Economic Benchmarking Assessment of Operating Expenditure for NSW and ACT Electricity DNSPs

Report prepared for
Australian Energy Regulator

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DNSP NAME ABBREVIATIONS

The following table lists the DNSP name abbreviations used in this report and the State in which the DNSP operates.

Abbreviation	*DNSP name*	*State*
ACT	ActewAGL	Australian Capital Territory
AGD	Ausgrid	New South Wales
AND	AusNet Distribution	Victoria
CIT	CitiPower	Victoria
END	Endeavour Energy	New South Wales
ENX	Energex	Queensland
ERG	Ergon Energy	Queensland
ESS	Essential Energy	New South Wales
JEN	Jemena Electricity Networks	Victoria
PCR	Powercor	Victoria
SAP	SA Power Networks	South Australia
TND	TasNetworks Distribution	Tasmania
UED	United Energy	Victoria

EXECUTIVE SUMMARY

The Australian Energy Regulator has engaged Economic Insights to assist with the application of economic benchmarking and to advise on:

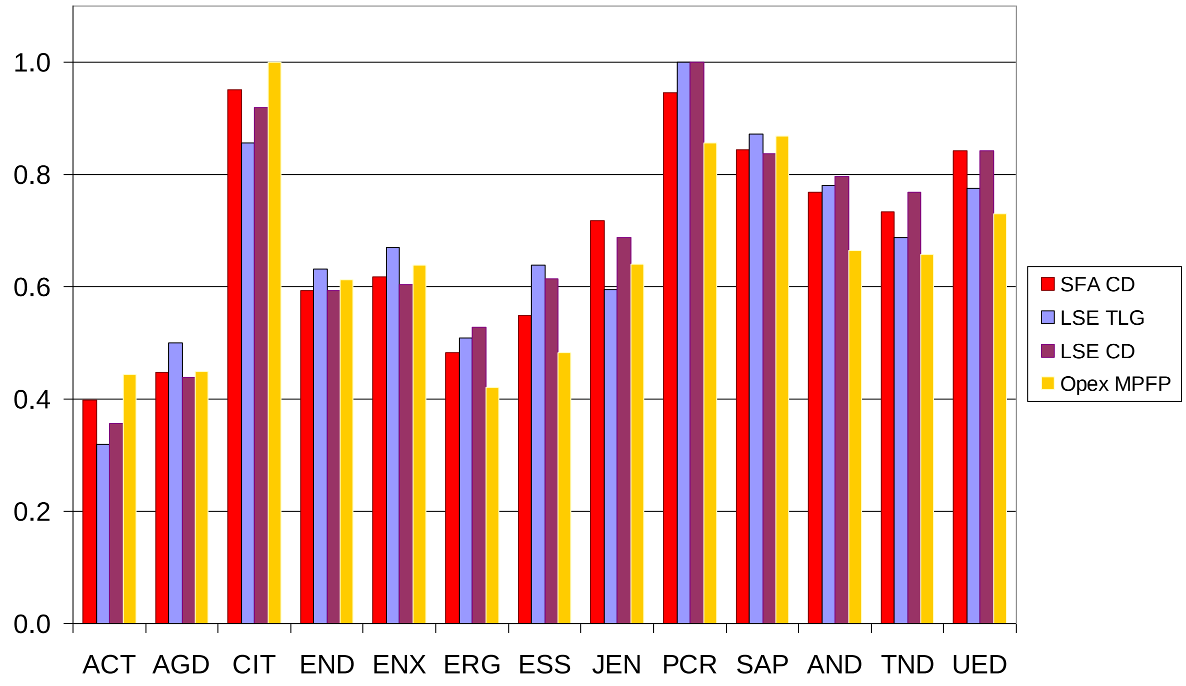
a) whether the AER should make adjustments to base operating expenditure (opex) for the NSW/ACT DNSPs based on the results from economic benchmarking models, and

b) the productivity change to be applied to forecast opex for the NSW/ACT DNSPs.

Base year opex adjustments

In this report we have used a range of economic benchmarking methods to assess the relative opex cost efficiency of Australian DNSPs. The methods include a Cobb Douglas stochastic frontier analysis (SFA CD) opex cost function model, Cobb Douglas and translog least squares econometrics (LSE) opex cost function models and opex multilateral partial factor productivity (MPFP) indexes. MPFP scores are derived using the AER's economic benchmarking Regulatory Information Notice (RIN) data while the econometric models use a database covering 68 DNSPs based on the RIN data combined with comparable regulators' data from New Zealand and Ontario. The overseas data are included to improve the robustness and accuracy of parameter estimates.

Figure A **DNSP average opex cost efficiency scores, 2006–2013**



The resulting average opex cost efficiency scores are presented in figure A. Opex MPFP index values and LSE dummy variable coefficients are converted to efficiency scores so that the most efficient DNSP's score is one. Efficiency scores are calculated directly in SFA with the highest score generally being somewhat less then one due to allowance for white noise, averaging and other statistical effects. Scores less than one are progressively less efficient.

The average efficiency scores for 2006–2013 across the three econometric models are relatively close to each other for each DNSP and they are, in turn, relatively close to the corresponding MPFP score. Our preferred results are those from the SFA Cobb–Douglas model due to its direct estimation of the efficiency score and superior statistical properties.

The opex efficiency scores indicate very large efficiency gaps for the NSW/ACT DNSPs relative to the frontier performers on opex efficiency, CitiPower and Powercor. These two Victorian DNSPs have contrasting metropolitan and rural coverage and share common ownership with SA Power Networks which is the third best performer. There are estimated efficiency gaps of around 60 per cent for ActewAGL, 55 per cent for Ausgrid, 45 per cent for Essential Energy and 40 per cent for Endeavour. However, before presenting our findings on indicative base year opex adjustments from the model results, we need to consider three issues as follows:

1) choice of the appropriate benchmark and allowance for modelling limitations
2) allowance for operating environment factors not explicitly included in the models, and
3) how to move from average results for the period to base year (2013) results.

Rather than adopt the frontier DNSP as the benchmark for efficiency comparisons, we are of the view that it would be prudent to instead adopt a weighted average of the efficiency scores in the top quartile of the efficiency score range in calculating the cost efficiency target for the NSW/ACT DNSPs. We thus take a weighted average of the efficiency scores greater than or equal to 0.75, where customer numbers are used as the basis for forming the weighted average.

The weighted average efficiency score of the five Victorian and South Australian DNSPs with efficiency scores greater than 0.75 is 0.86. This reduction of the efficiency benchmark by 9 percentage points compared to the frontier DNSP efficiency score allows for general limitations of the models with respect to the specification of outputs and inputs, data imperfections and other uncertainties.

Based on the available evidence, we are of the view that it is reasonable to assume that the opex of the Victorian and South Australian DNSPs would be less than 10 per cent higher if they had to operate under the same system subtransmission intensiveness as the NSW DNSPs and if they faced the same OH&S regulations as the NSW/ACT DNSPs. Nonetheless, we propose to make a conservative allowance of a 10 per cent input margin on the benchmark Victorian and South Australian DNSPs to cover these factors for the NSW DNSPs. This includes allowance for a number of factors that, while individually not significant, may collectively be significant.

In the case of ActewAGL, five factors have been identified which impact ActewAGL's reported opex differently to the other DNSPs in the sample including ActewAGL's capitalisation policy, different standard control services connections coverage, backyard reticulation, different jurisdictional taxes and levies, and occupational health and safety regulations. The most important of these is the different capitalisation policy employed by ActewAGL. We propose to make an allowance of a 30 per cent input margin on the benchmark Victorian and South Australian DNSPs to cover these factors. Again, this also includes allowance for a number of factors that, while individually not significant, may collectively be significant.

Rather than simply applying the average 2006–2013 efficiency results to data for 2013, we need to allow for opex movements between the average (approximately midpoint) of the period and 2013. Some DNSPs' opex growth has increased rapidly over the period, some have declined somewhat and some DNSPs appear to have anomalous opex reductions in 2013, in some cases due to provisions changes.

The most logical and consistent method to use to roll forward the target efficient opex for each DNSP from the average–of–the–period result to 2013 is the same rate of change method as used to roll forward base year efficient opex to forecast opex in the out–years. That is, we use the rate of change method which rolls opex forward by the sum of growth in output and in opex prices less the growth in opex partial productivity.

DNSPs whose opex has increased faster over the second half of the period than the rate of change indicates will get larger cuts to their base year opex than those suggested by their average score while those DNSPs whose opex has increased less than rate of change indicates will get lower cuts to their base year opex than those suggested by their average score.

In table A we list the NSW/ACT DNSPs' efficiency scores, efficiency targets and the adjustments to average opex and 2013 network services opex that would be required to reach this target.

Table A **NSW/ACT DNSP opex efficiency scores, efficiency targets and average and 2013 network services opex adjustments to reach the target**[a]

DNSP	*Efficiency score*	*Efficiency Target*	*Implied opex reduction to reach average efficiency target*	*Reduction to 2013 network services opex*
Ausgrid	45%	78%	43%	33%
Endeavour	59%	78%	24%	13%
Essential Energy	55%	78%	30%	35%
ActewAGL	40%	66%	40%	45%

[a] Based on Economic Benchmarking RIN data including changes in provisions

It can be seen that substantial 2013 network services opex reductions are required for three of the four NSW/ACT DNSPs to reach the relatively conservatively set efficiency target of 78 per cent. Opex reductions of around 45 per cent would be required for ActewAGL and around one third for Ausgrid and Essential Energy. A smaller reduction of around 13 per cent would be required for Endeavour.

Opex productivity growth forecast to include in the rate of change

We form opex partial productivity forecasts using the SFA Cobb–Douglas opex cost function estimated parameters and the forecast output and operating environment factor changes included in the NSW/ACT DNSPs' reset RINs. These forecast opex partial productivity growth rates were around –1.6 per cent for Ausgrid and ActewAGL, –1.5 per cent for

Endeavour and –1.3 per cent for Essential Energy, implying ongoing increases in opex, all else equal.

We note the impact of step changes in opex allowances made in a number of recent resets – particularly those in Victoria – and their consequent depression of measured opex productivity growth rates. All else equal, failure to allow for the effect of past reset opex step changes in subsequent resets will lead to DNSPs being over–renumerated as the measured opex productivity growth rate will underestimate the actual opex productivity growth rate.

We are of the view that a forecast opex productivity growth rate of zero should be used in the rate of change formula. There is a reasonable prospect of opex productivity growth moving from negative productivity growth towards zero change in productivity in the next few years as energy use and maximum demand stabilise, given the excess capacity that will exist in the short to medium term and as the impact of abnormal one–off step changes recedes.

We have concerns with the incentive effects of including negative opex partial productivity growth rates in the rate of change formula – to some extent this would be akin to rewarding the DNSPs for having previously overestimated future output growth and now entrenching productivity decline as the new norm. If the effects of step changes can be clearly identified, the forecast opex growth rates should be adjusted to net these effects out.

1 INTRODUCTION

The Australian Energy Regulator (AER) is currently reviewing the expenditure proposals of electricity distribution network service providers (DNSPs) in New South Wales (NSW) and the Australian Capital Territory (ACT) for the five year regulatory period commencing on 1 July 2014.

AER (2013a) presented expenditure forecast assessment (EFA) guidelines to be used for future electricity distribution and transmission regulatory resets. The development of the EFA guidelines followed a long consultation process as part of the AER's *Better Regulation* program responding to the Australian Energy Market Commission's rule changes for electricity network regulation (AEMC 2012). The rule changes clarified the AER's powers to undertake benchmarking and the EFA guideline indicates that economic benchmarking will be one of a number of assessment techniques the AER will use in assessing DNSP expenditure proposals.

The AER has engaged Economic Insights to assist with the application of economic benchmarking and to advise on:

a) whether the AER should make adjustments to base operating expenditure (opex) for the NSW/ACT DNSPs based on the results from economic benchmarking models, and

b) the productivity change to be applied to forecast opex for the NSW/ACT DNSPs.

1.1 The opex assessment process

AER (2013a) states that the 'base–step–trend' method will be the preferred method for assessing DNSP opex proposals. Under this method a nominated year (or years) from the previous regulatory period is determined to be the base from which forecast opex for future years is rolled forward for each DNSP. If the DNSP is assessed to have an efficient level of opex in the base year then the DNSP's actual opex in that year will be rolled forward using a rate of change formula. If the DNSP's base year opex is assessed to be inefficient then it may be adjusted downwards by the assessed amount of inefficiency and the adjusted amount would then be rolled forward to form the forecast of efficient opex. Step changes may be added (or subtracted) for any other costs not otherwise captured in base opex or the rate of change that are required for forecast opex to meet the National Electricity Rules opex criteria. The base–step–trend method can thus be summarised as follows:

$$Opex_t = \prod_{i=1}^{t}(1 + rate\ of\ change_i) \times (A_f^* - efficiency\ adjustment) \pm step\ changes_t \qquad (1.1)$$

where:

- *rate of change*$_i$ is the annual percentage rate of change in year *i*
- A_f^* is the actual opex in the base year
- *efficiency adjustment* is an adjustment for the difference between efficient and actual opex in the base year, and

- *step changes*$_t$ is the determined step change in year *t*.

Under this assessment approach the product of the annual rates of change accounts for changes in real opex input prices (changes in opex input prices relative to changes in the consumer price index), output growth and opex partial productivity in the forecast regulatory control period. The rate of change can be summarised as:

$$\textit{Rate of change}_t = \textit{output growth}_t + \textit{real price growth}_t - \textit{productivity growth}_t \qquad (1.2)$$

Economic benchmarking can be used to assist in reviewing the relative efficiency of historical DNSP opex and whether base year opex can be directly trended forward or whether it may be necessary to make adjustments to base year opex to remove observed inefficiencies. Economic benchmarking can also be used in quantifying the feasible rate of opex partial productivity growth that a business could be expected to achieve over the next regulatory period.

