Energy Network Total Factor Productivity Sensitivity Analysis

Report prepared for
Australian Energy Market Commission

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EXECUTIVE SUMMARY

The Australian Energy Market Commission (AEMC) has initiated a review into the possible uses of total factor productivity (TFP) methodologies for the regulation of prices and revenues in national energy networks. An issue that has arisen is the degree of prescription that should be incorporated in any resulting National Electricity Law rule change.

To help inform its decision on this issue, the AEMC has requested Economic Insights to conduct a sensitivity analysis of TFP estimates to variations in the methodology used in their construction to determine whether this is a material issue. The focus of the report is on examining sensitivity to different output and input specifications, lengths of the time period used, index and weighting methods used and the method used to calculate average growth rates. The purpose of the report is not to determine the correct specification for TFP studies.

Productivity is a measure of the physical output produced from the use of a given quantity of inputs. Growth rates for individual outputs and inputs are weighted together using output cost or revenue 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.

To operationalise TFP measurement, a large number of decisions have to be made regarding how to specify outputs and inputs, how to weight outputs and inputs together into indexes of total output and total input, what indexing method to use, over what time period to calculate TFP growth rates and what method to use to calculate those growth rates.

Whether TFP results are sensitive to differences in output and input specification will depend on whether the alternative outputs and inputs are growing at similar or different rates. If all possible outputs are growing at a similar rate then it will make little difference to the results in practice which ones are chosen and how they are weighted. If they are growing at different rates then the results could be quite sensitive to the specification used. The same applies on the input side.

To assess the magnitude of likely differences in the growth rates of different outputs and different inputs, we use aggregate Victorian state level data for both electricity and gas distribution. The electricity data covers the years 1995 to 2007 while the gas data covers the years 1998 to 2007.

Table A: **Victorian electricity distribution output component growth rates (per cent pa)**

Year	*Customers numbers*	*On-peak GWh*	*Off-peak GWh*	*Peak demand*	*MVAkms*	*KVA*kms*
1995-2007	1.71%	2.85%	3.03%	3.07%	1.77%	4.02%
2002-2007	1.61%	2.53%	1.77%	3.25%	1.58%	4.23%

Source: PEG (2008a) and Lawrence (2005)

Starting with electricity distribution, we examine the growth rates of six output components in table A over two time periods: 1995 to 2007 and 2002 to 2007. The output components are customer numbers, on–peak and off–peak throughput, non–coincident peak demand, MVAkms and KVA*kms. The last two components are alternative measures of overall system capacity – MVAkms measures only line capacity while KVA*kms incorporates both line and transformer capacity.

There is a wide range in the growth rates of the individual output components over the period 1995 to 2007. Customer numbers grow the slowest over the period with a (logarithmic) average annual growth rate of 1.7 per cent. System capacity measured in MVAkms grows the next most slowly at 1.8 per cent. On–peak throughput, off–peak throughput and peak demand all grow by around 3 per cent and the alternative system capacity measure, KVA*kms, grows the fastest at around 4 per cent. Clearly, TFP measures formed from output indexes which place a higher weight on throughput and peak demand will reflect higher growth rates than those which place a higher weight on customer numbers and the line–based system capacity measure.

In most cases growth rates are somewhat lower for the more recent period 2002 to 2007. This is particularly the case for off–peak throughput where the growth rate almost halves. The exceptions are the growth rates for peak demand and the alternative system capacity measure, KVA*kms. This reflects the growing penetration of domestic airconditioning in the former case and the more rapid growth of transformer capacity in recent years in the latter case.

Examination of the year by year quantities of the six output components indicates that the throughput and peak demand outputs have been considerably more volatile than either customer numbers or the system capacity outputs. Consequently, TFP indexes based on output indexes placing a high weight on throughput and peak demand will correspondingly show a high degree of volatility compared to those placing less weight on these components.

Table B: **Victorian electricity distribution output quantity index growth rates (% pa)**

Year	*GWh*	*GWh & Customers – Cost weights*	*GWh & Customers – Revenue weights*	*PEG: Cust, On-peak & off-peak GWh, Peak demand – Revenue weights*	*Lawrence: GWh, Cust, MVAkms – Cost weights*	*Lawrence: GWh, Cust, KVA*kms – Cost weights*
1995-2007	2.91%	2.16%	2.47%	2.73%	2.00%	2.71%
2002-2007	2.27%	1.86%	2.03%	2.52%	1.75%	2.60%

Source: Economic Insights estimates

In table B we present 6 alternative output indexes based on combinations of the output components in table A that have been used in earlier TFP studies. It can be seen that the average annual growth rate of the output index is relatively sensitive to its specification with previously used specifications providing estimates ranging from 2.0 per cent to 2.9 per cent.

The first column reflects the throughput measure of output used in early electricity industry TFP studies (eg Lawrence, Swan and Zeitsch 1991). It shows the highest growth rate over the whole period of 2.9 per cent. The second output index combines throughput and customer numbers using the output cost share weights used by PEG (2008c) of 37 per cent to throughput and 63 per cent to customer numbers. It shows a growth rate of 2.2 per cent. The third output index also includes only throughput and customer numbers but uses revenue weights consistent with those used in PEG (2004) of 63 per cent to throughput and 37 per cent to customer numbers. This has the effect of increasing the output index's growth rate to 2.5 per cent as more weight is now placed on the higher growing output.

The fourth output index presented in table B is that used in PEG (2004, 2008a). This combines customer numbers, on–peak throughput, off–peak throughput and non–coincident peak demand using revenue shares of 15 per cent, 59 per cent, 4 per cent and 22 per cent, respectively. By placing 85 per cent of the weight on the fastest growing output components, this index exhibits the highest annual growth rate over the whole period of over 2.7 per cent. It is also correspondingly relatively volatile given the weight placed on volatile components.

The fifth output index presented in table B uses the specification of Lawrence (2003, 2005) which combines throughput, customer numbers and MVAkms system capacity with output cost share weights of 22 per cent, 46 per cent and 32 per cent, respectively. Because of the weight placed on the slower growing output components of customer numbers and MVAkms, this index shows the slowest annual growth over the whole period of 2 per cent. It is correspondingly less volatile than the other output indexes.

The last output index reported in table B use the Lawrence (2003, 2005) weights but uses an alternative measures of system capacity. It uses the line and transformer capacity–based measure of KVA*kms which produces an annual output index growth rate of 2.7 per cent.

Most network TFP studies have included two broad input categories: operations and maintenance expenditure (opex) and capital. There are a number of different approaches to measuring the quantity of capital inputs. It can be measured either directly in quantity terms (eg using line length measures) or indirectly using the constant price depreciated asset value.

Table C: **Victorian electricity distribution input quantity index growth rates (% pa)**

Year	*Opex*	*Depr Asset Value*	*Overhead MVAkms*	*U/ground MVAkms*	*Transform . MVA*	*Lawrence capital*	*PEG Inputs*	*Lawrence Inputs*
1995-2007	-2.48%	1.66%	1.73%	2.57%	2.68%	2.30%	0.57%	1.04%
2002-2007	1.06%	1.21%	1.51%	2.85%	3.01%	2.41%	1.15%	2.04%

Source: PEG (2008a), Lawrence (2005) and Economic Insights estimates

From table C the opex quantity index average annual growth rate was –2.5 per cent over the whole period and 1.1 per cent since 2002. All capital quantity measures showed substantially higher growth rates than did opex. Clearly, any approach to weighting which places relatively more weight on opex will lead to a slower growing input index (and correspondingly higher growing TFP index) than one which places relatively more weight on capital.

Table C shows that the constant price depreciated asset value capital quantity proxy increases less than the three physical quantity components with an average annual growth rate of just under 1.7 per cent. Overhead lines MVAkms increases only slightly more quickly than the constant price depreciated asset value with an average annual growth rate of just over 1.7 per cent. But underground cables MVAkms and transformer capacity both increase substantially faster with average annual growth rates of 2.6 and 2.7 per cent, respectively. Combining the three physical measures into a capital quantity index using the asset value shares from Lawrence (2005) leads to a capital quantity index average annual growth rate of 2.3 per cent.

We next combine the alternative capital input quantity proxies with the common opex quantity index. For the constant price depreciated asset value capital input approach used by PEG (2008a) this produces an average annual input quantity index growth rate of 0.6 per cent for the whole period. For the physical quantity–based capital input approach used by

Lawrence (2003, 2005) this produces an average annual input quantity index growth rate of just over 1 per cent for the whole period.

The difference between the two capital approaches is more pronounced for the period since 2002 with average annual growth input rates of 1.2 per cent for the asset value–based method and over 2 per cent for the physical quantity–based method. This reflects the higher growth of undergrounding and transformer capacity in recent years.

As was the case with the output specification, the average annual growth rate of the input index is also relatively sensitive to its specification with estimates ranging from 0.6 per cent to over 1 per cent over the whole period and a larger difference for the period since 2002.

Table D: **Alternative Victorian energy distribution TFP index growth rates**

Period	*PEG TFP*	*Lawrence TFP*	*Hybrid TFP1 – PEG Output, Lawrence Input*	*Hybrid TFP2 – Lawrence Output, PEG Input*
Electricity distribution				
1995-2007	2.16%	0.96%	1.69%	1.42%
2002-2007	1.37%	-0.29%	0.48%	0.60%
Gas distribution				
1998-2007	2.80%	2.15%	1.45%	3.49%
2002-2007	3.79%	2.70%	2.01%	4.48%

Source: PEG (2008a,b), Lawrence (2005, 2007a) and Economic Insights estimates

Depending on which TFP specification we choose for electricity distribution, we observe TFP growth rates from table D ranging between 1 per cent and 2.2 per cent over the period since 1995 – that is, the upper end of the range is more than double that of the lower end.

