Jemena Gas Networks (NSW) – Access Arrangement Information – Appendix 6.7

Economic Insights: The Productivity Performance of Jemena Gas Networks' NSW Gas Distribution System

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The Productivity Performance of Jemena Gas Networks' NSW Gas Distribution System

Report prepared for
Jemena Gas Networks (NSW) Ltd

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EXECUTIVE SUMMARY

Jemena Gas Networks (NSW) Ltd (‘JGN’) has commissioned Economic Insights to examine the total factor productivity (TFP) and partial factor productivity (PFP) performance of JGN’s New South Wales gas distribution system. As well as examining the TFP and PFP growth of the NSW gas distribution system, Economic Insights has been requested to compare productivity levels with those of the three Victorian gas distribution businesses (GDBs) – Envestra, Multinet and SP AusNet – as reported in Lawrence (2007). The study is part of the information being compiled by JGN for input to the Gas Access Arrangement Review for 2011 to 2015 being conducted by the Australian Energy Regulator (AER).

The primary data source for this study is information supplied by JGN and the three Victorian GDBs in response to common detailed data surveys. The surveys covered key output and input value, price and quantity information for the historic period 1998 to 2006 and forecast data for the period 2007 to 2012 in the case of Victoria and for the historic period 1999 to 2009 and forecast data for the period 2010 to 2015 in the case of JGN. Because an important part of this study is comparisons with the Victorian GDB results presented in Lawrence (2007), a number of adjustments have been made to the functional coverage of JGN’s data to ensure more like–with–like comparisons.

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

JGN’s changes in output and input quantities have led to a strong productivity performance over the last 11 years, driven largely by significant reductions in opex. The partial productivity of opex has grown strongly at the very high annual rate of 6.8 per cent since 1999. However, the rate of growth was somewhat lower at 4.8 per cent over the last 6 years and is forecast to decrease to a still quite strong 1.7 per cent over the next 6 years.

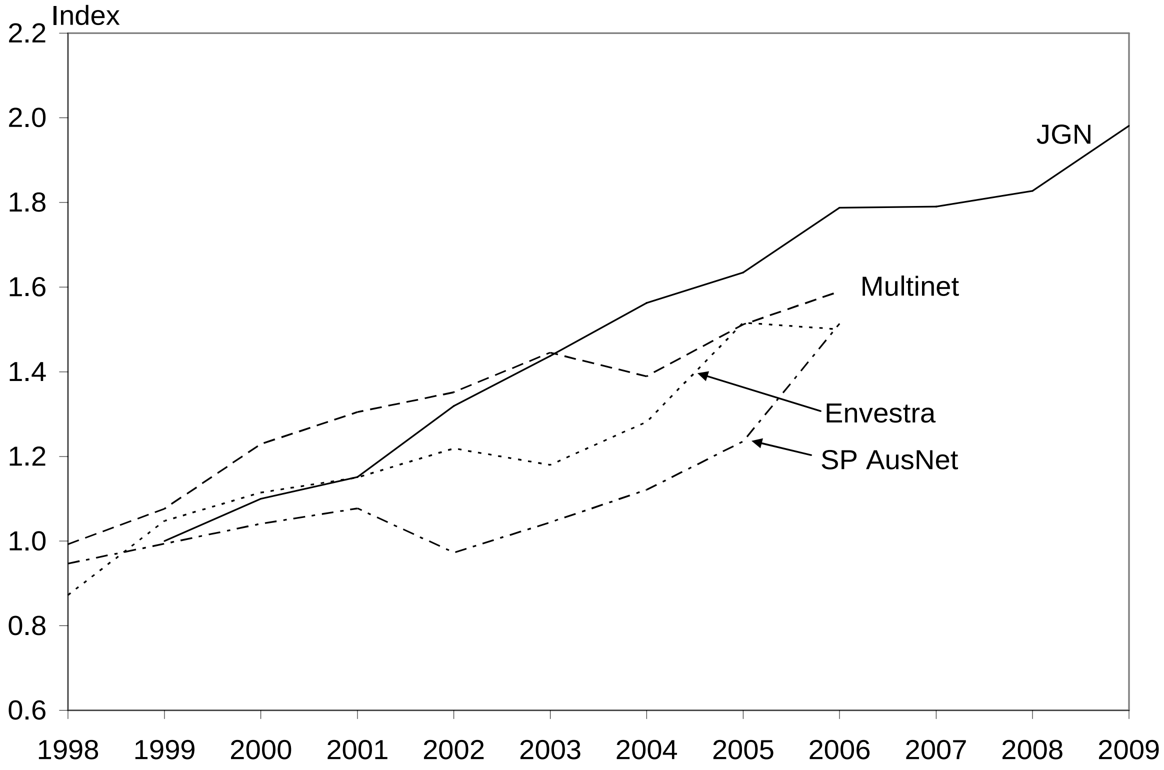
The opex PFP growth pattern exhibits the ‘convergence effect’ we would expect, starting at high growth rates in the early stages of reform tapering off over time to a more sustainable rate reflecting the underlying rate of technical change. Annual growth in the partial productivity of capital has been slightly negative over the last 11 years at –0.2 per cent and is expected to decrease marginally to –0.4 per cent going forward.

JGN’s TFP index exhibited relatively strong growth over the past 11 years. The average annual growth rate was 1.9 per cent for the period 1999 to 2009 although this was only just over 1 per cent for the last 6 years. Going forward the annual growth rate is forecast to reduce to 0.2 per cent for the next 6 years. JGN has been able to achieve relatively strong productivity growth rates because of its increasing penetration rates and, principally, by cutting opex input use. However, caution needs to be exercised in using past productivity growth rates as a guide to likely future attainable efficiency improvements. The combination of the convergence effect and expected changes to safety and compliance requirements GDBs will face are expected to lead to a much more modest TFP performance going forward.

Despite slightly different patterns in the intervening years, JGN's TFP growth over the period 1999 to 2006 was practically identical to that of Victoria with average annual growth rates of 2.5 per cent and 2.3 per cent, respectively. JGN's opex PFP growth performance has been generally much stronger than that of Victoria from 2001 to 2009 while its capital PFP growth performance has been slightly below that of Victoria. The formation of Agility in mid 2000 is likely to have allowed JGN to reap significant opex economies over this period.

JGN comes very close to matching the Victorian GDBs in terms of overall productivity levels. Its TFP level is comparable to that of SP AusNet (the lowest of the Victorian GDBs) for the years 2003 to 2005. This is a somewhat surprising result given that JGN has much lower customer density, lower customer penetration and a less intermeshed network.

Figure A: **JGN and Victorian GDB multilateral opex PFP indexes, 1998–2009**



Source: Economic Insights GDB database

JGN's opex multilateral PFP levels are higher than those of the Victorian GDBs from 2004 onwards (figure A). This results from JGN's strong opex PFP growth between 2001 and 2004 relative to the Victorian GDBs. In 2006 JGN's opex multilateral PFP was around 12 per cent higher than Multinet's and around 19 per cent higher than those of Envestra and SP AusNet. In terms of capital multilateral PFP levels, JGN was 4 per cent below SP AusNet and 6 per cent below Multinet. Given the differences in system structures – dendritic for JGN versus intermeshed for the Victorian GDBs – which could be expected to put JGN at a significant disadvantage, JGN's capital multilateral PFP performance is relatively strong.

Overall – and particularly once differences in network density and system structure are taken into account – the results of this study indicate that JGN is a relatively efficient performer compared to the three Victorian GDBs.

1 INTRODUCTION

Jemena Gas Networks (NSW) Ltd (‘JGN’) has commissioned Economic Insights Pty Ltd (‘Economic Insights’) to examine the total factor productivity (TFP) and partial factor productivity (PFP) performance of JGN’s New South Wales gas distribution system. As well as examining the TFP and PFP growth of the NSW gas distribution system, Economic Insights has been requested to compare productivity levels with those of the three Victorian gas distribution businesses (GDBs) – Envestra, Multinet and SP AusNet – as reported in Lawrence (2007).

The study concentrates on performance in the period from 1999 to 2009 and also presents forecasts of TFP and PFP performance for the period 2010 to 2015 based on JGN’s current forecasts of expected changes in its outputs and inputs over this period. The study is part of the information being compiled by JGN for input to the Gas Access Arrangement Review for 2011 to 2015 being conducted by the Australian Energy Regulator (AER).

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.

Industry level TFP performance plays a key role in setting prices in a competitive market. It is, hence, of interest to regulators where the aim of regulation is typically to mimic the outcome of a competitive market in an industry operating under natural monopoly conditions. Information from TFP studies can be one ingredient in the setting of 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.

While there have been some earlier studies of the efficiency performance of Australian GDBs at particular points in time, the Lawrence (2007) study of the three Victorian GDBs is the most comprehensive study of the TFP performance of GDBs in Australia. The same methodology as used in Lawrence (2007) is used in this study.

The following parts of this section of the report summarise the terms of reference for the study and list Economic Insights’ productivity measurement experience and the qualifications of the consultants involved.

In the following sections of the report we outline the basics of TFP, why it is of interest to regulators and briefly summarise earlier GDB efficiency and productivity reports. We then discuss a number of key measurement issues affecting outputs, inputs and the indexing method in section 3 before describing the specifications and data used in section 4. Productivity growth results for JGN are then presented in section 5 and multilateral TFP results comparing JGN’s productivity levels with those of the three Victorian GDBs are presented in section 6. We then draw conclusions in section 7.

1.1 Terms of reference

JGN's terms of reference asked Economic Insights to provide a report 'detailing its analysis of Time Series and Multilateral Total Factor Productivity (TFP) efficiency estimates, and Partial Factor Productivity (PFP) estimates, that is suitable for validating JGN's opex and capex forecast and use in support of statements about JGN's relative cost performance'. The report went on to ask Economic Insights to use historic cost and output data provided by JGN and, subject to agreement by the Victorian gas distributors, the database prepared for Denis Lawrence's report *The Total Factor Productivity Performance of Victoria's Gas Distribution Industry* prepared by Meyrick and Associates for Envestra, Multinet and SP AusNet on 23 March 2007 and submitted to the Essential Services Commission's review of 2008–12 Victorian gas access arrangements.

