	0.82%	-0.44%	-2.87%	0.85%	3.80%	-0.03%	1.27%

Source: Economic Insights (2012b, p.28)

Table 3.5: **AusNet gas distribution productivity indexes, 1999–2011**

Year	Output quantity	Input quantity	Opex input quantity	Capital input quantity	Opex PP	Capital PP	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	1.030	1.035	0.998	1.014
2002	1.064	1.059	1.081	1.043	0.984	1.020	1.005
2003	1.086	1.069	1.037	1.094	1.047	0.992	1.015
2004	1.098	1.071	1.008	1.122	1.090	0.979	1.025
2005	1.142	1.018	0.848	1.159	1.346	0.985	1.122
2006	1.175	1.006	0.789	1.180	1.490	0.996	1.169
2007	1.188	0.994	0.741	1.194	1.603	0.995	1.195
2008	1.230	0.983	0.680	1.214	1.807	1.013	1.251
2009	1.254	1.001	0.673	1.248	1.864	1.005	1.253
2010	1.285	0.989	0.585	1.278	2.197	1.005	1.299
2011	1.304	1.010	0.576	1.317	2.262	0.990	1.291
Average Annual Change							
1999–2011	2.24%	0.08%	-4.49%	2.32%	7.04%	-0.08%	2.15%

Source: Economic Insights (2012b, p.31)

Table 3.6: **AGN SA gas distribution productivity indexes, 1999–2010**

Year	Output quantity	Input quantity	Opex input quantity	Capital input quantity	Opex PP	Capital PP	TFP
1999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2000	1.023	1.006	0.969	1.032	1.055	0.991	1.017
2001	1.066	0.986	0.900	1.046	1.184	1.018	1.081
2002	1.087	1.013	0.947	1.061	1.147	1.025	1.072
2003	1.099	0.973	0.825	1.076	1.331	1.021	1.129
2004	1.100	1.008	0.879	1.097	1.252	1.002	1.091
2005	1.110	0.999	0.847	1.106	1.311	1.004	1.111
2006	1.127	1.008	0.837	1.129	1.347	0.998	1.118
2007	1.139	1.007	0.812	1.144	1.403	0.996	1.132
2008	1.153	1.005	0.784	1.162	1.470	0.992	1.147
2009	1.167	1.010	0.780	1.175	1.496	0.993	1.155
2010	1.186	1.011	0.749	1.198	1.583	0.990	1.174
Average Annual Change							
1999–2010	1.55%	0.10%	–2.62%	1.64%	4.17%	–0.09%	1.46%

Source: Economic Insights (2010a, p.25)

Table 3.7 provides a brief summary of the TFP growth trends for each of the GDBs for comparison with JGN, and includes similar summaries for opex and capital PFP. The table shows that between 1999 and 2011, AGN Vic and AusNet had the largest TFP gains, averaging around 2.2 per cent per year. Over the same period JGN, Multinet and AGN SA had lower productivity growth, averaging between 1.2 per cent and 1.4 per cent per year.

Most GDBs, with the exception of AusNet, had considerably lower TFP growth in the period after 2006 than during the period up to 2006. The reversal was most significant with AGN Vic, JGN and Multinet. The latter two GDBs had negative TFP growth over the period after 2006.

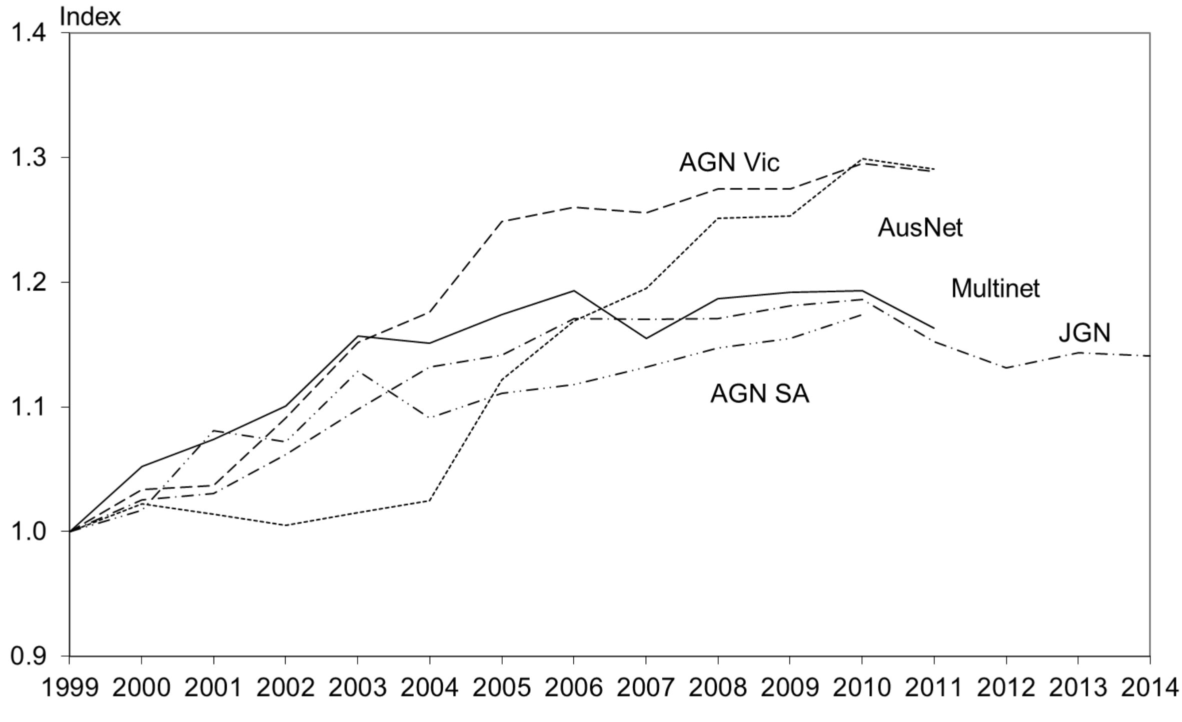
Table 3.7: **Gas distribution TFP growth summary, 1999–2011 (per cent)**

Year	JGN	AGN Vic	Multinet	Ausnet	AGN SA
		TFP			
1999-2006	2.28	3.36	2.55	2.26	1.61
2006-2011	-0.31	0.46	-0.51	2.01	0.98*
1999–2011	1.19	2.14	1.27	2.15	1.35*
		Opex PFP			
1999-2006	8.04	8.09	5.40	5.86	4.35
2006-2011	0.57	0.79	1.60	8.71	4.12*
1999–2011	4.86	4.99	3.80	7.04	4.26*
		Capital PFP			
1999-2006	-0.08	0.23	0.98	-0.06	-0.03
2006-2011	-0.65	0.27	-1.44	-0.12	-0.20*
1999–2011	-0.32	0.25	-0.03	-0.08	-0.09*

*Period to 2010 only.

Source: Economic Insights

Figure 3.3: **Victorian GDB, JGN, and AGN SA TFP indexes, 1999–2014**

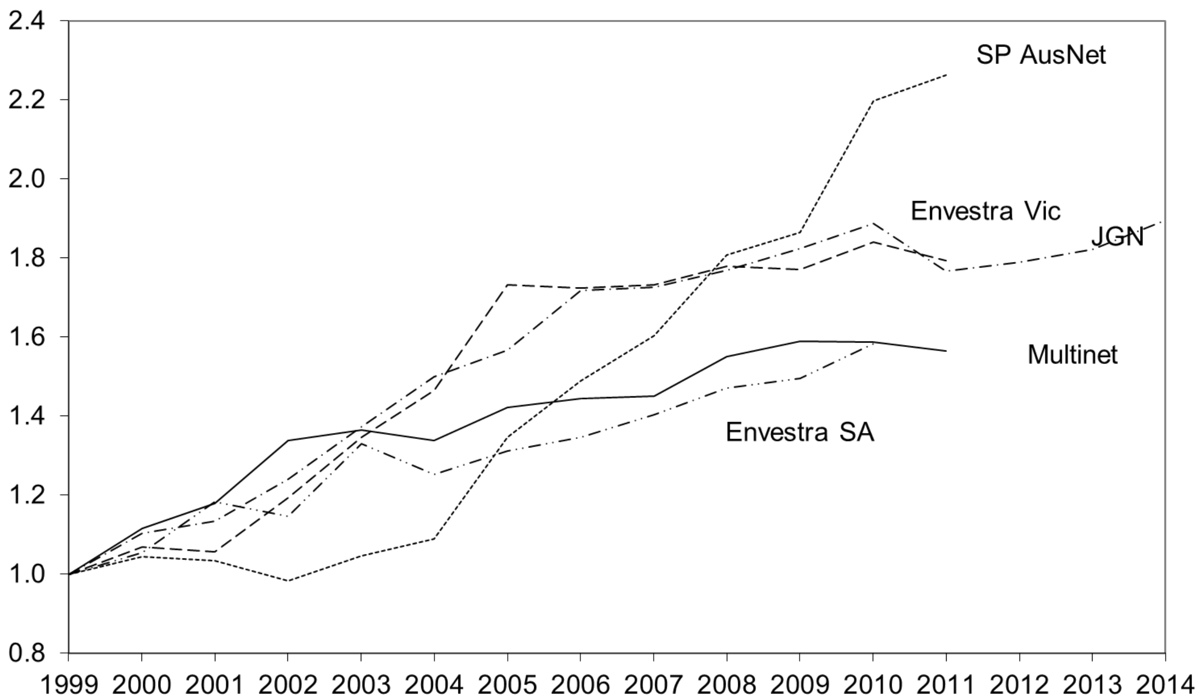


Source: Economic Insights GDB database

Figure 3.3 plots the trends in TFP for each GDB over the periods for which these estimates are available. JGN's TFP index followed a broadly similar pattern to those of Multinet and AGN SA. On the other hand, AGN Vic had exceptionally strong TFP growth during the period 1999 to 2006 (3.4 per cent per annum), and AusNet had particularly strong TFP growth in the period from 2006-2011 (2.0 per cent per year). It should be noted these results do not include allowance for differences in productivity levels (which will be examined in section 4).

Opex partial productivity indexes for JGN, the three Victorian GDBs and AGN SA are plotted in figure 3.4 starting from 1999. All 5 included GDBs have exhibited strong opex partial productivity growth over the period 1999 to 2006. For example, JGN and AGN Vic both had average annual opex PFP growth rates over this period of approximately 8.0 per cent. The corresponding average opex PFP growth rates for AusNet, Multinet and AGN SA were 5.9 per cent, 5.4 per cent and 4.4 per cent respectively. However, in most cases there was much slower opex partial productivity growth in the period from 2006 to 2011. For example, JGN, AGN Vic and Multinet's average annual opex PFP growth rates fell to 0.6 per cent, 0.8 per cent and 1.6 per cent respectively. During the whole 1999-2011 period, AusNet had the highest opex partial productivity growth with average annual rate of 7.0 per cent. AGN Vic, JGN and AGN SA had slightly lower opex partial productivity growth rates of 5.0 per cent, 4.9 per cent and 4.3 per cent, respectively.[13]

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



Source: Economic Insights GDB database

[13] The figure reported for AGN SA is for the period from 2006 to 2010.

The trends in capital partial productivity were not graphed because they would essentially be a set of relatively flat lines, as the growth rates in Table 3.7 make clear. Only AGN Vic's partial capital productivity grew over the period from 1999 to 2011, at an average annual rate of 0.3 per cent. All of the remaining GDBs had slightly declining partial capital productivity over this period.

3.8 Summary conclusions

To summarise the findings of this section, JGN's TFP grew at an average annual rate of 1.2 per cent between 1999 and 2011, but taken over the period to 2014, the average was 0.9 per cent due to small productivity reductions in the period from 2011 to 2014. JGN's TFP growth over the period 1999 to 2011 was at a similar rate to those of Multinet and AGN SA, although AGN Vic and AusNet both achieved average TFP growth rates of over 2 per cent over the same period. The main source of TFP growth for most GDBs over this period was strong growth in opex partial productivity in the period from 1999 to 2006. JGN had the equal highest growth rate of opex partial productivity over this period. For most GDBs, this source of productivity gain was considerably more modest in the period from 2006 to 2011. Furthermore, capital partial productivity for most GDBs was flat or slowly declining over the whole period from 1999 to 2011, and thus capital partial productivity mostly did not contribute to TFP growth and in fact it slightly weakened TFP growth in general.

4 COMPARATIVE PRODUCTIVITY LEVEL RESULTS

4.1 Multilateral TFP indexes

Traditional measures of TFP such as those discussed in chapter 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 (2003a) and PEG (2004) also use this index to compare electricity distribution business TFP levels and Lawrence (2007) used it to compare TFP levels across the three Victorian GDBs.

The Caves, Christensen and Diewert (CCD) multilateral translog index is given by:

$$(4.1) \qquad \log (TFP_m/TFP_n) = \Sigma_i (R_{im}+R_i^*) (\log Y_{im} - \log Y_i^*)/2 - \Sigma_i (R_{in}+R_i^*) (\log Y_{in} - \log Y_i^*)/2 - \Sigma_j (S_{jm}+S_j^*) (\log X_{jm} - \log X_j^*)/2 + \Sigma_j (S_{jn}+S_j^*) (\log X_{jn} - \log X_j^*)/2$$

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 this analysis we have three outputs (throughput, customers and system capacity) and, hence, *i* runs from 1 to 3. We have 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.

Formula (4.1) 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 using equation (4.1) 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 2009 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^*.

For consistency with the previous related studies, the MTFP analysis in this section uses AGN Vic 1999 as the base. As noted above, the results are invariant to the choice of the base observation.

4.2 Data

The database used in the MTFP analysis is the same as that used for the analysis of productivity trends, described in section 3.2, with one important difference. Transmission and sub-transmission mains were included when measuring productivity growth (section 3) in order to reflect the whole business of each GDB, but in the analysis of comparative productivity levels they are excluded to ensure comparability between GDBs. The functional coverage of JGN differs somewhat from that of the Victorian GDBs, AGN SA and AGN Queensland with JGN having considerably longer lengths of trunk and primary mains given the relatively spread out territory it serves. The Victorian GDBs, AGN SA and AGN Qld have few transmission pipelines. To ensure comparability, trunk and primary mains for JGN (and associated opex[14]) are excluded for JGN and transmission mains are excluded for the three Victorian GDBs, AGN SA and AGN Queensland in the comparison of productivity levels presented in this section. Because transmission and sub-transmission inputs are excluded, GDB productivity trends reported in this section differ somewhat from those reported in the last section.

4.3 Australian GDB productivity levels comparisons

We commence by comparing the TFP productivity levels of JGN against five other GDBs for the period 1999 to 2010 or 2011. The survey database extends to 2014 for JGN, 2011 for the Victorian GDBs and 2010 for the South Australian and Queensland GDBs. Multilateral opex partial factor productivity (PFP) is presented in section 4.4.

Multilateral TFP indexes are presented in table 4.1, and plotted in figure 4.1.[15] In 1999, with the exception of AGN Queensland, the GDBs had broadly similar productivity levels. JGN and AGN SA's productivity levels were 10 per cent below AGN Vic, while Multinet and AusNet's productivity levels were 4-8 per cent lower than AGN Vic. On the other hand, AGN Queensland's productivity level was much lower than the other 5 GDBs, being approximately 33 per cent below that of the highest productivity GDB (AGN Vic).

[14] As estimated by JGN.

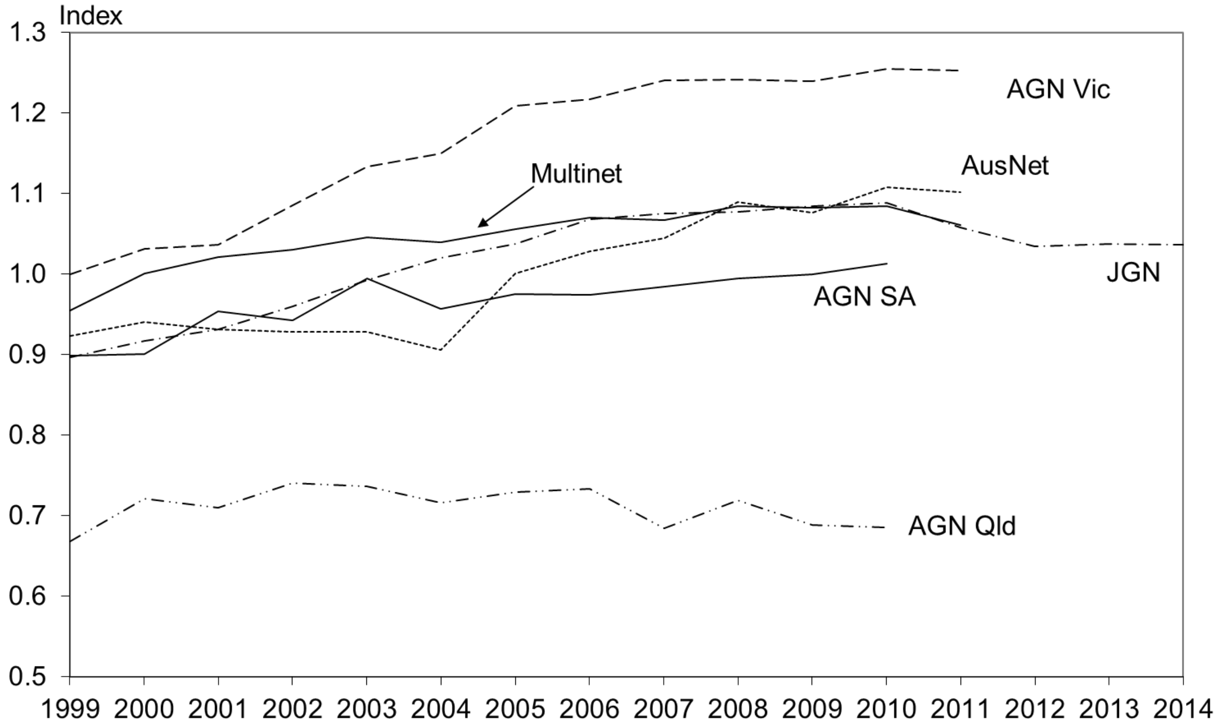
[15] The indexes are presented relative to Envestra Victoria in 1999 having a value of one.