In the case of gas distribution, depending on which TFP specification we choose, we observe TFP growth rates ranging between 1.5 per cent and 3.5 per cent over the period since 1998 – that is, the upper end of the range is again more than double that of the lower end. For the more recent period since 2002, the difference is even greater with a growth rate difference of 2.5 percentage points.

Apart from the composition of outputs and inputs and the methods used to weight them together, different TFP studies have used different indexing methods and different ways of calculating the TFP growth rate. The Fisher index technique is increasingly favoured by statistical agencies because it satisfies all the desirable axiomatic properties for price and productivity indexes. Some analysts still use the older Törnqvist index method. While the difference in results obtained from using the Fisher and Törnqvist index methods is not significant in this case, we show that the difference between using endpoint–based versus regression–based methods for calculating growth rates can be substantial. This is particularly the case for output indexes where more volatile components such as throughput and peak demand receive a high weight.

Based on our findings for electricity and gas distribution in Victoria, we conclude that TFP analyses of Australian energy distribution systems will be relatively sensitive to the specifications chosen and the method used to calculate growth rates. This makes it important to specify the correct methodology in any implementation of TFP–based regulation.

1 INTRODUCTION

The Australian Energy Market Commission (AEMC) has initiated a review into the possible uses of a total factor productivity (TFP) methodology for the regulation of prices and revenues in the national energy networks.

An issue that has arisen in this review is the degree of prescription that should be incorporated in any resulting National Electricity Law rule change regarding both the methodology for deriving TFP estimates and the design of the TFP–based methodology for setting revenue and prices. AEMC (2008, pp.47–8) notes:

> ‘Key matters for decision would be how to specify the methodology in the Rules and how to determine the balance between what specification would be needed in the Rules and what issues may be explained in supporting guidelines and other documents made by the regulator. The trade off between prescription and certainty for market participants versus operational flexibility and adaptability to individual circumstances would need to be managed. …
>
> ‘Although this is a matter of detailed regulatory design, there seems to be significant reasons for specifying clearly in the Rules the essential features of any TFP based regulatory methodology. The reasons include the fact that a TFP based methodology would affect the commercial returns of the businesses and also because TFP has yet to be applied in Australia. Also, one of the findings of the Brattle [2008] Report, is that the lack of prescription in the legislative framework can lead to disagreements on how TFP is applied and variations in the TFP approach between regulatory periods.’

To help inform its decision on this issue, the AEMC has requested Economic Insights Pty Ltd (Economic Insights) to conduct a sensitivity analysis of TFP estimates to variations in the methodology used in their construction to determine whether this is a material issue.

The purpose of the exercise is to determine the possible range of TFP estimates resulting from different specifications and hence the likely need for more or less direction in the Rules. If results are quite sensitive to the specification adopted then it may be desirable to have a higher degree of direction regarding allowable specifications in the Rules to promote certainty among the regulated businesses. If results are relatively insensitive to specifications adopted then leaving a higher degree of discretion to subsequent Australian Energy Regulator (AER) Guidelines processes may not have an adverse effect on the level of uncertainty businesses face.

The major electricity distribution TFP studies undertaken in Australia have been a series of studies by Lawrence (2000, 2005) and Pacific Economics Group (PEG 2004, 2008a and ESC and PEG 2006). A report by Lawrence (2003) also formed the basis of productivity–based electricity distribution regulation in New Zealand. This study was updated in Lawrence (2007b). The major study of gas distribution TFP in Australia is that of Lawrence (2007a) while a less detailed study using a different methodology was undertaken by PEG (2008b).

The major differences between the Lawrence and PEG TFP reports for both electricity and gas distribution relate to the way outputs are measured and whether system capacity is included, the way output quantities are weighted together to form a total output index and the way capital input quantities are measured.

Whether TFP results are sensitive to differences in specification will depend on whether the alternative outputs and inputs are growing at similar or different rates. If all possible outputs are growing at a similar rate then it will make little difference to the results which ones are chosen and how they are weighted. If they are growing at different rates then the results could be quite sensitive to the specification used. The same applies on the input side: if deflated depreciated asset values are declining while physical quantity measures are increasing or remaining steady then using deflated depreciated asset values to proxy the capital input quantity will produce higher TFP growth rates than using physical quantity proxies.

To assess the magnitude of these effects we need to use realistic Australian data. Synthetic databases can be built which will indicate either high sensitivity or negligible sensitivity depending on the degree of difference in output and input growth rates built into the data. Only by using actual (or close to actual) Australian data will we get a feel for the answer to this question in the current context. The state with the most readily compilable data is Victoria. In this report we use aggregate Victorian state level data for both electricity and gas distribution. Where possible we use data presented in PEG (2008a,b). With the agreement of the relevant electricity and gas distribution businesses, these data are supplemented by data on physical system characteristics compiled by Lawrence (2005, 2007a).

The following section of the report briefly reviews how TFP estimates are constructed and some of the major methodological choices which have to be made. Sections 3 and 4 report the results of sensitivity analyses for electricity and gas distribution, respectively. The output sensitivity analyses cover:

- differences between (a) throughput only, (b) throughput and customer number and (c) throughput, customer number and system capacity specifications;
- differences between alternative system capacity specifications (eg adjusted line length–based versus peak demand–based); and,
- differences between revenue weighting versus output cost share weighting.

The input sensitivity analyses cover the difference between using deflated depreciated asset value capital quantity proxies and physical measure capital quantity proxies. Finally, section 5 of the report draws conclusions.

2 MEASURING 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 and, hence the prices charged to energy consumers, through productivity improvements. 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: total factor productivity and partial factor productivity. TFP measures total output quantity relative to the quantity of all inputs used. Output can be increased by using more inputs, making better use of the current level of inputs and by exploiting economies of scale. The TFP index measures the impact of all the factors effecting growth in output other than changes in input levels. Partial factor productivity (PFP) measures one or more outputs relative to one particular input (eg labour productivity is the ratio of output to labour input).

To operationalise this concept we use index number theory to combine changes in diverse outputs and inputs into measures of change in total outputs and total inputs. Growth rates for individual outputs and inputs are weighted together using output cost or revenue 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. Different index number methods take this weighted average change in different ways.

Mathematically, growth in TFP is given by:

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

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.

Diewert (1993) recommended that the Fisher ideal index be used for TFP work as it is the only index that satisfies all desirable axiomatic properties for productivity measurement. 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.

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 index 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 output cost shares we require additional information on how cost drivers link to output components.

2.2 Measuring network outputs

Early energy supply productivity studies simply measured output by system throughput. However, this simple measure ignores important aspects of what energy distribution businesses (DBs) really do. Like all network infrastructure industries, a major part of DBs' output is providing the capacity to supply the product. In this sense, there is an analogy between an energy distribution system and a road network. The DB 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 DB'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 DB provides are directly related to its number of connections ('local access roads') as well as call centre operations responding to queries, connection requests, etc.

To capture these multiple dimensions of electricity DB output, Lawrence (2003) 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 adjusted kilometre of line) directly into the output measure. System line capacity was measured by MVA–kilometres, an engineering measure which takes account of line length, voltage and the effective capacity of an individual line based on the number, material and size of conductors used, the allowable temperature rise as well as limits through stability or voltage drop. A broadly analogous measure for gas distribution output was developed in Lawrence (2007b).

Pacific Economics Group (2004, 2008a) 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. While this measure captures the peak end–point delivery capacity required, it does not incorporate any measure of line length and so may be less appropriate for comparing DBs of varying customer densities.

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. How such an output should be weighted in a TFP study has also proven problematic.

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.

Different analysts have used different weighting approaches on different occasions. For instance, PEG (2004, 2008a) has used revenue shares to weight outputs for electricity distribution but PEG (2008c) used output cost shares. While Lawrence (2003, 2005, 2007a,b) has consistently used output cost shares in energy distribution applications, Lawrence (2007c) has used revenue weights for postal network productivity as no information on output cost shares was available.

2.3 Measuring network inputs

Most network TFP studies have included two broad input categories: operations and maintenance expenditure (opex) and capital. Some North American studies have separated opex into labour and materials and services. However, with the increase in contracting out, separate measures of labour input have become increasingly difficult to obtain and potentially unrepresentative.

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 depreciated 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, a rate reflecting the opportunity cost of capital and the rate of capital gains to the depreciated asset value 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 poles and wires or pipelines. A potential problem with basing capital quantities on constant price depreciated asset value measures is that they usually incorporate some variant of either the declining balance or straight line approaches to measuring depreciation. DB 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 proxy the quantity of capital input by the physical quantity of the principal assets. This approach is also invariant to different depreciation profiles that may have been used by different DBs. 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 ‘user cost’ reflecting depreciation, the opportunity cost of capital and capital gains 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 by most recent Australian DB TFP studies. Given that the implicit rates of return in the Victorian DB database could be expected to be all of broadly similar magnitude given the history of building block regulation, in this study we use the indirect approach for simplicity.