The main economic benchmarking techniques include:

- total factor productivity (TFP) indexes which calculate growth rates of the total output quantity relative to total input quantity for an NSP over time
- multilateral TFP (MTFP) indexes which allow productivity levels as well as growth rates to be compared across NSPs
- econometric cost function models
- stochastic frontier analysis (SFA) which constructs an efficient production frontier from the included observations using statistical methods, and
- data envelopment analysis (DEA) which uses linear programming to construct an efficient production frontier from the included observations.

In this report we use multilateral opex partial factor productivity (MPFP) indexes, econometric operating cost functions and SFA operating cost functions to assess DNSP base year opex efficiency and to forecast opex partial productivity growth for the next regulatory period.

Economic Insights (2013) provides a detailed discussion of economic benchmarking methods, variable specification considerations and data requirements.

1.2 Economic benchmarking RINs

Following lengthy consultation with DNSPs and other stakeholders over the course of 2013, the AER issued economic benchmarking Regulatory Information Notices (RINs) to the 13 DNSPs in the Australian National Electricity Market in November 2013. The RINs required the DNSPs to supply and document detailed data on the values and quantities of outputs, inputs and operating environment factors for the 8–year period 2005–06 to 2012–13. The AER provided detailed definitions of all variables and instructions on the coverage of activities to be included in reporting. DNSPs were given three months to supply an initial draft of their data to be signed off at Chief Executive Officer level and a further two months to provide a final data return with the most recent five years of value information to be signed off by auditors and quantity information to be certified by engineering experts.

Upon receipt of the draft data the AER commenced a detailed data checking process with any apparent errors or anomalies being notified to DNSPs for explanation or correction. Data were checked against other pre–existing reporting sources and subjected to extensive ratio and other filtering ‘sanity checks’. The documented basis of preparation statements were checked in detail to identify any differences in the way DNSPs had interpreted the instructions provided. All RIN data were published on the AER website following receipt of final audited/certified data. DNSPs were then given an additional period in which to lodge cross submissions on other DNSPs’ data where any differences in bases of preparation had been identified by the DNSP.

While no dataset will likely ever be perfect, the AER’s economic benchmarking RIN data provides the most consistent and thoroughly examined DNSP dataset yet assembled in Australia. Previous datasets have reflected differences in reporting requirements across jurisdictions and, in most cases, over time as jurisdictional reporting requirements progressively evolved in response to changes in the application of building blocks regulation, in many cases to counter any possible gaming by DNSPs. The AER’s economic benchmarking RIN data have been supplied using a consistent set of definitions and coverage both over time and across jurisdictions. In our assessment, the AER’s economic benchmarking RIN data are also considerably more detailed, comprehensive and consistent than regulatory data in comparable countries, including the United States. The Australian output and input data used in this study are thus considered to be quite robust and to compare more than favourably with overseas datasets used in previous studies.

Given the extensive process that has been gone through in forming the AER’s economic benchmarking RIN database to ensure maximum consistency and comparability both across DNSPs and over time, the database is fit for the purpose of undertaking economic benchmarking to assess DNSP opex efficiency levels and to estimate models that can be used to forecast future opex partial productivity growth rates. The AER also requested, as part of the DNSPs’ reset RINs, the NSW/ACT DNSPs to supply forecasts for the next regulatory period of the same output variables as reported in the economic benchmarking RIN. These forecast data are used in the application of the rate of change formula presented in this report.

The following section of the report presents more detail on the economic benchmarking methods used in the study. Section 3 then discusses output and input specification issues and the preferred specifications adopted. It also reports key productivity series by way of background. Section 4 presents the MPFP analysis of DNSP opex efficiency levels and opex partial productivity growth rates. Econometric and SFA opex cost function analyses of opex efficiency levels are presented in section 5 and corresponding forecasts of NSW/ACT opex PFP growth rates are presented in section 6. We draw the various analyses together in section 7 and present our recommendations on NSW/ACT DNSP base year opex adjustments and forecast opex PFP growth rates.

2 ECONOMIC BENCHMARKING METHODS TO ASSESS OPEX EFFICIENCY AND PRODUCTIVITY

In this section we describe, in general terms, the methods that are used in this report to measure the relative opex efficiency and opex partial productivity growth rates of DNSPs. We make use of a number of efficiency measurement methods that have been widely used in both academic and regulatory analyses of efficiency in electricity distribution and many other industries.

The four most commonly used efficiency measurement methodologies are:

1. Productivity index numbers (PIN)
2. Least squares econometrics (LSE)
3. Stochastic frontier analysis (SFA)
4. Data envelopment analysis (DEA)

These methodologies are described in some detail in Coelli et al (2005) and also in ACCC (2012), the latter publication containing particular reference to electricity industry applications.

We have chosen to use the first three of these methods (PIN, LSE and SFA) in this analysis. In the remainder of this section we provide a brief outline of these three methods and then conclude with a discussion of the relative merits of the four methods listed above.

2.1 Productivity index numbers

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

Productivity is measured by constructing a ratio of output produced over inputs used. There are two types of productivity measures considered in this study: TFP and PFP. TFP measures total output relative to an index of all inputs used. Output can be increased by using more inputs, making better use of the current level of inputs and by exploiting economies of scale. PFP measures total output relative to one particular input (eg opex partial productivity is the ratio of total output to opex input).

Total factor productivity indexes are formed by aggregating output quantities into a measure of total output quantity and aggregating input quantities into a measure of total input quantity. The productivity index is then the ratio of the total output quantity to the total input quantity or, if forming a measure of productivity growth, the change in the ratio of total output quantity to total input quantity over time.

To form the total output and total input measures we need a price and quantity for each output and each input, respectively. The quantities enter the calculation directly as it is changes in output and input quantities that we are aggregating. The relevant output and input prices are used to weight together changes in output quantities and input quantities into measures of total output quantity and total input quantity.

Traditional measures of TFP have enabled comparisons to be made of *rates of change* of productivity between firms but have not enabled comparisons to be made of differences in the *absolute levels* of productivity in combined time series, cross section firm 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*. Multilateral Total Factor Productivity (MTFP) and Multilateral Partial Factor Productivity (MPFP) index numbers use a more sophisticated indexing method which does satisfy the transitivity property and can be used to obtain an estimate of productivity growth over time and also to measure productivity differentials across DNSPs (Caves, Christensen and Diewert 1982).

Opex Multilateral Partial Factor Productivity (Opex MPFP) measures are obtained by forming the ratio of a multilateral total output quantity index divided by a multilateral opex input quantity index for each DNSP in each time period. These opex MPFP measures can be used to provide a measure of relative opex efficiency for each of the 13 DNSPs in each of the 8 time periods by dividing all 104 opex MPFP index numbers by the largest opex MPFP index number. This has the effect of scaling the measures so that the most efficient observation has a value of one and all other opex efficiency measures are less than one.

MTFP 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 identify than using some of the alternative econometric techniques.

One of the potential disadvantages of index number methods is that they are deterministic in nature, and hence do not attempt to account for the effects of random noise (eg measurement error, climatic events, etc.). Hence, in this study we have chosen to calculate the averages of the values of the opex MPFP measures over the 8 time periods for each DNSP. This has the effect of reducing the impact of random factors that may affect the data from year to year. With these 13 average opex MPFP measures we then obtain a measure of opex efficiency for each of the 13 DNSPs by dividing each of these 13 measures by the largest average opex MPFP measure. This has the effect of scaling the measures so that the most efficient DNSP has an opex efficiency measure equal to one and all other average opex efficiency measures are less than one.

2.2 Least squares econometrics

Least squares econometric (LSE) methods have been used for the measurement of efficiency for a number of decades. An early reference to this method is that of Winsten (1957) who proposed the Ordinary Least Squares (OLS) estimation of a production function using sample data on a group of firms, that is then shifted (by the value of the largest estimated residual) so as to envelope the sample data and form a frontier production function. Efficiency scores are then obtained by forming ratios of observed production over the predicted frontier production, for each firm in the sample.

This method has become known as Corrected Ordinary Least Squares (COLS) and has been widely applied in many settings, but can be criticised because it is essentially deterministic in nature (Kumbhakar and Lovell, 2000). That is, it assumes that all observed deviations from the frontier are due to firm inefficiency and not due to the effects of random noise. If random noise is a factor in the sample data this can affect the position of the estimated frontier and the size of the efficiency measures obtained (in a positive or negative manner).

This criticism can be addressed in a number of ways. One option is to follow Pitt and Lee (1981) and make use of data on a sample of firms observed over a number of time periods (panel data) to estimate a panel data least squares model. The advantage of using panel data is that one can measure firm-level efficiency by including firm-level dummy variables in the regression model while also retaining a standard random disturbance term to capture the effects of random noise.

The above brief discussion of the history of frontier estimation and efficiency measurement refers to the estimation of *production* frontiers and the calculation of *technical* efficiency measures. One can equivalently estimate *cost* frontiers and calculate *cost* efficiency measures. The methods are very similar, except that one defines a cost function and then shifts it downwards to envelope the sample data from below so as to define a *minimum* cost frontier (as opposed to a *maximum* production frontier).

The least squares opex cost functions we estimate take the general form:

(3) Opex = f(output quantities, opex input prices, capital quantities, operating environment factors, DNSP dummy variables).

Opex would be expected to increase with an increase in output quantities and with an increase in opex input prices. Capital inputs are generally substitutable with opex inputs and so this relationship is generally expected to be negative. However, capital inputs and opex could also be perfect complements (as occurs, for example, with a Leontief technology), in which case the coefficient of the capital quantity variable would be expected to be zero. Operating environment factors could be either positively or negatively related to opex. The extent of undergrounding could, for instance, be expected to be negatively related to opex, ie an increase in the proportion of lines underground could be expected to increase capital costs but reduce opex costs as less maintenance is needed for cables than for overhead lines.

The DNSP–specific dummy variables pick up the underlying differences in opex once the effects of the other included variables are allowed for. The most efficient DNSP will have the lowest underlying opex and thus the lowest valued dummy variable coefficient. We transform the dummy variables coefficients to efficiency scores so that the most efficient DNSP has an efficiency score of one and the other DNSPs have efficiency scores less than one.

2.3 Stochastic frontier analysis

An opex cost function can also be estimated with the Stochastic frontier analysis (SFA) method. This is an econometric method that is similar to least squares, except that an additional one–sided error term is added to the model to capture the effects of inefficiency. That is, the model has two error terms, a standard two–sided error term to capture the effects of random data noise and a one–sided error term to capture the effects of inefficiency. These are normally specified with a normal distribution and a truncated normal distribution, respectively (Coelli, Rao and Battese 1998).

The SFA method estimates the cost frontier directly. That is, there is no need to shift the estimated function so that it envelopes the sample data because the estimated SFA model is explicitly designed to envelope the data (in a stochastic manner). Efficiency scores may then obtained for each DNSP using a standard efficiency prediction formula (see further detail later in this report).

2.4 Relative merits of the alternative methods

Here we discuss the relative advantages and disadvantages of the four alternative efficiency measurement methods.

Data Envelopment Analysis (DEA) is an additional efficiency measurement methodology that is widely used. DEA involves the use of linear programming methods to construct a piece-wise linear frontier over the sample data and then measure efficiency scores. DEA has the advantage that it is non–parametric, and hence does not require the specification of a functional form for the frontier or a distributional form for the inefficiency effects. However, it has the disadvantage that it is deterministic in nature and hence the efficiency scores obtained can be quite sensitive to the effects of random factors and data errors. Hence we have chosen to not use DEA in this study.

Productivity Index Number (PIN) methods are also deterministic in nature and hence have the disadvantage that they can be affected by data noise. We address this issue to some extent by using firm-level averages over the sample period in this study (as noted earlier). One clear advantage of PIN is that they can be calculated using very small data sets (a minimum of two observations are needed) while the other three frontier-based methods require large sample sizes for one to obtain reliable results. It is also a transparent and reproducible method that is relatively robust.

Least Squares Econometric (LSE) models have the advantage of being statistical rather than deterministic methods and can thus allow for random noise. They also have the advantages (relative to PIN) that they allow for economies and diseconomies of scale and that one can include environmental factors (eg percentage of underground lines) in the regression models, which are potentially important issues in this study.

Stochastic frontier analysis (SFA) also shares these particular scale and environment advantages with LSE. It has the additional advantage (relative to LSE) that the inefficiency effects are explicitly included in the model and hence the method directly estimates a *frontier* cost function while the LSE method estimates an *average* cost function and then assumes that the frontier function is a parallel shift (in logarithms) of the average function. However, SFA has the disadvantage (relative to LSE) that a particular distributional form needs to be assumed for the inefficiency effects and that the method tends to be more data hungry and hence more unstable when applied to small data sets.

3 DNSP OUTPUTS, INPUTS AND PRODUCTIVITY PERFORMANCE

In this section we review a number of output and input specification issues and describe the specifications adopted in the remainder of the study. We also present MTFP results for the industry by way of background to subsequent discussion of opex efficiency and opex MPFP growth rates.

3.1 DNSP output specification

DNSP output specification issues were discussed at length in Economic Insights (2013) and during the AER's preceding consultation process. It was noted that under building blocks regulation there is typically not a direct link between the revenue requirement that the DNSP is allowed by the regulator and how the DNSP structures its prices. Rather, the regulator typically sets the revenue requirement based on the DNSP being expected to meet a range of performance standards (including reliability performance) and other deliverables (or functional outputs) required to meet the expenditure objectives set out in clauses 6.5.6(a) and 6.5.7(a) of the National Electricity Rules (NER). DNSPs then set prices on the outputs they charge for that have to be consistent with broad regulatory pricing principles but this is a separate process from setting the revenue requirement[1].