A full copy of the terms of reference for the study is presented in appendix B.

1.2 Economic Insights' experience and consultants' qualifications

Economic Insights has been operating in Australia for 15 years as a specialist economics consulting firm. Economic Insights provides strategic policy advice and rigorous quantitative research to industry and government, particularly on infrastructure matters. Economic Insights' experience and expertise covers a wide range of economic and industry analysis topics including:

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

This report has been prepared by Dr Denis Lawrence, Director of Economic Insights, with assistance from Economic Insights' Associate John Kain.

Denis Lawrence has undertaken several major energy supply industry productivity measurement studies including: measuring the productivity growth and productivity levels of Victoria's gas distribution businesses, measuring the productivity of New Zealand's 29 electricity lines businesses and advising the Commerce Commission on appropriate X factors for each of the distribution businesses; measuring the productivity performance of Australian and New Zealand gas distribution businesses for the Commerce Commission; benchmarking the productivity performance of the Australian state electricity systems against best practice in the US and Canada at both the system–wide level and for individual power plants; benchmarking the productivity, service quality and financial performance of 13 Australian electricity distribution businesses; and reviewing productivity measurement work undertaken for regulators in NSW and Victoria. Denis has worked on regulatory issues for electricity utilities, regulators, state Treasury departments, international agencies and prospective investors. He is currently providing expert advice to the Australian Energy Market Commission's review of productivity–based regulation.

Denis holds a PhD in Economics from the University of British Columbia, Canada, where he studied under Prof Erwin Diewert, one of the world's leading productivity analysts. Denis' summary CV is presented in appendix C.

John Kain is an Associate of Economic Insights and Principal of Erldunda Associates. Prior to becoming a consultant John was employed by ACT Electricity and Water (ACTEW) as Chief Engineer and General Manager Engineering. Since leaving ACTEW, John has operated as an independent consultant in the energy distribution industry, specialising in the analysis of network costs and tariffs. John's clients have included the ACCC and distribution businesses. He has worked on several major productivity measurement studies for Economic Insights including assisting the NZ Commerce Commission with setting CPI–X thresholds for lines businesses. John holds Science and Engineering degrees from Sydney University.

Denis Lawrence 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 appendix D to the report.

2 ABOUT TFP

2.1 What is TFP?

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 gas 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.

In practice, 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 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 (eg 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 GDB 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 the same output. Finding out why TFP levels differ between businesses will involve examining partial productivity measures to find out which inputs appear to be a problem for the business concerned. More detailed benchmarking exercises between GDBs and similar organisations in other sectors may then be necessary to identify specific options for improving productivity performance.

2.2 Why is TFP of interest to regulators?[1]

Government agencies and inquiries including the Expert Panel on Access Pricing (2006) have advocated consideration of ‘productivity based’ approaches to regulation whereby X factors are set using information on industry productivity trends. In this section we review the underlying rationale behind using TFP measures in setting price caps.

The principal objective of CPI–X regulation is to mimic the outcomes that would be achieved in a competitive market. Competitive markets normally have a number of desirable properties. The process of competition leads to industry output prices reflecting industry unit costs, including a normal rate of return on the market value of assets after allowing for the risk. Because no individual firm can influence industry unit costs, each firm has a strong

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[1] This section draws on Lawrence (2003b).

incentive to maximise its productivity performance to achieve lower unit costs than the rest of the industry. This will allow it to keep the benefit of new, more efficient processes that it may develop until such times as they are generally adopted by the industry. This process leads to the industry operating as efficiently as possible at any point in time and the benefits of productivity improvements being passed on to consumers relatively quickly.

Because infrastructure industries such as the provision of gas distribution networks are often natural monopolies, competition is normally limited and incentives to minimise costs and provide the cheapest and best possible quality service to users are not strong. The use of CPI–X regulation in such industries attempts to strengthen the incentive to operate efficiently by imposing similar pressures on the network operator to the process of competition. The change in output prices is 'capped' as follows:

$$\Delta P = \Delta W - X \pm Z \tag{1}$$

where Δ represents the proportional change in a variable, P is the maximum allowed output price, W is a price index taken to approximate changes in the industry's input prices, X is the estimated productivity change for the industry and Z represents relevant changes in external circumstances beyond managers' control which the regulator may wish to allow for. There are several alternative ways of choosing the index W to reflect industry input prices. Perhaps the best way of doing this is to use a specially constructed index which weights together the prices of inputs by their shares in industry costs. However, this price information is often not readily or objectively available, particularly in regulatory regimes that have yet to fully mature. A commonly used alternative is to choose a generally available price index such as the consumer price index or GDP deflator.

The framework that underlies the CPI–X approach can be illustrated as follows. We start with the index number definition of TFP growth:

$$\begin{aligned} \Delta TFP &\equiv [Y^1/Y^0]/[X^1/X^0] \\ &= \{[R^1/R^0]/[P^1/P^0]\}/\{[C^1/C^0]/[W^1/W^0]\} \\ &= \{[M^1/M^0][W^1/W^0]\}/[P^1/P^0] \end{aligned} \tag{2}$$

where the superscripts represent different time periods, R^t (C^t) is revenue (cost) in period t, M^t is the period t markup and $R^t = M^t C^t$. As a normal return on assets (after allowing for risk) is included in the definition of costs, a firm earning normal returns will have a markup factor of one while a firm earning excess returns will have a markup of greater than one. Rearranging the above equation gives:

$$P^1/P^0 = \{[M^1/M^0][W^1/W^0]\}/\ \Delta TFP \tag{3}$$

where W^1/W^0 is the firm's input price index (which includes intermediate inputs). Equation (3) is approximately equal to:

$$\Delta P = \Delta M + \Delta W - \Delta TFP. \tag{4}$$

Thus, the admissible rate of output price increase ΔP is equal to the rate of increase of input prices ΔW less the rate of TFP growth ΔTFP provided the regulator wants to keep the monopolistic markup constant (so that $\Delta M = 0$). Equation (3) or its approximation (4) is the key equation for setting up an incentive regulation framework: the term W^1/W^0 would be an input price index of the target firm's peers and the term ΔTFP would be the average TFP growth rate for the target firm's peers. The markup growth term could be set equal to zero under normal circumstances but if the target firm was making an inadequate return on capital due to factors beyond its control, this term could be set equal to a positive number. On the other hand, if the target firm was making monopoly profits or excessive returns, then this term could be set negative. This effectively sets a 'glide path' to bring firms closer to earning a normal or average rate of return.

The next issue to be considered in operationalising (4) is the choice of the price index to reflect changes in the industry's input prices, W. The most common choice for this index is the consumer price index (CPI). But this is actually an index of output prices for the economy rather than input prices. Normally we can expect the economy's input price growth to exceed its output price growth by the extent of economy–wide TFP growth (since labour and capital ultimately get the benefits from productivity growth). We assume that the markup factors for the economy as a whole are one so that the counterpart to equation (2) applied to the entire economy becomes:

$$P_E^1/P_E^0 = [W_E^1/W_E^0]/\ \Delta TFP_E. \tag{5}$$

Substituting the rate of change of the CPI for the economy–wide output price index on the left hand side of (5) and rearranging terms leads to the following identity:

$$1 = [CPI^1/CPI^0]\ \Delta TFP_E/[W_E^1/W_E^0]. \tag{6}$$

Substituting the right hand side of (6) into (2) produces the following equation:

$$\begin{aligned} P^1/P^0 &= \{[CPI^1/CPI^0]\Delta TFP_E\ /[W_E^1/W_E^0]\}\{[M^1/M^0][W^1/W^0]\}/\ \Delta TFP \\ &= [CPI^1/CPI^0][\Delta TFP_E\ /\Delta TFP]\{[W^1/W^0]/[\ W_E^1/W_E^0]\}[M^1/M^0]. \end{aligned} \tag{7}$$

Approximating the terms in (7) by finite percentage changes leads to the following:

$$\Delta P = \Delta CPI + \Delta M + [\Delta W - \Delta W_E] - [\Delta TFP - \Delta TFP_E] \tag{8}$$

so that the X factor is defined as:

$$X \equiv [\Delta TFP - \Delta TFP_E] - [\Delta W - \Delta W_E] - \Delta M. \tag{9}$$

What equation (9) tells us is that the X factor can effectively be decomposed into three terms. The first differential term takes the difference between the industry's TFP growth and that for the economy as a whole while the second differential term takes the difference between the firm's input prices and those for the economy as whole. Thus, taking just the first two terms, if the regulated industry has the same TFP growth as the economy as a whole and the same rate of input price increase as the economy as a whole then the X factor in this case is zero. If the regulated industry has a higher TFP growth than the economy then X is positive, all else equal, and the rate of allowed price increase for the industry will be less than the CPI. Conversely, if the regulated industry has a higher rate of input price increase than the economy as a whole then X will be negative, all else equal, and the rate of allowed price increase will be higher than the CPI. As noted above, the markup growth term could be set equal to zero under normal circumstances but if the target firm was making excessive returns, then this term could be set negative (leading to a higher X factor).

Normally, firms that are at the forefront of industry performance have high productivity levels but low productivity growth rates. This is because they have removed almost all unnecessary slack from their operations and are only able to increase productivity at the rate of technological change for the industry. Conversely, firms that are not operating at high levels of efficiency should be able to achieve higher productivity growth rates as they catch up. As all firms become efficient (eg in response to incentive regulation) then productivity growth rates will converge to the long run rate of technological change in the industry.