3 ELECTRICITY DISTRIBUTION TFP SENSITIVITY ANALYSIS

3.1 Data sources

The primary electricity distribution data source for this report is Victorian state level data for the years 1995–2007 presented in PEG (2008a). We source data on revenues, customer numbers, on–peak and off–peak throughput, non–coincident peak demand, opex and depreciated asset values from this report. However, PEG (2008a) contains no information on system physical characteristics. Confidential data on line length by voltage class and on transformer capacity was sourced from Lawrence (2005), with the agreement of the relevant EDBs, and aggregated to the Victorian state level. Annual data for the years 1999–2003 were available from this source. Data for 2004–2007 were derived by extrapolating the 2003 data using the average growth rate of the years 2001–2003 and data for the years 1995–1998 were derived by extrapolating data for 1999 using the average growth rate of the years 2000–2002.

3.2 Output sensitivity analysis

In this section we examine five individual output components that are used in PEG (2008a) and Lawrence (2003, 2005) plus an alternative measure of system capacity. The output components are customer numbers, on–peak and off–peak throughput, non–coincident peak demand, MVAkms and KVA*kms. The first four of these are used in PEG (2008a) to form an output index using revenue weights. Customer numbers, total throughput and MVAkms are used in Lawrence (2003, 2005) to form an output index using output cost share weights.

As noted earlier, MVAkms is a measure of system capacity which takes account of line length, voltage and the effective capacity of an individual line based on the number, material and size of conductors used, the allowable temperature rise as well as limits through stability or voltage drop. However, overall system capacity is influenced by transformer capacity as well as line capacity. A limitation of the MVAkms measure is that it only takes account of the line dimension of system capacity and excludes the transformers component. In recent years transformer capacity has tended to grow faster than line lengths in many Australasian electricity distribution systems (see section 3.3). An alternative engineering system capacity measure that takes account of both line lengths and transformer capacity is KVA*kms, the product of total transformer capacity in KVA and total line circuit length in kilometres.

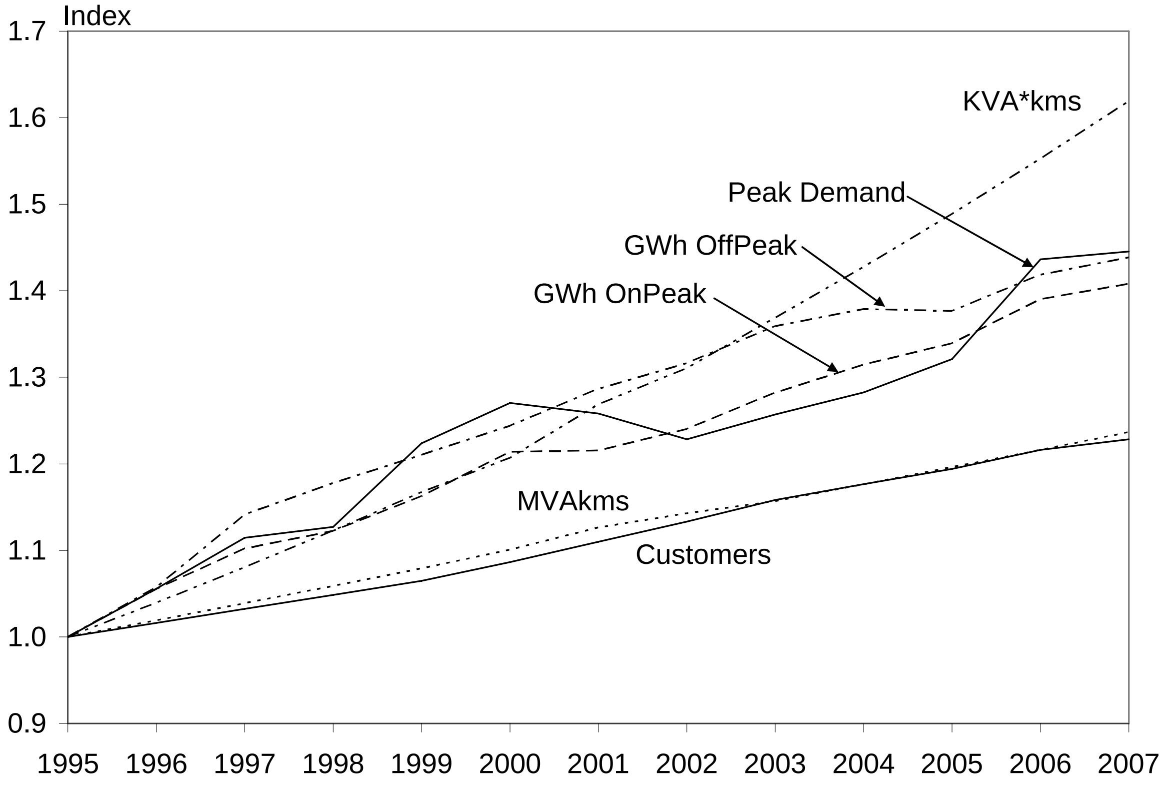
In table 1 and figure 1 we list and plot the six individual output components in index form (ie each series is normalised to equal one in 1995). From table 1 we see that there is a wide range in the growth rates of the individual output components over the period 1995 to 2007. Customer numbers grow the slowest over the period with a (logarithmic) average annual growth rate of 1.7 per cent. System capacity measured in MVAkms grows the next most slowly at 1.8 per cent. On–peak throughput, off–peak throughput and peak demand all grow by around 3 per cent and the alternative system capacity measure, KVA*kms, grows the fastest at around 4 per cent. Clearly, TFP measures formed from output indexes which place a higher weight on throughput and peak demand will reflect higher growth rates than those which place a higher weight on customer numbers and the line–based system capacity measure.

Table 1: **Victorian electricity distribution output components, 1995–2007 (indexes)**

Year	*Customers numbers*	*On-peak GWh*	*Off-peak GWh*	*Peak demand*	*MVAkms*	*KVA*kms*
1995	1.000	1.000	1.000	1.000	1.000	1.000
1996	1.016	1.055	1.057	1.056	1.019	1.039
1997	1.032	1.102	1.142	1.115	1.039	1.080
1998	1.049	1.123	1.178	1.127	1.059	1.123
1999	1.065	1.163	1.210	1.224	1.079	1.167
2000	1.086	1.214	1.244	1.270	1.101	1.207
2001	1.110	1.216	1.287	1.258	1.126	1.269
2002	1.133	1.240	1.316	1.228	1.143	1.310
2003	1.158	1.282	1.359	1.257	1.157	1.369
2004	1.177	1.315	1.379	1.283	1.176	1.428
2005	1.194	1.339	1.377	1.321	1.196	1.489
2006	1.216	1.390	1.419	1.436	1.216	1.553
2007	1.228	1.408	1.439	1.446	1.237	1.619
Growth Rate						
1995-2007	1.71%	2.85%	3.03%	3.07%	1.77%	4.02%
2002-2007	1.61%	2.53%	1.77%	3.25%	1.58%	4.23%

Source: PEG (2008a) and Lawrence (2005)

Figure 1: **Victorian electricity distribution output components, 1995–2007 (indexes)**



Source: PEG (2008a) and Lawrence (2005)

The other thing we observe from table 1 is that, in most cases, growth rates are somewhat lower for the more recent period 2002 to 2007. This is particularly the case for off–peak throughput. The exceptions are the growth rates for peak demand and the alternative system capacity measure, KVA*kms. This most likely reflects the growing penetration of domestic airconditioning in the former case and reflects the more rapid growth of transformer capacity in recent years in the latter case.

An important observation from figure 1 is that the throughput and peak demand outputs have been considerably more volatile than either customer numbers or the system capacity outputs. Consequently, TFP indexes based on output indexes placing a high weight on throughput and peak demand will correspondingly show a high degree of volatility compared to those placing less weight on these components.

Table 2: **Victorian electricity distribution output quantity indexes, 1995–2007**

Year	*GWh*	*GWh & Customers – Cost weights*	*GWh & Customers – Revenue weights*	*PEG: Cust, On-peak & off-peak GWh, Peak demand – Revenue weights*	*Lawrence: GWh, Cust, MVAkms – Cost weights*	*Lawrence: GWh, Cust, Peak demand – Cost weights*	*Lawrence: GWh, Cust, KVA*kms – Cost weights*
1995	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1996	1.056	1.031	1.041	1.049	1.026	1.037	1.032
1997	1.115	1.062	1.084	1.095	1.052	1.076	1.065
1998	1.141	1.082	1.106	1.114	1.072	1.093	1.092
1999	1.179	1.106	1.135	1.162	1.094	1.138	1.121
2000	1.224	1.135	1.171	1.207	1.120	1.173	1.154
2001	1.239	1.156	1.190	1.210	1.143	1.184	1.187
2002	1.266	1.181	1.215	1.224	1.164	1.192	1.217
2003	1.308	1.212	1.251	1.260	1.189	1.221	1.255
2004	1.336	1.233	1.275	1.289	1.210	1.244	1.287
2005	1.352	1.250	1.291	1.314	1.228	1.268	1.317
2006	1.400	1.281	1.329	1.373	1.254	1.323	1.356
2007	1.418	1.296	1.345	1.388	1.271	1.336	1.385
Growth Rate							
1995-2007	2.91%	2.16%	2.47%	2.73%	2.00%	2.41%	2.71%
2002-2007	2.27%	1.86%	2.03%	2.52%	1.75%	2.28%	2.60%

Source: Economic Insights estimates

In table 2 we present 7 alternative output indexes based on combinations of the output components in table 1 that have been used in earlier TFP studies. The first column reflects the throughput measure of output used in early electricity industry TFP studies (eg Lawrence, Swan and Zeitsch 1991). It shows the highest growth rate over the whole period of 2.9 per cent. The second output index combines throughput and customer numbers using the output cost share weights used by PEG (2008c) of 37 per cent to throughput and 63 per cent to customer numbers. It shows a growth rate of 2.2 per cent. This approach has been commonly used in North American TFP studies. The third output index also includes only throughput and customer numbers but uses revenue weights consistent with those used in PEG (2004) of 63 per cent to throughput and 37 per cent to customer numbers. This has the effect of increasing the output index's growth rate to 2.5 per cent as more weight is now placed on the higher growing output.