Given that the outputs to be included in economic benchmarking for building blocks expenditure assessments will need to be chosen on a functional basis, Economic Insights (2013) specified criteria to guide the selection of outputs to be included in economic benchmarking based on those proposed by the AER (2012, p.74):

1) the output aligns with the National Electricity Law and National Electricity Rules objectives
2) the output reflects services provided to customers, and
3) the output is significant.

The first selection criterion states that economic benchmarking outputs should reflect the deliverables the AER expects in setting the revenue requirement which are, in turn, those the AER believes are necessary to achieve the expenditure objectives specified in the NER. The NER expenditure objectives for both opex and capex are to:

- meet or manage the expected demand for standard control services over that period;
- comply with all applicable regulatory obligations or requirements associated with the provision of standard control services;
- to the extent that there is no applicable regulatory obligation or requirement in relation to:
    i. the quality, reliability or security of supply of standard control services; or
    ii. the reliability or security of the distribution system through the supply of standard

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[1] Clause 6.18 of the national electricity rules sets out the distribution pricing rules to which DNSPs must adhere when determining their tariffs.

control services,

to the relevant extent:

iii. maintain the quality, reliability and security of supply of standard control services; and

iv. maintain the reliability and security of the distribution system through the supply of standard control services; and

- maintain the safety of the distribution system through the supply of standard control services.

The second selection criterion is intended to ensure the outputs included reflect services provided directly to customers rather than activities undertaken by the DNSP which do not directly affect what the customer receives. If activities undertaken by the DNSP but which do not directly affect what customers receive are included as outputs in economic benchmarking, then there is a risk the DNSP would have an incentive to oversupply those activities and not concentrate sufficiently on meeting customers' needs at an efficient cost.

The third selection criterion requires that only significant outputs be included. DNSPs provide a wide range of services but DNSP costs are dominated by a few key outputs and only those key services should be included to keep the analysis manageable and to be consistent with the high level nature of economic benchmarking. For instance, call centre operations are not normally a large part of DNSP costs and so call centre performance is not normally included as an output in DNSP economic benchmarking studies.

Economic Insights (2013) presented a preferred output specification which included outputs of energy throughput, system capacity (measured as the product of line plus cable circuit length and the total installed capacity of distribution level transformers), customer numbers (capturing fixed elements of DNSP output) and reliability (measured by total customer minutes off–supply and entering as a negative output).

This specification concentrated on the supply side, giving DNSPs credit for the network capacity they have provided. It has the advantage of capturing both line and transformer dimensions of system capacity. A similar specification (but excluding reliability) has previously been used at the electricity distribution industry level (eg Economic Insights 2009) where it captures the key functional elements of DNSP output well. However, it has not previously been used to benchmark a diverse range of DNSPs of differing sizes. A potential disadvantage of the specification in the economic benchmarking context is the multiplicative nature of the system capacity variable which introduces a degree of non–linearity thereby potentially advantaging large DNSPs.

This has led us to examine an output specification which includes the same key elements but in a non–multiplicative way which does not artificially advantage large DNSPs at the expense of small DNSPs. An output specification used recently by Pacific Economics Group Research (PEGR 2013) in work for the Ontario Energy Board included outputs of energy throughput, ratcheted maximum demand, customer numbers and circuit length. It covers similar components to our system capacity measure but not in a multiplicative form and so has attractions given the widely varying sizes of the Australian DNSPs.

This output specification also has the advantage of capturing both the demand side transformer dimension of system capacity and the line length dimension. It thus addresses another criticism of the preferred specification listed in Economic Insights (2013) which was that it placed insufficient weight on demand side outcomes. In consultation undertaken by the AER in 2013, some user groups argued for the inclusion of demand side functional outputs so that the DNSP is only given credit for network capacity actually used and not for capacity that may be installed but excess to users' current or reducing requirements (AER 2013d). Including observed maximum demand instead of network capacity was argued to be a way of achieving this. However, this measure would fail to give the DNSP credit for capacity it had been required to provide to meet previous maximum demands which may have been higher than those currently observed.

Economic Insights (2013) suggested that inclusion of a 'ratcheted peak demand' variable may be a way of overcoming this problem and PEGR (2013) also used the same variable (that it described as 'system peak demand'). This variable is simply the highest value of peak demand observed in the time period up to the year in question for each DNSP. It thus recognises capacity that has actually been used to satisfy demand and gives the DNSP credit for this capacity in subsequent years, even though annual peak demand may be lower in subsequent years.

PEGR (2013, p.76) noted:

> 'We began by noting that four of the seven cost driver variables were related to distribution output: customer numbers; system peak demand; kWh deliveries; and circuit km of line. For each distributor, these four output variables can be aggregated into a comprehensive output quantity index using the cost elasticity shares presented ... This approach weights each of the four outputs by its respective, estimated impact on distribution cost.'

PEGR (2013, p.48) noted the following regarding the inclusion of circuit length:

> 'The circuit km variable clearly has an output–related dimension, because it reflects customers' location in space and distributors' concomitant need to construct delivery systems that transport electrons directly to the premises of end–users.'

Because of data limitations in Ontario – PEGR only had reliable data on DNSP average line length over the period rather than year–by–year line length data – PEGR (2013) only included the line length variable in its cross–sectional benchmarking analysis and not its time–series analysis. However, we agree with PEGR that the four output specification covering energy throughput, ratcheted maximum demand, customer numbers and circuit length represents a useful way forward as it captures the key elements of DNSP functional output in a linear fashion and introduces an important demand side element to the measurement of system capacity outputs. Because we have reliable data on all four output variables, all four are included in our analysis. We also add a fifth output of reliability (measured by customer minutes off supply and entering as a negative output).

This specification performs well using the selection criteria listed in Economic Insights (2013). It recognises key aspects of the expenditure objectives by including both energy throughput and peak demand. By including the key dimensions of system capacity it recognises the importance of maintaining the quality, reliability and security of standard control services. And it also includes measures of reliability directly. It also performs well against the second criterion as it directly reflects the range of services provided to customers, including energy throughput, peak demand and reliability along with the key element of system capacity required to support delivery of those services to customers. And it covers the most significant outputs and thus performs well against the third criterion.

To operationalise our preferred five output specification in index number methods we have to next derive output cost–based weights. Attempts to derive weights for outputs (other than reliability) from a translog cost function were unsuccessful as some outputs had negative first order coefficients. We therefore derived output cost share weights using the simpler Leontief cost function approach used in Lawrence (2003). This method is described in appendix A. Estimated output cost shares were energy 12.8 per cent, ratcheted maximum demand 17.6 per cent, customer numbers 45.8 per cent and circuit length 23.8 per cent. Minutes off–supply were again treated as a negative output with a weight based on the value of consumer reliability (VCR).

The Australian Energy Market Operator (AEMO 2014b) has recently released its updated estimates of the VCRs for the NEM jurisdictions. These are converted to DNSP–specific VCRs based on each DNSP’s customer mix and are used to weight minutes off–supply. The updated AEMO VCR–based weights are less than two thirds of those derived from AEMO’s previous VCRs and are more in line with those found in previous productivity studies (eg Lawrence 2000, Coelli et al 2008, Coelli et al 2012).

3.2 DNSP input specification

Input specification issues were discussed at some length in Economic Insights (2013). The preferred specification in Economic Insights (2013) and AER (2013c) used network services opex deflated by a price index comprising labour and materials and services price indexes to proxy the quantity of opex inputs. It used overhead MVAkms to proxy the annual input quantity of overhead lines capital input, cables MVAkms to proxy the annual input quantity of underground cables, and total transformer MVA to proxy the annual input quantity of transformers and other capital inputs. Use of the MVAkms measure allows the aggregation of lines and cables of differing voltages and capacities into a single robust measure. MVAkms measures are formed using the MVA ratings for each voltage class specified by each DNSP and its reported circuit length[2]. The annual user cost of capital is made up of the return of capital, return on capital and tax components calculated in a way which approximates the corresponding building blocks calculations and is pro–rated across the three capital inputs based on their relative shares in the regulated asset base.

In this report we have made two important refinements to our measurement of capital input quantities. Firstly, we divide overhead lines into overhead subtransmission lines (defined as lines of 33 kV and higher) and distribution lines (defined as lines of less than 33 kV). A

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[2] One exception is that we substitute a rating of 4 MVA for Energex’s 11 kV lines and cables. The Energex rating of around 0.9 for lines was well below the ratings for comparable DNSPs. The average for Ausgrid and Endeavour was around 4 MVA and this was also the average for all DNSPs other than Energex. It is also the value recommended in Parsons Brinckerhoff (2003) which we have used in previous productivity studies.

similar disaggregation of underground cables into underground subtransmission cables and underground distribution cables is also made. Including this disaggregation allows for the fact that subtransmission lines and cables account for a high proportion of most DNSPs' total overhead MVAkms and total underground MVAkms, respectively, but a much smaller proportion of overhead lines and underground cables asset values and annual user costs. For the industry as a whole in 2013, for example, overhead subtransmission lines accounted for around two thirds of total overhead line MVAkms but only a quarter of the annual user cost of overhead lines. Undertaking this disaggregation thus allows a more accurate measure of total input quantity to be formed.

This input specification has the advantage of best reflecting the physical depreciation profile of DNSP assets. Movements in the quantities of each of the five capital inputs over time are relatively smooth as one would expect DNSP capital input quantities to be given the long–lived nature of DNSP assets. It best fulfilled the selection criteria identified in Economic Insights (2013) of:

1) input coverage is comprehensive and non–overlapping
2) measures of capital input quantities are to accurately reflect the quantity of annual capital service flow of assets employed by the NSP
3) capital user costs are to be based on the service provider's regulatory asset base (RAB) and should approximate the sum of the return of and return on capital components used in building blocks, and
4) specification to be consistent with the NEL and NER.

The second input specification refinement used in this study compared to that listed in Economic Insights (2013) relates to transformer inputs. Both the MVA and annual user cost of the Transformers and other capital component are reduced to exclude the first stage zone substation transformer capacity of those systems (mainly in NSW and Qld) that have two stage transformation from the higher voltages. The MVA quantity of Transformers and other capital inputs is now the sum of single stage transformation at the zone substation level, the second stage of two stage transformation at the zone substation level, and distribution transformer capacity.

The Transformers and other annual user cost is reduced according to the share of first stage MVA capacity in overall zone substation capacity after allowing for the split between zone substation and distribution transformer annual user cost (assumed to be the same as the capacity split) and the split between transformer annual user cost and other annual user cost (assumed to be in line with relevant asset values).

The purpose of this modification is to allow for the more complex system structures and different transmission/distribution boundaries some states have inherited relative to others. Those DNSPs with more complex system structures because they have inherited more 'upstream' distribution boundaries will be at a disadvantage in efficiency comparisons relative to DNSPs with simpler system structures and a more 'downstream' boundary. Excluding the first stage of two stage transformation at the zone substation level for those DNSPs with more complex system structures allows more like–with–like comparisons to be made across DNSPs.

As noted above, opex is taken to be network services opex. Net changes in provisions are included. The price of opex is taken as a weighted average of the Electricity, gas, water and waste sector (EGWW) Wages price index (WPI) and five ABS Producer price indexes (PPIs) as used in Economic Insights (2012a) and using opex shares reported in PEG (2004) based on analysis of Victorian electricity DNSP regulatory accounts data[3]. The component price indexes and weights are as follows:

- EGWW sector WPI – 62.0 per cent
- Intermediate inputs – domestic PPI – 19.5 per cent
- Data processing, web hosting and electronic information storage PPI – 8.2 per cent
- Other administrative services PPI – 6.3 per cent
- Legal and accounting PPI – 3.0 per cent, and
- Market research and statistical services PPI – 1.0 per cent.

3.3 DNSP operating environment factors

Economic Insights (2013) identified a range of operating environment factors which may impact DNSP efficiency levels. These included a range of network density variables, the extent of undergrounding, climatic factors and terrain measures. The AER economic benchmarking RIN commenced the collection of operating environment data covering density measures, a range of vegetation management measures, climatic variables and network dispersion measures. DNSPs provided complete and consistent data for the network density variables. However, because the other variables are relatively new, DNSPs appear to have interpreted some of the variables in different ways. Because of this, and because these variables were only requested for a shorter period, more refinement and extension of these variables is required before they could be used in economic benchmarking.

As noted above, distribution network complexity is also likely to be a factor influencing efficiency levels which is largely beyond current management control in the short term. Those DNSPs that have inherited a more ‘upstream’ boundary with the transmission network and, hence, may have more subtransmission and possible two–stage transformation at the zone substation level may require more inputs to produce the same amount of (measured) output than DNSPs with more ‘downstream’ boundaries and single–stage transformation.

In this study we allow for three key operating environment factors, where possible. These are:

1. Network density differences: by including customer numbers, network length, energy throughput and peak demand as outputs we effectively allow for differences in customer density (customers per line/cable kilometre), energy density (energy delivered per

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[3] Ideally the forecast opex price index used in the rate of change formula should have the same composition as that used in the economic benchmarking. We note that in recent determinations the AER has used the consumer price index (CPI) to escalate non–labour opex costs instead of disaggregated PPIs. A sensitivity analysis of the effect of using the CPI compared to the five disaggregated PPIs indicated no material difference in results. To implement rate of change calculations it will be necessary to use CPI forecasts for the non–labour component of opex as forecasts of disaggregated PPIs are not currently available and would be unlikely to be sufficiently robust.

customer) and demand densities (peak demand per customer and peak demand per line/cable kilometre) in the analysis. This is because a DNSP with a low customer density, for example, will receive output credit for having a longer line and cable length than an otherwise equivalent DNSP with high customer density.

2. Undergrounding: by including an operating environment variable for the proportion of underground cables in total line and cable length in our cost functions, we explicitly allow for the impact of this factor.
3. System complexity: by excluding the first stage of two stage transformation at the zone substation level from our productivity analysis we put DNSPs on a more comparable footing and, in our econometric analysis, we make ex post allowance for this effect before forming our recommendations.