This process of 'convergence' to the long rate of technological change in the industry also has important implications for the interpretation of measures of historical TFP growth at the industry level for regulatory purposes. JGN has now undergone a long period of reform. In most infrastructure industries we normally see a period of high productivity growth when the reform process is started and easy 'catch–up' gains are made. As performance moves closer to best practice, industry productivity growth usually slows down as marginal improvements become harder to achieve.

The rate of technological change in distribution businesses is likely to be relatively slow given the mature and stable nature of the technology used. Extreme caution is thus required in drawing inferences about attainable future productivity growth from studies of historical performance following reform. For regulatory purposes we thus need to extend the analysis beyond TFP growth rates to place the analysis in a broader perspective, particularly comparing productivity levels to industry best practice. In this study we examine likely future TFP growth based on the best currently available forecasts of future output and input levels to place historical performance in context given the likely importance of the convergence effect. We also examine JGN's TFP levels relative to the Victorian GDBs to provide information on where it stands in terms of relative efficiency.

Economic Insights (2009a,b) has recently extended the X factor framework presented in equation (9) above to allow for the importance of sunk costs and the regulatory principle of financial capital maintenance. The extended framework involves using approved amortisation charges as the weight for capital input quantities in calculating TFP and in forming the input price differential. Since this report looks at productivity only comparisons with Lawrence (2007) results for Victoria, the same approach to productivity measurement adopted in Lawrence (2007) is adopted here.

2.3 Past gas distribution efficiency and TFP studies

There have been seven studies undertaken previously of gas pipeline efficiency performance in Australasia. These are Bureau of Industry Economics (1994), IPART (1999), Pacific Economics Group (2001a,b,c), Lawrence (2004a, 2004b, 2007) and Pacific Economics Group (2008).

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 (eg cast iron versus polyethylene).

Under the assumptions of constant returns to scale and no differences in operating environments, the Australian utilities were found to be around 20 per cent behind industry best practice. Canadian and Japanese utilities were found to be the most efficient on average. Including the operating environment condition variables of climate and density in the DEA analysis lead to the Australian utilities increasing their average efficiency score to 10 per cent behind best practice.

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 (2001)

In 2001 Pacific Economics Group (PEG) benchmarked the Australian gas distribution operations of three Victorian utilities – Multinet (United Energy), TXU, and Envestra Victoria (PEG 2001a,b,c) – 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 (ie including forecast data from 2004 onwards) the trend annual rate of TFP increase was a still relatively high 2.5 per cent.

While being New Zealand's third largest GDB with around 56,000 customers, NGC Distribution was only around one tenth the size of the Victorian GDBs. The New Zealand gas distribution industry is generally less mature than Victoria's with penetration rates still increasing relatively quickly. For instance, NGC Distribution's customer density increased from 18.5 customers per kilometre in 1997 to 20.4 customers per kilometre in 2003. It was forecast to increase further to 22 customers per kilometre by 2008. All else equal, this could be expected to lead to the New Zealand GDBs having relatively high TFP growth.

Lawrence (2007)

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 past 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 (2007) 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 (2007) 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.

3 MEASUREMENT ISSUES

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

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

In common with other network infrastructure industries, measuring the performance of gas pipelines presents a number of challenges, not the least of which is defining exactly what a GDB's output is. In this section we examine a number of difficult measurement issues including how to define GDB outputs and inputs and the likely impact of operating environment conditions.

3.1 Measuring GDB outputs

Early energy supply productivity studies simply measured output by system throughput. However, this simple measure ignores important aspects of what pipelines really do. Like all network infrastructure industries, a major part of pipelines' output is providing the capacity to supply the product. In this sense, there is an analogy between a gas distribution system and a road network. The GDB has the responsibility of providing the 'road' and keeping it in good condition but has little, if any, control over the amount of 'traffic' that goes down the road. Consequently, the GDB's output should also be mainly measured by the availability of the infrastructure it has provided and the condition in which it has maintained it. Other outputs the distributor provides are directly related to its number of connections ('local access roads') as well as call centre operations responding to queries, connection requests, etc.

In Lawrence (2003a), to capture these multiple dimensions of electricity DB output we measured distribution output using three outputs: throughput, system line capacity and connection numbers. This also had the advantage of incorporating the major density effects (consumption per customer and customers per MVA–kilometre of line) directly into the output measure. A similar output specification would be appropriate for gas distribution as gas network output has similar dimensions and density considerations to that for electricity networks. A broadly similar measure has been developed for this study in consultation with the GDBs' engineers.

Pacific Economics Group (2004, 2006) also included three output dimensions in their electricity DB TFP study: throughput, customer numbers and non–coincident peak demand. This measure of peak demand was used as a proxy for maximum contracted demand since it was argued that using billable outputs was appropriate. While this measure captured the peak input required to the system, it did not incorporate any measure of line length and so would be less appropriate for comparing DBs of varying customer densities.

Economic Insights (2009b) has shown that when regulation involves several firms and past average rates of TFP growth are used in setting a common rate of change going forward, then the measurement of output in the TFP calculation becomes critical. In particular, it is necessary for the output measure to capture as fully as possible what regulated services are being provided by the firms in the group, independently of the institutional and historical factors that determine how the firms happen to charge consumers. When the increasing returns to scale nature of the industry and the role of sunk cost assets is taken into account allocative efficiency requires that all functional outputs (of which billable outputs will be a subset) be included and the deviation of market prices from marginal costs be allowed for.

Ideally, service quality would be included as a fourth output. However, attempts to include reliability measures as a fourth output in energy distribution efficiency and TFP studies have proven unsuccessful due to the way output is measured. As both the frequency and duration of interruptions are measured by indexes where a decrease in the value of the index represents an improvement in service quality, it would be necessary to either include the indexes as 'negative' outputs (ie a decrease in the measure represents an increase in output) or else to convert them to measures where an increase in the converted measure represents an increase in output. Most indexing methods cannot readily incorporate negative outputs and inverting the measures to produce an increase in the measure equating to an increase in output leads to non–linear results. They have not been included in previous gas supply efficiency studies and are again excluded in this study. Service quality issues are generally less of a problem in gas supply than they in electricity supply where outages are more frequent given the more exposed nature of overhead wires compared to buried pipelines.

To aggregate the outputs into a total output index using indexing procedures, we have to allocate a weight to each output. For most competitive industries which produce multiple outputs these output weights are taken to be the revenue shares. However, in this case we cannot observe separate amounts being paid for the different output components and the non–competitive nature of the industry may lead to a divergence between prices and marginal costs for the different output components. In this case we can either make some arbitrary judgements about the relative importance of the output components or we can draw on econometric evidence. One way of doing this using econometrics is to use the relative shares of cost elasticities derived from an econometric cost function. The latter approach is often used in industries not subject to high levels of competition because the cost elasticity shares reflect the marginal cost of providing an output and is the approach we adopt in this study.

3.2 Measuring GDB inputs

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

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

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

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

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

3.3 Normalisation for operating environment conditions

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

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

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

3.4 TFP indexing methods

A TFP index is generally defined as the ratio of an index of output growth divided by an index of input growth. 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. 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.

Mathematically, the TFP index is given by:

$$TFP = \Delta Q / \Delta I \tag{10}$$

where ΔQ is the proportional change in the quantity of total output between the current period and the base period and ΔI is the corresponding proportional change in the quantity of total inputs.

To operationalise this concept we need a way to combine changes in diverse outputs and inputs into measures of change in total outputs and total inputs. Different index number methods take this weighted average change in different ways.

Diewert (1993) reviewed alternate index number formulations to determine which index was best suited to TFP calculations. Alternative index number methods were evaluated by assessing their performance relative to a number of axiomatic tests. These included:

- 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;
- 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;
- 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,
- 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.

The four most popular index formulations were evaluated against these tests. The indexes evaluated included:

- the Laspeyres base period weight index;
- the Paasche current period weight index;
- the Fisher ideal index which is the square root of the product of the Paasche and Laspeyres index; and
- the Törnqvist index which has been used extensively in previous TFP work, including that of PEG (2004, 2006).

When evaluated against the tests listed above, only the Fisher ideal index passed all four tests. The Laspeyres and Paasche index fail the time reversal test while the Törnqvist index fails the constant basket test.

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. In this study the Fisher ideal index was therefore chosen as the preferred index formulation. It is also increasingly the index of choice of leading national statistical agencies.

Mathematically, the Fisher ideal output index is given by:

$$(11) \quad Q_F^t = [(\textstyle\sum_{i=1}^m P_i^B Y_i^t / \sum_{j=1}^m P_j^B Y_j^B)(\sum_{i=1}^m P_i^t Y_i^t / \sum_{j=1}^m P_j^t Y_j^B)]^{0.5}$$

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

P_i^B is the price of the ith output for the base observation;

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

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

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

Similarly, the Fisher ideal input index is given by:

$$(12) \quad I_F^t = [(\textstyle\sum_{i=1}^n W_i^B X_i^t / \sum_{j=1}^n W_j^B X_j^B)(\sum_{i=1}^n W_i^t X_i^t / \sum_{j=1}^n W_j^t X_j^B)]^{0.5}$$

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

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

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

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

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

The Fisher ideal TFP index is then given by:

$$(13) \quad TFP_F^t = Q_F^t / I_F^t .$$

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:

$$(14) \qquad Q_F^{1,t} = 1 \times Q_F^{1,2} \times Q_F^{2,3} \times \ldots . \times Q_F^{t-1,t} \; .$$

In this study we use the cost function method developed in Lawrence (2003a) and applied to GDB data in Lawrence (2007) to form output cost shares for the included output components. This methodology is described in appendix A.

4 DATA USED

The primary data source for this study is information supplied by JGN and the three Victorian GDBs in response to common detailed data surveys. The surveys covered key output and input value, price and quantity information for the historic period 1998 to 2006 and forecast data for the period 2007 to 2012 in the case of Victoria[2] and for the historic period 1999 to 2009 and forecast data for the period 2010 to 2015 in the case of JGN.