The fourth output index presented in table 2 is that used in PEG (2004, 2008a)[1]. This combines customer numbers, on–peak throughput, off–peak throughput and non–coincident peak demand using revenue shares of 15 per cent, 59 per cent, 4 per cent and 22 per cent, respectively. By placing 85 per cent of the weight on the fastest growing output components, this index exhibits the highest annual growth rate over the whole period of over 2.7 per cent. It is also correspondingly relatively volatile given the weight placed on volatile components.

The fifth output index presented in table 2 uses the specification of Lawrence (2003, 2005) which combines throughput, customer numbers and MVAkms system capacity with output cost share weights of 22 per cent, 46 per cent and 32 per cent, respectively. Because of the weight placed on the slower growing output components of customer numbers and MVAkms, this index shows the slowest annual growth over the whole period of 2 per cent. It is correspondingly less volatile than the other output indexes.

The last two output indexes reported in table 2 use the Lawrence (2003, 2005) framework and weights but use alternative measures of system capacity. The first uses non–coincident peak demand as the system capacity measure which produces an output index annual growth rate of 2.4 per cent. The second uses the line and transformer capacity–based measure of KVA*kms which produces an annual output index growth rate of 2.7 per cent (similar to that obtained using the PEG (2008a) specification).

It can be seen that the average annual growth rate of the output index is relatively sensitive to its specification with previously used specifications providing estimates ranging from 2.0 per cent to 2.9 per cent.

3.3 Input sensitivity analysis

In this section we examine five individual input components that are used in PEG (2008a) and Lawrence (2003, 2005). The input components are operating and maintenance expenses (opex), depreciated asset values, overhead line MVAkms, underground cable MVAkms and transformer capacity in MVA. The first two of these are used in PEG (2008a) to form an input index. Opex and the three physical capital measures are used in Lawrence (2003, 2005) to form an input index. In this exercise, for convenience we use cost weights based on opex and a residual overall cost of capital based on the difference between revenue and opex.

As noted earlier, the decision of whether to use the constant price depreciated asset value or physical quantity measures to proxy the quantity of annual capital input to the production process involves assumptions about the physical (as opposed to financial) depreciation profile of network assets. Using the constant price depreciated asset value proxy implicitly assumes that the physical depreciation profile of network assets is either geometric or straight–line in nature (depending on which method was used to form the asset value). Using a physical measure proxy assumes that network assets are better represented by a one–hoss–

[1] The index reported here differs slightly from that in PEG (2008a) due to the use of the Fisher index instead of the Törnqvist index and the use of constant revenue shares derived from PEG (2004).

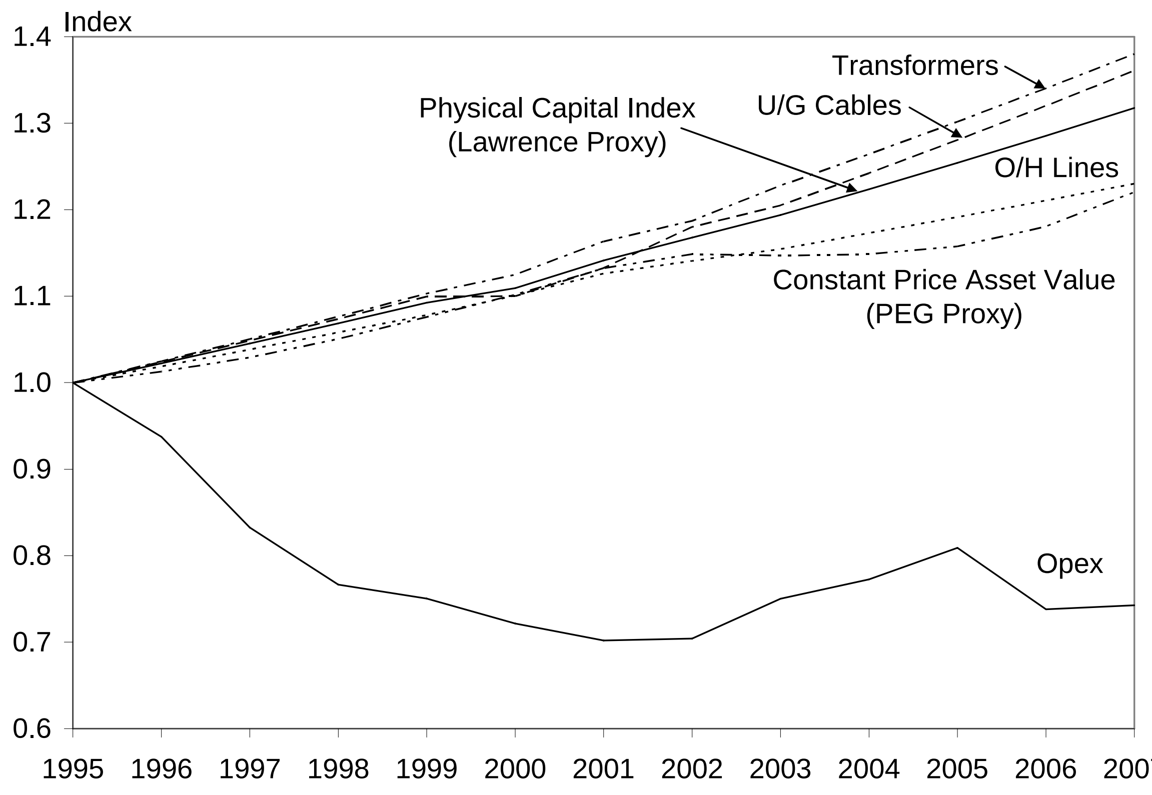
shay physical depreciation profile where assets exhibit negligible physical depreciation until the end of their lives.

Table 3: **Alternative Victorian electricity distribution input quantity indexes, 1995–2007**

Year	*Opex*	*Depr Asset Value*	*Overhead MVAkms*	*U/ground MVAkms*	*Transform . MVA*	*Lawrence capital*	*PEG Inputs*	*Lawrence Inputs*
1995	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1996	0.937	1.013	1.019	1.024	1.025	1.022	0.989	0.995
1997	0.833	1.029	1.038	1.049	1.050	1.045	0.968	0.978
1998	0.766	1.051	1.058	1.074	1.076	1.069	0.963	0.975
1999	0.750	1.076	1.078	1.100	1.103	1.093	0.976	0.987
2000	0.721	1.102	1.101	1.100	1.125	1.109	0.985	0.989
2001	0.702	1.132	1.126	1.133	1.163	1.141	1.000	1.005
2002	0.704	1.149	1.141	1.180	1.187	1.168	1.011	1.023
2003	0.750	1.147	1.154	1.205	1.228	1.194	1.027	1.057
2004	0.773	1.149	1.173	1.242	1.264	1.224	1.036	1.085
2005	0.809	1.158	1.192	1.281	1.302	1.254	1.054	1.118
2006	0.738	1.181	1.211	1.320	1.340	1.285	1.044	1.111
2007	0.743	1.220	1.230	1.361	1.380	1.318	1.071	1.133
Growth Rate								
1995-2007	-2.48%	1.66%	1.73%	2.57%	2.68%	2.30%	0.57%	1.04%
2002-2007	1.06%	1.21%	1.51%	2.85%	3.01%	2.41%	1.15%	2.04%

Source: PEG (2008a), Lawrence (2005) and Economic Insights estimates

Figure 2: **Victorian electricity distribution input components, 1995–2007 (indexes)**



Source: PEG (2008a), Lawrence (2005) and Economic Insights estimates

In table 3 and figure 2 we list and plot the individual input components in index form. Based on the PEG (2008a) data, the opex quantity index decreased rapidly from 1995 to 2002, then increased to 2005 before again falling somewhat. The average annual growth rate of the opex quantity was –2.5 per cent over the whole period and 1.1 per cent since 2002.

All capital quantity measures showed substantially higher growth rates than did opex over this period. Clearly, any approach to weighting which places relatively more weight on opex will lead to a slower growing input index (and correspondingly higher growing TFP index) than one which places relatively more weight on capital. In this study, however, we use only the endogenous approach to forming a capital input cost so this issue is not examined further. Under the endogenous approach an average of 26 per cent of the input cost is accounted for by opex and 74 per cent by capital.