Table 4.1: **Australian GDB Multilateral TFP indexes, 1999–2014**

	AGN Vic	Multinet	AusNet	JGN	AGN SA	AGN Qld
1999	1.000	0.955	0.923	0.897	0.899	0.668
2000	1.032	1.000	0.941	0.918	0.901	0.722
2001	1.037	1.021	0.932	0.932	0.953	0.710
2002	1.085	1.031	0.928	0.960	0.943	0.740
2003	1.133	1.045	0.928	0.992	0.995	0.737
2004	1.150	1.039	0.906	1.020	0.957	0.717
2005	1.209	1.056	1.001	1.038	0.975	0.729
2006	1.217	1.070	1.029	1.069	0.974	0.733
2007	1.241	1.067	1.045	1.075	0.984	0.685
2008	1.242	1.085	1.090	1.077	0.995	0.720
2009	1.240	1.083	1.076	1.085	1.000	0.689
2010	1.255	1.085	1.108	1.088	1.013	0.686
2011	1.253	1.061	1.102	1.058	.	.
2012	.	.	.	1.035	.	.
2013	.	.	.	1.038	.	.
2014	.	.	.	1.037	.	.

Source: Calculations using Economic Insights GDB database

Figure 4.1: **Australian GDB Multilateral TFP indexes, 1999–2014**



Source: Economic Insights GDB database

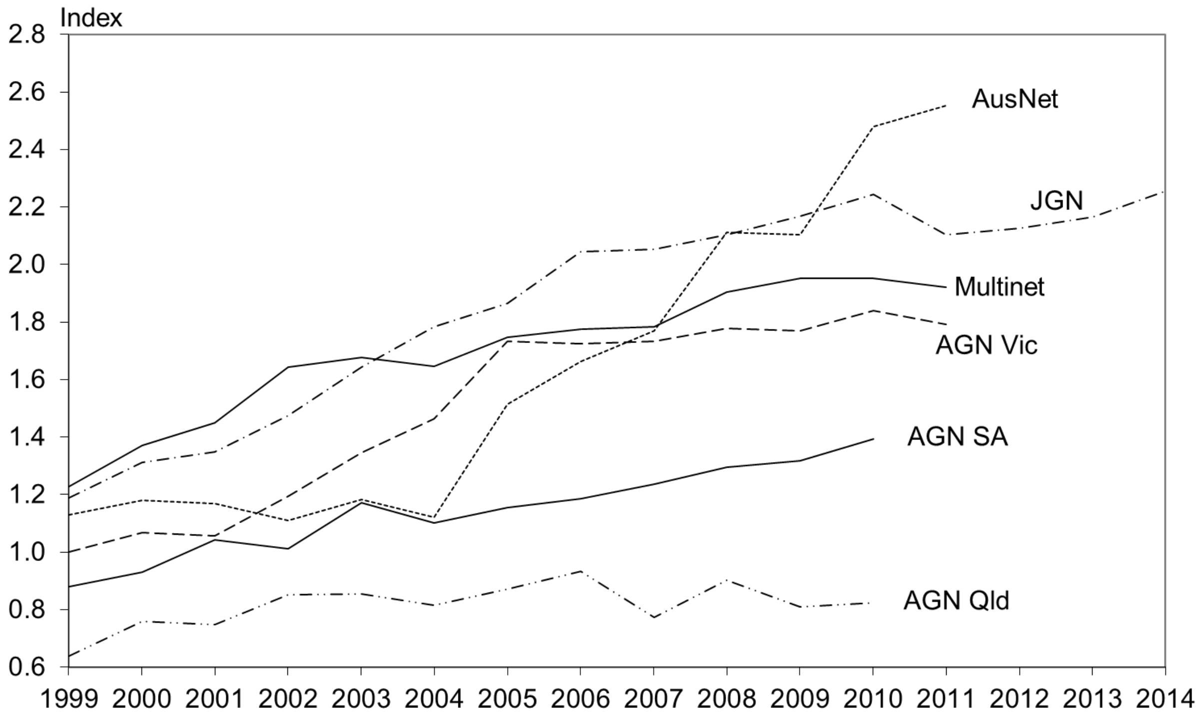
Over the period to 2010, the spread of comparative productivity levels between GDBs widened. The GDB with highest productivity in 1999 (AGN Vic) also had the highest productivity growth over the 12 year period to 2010, while the lowest productivity GDB in 1999 (AGN Queensland), had virtually no net TFP growth over the same period. JGN and AusNet had stronger TFP growth than Multinet and AGN SA, and by 2008-2010, JGN's productivity was at a similar level to Multinet and AusNet.

Since 2010, JGN's productivity level has declined by approximately 5 per cent. Although we do not have comparator GDBs available in the period after 2011, the three Victorian GDBs also had flat or declining productivity in 2011.

4.4 Multilateral Opex & Capital PFP Indexes

The multilateral opex PFP indexes are presented in table 4.2 and figure 4.2, and multilateral capital PFP indexes are presented in table 4.3 and figure 4.3.

Figure 4.2: **Australian GDB multilateral Opex PFP indexes, 1999–2014**



Source: Economic Insights GDB database

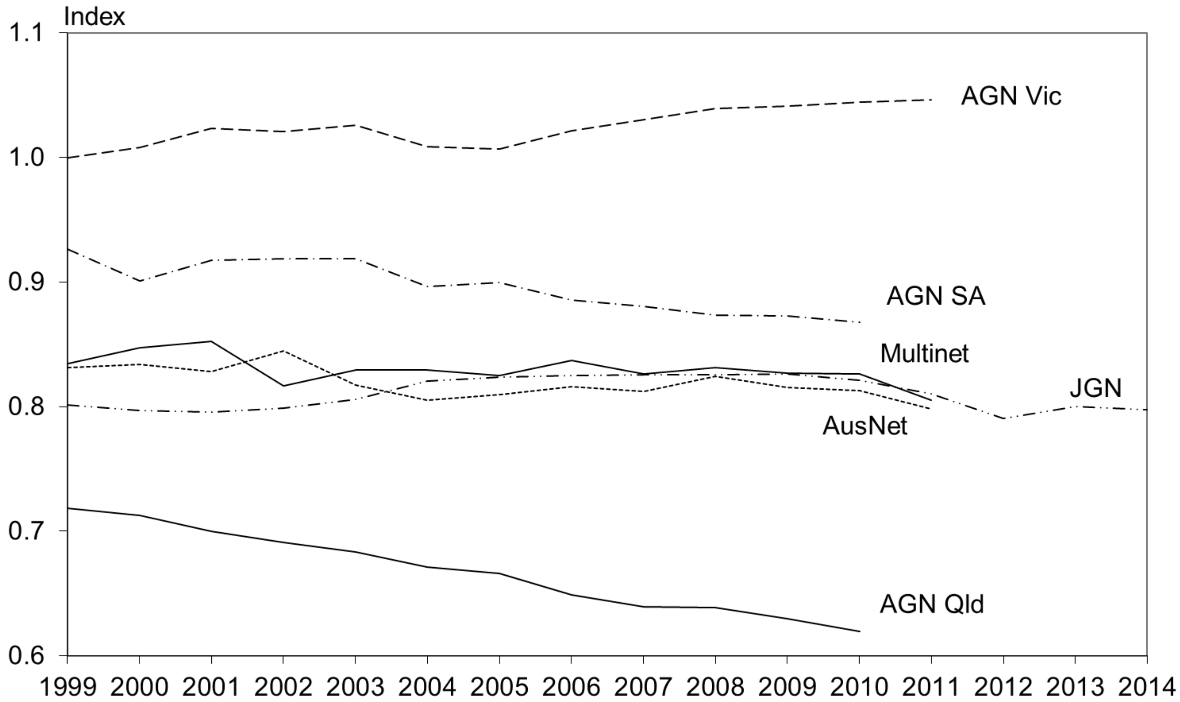
JGN and AusNet had the highest opex partial productivity levels over most of the period 1999 to 2011. By 2010, AusNet and JGN's opex PFP were 2.5 times and 2.2 times that of AGN Vic in 1999 (the basis of comparisons). These were closely followed by Multinet and AGN Victoria, which had opex PFP indexes of 2.0 and 1.8 in 2010, respectively. The strong growth and resulting high comparative levels of opex PFP for these four GDBs is contrasted with AGN SA and AGN Queensland, which had opex PFP indexes in 2010 of 1.4 and 0.8 respectively. The comparatively high proportion of cast iron pipes and low energy density are likely to have affected the ability of these two smaller GDBs to match the opex partial productivity levels of the larger GDBs.

Table 4.2: **Australian GDB Multilateral Opex PFP indexes, 1999–2014**

	AGN Vic	Multinet	AusNet	JGN	AGN SA	AGN Qld
1999	1.000	1.229	1.129	1.189	0.881	0.640
2000	1.068	1.371	1.180	1.313	0.930	0.760
2001	1.057	1.449	1.169	1.348	1.042	0.747
2002	1.193	1.644	1.111	1.474	1.011	0.851
2003	1.347	1.677	1.183	1.642	1.172	0.855
2004	1.464	1.645	1.121	1.784	1.103	0.817
2005	1.732	1.747	1.513	1.864	1.155	0.871
2006	1.724	1.775	1.664	2.044	1.187	0.933
2007	1.732	1.783	1.770	2.052	1.236	0.774
2008	1.779	1.904	2.112	2.103	1.295	0.902
2009	1.770	1.953	2.105	2.169	1.318	0.811
2010	1.840	1.951	2.478	2.244	1.394	0.825
2011	1.793	1.922	2.552	2.102	.	.
2012	.	.	.	2.127	.	.
2013	.	.	.	2.166	.	.
2014	.	.	.	2.254	.	.

Source: Calculations using Economic Insights GDB database

Figure 4.3: **Australian GDB multilateral capital PFP indexes, 1999–2014**



Source: Economic Insights GDB database

With regard to capital multilateral partial productivity levels, there has generally been little or no improvement in capital productivity among the GDBs over the period 1999 to 2010 or 2011, with AGN Vic being the only GDB to achieve a significant improvement. By 2011, its capital PFP index had increased by 5 per cent compared to 1999, while JGN's remained static, and all of the others declined slightly, or in the case of AGN Queensland, significantly. By 2010 or 2011, capital PFP for Multinet, AusNet, JGN and AGN SA were all around 20-25 per cent below that of AGN Vic.

Table 4.3: **Australian GDB multilateral capital PFP indexes, 1999–2014**

	Env. Vic	Multinet	SP AusNet	JGN	Env. SA	Env. Qld
1999	1.000	0.834	0.831	0.802	0.926	0.719
2000	1.008	0.847	0.834	0.797	0.901	0.713
2001	1.023	0.852	0.828	0.796	0.918	0.700
2002	1.021	0.817	0.845	0.799	0.919	0.691
2003	1.026	0.829	0.817	0.806	0.919	0.684
2004	1.008	0.830	0.805	0.821	0.897	0.672
2005	1.007	0.825	0.810	0.824	0.900	0.666
2006	1.021	0.837	0.816	0.825	0.886	0.649
2007	1.031	0.826	0.812	0.826	0.880	0.639
2008	1.039	0.832	0.824	0.825	0.873	0.639
2009	1.041	0.827	0.816	0.827	0.873	0.630
2010	1.045	0.826	0.813	0.821	0.868	0.620
2011	1.047	0.805	0.798	0.810	.	.
2012	.	.	.	0.791	.	.
2013	.	.	.	0.800	.	.
2014	.	.	.	0.797	.	.

Source: Calculations using Economic Insights GDB database

4.4 Summary conclusions

In summary, JGN has had the highest or second highest level of opex multilateral partial productivity for the last 15 years, exceeded only by AusNet in 2010 and 2011. JGN's opex partial productivity increased by almost 90 per cent over the period 1999 to 2014. JGN has had similar capital multilateral partial productivity levels to Multinet and AusNet over the last decade but lower than those of AGN Vic and AGN SA. Looking at the overall productivity result, JGN has had similar multilateral TFP levels to AusNet and Multinet since around 2005. AGN Vic has had consistently higher multilateral TFP levels than these three GDBs but they have had higher multilateral TFP levels than AGN SA and AGN Queensland.

The index number analysis thus shows JGN to have been a good performer in terms of both opex partial productivity levels and growth rates. And it has had similar TFP levels to two of the three Victorian GDBs for the last decade.

We now turn to statistical analysis and the econometric estimation of an opex cost function in the following section to further investigate JGN's relative efficiency levels and achievable future opex partial productivity growth.

PART C: ECONOMETRIC COST FUNCTION ANALYSIS

In this part of the report, we estimate the opex cost function for gas distribution businesses, and use this to examine JGN's opex efficiency compared to the other GDBs. The opex cost function is also used to forecast JGN's opex partial productivity growth rate for the period 2015-16 to 2019-20.

The use of cost function analysis to derive efficiency scores adjusted for environmental and operating effects has a long history. In the United States, Barcella (1992) estimated the cost function of gas distribution businesses based on a sample of 50 companies over the period 1969-1988. In the context of Australia and New Zealand, Pacific Economics Group (2001a, 2001b, 2001c) evaluated the opex performance of the three Victorian GDBs relative to that of US gas distribution utilities by estimating an econometric cost function model that explained the effect on a company's gas distribution cost of some measurable 'business conditions'. The parameters of the model were estimated by established statistical methods using data from a large sample of American investor–owned gas distribution utilities. The model was used to predict opex for the Australian utilities given the values for the (included) business conditions that the utilities faced. The business condition variables included input prices, the amount of outputs supplied and certain characteristics of the customer base and service territory. The model therefore controlled, among other things, for differences in realised scale economies. Cost performance was evaluated by comparing the Australian utilities' actual opex with those predicted by the model for an average US utility facing similar business conditions.

Economic Insights (2012a) used econometric analysis of the total cost function for gas distribution businesses to assess the comparative efficiency of SP AusNet. This analysis was based on a sample of 9 Australian GDBs and 2 New Zealand GDBs using data sourced from the public domain to the maximum extent possible. Total cost function analysis takes into account opex and capital input trade–offs, price effects and controls for certain operating environment factors in the analysis of comparative cost efficiency. The study also developed econometric estimates of the variable or operating cost function and the parameters of this function were combined with forecasts of output and capital input levels to forecast SP AusNet's future GDB opex partial productivity growth rates. Such forecasts are used in the 'rate of change' formula for rolling forward opex allowances often used in the application of building blocks regulation (see: ESC, 2008, pp. 224–250; AER, 2012a Appendix C).

The analysis in this part of the report is similar to that previously undertaken by Economic Insights in 2012. In this case the focus is on the comparative efficiency and forecast partial productivity of JGN. This study uses additional data available since the 2012 study was undertaken and includes a number of other enhancements. These include allowance for a wider range of operating environment factors, the use of more advanced econometric estimation methods and directly estimating opex efficiency levels in the opex cost function itself.

5 FORECASTING FUTURE OPEX PRODUCTIVITY GROWTH

In this section we estimate an opex cost function to assess JGN's opex efficiency level, and to use as an input to forecasting JGN's future opex partial productivity growth. Assessing JGN's opex efficiency level statistically provides information on whether the base year revealed costs are a reasonable starting point for calculating opex requirements for the next regulatory period. And the opex cost function parameter estimates can be used as input to an objective way of calculating future opex partial productivity growth to be included in rate of change calculations for recurrent opex requirements.

An operating cost function, or variable cost function, represents the minimum cost that can be achieved by a firm in the short–run, when capital inputs are fixed or quasi-fixed within the decision period. It differs from a total cost function which represents the minimum total cost when all inputs are fully variable and can be adjusted in response to changes in input prices within the decision period. The relationships between the short-run variable cost function, the short-run and long-run total cost functions, and short-run and long-run marginal costs, are defined in Varian (1984, pp. 35–36).