Wherever possible, Victorian data supplied excluded 'new towns' operations of the GDBs as the focus of the Lawrence (2007) study was on the GDBs' primary operations in the mature Melbourne metropolitan market. The data supplied were consistent with the GDBs' Regulatory Accounts but the focus was on ensuring data reflected 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. Similarly, Victorian asset value data was based on original DORC valuation rather than the 'adjusted' asset values. The expense data used also excluded unaccounted for gas and license fees but included an estimated amount for full retail contestability for the period 1998 to 2002 so that the functional responsibility of the GDBs was consistent throughout the period.

Because an important part of this study is comparisons with the Victorian GDB results presented in Lawrence (2007), 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 6). These items are, however, included where productivity growth comparisons are made (section 5). 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.

4.1 Output definitions

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 Tariff V domestic and non–domestic customers and Tariff D customers for Victoria and equivalent categories for JGN.

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[2] Note that the Lawrence (2007) Victorian GDB database was assembled prior to the ESC's final GAAR determination which contained significant cuts to both opex and capex. Consequently, the forecasts for Victoria for 2007 to 2012 are likely to be higher than what actual outcomes for this period will be.

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

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

The system capacity measure used in this study is that developed in Lawrence (2007) which is the volume of gas held within a gas network converted to standard cubic meters using a pressure correction factor based on the average operating pressure. The volume of the distribution network is calculated based on pipeline length data for high, medium and low distribution pipelines and estimates of the average diameter of each of these pipeline types. 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.

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.

Output weights

To aggregate a diverse range of outputs into an aggregate output index using indexing procedures, we have to allocate a weight to each output. For most industries which produce multiple outputs these output weights are taken to be the revenue shares. However, in this case we cannot observe separate amounts being paid for some of the different functional output components and, given the non–competitive nature of the distribution activity, prices may bear little relationship to marginal cost. As discussed in section 3, in this case we use the estimated output cost shares derived from the econometric cost function outlined in appendix A used in Lawrence (2007) 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 (2003a). This produced an output cost share for throughput of 13 per cent, for customers of 49 per cent and for system capacity of 38 per cent.

Total GDB revenue is the sum of revenue from Tariff V domestic and non–domestic customers and Tariff D customers for the Victorian GDBs and equivalent categories for JGN.

4.3 Input definitions

Input quantities

Opex: The quantity of the GDB's opex is derived by deflating the value of opex by the opex price deflator developed by PEG (2006). As noted above, the opex values supplied by the GDBs were consistent with the GDBs' Regulatory Accounts but the focus has been on ensuring data reflects actual year–to–year operations. A number of accounting adjustments such as allowance for provisions have been excluded as they do not reflect the actual inputs used by the businesses in a particular year which is what we need for TFP purposes. To ensure consistency in functional coverage throughout the period, each GDB's constant price opex for the years 1998 to 2002 is increased by the amount of full retail contestability (FRC) expenses incurred in 2003. In these early years FRC was expected to have only affected opex (and not capital) requirements.

The PEG (2006) opex price deflator was developed for electricity DBs. It is made up of a 62 per cent weighting on the Electricity, gas and water sector Labour cost index with the balance of the weight being spread across five Producer price indexes covering business, computing, secretarial, legal and accounting, and advertising services. Since the functions of electricity and gas distribution are broadly analogous, the PEG (2006) deflator is considered the best currently available for GDB opex as well. It increased at an average of 3.5 per cent per annum over the five years to 2006 and this rate of increase is used for the Victorian GDBs' forecast opex data. This compared to the corresponding CPI increase of around 2.5 per cent for the five years to 2006. For JGN the nominal escalators used in forecasting opex requirements for the period 2010 to 2015 are used as the opex price for this period.

Transmission network: The quantity of each Victorian GDB's transmission network is proxied by its transmission pipeline length while that for JGN is proxied by the sum of its trunk and primary mains length.

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.

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 meters.

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.

Capital constant price and nominal values

The starting point for our Victorian GDB asset values are the 1997 valuations done by GHD (reported in SKM 1998). These valuations present DORC valuations for 12 asset categories for each of the three GDBs. Asset life and remaining asset life estimates are also provided for each of the 12 asset categories. As distribution pipelines are presented as one category in the GHD valuations, we distribute this value between high, medium and low pressure pipelines using a common formula across the three GDBs based on their specific line lengths by pressure type and estimates of relative construction costs for each of the three pressure types.

We form disaggregated constant price depreciated capital stock estimates by rolling forward the opening DORC values by taking away straight line depreciation based on remaining asset life of the opening capital stock and adding in yearly constant price capital expenditure and subtracting yearly constant price depreciation on capital expenditure for 1998 and subsequent years calculated using straight line depreciation based on asset–specific asset lives. Disaggregated nominal DORC series are formed by multiplying the constant price series by the implicit price deflator for the Electricity, gas and water sector net capital stock (ABS 2006).

For JGN the 1999 IPART RAB is used as the starting point for the asset roll forward. The roll forward is done on the same basis as the Victorian GDB data to maintain comparability.

Input weights

Following PEG (2006) we use the endogenous rate of return method for forming estimates of the user cost of capital. Using this approach the value of total costs equals total revenue by definition. As noted in Lawrence (2007), the implicit gross rate of return for the three Victorian GDBs was relatively stable over the period up to 2006 and also across the three GDBs so there would be little difference in TFP estimates formed using this approach and the exogenous user cost method. The JGN implicit gross rate of return is also relatively stable over the period to 2009 although marginally higher than that observed for the Victorian GDBs. The input weight given to opex is simply the ratio of opex to total revenue. The aggregate capital input is simply given the difference between one and 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.

4.4 Key characteristics of JGN and the Victorian GDBs

The key characteristics of JGN and the three Victorian GDBs are presented in table 1 for 2006, the latest year for which actual Victorian data are available in the database. In terms of throughput and customer numbers JGN is roughly half as big again as each of the Victorian GDBs. However, it has around three times the system capacity of each of the Victorian GDBs and around three times the distribution mains length. As a result JGN's energy density is higher than Multinet's but considerably lower than Envestra's and SP AusNet's. A more consistent difference is observed in customer density with JGN's customer density being only around 70 per cent of that of Envestra and SP AusNet and only around 60 per cent of that of Multinet.

Table 1: **GDBs' key characteristics, 2006**

GDB	Throughput *TJ*	Customers *No*	System capacity Sm^3	Distribution mains length *kms*	Energy density *GJ/customer*	Customer density *customers/km*
JGN	94,788	975,033	358,799	23,149	97	42
Envestra	57,430	498,807	114,375	8,647	115	58
Multinet	60,138	647,572	111,859	9,332	93	69
SP AusNet	71,294	520,289	112,667	8,941	137	58

Source: Economic Insights GDB database

The difference in customer densities results from the fundamental differences in the JGN and Victorian systems. The Victorian systems are concentrated on greater Melbourne and so are characterised by a radial, meshed pattern. The JGN system, on the other hand, covers Sydney, Newcastle and Wollongong, the NSW Central Coast and the Blue Mountains and a number of country towns within NSW. The JGN is more 'dendritic' in nature as mains have to support enough gas flow to support a number of spreadout pockets of consumption. Climatic differences also play an important part with the warmer NSW winters, particularly in the major coastal consumption centres, reducing demand for gas for space heating compared to the Melbourne residential and commercial market. By way of example, JGN's average residential customer energy density in 2006 was less than one third that of Multinet.

The JGN system is also less mature than the Victorian systems with much lower but still increasing penetration rates compared to the higher but more stable penetration rates observed in Melbourne.

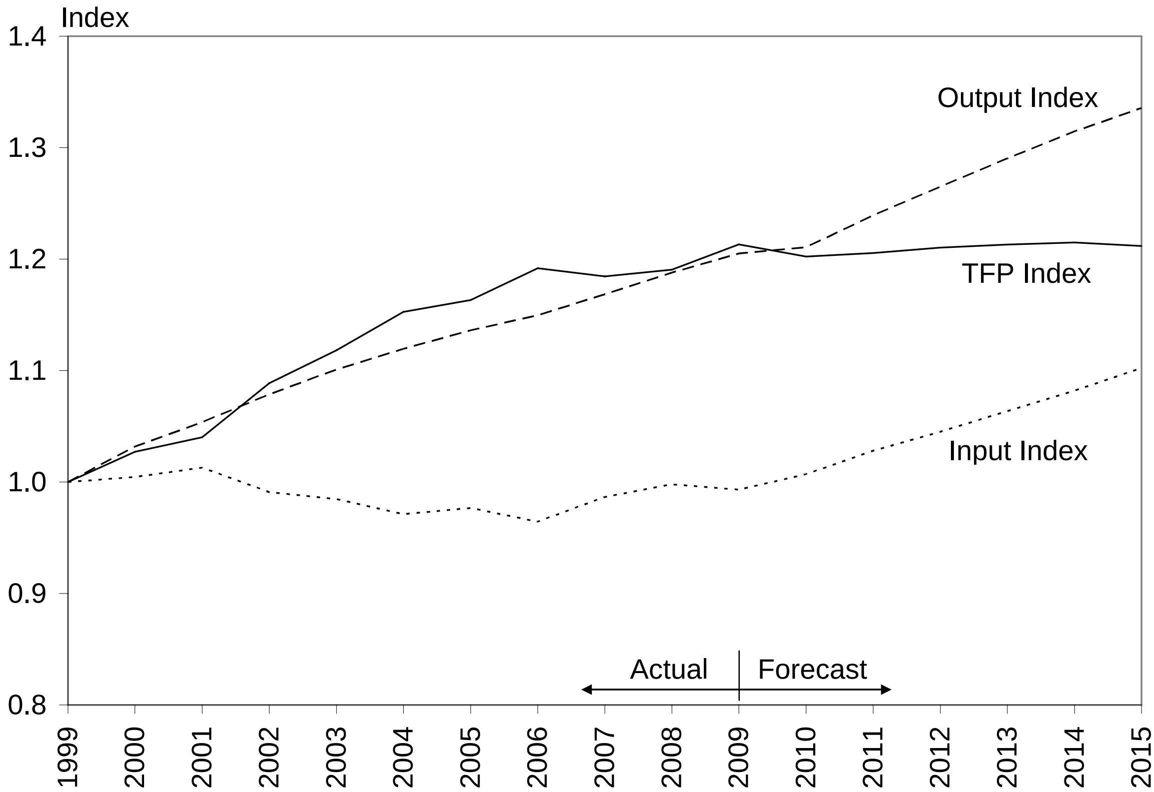
5 PRODUCTIVITY GROWTH RESULTS

5.1 JGN historical and forecast results, 1999 to 2015

In this section we present the key productivity results for JGN for the 11 year period to 2009 along with estimates through to 2015 based on JGN's current forecasts of changes in output and input quantities and values. Results are presented using the specification outlined in section 4 of three outputs (throughput, customer numbers and system capacity) and 8 inputs (opex, lengths of transmission pipelines, high pressure pipelines, medium pressure pipelines, low pressure pipelines and services, meters, and other capital).