3.4 DNSP MTFP performance

Before presenting the overall DNSP MTFP results, we first present the multilateral index number methodology.

Caves, Christensen and Diewert (1982) developed the multilateral Törnqvist 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) used this index to compare the productivity levels and growth rates of the five major Australian state electricity systems and the United States investor–owned system. Lawrence (2003) and PEG (2004) also use this index to compare electricity distribution business TFP levels and Lawrence (2007c) and Economic Insights (2012a) used it to compare TFP levels across the three Victorian GDBs.

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

$$\begin{aligned} \log (TFP_m/TFP_n) \quad = \quad & \textstyle\sum_i (R_{im}+R_i^*) (\log Y_{im} - \log Y_i^*)/2 - \\ & \textstyle\sum_i (R_{in}+R_i^*) (\log Y_{in} - \log Y_i^*)/2 - \\ & \textstyle\sum_j (S_{jm}+S_j^*) (\log X_{jm} - \log X_j^*)/2 + \\ & \textstyle\sum_j (S_{jn}+S_j^*) (\log X_{jn} - \log X_j^*)/2 \end{aligned} \tag{3.1}$$

where R_i^* (S_j^*) is the revenue (cost) share of the *i*–th output (*j*–th input) averaged over all utilities and time periods and $\log Y_i^*$ ($\log X_j^*$) is the average of the log of output *i* (input *j*). In this analysis we have five outputs and, hence, *i* runs from 1 to 5. Revenue shares are derived from cost–reflective shadow prices. We have four inputs and, hence, *j* runs from 1 to 4. 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.

Equation (3.1) gives the proportional change in MTFP between two 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 (3.1) comparisons between any two observations m and n will be both base–DNSP and base–year independent. Transitivity is satisfied since comparisons between, say, two DNSPs for 2009 will be the same regardless of whether they are compared directly or via, say, one of the DNSPs in 2012. An alternative interpretation of this index is that it compares each observation to a hypothetical average DNSP with output vector Y_i*, input vector X_j*, revenue shares R_i* and cost shares S_j*.

As discussed earlier in this section, the DNSP MTFP measure has five outputs included:

- Energy throughput (with 12.8 per cent share of gross revenue)
- Ratcheted maximum demand (with 17.6 per cent share of gross revenue)
- Customer numbers (with 45.8 per cent share of gross revenue)
- Circuit length (with 23.8 per cent share of gross revenue), and
- (minus) Minutes off–supply (with the weight based on current AEMO VCRs).

The DNSP MTFP measure includes six inputs:

- Opex (network services opex deflated by a composite labour, materials and services price index)
- Overhead subtransmission lines (quantity proxied by overhead subtransmission MVAkms)
- Overhead distribution lines (quantity proxied by overhead distribution MVAkms)
- Underground subtransmission cables (quantity proxied by underground subtransmission MVAkms)
- Underground distribution cables (quantity proxied by underground distribution MVAkms), and
- Transformers and other capital (quantity proxied by distribution transformer MVA plus the sum of single stage and the second stage of two stage zone substation level transformer MVA).

In all cases, the annual user cost of capital is taken to be the return on capital, the return of capital and the tax component, all calculated in a broadly similar way to that used in forming the building blocks revenue requirement.

DNSP MTFP results are presented in table 3.1 and figure 3.1. For presentational purposes the observation for ActewAGL in 2006 is given the value one[4].

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[4] Relative MTFP levels are invariant to which DNSP is chosen as the base.

Table 3.1 **DNSP multilateral total factor productivity indexes and annual growth rates, 2006–2013**

DNSP	*Average MTFP index level*	*Average annual MTFP growth rate*
CIT	1.734	–1.82%
SAP	1.518	–2.29%
UED	1.483	–1.40%
JEN	1.382	–0.49%
PCR	1.278	–1.55%
ENX	1.260	–1.84%
END	1.220	–2.03%
AND	1.209	–2.19%
ESS	0.985	–3.79%
AGD	0.985	–0.86%
ERG	0.970	1.42%
ACT	0.953	–1.51%
TND	0.936	–4.16%

CitiPower can be seen to have had the highest MTFP level on average over the 8 year period, followed by SA Power Networks and three of the other Victorian DNSPs. Energex comes next followed by Endeavour, AusNet Distribution, Essential Energy, Ausgrid, Ergon Energy and then ActewAGL and the Tasmanian DNSP which have the lowest MTFP levels.,

MTFP has declined for 12 of the 13 DNSPs over the 8 year period with average annual growth rates ranging from 1.4 per cent for Ergon Energy to –4.2 per cent for the Tasmanian DNSP.

Figure 3.1 **DNSP multilateral total factor productivity indexes, 2006–2013**

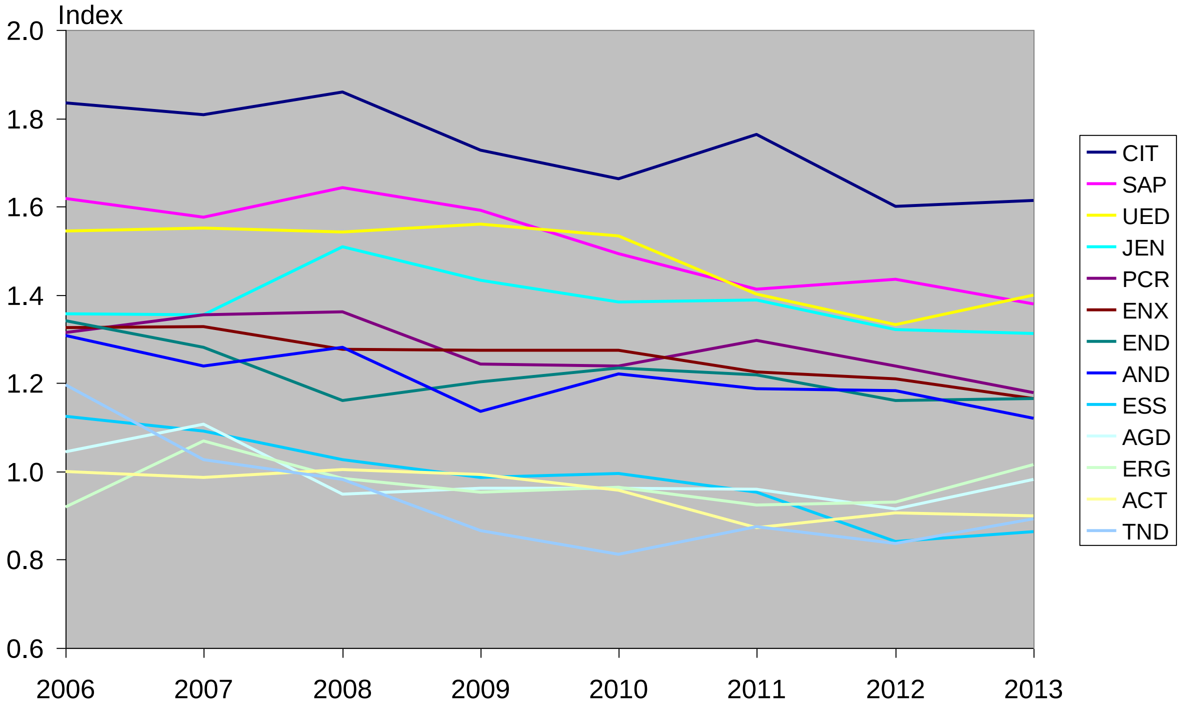
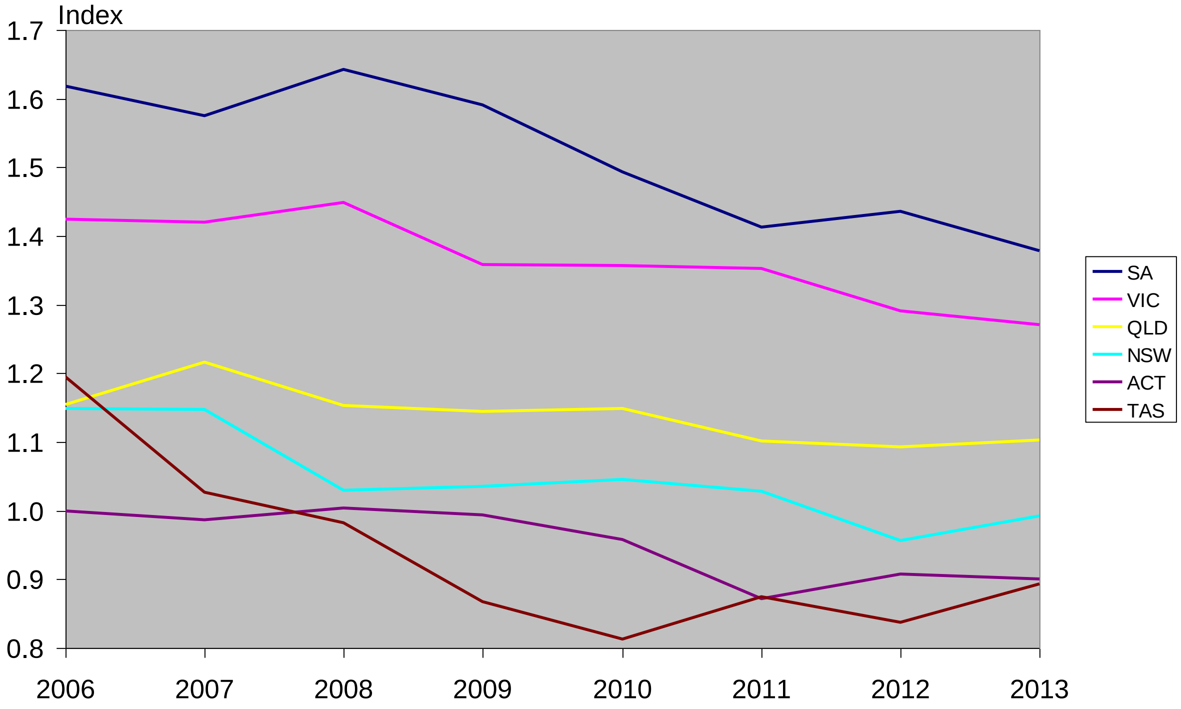


Figure 3.2 **State–level DNSP multilateral total factor productivity indexes, 2006–2013**



Weighted average state–level MTFP indexes for electricity distribution are presented in figure 3.2. South Australia has had the highest MTFP levels over the period, followed by Victoria which was around 10 per cent behind South Australia on average. Queensland was 25 per cent behind the South Australia MTFP level on average, while NSW was just over 30 per cent behind. The ACT and Tasmania were both around 38 per cent below the MTFP level of South Australia on average.

3.5 DNSP MTFP sensitivity analyses

We have undertaken two sensitivity analyses on the specification of MTFP reported in this section. The sensitivity analyses cover:

- the allowance for more complex system structures, and
- MVA conversion factors used.

System complexity

To allow for differences in the complexity of system structures and to put MTFP comparisons on a more like–with–like basis, we have excluded the first stage of two stage transformation at the zone substation level for those DNSPs that have inherited more complex structures and which, as a result, have more ‘upstream’ boundaries with transmission networks[5]. To gauge the impact of this adjustment, we have also calculated MTFP including all transformation at the zone substation level for all DNSPs.

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[5] It should also be noted that Tasmania Networks Distribution (formerly Aurora) has a more ‘downstream’ boundary with transmission than other DNSPs and thus operates at lower voltages and with fewer zone substations than other DNSPs.

Making the adjustment for system complexity leads to small increases in MTFP levels for those DNSPs with more complex system structures (results are presented in appendix B). Compared to the best performer, Energex's and Endeavour's MTFP levels are both increased by around 6 percentage points, Ausgrid's by 3 percentage points, Ergon Energy's by 2 percentage points and Essential Energy's by 1 percentage point when system complexity is allowed for. Ausgrid's MTFP ranking falls by three places when system complexity is not allowed for while rankings for Endeavour, Energex and Ergon Energy each fall by one place. Essential Energy's ranking remains unchanged. The effect is not sufficient to change the conclusions that can be drawn from the analysis.

DNSP–specific versus common MVA conversion factors

In some cases DNSPs have reported a relatively wide range of MVA ratings for lines and cables of the same voltage class. This range could reflect different conductor capacities used by different DNSPs or it could, to some extent, also reflect different bases on which different DNSPs have calculated reported MVA ratings. To test the sensitivity of the results to reported MVA ratings we have also calculated MTFP results based on common MVA ratings using the ratings reported in Parsons Brinckerhoff (2003)[6].

Although there are some changes in MTFP rankings, the two sets of average MTFP results have a Spearman Rank Correlation Coefficient of 0.82 which means the two sets of rankings are very highly correlated[7] (results are presented in appendix B). The predominantly rural DNSPs generally reduce their rankings using the common MVA conversion rates with Essential Energy reducing its ranking by 4 places, SA Power Networks and AusNet Services each reducing their rankings by 2 places, and Ergon Energy by one place. The predominantly urban DNSPs generally increase their rankings. Since we would expect predominantly rural networks to have generally lower capacity conductors than predominantly urban distribution networks, this lends support to generally using the DNSP–specific MVA ratings collected in the RINs. It should be noted that the opex partial productivity results which are the focus of this report are not affected by which MVA ratings are used nor which proxy for capital input quantity is used in the MTFP analysis.

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[6] We use a common rating for overhead SWER of 0.05 MVA per kilometre instead of 0.05 per SWER line as recommended by Parson Brinckerhoff (2003). This is broadly in line with rates reported by the DNSPs and the same as the rate previously used in Lawrence (2005). Rates for voltage classes not reported in Parsons Brinckerhoff (2003) are derived on a pro–rata basis.

[7] The 1 per cent critical value for a two–sided test of there being no correlation is 0.70.