Some studies estimate the variable cost function in preference to the total cost function, particularly where the quantities of capital employed are lumpy and generally sunk in nature once put in place. Variable cost functions are also useful within the building block regulatory model, where capital expenditure plans and expenditures are separately forecast, and may be treated as given when forecasting efficient levels of operating costs.

5.1 Methodology

5.1.1 Opex cost function specification

In this study we estimate a translog variable cost function model for the pooled data set and use the parameter estimates to make inferences about the efficiency of JGN's opex relative to the sample average. The translog specification has been widely used in economic research and in regulatory hearings (eg: Barcella, 1992; Fabbri, Fraquelli and Giandrone, 2000; Farsi, Filippini and Kuenzle, 2007; Lowry and Getachew, 2009). It has the advantage of providing an approximation to a wide range of functional forms and is generally a robust functional form for empirical work. The economic theory that underlies the translog cost function also enables a number of parameter restrictions to be imposed that are economically sensible and also facilitate estimation. These include: linear homogeneity in prices (so that a doubling of all input prices is reflected in a doubling of costs without any substitution effects occurring); and symmetry in the parameters of price terms (inputs respond in a symmetric manner to relative price effects).

We estimate a translog cost function model that includes the following variables:

- output as measured by the total number of customers and the quantity of gas throughput;
- opex input prices;
- capital inputs;
- a time trend representing technological change; and

- operating environment factors, including customer density as measured by total customers per kilometre of mains, network age as measured by the proportion of the network that is not made of cast iron or unprotected steel and network fragmentation as measured by the number of city gates supplying the GDB from the transmission system.

The translog variable cost function has the following form (in full):

(5.1)

$$\ln VC = a_0 + a_t t + c_1 \ln K + \sum_h a_h \ln N_h + \sum_j \theta_j \ln Y_j + \sum_l b_l \ln P_l + c_2 \left[\ln K \right]^2$$
$$+ \frac{1}{2}\sum_h \sum_i a_{hi} \ln N_h \ln N_i + \frac{1}{2}\sum_j \sum_k \theta_{jk} \ln Y_j \ln Y_k + \frac{1}{2}\sum_l \sum_m b_{lm} \ln P_l \ln P_m$$
$$+ \sum_l \sum_j d_{lj} \ln P_l \ln Y_j + \sum_l \sum_h e_{lh} \ln P_l \ln N_h + \sum_j \sum_h f_{jh} \ln Y_j \ln N_h$$
$$+ \sum_h g_{Nh} \ln N_h \ln K + \sum_j g_{Yj} \ln Y_j \ln K + \sum_l g_{Pl} \ln P_l \ln K$$

where:

- Y_j (or Y_k) are outputs; j,k = 1, 2, …
- P_l (or P_m) are price indices of variable inputs, l,m = 1, 2, …
- N_h (or N_i) are variables that measure relevant operating environment factors; h,i = 1, 2, …
- K is a service flow measure of fixed capital,[16] and
- t is a measure of time and reflects the principle that, all else unchanged, costs decrease marginally each year due to technical change.

The restrictions on this function from economic theory are as follows.

Symmetry: $b_{lm} = b_{ml}$, $\theta_{jk} = \theta_{kj}$

Linear homogeneity: $\sum_l b_l = 1$, $\sum_l b_{lm} = 0$, $\sum_j d_{ij} = 0$

Other implied restrictions: $\sum_k \theta_{jk} = 0$, $\sum_m b_{lm} = 0$

When there are not very many outputs and inputs, the foregoing restrictions derived from economic theory can greatly reduce the number of parameters that need to be estimated. In this study there are just two inputs, capital services and constant price opex, which means that nominal opex is a function of the quantities of the two outputs (customer numbers and throughput), an index of opex input prices, the quasi-fixed quantity of capital services,

[16] This refers to the annual capital input quantity. Due to its durable nature, capital has two distinct economic characteristics, as a source of capital services in production and as a store of wealth. Measures of these characteristics will often be different, and the appropriate measure depends on the analytical context. Wealth measures of capital are more commonly available, and in some circumstances may be used as a proxy measure of capital services (as is the case in this study). Information on capital measurement is provided in (OECD, 2009).

operating environment factors and technological change. When cost functions are estimated, it is usually desirable to jointly estimate the cost function with the implied input demand functions, which provides for more robust estimation of common parameters. However, in this case, with only one variable input, this approach is not available, and the variable cost function is estimated as a single equation.[17]

The various interaction terms in the translog specification can require many parameters to be estimated, which may be problematic when the size of the sample is not large. One means of reducing the number of parameters to be estimated is to exclude some of the quadratic and interaction terms. Given the limited size of the sample used in this study, restrictions of this kind are found to be necessary and have been imposed on capital inputs, and on most of the operating environment variables, to better identify the main effects of the model. Data limitations are discussed in section 5.2.1.

5.1.2 Method of forecasting opex productivity growth

To forecast future opex partial productivity growth we use an approach similar to that presented in Pacific Economics Group (2004), Lawrence (2007b) and Economic Insights (2012a). The starting point for this analysis is the following relationship between a GDB's actual opex, C_{OM}, and its efficient opex, C^*_{OM}:

(5.2) $$C_{OM} = C^*_{OM}.\eta$$

where η is an inefficiency factor. Using standard microeconomic theory, the GDB's efficient opex cost can be shown to be a function of vectors of opex prices (**W**), opex quantities (**Y**), capital quantities (**K**), operating environment variables (**Z**) and time (*T*) as follows:

(5.3) $$C^*_{OM} = g\left(\mathbf{W},\mathbf{Y},\mathbf{K},\mathbf{Z},T\right)$$

Totally differentiating (5.3) with respect to time produces the following:

(5.4) $$\dot{C}^*_{OM} = \left(\sum_i \varepsilon_{Y_i}.\dot{Y}_i + \sum_j \varepsilon_{W_j}.\dot{W}_j + \sum_m \varepsilon_{K_m}.\dot{K}_m + \sum_n \varepsilon_{Z_n}.\dot{Z}_n\right) + \dot{g}$$

The ε coefficients are elasticities of opex cost with respect to the variable, and the dot over a variable represents the variable's growth rate. Combining equations (5.2) and (5.4) we get:

(5.5) $$\dot{C}_{OM} = \left(\sum_i \varepsilon_{Y_i}.\dot{Y}_i + \sum_j \varepsilon_{W_j}.\dot{W}_j + \sum_m \varepsilon_{K_m}.\dot{K}_m + \sum_n \varepsilon_{Z_n}.\dot{Z}_n\right) + \dot{g} + \dot{\eta}$$

The growth rate in actual opex is the sum of:

- the products of the growth rates of each output, input price, capital input and operating environment variable and the elasticity of the opex cost function with respect to that variable;
- the shift in the cost function over time; and

[17] The restrictions from economic theory imply that one of the factor demand functions must be omitted, and there is only one variable factor.

- the growth rate of the inefficiency factor.

Applying Shephard's Lemma (which states that the derivative of the efficient cost with respect to an input price is equal to the efficient quantity of that input), the elasticity of efficient cost with respect to the price of each input can be shown to be equal to the optimal cost share of that input in the minimum cost combination of inputs (SC_j^*). Equation (5.5) can be rewritten as:

(5.6) $$\dot{C}_{OM} = \sum_i \varepsilon_{Y_i}.\dot{Y}_i + \dot{W}_{OM}^* + \sum_m \varepsilon_{K_m}.\dot{K}_m + \sum_n \varepsilon_{Z_n}.\dot{Z}_n + \dot{g} + \dot{\eta}$$

where $\dot{W}_{OM}^* = \sum_j SC_j^*.\dot{W}_j$ is an index of input price growth rates with the efficient cost shares as the weights, and $SC_j^* = \varepsilon_{W_j}$ by Shephard's Lemma, as discussed.

We next define the growth rate of the elasticity weighted output index is defined as:

(5.7) $$\dot{Y}^\varepsilon = \sum_j \left(\varepsilon_j / \sum \varepsilon_j\right)\dot{Y}_j$$

Thus $\left(\sum_i \varepsilon_{Y_i}\right)\dot{Y}^\varepsilon = \sum_i \varepsilon_{Y_i}.\dot{Y}_i$, which is substituted into (5.6):

(5.8) $$\dot{C}_{OM} = \left(\sum_i \varepsilon_{Y_i}\right)\dot{Y}^\varepsilon + \dot{W}_{OM}^* + \sum_m \varepsilon_{K_m}.\dot{K}_m + \sum_n \varepsilon_{Z_n}.\dot{Z}_n + \dot{g} + \dot{\eta}$$

We make use of two definitions. The growth rate of opex partial productivity, $P\dot{F}P_{OM}$, is defined as:

(5.9) $$P\dot{F}P_{OM} = \dot{Y}^\varepsilon - \dot{X}_{OM}$$

where $\dot{X}_{OM}$ is the growth rate of the opex input quantity, which is equal to the difference between the rates of change of opex and the opex price index:

(5.10) $$\dot{X}_{OM} = \dot{C}_{OM} - \dot{W}_{OM}$$

Substituting (5.10) into (5.9) and using (5.8) we have:

(5.11) $$\begin{aligned} P\dot{F}P_{OM} &= \dot{Y}^\varepsilon + \dot{W}_{OM} - \dot{C}_{OM} \\ &= \left\{1 - \left(\sum_j \varepsilon_{Yj}\right)\right\}\dot{Y}^\varepsilon - \sum_m \varepsilon_{K_m}.\dot{K}_m - \sum_n \varepsilon_{Z_n}.\dot{Z}_n - \dot{g} - \dot{\eta} \end{aligned}$$

Equation (5.11) provides an objective basis for forecasting future opex partial productivity growth based on estimated industry characteristics and GDB–specific output and non–opex input changes. The partial productivity of opex can be seen from (5.11) to incorporate a range of factors including scale economies, capital interaction effects, the impact of changes in operating environment factors, technological change and changes in efficiency levels. No additional allowance, thus, needs to be made for any of these factors as they should be captured by the change in opex partial productivity.

To operationalise equation (5.11) we require parameter estimates for an operating cost function from which we can derive the necessary elasticities and forecasts of future output growth, non–opex input growth and changes in operating environment factors. Note also that when the translog specification is used to estimate the opex cost function, and when all variables (excluding the time trend) are divided by their respective mean values prior to estimation, the estimated first order coefficients represent the elasticities required for forecasting opex growth. The combined term $-(\dot{g}+\dot{\eta})$ in equation (5.11) is estimated by the coefficient of the estimated opex function with respect to time.

The AER made the following observation regarding the methodology presented in Economic Insights (2012a):

> 'The AER considers the total cost function parameters estimated by Economic Insights using data from 11 gas distribution businesses from Australia and New Zealand represents a reasonable benchmark of opex PFP growth for the Australian gas distribution industry.' (2012a, p. 8)

With regard to Economic Insights (2009) the AER commented:

> '… it can be accepted that the report provides a supporting opinion that Jemena has obtained value for money for its past operating expenditures and, without evidence to the contrary, is likely to continue to do so.' (AER, 2010, p. 218)

5.2 Data Sources & Sample

5.2.1 Data limitations

Despite the existence of the National Gas Law and Regulations and their predecessors, the amount of reliable, publicly available GDB data below high level aggregate variables has been very limited to-date. Regulatory data have to date concentrated almost exclusively on financial variables, and where detailed operational information has been provided by regulators or GDBs, it often differs in coverage between jurisdictions and over time, and is not typically drawn together in the one location.

These limitations are being addressed by the Australian Energy Regulator (AER), which recently developed regulatory information notices (RINs) for the purpose of gathering information from electricity network businesses for benchmarking purposes (AER 2013). This will include historical data. The RINs published to date apply to electricity transmission and distribution businesses.

Because of the data limitations, the amount of detail we can include in the operating cost function remains relatively limited. There is no available disaggregation of opex into components such as labour and materials costs or into operating and maintenance costs which is consistent across GDBs. This implies that only a single input can be used in the variable cost function. Similarly, there is only limited available information on operating environment factors. That said, this study uses a wider set of operating environment factors than previous studies of this kind. In addition to the key characteristic of customer density, this study also uses data for the geographical fragmentation or dispersion of networks operated by each

GDB, and network age-related characteristics such as the proportion of mains that are made of cast iron or unprotected steel.

5.2.2 Data sources

The data used in this part of the study has been sourced from documents in the public domain to the maximum extent possible and relates to the period from 1999 onwards. Data for most of the Australian GDBs in the study are publicly available for most of this period, but there are fewer consistent observations publicly available for the New Zealand GDBs, reflecting the impact of mergers, asset sales and industry restructuring. As a result, of the two New Zealand GDBs included in the sample, Powerco only has observations for 2004 onwards and Vector for 2006 onwards. For JGN, only historical data up to 2014 is included. For the other Australian GDBs, regulators' forecasts for years beyond 2012 or 2013 (as applicable) are also included, where available in final regulatory determinations. The database used in this study includes a total of 171 observations. This compares to 144 observations used in Economic Insights (2012a).

The public domain data sources used for the Australian GDBs include:

- Access Arrangement Information (AAI) filings as proposed and as amended by a regulator's decision;
- Asset Management Plans (AMPs), whether appended to AAI or published separately;
- Regulators' final decisions, sometimes with amendment following appeal; and
- Annual Reports from the GDB or its parent firm.

The principal public domain data sources used for the NZ GDBs are the Information Disclosure Data filings required by the *Gas (Information Disclosure) Regulations 1997*, and published AMPs and Annual Reports.

The Australian GDBs included in the database are:

- ActewAGL, Australian Capital Territory
- APT Allgas Pty Ltd (Allgas), Queensland
- ATCO Gas Australia, Western Australia
- AGN Queensland, Queensland
- AGN SA, South Australia
- AGN Vic, Victoria
- JGN, NSW
- Multinet, Victoria
- AusNet, Victoria

The New Zealand GDBs included in the database are:

- Powerco Limited
- Vector Ltd

The dataset developed from the public domain sources relates to the time periods normally reported by each GDB – some GDBs use calendar year reporting while others use financial year reporting. The public domain data were in a mix of nominal and real terms based on different years. All cost data were first converted to nominal terms (where necessary) using the all groups consumer price indexes for each country. The New Zealand data were then converted to Australian dollars using the OECD (2011) purchasing power parity for 2010. Purchasing power parities are the rates of currency conversion that eliminate differences in international price levels and are commonly used to make comparisons of real variables between countries.

While relatively recent regulatory reviews are available for most Australian States, this is not the case for NSW where the last regulatory review was undertaken by the AER in 2009. Consequently, we use data from our survey of JGN up to 2014 in preference to now relatively old public domain sources. Conversely, public domain data for the Victorian GDBs are now more up to date than the survey data used in Economic Insights (2012a) and AER final determination forecasts are available out to 2017. As a result we follow the same practice as in Economic Insights (2012a) of using public domain data for all GDBs other than the one we are producing opex productivity forecasts for, and use survey data for that GDB, in this case JGN.

In a few cases missing observations were estimated based on growth rates for the variable or a related variable before and after the missing year. In a number of cases adjustments were made to ensure the data related to comparable activities and measures. The most important of these is adjustment of the opex of non–Victorian GDBs to exclude unaccounted for gas allowances in order to put those GDBs on a comparable basis with Victorian reporting. The AER's final determination forecasts, which have been undertaken at various times, have not been adjusted for any differences in assumptions made about carbon taxes. JGN's survey data is used in this analysis, which excludes carbon costs in 2012 to 2014.

The data used for the Australian GDBs covers only their regulated activities, and may exclude some large industrial users whose supply is not regulated. Data for unregulated activities was not included in part because the information is not generally in the public domain and in part because this might diminish the comparability between GDBs. While every effort has been made to make the publicly available data used in this study as consistent as possible, the limitations of currently available public domain data mentioned previously need to be recognised.

5.2.3 Variables used

GDB data used includes: nominal opex; the opex input price index; constant price regulatory asset value; gas throughput; customer numbers; GDB pipeline length; the length of mains that are made of cast iron or unprotected steel; and the number of city gates serving the GDB's network.

Opex covers distribution activities only and excludes all capital costs and transmission fees. It includes all directly employed labour costs, contracted services and materials and consumables costs associated with operating and maintaining the distribution service. Unaccounted for gas is excluded from opex in all cases. The operating and maintenance price index is a weighted average of labour costs (62 per cent) and other costs represented by a range of producer price indexes (38 per cent) as reported in Economic Insights (2012c). We have used the ABS wage price index (WPI), Electricity, gas, water and waste services (EGWW) sector, for the labour component and a weighted average of five economy–level Producer Price Indexes for the non–labour component. For the New Zealand GDBs the opex price index is a similar weighted average of labour costs and the consumer price index. These opex price indexes were projected forward beyond 2013 based on the average annual growth rate over the five years from 2008 to 2013.