As expected, table 3 and figure 2 show that the constant price depreciated asset value capital quantity proxy increases less than the three physical quantity components with an average annual growth rate of just under 1.7 per cent. Overhead lines MVAkms increases only slightly more quickly than the constant price depreciated asset value with an average annual growth rate of just over 1.7 per cent. But underground cables MVAkms and transformer capacity both increase substantially faster with average annual growth rates of 2.6 and 2.7 per cent, respectively. Combining the three physical measures into a capital quantity index using the asset value shares from Lawrence (2005) leads to a capital quantity index average annual growth rate of 2.3 per cent. The average weights used in forming this index are around 37 per cent for each of overhead lines and transformers (where other capital is rolled in with transformers and assumed to grow at the same rate as transformers) and 26 per cent for underground cables.

We next combine the alternative capital input quantity proxies with the common opex quantity index. For the constant price depreciated asset value capital input approach used by PEG (2008a) this produces an average annual input quantity index growth rate of 0.6 per cent for the whole period. For the physical quantity–based capital input approach used by Lawrence (2003, 2005) this produces an average annual input quantity index growth rate of just over 1 per cent for the whole period. The difference between the two capital approaches is more pronounced for the period since 2002 with average annual growth input rates of 1.2 per cent for the asset value–based method and over 2 per cent for the physical quantity–based method. This reflects the higher growth of undergrounding and transformer capacity in recent years.

As was the case with the output specification, the average annual growth rate of the input index is also relatively sensitive to its specification with previously used specifications providing estimates ranging from 0.6 per cent to over 1 per cent over the whole period and a larger difference for the period since 2002.

3.4 TFP sensitivity analysis

Since we have already found that both the output and the input quantity indexes are sensitive to the specification chosen, it follows that the TFP index (which is the ratio of the output and input quantity indexes) will also be sensitive to specification. In this section we examine four alternative TFP indexes: the specification used by PEG (2008a), that used by Lawrence (2003, 2005) and two hybrid indexes – one using the PEG output index and the Lawrence input index and one using the Lawrence output index and the PEG input index. These four indexes span the range of results arising from the preceding sections.

Table 4: **Alternative Victorian electricity distribution TFP indexes, 1995–2007**

Year	*PEG TFP*	*Lawrence TFP*	*Hybrid TFP1 – PEG Output, Lawrence Input*	*Hybrid TFP2 – Lawrence Output, PEG Input*
1995	1.000	1.000	1.000	1.000
1996	1.061	1.031	1.055	1.038
1997	1.132	1.075	1.120	1.087
1998	1.157	1.099	1.143	1.112
1999	1.190	1.108	1.177	1.120
2000	1.224	1.132	1.219	1.137
2001	1.211	1.137	1.205	1.143
2002	1.210	1.138	1.196	1.151
2003	1.228	1.125	1.192	1.159
2004	1.244	1.115	1.188	1.168
2005	1.246	1.098	1.175	1.165
2006	1.315	1.129	1.236	1.202
2007	1.296	1.122	1.225	1.186
Growth Rate				
1995-2007	2.16%	0.96%	1.69%	1.42%
2002-2007	1.37%	-0.29%	0.48%	0.60%

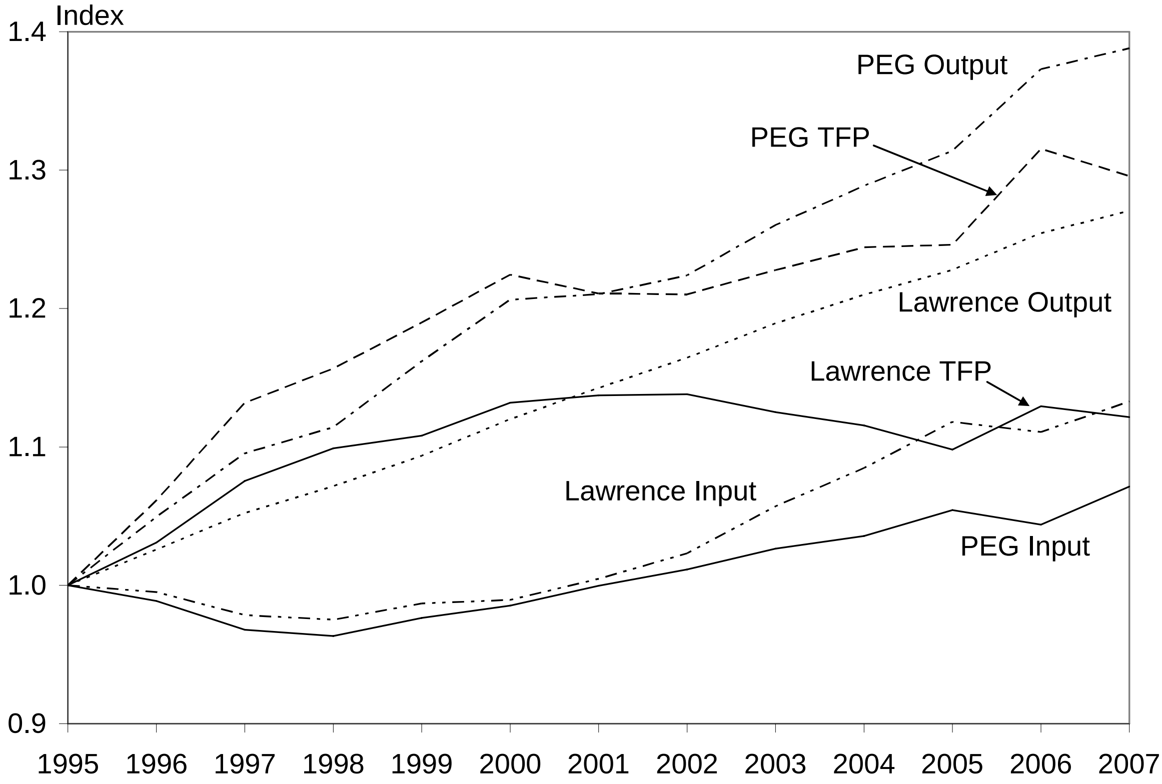
Source: PEG (2008a), Lawrence (2005) and Economic Insights estimates

From table 4 and figure 3 we see that the PEG TFP index increases the most over the period with an average annual growth rate of 2.2 per cent. This is because it has the output index which increases the most and the input index which increases the least. This is because the output index is weighted towards the faster growing throughput and peak demand output components and the input index uses a constant price depreciated asset value proxy for the capital quantity which increases less than corresponding physical measures. The Lawrence TFP index, on the other hand, increases the least with an average annual growth rate of around 1 per cent. Its output index increases less and its input index increases more than those of the PEG TFP index. This is because the output index places most weight on the customer numbers and system capacity output components and the input index uses physical quantity proxies for the capital input quantity. The Lawrence TFP index is also somewhat less volatile than the corresponding PEG index because the latter includes the volatile peak demand output and places most weight on throughput which varies more from year to year.

Over the period since 2002 there has also been a marked difference between the two TFP indexes with the PEG TFP index producing an average annual growth rate of 1.4 per cent while the Lawrence TFP index producing an average annual growth rate of –0.3 per cent.

The two hybrid TFP indexes lie between the PEG and Lawrence TFP indexes. Using the PEG output index and the Lawrence input index produces an average annual TFP growth rate of 1.7 per cent and using the Lawrence output index and the PEG input index produces an average annual TFP growth rate of 1.4 per cent. The first hybrid TFP index produces a higher growth rate than the second because there was a greater difference between the two output indexes than there was between the two input indexes.

Figure 3: **Victorian electricity distribution output, input and TFP indexes, 1995–2007**



Source: PEG (2008a), Lawrence (2005) and Economic Insights estimates

Depending on which TFP specification we choose, we observe TFP growth rates ranging between 1 per cent and 2.2 per cent over the whole period – that is, the upper end of the range is more than double that of the lower end. For the more recent period since 2002, the difference is even greater with a growth rate difference of 1.7 percentage points. To put this in perspective, if these rates were used to set the CPI–X price cap for the industry, the difference in allowable annual distribution revenue would be between $20 million and $27 million depending on which TFP specification and which time period was chosen.

4 GAS DISTRIBUTION TFP SENSITIVITY ANALYSIS

4.1 Data sources

The primary gas distribution data source for this report is Victorian state level data for the years 1998–2007 presented in PEG (2008b). We source data on revenues, customer numbers, throughput for Tariff V customers, peak demand for Tariff D customers, opex and depreciated asset values from this report. However, PEG (2008b) contains no information on system physical characteristics nor total throughput. Confidential data on total throughput, pipeline length by pressure class, meter numbers and an engineering–based measure of system capacity were sourced from Lawrence (2007a), with the agreement of the relevant GDBs, and aggregated to the Victorian state level. Annual data for the years 1998–2007 were available from this source.

4.2 Output sensitivity analysis

In this section we examine five individual output components that are used in PEG (2008b) and Lawrence (2007a). The output components are customer numbers, throughput for Tariff V customers, peak demand for Tariff D customers (typically industrial and large commercial customers), total throughput and system capacity. The first three of these are used in PEG (2008b) to form an output index using revenue weights. Customer numbers, total throughput and system capacity are used in Lawrence (2007a) to form an output index using output cost share weights.

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 required is somewhat analogous to the MVA–kilometre system capacity measure used in the preceding section but, in this case, it needs to also capture the interim storage function of pipelines. The system capacity measure used in this study 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. Dependent on the pressure used, different amounts of molecular gas could be compacted into the system. Thus, a conversion to an equivalent measure using a pressure correction factor was used for networks operating at different pressures (see Lawrence 2007a).