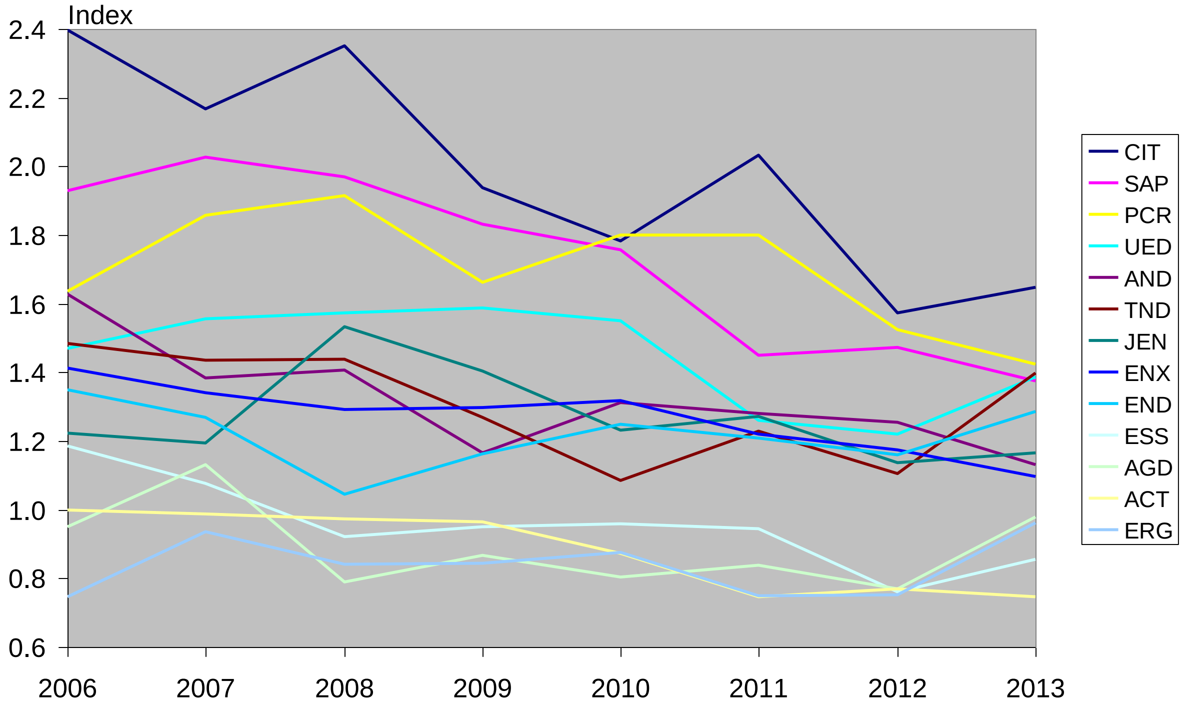
4 OPEX MPFP INDEX RESULTS

We now turn to the DNSP opex MPFP results which are presented in table 4.1 and figure 4.1.

Table 4.1 **DNSP opex multilateral partial factor productivity indexes and annual growth rates, 2006–2013**

DNSP	*Average opex MPFP index level*	*Average annual opex MPFP growth rate*
CIT	1.986	–5.37%
SAP	1.726	–4.84%
PCR	1.702	–2.01%
UED	1.450	–0.84%
AND	1.320	–5.18%
TND	1.305	–0.83%
JEN	1.270	–0.69%
ENX	1.269	–3.62%
END	1.217	–0.67%
ESS	0.957	–4.67%
AGD	0.891	0.46%
ACT	0.883	–4.16%
ERG	0.838	3.62%

Figure 4.1 **DNSP opex multilateral partial factor productivity indexes, 2006–2013**



As discussed in section 3, the DNSP opex MPFP measure we use has five outputs included:

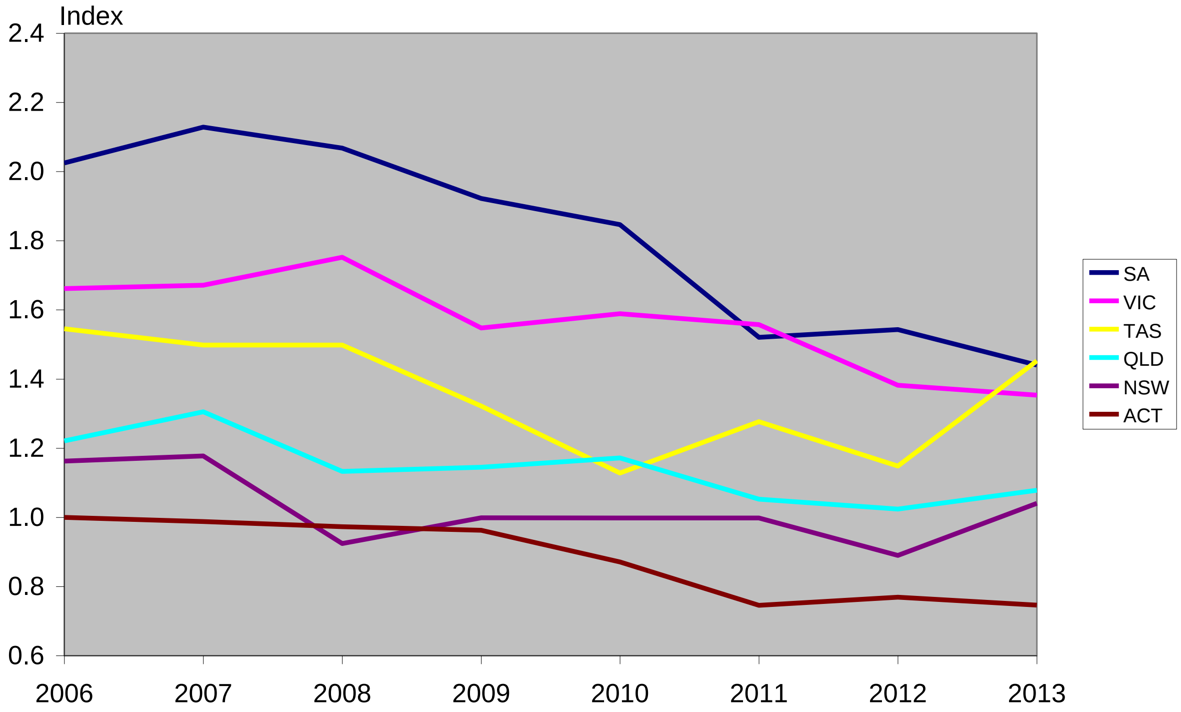
- Energy throughput (with 12.8 per cent share of gross revenue)

- Ratcheted maximum demand (with 17.6 per cent share of gross revenue)
- Customer numbers (with 45.8 per cent share of gross revenue)
- Circuit length (with 23.8 per cent share of gross revenue), and
- (minus) Minutes off–supply (with the weight based on current AEMO VCRs).

The multilateral output quantity index is then divided by an opex input quantity index to form the opex MPFP measure. The opex quantity index is network services opex deflated by a composite labour, materials and services price index.

From table 4.1 and figure 4.1, CitiPower can be seen to have had the highest opex MTFP level on average over the 8 year period, followed by SA Power Networks and Powercor. The other three Victorian DNSPs, the Tasmanian DNSP, Energex and Endeavour form a middle performing group and the other two NSW DNSPs, ActewAGL and Ergon Energy form the lowest performing group in terms of opex MPFP levels.

Figure 4.2 **State–level DNSP opex multilateral partial factor productivity indexes, 2006–2013**



Weighted average state–level opex MPFP indexes for electricity distribution are presented in figure 4.2. South Australia has had the highest opex MPFP levels over the period, followed by Victoria which was around 11 per cent behind South Australia on average. Tasmania and Queensland were around 24 per cent and 37 per cent, respectively, behind the South Australian opex MPFP level, while NSW was around 42 per cent behind and the ACT achieved less than half the opex MPFP level of South Australia.

Opex MPFP has declined for 11 of the 13 DNSPs over the 8 year period with average annual growth rates ranging from 3.6 per cent for Ergon Energy to –5.4 per cent for CitiPower. Significant increases in opex following the February 2009 bushfires have contributed to the reduction in opex MPFP levels for the Victorian DNSPs in the second half of the period. The

Victorian DNSPs were granted step changes averaging nearly 10 per cent in the regulatory period commencing in 2011. Much of this was related to one–off expenditures such as installing line spacers and dampeners.

In table 4.2 we convert the opex MPFP indexes into average efficiency scores where the DNSP with the highest average opex MPFP level is given a value of one and the efficiency score for other DNSPs is the fraction that their average opex MPFP level makes up of the average MPFP level of the most efficient DNSP.

Table 4.2 **DNSP opex efficiency scores and implied opex reductions to reach full efficiency, 2006–2013**

DNSP	*Average opex efficiency score*	*Implied opex reduction to reach full efficiency*
CIT	1.000	0%
SAP	0.869	13%
PCR	0.857	14%
UED	0.730	27%
AND	0.665	34%
TND	0.657	34%
JEN	0.639	36%
ENX	0.639	36%
END	0.613	39%
ESS	0.482	52%
AGD	0.449	55%
ACT	0.445	56%
ERG	0.422	58%

On the assumption that the overall output quantity remained constant, the implied opex reductions for the NSW and ACT DNSPs to achieve full opex efficiency (ie an efficiency score of one) are quite large. Endeavour and Essential Energy would have to reduce their opex by in the order of 39 per cent and 52 per cent, respectively, while Ausgrid and ActewAGL would both have to more than halve their opex usage.

4.1 DNSP opex MPFP sensitivity analyses

We have undertaken three sensitivity analyses on the specification of opex MPFP reported in this section. The sensitivity analyses cover:

- treatment of provisions
- the use of AWOTE in forming the opex price index, and
- additional allowance for operating environment differences.

Treatment of provisions

The opex MPFP results presented thus far include changes in provisions in annual network services opex. We have also calculated opex MPFP indexes excluding changes in provisions. The impact of this change is quite minor for the NSW and ACT DNSPs in terms of efficiency scores and does not lead to a change in rankings. The impact is also quite minor for DNSPs outside of NSW and the ACT although one pair reverse their rankings but the changes in relative opex MPFP levels are minor in all cases. Results are presented in appendix B.

Use of AWOTE instead of WPI

Using the faster growing average weekly ordinary time earnings (AWOTE) index as the price index for the labour component of opex instead of the slower growing wages price index (WPI) has no impact on the average efficiency scores of the DNSPs or their rankings. It does, however, lead to opex MPFP growing somewhat faster than under using the WPI. DNSP average opex MPFP growth annual rates range from –4.7 per cent to 4.3 per cent using AWOTE compared to a range of –5.4 per cent to 3.6 per cent using the WPI.

Allowance for additional operating environment differences

To test whether the model specification was adequately adjusting for differences in network densities (via the output specification) and to see whether other factors not explicitly included in the model had a statistically significant impact on the index number results, we undertook second stage regression analysis of the opex MPFP results.

Two stage regression analysis has the advantage of combining the strengths of both the standard index number based approach to calculating productivity and the econometric approach to adjusting for operating environment effects. In the first stage, the opex MPFP index is calculated and then in the second stage it is regressed against a range of operating environment effects. The main advantage of second stage regression analysis of partial productivity scores is that it has the potential to adjust measured efficiency for a greater number of operating environment factors. It can also be used to check whether direct allowance for operating environment differences within the index number specification adequately allows for these effects. If second stage regression of the opex MPFP indexes against network density variables indicates the coefficients of these variables are not statistically significant, this would indicate adequate allowance for these effects has already been made in the output specification used in forming the opex MPFP indexes.

Coelli, Rao and Battese (1998, p,170) describe the second stage regression process in the following terms:

> ‘In the second stage, the efficiency scores from the first stage are regressed upon the environmental variables. The sign of the coefficients of the environmental variables indicate the direction of the influence, and standard hypothesis tests can be used to assess the strength of the relationship. The second–stage regression can be used to “correct” the efficiency scores for environmental factors by using the estimated regression coefficients to adjust all efficiency scores to correspond to a common level of environment (eg the sample means).’

We have used a linear in logarithms regression[8] of opex MPFP indexes against the following 7 operating environment factors:

- customer numbers (to check whether additional scale effects are significant)

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[8] Using the POOL command in Shazam (Northwest Econometrics 2007) with allowance for first–order autoregression and with panel–corrected standard errors.

- customer, energy and demand network densities
- the share of underground cable length in total circuit kilometres
- the share of single stage transformation capacity in single stage plus the second stage of two stage transformation capacity at the zone substation level, and
- system average interruption duration index (SAIDI)[9].

Table 4.3 **DNSP opex MPFP second stage regression results**

Variable	*Coefficient*	*t–statistic*
Customer numbers	0.073	0.47
Customer density	0.010	0.11
Energy density	–0.365	–0.99
Demand density	0.171	1.43
Share of underground in circuit kms	–0.037	–0.32
Share of single stage transformation	0.157	0.99
SAIDI	–0.050	–0.91
Year (technology proxy)	–0.033	–2.93
Constant	1.533	1.17

The second stage regression results presented in table 4.3 show that neither the scale variable (represented by customer numbers) nor any of the six included operating environment variables (customer density, energy density, demand density, share of underground, share of single stage transformation and SAIDI) are statistically significant. The opex specification used thus appears to adequately allow for these operating environment factors.

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[9] Customer minutes off supply are not included as a negative output in the opex MPFP indexes used in the second stage regression.

5 OPEX COST FUNCTION EFFICIENCY ASSESSMENT

In this section we present our opex cost function econometric estimates and efficiency measurement results. We first outline the opex cost function methodologies used before describing the database we have used. We then present the efficiency assessment results.