Constant price asset value was calculated using reported historical real regulatory asset base (RAB) values and regulator approved forecasts. Given the relatively "one hoss shay" physical depreciation characteristics of pipelines,[18] using the constant price depreciated asset value is generally less preferred to using pipeline length as the proxy measure for the capital input quantity. Nevertheless, we use the constant price RAB as a proxy for the quantity of capital in this econometric analysis, rather than a physical proxy such as the kilometres of mains, to avoid multicollinearity problems given that mains length is used in the measurement of the important operating environment factor of customer density.

Table 5.1 summarises the variables used in the opex cost function analysis.

Table 5.1: **Summary of outputs, inputs & business environment variables**

Outputs	Inputs	Operating Environment Factors
Gas throughput (TJ)	Constant price opex	Customer density (customers/km mains)
Customer numbers	Capital services measured by constant price asset value	Network age (proxied by the proportion of total mains length not made of cast iron or unprotected steel)
		Service area dispersion (proxied by the number of city gates)

Operating environment factors are exogenous influences affecting the cost efficiency of the network which are largely beyond management's control. They include the climate, geography, topography and demography of the GDB's service area. Unless the key operating environment factors are allowed for in the analysis, an inaccurate and misleading estimate of the scope for opex productivity growth and of relative efficiency levels may result because like is not being compared with like. The key operating environment factors which influence an energy distribution business' operating cost levels, and that were included in this study are:

- *Customer density* (customers per kilometre of mains): This variable was included in the Economic Insights (2012a) study. Customer density is largely a product of the degree of

[18] "One hoss shay" is a term used in economics to refer to a depreciation time-profile in which a capital good delivers the same services throughout its lifetime until it fails, having no remaining productive or scrap value after that.

urban density in the GDB's reticulated areas and the rate of gas penetration in these areas. The rate of gas penetration is heavily influenced by the coldness of the winter climate which is an important factor in demand for gas for household heating purposes, although other influences such as the prices of alternative heating fuels may also be important.

- *Proportion of cast iron/unprotected steel mains*: Gas networks that are made of cast iron and unprotected steel have higher maintenance requirements because they are subject to corrosion, water ingress and relatively high rates of breakage. The network age proxy variable, the proportion of cast iron/unprotected steel mains, was included for the following reasons. Economic Insights previously expressed reservations with regard to the use of depreciated constant price asset value as a measure of capital inputs because "differences in average asset age will play a role in the resulting capital asset efficiency comparisons" (Economic Insights 2012b, p. 25). Further, it is well established that maintenance requirements may increase with the age of certain types of assets (Diewert 2009). The inclusion of a variable related to asset age is intended to control for effects of these kinds. The proportion of cast iron/unprotected steel mains is correlated with, and effectively a proxy for, the average network age (UMS 2001, p. 28). It is likely to be a more useful variable than average network age because "materials such as PE and cathodically protected steel do not generally exhibit a useful life and may be considered to have an indefinite life if well-constructed and maintained" (Multinet 2012, p. 18). The progressive replacement of cast iron/unprotected steel mains with new mains made with modern materials substitutes capital for non-capital inputs and is a source of reduction in maintenance costs over time. Failing to take into account this source of reduction in maintenance cost would confuse factor substitution with productivity change. It would place at a disadvantage those GDBs that have renewed their former cast iron/unprotected steel networks, and no longer have this as an ongoing source of reducing opex.
- *Service area dispersion:* A measure of network fragmentation, proxied by the number of city gates was also included. Some GDBs have a large number of discrete networks serving smaller cities and townships, whilst others have fewer networks serving larger urban areas. The former will not only have a smaller typical operating scale, but the greater dispersion of the area supplied may reduce the efficiency of work crews that maintain the networks and necessitate more duplication of some inputs than would be the case for a GDB serving a very compact and contiguous area. Similarly, a network that is more 'dendritic' in nature will require more mains to support enough gas flow to service spread out pockets of consumption compared to a network that is more compact and intermeshed. Failing to allow for this operating environment difference in efficiency comparisons would place the fragmented and dendritic networks at an unreasonable disadvantage and the compact and intermeshed networks at an artificial advantage.

We also tested climate–related variables, particularly measures of the average heating degree days in each region. However, for reasons given above, we considered that customer density takes into account most of the influence of climate on gas distribution networks. That is, the rate of gas penetration in reticulated areas is correlated with the demand for gas for heating. Average gas use per household is also related to climate, but the measure of gas throughput used in this study includes commercial and industrial uses also, which are less weather sensitive. The relative importance of commercial and industrial load differs between networks, and this is an important factor in the comparative levels of throughput per customer. Climate is not a sufficiently significant factor in this sample given that most of its influence is taken into account by the customer density variable.

5.2.4 Key characteristics of included utilities

The 11 Australasian distribution businesses operate in varying environments with often substantial differences in network size, amount of throughput, demand growth, number and type of customers, and the mix of rural, urban and CBD customers. Table 5.2 presents summary data for the GDBs included in the sample for 2012, including outputs, inputs and key operating environment factors.

Table 5.2: **GDBs' key characteristics, 2012**

GDB	Throughput	Customers	Nominal opex	Real Reg. Asset Value
	TJ	no.	$m	$m
AGN Vic	55,492	576,804	56.3	1,063
Multinet	56,858	669,631	56.1	1,004
AusNet	74,707	609,290	46.3	1,213
AGN SA	22,256	411,199	52.1	1,047
AGN Qld	6,030	89,098	17.8	324
Allgas Qld	9,897	87,315	17.0	436
JGN	90,877	1,139,711	129.9	2,223
ActewAGL	7,696	123,470	22.8	315
ATCO WA	28,103	640,936	54.0	880
Powerco NZ	9,067	102,696	17.8	367
Vector NZ	21,740	153,585	28.8	440

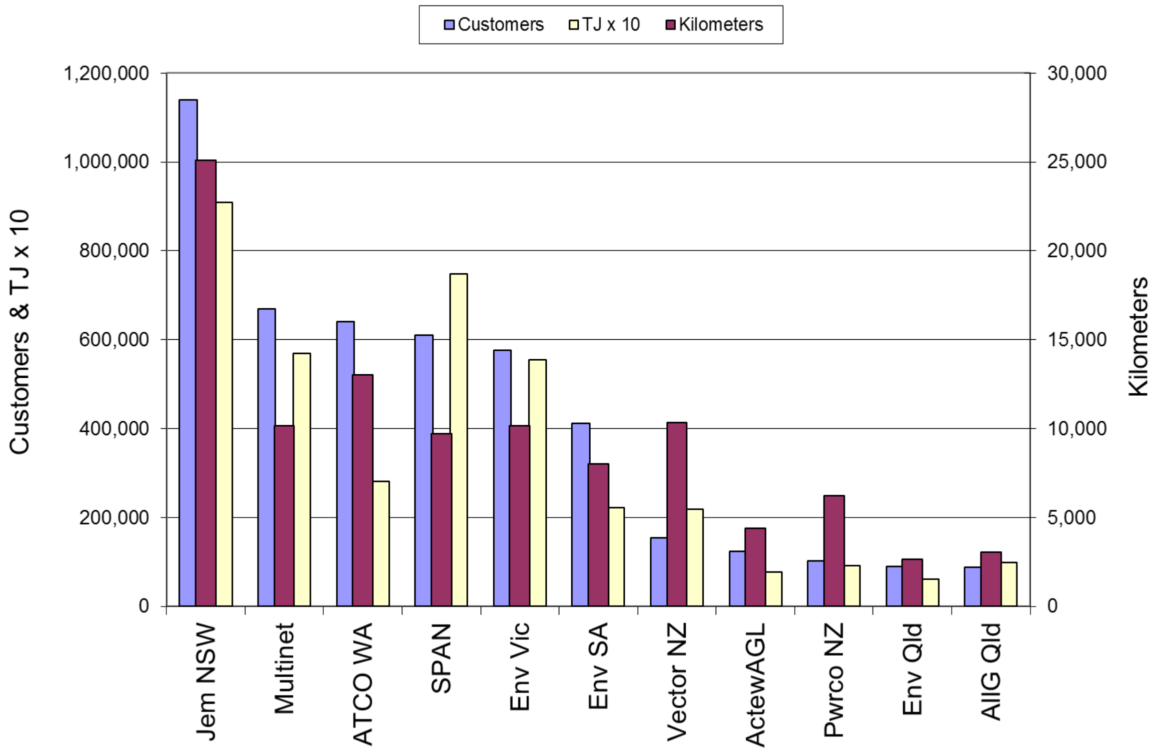
Table 5.2: **GDBs' key characteristics, 2012 (cont'd)**

GDB	Total mains length	Customer density	Cast iron/ unprotected steel mains	City Gates
	kms	cust./km	%	no.
AGN Vic	10,135	56.9	3.7	56
Multinet	10,147	66.0	13.2	6
AusNet	9,719	62.7	8.0	38
AGN SA	8,010	51.3	15.4	16
AGN Qld	2,643	33.7	8.5	11
Allgas Qld	3,022	28.9	15.7	7
JGN	25,076	45.5	0.6	74
ActewAGL	4,364	28.3	0.0	2
ATCO WA	13,035	49.2	0.2	15
Powerco NZ	6,216	16.5	0.1	36
Vector NZ	10,326	14.9	0.5	63

Source: Economic Insights GDB database

Figure 5.1 shows the comparative sizes of the GDBs in the sample using three different measures of business size. JGN's NSW distribution network is by far the largest of the 11 included GDBs, with the three Victorian GDBs and ATCO in WA being the next largest in terms of customer numbers.

Figure 5.1: **Key measures of GDB size, 2012**



Source: Economic Insights gas utility database

Table 5.2 shows that the three Victorian GDBs have the highest customer density in the sample, in part due to the cool winter climate and associated high gas demand for household area heating. By contrast, the two Queensland GDBs have customer densities that are approximately half the levels of the Victorian utilities, in part due to Queensland's warm winter climate, which reduces the likelihood that households will choose to have reticulated gas supplied to their home. JGN, AGN SA and ATCO all have customer densities that are between those of the Victorian and Queensland GDBs. In some areas that have cold winter climates, such as New Zealand and the ACT, customer density is comparatively low. This may in part be due to relatively lower urban density. Higher or lower density is largely driven by factors external to the GDB, and if the differing densities are not allowed for in the analysis, the effects of lower density on opex may be incorrectly attributed to comparative inefficiency of those GDBs. The approach of taking customer numbers as an output measure with customer density as separate operating environment variable was used by Pacific Economics Group (2004) and Economic Insights (2012a).

As shown in table 5.2, five of the GDBs in the sample have significant amounts of cast iron and unprotected steel mains in their networks. These include Multinet and Ausnet in Victoria, AGN SA, and Allgas and AGN Queensland. These networks are generally the oldest in the sample. The network that is the newest in the sample – ActewAGL in the ACT – has no cast iron and unprotected steel mains. JGN has only 0.6 per cent of its mains made up of cast iron and unprotected steel due to an AGL replacement program in the 1990s. Where there remain significant amounts of cast iron and unprotected steel mains, and as these mains are replaced with more modern pipeline materials over time, maintenance costs will be progressively reduced due to the substitution of capital for labour. Including this variable in the analysis enables this substitution effect to be separated from the measurement of technical change. Failure to do this would lead to the rate of opex productivity growth being overestimated both historically and in resulting forecasts for future achievable gains.

The three GDBs with the highest number of city gates are JGN, Vector NZ and AGN Vic. These GDBs supply a large number of regional cities and towns in addition to their main city markets. The three GDBs with the smallest number of city gates are ActewAGL, Multinet and Allgas Queensland. These GDBs largely supply metropolitan areas and relatively few regional cities and towns. It is useful to take into account the separate effects on opex of this spatial dimension of network configuration in order to achieve more like–with–like comparisons of fragmented and dendritic networks versus compact and intermeshed networks in efficiency level comparisons and to obtain an unbiased estimate of the rate of technical change.

5.3 Econometric Results

5.3.1 Enhancements and changes relative to Economic Insights (2012a)

In this analysis we have been able to further develop the model presented in Economic Insights (2012a). Specifically:

- The analysis benefits from a larger data sample by including additional observations now available, and recent AER approved forecast values for the Victorian GDBs. The analysis also uses the most up-to-date historical data for JGN drawn from the survey.
- Given the larger number of observations, we can now estimate opex efficiency levels directly within the operating cost function itself rather than indirectly through a total cost function system as done in Economic Insights (2012a). The total cost function method used in Economic Insights (2012a) relied on estimates of opex cost shares to derive implicit forecast opex levels and opex efficiency information. But because information on the goodness–of–fit of individual equations within an equation system is generally less reliable (Berndt, 1990, p. 468), the accuracy of the opex efficiency estimates using that method is less certain. Deriving opex efficiency information directly from the operating cost function provides more information about the goodness–of–fit, and hence confidence in the accuracy of the estimates.
- Additional operating environment factors relating to network age and the dispersion of distribution networks supplied by each GDB have been included in the model.
- Improved econometric methods have been used which enables the relative opex efficiency of GDBs to be directly measured. Two different econometric techniques are used to estimate the preferred opex cost function specification, providing for more

robust forecasting of the rate of change in opex partial productivity while also permitting estimation of comparative opex technical efficiency levels.

5.3.2 Opex cost function specification

The specification shown in equation (5.12) is, by necessity simplified when compared to the full translog specification of the variable cost function discussed in section 5.1.1. The model has two outputs, namely gas throughput and customer numbers, and second order terms for these outputs are included. The opex input price is restricted to have a coefficient of one to ensure homogeneity of degree one in input prices. The constant price asset value was used as the capital quantity proxy and a time trend as the technological change proxy. Second order terms relating to capital inputs were not included.

The model includes three operating environment variables – customer density, the proportion of mains that are not cast iron or unprotected steel (NCI) and the measure of service area dispersion (i.e. the number of city gates, CG) – which all enter the model in log form.

$$\begin{aligned}(5.12)\quad \ln C_{OM} &= \ln W_{OM} + b_0 + b_D \ln D + b_C \ln C + 0.5 b_{DD} (\ln D \ln D) + b_{DC} (\ln D \ln C) \\ &+ 0.5 b_{CC} (\ln C \ln C) + b_{CPAV} \ln CPAV + b_t t + b_{NCI} \ln NCI + b_{CD} \ln CD \\ &+ 0.5 b_{CDCD} (\ln CD \ln CD) + b_{CG} \ln CG\end{aligned}$$

5.3.3 Econometric estimation methods & results

Two estimation methods were used for this analysis. The first is the feasible generalised least squares (FGLS) estimator, allowing for heteroscedastic panels. This method was used to estimate the coefficients of equation (5.12), but does not provide estimates of the comparative efficiency of the GDBs. The second method is stochastic frontier analysis (SFA) with time invariant firm-specific inefficiency. These two models, taken together, aim to update the models reported in Economic Insights (2012a) but include more operating environment effects and use improved econometric estimation methods. The SFA model is used to provide estimates of the technical efficiency of each GDB in the sample. It thus advances the model reported in Economic Insights (2012a) to incorporate direct estimation of opex efficiency levels within the operating cost function.

We report, and combine, the results from both the FGLS and SFA methods because each has different assumptions regarding the nature of the stochastic disturbance term (not shown in equation (5.12)) to be assumed when estimating the model. Each has particular advantages that are appropriate to this application.

These two methods and the reasons for their use in this study can be explained as follows. Let ε_{it} represent the stochastic disturbance term included in the variable cost function, where i = 1 …n are panels (or firms) in the sample and t is the year of each observation. The FGLS estimation method used here has the advantage that the variance matrix of the disturbance terms can take the form:

(5.13) $$E\left[\varepsilon\varepsilon'\right] = \mathbf{\Omega} = \begin{pmatrix} \sigma_1^2 I & \dots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \dots & \sigma_n^2 I \end{pmatrix}$$

for panels 1 to n, so that the random error term has zero mean across the whole sample, and in each panel of the dataset it has a different variance. This assumption is appropriate in this context because there is wide variation in the sizes of the GDBs in the sample, so the dependent variables, and some of the explanators, are of different orders of magnitude for some GDBs compared to others. So it is reasonable to expect the scale of the variances may also differ. The FGLS estimator is equivalent to maximum likelihood estimation (see: Davidson and MacKinnon 1993, s 9.5; Wooldridge 2002, s 7.6).

The SFA method used here has the advantage that the stochastic disturbance term can be decomposed into a white noise term (v_{it}) and a cross-sectional (firm-specific) strictly positive random term (u_i), which is interpreted as a measure of inefficiency. That is:

(5.14) $$\varepsilon_{it} = v_{it} + u_i; \quad v_{it} \sim N(0,\sigma_v^2); \quad u_i \sim N^+(0,\sigma_u^2)$$

The component u_i is positive and distributed according to a half-normal distribution. It is interpreted as a time invariant firm-specific inefficiency measure (see: Kumbhakar and Lovell 2000; Greene 2008). This method has the advantage that it can be used to estimate the coefficients of equation (5.12) while also providing estimates of the technical efficiency of each GDB in the sample.