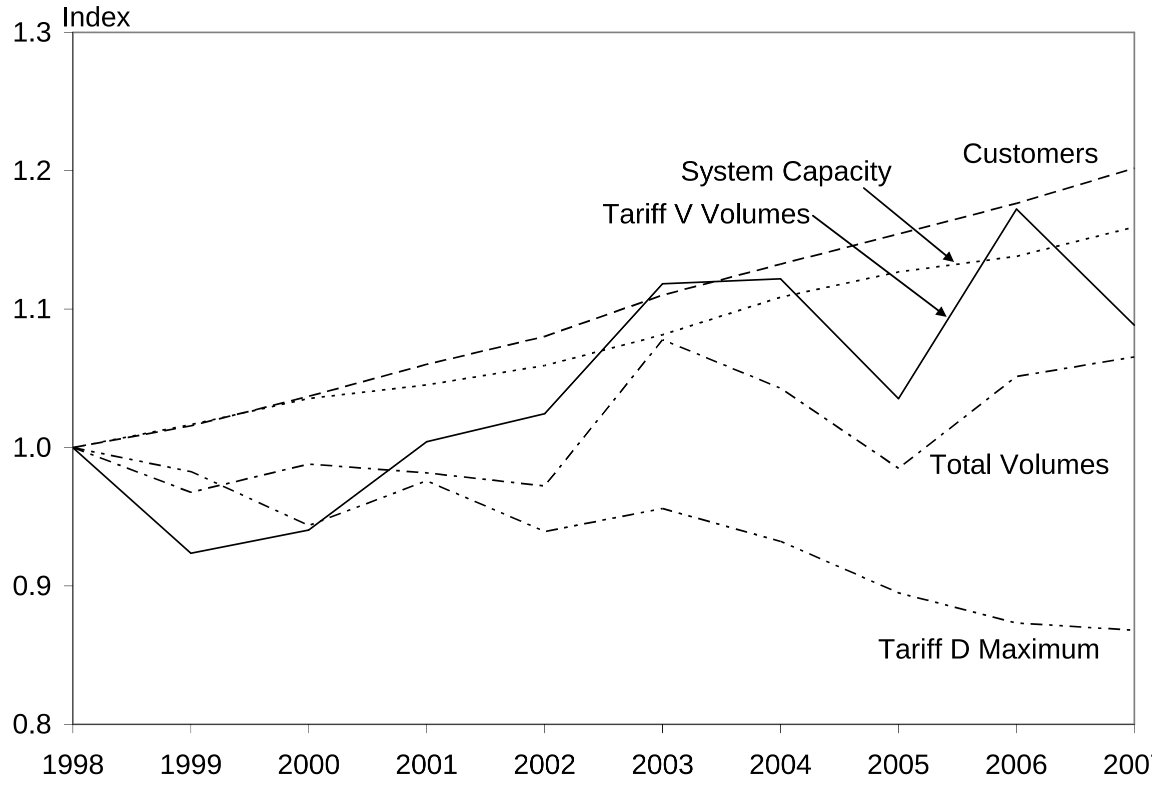
In table 5 and figure 4 we list and plot the five individual output components in index form (ie each series is normalised to equal one in 1998). From table 5 we see that there is a wide range in the growth rates of the individual output components over the period 1998 to 2007. Unlike the case in electricity distribution, customer numbers grow the fastest over the period with a (logarithmic) average annual growth rate of over 2 per cent. System capacity grows the next most quickly at 1.6 per cent. Tariff V throughput and total throughput both grow by less than 1 per cent while Tariff D peak demands actually contract with an average annual growth rate of –1.6 per cent. Clearly, in this case, TFP measures formed from output indexes which place a higher weight on customer numbers and system capacity will reflect higher growth rates than those which place a higher weight on throughput and Tariff D peak demand.

Table 5: **Victorian gas distribution output components, 1998–2007 (indexes)**

Year	*Customers numbers*	*Tariff V Volume*	*Tariff D Peak*	*Total Volume*	*System Capacity*
1998	1.000	1.000	1.000	1.000	1.000
1999	1.016	0.924	0.983	0.968	1.017
2000	1.037	0.940	0.943	0.988	1.035
2001	1.060	1.004	0.976	0.982	1.045
2002	1.080	1.024	0.939	0.972	1.059
2003	1.110	1.118	0.956	1.078	1.082
2004	1.133	1.122	0.932	1.043	1.109
2005	1.154	1.035	0.895	0.985	1.127
2006	1.176	1.172	0.873	1.051	1.138
2007	1.202	1.088	0.868	1.065	1.159
Growth Rate					
1998-2007	2.04%	0.94%	-1.57%	0.70%	1.64%
2002-2007	2.14%	1.21%	-1.58%	1.83%	1.81%

Source: PEG (2008b) and Lawrence (2007a)

Figure 4: **Victorian gas distribution output components, 1998–2007 (indexes)**



Source: PEG (2008b) and Lawrence (2007a)

The other thing we observe from table 5 is that, unlike electricity distribution, output growth rates are somewhat lower for the more recent period 2002 to 2007. This is particularly the case for the throughput measures. Another important observation from figure 4 is that the throughput outputs have been considerably more volatile than either customer numbers or the system capacity outputs and even the Tariff D peak demand output. Consequently, TFP indexes based on output indexes placing a high weight on throughput will correspondingly show a high degree of volatility compared to those placing less weight on this component.

Table 6: **Victorian gas distribution output quantity indexes, 1998–2007**

Year	*Throughput*	*Throughput & Customers – Cost weights*	*Throughput & Customers – Approx Revenue weights*	*PEG: Customers, Tariff V Throughput, Tariff D Peak demand – Revenue weights*	*Lawrence: Throughput, Customers, System Capacity – Cost weights*
1998	1.000	1.000	1.000	1.000	1.000
1999	0.968	1.003	0.980	0.935	1.010
2000	0.988	1.024	1.001	0.951	1.030
2001	0.982	1.039	1.002	1.010	1.044
2002	0.972	1.051	0.999	1.028	1.058
2003	1.078	1.102	1.086	1.113	1.095
2004	1.043	1.108	1.065	1.118	1.111
2005	0.985	1.108	1.026	1.047	1.120
2006	1.051	1.143	1.082	1.163	1.145
2007	1.065	1.165	1.099	1.096	1.167
Growth Rate					
1998-2007	0.70%	1.70%	1.05%	1.02%	1.72%
2002-2007	1.83%	2.06%	1.91%	1.28%	1.97%

Source: Economic Insights estimates

In table 6 we present 5 alternative output indexes based on combinations of the output components in table 5 that have been used in earlier TFP studies. The first column reflects the throughput measure of output used in early energy industry TFP studies. It shows the lowest annual growth rate over the whole period of 0.7 per cent. The second output index combines throughput and customer numbers using the output cost share weights used by PEG (2007) of 26 per cent to throughput and 74 per cent to customer numbers. It shows a growth rate of 1.7 per cent. This approach has been commonly used in North American TFP studies. The third output index also includes only throughput and customer numbers but reverses the weights to 74 per cent to throughput and 26 per cent to customer numbers which is approximately consistent with the revenue weights used in PEG (2008b). This has the effect of reducing the output index's growth rate to 1.1 per cent as more weight is now placed on the slower growing throughput output.

The fourth output index presented in table 5 is that used in PEG (2008b)[2]. This combines customer numbers, Tariff V throughput and Tariff D peak demand using revenue shares of around 12 per cent, 85 per cent and 3 per cent, respectively. By placing 88 per cent of the

[2] The index reported here differs slightly from that in PEG (2008b) due to rounding and the use of the Fisher index instead of the Törnqvist index.

weight on the slowest growing output components, this index exhibits the second lowest annual growth rate over the whole period of just over 1 per cent. It is also correspondingly relatively volatile given the weight placed on volatile components.

The fifth output index presented in table 6 uses the specification of Lawrence (2007a) which combines throughput, customer numbers and system capacity with output cost share weights of 13 per cent, 49 per cent and 38 per cent, respectively. Because of the weight placed on the faster growing output components of customer numbers and system capacity, this index shows the highest annual growth over the whole period of over 1.7 per cent. It is correspondingly less volatile than the other output indexes.

It can be seen that the average annual growth rate of the output index is relatively sensitive to its specification with previously used specifications providing estimates ranging from 0.7 per cent to over 1.7 per cent.

4.3 Input sensitivity analysis

In this section we examine five individual input components that are used in PEG (2008b) and Lawrence (2007a). The input components are opex, depreciated asset values, high pressure pipeline length, low pressure pipeline length and services length. The first two of these are used in PEG (2008b) to form an input index. Opex and 7 physical capital measures are used in Lawrence (2007a) to form an input index, with the three physical measures discussed here accounting for around 80 per cent of capital user costs. In this exercise, for convenience we use cost weights based on opex and a residual overall cost of capital based on the difference between revenue and opex.