5.1 Opex cost function methodologies

While the opex MPFP analysis presented in the preceding section has the advantage of producing robust results even with small datasets, it is a deterministic method that does not facilitate the calculation of confidence intervals. We thus now turn to examine econometric operating cost functions which do facilitate this and which potentially allow the direct inclusion of adjustment for a wider range of operating environment factors.

To outline our methods we begin by defining the following notation:

C = nominal opex;

$Y = (Y_1, Y_2, ..., Y_G)$ = a G×1 vector of output quantities;

$K = (K_1, K_2, ..., K_H)$ = an H×1 vector of capital quantities;

$Z = (Z_1, Z_2, ..., Z_R)$ = an R×1 vector of operating environment factors; and

$W = (W_1, W_2, ..., W_S)$ = an S×1 vector of input prices.

To simplify our notation we define a vector (X) of length $M=G+H+R+S$ which contains these four vectors together:

$X = (Y, K, Z, W) = (X_1, X_2, ..., X_M)$ = an M×1 vector of output quantities, capital quantities, operating environment factors and input prices.

We use lower case notation to define the natural logarithms of variables. For example, $x_1 = \log(X_1)$.

5.1.1 Least squares opex cost function methods

The two most commonly used functional forms in econometric estimation of cost functions are the Cobb–Douglas and translog functional forms. These functions are linear in logs and quadratic in logs, respectively.

The Cobb–Douglas cost function may be written as:

$$c_{it} = \beta_0 + \sum_{m=1}^{M} \beta_m x_{mit} + \lambda_1 t + v_{it}, \qquad (5.1)$$

while the translog cost frontier may be specified as:

$$c_{it} = \beta_0 + \sum_{m=1}^{M} \beta_m x_{mit} + 0.5 \sum_{m=1}^{M} \sum_{l=1}^{M} \beta_{ml} x_{mit} x_{lit} + \lambda_1 t + v_{it}, \qquad (5.2)$$

where subscripts i and t denote DNSP and year, respectively. Furthermore, the regressor variable 't' is a time trend variable used to capture the effects of year to year technical change (and other factors not modelled that have changed over time such as increasing regulatory obligations), v_{it} is a random disturbance term and the Greek letters denote the unknown parameters that are to be estimated.

One can then include a set of N–1 dummy variables into this model to capture efficiency differences across the N firms in the sample (see Pitt and Lee 1981 and Kumbhakar and Lovell 2000). These dummy variables are defined as:

$D_{nit} = 1$ when $n = i$, and is 0 otherwise, $(n = 2,...,N)$.

Including these dummy variables into models (5.1) and (5.2) we obtain

$$c_{it} = \beta_0 + \sum_{m=1}^{M} \beta_m x_{mit} + \sum_{n=2}^{N} \delta_n D_{nit} + \lambda_1 t + v_{it} \qquad (5.3)$$

and

$$c_{it} = \beta_0 + \sum_{m=1}^{M} \beta_m x_{mit} + 0.5 \sum_{m=1}^{M} \sum_{l=1}^{M} \beta_{ml} x_{mit} x_{lit} + \sum_{n=2}^{N} \delta_n D_{nit} + \lambda_1 t + v_{it}, \qquad (5.4)$$

respectively.

In this study, the models in equations (5.3) and (5.4) are estimated using a variant of *ordinary least squares* (OLS) regression, where OLS is applied to data that has been transformed to correct for serial correlation (assuming a common autoregressive parameter across the DNSPs). We have also chosen to report *panel–corrected standard errors*, where the standard errors have been corrected for cross–sectional heteroskedasticity. The estimation methods used follow those described in Beck and Katz (1995) and Greene (2000, Ch15) and have been calculated using the *xtpcse* command in *Stata Release 13* (StataCorp 2013).

The estimated coefficients of the dummy variables are then used to predict firm–level cost efficiency scores as:

$$CE_n = \exp[\min(\hat{\delta}_n) - \hat{\delta}_n], \quad (n = 1, 2,...,N), \qquad (5.5)$$

where $\delta_1 = 0$ by definition because it is arbitrarily chosen as the base firm.

These cost efficiency scores vary between zero and one with a value of one indicating full cost efficiency, while a value of 0.8 (for example) would imply that the inefficient firm could reduce its opex by 20 per cent and still produce the same level of output.

As discussed in previous sections, there are many explanatory variables that could be of interest in this study. For example, output quantity variables could include energy, customer numbers, network length and maximum demand (G=4); capital quantity variables could include lines, cables, and transformers and other (H=3); operating environment variables could include percentage of underground lines, percentage of two stage transformation, network density and supply reliability (R=4); and input price variables could include labour, materials and services (S=3), providing a total of M=4+3+4+3=14 variables.

These variables would imply the need to estimate $M + N + 1$ parameters for the Cobb–

Douglas function and $M + N + 1 + M(M+1)/2$ for the translog function. If M=14 and N=13, this equates to 28 parameters for the Cobb–Douglas and 133 parameters for the translog. It is tempting to choose the Cobb–Douglas functional form because it involves the estimation of fewer parameters. However, given that it only provides a first–order approximation to the true unknown functional form, it has a number of limitations. For example, it assumes that output elasticities remain constant over all data points, and hence that scale economies must also be constant across firms. Furthermore, in multi–output settings it cannot accommodate a production possibility curve that is concave to the origin (i.e. one which incorporates the property of diminishing returns). Hence, we will use the translog model as our first choice in the least squares analysis, and then conduct a formal statistical test to see if the restrictions implicit in the Cobb–Douglas apply in our data.

5.1.2 Stochastic frontier analysis opex cost function methods

The above least squares dummy variables approach to estimating cost functions and predicting firm–level cost efficiencies requires access to panel data and an assumption that cost inefficiencies are invariant over time. An alternative approach (that can also be applied to cross–sectional data) is the stochastic frontier analysis (SFA) method proposed by Aigner, Lovell and Schmidt (1977), which we outline below. Following Pitt and Lee (1981), Battese and Coelli (1988) and Kumbhakar and Lovell (2000), we add a one–sided, time–invariant inefficiency disturbance term to the cost function models in (5.3) and (5.4) to obtain a Cobb–Douglas stochastic cost frontier:

$$c_{it} = \beta_0 + \sum_{m=1}^{M} \beta_m x_{mit} + \lambda_1 t + v_{it} + u_i , \tag{5.6}$$

and a translog stochastic cost frontier:

$$c_{it} = \beta_0 + \sum_{m=1}^{M} \beta_m x_{mit} + 0.5 \sum_{m=1}^{M} \sum_{l=1}^{M} \beta_{ml} x_{mit} x_{lit} + \lambda_1 t + v_{it} + u_i , \tag{5.7}$$

where it is assumed that the random disturbance term v_{it} is normally distributed $N(0, \sigma_v^2)$ and independent of the one-sided inefficiency disturbance term u_i, which is assumed to have a truncated normal distribution $\left| N(\mu, \sigma_u^2) \right|$.

Given these distributional assumptions, the unknown parameters in models (5.6) and (5.7) can be estimated using Maximum Likelihood Estimation (MLE) methods. In this study we do this using the *xtfrontier* command in *Stata Release 13*.

The cost efficiency score of the *n*–th firm is defined as:

$$CE_n = \exp[u_n], \quad (n = 1, 2, ..., N). \tag{5.8}$$

However, given that u_n is unobservable, *Stata* makes use of the results in Battese and Coelli (1988) to predict the cost efficiency scores using the conditional expectation:

$$CE_n = E[\exp(u_n) \mid (v_n + u_n)], \quad (n = 1, 2, ..., N), \tag{5.9}$$

where $v_n = (v_{n1}, v_{n2} ... v_{nT})$.

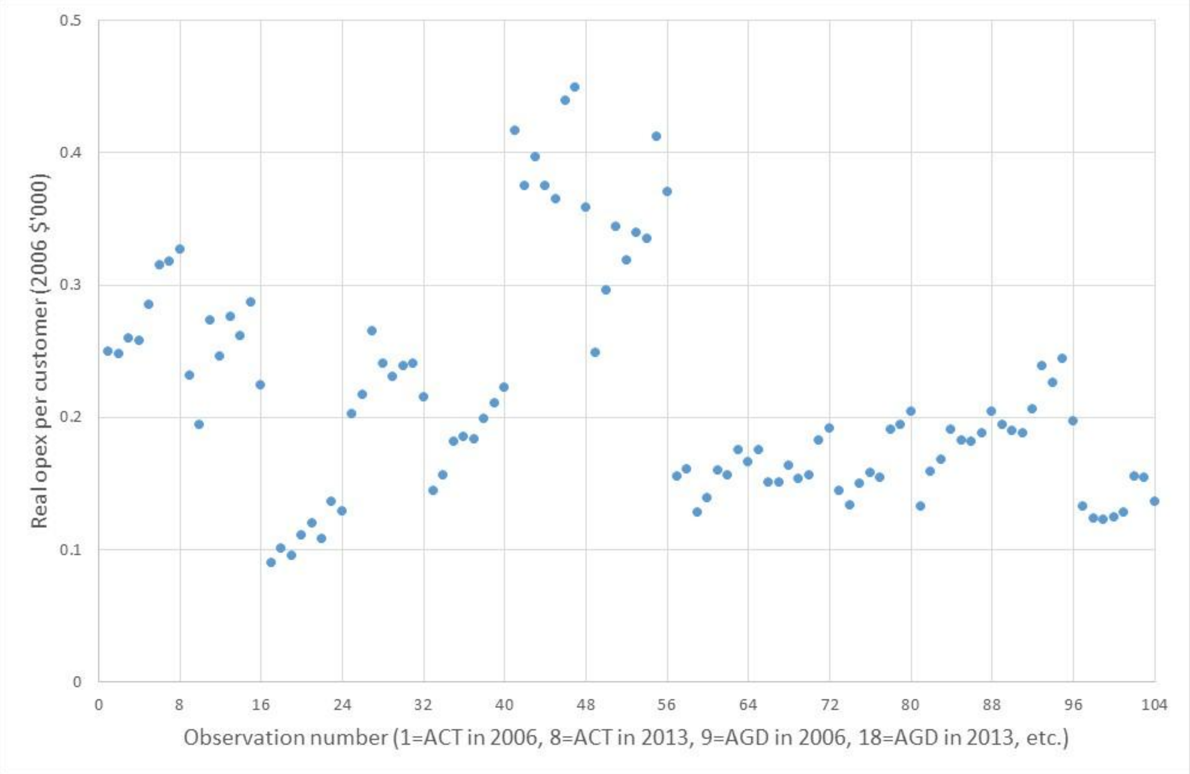
Confidence intervals for these predictions can be obtained using the formula presented in Horrace and Schmidt (1996). We have calculated these using the *frontier_teci* Stata ado code written by Merryman (2010).

Because the SFA method provides a direct estimate of opex cost efficiency relative to an estimated frontier, it is generally preferred to the least squares method.

5.2 Databases used in the analysis

We first examined the scope to estimate an opex cost function using only the AER's economic benchmarking RIN data on 13 DNSPs over an 8 year period (104 observations in total). However, this produced econometric estimates that were relatively unstable. We tried both Cobb–Douglas and translog functional forms using both SFA and LSE methods and tried a range of different sets of regressor variables. We observed that small changes in variable sets (and methods and functional forms) could have a substantial effect on the output elasticity estimates obtained and the subsequent efficiency measures derived from these models.

Figure 5.1 **Real Opex per Customer for Australian DNSPs, 2006–2013**



After a careful analysis of the economic benchmarking RIN data we concluded that there was insufficient variation in the data set to allow us to reliably estimate even a simple version of an opex cost function model (eg a Cobb–Douglas LSE model with three output variables and two operating environment variables). The sample data plotted in figure 5.1 provides an illustration of the problem with the data from an econometric perspective. In essence, the time series pattern of the data is quite similar across the 13 DNSPs. Hence, in this case, there is little additional data variation supplied by moving from a cross–sectional data set of 13 observations to a panel data set of 104 observations. As a consequence we are essentially trying to use a data set with 13 observations to estimate a complex econometric model. The 'implicit' degrees of freedom are near zero or even negative in some cases, producing model estimates that are relatively unstable and unreliable.

We thus concluded that to obtain robust and reliable results from an econometric opex cost function analysis we needed to look to add additional cross sectional observations which meant drawing on overseas data, provided largely comparable DNSP data were available. Similar types of electricity DNSP productivity analysis have previously been undertaken in New Zealand, the Canadian province of Ontario and the United States. We therefore examined the scope to include data from these jurisdictions in the opex cost function analysis.

5.2.1 Data from New Zealand and Ontario

New Zealand has a relatively long history of productivity measurement of electricity DNSPs. Productivity measures have been used in economic regulation in New Zealand since 2003 utilising detailed annual Information Disclosure Data which is available from the mid–1990s onwards. We have undertaken a number of DNSP productivity studies for the New Zealand Commerce Commission previously (eg Lawrence 2003 and Economic Insights 2009) and have just completed a study using a similar output and input specification to that reported in section 3 (Economic Insights 2014a). The database used in Economic Insights (2014a) is in the public domain and includes data for just under 30 DNSPs for 18 years each (from 1996 to 2013). Given that the New Zealand database has been constructed in a largely similar fashion to the AER's economic benchmarking RIN database in terms of variable coverage, it is a prime candidate for use in supplementing the number of observations available from the RIN database.

The other jurisdiction that has a relatively long and consistent history of electricity DNSP productivity measurement is Ontario. Pacific Economic Group Research (PEGR 2013) recently undertook productivity benchmarking work for the Ontario Energy Board (OEB) using a similar output specification to that used in section 3 above. The OEB has put the database used in the public domain. While the Ontario database has similar coverage of outputs (other than reliability) to that used above and has good detail on opex, it is much more limited with regard to capital input and operating environment factor variables. Asset values are based on historic cost, for example, and, while there is data on the number of transformers, there is no data on transformer capacity. While Ontario's climate is somewhat different to Australia's, a significant attraction of the OEB database is the number of observations it offers with data for 73 DNSPs over 11 years from 2002 to 2012.