Table 5.3: **Opex cost function regression estimates**

FGLS model[1]			SFA model[2]		
Coefficient	Estimate	t–statistic[3]	Coefficient	Estimate	t–statistic[3]
b_0	0.1523	7.59	b_0	0.0125	0.11
b_D	0.3815	8.93	b_D	0.2370	2.19
b_C	0.2164	4.10	b_C	0.1303	0.69
b_{DD}	1.2513	7.92	b_{DD}	1.2598	6.02
b_{DC}	-0.7469	-5.44	b_{DC}	-1.1020	-6.44
b_{CC}	0.2086	1.65	b_{CC}	0.7347	4.02
b_{CPAV}	0.4489	9.05	b_{CPAV}	0.6345	6.41
b_t	-0.0069	-3.42	b_t	-0.0071	-2.11
b_{NCI}	-0.3865	-3.60	b_{NCI}	-0.3565	-1.63
b_{GT}	-0.0027	-0.27	b_{GT}	0.0945	2.71
b_{CD}	-0.6165	-8.72	b_{CD}	-0.9982	-3.63
b_{CDCD}	-0.6953	-5.16	b_{CDCD}	-1.4770	-3.43

1 R^2 between observed and predicted is 0.96.
2 R^2 between observed and predicted is 0.98.
3 Critical t-statistics for testing are: 1.289, 1.658, 1.980 and 2.617 for the 20, 10, 5 and 1 per cent significance levels, respectively. A 5 per cent level of significance is used as the standard measure and less than 1 per cent is considered to be a very high level of significance. Results at the 10 per cent level of significance are also considered to be statistically meaningful.

The results of estimating these two models are shown in table 5.3. In both cases the estimated model has the same variables in the form shown in equation (5.12). Where a variable is significantly different from zero in one model (at least to a 90 per cent level of confidence), but insignificant in the other model, the variable has been retained in both models. Differences in the models are then entirely due to the different estimation methods. Taken together, these two estimated models provide a suitable representation of the opex cost drivers of GDBs, and together provide a robust basis for forecasting partial productivity. The two models provide similar estimates of opex partial productivity growth under different assumptions relating to the stochastic process. Each model has merit with neither model preferred over the other, and it is appropriate to take the average of the two sets of results for use in the opex rate of change analysis. This approach was used in previous analysis of this kind by Economic Insights (2012a, p. 23) and the same approach is followed in this report.

5.3.4 Discussion of parameter values

GDBs are found to have strong economies of scale in regard to opex, as indicated by the sum of the elasticities of opex with respect to gas deliveries and customer numbers ($b_D + b_C$). In the first model this is equal to: (0.382 + 0.216 =) 0.598, and in the second model it is: (0.237 + 0.130 =) 0.367. This means a one per cent proportionate increase in outputs results in an opex increase of approximately half of one per cent.

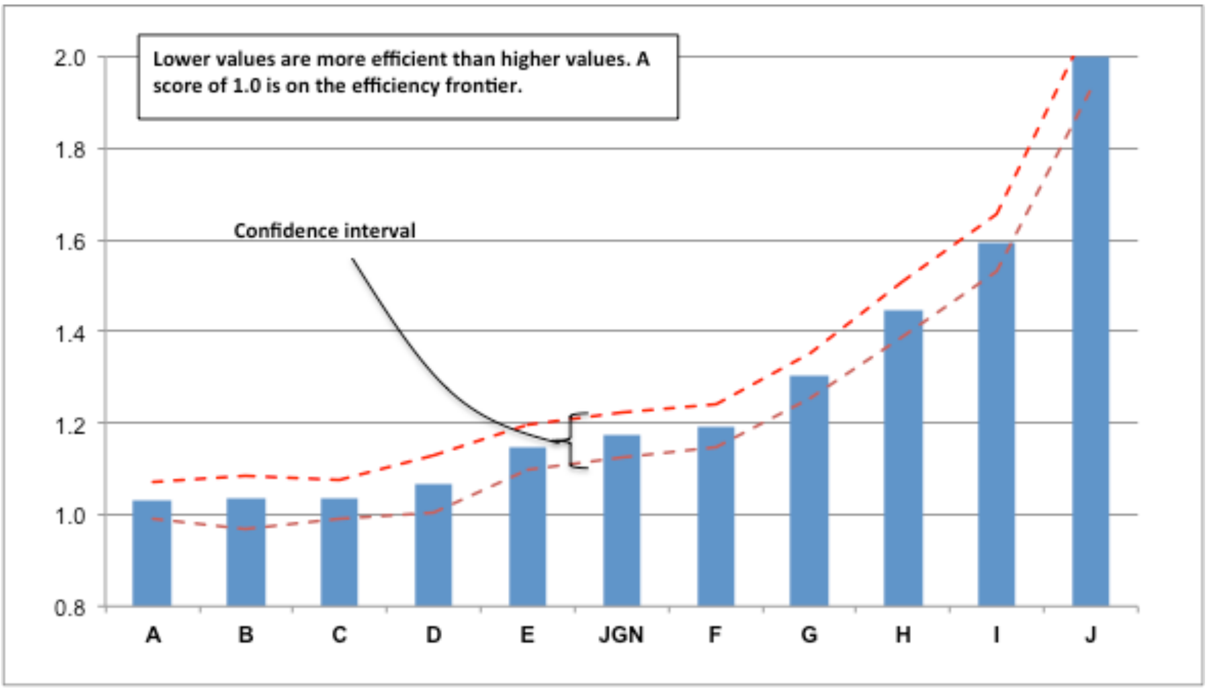
The negative values of the coefficient b_{NCI} , which is the elasticity of opex with respect to changes in the percentage of mains that are not cast iron or unprotected steel, indicates that opex decreases when cast iron mains are replaced with PE or PVC mains. In the SFA model, the positive significant coefficient b_{GT} , which measures the elasticity of opex with respect to changes in the fragmentation of the networks supplied by a GDB, indicates that opex will be higher for networks that are more fragmented. The negative values on the elasticity of opex with respect to changes in customer density, b_{CD}, indicates that opex decreases significantly with increased network density, all other things remaining constant. These effects are all consistent with prior expectations.

5.3.4 Estimates of opex cost efficiency

Having estimated the operating cost function model, we can now proceed to examine the comparative efficiency of each of the included GDBs with respect to opex. The stochastic frontier model produces estimates of the opex cost inefficiency of each GDB in the sample. They are shown in Figure 5.2 plotted in rank order from highest efficiency (where the inefficiency measure is close to one) to lowest efficiency (where the inefficiency measure is significantly higher than one). None of the GDBs are identified except for JGN. The other GDBs are identified only by the letters A, B, C, etc.

Figure 5.2 **Opex cost function – comparative cost inefficiency (per cent)***

All GDBs in Sample – showing 95 per cent confidence interval



Source: Economic Insights estimates

From figure 5.2 we can see that JGN is among the six GDBs that are closest to the opex cost efficiency frontier, after taking into account the largely exogenous operating environment effects. JGN's estimated opex cost efficiency is approximately 10 per cent lower than the three GDBs that are closest to the efficiency frontier. Although JGN's opex efficiency is statistically different from the efficient frontier level, we do not believe that any clear inferences can be drawn from this. It is likely there are some differences in the scope of activities undertaken by businesses, since the sources of information are not uniform, and there are differences in regulatory jurisdictions and changes over time. It is our understanding that JGN carries out a wider range of activities compared to GDBs in most other jurisdictions, such as operating relatively more transmission–equivalent mains, undertaking more marketing due to the discretionary nature of gas consumption in NSW, and it incurs local government taxes which may not apply to other GDBs. The observed small differences in the cost efficiency of the more efficient GDBs in the sample may be due to these differences.

5.4 Forecasting JGN's Opex Partial Productivity

In table 5.4, the parameter estimates reported in table 5.3 are combined with JGN's latest forecasts of average growth in throughput, customer numbers and pipeline length over the next regulatory period to form forecasts of opex partial productivity growth using the method previously discussed (see section 5.1.2). In calculating the effects of changes in the included operating environment factors, it has been assumed there is no change in the number of city gates, and we have made estimates of the future rate of change of the proportion of mains that are not cast iron or unprotected steel by extrapolating past rates of change. The resulting estimates of the average opex partial productivity growth rate for JGN for the next period regulatory period are 0.55 per cent, using the FGLS model, and 0.66 per cent using the SFA model, as shown in the last row of Table 5.4. Following the approach adopted in Economic Insights (2012a), our preferred estimate of the opex partial productivity growth over the period from 2015 to 2020 is the average of these two estimates, which is 0.60 per cent per year. Technical change is the main source of improvement in opex partial productivity. The effect of economies of scale has a smaller complementary effect.

Table 5.4: **Opex cost function partial productivity forecasts – Average 2016 to 2020**

	FGLS model	SFA model	Average
1) Model's estimated cost elasticities			
Energy	0.3815*	0.2370**	
Customers	0.2164*	0.1303**	
Customer density	-0.6165	-0.9982	
Capital (constant price asset value)	0.4489	0.6345	
Technology	-0.0069	-0.0071	
Non-cast iron mains	-0.3865	-0.3565	
Network fragmentation	-0.0027	0.0945	
2) JGN's forecast driver growth rates (2015-2020)			
Energy	-1.09%	-1.09%	
Customers	2.33%	2.33%	
Weighted Average Output Growth	0.15%*	0.13%**	
Customer density	1.15%	1.15%	
Capital (constant price RAB)	2.05%	2.05%	
Non-cast iron mains	0.05%	0.05%	
Network fragmentation	0.00%	0.00%	
3) PP Opex Growth Rates Forecast			
Technology (A)	0.69%	0.71%	
Returns to Scale (B)	0.06%	0.08%	
Operating environment factors (C)	0.19%	0.14%	
PP Opex Growth Rates (=A+B–C)	*0.55%*	*0.66%*	*0.60%*

Sources: JGN forecasts and Economic Insights estimates
* The implied proportionate cost-elasticity weights in the FGLS model are 63.8% for energy and 36.2% for customers.
** The implied proportionate cost-elasticity weights in the SFA model are 64.5% for energy and 35.5% for customers.

These results are broadly comparable to those shown in our 14 April and 2 October 2014 reports, with changes mainly reflecting updated forecasts for the cost drivers.

The opex partial productivity growth rate presented in table 5.4 is an average for a five year forecast period. This forecast can be broken down into separate years, as shown in table 5.5 for both the FGLS and SFA models. It shows that a large decline in gas demand is forecast in 2014-15, the year before the five-year period ending 2019-20. This, together with continued strong capital growth in the same year, is anticipated to lead to negative partial productivity growth in that year. Partial productivity is forecast to grow more steadily at around historical trend rates from 2016-17.

Table 5.5: **Annual opex partial productivity forecasts, 2015–2020**

Year	*2014-15*	*2015-16*	*2016-17*	*2017-18*	*2018-19*	*2019-20*
JGN's forecast driver growth rates (2015-2020):						
Energy	-7.04%	-1.53%	-0.97%	-1.02%	-1.03%	-0.89%
Customers	2.99%	2.83%	2.57%	2.32%	2.08%	1.87%
Customer density	1.60%	1.45%	1.31%	1.19%	0.99%	0.79%
Capital (constant price RAB)	3.61%	3.25%	2.41%	2.31%	1.35%	0.91%
Non-Cast iron Mains	0.05%	0.05%	0.05%	0.05%	0.05%	0.05%
Network fragmentation	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
PP Opex Growth Rates Forecast – FGLS model						
Technology (A)	0.69%	0.69%	0.69%	0.69%	0.69%	0.69%
Returns to Scale (B)	-1.37%	0.02%	0.12%	0.08%	0.04%	0.04%
Operating environment (C)	0.61%	0.55%	0.26%	0.28%	-0.03%	-0.10%
PP Opex Growth Rates	*-1.30%*	*0.16%*	*0.55%*	*0.48%*	*0.75%*	*0.83%*
PP Opex Growth Rates Forecast – SFA model						
Technology (A)	0.71%	0.71%	0.71%	0.71%	0.71%	0.71%
Returns to Scale (B)	-2.20%	0.01%	0.18%	0.10%	0.05%	0.06%
Operating environment (C)	0.67%	0.60%	0.21%	0.26%	-0.15%	-0.23%
PP Opex Growth Rates	*-2.17%*	*0.12%*	*0.68%*	*0.55%*	*0.91%*	*1.00%*
Avg PP Opex Growth Rate	*-1.73%*	*0.14%*	*0.62%*	*0.52%*	*0.83%*	*0.92%*

Source: JGN forecasts and Economic Insights estimates

5.5 Method of Applying Opex PP Growth Rates

It remains to explain how the opex PFP results in Table 5.5 can be used to forecast real opex. Using the 'Δ' symbol to stand for 'the rate of change in' (or difference in logs), the formula for the opex rate of change can be stated as (Economic Insights, 2012d, p. 3):

(5.12) $\Delta\text{Real Opex} = \Delta\text{Real Opex Price} - \Delta\text{Opex Partial Productivity} + \Delta\text{Output Quantity}$

The rate of change in opex is equal to the rate of change in an index of opex prices less the opex partial productivity growth rate plus the rate of change in an index of output quantities.

The weights for the output index are given in the notes to table 5.4, and are derived from the estimated elasticities of cost with respect to each output shown in the same table. The FGLS and SFA models each have different estimated elasticities with respect to the two outputs, and different weights. The appropriate output index to use in equation (5.12) is the average of the two output indexes associated with the FGLS and SFA models.

Ideally, the forecast opex price index would have a broadly similar construction to the opex price index used in the variable cost function, which was described in section 5.2.1. The WPI index for the labour component of opex prices has been used in the opex price index (as with previous Economic Insights studies of GDB productivity). Note that here real opex excludes unaccounted for gas.

5.6 Summary Conclusions

In summary, the main findings from the operating cost function analysis are:

- JGN is among the more efficient of the GDBs in terms of opex cost efficiency, when the effects of scale, customer density, network age and network fragmentation are taken into account. Although JGN's opex efficiency is slightly lower and statistically different from the three most cost efficient GDBs in the sample, we do not believe that any clear inferences can be drawn from this. It is likely there are some differences in the scope of activities undertaken by businesses, since the sources of information are not uniform, and there are differences in regulatory jurisdictions and changes over time. It is our understanding that JGN carries out a wider range of activities compared to GDBs in most other jurisdictions, such as operating relatively more transmission-equivalent mains, undertaking more marketing due to the discretionary nature of gas consumption in NSW, and it incurs local government taxes which may not apply to other GDBs. The observed small differences in the cost efficiency of the more efficient GDBs in the sample may be due to differences of this kind.
- Based on JGN's latest forecasts of throughput, customer numbers, pipeline length and capital over the next regulatory period, JGN's forecast average annual opex partial productivity growth rate over the period 2015-16 to 2019-20 is 0.60 per cent.

6 CONCLUSIONS

This report has sought to:

- examine JGN's TFP and opex PFP performance over the last 15 years
- assess the relative efficiency of JGN's opex, and
- forecast JGN's achievable opex productivity growth over the next regulatory period given forecast output and capital input levels and important operating environment factors.

JGN's TFP grew at an average annual rate of 1.2 per cent between 1999 and 2011, but taken over the period to 2014, the average is 0.9 per cent due to productivity reductions after 2011. JGN's TFP growth over the period 1999 to 2011 was at a similar rate to those of Multinet and AGN SA, although AGN Vic and AusNet both achieved average TFP growth rates of over 2 per cent over the same period.

The main source of TFP growth for most GDBs over this period was strong growth in opex partial productivity in the period from 1999 to 2006. JGN had the equal highest growth rate of opex partial productivity over this period. For most GDBs, this source of productivity gain was considerably more modest in the period from 2006 to 2011.

JGN has had the highest or second highest level of opex multilateral partial productivity for the last 15 years, exceeded only by AusNet in 2010 and 2011. JGN's opex partial productivity increased by almost 90 per cent between 1999 and 2014. JGN has had similar capital multilateral partial productivity levels to Multinet and SP AusNet over the last decade but lower than those of AGN Vic and AGN SA. Looking at the overall productivity result, JGN has had similar multilateral TFP levels to SP AusNet and Multinet since around 2005.

The index number analysis thus shows JGN to have been a good performer in terms of both opex partial productivity levels and growth rates. And it has had similar TFP levels to two of the three Victorian GDBs for the last decade.

To assess JGN's opex efficiency levels and forecast its achievable opex productivity growth for the next regulatory period, we have used an operating cost function model similar to that reported in Economic Insights (2012a). The operating cost function model presented here contains several advances compared to our earlier study. In particular, two additional operating environment factors – network age and network fragmentation – are included and the larger number of observations now available has enabled us to directly estimate GDB opex efficiency levels using a stochastic frontier model.