The output, input and TFP indexes for the JGN gas distribution system are presented in figure 1 and table 2.

Figure 1: **JGN gas distribution output, input and TFP indexes, 1999–2015**



Source: Economic Insights GDB database

The increase in the output quantity index over the last 11 years has been relatively steady with an average annual growth rate of 1.9 per cent although this reduced to 1.5 per cent per annum for the more recent period 2004 to 2009. Overall annual output growth is forecast to increase again to 2 per cent over the next 6 years. The continued strong output growth reflects JGN's relatively low and still increasing penetration rates.

Input quantity fell by a total of around 4 per cent between 1999 and 2006 before increasing again to be close to its 1999 level by 2009. Overall input use had an average annual growth rate of –0.1 per cent between 1999 and 2009 although the average annual growth rate for the more recent period 2004 to 2009 was 0.5 per cent. Input use is forecast to continue to increase over the next 6 years with an average annual growth rate of 1.8 per cent.

Table 2: **JGN gas distribution productivity indexes, 1999–2015**

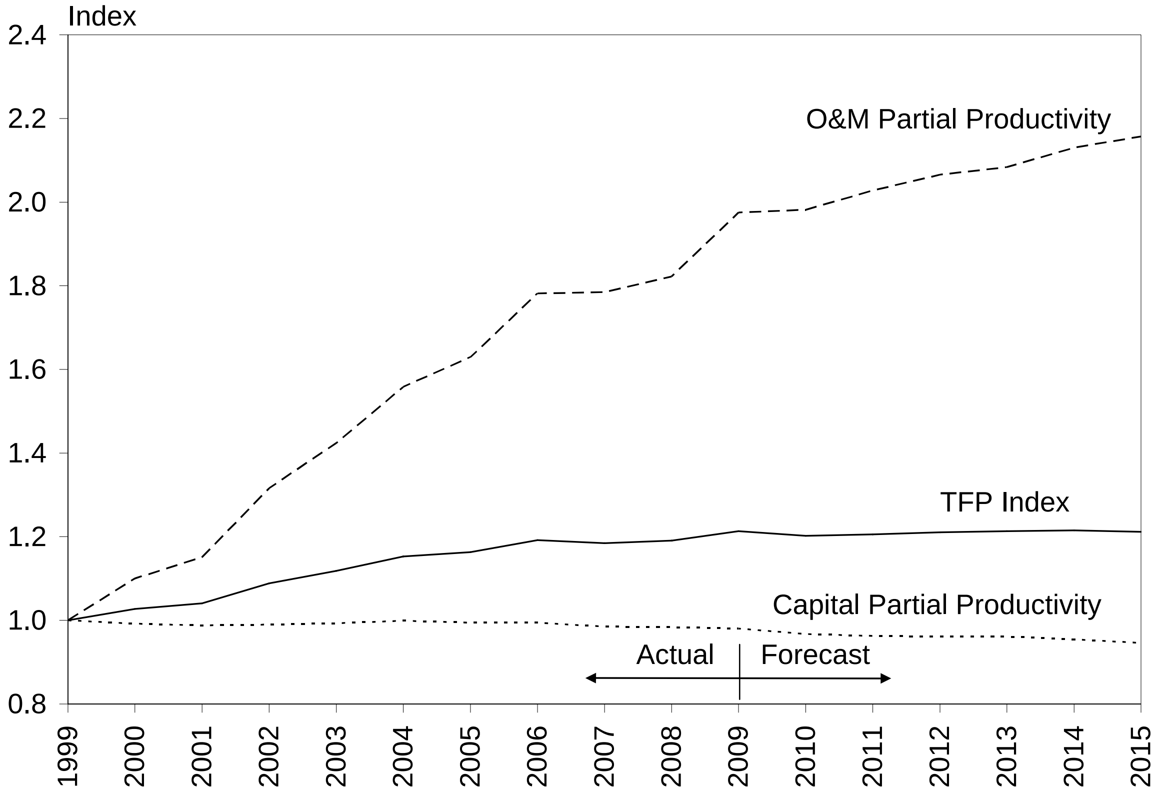
Year	Output	Input	Opex	Capital	PP Opex	PP Capital	TFP
1999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2000	1.032	1.005	0.938	1.040	1.100	0.992	1.027
2001	1.054	1.013	0.915	1.067	1.151	0.988	1.040
2002	1.079	0.991	0.820	1.090	1.316	0.990	1.089
2003	1.101	0.985	0.773	1.109	1.424	0.993	1.118
2004	1.120	0.971	0.719	1.121	1.558	0.999	1.153
2005	1.136	0.977	0.697	1.142	1.629	0.995	1.163
2006	1.150	0.964	0.645	1.156	1.782	0.994	1.192
2007	1.169	0.987	0.655	1.186	1.785	0.985	1.184
2008	1.188	0.998	0.652	1.207	1.822	0.984	1.190
2009	1.205	0.993	0.610	1.229	1.975	0.980	1.213
2010	1.211	1.007	0.611	1.252	1.982	0.967	1.202
2011	1.239	1.028	0.611	1.287	2.028	0.963	1.205
2012	1.265	1.045	0.612	1.316	2.066	0.961	1.210
2013	1.290	1.064	0.619	1.343	2.084	0.961	1.213
2014	1.315	1.082	0.617	1.377	2.130	0.955	1.215
2015	1.336	1.102	0.619	1.412	2.157	0.946	1.212
Average Annual Change							
1999–2009	1.87%	-0.07%	-4.94%	2.06%	6.81%	-0.20%	1.93%
2004–2009	1.47%	0.45%	-3.28%	1.85%	4.75%	-0.38%	1.02%
2010–2015	1.97%	1.81%	0.27%	2.41%	1.70%	-0.44%	0.16%
1999–2015	1.81%	0.61%	-3.00%	2.15%	4.81%	-0.35%	1.20%

Source: Calculations using Economic Insights GDB database

The pattern of growth has differed markedly between opex and capital. Opex quantity has fallen rapidly over the last 11 years to be at around 60 per cent of its 1999 level in 2009. The average annual rate of reduction was 4.9 per cent for the last 11 years although this reduced to 3.3 per cent over the last 6 years. Opex quantity is forecast to increase marginally over the next 6 years with an average annual growth rate of 0.3 per cent. Capital input usage, on the other hand, has continued to increase over the period with an average annual growth rate of 2.1 per cent over the last 11 years. This is forecast to increase to 2.4 per cent over the next 6 years. The quantity of capital employed was 23 per cent higher in 2009 than it was in 1999 and is forecast to increase by another 15 per cent over the next 6 years.

These changes in output and input quantities have led to a strong productivity performance over the last 11 years, driven largely by significant reductions in opex. From figure 2 and table 2 we see that the partial productivity of opex has grown strongly at the very high annual rate of 6.8 per cent since 1999. However, the rate of growth was somewhat lower at 4.8 per cent over the last 6 years and is forecast to decrease to a still quite strong 1.7 per cent over the next 6 years. Note that the opex PFP growth pattern exhibits the 'convergence effect' we would expect, starting at high growth rates in the early stages of reform tapering off over time to a more sustainable rate reflecting the underlying rate of technical change. Annual growth in the partial productivity of capital has been slightly negative over the last 11 years at –0.2 per cent and is expected to decrease marginally to –0.4 per cent going forward.

Figure 2: **JGN gas distribution partial productivity indexes, 1999–2015**



Source: Economic Insights GDB database

The TFP index (which is effectively a weighted average of the two partial productivity indexes) exhibits relatively strong growth over the past 11 years. The average annual growth rate was 1.9 per cent for the period 1999 to 2009 although this was only just over 1 per cent for the last 6 years. Going forward the annual growth rate is forecast to reduce to 0.2 per cent for the next 6 years. JGN has been able to achieve relatively strong productivity growth rates because of its increasing penetration rates and, principally, by cutting opex input use. However, caution needs to be exercised in using past productivity growth rates as a guide to likely future attainable efficiency improvements. 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 expected changes to safety and compliance requirements GDBs will face are expected to lead to a much more modest TFP performance going forward.

5.2 Comparison with Victorian GDB productivity growth

This section compares JGN's productivity growth with the Victorian GDB results reported in Lawrence (2007). The Victorian output, input and productivity indexes and growth rates from Lawrence (2007) are presented in table 3. Note that the Victorian data starts one year earlier in 1998 but growth rates are calculated over shorter periods as the study was done two years earlier and actual data only went to the end of (calendar) 2006 and not (financial year) 2009 as in the case of JGN. Similarly, the forecast period in Victoria only went to 2012 and was based on forecast data preceding the ESC's final determination. Since the final determination imposed significant reductions in both opex and capex compared to the forecasts, actual Victorian GDB productivity performance may be higher than that presented in the forecasts.