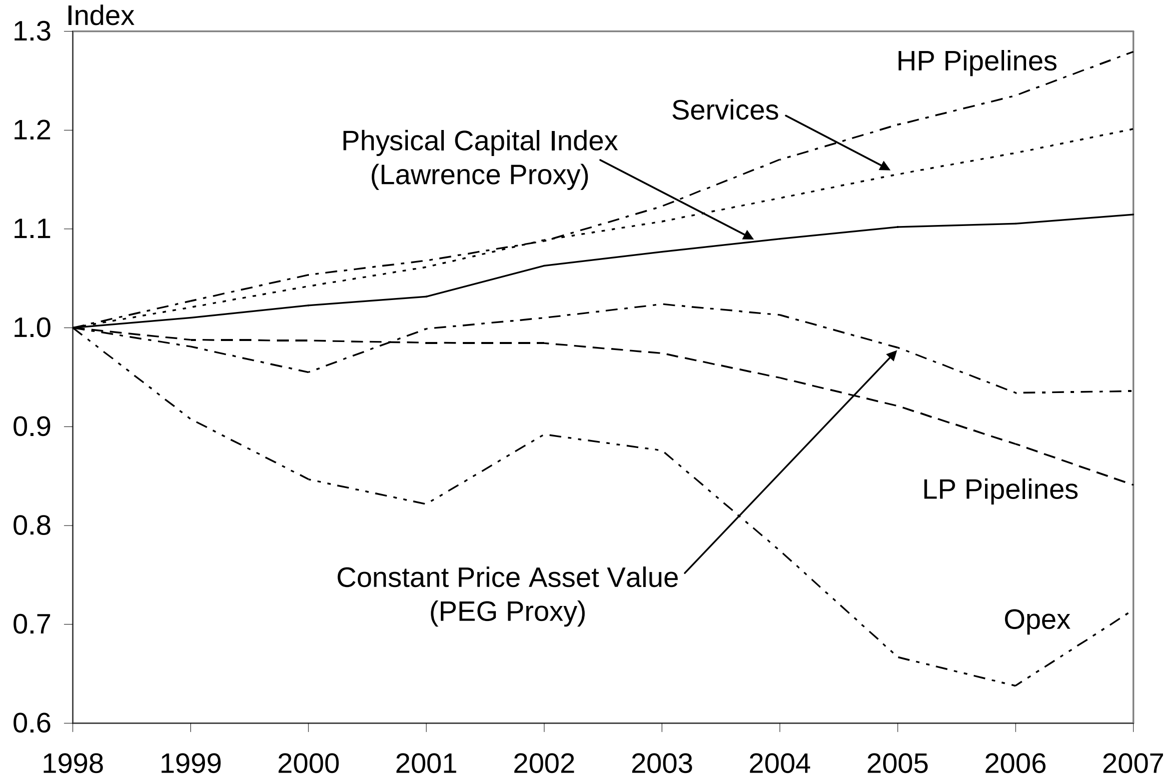
Table 7: **Alternative Victorian gas distribution input quantity indexes, 1998–2007**

Year	*Opex*	*Depr Asset Value*	*High pressure kms*	*Low pressure kms*	*Services kms*	*Lawrence capital*	*PEG Inputs*	*Lawrence Inputs*
1998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1999	0.908	0.981	1.027	0.988	1.021	1.010	0.954	0.972
2000	0.847	0.955	1.054	0.987	1.042	1.023	0.914	0.955
2001	0.822	0.999	1.068	0.985	1.062	1.032	0.933	0.951
2002	0.892	1.010	1.088	0.985	1.089	1.063	0.966	0.998
2003	0.876	1.024	1.123	0.974	1.107	1.077	0.969	1.000
2004	0.775	1.013	1.170	0.949	1.131	1.090	0.925	0.969
2005	0.667	0.980	1.206	0.921	1.155	1.102	0.865	0.936
2006	0.638	0.934	1.235	0.883	1.177	1.105	0.825	0.927
2007	0.715	0.936	1.279	0.841	1.201	1.115	0.852	0.962
Growth Rate								
1998-2007	-3.73%	-0.73%	2.74%	-1.93%	2.04%	1.21%	-1.78%	-0.43%
2002-2007	-4.44%	-1.52%	3.25%	-3.16%	1.97%	0.95%	-2.51%	-0.73%

Source: PEG (2008b), Lawrence (2007a) and Economic Insights estimates

In table 7 and figure 5 we list and plot the individual input components in index form. Based on the PEG (2008b) data, the opex quantity index decreased rapidly from 1998 to 2001, then increased in 2002 before again falling sharply. The average annual growth rate of the opex quantity was –3.7 per cent over the whole period and –4.4 per cent since 2002.

Figure 5: **Victorian gas distribution input components, 1998–2007 (indexes)**



Source: PEG (2008b), Lawrence (2007a) and Economic Insights estimates

Most capital quantity measures showed substantially higher growth rates than did opex over this period. Clearly, any approach to weighting which places relatively more weight on opex will lead to a slower growing input index (and correspondingly higher growing TFP index) than one which places relatively more weight on capital. In this study, however, we use only the endogenous approach to forming a capital input cost so this issue is not examined further. Under the endogenous approach an average of 32 per cent of the input cost is accounted for by opex and 68 per cent by capital.

Table 7 and figure 5 show that the constant price depreciated asset value capital quantity proxy decreases over the period with an average growth rate of –0.7 per cent. Two of the three physical quantity components – high pressure pipelines and services lines – increase relatively quickly with average annual growth rates of 2.7 per cent and 2 per cent, respectively. These two capital components accounted for two thirds of capital costs in 2007. Low pressure pipelines, which are old and progressively being replaced by high pressure lines, decreased with an average annual growth rate of –1.9 per cent but only accounted for 14 per cent of capital costs in 2007. Combining the three physical measures shown and the other four measures used in Lawrence (2007a) into a capital quantity index using asset value shares leads to a capital quantity index average annual growth rate of 1.2 per cent.

We next combine the alternative capital input quantity proxies with the common opex quantity index. For the constant price depreciated asset value capital input approach used by PEG (2008a) this produces an average annual input quantity index growth rate of –1.8 per cent for the whole period. For the physical quantity–based capital input approach used by Lawrence (2007a) this produces an average annual input quantity index growth rate of –0.4 per cent for the whole period. The difference between the two capital approaches is more pronounced for the period since 2002 with average annual growth input rates of –2.5 per cent for the asset value–based method and –0.7 per cent for the physical quantity–based method.

4.4 TFP sensitivity analysis

Since we have already found that both the output and the input quantity indexes are sensitive to the specification chosen, it follows that the TFP index (which is the ratio of the output and input quantity indexes) will also be sensitive to specification. In this section we examine four alternative TFP indexes: the specification used by PEG (2008b), that used by Lawrence (2007a) and two hybrid indexes – one using the PEG output index and the Lawrence input index and one using the Lawrence output index and the PEG input index. These four indexes span the range of results arising from the preceding sections.

Table 8: **Alternative Victorian gas distribution TFP indexes, 1998–2007**

Year	*PEG TFP*	*Lawrence TFP*	*Hybrid TFP1 – PEG Output, Lawrence Input*	*Hybrid TFP2 – Lawrence Output, PEG Input*
1998	1.000	1.000	1.000	1.000
1999	0.981	1.039	0.963	1.059
2000	1.040	1.078	0.995	1.126
2001	1.082	1.097	1.061	1.119
2002	1.064	1.060	1.031	1.094
2003	1.149	1.095	1.113	1.130
2004	1.209	1.146	1.153	1.202
2005	1.210	1.197	1.118	1.295
2006	1.410	1.234	1.254	1.387
2007	1.286	1.213	1.139	1.369
Growth Rate				
1998-2007	2.80%	2.15%	1.45%	3.49%
2002-2007	3.79%	2.70%	2.01%	4.48%

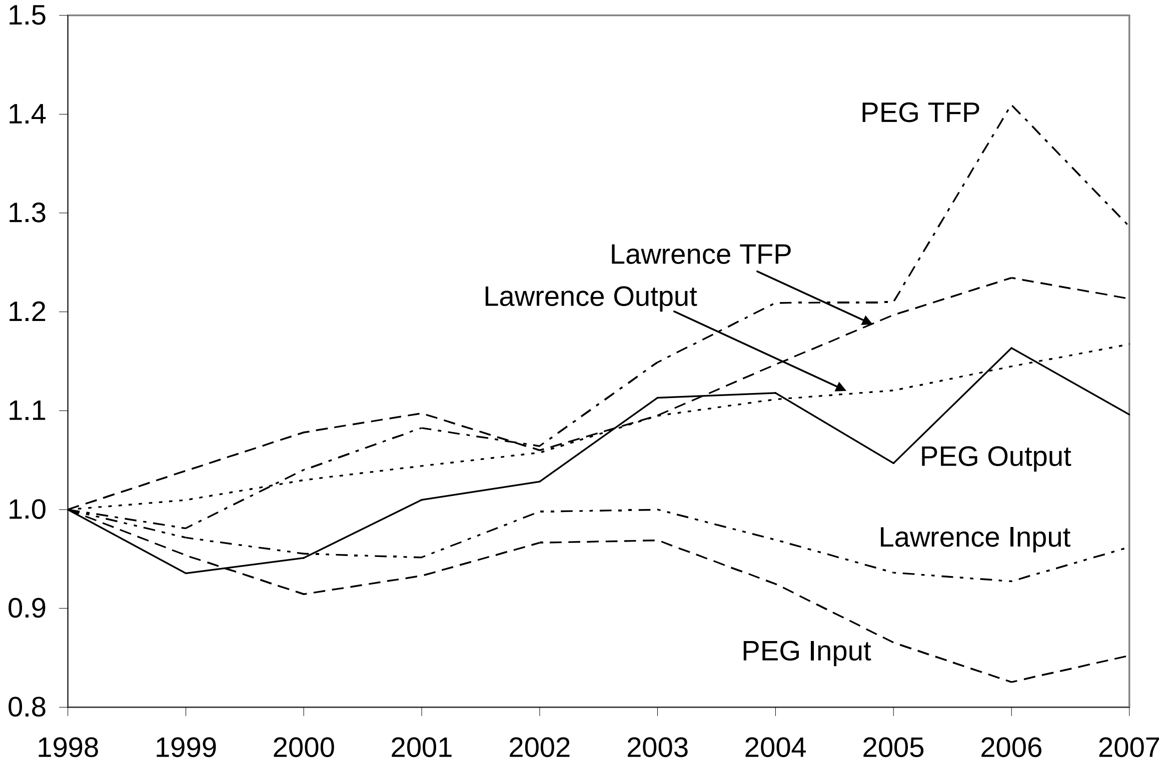
Source: PEG (2008b), Lawrence (2007a) and Economic Insights estimates