JGN is found to be among the more efficient of the GDBs in terms of opex cost efficiency when the effects of scale, customer density, network age and network fragmentation are taken into account. Although JGN's opex efficiency is slightly lower and statistically different from the three most cost efficient GDBs in the sample, we do not believe that any clear inferences can be drawn from this. It is likely there are some differences in the scope of activities undertaken by businesses, since the sources of information are not uniform, and there are differences in regulatory jurisdictions and changes over time. It is our understanding that JGN carries out a wider range of activities compared to GDBs in most other jurisdictions, such as operating relatively more transmission-equivalent mains, undertaking more marketing due to the discretionary nature of gas consumption in NSW, and it incurs local government taxes which may not apply to other GDBs. The observed small differences in the cost efficiency of the more efficient GDBs in the sample may be due to differences of this kind.

Based on JGN's latest forecasts of throughput, customer numbers, pipeline length and capital over the next regulatory period, JGN's forecast average annual opex partial productivity growth rate over the period 2015-16 to 2019-20 is 0.60 per cent when returns to scale, the impact of operating environment factors and technical change are allowed for.

APPENDIX A: GDBS INCLUDED IN THE STUDY

The database used for the econometric analysis in Part C of this report includes 9 Australian GDBs and 2 New Zealand GDBs and uses public domain information to the maximum extent possible. The database used for the index analysis in Part B does not include all of these GDBs (see Table 3.1) and is based on survey information collected directly from the relevant GDBs. A brief summary of the operations of the included GDBs follows.

A.1 Australian GDBs

ActewAGL, Australian Capital Territory

ActewAGL Distribution is the distribution business supplying gas and electricity in the Australian Capital Territory (ACT), which is jointly owned by the ACT Government and SGSP (Australia) Assets Pty Ltd.[19] The total population of the ACT in 2013 was 383,000. Gas is distributed to a predominantly residential customer base with Canberra the largest market. Outside the ACT ActewAGL supplies gas to Queanbeyan and Bungendore in NSW. There are few industrial users of any significance in its supply area. Canberra covers a large geographical area and the majority of urban development is low density. Moreover, gas distribution in residential areas utilises a dual mains configuration with mains on both sides of a street, rather than a single sided system with longer cross-road service connection. For these reasons it is a low density distribution network when measured in terms of customers per kilometre of main.

In 2012 ActewAGL supplied 123,470 customers with 7,696 TJ of gas from a distribution network of around 4,364 kilometres of mains.

Allgas Energy Pty Ltd (Allgas), Queensland

Allgas is owned by Marubeni Corporation, RREEF and the APA Group. It supplies gas to consumers in several areas in and around Brisbane and to several Queensland regional areas. The Allgas distribution system is separated into three operating regions. These are:

- the Brisbane region (south of the Brisbane river to the Albert River);
- the Western region (including Toowoomba and Oakey); and,
- the South Coast region (including the Gold Coast, and Tweed Heads in NSW).

About 59 per cent of the network is located in Brisbane, 19 per cent in the Western region and the remaining 22 per cent on the South Coast and Tweed Heads.

Queensland's mild to hot climate means that residential and commercial heating demand is low. Residential demand for gas is mainly for hot water systems and cooking. In June 2011 southeast Queensland's population was around 3,178,000. More than 70 per cent of Allgas' gas demand is from around 100 large demand class customers.

In 2012 Allgas supplied 87,315 customers with 9,897 TJ of gas from a distribution network of 3,022 kilometres of mains.

[19] ActewAGL Distribution is a related entity to ACTEWAGL Retail, which is owned equally by ACTEW Corporation and AGL Energy

ATCO Gas Australia, Western Australia

ATCO acquired the network previously operated by WA Gas Networks (WAGN) in July 2011. ATCO Gas Australia is the principal GDB for Western Australian businesses and households. It operates the gas distribution system in the mid-west and south-west of Western Australia, including the greater Perth Metropolitan region (including Busselton and Bunbury), Geraldton, Kalgoorlie and the Albany region, each with separate gas distribution networks (Albany is supplied with reticulated LPG).

In 2012, ATCO supplied 640,936 customers with 28,103 TJ of gas from a distribution network of 13,035 kilometres of mains.

AGN Queensland, Queensland

AGN Queensland is an operating division of Australian Gas Networks Limited (AGN), a wholly owned subsidiary of Cheung Kong Consortium. AGN Queensland's distribution network can be divided into two regions:

- the Brisbane region (including Ipswich and suburbs north of the Brisbane river); and
- the Northern region (serving Rockhampton, Gladstone and Bundaberg).

The network consists of 2,643 kilometre of low, medium, high and transmission pressure mains. Assets used to service the Brisbane region comprise 88 per cent of the network with the balance of 12 per cent attributable to the Northern region.

AGN Queensland is subject to similar climatic influences on residential gas demand as Allgas. Customer numbers are greater than those for Allgas but regulated volumes are smaller. However, AGN Queensland has a number of unregulated industrial customers with very large volumes that are not reflected in the data used in this study. In 2012 there were 89,098 customers consuming 6,030 TJ of gas.

AGN SA, South Australia

AGN SA's distribution network services: greater Adelaide; to the north-east of Adelaide, the Barossa Valley, Riverland and Mildura in Victoria; to the north, Peterborough, Port Pirie and Whyalla; and in the east and south-east regions, Murray Bridge and Mt Gambier. Adelaide's population in 2011 was 1.23 million. As with Melbourne, Adelaide's winter climate is conducive to relatively high residential gas demand for heating.

In 2012, AGN SA supplied 411,199 customers with 22,256 TJ of gas from a distribution network of 8,010 kilometres of mains. The Adelaide network makes up 93 per cent of the total network length.

AGN Vic, Victoria

AGN Vic serves parts of the greater Melbourne metropolitan area (population of 4.25 million in 2012) including the northern suburbs, the Mornington Peninsula and Pakenham/Cranbourne. AGN Vic also supplies the north central Victorian area (including Seymour, Wodonga, Wangaratta, Shepparton-Mooroopna and Echuca among others). It also supplies rural townships and cities in the Gippsland region (including Bunyip, Drouin, Warragul, Traralgon, Morwell and Sale among others), and a number of outlying towns in

East Gippsland such as Bairnsdale and Paynesville (which are in the new Eastern Zone). The Distribution System is divided into four Zones – North, Central, Murray Valley and Eastern.'

Melbourne's gas market is well established and cool to mild climatic conditions result in high residential gas consumption for heating, cooking and hot water systems. A relatively high concentration of industry also supports industrial gas demand provided that prices are competitive with other sources of energy supply. In 2012 there were 553,604 residential customers and 23,200 non–residential customers.

In 2012, AGN Vic supplied its 576,804 customers with 56,492 TJ of gas from a distribution network of 10,135 kilometres of mains.

Jemena Gas Networks (JGN), NSW

JGN was formed from the sale of Alinta Ltd in 2007, Alinta itself having acquired the gas assets of AGL Gas Networks (AGLGN) in 2006. It is now co-owned by State Grid Corporation of China and Singapore Power. The JGN network provides gas to more than 1,170,000 customers in Sydney, Newcastle, Wollongong and the Central Coast, and over 20 country centres including those within the Central Tablelands, Central West, Southern Tablelands and Riverina regions of NSW.

Jemena has the largest distribution network and customer base of the Australian GDBs. In 2012 JGN supplied 90,877 TJ of gas from a distribution network of 23,628 kilometres of mains.

Multinet Gas, Victoria

Multinet is owned by the DUET Group, an ASX-listed energy infrastructure business. The Multinet gas distribution system covers the eastern and south–eastern suburbs of Melbourne extending over an area of approximately 1,600 square kilometres as well as comparatively recent extensions of supply to townships in the Yarra Valley and South Gippsland. In 2012 there were 652,931 residential customers and 16,700 non–residential customers.

In 2010, Multinet supplied its 669,631 customers with 56,858 TJ of gas from a distribution network of 10,147 kilometres of mains. Multinet has the highest customer density per kilometre of mains of the Australasian GDBs (66 customers per km of main).

AusNet Services (AusNet), Victoria

AusNet is a Victorian gas distribution business which is ASX-listed. It was formerly SP AusNet (when affiliated with Singapore Power), formerly TXU Networks and before that Westar (Assets) Pty Ltd. AusNet's gas distribution business delivers gas to over 600,000 customers across a geographically diverse region spanning the western half of Victoria, including the Western part of Melbourne, from the Hume highway in metropolitan Melbourne west to the South Australian border and from the southern coast to Horsham and just north of Bendigo. Its supply area includes the major Victorian regional centres of Geelong, Ballarat and Bendigo, and many other cities and towns in western Victoria. In 2012 there were 593,218 residential customers and 16,072 non–residential customers.

In 2012, AusNet supplied its 609,290 customers with 74,707 TJ of gas from a distribution network of 9,719 kilometres of mains.

A.2 New Zealand GDBs

The New Zealand gas distribution industry is generally less mature than Victoria's with penetration rates still increasing relatively quickly, but comparatively low customer density at present.

Powerco Limited

Powerco is based in New Plymouth (population 53,400 in 2013) and distributes gas in the central and lower North Island regions. It is a dual gas and electricity network business. Powerco's gas networks in the central North Island region include the Taranaki (including New Plymouth), Manawatu and Horowhenua (including Palmerston North, population 83,800), and Hawkes Bay networks (including Napier-Hastings, population 125,300). In the lower North Island it supplies Wellington City (population of 203,100), Hutt Valley (estimated population 141,700) and Porirua (district population of 53,100). Powerco acquired part of UnitedNetworks' gas operations in 2002 comprising the Hawkes Bay, Wellington, Horowhenua and Manawatu networks.

In 2012, Powerco supplied its 102,696 customers with 9,067 TJ of gas from a distribution network of 6,216 kilometres of mains.

Vector Ltd

Vector Ltd operates the gas distribution network in Auckland (estimated population of 1,418,000 including North Shore City, and the urban parts of Waitakere and Manukau cities) as well as other major North Island centres and 40 smaller towns and cities.

Vector acquired the remaining part of UnitedNetworks' gas operations in 2002 comprising its Auckland gas network and the National Gas Corporation's gas distribution business in 2004 and 2005. The Vector data from 2006 represent the combined operations of Vector and the former NGC Distribution. In 2012, Vector supplied 153,585 gas distribution customers with 21,740 TJ of gas from a distribution network of 10,326 kilometres of mains.

Vector also owns and operates significant transmission pipelines and power line networks throughout the North Island. It is listed on the NZ Stock Exchange, but is around 75 per cent owned by the Auckland Energy Consumer Trust.

APPENDIX B: PAST GDB EFFICIENCY & TFP STUDIES

There have been several studies undertaken previously of gas pipeline efficiency performance in Australasia. These include Bureau of Industry Economics (1994), IPART (1999), Pacific Economics Group (2001), Lawrence (2004a, 2004b, 2007a), Pacific Economics Group (2008), Economic Insights (2009, 2010, 2012a, 2012b, 2012c).

Bureau of Industry Economics (1994)

While now somewhat dated, the Bureau of Industry Economics (BIE 1994) international benchmarking study was the first major comparative study of gas supply performance in Australia. It compared prices and technical efficiency of 42 utilities including five Australian utilities, 23 US utilities, nine Canadian utilities, four Japanese utilities and one UK utility. Technical efficiency was calculated using the quantity only version of data envelopment analysis (DEA) using energy deliveries and customer numbers as the outputs, employee numbers, distribution kilometres of mains and transmission kilometres of mains as the inputs and the number of degree days and customer density (customers per kilometre of main) as operating environment variables.

The BIE noted that input coverage was likely to be somewhat inconsistent due to varying amounts of contracting out between utilities and the unavailability of data on operating and maintenance expenses. No account was able to be taken of differences in pipeline age and construction methods (e.g. cast iron versus polyethylene).

IPART (1999)

In 1999, the New South Wales Independent Pricing and Regulatory Tribunal (IPART) published a research paper titled *Benchmarking the Efficiency of Australian Gas Distributors*. Eight Australian distributors were benchmarked against a sample of 51 US local distribution companies (LDCs) using the quantity only version of data envelopment analysis. Sensitivity testing of the DEA efficiency scores against efficiency scores derived from stochastic frontier analysis (SFA) and corrected ordinary least squares (COLS) was also undertaken.

The outputs included in the study were energy deliveries (in terajoules), residential customer numbers, the number of non–residential customers and the reciprocal of unaccounted for gas. The inputs included were the length of mains in kilometres and operating and maintenance expenditure. The number of heating degree–days and the age of the network were included as operating environment variables in a second stage Tobit regression.

The Australian distributors were found to be around 27 per cent behind best practice on average. The Victorian distributor Multinet was found to achieve best practice while the least efficient of the Australian distributors was AGLGN (ACT) (the forerunner of ActewAGL) at 58 per cent behind best practice. IPART found that neither of its included operating environment variables of climate and density were statistically significant. It rationalised the climate result by stating that the higher demand for gas in the northern hemisphere is likely to be offset by higher input requirements to deal with the adverse conditions.

Pacific Economics Group (2001a, 2001b, 2001c)

In 2001 Pacific Economics Group (PEG) benchmarked the Australian gas distribution operations of three Victorian utilities – Multinet (United Energy), TXU, and Envestra Victoria (2001a, 2001b, 2001c) – against its database of US gas utilities. The variables included in the analyses were:

- Number of gas delivery customers (outputs);
- Total gas throughput (outputs);
- Operation and maintenance (O&M) expenses (inputs);
- Value of plant (inputs);
- Labour costs (inputs);
- Percentage of distribution miles in total distribution and transmission miles (operating environment);
- Percentage of distribution mains that are cast iron (operating environment);
- Percentage of electricity distribution capital in the gross value of distribution plant (operating environment); and
- Percentage of sales volume to non–industrial users (operating environment).

PEG benchmarked the O&M cost performance of the Australian gas distributors against those of 43 distributors in the United States using a translog econometric cost function. PEG uses standard regression techniques to compare the O&M actual cost for the utility in question with that predicted by the model. The model predicted O&M cost is that for an average utility after adjusting for the included operating environment conditions.

PEG found that Multinet's actual O&M cost was nearly 50 per cent below the model's point prediction making Multinet a superior performer compared to the sample of US utilities. Similarly, Envestra Victoria's and TXU Networks' actual O&M costs were 34 per cent and 28 per cent, respectively, below the model's predictions.

Lawrence (2004a)

Denis Lawrence undertook a comparative benchmarking study of Australian and New Zealand gas transmission and distribution pipeline businesses for the New Zealand Commerce Commission using data sourced from New Zealand and Australian regulatory data. The study used the multilateral TFP index method applied to 2003 data to obtain a snapshot of comparative performance. Cost efficiency comparisons were presented for 10 Australian and four New Zealand GDBs. The distribution model contained two outputs (throughput and customer numbers) and two inputs (operating and maintenance expenditure and capital measured by kilometres of main).

Undertaking proxy adjustments for both customer and energy density differences led to the productivity levels of the New Zealand GDBs being found to be around 21 per cent behind those of the Australian GDBs. The three Victorian GDBs were among the most efficient performers after allowing for operating environment differences.

Lawrence (2004b)

The Commerce Commission also engaged Denis Lawrence to undertake an analysis of the rate of TFP growth in New Zealand's gas distribution networks. Changes in the structure of the New Zealand distribution industry in recent years, particularly the splitting up of UnitedNetworks' gas distribution operations between Powerco and Vector, made it difficult to obtain consistent data through time. Only data for NGC Distribution (which has subsequently been taken over by Vector) was available for any length of time on a consistent basis.

The distribution TFP model again contained two outputs (throughput and customer numbers) and two inputs (operating and maintenance expenditure and capital measured by kilometres of main). For the 7 year period from 1997 to 2003 NGC Distribution's TFP increased at a relatively high trend annual rate of 2.8 per cent. For the 12 year period from 1997 to 2008 (i.e. including forecast data from 2004 onwards) the trend annual rate of TFP increase was still relatively high at 2.5 per cent. Based on forecast strong increases in NGC Distribution's customer density, it was expected, all else equal, that the New Zealand GDBs would enjoy relatively high TFP growth.

Lawrence (2007a)

The three Victorian GDBs commissioned Denis Lawrence to examine the total factor productivity (TFP) performance of the Victorian gas distribution industry. The study concentrated on performance in the post privatisation period from 1998 to 2006 and also presented forecasts of TFP performance for the period 2007 to 2012 based on the GDBs' forecasts of expected changes in their outputs and inputs over this period.

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.

The first major finding of this study was that the Victorian gas distribution industry had exhibited strong TFP growth over the 9 years following privatisation. TFP grew at an average annual rate of 2.7 per cent. Envestra and Multinet achieved average annual TFP growth rates of around 3 per cent while SP AusNet achieved around 2.3 per cent.