Table 3: **Gas distribution productivity indexes for Victoria, 1998–2012**

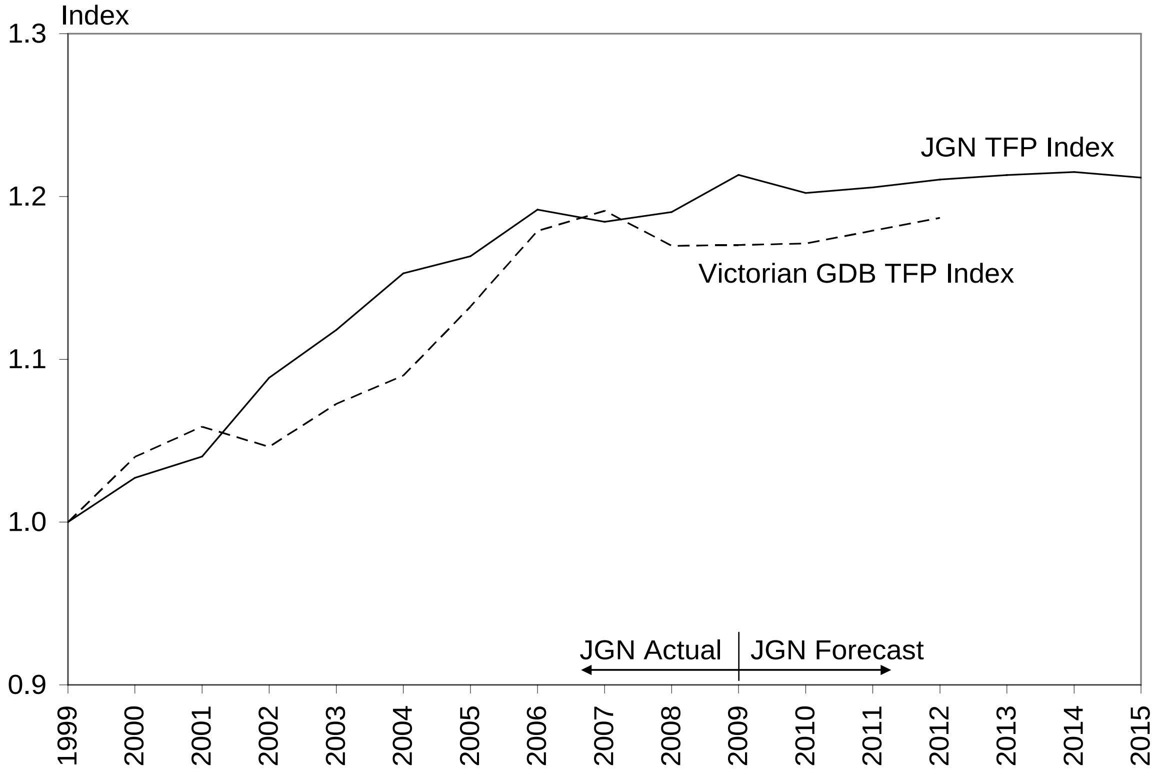
Year	Output	Input	Opex	Capital	PP Opex	PP Capital	TFP
1998	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1999	1.0146	0.9702	0.9156	1.0103	1.1082	1.0043	1.0458
2000	1.0376	0.9540	0.8627	1.0226	1.2027	1.0147	1.0876
2001	1.0499	0.9485	0.8377	1.0316	1.2533	1.0178	1.1070
2002	1.0672	0.9754	0.8590	1.0628	1.2424	1.0042	1.0942
2003	1.1001	0.9809	0.8536	1.0768	1.2888	1.0216	1.1215
2004	1.1166	0.9797	0.8334	1.0900	1.3398	1.0244	1.1397
2005	1.1256	0.9505	0.7500	1.1021	1.5008	1.0213	1.1842
2006	1.1501	0.9330	0.7039	1.1054	1.6339	1.0405	1.2327
2007	1.1715	0.9404	0.7088	1.1147	1.6528	1.0510	1.2457
2008	1.1939	0.9760	0.7656	1.1355	1.5594	1.0514	1.2233
2009	1.2156	0.9934	0.7717	1.1615	1.5753	1.0466	1.2237
2010	1.2369	1.0100	0.7821	1.1828	1.5816	1.0458	1.2247
2011	1.2584	1.0206	0.7920	1.1939	1.5890	1.0540	1.2330
2012	1.2807	1.0318	0.8016	1.2063	1.5976	1.0617	1.2412
Average Annual Change							
1998–2006	1.77%	–0.85%	–4.22%	1.26%	6.41%	0.50%	2.67%
2002–2006	1.89%	–1.09%	–4.79%	0.99%	7.14%	0.90%	3.03%
2006-–2012	1.81%	1.70%	2.22%	1.47%	–0.34%	0.34%	0.12%

Source: Lawrence (2007, p.28)

JGN's TFP performance is plotted against that of the Victorian distribution industry in figure 3 for the period starting in 1999. Despite slightly different patterns in the intervening years, JGN's TFP growth over the period 1999 to 2006 was practically identical to that of Victoria with average annual growth rates of 2.5 per cent and 2.3 per cent, respectively. The Victorian GDBs forecast a fall in TFP performance in 2008 and only very modest growth after that whereas JGN's TFP peaks somewhat in 2009 before resuming modest growth. No information is available to confirm whether the Victorian TFP forecasts were relatively accurate.

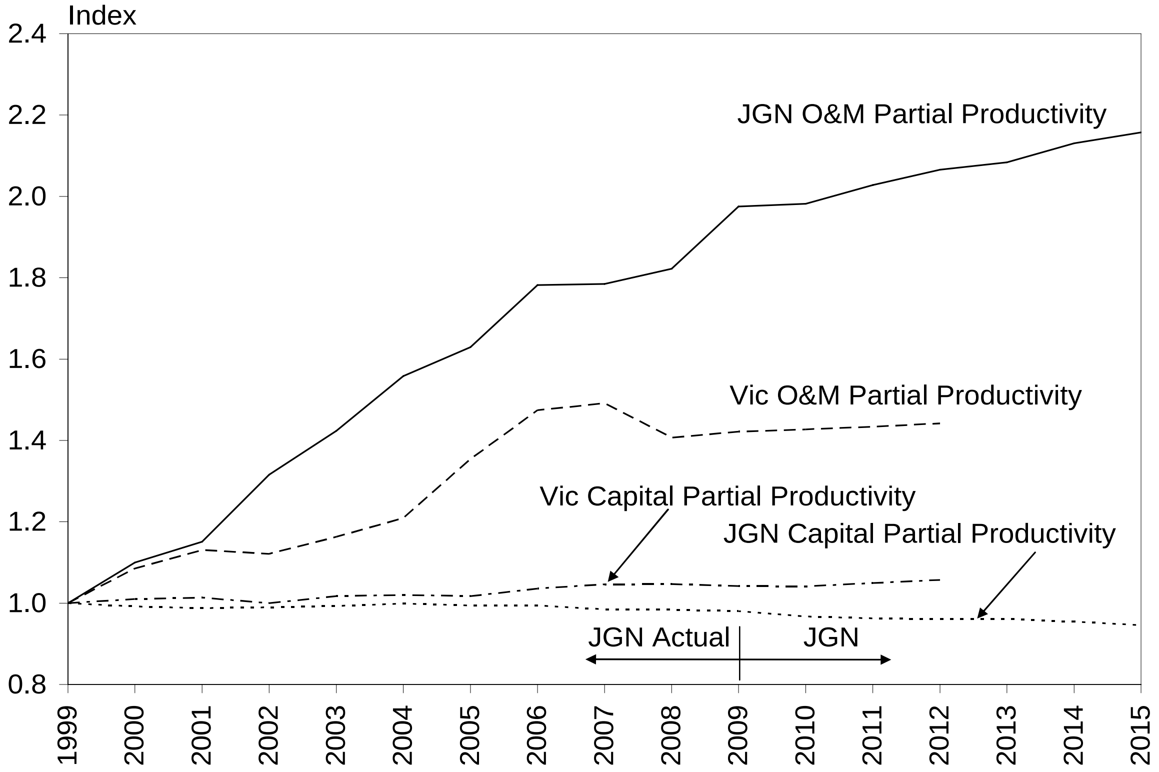
The JGN and Victorian PFP indexes are plotted in figure 4 starting from 1999. JGN's opex PFP performance has been generally much stronger than that of Victoria from 2001 to 2009 while its capital PFP performance has been slightly below that of Victoria.

Figure 3: **JGN and Victorian GDB TFP indexes, 1999–2015**



Source: Economic Insights GDB database

Figure 4: **JGN and Victorian GDB PFP indexes, 1999–2015**



Source: Economic Insights GDB database

There was a marked divergence in the opex PFP performance of JGN and the Victorian GDBs between 2001 and 2004 with JGN exhibiting very strong opex PFP growth over this period while the Victorian GDBs' opex PFP growth rate reduced over this period. The formation of Agility in mid 2000 is likely to have allowed JGN to reap significant economies over this period. The Victorian GDBs' opex PFP growth rate increased again between 2004 and 2006 to mirror JGN's ongoing opex PFP growth for the same period. Between 1999 and 2006 JGN's opex PFP grew at an average annual rate of 8.3 per cent while the aggregate Victorian GDB opex PFP growth rate was 5.5 per cent.

Between 1999 and 2006 JGN's capital PFP average annual growth rate was marginally negative while the aggregate Victorian GDB capital PFP average annual growth rate was 0.5 per cent. Among other things, this is likely to reflect JGN's need for ongoing increase in its pipeline lengths to achieve its increasing penetration rate, particularly given the more dendritic structure of the JGN system.