5.2.2 Data from the United States

The other jurisdiction that has a relatively long history of electricity DNSP data collection and reporting is the United States. Productivity measurement has been used in DNSP regulation in some US states. The AER engaged Pacific Economics Group to examine the scope to construct a comparable dataset for US DNSPs to that available from the economic benchmarking RIN. This exercise has highlighted the significant limitations of current US data collection and reporting. While a large amount of data is reported in the US, this mainly concentrates on financial variables and many quantity measures that are fundamental to productivity measurement are either not reported at all or are not reported consistently. For example, there is very little line length data available for the US and what there is available is typically not consistently reported and is for route length rather than circuit length. There is also no data available for distribution transformer capacity and no consistently reported data for key output variables including maximum demand and reliability. PEG (2014) was only able to assemble data for 15 US DNSPs that had the minimal data required for two or more years. However, these data are not generally comparable in terms of coverage and definition with the New Zealand and Ontario data and did not support our preferred specification using Australian data. A further complication with the US data is that many network businesses are vertically integrated with generation and other activities and thus cost allocation issues can be significant. Given that the US data is relatively incomplete in key areas and is less comparable with the Australian DNSP data, we decided not to include US data in our analysis.

5.2.3 The databases used

Our review of overseas electricity DNSP databases indicated that the most comparable and consistent DNSP data to supplement the RIN data with were available from the New Zealand and Ontario regulators. However, one difference between Australia and New Zealand and Ontario is that New Zealand and Ontario both have a small number of larger DNSPs and a large number of small DNSPs, reflecting the evolution of DNSPs in both jurisdictions from the local government level. We have therefore worked with several different databases spanning Australia, New Zealand and Ontario with differing DNSP size coverage in terms of customer numbers. In all cases all 13 Australian DNSPs are included it the analysis but having customer number cut–offs of at least 100,000 customers, at least 50,000 customers, at least 20,000 customers and at least 10,000 customers for New Zealand and Ontario leads to differing size databases as shown in table 5.1.

Table 5.1 **Database DNSP numbers using different customer number cut–offs**

Version (by number of observations)	*Customer number criterion*	*Australia number of DNSPs*	*New Zealand number of DNSPs*	*Ontario number of DNSPs*	*Total number of DNSPs*
Full	all included	13	27	73	113
Large	>10,000	13	23	50	86
Medium	>20,000	13	18	37	68
Small	>50,000	13	6	18	37
Very small	>100,000	13	3	9	25

Although longer time series are available for New Zealand and Ontario, we have used a balanced panel covering the last 8 years of available data for each DNSP. Australian and NZ

DNSP data thus runs from 2006–2013 while Ontario DNSP data runs from 2005–2012. We have focused on the large, medium and small versions of the dataset which cover totals of 86, 68 and 37 DNSPs and 688, 544 and 296 observations, respectively.

We use OECD GDP purchasing power parities to convert dollar value series from New Zealand and Canadian dollars to Australian dollars. We cannot be certain that we have exactly the same opex coverage across the three countries so we have included country dummy variables for New Zealand and Ontario to pick up differences in opex coverage (as well as systematic differences in operating environment factors such as the impact of harsher winter conditions in Ontario). The country dummies will also pick up differences in conversion factors not adequately captured by our use of OECD GDP purchasing power parities to convert financial variables to Australian dollars.

Opex input price indexes were calculated in a broadly analogous manner across the three jurisdictions with separate inclusion of a labour price index and a materials and services input price proxy. For Australia we use the WPI for labour and the five PPIs outlined in section 3.2. For New Zealand we use the WPI for labour and the overall economy–wide PPI for materials and services. And for Ontario we use average weekly earnings for labour and the gross domestic product implicit price deflator for materials and services.

5.3 Opex cost function estimates

The econometric results reported in this section are obtained using the dataset comprising Australian, New Zealand and Ontario DNSPs. As noted above, because of the smaller average sizes of the DNSPs in the New Zealand and Ontario data, we have investigated a range of datasets of different sizes – namely the Full, Large, Medium and Small datasets (as detailed above) with the Small data set omitting many of the smaller DNSPs while the Full dataset contains all available DNSPs.

It should be emphasised that the reason for the inclusion of the overseas data is to increase the sample size so as to obtain more robust estimates of the slope coefficients in the cost function. This will then allow us to undertake more robust opex efficiency comparisons among the Australian DNSPs. Benchmarking the Australian DNSPs against their international counterparts is not one of our objectives. We have hence explicitly included country–level dummy variables (for New Zealand and Ontario) in our cost functions to control for possible cross–country differences/inconsistencies in accounting definitions, price measures, regulatory and physical operating environments, etc. As a consequence, all cost efficiency scores obtained are relative to Australian best practice and NOT relative to international best practice.

We have also chosen to omit opex input price variables from the set of cost function regressors and instead use price indexes (detailed above) to obtain a measure of real opex by deflating the nominal opex measures and we then use real opex as the dependent variable in these regressions. Given that many Australian DNSPs face quite similar opex input prices (for labour, materials and services), there would be minimal variation in these price data, meaning that there would be little value to be gained from including these extra price variables as regressor variables and subsequently reducing the degrees of freedom in the models.

With regard to operating environment variables, due to the lack of operating environment data available for Ontario, we were limited to the inclusion of the share of underground cable length in total line and cable length (*ShareUGC* variable) in this instance.

With regard to capital variables, due to the lack of comparable capital data available for Ontario, we were unable to include a capital measure in this instance. However, we do note that in the Australian data the aggregate capital quantity variable formed by aggregating physical measures of lines, cables and transformers and using annual user costs as weights has a very high correlation of 0.95 with the energy delivered (*Energy*) output and of 0.94 with the ratcheted maximum demand (*RMDemand*) output. Similarly the constant price capital stock variable had a correlation of 0.88 with both the customer number (*CustNum*) and *RMDemand* output variables. This suggests that the omission of a capital input variable is unlikely to have a significant bearing on the results as it is likely to be highly correlated with the included output variables.

The subsequent empirical model that we have estimated involves using real opex as the dependent variable and having a set of regressor variables involving four output measures (*Energy*, *CustNum*, circuit length (*CircLen)* and *RMDemand*), one operating environment variable (*ShareUGC*), a time trend variable used to capture the effects of technical change over time, two country–level dummy variables (for New Zealand and Ontario) and 12 Australian DNSP–level dummy variables (in the LSE model). The outputs included are similar to those included in the MPFP index number analysis in section 4 (with the exception of minutes off supply because it is not consistently available across the three countries).

The above model was estimated using the Full, Large, Medium and Small data sets using the Cobb–Douglas and translog functional forms using both LSE and SFA methods (a total of 16 models). It was observed that the estimated coefficients of either *Energy* or *RMDemand* were generally insignificant in these models. Upon investigation it was found that the sample correlation coefficient between these two variables was larger than 0.99 and the behaviour of their coefficients was almost certainly a consequence of multicollinearity problems (ie these variables are so closely related that the model is not able to distinguish their effects). We hence decided to drop *Energy* from the model and re–estimated these 16 models including three output variables (*CustNum*, *CircLen* and *RMDemand*).

This model performs consistently well with good significance levels on the estimated coefficients and the coefficients all being of the expected sign. Furthermore, the opex cost efficiency results obtained from the Cobb–Douglas LSE and SFA models and the translog LSE model are all relatively similar and are relatively insensitive to the dataset used and changes in specification such as moving from four to three outputs. The translog SFA model produced somewhat different efficiency scores for three of the Australian DNSPs.

We next investigated the monotonicity properties of the translog models (this requirement states that an increase in output can only be achieved with an increase in cost – since the translog model includes second order terms we need to check the sign of the output cost elasticities to ensure they are positive so that an increase in output leads to an increase in opex cost, all else equal). For the large dataset, all bar one of the Australian DNSPs satisfied monotonicity for the LSE model (and that violation was quite small) but 11 of the Australian DNSPs had monotonicity violations for the SFA model (some of which were quite large). For the medium dataset, all the Australian DNSPs satisfied monotonicity for the LSE model but 7 of the Australian DNSPs had monotonicity violations for the SFA model. For the small dataset, monotonicity violations were larger and more widespread for the Australian DNSPs in both the LSE model and the SFA model. We therefore conclude that the medium dataset produces the most robust and reliable results (although the large dataset comes close to it). We also conclude that the translog SFA model does not produce robust and reliable results in any of the datasets and it is therefore not further considered.

Given this result and our discussion of the relative merits of the various methods, we select the SFA Cobb–Douglas model as our preferred model. The econometric estimates of the SFA Cobb–Douglas model obtained using the medium dataset are presented in table 5.2, where we observe that the majority of estimated coefficients have *t*–ratios in excess of 1.96, indicating that they are statistically different from zero at the five per cent level of significance.

Table 5.2 **SFA Cobb–Douglas cost frontier estimates using medium dataset**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.667	0.091	7.360
ln(CircLen)	0.106	0.038	2.780
ln(RMDemand)	0.214	0.080	2.660
ln(ShareUGC)	–0.131	0.034	–3.850
Year	0.018	0.002	9.120
Country dummy variables:			
New Zealand	0.050	0.101	0.490
Ontario	0.157	0.074	2.110
Constant	–26.526	3.944	–6.730
Variance parameters:			
Mu	0.385	0.009	5.600
SigmaU squared	0.039	0.009	4.153
SigmaV squared	0.010	0.001	15.396
LLF			372.620

We first discuss the coefficients of the three output variables. All three output coefficients have the expected positive signs, implying that extra output incurs extra costs. The estimated coefficient of the *CustNum* output is 0.667, implying that a 1 per cent increase in customer numbers will lead to a 0.667 per cent increase in opex (all else held constant). The corresponding coefficients of *CircLen* and *RMDemand*, are 0.106 and 0.214, respectively, implying elasticities of 0.106 per cent and 0.214 per cent, respectively.

When added together, these three output elasticity estimates provide a total elasticity measure of 0.667+0.106+0.214=0.987, implying that a 1 per cent increase in all outputs will lead to a 0.987 per cent increase in costs, implying near constant returns to scale.

The coefficient of the *ShareUGC* operating environment variable also has an elasticity interpretation. The estimated value of –0.131, indicates that a 1 per cent increase in the share of underground cabling will lead to a 0.131 per cent decrease in opex (all else held constant). This negative relationship is as one would expect, given that underground cables are less prone to damage by climatic events, etc.

The coefficient of the *Year* (time trend) variable is 0.018, indicating that costs *increase* at a rate of 1.8 per cent per year (all else held constant) during this sample period. This implies technical *regress* as opposed to technical *progress*. This is not what one would normally expect to find in most industries, where rates of technical *progress* of 1 to 2 per cent are not uncommon (see, for example, Economic Insights 2012b, 2014b). The finding is, however, consistent with the trend decline in opex MPFP reported in the index number analysis in section 4 and could result, for example, from increasing regulatory obligations over time which are not excluded from the data.

Table 5.3 **LSE Cobb–Douglas cost function estimates using medium dataset**

Variable	*Coefficient*	*Standard error*	*t–ratio*
log(Custnum)	0.652	0.067	9.740
log(CircLen)	0.097	0.029	3.290
log(RMDemand)	0.253	0.067	3.790
log (ShareUGC)	–0.201	0.023	–8.560
Year	0.020	0.003	6.170
Country dummy variables:			
New Zealand	–0.553	0.052	–10.630
Ontario	–0.416	0.054	–7.720
DNSP dummy variables:			
AGD	–0.206	0.114	–1.810
CIT	–0.947	0.089	–10.620
END	–0.508	0.077	–6.560
ENX	–0.527	0.065	–8.140
ERG	–0.392	0.094	–4.170
ESS	–0.544	0.109	–4.980
JEN	–0.657	0.085	–7.770
PCR	–1.031	0.082	–12.620
SAP	–0.852	0.082	–10.450
AND	–0.803	0.081	–9.890
TND	–0.768	0.084	–9.140
UED	–0.859	0.078	–11.060
Constant	–29.036	6.370	–4.560
R–Square			0.994

The econometric estimates obtained for the LSE models (Cobb–Douglas and translog) using the medium dataset are also presented in Tables 5.3 and 5.4. It is reassuring to note that the estimates of the elasticities and technical change measures are very similar across these two functional forms and also very similar to those obtained in the SFA model.[10] We include

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[10] It is important to note that the output variables have been mean–corrected prior to estimation (in all the econometric models in this report). This does not change the substance of the empirical results in any way, but

dummy variables for each of the Australian DNSPs other than ActewAGL (as well as the separate country dummy variables for New Zealand and Ontario DNSPs). A significantly negative dummy variable coefficient would therefore indicate that the DNSP was significantly lower cost (ie more cost efficient) than ActewAGL while a significantly positive dummy variable coefficient would indicate the DNSP was significantly higher cost (ie less cost efficient) than ActewAGL. The DNSP dummy variable coefficients are converted into efficiency scores in the next section. Overall we note that the large majority of estimated coefficients have *t*–ratios in excess of 1.96, as seen in the SFA results.