Most of the high TFP growth rate had been achieved by reductions in GDB operating and maintenance expenditure (opex) which fell by 4 per cent annually in constant price terms. All three GDBs achieved average annual opex partial productivity growth rates in excess of 6 per cent for the previous 9 years. Capital partial productivity growth, on the other hand, had been relatively flat as the GDBs continued expanding their pipeline networks and replacing low pressure mains with high pressure mains.

The second key finding of the study was that GDB productivity growth was expected to flatten over the 6 years from 2006 onwards based on forecasts of GDB outputs and inputs. The combination of the convergence effect (whereby productivity growth becomes constrained by the rate of technological change in the industry once all identifiable inefficiencies are removed) and anticipated changes to the safety and compliance requirements facing GDBs were expected to reduce annual TFP growth to around 0.1 per cent going forward. The scope to further reduce opex was expected to be limited and opex partial productivity growth was forecast to reverse and decline by around 0.3 per cent per annum.

Lawrence (2007a) also examined productivity levels as well as growth rates and found that the three GDBs all started from a similar productivity level in 1998. The similar starting productivity levels were not surprising given that the three GDBs all came out of the one predecessor organisation and all operated in suburban Melbourne.

Pacific Economics Group (2008)

PEG (2008) calculated the TFP trend for Victoria's GDBs using a less detailed model than Lawrence (2007a) with three outputs and two inputs. The sample period was 1998 to 2007. PEG estimated that TFP for Victoria's gas distribution industry grew at an average annual rate of 2.9 per cent over the 1998 to 2007 period. Output quantity grew at an average rate of 1.1 per cent per annum while input quantity was reported to have declined at 1.8 per cent per annum over the same period.

Economic Insights (2009)

Economic Insights (2009) extended the Lawrence (2007a) TFP study of the three Victorian GDBs to include data for JGN's NSW distribution system. Given JGN's inclusion of relatively more transmission–equivalent trunk and primary pipelines in its distribution business given its geographic coverage, a number of adjustments were made to the functional coverage of JGN's data to ensure more like–with–like comparisons. The results of this study indicated that overall JGN was a relatively efficient performer compared to the three Victorian GDBs.

Economic Insights (2010)

Economic Insights (2010) further extended the Economic Insights (2009) TFP study of the three Victorian GDBs and JGN's NSW distribution system to include data for Envestra SA and Envestra Qld. The results of this study indicated that Envestra SA performs relatively well by almost matching the performance of the larger included GDBs. Taking the differences in network density and size into account, the results of this study indicated that Envestra SA is likely to be a relatively efficient performer.

Economic Insights (2012a)

SP AusNet commissioned Economic Insights to assess the efficiency of its gas distribution business (GDB) within a statistical framework taking opex and capital input trade–offs and business conditions into account. The study also forecast SP AusNet's future GDB opex partial productivity growth rate.

Econometric estimates of total cost function and operating cost function parameters were developed using data for 9 Australian GDBs and 2 New Zealand GDBs. The estimated total cost function parameters were used to form predicted total costs and opex, which were compared with actual total costs and opex in assessing overall and opex efficiency respectively. The estimated operating cost function parameters were combined with forecasts of output and capital input levels to form forecasts of future opex partial productivity growth.

In the total cost function efficiency analysis, customer density and energy density were found to be significant operating environment factors that influenced GDB total costs. SP AusNet was found to be the best overall cost efficiency performer compared to its peers when scale, customer density and energy density effects. It also had the best opex cost efficiency, with actual opex cost being 38.4 per cent less than the model's prediction in 2010.

Two opex cost function models were estimated. One model predicted that technological change would lead to a 0.6 per cent increase in annual forecast opex partial productivity growth for both SP AusNet and Multinet (a close peer). The other model predicted that partial opex productivity would increase at an annual rate of 1.1 per cent for SP AusNet and 0.9 per cent for Multinet. These results were averaged to yield a forecast opex partial productivity growth rate of 0.8 per cent for both SP AusNet and Multinet.

Economic Insights (2012b)

Economic Insights was engaged by the three Victorian gas distribution businesses (GDBs) – Envestra Victoria, Multinet and SP AusNet – to compare their efficiency performance of over the period 1999–2010 within a group of 11 Australian GDBs and 3 New Zealand GDBs. This report uses a range of partial productivity performance indicators to compare the opex and capital input efficiency performance of these businesses with one another. It also assessed the efficiency of each GDB's performance by comparing their cost outcomes.

The study noted that while partial productivity indicators are relatively easy to construct and understand, care needs to be exercised in interpreting the partial performance indicator results. To gain an indication of overall relative performance, the partial indicators need to be considered together and jointly with key operating environment indicators. Using this approach, the Victorian GDBs were found to have performed well on most indicators. Opex efficiency was been particularly strong considering that the Victorian GDBs had older systems and higher proportions of cast iron and other low pressure mains.

Some of the indicator growth rates observed in the first half of the period in the immediate aftermath of reform and ownership changes were found to have slowed in the second half of the period as cost reductions become progressively harder to achieve after these initial gains are made. Future growth rates of key indicators were expected to reflect the generally lower average growth rates of the more recent period due to a 'convergence' effect.

Economic Insights (2012c)

The three Victorian gas distribution businesses (GDBs) commissioned Economic Insights to examine their total factor productivity (TFP) and partial factor productivity (PFP) performance, and to compare their productivity levels with JGN, Envestra SA and Envestra Qld using multilateral index analysis.

The Victorian gas distribution industry as a whole has exhibited relatively continuous TFP growth over the 13 years covered in the study, with the annual TFP growth rate averaging 1.7 per cent for the 10 years to 2011. However, the rate of TFP growth slowed in the latter part of this period. TFP growth was been driven largely by significant reductions in opex. The three

Victorian utilities showed quite different TFP trends with average annual TFP growth rates of 2.2 per cent for Envestra Vic, 0.8 per cent for Multinet and 2.4 per cent for SP AusNet, over the 10 years ending 2011.

The multilateral TFP analysis suggested that the three Victorian GDBs together with JGN had comparable rates of TFP growth in the period up to 2009, with average annual TFP growth rates in the range 1.8 to 2.4 per cent. The smaller Envestra SA a lower TFP growth rate of 1.4 per cent, still very reasonable. Turning to productivity levels, JGN and SP AusNet achieved the highest opex partial productivity levels in 2009, followed by Multinet and Envestra Victoria. In terms of capital multilateral partial productivity levels, Envestra Victoria is the best performer followed by Envestra SA and then Multinet, SP AusNet and JGN which all had similar capital productivity performance. The overall conclusion from the multilateral productivity index analysis was that the Victorian GDBs were operating efficiently.

APPENDIX C: ECONOMETRIC ANALYSIS WITH ALTERNATIVE WEIGHTS FOR THE OPEX PRICE INDEX

As discussed in section 3.2.3, nominal opex data has been deflated using a price index derived from several relevant input price indexes published by the Australian Bureau of Statistics (ABS), which are combined using fixed weights. The method follows the opex price deflator developed by PEG (2006), and is based on six ABS input price indexes, the most important of which is the Wage Price Index.[20] The weights used 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.

The overall weight given to the Wage Price Index in the overall opex input price index in the analysis presented in the body of this report in 62.6 per cent. The combined weights of the other five indexes are equal to the remaining 37.4 per cent. JGN has indicated that the actual proportion of direct labour costs in its 2014 opex was 32.8 per cent, while contractors represented 38.3 per cent and the remaining 28.9 per cent was spent on materials. Economic Insights has been asked to carry out a sensitivity analysis using a revised set of opex input price index weights for JGN, based on this data. Accordingly, the weight attributed to the Wage Price index for JGN in this sensitivity analysis is 71.1 per cent, and the weights attributed to the other input price indexes are decreased proportionately to sum to 28.9 per cent. The opex input price weights applying to the other GDBs in the sample remain unchanged.

Two particular reservations are relevant when making inferences from the results of the analysis presented in this appendix. Firstly, the category of costs relating to contracts need not be solely related to labour inputs, and may include materials, depending on the nature of those contracts. To the extent that contracts do not represent only labour, there would be some inaccuracy in the weights adopted for JGN in this sensitivity analysis. Second, the data available for this scenario is for 2014 and may not be representative of the whole period. Bearing these considerations in mind, this analysis using alternative opex price index weights is presented here as an alternative scenario.

Econometric Results

The econometric methodology and model specification is the same as described in chapter 5. The results of estimating the two econometric models with the revised data are shown in table C.1. All of the same variables used in the model presented in Table 5.3 are also used in the scenario presented in Table C.1.

The estimated model is quite similar to the preferred model presented in section 5.3, and has the same implications in terms of the estimated degree of economies of scale and the direction of the influences of the independent variables.

[20] 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.

Table 5.3: **Opex cost function regression estimates**

FGLS model[1]			SFA model[2]		
Coefficient	Estimate	t–statistic[3]	Coefficient	Estimate	t–statistic[3]
b_0	0.1535	7.68	b_0	0.0036	0.03
b_D	0.3806	8.99	b_D	0.2505	2.31
b_C	0.1932	3.69	b_C	0.1008	0.53
b_{DD}	1.2694	8.11	b_{DD}	1.2882	6.16
b_{DC}	-0.7721	-5.68	b_{DC}	-1.1179	-6.55
b_{CC}	0.2162	1.73	b_{CC}	0.7338	4.02
b_{CPAV}	0.4391	8.90	b_{CPAV}	0.6355	6.42
b_t	-0.0070	-3.53	b_t	-0.0070	-2.06
b_{NCI}	-0.3666	-3.43	b_{NCI}	-0.3462	-1.59
b_{GT}	-0.0019	-0.19	b_{GT}	0.0948	2.72
b_{CD}	-0.5763	-8.18	b_{CD}	-0.9753	-3.55
b_{CDCD}	-0.6479	-4.83	b_{CDCD}	-1.4433	-3.36

1 R^2 between observed and predicted is 0.95.

2 R^2 between observed and predicted is 0.98.

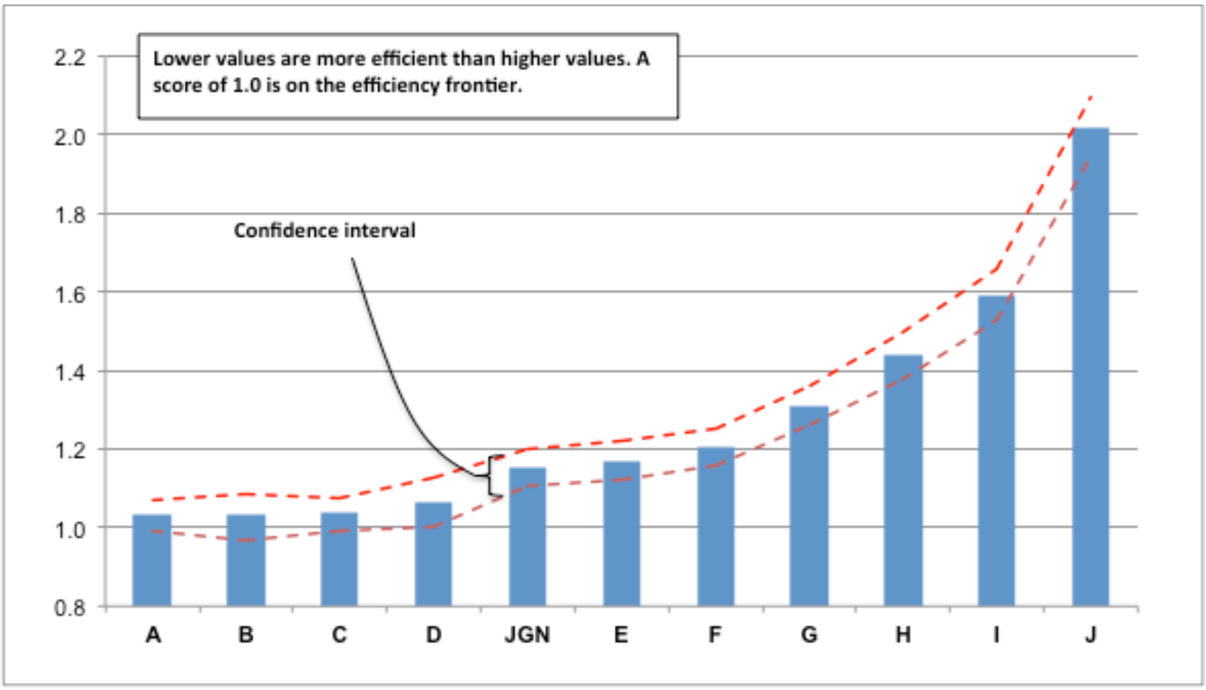
3 Critical t-statistics for testing are: 1.289, 1.658, 1.980 and 2.617 for the 20, 10, 5 and 1 per cent significance levels, respectively. A 5 per cent level of significance is used as the standard measure and less than 1 per cent is considered to be a very high level of significance. Results at the 10 per cent level of significance are also considered to be statistically meaningful.

The implications of the SFA model, in the right-side panel of table C.1, for the estimated comparative efficiency of each of the included GDBs with respect to opex are shown in figure C.1. The estimates of comparative inefficiency under the alternative opex input price index scenario, shown in figure C.1, are quite similar to those presented in section 5.3.4. JGN is here ranked as fifth (rather than sixth) in terms of efficiency, although with a similar efficiency score.

In table C.2 shows forecast opex partial productivity growth, under the alternative opex price index scenario, using the method previously discussed. This forecast relies on the parameter estimates reported in table C.1 together with JGN's latest forecasts of average growth in throughput, customer numbers and pipeline length over the next regulatory period. Assumptions relating to operating environment factors are unchanged. The resulting estimate of the average opex partial productivity growth rate for JGN for the next period regulatory period is 0.49 per cent per year, using the average of the estimates obtained from the two models.

A breakdown of this forecast for opex partial productivity into separate years over the regulatory period is shown in table C.3 for the FGLS and SFA models separately, and showing the average for the two models in each year.

Figure C.1 **Comparative opex cost inefficiency (per cent)***
All GDBs in Sample – showing 95 per cent confidence interval



Source: Economic Insights estimates

Table C.2: **Opex cost function partial productivity forecasts – Average 2016 to 2020**

	FGLS model	SFA model	Average
A. Model's estimated cost elasticities			
Energy	0.3806*	0.2505**	
Customers	0.1932*	0.1008**	
Customer density	-0.5763	-0.9753	
Capital (constant price asset value)	0.4391	0.6355	
Technology	-0.0070	-0.0070	
Non-cast iron mains	-0.3666	-0.3462	
Network fragmentation	-0.0019	0.0948	
B. JGN's forecast driver growth rates (2015-2020)			
Energy	-1.09%	-1.09%	
Customers	2.33%	2.33%	
Weighted Average Output Growth	0.06%*	-0.11%**	
Customer density	1.15%	1.15%	
Capital (constant price RAB)	2.05%	2.05%	
Non-cast iron mains	0.05%	0.05%	
Network fragmentation	0.00%	0.00%	
C. PP Opex Growth Rates Forecast			
Technology (A)	0.70%	0.70%	
Returns to Scale (B)	0.03%	-0.07%	
Operating environment factors (C)	0.22%	0.17%	
PP Opex Growth Rates (=A+B–C)	*0.51%*	*0.46%*	*0.49%*

Sources: JGN forecasts and Economic Insights estimates
* The implied proportionate cost-elasticity weights in the FGLS model are 66.3% for energy and 33.7% for customers.
** The implied proportionate cost-elasticity weights in the SFA model are 71.3% for energy and 28.7% for customers.

Table C.3: **Annual opex partial productivity forecasts, 2015–2020**

Year	*2014-15*	*2015-16*	*2016-17*	*2017-18*	*2018-19*	*2019-20*
JGN's forecast driver growth rates (2015-2020):						
Energy	-7.04%	-1.53%	-0.97%	-1.02%	-1.03%	-0.89%
Customers	2.99%	2.83%	2.57%	2.32%	2.08%	1.87%
Customer density	1.60%	1.45%	1.31%	1.19%	0.99%	0.79%
Capital (constant price RAB)	3.61%	3.25%	2.41%	2.31%	1.35%	0.91%
Non-Cast iron Mains	0.05%	0.05%	0.05%	0.05%	0.05%	0.05%
Network fragmentation	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
PP Opex Growth Rates Forecast – FGLS model						
Technology (A)	0.70%	0.70%	0.70%	0.70%	0.70%	0.70%
Returns to Scale (B)	-1.56%	-0.03%	0.09%	0.04%	0.01%	0.02%
Operating environment (C)	0.64%	0.58%	0.29%	0.31%	0.00%	-0.08%
PP Opex Growth Rates	*-1.50%*	*0.10%*	*0.51%*	*0.44%*	*0.71%*	*0.80%*
PP Opex Growth Rates Forecast – SFA model						
Technology (A)	0.70%	0.70%	0.70%	0.70%	0.70%	0.70%
Returns to Scale (B)	-2.70%	-0.18%	0.03%	-0.04%	-0.09%	-0.06%
Operating environment (C)	0.72%	0.64%	0.24%	0.29%	-0.13%	-0.21%
PP Opex Growth Rates	*-2.72%*	*-0.12%*	*0.48%*	*0.36%*	*0.74%*	*0.85%*
Avg PP Opex Growth Rate	*-2.11%*	*-0.01%*	*0.50%*	*0.40%*	*0.72%*	*0.82%*

Source: JGN forecasts and Economic Insights estimates

ATTACHMENT A: TERMS OF REFERENCE

Jemena

Expert Terms of Reference – productivity study

Jemena Gas Networks
2015-20 Access Arrangement Review

AA15-570-0041

4 November 2013

Contact Person

Eli Grace-Webb

Manager Regulatory Analysis and Strategy

eli.grace-webb@jemena.com.au

(03) 8544 9164

Jemena Gas Networks (NSW) Ltd

ABN 87 003 004 322

321 Ferntree Gully Road
Mt Waverley VIC 3149

Postal Address:

Locked Bag 7000
Mt Waverley VIC 3149

Ph: (03) 8544 9000

Fax: (03) 8544 9888

Contents

1 Background

Jemena Gas Networks (NSW) Ltd (**JGN**) is the principal gas distribution service provider in New South Wales. JGN owns more than 25,000 kilometres of natural gas distribution system, delivering approximately 100 petajoules of natural gas per annum to over one million homes, businesses and large industrial consumers across NSW.