From table 8 and figure 6 we see that the PEG TFP index increases more than does the Lawrence TFP index over the period with an average annual growth rate of 2.8 per cent compared to 2.2 per cent. While the PEG output index increases less than does the Lawrence output index, the PEG input index falls substantially more does the Lawrence input index. This is because the PEG output index is weighted towards the slower growing and, indeed, contracting Tariff V throughput and Tariff D peak demand output components and the input index uses a constant price depreciated asset value proxy for the capital quantity which decreases over the period whereas most of the corresponding physical measures have increased. The Lawrence TFP index, on the other hand, is based on an output index that places most weight on the, in this case, more rapidly growing customer numbers and system capacity output components and the input index uses physical quantity proxies for the capital input quantity which increase in aggregate. The Lawrence TFP index is also considerably less volatile than the corresponding PEG index because the latter places most weight on throughput which varies more from year to year.

Over the period since 2002 there has also been a wider gap between the two TFP indexes with the PEG TFP index producing an average annual growth rate of 3.8 per cent and the Lawrence TFP index producing an average annual growth rate of 2.7 per cent.

Unlike the case in electricity distribution, the two hybrid TFP indexes lie outside the range of the PEG and Lawrence TFP indexes. This is because the PEG specification has a less quickly growing output index and a much less rapidly growing input index. Using the PEG output index and the Lawrence input index produces an average annual TFP growth rate of 1.5 per cent and using the Lawrence output index and the PEG input index produces an average annual TFP growth rate of 3.5 per cent.

Figure 6: **Victorian gas distribution output, input and TFP indexes, 1998–2007**



Source: PEG (2008b), Lawrence (2007a) and Economic Insights estimates

Depending on which TFP specification we choose, we observe TFP growth rates ranging between 1.5 per cent and 3.5 per cent over the whole period – that is, the upper end of the range is more than double that of the lower end. For the more recent period since 2002, the difference is even greater with a growth rate difference of 2.5 percentage points. To put this in perspective, if these rates were used to set the CPI–X price cap for the industry, the difference in allowable annual distribution revenue could be up to between \$8.4 million and \$10.5 million depending on which TFP specification and which time period was chosen.

4.5 Indexing and growth rate methods

Apart from the composition of outputs and inputs and the methods used to weight them together, different TFP studies have used different indexing methods and different ways of calculating the TFP growth rate.

As noted in section 2.1, the Fisher index technique is increasingly favoured by statistical agencies because it satisfies all the desirable axiomatic properties for price and productivity indexes. PEG (2004, 2008a,b) has used the older Törnqvist index method but has noted that in practice Törnqvist index results are little different to those of the Fisher index.

Running the Törnqvist index method on the PEG gas distribution specification yielded index numbers for outputs, inputs and TFP which were the same as those obtained using the Fisher index up to the fourth or fifth decimal place.

It has been our experience that the Fisher and Törnqvist index methods do produce very similar results where the shares used are relatively stable over time. Where shares tend to increase rapidly from very low values (eg where the uptake of a new technology suddenly increases), the Törnqvist index method can produce inaccurate results whereas the Fisher index will continue to produce accurate results in this situation.

Another area where Australasian TFP studies have differed in their approaches is the method used to calculate the TFP growth rate. PEG (2004, 2008a,b) has used the average annual growth rate between the first and last observations calculated using the logarithm of the ratio of the index values divided by the difference between the first and last years. For convenience, this method has also been used it this report. Lawrence (2003), on the other hand, has used a regression–based trend method which regresses the logarithm of the relevant variable against a constant and a linear time trend. The time trend regression coefficient is then the relevant growth rate.

Table 9: **Average and trend growth rates, Victorian gas distribution, 1998–2007**

Method	*PEG Output*	*PEG Input*	*PEG TFP*
Average growth rate	1.02%	-1.78%	2.80%
Trend growth rate	1.95%	-1.67%	3.62%

Source: Economic Insights estimates

Whether the difference between the two methods is material depends on whether the relevant series is stable or volatile and whether the first and last observations are relative outliers from the trend of the intervening years. From table 9 and figure 6 we can see that the PEG output index for gas distribution is relatively volatile with the first year above trend and the last year below trend. This means that calculating an average growth rate based on these two observations will, in this case, give a significantly lower growth rate than the regression–based method which fits a line of best fit to all the observations. In this case the growth rate from using the endpoints method is only just over half that obtained by the regression method.

From table 9 and figure 6 we can see that the endpoints on the PEG input index are broadly inline with the overall trend of the variable and so there is little difference between the growth rates calculated by the two methods. But the difference between the two TFP growth rates is substantial, mainly due to the difference in the output index growth rates.

While the difference in results obtained from using the Fisher and Törnqvist index methods is not likely to be significant given the characteristics of energy distribution, the difference between using endpoint–based versus regression–based methods for calculating growth rates can be substantial.

5 CONCLUSIONS

The objective of this study was to establish whether the specification of TFP studies is likely to have a material impact on the outcome of productivity–based revenue and price cap regulation. To address this issue we have undertaken a sensitivity analysis of TFP results using aggregate Victorian data for both electricity and gas distribution.

Whether TFP results are sensitive to differences in output and input specification will depend on whether the alternative outputs and inputs are growing at similar or different rates. If all possible outputs are growing at a similar rate then it will make little difference to the results which ones are chosen and how they are weighted. If they are growing at different rates then the results could be quite sensitive to the specification used. The same applies on the input side.

We have examined the range of individual output and input variables used in previous Australian energy network TFP studies and the combinations used in the two major streams of TFP work – those of Lawrence (2000, 2005, 2007a) and PEG (2004, 2008a,b).

In the case of electricity distribution, the average annual growth rate of the output index is relatively sensitive to its specification with previously used specifications providing estimates ranging from 2.0 per cent to 2.9 per cent. The average annual growth rate of the input index is also relatively sensitive to its specification with previously used specifications providing estimates ranging from 0.6 per cent to over 1 per cent over the period since 1995 and a larger difference for the period since 2002. Depending on which TFP specification we choose, we observe TFP growth rates ranging between 1 per cent and 2.2 per cent over the whole period – that is, the upper end of the range is more than double that of the lower end. To put this in perspective, if these rates were used to set the CPI–X price cap for the industry, the difference in allowable annual distribution revenue for Victoria would be between $20 million and $27 million depending on which TFP specification and which time period was chosen.

In the case of gas distribution, the average annual growth rate of the output index is also relatively sensitive to its specification with previously used specifications providing estimates ranging from 0.7 per cent to over 1.7 per cent. Depending on which method is used to measure capital input quantities, the average annual input quantity index growth rate ranges from –0.4 per cent to –1.8 per cent. This difference is more pronounced for the period since 2002 with average annual growth input rates ranging from –0.7 per cent to –2.5 per cent. Depending on which TFP specification we choose, we observe TFP growth rates ranging between 1.5 per cent and 3.5 per cent over the period since 1998 – that is, the upper end of the range is again more than double that of the lower end. For the more recent period since 2002, the difference is even greater with a growth rate difference of 2.5 percentage points.

Based on the findings for Victoria, we conclude that TFP analyses of Australian electricity and gas distribution systems will be quite sensitive to the specifications chosen. For electricity distribution, specifications which place more weight on throughput and peak demand output measures will exhibit higher TFP growth and more volatility than specifications that place more weight on customer number and system capacity output measures. For gas distribution, specifications which place more weight on customer number and system capacity output measures will exhibit higher TFP growth but less volatility. In both cases, TFP measures which use the constant price depreciated asset value as a proxy for capital input quantities will exhibit higher growth than those using physical proxies for capital input.

Apart from the composition of outputs and inputs and the methods used to weight them together, different TFP studies have used different indexing methods and different ways of calculating the TFP growth rate. The Fisher index technique is increasingly favoured by statistical agencies because it satisfies all the desirable axiomatic properties for price and productivity indexes. Some analysts still use the older Törnqvist index method. While the difference in results obtained from using the Fisher and Törnqvist index methods is not significant in this case, we show that the difference between using endpoint–based versus regression–based methods for calculating growth rates can be substantial. This is particularly the case for output indexes where more volatile components such as throughput and peak demand receive a high weight.

Based on our findings for electricity and gas distribution in Victoria, we conclude that TFP analyses of Australian energy distribution systems will be relatively sensitive to the output and input specifications chosen, the time period examined and the method used to calculate growth rates. This makes it important to specify the correct methodology in any future implementation of TFP–based regulation.

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