6 PRODUCTIVITY LEVEL RESULTS

6.1 Multilateral TFP indexes

Traditional measures of TFP such as those discussed in section 5 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 DB 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:

$$(15) \qquad \log(TFP_m/TFP_n) = \sum_i (R_{im}+R_i^*)(\log Y_{im} - \log Y_i^*)/2 - \sum_i (R_{in}+R_i^*)(\log Y_{in} - \log Y_i^*)/2 - \sum_j (S_{jm}+S_j^*)(\log X_{jm} - \log X_j^*)/2 + \sum_j (S_{jn}+S_j^*)(\log X_{jn} - \log X_j^*)/2$$

Where R_i^* (S_j^*) is the revenue (cost) share averaged over all utilities and time periods and $\log Y_i^*$ ($\log X_j^*$) is the average of the log of output *i* (input *j*). In the main application reported in the following section we have three outputs (throughput, customers and system capacity) and, hence, *i* runs from 1 to 3. 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.

The formula in (15) 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 (15) comparisons between any two observations *m* and *n* will be both base–distributor and base–year independent. Transitivity is satisfied since comparisons between the two GDBs for 1999 will be the same regardless of whether they are compared directly or via, say, one of the GDBs in 2002. An alternative interpretation of this index is that it compares each observation to a hypothetical average distributor with output vector $log\ Y_i*$, input vector $log\ X_j*$, revenue shares R_i* and cost shares S_j*.

6.2 Productivity levels comparisons

As noted in section 4, the functional coverage of JGN differs somewhat from that of the Victorian GDBs with JGN having considerably longer lengths of trunk and primary mains given the spreadout territory it serves. 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 presented here. Marketing and retail incentives, market operations expenses, meter reading, government levies and unaccounted for gas are also excluded from JGN's opex to put it on a comparable functional basis with data for the Victorian GDBs. It should be noted that because transmission inputs are excluded from the Victorian GDB data used in this section, Victorian GDB relativities differ somewhat from those reported in Lawrence (2007).

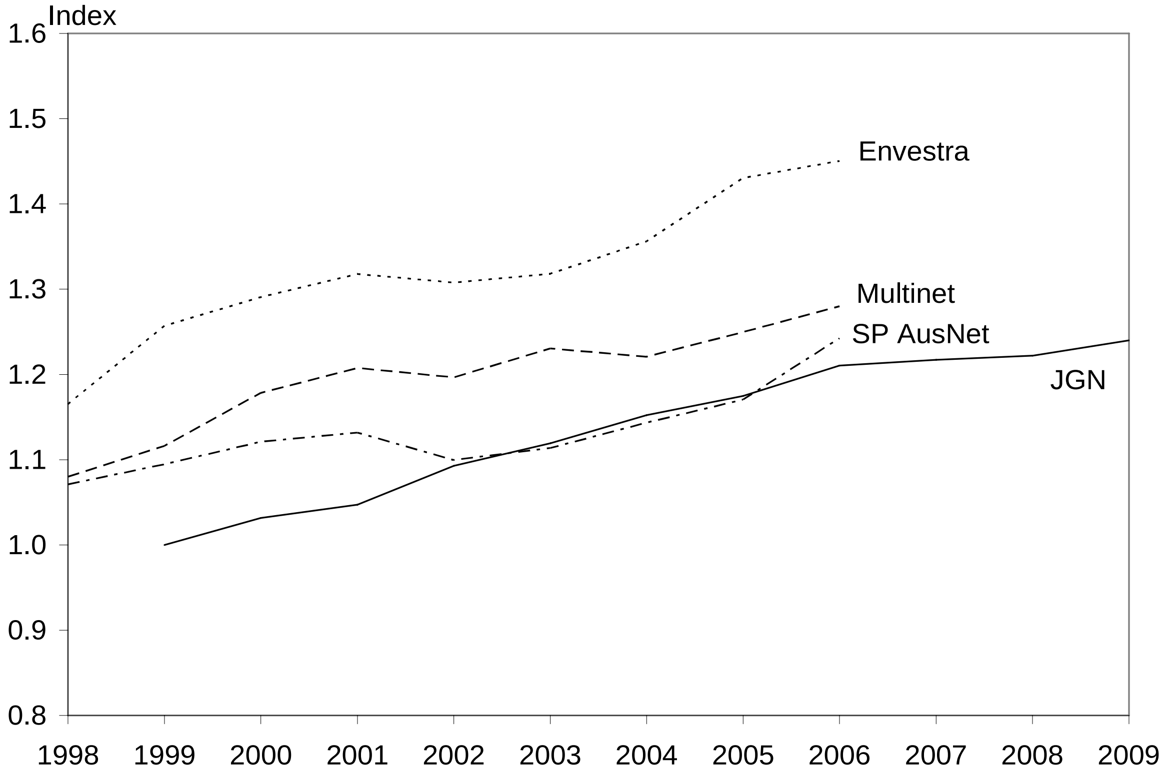
The multilateral TFP indexes are presented in table 4 and figure 5. The indexes are presented relative to JGN in 1999 having a value of one. No forecast data are used for either JGN or the Victorian GDBs. The MTFP results indicate that JGN comes very close to matching the Victorian GDBs in terms of overall productivity levels. Its TFP level is comparable to that of SP AusNet for the years 2003 to 2005. This is a somewhat surprising result given that JGN has a much less dense and less intermeshed network.

Table 4: **GDB multilateral output, input and TFP indexes, 1998–2006**

	Multilateral TFP				Multilateral Opex PFP				Multilateral Capital PFP			
	JGN	Env'a	M'net	SPA	JGN	Env'a	M'net	SPA	JGN	Env'a	M'net	SPA
1998		1.165	1.080	1.071		0.872	0.992	0.947		1.283	1.078	1.093
1999	1.000	1.257	1.116	1.095	1.000	1.048	1.076	0.993	1.000	1.294	1.081	1.097
2000	1.032	1.291	1.178	1.121	1.100	1.114	1.229	1.041	0.996	1.304	1.099	1.109
2001	1.047	1.318	1.208	1.132	1.151	1.150	1.305	1.077	0.996	1.324	1.106	1.105
2002	1.093	1.308	1.197	1.100	1.319	1.219	1.351	0.972	1.002	1.270	1.073	1.119
2003	1.119	1.318	1.231	1.114	1.437	1.180	1.445	1.044	1.012	1.301	1.091	1.094
2004	1.152	1.356	1.221	1.143	1.563	1.281	1.389	1.121	1.034	1.302	1.096	1.097
2005	1.175	1.430	1.250	1.171	1.634	1.516	1.511	1.235	1.041	1.307	1.093	1.078
2006	1.210	1.451	1.280	1.243	1.787	1.500	1.590	1.514	1.044	1.345	1.112	1.088
2007	1.217				1.790				1.046			
2008	1.222				1.828				1.048			
2009	1.240				1.981				1.048			

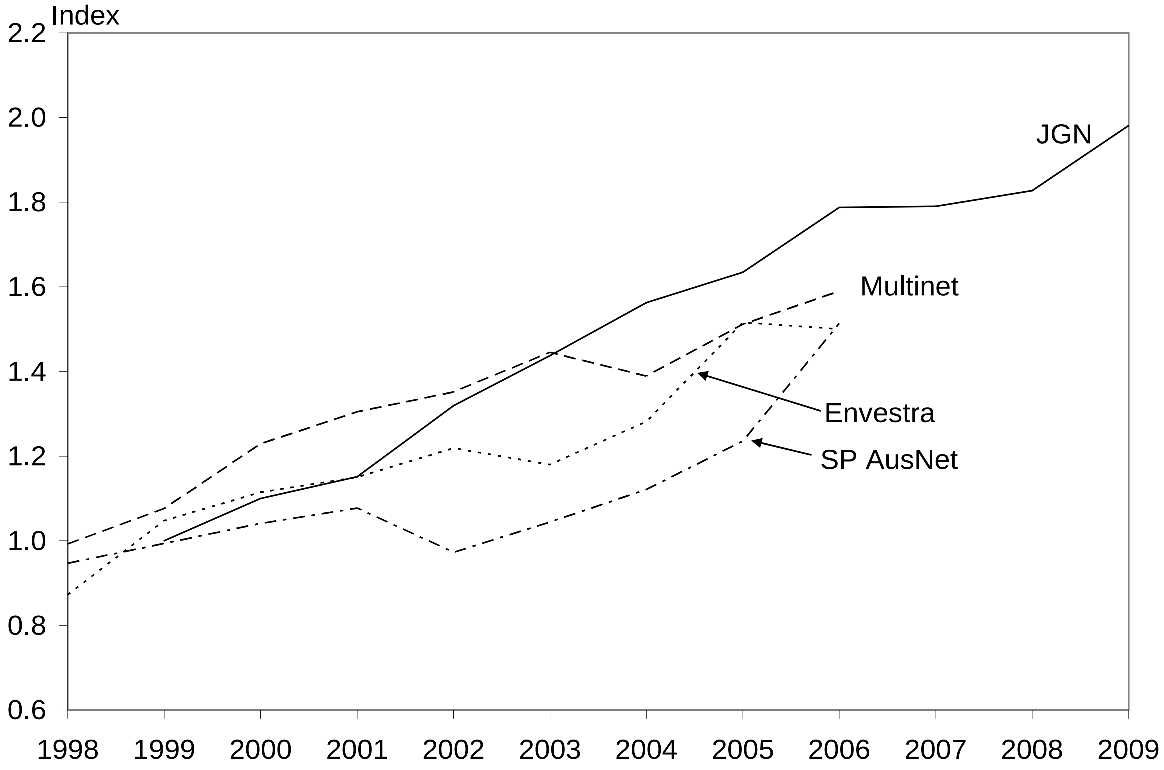
Source: Calculations using Economic Insights GDB database