JGN is currently preparing its revised Access Arrangement (**AA**) proposal with supporting information for the consideration of the Australian Energy Regulator (**AER**). The revised AA will cover the period 1 July 2015 to 30 June 2020 (July to June financial years). JGN must submit its revised AA proposal to the AER by 30 June 2014.

When considering JGN's revised AA proposal, the AER must have regard to the National Gas Objective, which is:

> "to promote efficient investment in, and efficient operation and use of, natural gas services for the long term interests of consumers of natural gas with respect to price, quality, safety, reliability and security of supply of natural gas."

The AER may also take into account the pricing principles in section 24(2) of the National Gas Law, and must do so when considering whether to approve a reference tariff:

> A service provider should be provided with a reasonable opportunity to recover at least the efficient costs the service provider incurs in—
>
> a) providing reference services; and
>
> b) complying with a regulatory obligation or requirement or making a regulatory payment.

Rule 72 of the National Gas Rules provides that, amongst other things, the supporting information to be submitted with a full AA proposal (**AA Information**) must include forecasts of both conforming capital and operating expenditure over the AA period, and the basis for these forecasts.

Some of the key rules that JGN must comply with in submitting its revised AA proposal are set out below.

Rule 74 of the National Gas Rules:

(1) Information in the nature of a forecast or estimate must be supported by a statement of the basis of the forecast or estimate.

(2) A forecast or estimate:

  (a) must be arrived at on a reasonable basis; and

  (b) must represent the best forecast or estimate possible in the circumstances.

Rule 79 of the National Gas Rules:

(1) Conforming capital expenditure is capital expenditure that conforms with the following criteria:

(a) the capital expenditure must be such as would be incurred by a prudent service provider acting efficiently, in accordance with accepted good industry practice, to achieve the lowest sustainable cost of providing services;

(b) the capital expenditure must be justifiable on the ground stated in subrule (2).

(2) Capital expenditure is justifiable if:

(a) the overall economic value of the expenditure is positive; or

(b) the present value of the expected incremental revenue to be generated as a result of the expenditure exceeds the present value of the capital expenditure; or

(c) the capital expenditure is necessary:

(i) to maintain and improve the safety of services; or

(ii) to maintain the integrity of services; or

(iii) to comply with a regulatory obligation or requirement; or

(iv) to maintain the service provider's capacity to meet levels of demand for services existing at the time the capital expenditure is incurred (as distinct from projected demand that is dependent on an expansion of pipeline capacity); or

(d) the capital expenditure is an aggregate amount divisible into 2 parts, one referable to incremental services and the other referable to a purpose referred to in paragraph (c), and the former is justifiable under paragraph (b) and the latter under paragraph (c).

Rule 91(1) of the National Gas Rules:

Operating expenditure must be such as would be incurred by a prudent service provider acting efficiently, in accordance with accepted good industry practice, to achieve the lowest sustainable cost of delivering pipeline services.

Accordingly, JGN seeks the independent opinion of Economic Insights Pty Ltd, as a suitably qualified expert (**Expert**) on efficiency measurement and benchmarking in the gas distribution sector, as outlined below. This opinion will assist JGN to develop and justify the expenditure forecasts to be included in its revised AA proposal.

2 Scope of Work

The Expert is to provide an expert report detailing:

a) its analysis of time series and multilateral total factor productivity (**TFP**) estimates and partial factor productivity (**PFP**) estimates, where that analysis is to be suitable for comparing JGN's productivity level and productivity growth rate performance with the Victorian, South Australian and Queensland gas distribution businesses (**GDBs**) for which similar analysis has previously been undertaken; and

b) its estimate of the opex cost function and forecast opex partial productivity growth rate for JGN, in a form that is suitable for incorporation into the rate of change approach for forecasting opex in JGN's revised AA proposal.

For clarity, this scope of work entails:

a) updating the analysis that Economic Insights undertook for JGN in 2009 as reported in Economic Insights, *The Productivity Performance of Jemena Gas Networks' NSW Gas Distribution System*, 18 August 2009[1];

b) applying an analysis similar to that reported in Economic Insights, *Econometric Estimates of the Victorian Gas Distribution Businesses' Efficiency and Future Productivity Growth*, 28 March 2012 [2], to JGN

and providing a report to JGN on those analyses (see "Deliverables" below).

The engagement does not include strategic advice on JGN's revised AA proposal, or any related step change issues.

3 Information to be considered

The Expert is expected to draw upon the following information:

- historical and forecast cost, input and output data provided by JGN;
- subject to the agreement of the relevant GDBs, the data set that informed Economic Insights, *Econometric Estimates of the Victorian Gas Distribution Businesses' Efficiency and Future Productivity Growth*, 28 March 2012 [3];
- relevant published research literature;
- relevant government decisions on energy policy and policy implementation;

[1] Report submitted to the AER by JGN on 25 August 2009.

[2] Report submitted to the AER by SP AusNet on 30 March 2012.

[3] Report submitted to the AER by SP AusNet on 30 March 2012.

- factors such as the scale, topography and configuration of the JGN network, that may contribute to or explain observed differences between the results obtained for JGN and for other GDBs in the data set on which the analysis is based;
- recent regulatory reviews for gas that have considered efficiency measures within the context of establishing cost forecasts; and
- such other information that, in the Expert's opinion, should be taken into account to address the scope of work set out in Section 2.

4 Deliverables

At the completion of its review the Expert will provide an independent expert report which addresses the scope of work set out in Section 2 and:

- is of a professional standard suitable for submission to the AER;
- includes an executive summary which highlights key aspects of the Expert's work and conclusions;
- includes detailed reasons for the Expert's opinions;
- fully documents the methodology used and discusses the results obtained;
- lists the facts, matters and assumptions on which the Expert's opinions are based and the source of those facts, matters and assumptions, and lists all reference material and information on which the expert has relied;
- lists any limitations, incomplete matters or qualifications to the Expert's opinions;
- identifies and summarises the experience and qualifications of, and includes a curriculum vitae for, each person who assisted in preparing the report or in carrying out any research or test for the purposes of the report;
- summarises JGN's instructions and attaches these terms of reference; and
- is prepared in accordance with the Federal Court Guidelines for Expert Witnesses set out in Attachment 1[4] and includes an acknowledgement that the Expert has read the guidelines.

The Expert is required to present its draft findings and report to JGN for discussion prior to finalising them.

Use of the report

JGN expects to submit the Expert's report to the AER as part of JGN's revised AA proposal for the period from 1 July 2015 to 30 June 2020. The AER may provide the report to its own advisers. The report must be expressed so that it may be relied upon by both JGN and the AER.

[4] Available at: http://www.fedcourt.gov.au/how/prac_direction.html.

The AER may ask questions in respect of the report and the Expert will be required to assist JGN in answering those questions. In addition, the AER may choose to interview the Expert and, if so, the Expert will be required to participate in any such interview.

The Expert must be available to assist JGN in connection with the work defined in the scope of work (Section 2), until such time as JGN has responded to the AER's draft decision on JGN's revised AA proposal.

Compliance with the code of conduct for expert witnesses

Attachment 1 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 (the **Code of Conduct**).

The Expert is required to be familiar with the Code of Conduct and comply with it at all times in the course of the engagement by JGN. In particular, the expert report prepared for JGN 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.

In particular, the report should contain particulars of the timing, study or experience by which the Expert has acquired specialised knowledge. The report should also 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 be signed by the Expert and a declaration that:

> "[the expert] has made all the inquires 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."

As noted previously, JGN requires a copy of these terms of reference to be attached to the Expert's report, as well as copies of the curriculum vitae of each of the report's authors.

5 Timetable

The Expert will deliver its required output to JGN as follows:

- analysis of time series and multilateral TFP estimates and PFP estimates; estimate of the opex cost function and forecast opex partial productivity growth rate; and draft written report, by 7 March 2014; and
- final written report by 25 April 2014.

6 Terms of Engagement

The terms on which the Expert will be engaged to provide the requested advice shall be as set out in JGN's standard form of consultancy agreement, a copy of which is included as Attachment 2.

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).

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.

Michael Bradbury Cunningham

25 March 2015

REFERENCES

Australian Energy Market Commission (AEMC) (2012), "Economic Regulation of Network Service Providers, and Price and Revenue Regulation of Gas Services, Final Position Paper," Sydney, November.

Australian Energy Regulator (AER) (2013a), "Better Regulation – Explanatory Statement: Expenditure Forecast Assessment Guideline," Melbourne, November.

--- (2013b), "Better regulation explanatory statement: Final regulatory information notices to collect information for economic benchmarking," November.

--- (2013c), "Better Regulation: Expenditure Forecast Assessment for Electricity Distribution," November.

--- (2012a), "Access arrangement draft decision: SPI Networks (Gas) Pty Ltd, 2013–17, Part 3, Appendices," Melbourne, September.

--- (2012b), "AER submission to the Productivity Commission Inquiry into Electricity Network Regulation," April.

--- (2012c), "Access Arrangement draft decision SPI Networks (Gas) Pty Ltd 2013-17, Part 2 Attachments."

--- (2010), "Jemena access arrangement proposal for the NSW gas networks, 1 July 2010 – 30 June 2015."

Barcella, Mary L. (1992), "The Cost Structure and Efficiency of Natural Gas Distribution Companies."

Berndt, Ernst (1990), *The Practice of Econometrics: Classic and Contemporary*, Addison-Wesley.

Bureau of Industry Economics (BIE) (1994), "International Performance Indicators - Gas Supply," *Reasearch Repotrt 62*, Canberra.

Coelli, T. et al. (2005), *An Introduction to Efficiency and Productivity Analysis*, 2nd ed., Springer.

Davidson, Russell and James MacKinnon (1993), *Estimation and Inference in Econometrics*, Oxford University Press.

Diewert, Erwin (2009), "The Aggregation of Capital over Vintages in a Model of Embodied Technical Progress'," *Journal of Productivity Analysis*, vol. 32.

Diewert, W.E. (1993), "The Measurement of Productivity: A Survey," Canberra, Swan Consultants.

Economic Insights (2012a), "Econometric Estimates of the Victorian Gas Distribution Businesses' Efficiency and Future Productivity Growth," *Report prepared for SP AusNet*, March.

--- (2012b), "Benchmarking the Victorian Gas Distribution Business' Operating and Capital Costs Using Partial Productivity Indictors," *Report prepared for Envestra Victoria, Multinet and SP AusNet*, Canberra, March.

--- (2012c), "The Total Factor Productivity Performance of Victoria's Gas Distribution Industry," *Report prepared for Envestra Victoria, Multinet and SP AusNet*, Canberra, March.

--- (2012d), "SP Ausnet's Gas Distribution Business Real Opex Rate of Change," *Report prepared for SP AusNet Pty Ltd*, Canberra, March.

--- (2010), "The Productivity Performance of Envestra's South Australian and Queensland Gas Distribution Systems," *Report prepared by Denis Lawrence for Envestra Ltd*.

--- (2009), "The Productivity Performance of Jemena Gas Networks' NSW Gas Distribution System," *Report by Denis Lawrence to Jemena Gas Networks (NSW) Ltd*, Canberra.

Essential Services Commission (ESC) (2008), "Gas Access Arrangement Review 2008-2012: Final Decision - Public Version," March.

Expert Panel on Energy Access Pricing (2006), "Report to the Ministerial Council on Energy."

Fabbri, P., G. Fraquelli and R. Giandrone (2000), "Costs, Technology and Ownership of Gas Distribution in Italy," *Managerial and Decision Economics*, vol. 21, No. 2.

Farsi, Mehdi, Massimo Filippini and Michael Kuenzle (2007), "Cost Efficiency in the Swiss Gas Distribution Sector," *Energy Economics*, vol. 29, No. 1.

Fisher, I. (1922), *The Making of Index Numbers*, Boston, Houghton Mifflin.

Greene, William (2008), "The Econometric Approach to Efficiency Analysis," *The Measurement of Productive Efficiency and Productivity Growth*, eds. Harold Fried, Knox Lovell, and Shelton Schmidt, Oxford University Press.

Independent Pricing and Regulatory Tribunal of New South Wales (IPART) (1999), "Benchmarking the Efficiency of Australian Gas Distributors," *Research Paper Gas99-9*.

Kumbhakar, Subal and Knox Lovell (2000), *Stochastic Frontier Analysis*, Cambridge University Press.

Laspeyres, E. (1871), "Die Berechnung einer mittleren Waarenpreissteigerung," *Jahrbucher fur Nationalokonomie und Statistik*, vol. 16.

Lawrence, Denis (2007a), "The Total Factor Productivity Performance of Victoria's Gas Distribution Industry," *Report by Meyrick and Associates for Envestra, Multinet and SP AusNet*, Canberra, May.

--- (2007b), "Victorian Gas Distribution Business Opex Rate of Change," *Report by Meyrick and Associates for Envestra, Multinet and SP AusNet*, Canberra, March.

--- (2004a), "Comparative Benchmarking of Gas Networks in Australia and New Zealand," *Report by Meyrick and Associates for the New Zealand Commerce Commission*, Canberra, May.

--- (2004b), "Productivity Growth in New Zealand Gas Distribution Networks," *Report prepared by Meyrick and Associates for the New Zealand Commerce Commission*, May.

--- (2003), "Regulation of Electricity Lines Businesses, Analysis of Lines Business Performance, 1996-2003," Canberra, December.

--- (1992), "Total Factor Productivity - A Useful Indicator of Overall Economic Performance," *Measuring the Total Factor Productivity of Government Trading Enterprises*, ed. Steering Committee on National Performance Monitoring of Government Trading Enterprises, Canberra.

Lawrence, Denis, John Fallon and John Kain (2007), "Efficiency Comparisons of Australian and New Zealand Gas Distribution Businesses Allowing for Operating Environment Differences," *Report prepared by Meyrick and Associates for Multinet Pty Ltd*, Canberra, March.

Lowry, Mark and Lullit Getachew (2009), "Econometric TFP Targets, Incentive Regulation and the Ontario Gas Distribution Industry," *Review of Network Economics*, vol. 8, No. 4.

OECD (2009), "Measuring Capital: OECD Manual."

Paasche, H. (1874), "Uber die Preisentwicklung der letzten Jahre nach den Hamberger Borsennotirungen," *Jahrbucher fur Nationalokonomie und Statistik*, vol. 23.

Pacific Economics Group (2008), "TFP Research for Victoria's Gas Distribution Industry," *Report prepared for the Essential Services Commission*, Madison, Wisconsin, December.

--- (2006), "TFP Research for Victoria's Power Distribution Industry: 2005 Update," *Report prepared for the Essential Services Commission*, Madison, Wisconsin.

--- (2004), "Predicting Growth in SPI's O&M Expenses," *Report prepared for SPI*, Madison, Wisconsin.

--- (2001a), "Envestra Gas Distribution Operations and Maintenance Cost Performance: Results from International Benchmarking," Madison, Wisconsin.

--- (2001b), "Multinet Gas Distribution Operations and Maintenance Cost Performance: Results from International Benchmarking," Madison, Wisconsin.

--- (2001c), "TXU Gas Distribution Operations and Maintenance Cost Performance: Results from International Benchmarking," Madison, Wisconsin.

Tornqvist, L. (1936), "The Bank of Finland's Consumption Price Index," *Bank of Finland Monthly Bulletin*, vol. 10.

UMS (2001), "Queensland Natural Gas Distribution Efficiency Study," *Study undertaken on behalf of the Queensland Competition Authority*.

Varian, Hal (1984), *Microeconomic Analysis*, 2nd ed., Norton.

Wooldridge, Jeffrey (2002), *Econometric Analysis of Cross Section and Panel Data*, USA, MIT Press.