Figure 5: **GDB multilateral TFP indexes, 1998–2009**



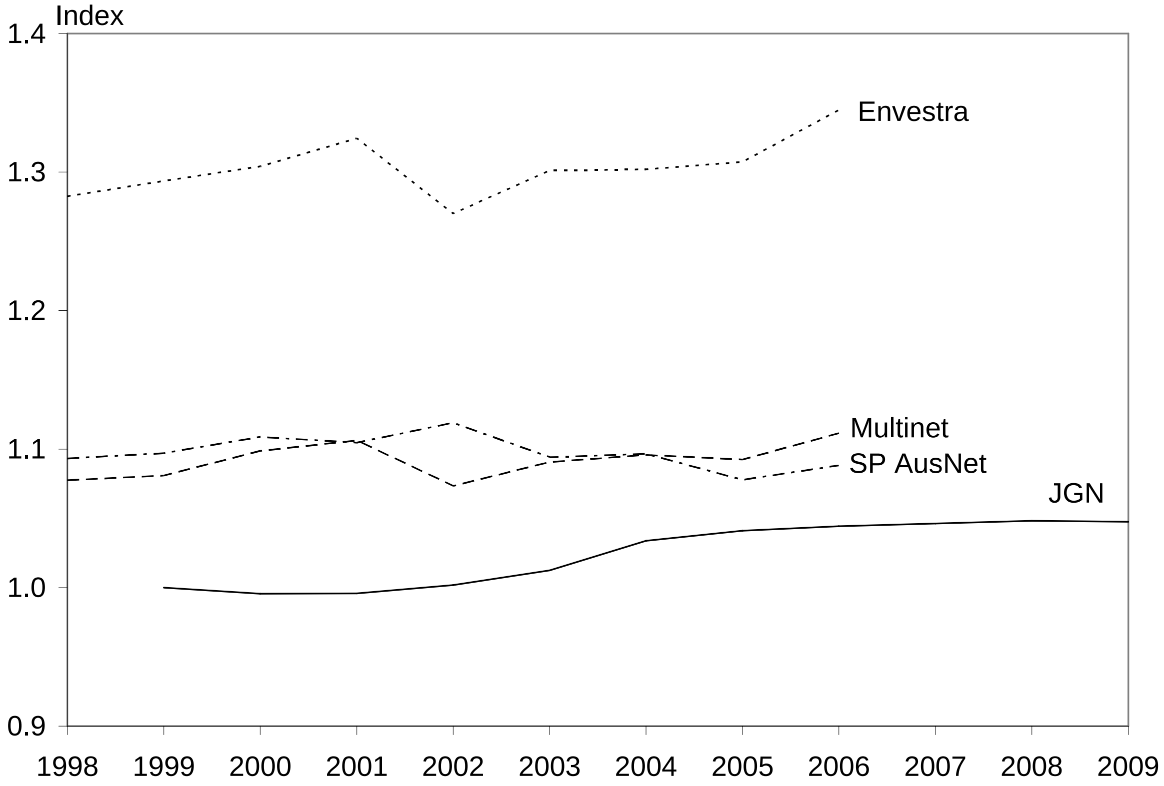
Source: Economic Insights GDB database

Figure 6: **JGN and Victorian GDB multilateral opex PFP indexes, 1998–2009**



Source: Economic Insights GDB database

Figure 7: **JGN and Victorian GDB multilateral capital PFP indexes, 1998–2009**



Source: Economic Insights GDB database

Opex and overall capital multilateral partial productivity indexes are presented in table 4 and figures 6 and 7, respectively. Of particular interest is figure 6 where JGN's opex multilateral PFP levels are shown to be higher than those of the Victorian GDBs from 2004 onwards. This results from JGN's strong opex PFP growth between 2001 and 2004 and each of the Victorian GDBs have reductions in their opex PFP levels for one year in this period (although the exact year this occurs varies across the three GDBs). In 2006 JGN's opex multilateral PFP was around 12 per cent higher than Multinet's and around 19 per cent higher than those of Envestra and SP AusNet. The ability of JGN to reap additional economies from the formation of Agility in mid 2000 may explain its superior opex PFP performance. Increasing penetration rates for JGN may also assist it in improving utilisation of opex resources. For the years 2008 to 2012 the ESC (2007) forecast average annual residential customer numbers growth of 1.9 per cent for the Victorian GDBs as a whole while the corresponding figure for JGN is 2.9 per cent.

In terms of capital multilateral PFP levels, JGN was 4 per cent below SP AusNet and 6 per cent below Multinet. Given the differences in system structures – dendritic for JGN versus intermeshed for the Victorian GDBs – which could be expected to put JGN at a significant disadvantage, JGN's capital multilateral PFP performance is relatively strong.

7 CONCLUSIONS

JGN’s changes in output and input quantities have led to a strong productivity performance over the last 11 years, driven largely by significant reductions in opex. The partial productivity of opex has grown strongly at the very high annual rate of 6.8 per cent since 1999. However, the rate of growth was somewhat lower at 4.8 per cent over the last 6 years and is forecast to decrease to a still quite strong 1.7 per cent over the next 6 years. The opex PFP growth pattern exhibits the ‘convergence effect’ we would expect, starting at high growth rates in the early stages of reform tapering off over time to a more sustainable rate reflecting the underlying rate of technical change. Annual growth in the partial productivity of capital has been slightly negative over the last 11 years at –0.2 per cent and is expected to decrease marginally to –0.4 per cent going forward.

JGN’s TFP index exhibited relatively strong growth over the past 11 years. The average annual growth rate was 1.9 per cent for the period 1999 to 2009 although this was only just over 1 per cent for the last 6 years. Going forward the annual growth rate is forecast to reduce to 0.2 per cent for the next 6 years. JGN has been able to achieve relatively strong productivity growth rates because of its increasing penetration rates and, principally, by cutting opex input use. However, caution needs to be exercised in using past productivity growth rates as a guide to likely future attainable efficiency improvements. The combination of the convergence effect and expected changes to safety and compliance requirements GDBs will face are expected to lead to a much more modest TFP performance going forward.

Despite slightly different patterns in the intervening years, JGN’s TFP growth over the period 1999 to 2006 was practically identical to that of Victoria with average annual growth rates of 2.5 per cent and 2.3 per cent, respectively. JGN’s opex PFP growth performance has been generally much stronger than that of Victoria from 2001 to 2009 while its capital PFP growth performance has been slightly below that of Victoria. The formation of Agility in mid 2000 is likely to have allowed JGN to reap significant opex economies over this period.

JGN comes very close to matching the Victorian GDBs in terms of overall productivity levels. Its TFP level is comparable to that of SP AusNet for the years 2003 to 2005. This is a somewhat surprising result given that JGN has much lower customer density, lower customer penetration and a less intermeshed network.

JGN’s opex multilateral PFP levels are higher than those of the Victorian GDBs from 2004 onwards. This results from JGN’s strong opex PFP growth between 2001 and 2004 relative to the Victorian GDBs. In 2006 JGN’s opex multilateral PFP was around 12 per cent higher than Multinet’s and around 19 per cent higher than those of Envestra and SP AusNet. In terms of capital multilateral PFP levels, JGN was 4 per cent below SP AusNet and 6 per cent below Multinet. Given the differences in system structures – dendritic for JGN versus intermeshed for the Victorian GDBs – which could be expected to put JGN at a significant disadvantage, JGN’s capital multilateral PFP performance is relatively strong.

Overall – and particularly once differences in network density and system structure are taken into account – the results of this study indicate that JGN is a relatively efficient performer compared to the three Victorian GDBs.

APPENDIX A: DERIVING OUTPUT COST SHARE WEIGHTS

This study uses the output cost share weights derived in Lawrence (2007) using a multi–output Leontief cost function. This functional form essentially assumes that GDBs use inputs in fixed proportions for each output and is given by:

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

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

The estimating equations were the M input demand equations:

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

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

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

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

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

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

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

Confidential terms of reference removed
(Appendix B)

APPENDIX C: CURRICULUM VITAE

Denis Lawrence

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For the past 20 years Dr Denis Lawrence has played a leading role in the regulation, benchmarking and performance measurement of infrastructure enterprises. He has advised Australian and overseas regulators and utilities on a wide range of quantitative and strategic issues in the energy, telecommunications, post and transport sectors.

Denis' consulting projects include advising the New Zealand Commerce Commission on the implementation of a leading–edge productivity based regulatory regime for electricity distribution; advising Australian electricity and gas distribution businesses on productivity measurement issues and their regulatory implications; advising the Commerce Commission on gas network benchmarking and regulation; reviewing the work of Australian regulators for utilities; advising the Australian Competition and Consumer Commission on incentive regulation in electricity supply; and, advising the Queensland Competition Authority on service quality incentives.

Denis has also advised electricity regulators and utilities in Canada, Saudi Arabia and Hong Kong.

Denis joined Economic Insights in 2008. Prior to that Denis was with Meyrick and Associates and Tasman Economics and held senior executive positions in the Australian Bureau of Industry Economics and the Australian Industry Commission.

Denis holds a PhD in Economics from the University of British Columbia, Canada, and a BEc (Hons) from the Australian National University.

Recent Projects

- Advice to the Australian Energy Market Commission on the data and other requirements for the implementation of productivity–based regulation
- Development and implementation of productivity–based regulation framework taking accounts of sunk costs and financial capital maintenance for the New Zealand Commerce Commission
- Advice to the Northern Territory Utilities Commission on the setting of key price control parameters for electricity distribution
- Advice to coalition of large distribution businesses on the development and implementation of the Ontario Energy Board's third generation incentive regulation regime
- Total factor productivity modelling and benchmarking of gas distribution businesses in Victoria and advice on implications for opex roll forward parameters
- Construction of detailed total factor productivity models of Australia Post's overall operations and its reserved services
- Advising the NZ Commerce Commission on the regulation of key gas distribution companies using the building blocks method
- Critique of total factor productivity modelling of electricity distribution in Victoria undertaken by the Essential Services Commission and assessment of regulatory implications
- Econometric modelling of the operating and maintenance expenditure efficiency of electricity distributors taking operating environment differences into account
- Development of service quality incentive schemes for electricity distribution businesses.

APPENDIX D: DECLARATION

I, Denis Anthony Lawrence, Director 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.

D. A. Lawrence

Denis Anthony Lawrence

18 August 2009

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