Table 5.4 **LSE translog cost function estimates using medium dataset**

Variable	*Coefficient*	*Standard error*	*t–ratio*
log(Custnum)=x1	0.580	0.079	7.300
log(CircLen)=x2	0.093	0.031	2.990
log(RMDemand)=x3	0.299	0.071	4.200
x1*x1/2	–0.223	0.319	–0.700
x1*x2	0.187	0.115	1.640
x1*x3	0.079	0.242	0.330
x2*x2/2	–0.032	0.044	–0.720
x2*x3	–0.147	0.089	–1.640
x3*x3/2	0.103	0.197	0.520
ln(ShareUGC)	–0.178	0.028	–6.430
Year	0.020	0.003	6.420
Country dummy variables:			
New Zealand	–0.633	0.056	–11.280
Ontario	–0.514	0.056	–9.120
DNSP dummy variables:			
AGD	–0.445	0.129	–3.440
CIT	–0.983	0.087	–11.320
END	–0.680	0.083	–8.180
ENX	–0.740	0.080	–9.250
ERG	–0.463	0.120	–3.860
ESS	–0.691	0.135	–5.120
JEN	–0.621	0.093	–6.680
PCR	–1.139	0.087	–13.160
SAP	–1.001	0.091	–11.020
AND	–0.892	0.092	–9.750
TND	–0.764	0.084	–9.130
UED	–0.886	0.093	–9.570
Constant	–29.686	6.233	–4.760
R–Square			0.994

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has the advantage that it allows one to interpret the translog first order coefficients as elasticities at the sample means, which saves considerable secondary calculations.

With regard to the LSE translog estimates in table 5.4, it is interesting to note that all of the six second–order output coefficients have t–ratios less than 1.96 in value, indicating that they are (individually) statistically insignificant from zero. A joint test of the statistical significance of these six parameters can also be conducted. In essence, this is a test between the Cobb–Douglas and translog functional form because the Cobb–Douglas is a special case of the translog where the second–order coefficients have been set to zero. A likelihood ratio test was conducted and it was found that the calculated value of 30.2 exceeded the 95 per cent table value of the Chi–square distribution (with six degrees of freedom) of 12.6, leading us to reject the null hypothesis of the Cobb–Douglas in favour of the translog form for the LSE method. This apparent contradiction between the individual t–ratios and the joint Chi–square test can be explained by the fact that the squares and cross products are highly correlated leading to large standard errors on these estimated coefficients and hence low (individual) t–ratios.

5.4 Opex cost function efficiency measures

Opex cost efficiency scores are calculated directly in the SFA Cobb–Douglas estimation process. For the LSE methods, some transformation of the dummy variable coefficients is required as set out in equation (5.5) above. Recall that an opex cost efficiency score of one implies the DNSP is fully efficient and scores less than one are progressively less efficient.

The opex cost efficiency scores (derived using the medium dataset) for the Australian DNSPs for the Cobb–Douglas SFA model and for the Cobb–Douglas and translog LSE models are presented in table 5.5, along with the implied opex reductions to reach full efficiency assuming that output remained unchanged.

Table 5.5 **Cost efficiency scores using medium dataset**

	Opex efficiency score			*Implied opex reduction to reach full efficiency*		
DNSP	*SFA CD*	*LSE CD*	*LSE TL*	*SFA CD*	*LSE CD*	*LSE TL*
ACT	0.399	0.357	0.320	60%	64%	68%
AGD	0.447	0.438	0.500	55%	56%	50%
CIT	0.950	0.920	0.856	5%	8%	14%
END	0.593	0.593	0.632	41%	41%	37%
ENX	0.618	0.604	0.671	38%	40%	33%
ERG	0.482	0.528	0.509	52%	47%	49%
ESS	0.549	0.615	0.639	45%	39%	36%
JEN	0.718	0.688	0.595	28%	31%	40%
PCR	0.946	1.000	1.000	5%	0%	0%
SAP	0.844	0.836	0.871	16%	16%	13%
AND	0.768	0.796	0.781	23%	20%	22%
TND	0.733	0.769	0.687	27%	23%	31%
UED	0.843	0.842	0.776	16%	16%	22%
Mean	0.684	0.691	0.680	32%	31%	32%

We note that the mean SFA CD cost efficiency score is 0.68, indicating that the average DNSP could potentially reduce its opex by approximately 32 per cent and still produce the same level of output (assuming that all operating environment factors have been captured by the model). We also observe that the efficiency scores across all three econometric models are relatively close to each other for each DNSP. This similarity in results, despite the differing methods used, further reinforces our confidence in the results.

ActewAGL is seen to be the least opex efficient, followed closely by Ausgrid, Ergon Energy, Endeavour, Essential Energy and Energex. The most efficient opex performers are seen to be Powercor, CitiPower, SA Power Networks, United Energy and AusNet Services[11].

It is important to note that these efficiency measures are predictions from a statistical model. The degree of precision involved can be indicated by constructing confidence intervals around these predictions. The 95 per cent confidence intervals for the cost efficiency predictions obtained from our preferred model (SFA Cobb–Douglas) are presented in table 5.6.

Table 5.6 **Confidence intervals for SFA Cobb–Douglas cost efficiency measures using medium dataset**

DNSP	*Cost efficiency score*	*95% lower bound*	*95% upper bound*
ACT	0.399	0.373	0.427
AGD	0.447	0.418	0.478
CIT	0.950	0.894	1.026
END	0.593	0.555	0.635
ENX	0.618	0.578	0.662
ERG	0.482	0.450	0.516
ESS	0.549	0.513	0.587
JEN	0.718	0.672	0.769
PCR	0.946	0.888	1.019
SAP	0.844	0.789	0.903
AND	0.768	0.718	0.822
TND	0.733	0.686	0.785
UED	0.843	0.788	0.902
Mean	0.399	0.373	0.427

The 95 per cent confidence intervals around the efficiency scores are relatively narrow and are generally around plus and minus 7 per cent of the efficiency score itself (as opposed to percentage points). The relatively large size of the medium database, with 544 observations, allows the efficiency scores to be estimated relatively accurately.

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[11] Formerly operating as SP AusNet up until August 2014.

6 OPEX PFP GROWTH FORECASTS

In addition to assessing DNSP opex efficiency levels, economic benchmarking can also play an important role in quantifying the feasible rate of opex partial productivity growth that a DNSP can be expected to achieve over the next regulatory period. This forms one of the three components of the rate of change formula set out in equation (1.2).

6.1 Opex partial productivity forecasting methodology

To forecast future opex partial productivity growth we use an approach similar to that presented in Pacific Economics Group (2004), Lawrence (2007b) and Economic Insights (2012b, 2014b). The starting point for this analysis is the following relationship between a DNSP's actual opex, C_{OM}, and its efficient opex, C^*_{OM}:

$$C_{OM} = C^*_{OM}.\eta \qquad (6.1)$$

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

$$C^*_{OM} = g(W, Y, K, Z, T) \qquad (6.2)$$

Totally differentiating (6.2) with respect to time produces the following:

$$\dot{C}^*_{OM} = (\sum_i \varepsilon_{Y_i}.\dot{Y}_i + \sum_j \varepsilon_{W_j}.\dot{W}_j + \sum_m \varepsilon_{K_m}.\dot{K}_m + \sum_n \varepsilon_{Z_n}.\dot{Z}_n) + \dot{g} \qquad (6.3)$$

The ε coefficients are elasticities of opex cost with respect to the variable, and the dot over a variable represents the variable's growth rate. Combining equations (6.1) and (6.3) we get:

$$\dot{C}_{OM} = (\sum_i \varepsilon_{Y_i}.\dot{Y}_i + \sum_j \varepsilon_{W_j}.\dot{W}_j + \sum_m \varepsilon_{K_m}.\dot{K}_m + \sum_n \varepsilon_{Z_n}.\dot{Z}_n) + \dot{g} + \dot{\eta} \qquad (6.4)$$

The growth rate in actual opex is the sum of:

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

Applying Shephard's Lemma (which states that the derivative of the efficient cost with respect to an input price is equal to the efficient quantity of that input), the elasticity of efficient cost with respect to the price of each input can be shown to be equal to the optimal cost share of that input in the minimum cost combination of inputs (SC^*_j). Equation (6.4) can be rewritten as:

$$\dot{C}_{OM} = \sum_i \varepsilon_{Y_i} . \dot{Y}_i + \dot{W}_{OM} + \sum_m \varepsilon_{K_m} . \dot{K}_m + \sum_n \varepsilon_{Z_n} . \dot{Z}_n + \dot{g} + \dot{\eta} \tag{6.5}$$

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

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

$$\dot{Y}^{\varepsilon} = \sum_j (\varepsilon_j / \sum \varepsilon_j) \dot{Y}_j \tag{6.6}$$

Thus $(\sum_i \varepsilon_{Y_i}) \dot{Y}^{\varepsilon} = \sum_i \varepsilon_{Y_i} . \dot{Y}_i$, which is substituted into (6.5):

$$\dot{C}_{OM} = (\sum_i \varepsilon_{Y_i}) \dot{Y}^{\varepsilon} + \dot{W}_{OM} + \sum_m \varepsilon_{K_m} . \dot{K}_m + \sum_n \varepsilon_{Z_n} . \dot{Z}_n + \dot{g} + \dot{\eta} \tag{6.7}$$

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

$$\dot{PFP}_{OM} = \dot{Y}^{\varepsilon} - \dot{X}_{OM} \tag{6.8}$$

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

$$\dot{X}_{OM} = \dot{C}_{OM} - \dot{W}_{OM} \tag{6.9}$$

Substituting (6.9) into (6.8) and using (6.7) we have:

$$\begin{aligned} \dot{PFP}_{OM} &= \dot{Y}^{\varepsilon} + \dot{W}_{OM} - \dot{C}_{OM} \\ &= \{1 - (\sum_i \varepsilon_{Y_i})\} \dot{Y}^{\varepsilon} - \sum_m \varepsilon_{K_m} . \dot{K}_m - \sum_n \varepsilon_{Z_n} . \dot{Z}_n - \dot{g} - \dot{\eta} \end{aligned} \tag{6.10}$$

Equation (6.10) provides an objective basis for forecasting future opex partial productivity growth based on estimated industry characteristics and DNSP–specific output and non–opex input changes. The partial productivity of opex can be seen from (6.10) to incorporate a range of factors including scale economies, capital interaction effects, the impact of changes in operating environment factors, technological change and changes in efficiency levels. No additional allowance, thus, needs to be made for any of these factors as they should be captured by the change in opex partial productivity.

6.2 Opex partial productivity growth forecasts

To operationalise equation (6.10) we require parameter estimates for an operating cost function from which we can derive the necessary elasticities and forecasts of future output growth, non–opex input growth and changes in operating environment factors. The combined term $-(\dot{g} + \dot{\eta})$ in equation (6.10) is estimated by the coefficient of the estimated opex function with respect to time.

We use the preferred Cobb–Douglas SFA opex cost function coefficient estimates presented in table 5.2 and forecasts of output components and operating environment factors contained in the ACT and NSW DNSPs' reset RINs[12]. Data for 2014 is estimated as the average of 2013 data from the economic benchmarking RIN and 2015 data from the reset RIN.

The resulting calculations and forecasts are presented in tables 6.1 to 6.4 for ActewAGL, Ausgrid, Endeavour and Essential Energy, respectively. The average result presented in the tables is for the 5–year regulatory period 2015–2019.

Table 6.1 **Annual opex partial productivity forecasts – ActewAGL, 2014–2019**

	2014	*2015*	*2016*	*2017*	*2018*	*2019*	*Average*
Forecast changes							
Customer numbers	–0.17%	–0.17%	1.35%	1.35%	1.35%	1.35%	1.05%
Circuit Length	0.67%	0.67%	1.30%	1.34%	1.27%	1.25%	1.17%
R'd Maximum Demand	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Weighted Average Output Growth	–0.04%	–0.04%	1.05%	1.05%	1.05%	1.04%	0.83%
Share Underground	0.86%	0.85%	1.61%	1.68%	1.47%	1.42%	1.41%
PP Opex Growth Rates Forecast							
Technology (A)	–1.79%	–1.79%	–1.79%	–1.79%	–1.79%	–1.79%	–1.79%
Returns to Scale (B)	0.00%	0.00%	0.01%	0.01%	0.01%	0.01%	0.01%
Business Conditions (C)	–0.11%	–0.11%	–0.21%	–0.22%	–0.19%	–0.19%	–0.18%
Growth Rates (=A+B-C)	–1.67%	–1.68%	–1.56%	–1.55%	–1.58%	–1.59%	–1.59%

Table 6.2 **Annual opex partial productivity forecasts – Ausgrid, 2014–2019**

	2014	*2015*	*2016*	*2017*	*2018*	*2019*	*Average*
Forecast changes							
Customer numbers	0.88%	0.88%	1.00%	1.11%	1.17%	1.13%	1.06%
Circuit Length	0.73%	0.73%	0.79%	0.78%	0.79%	0.77%	0.77%
R'd Maximum Demand	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Weighted Average Output Growth	0.67%	0.67%	0.76%	0.83%	0.87%	0.84%	0.79%
Share Underground	1.16%	1.15%	1.23%	1.19%	1.16%	1.13%	1.17%
PP Opex Growth Rates Forecast							
Technology (A)	–1.79%	–1.79%	–1.79%	–1.79%	–1.79%	–1.79%	–1.79%
Returns to Scale (B)	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
Business Conditions (C)	–0.15%	–0.15%	–0.16%	–0.16%	–0.15%	–0.15%	–0.15%
Growth Rates (=A+B-C)	–1.62%	–1.63%	–1.61%	–1.62%	–1.62%	–1.63%	–1.62%

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[12] Output is used as a driver of opex in the rate of change formula rather than capital. Using the latter would create adverse incentive effects and not be consistent with the underlying economic framework presented in section 6.1.

Table 6.3 Annual opex partial productivity forecasts – Endeavour, 2014–2019

	2014	*2015*	*2016*	*2017*	*2018*	*2019*	*Average*
Forecast changes							
Customer numbers	1.86%	1.83%	1.22%	1.24%	1.29%	1.44%	1.40%
Circuit Length	1.00%	0.99%	0.98%	0.97%	0.96%	0.95%	0.97%
R'd Maximum Demand	0.00%	0.00%	0.00%	0.00%	0.21%	0.72%	0.19%
Weighted Average Output Growth	1.36%	1.34%	0.92%	0.94%	1.02%	1.23%	1.09%
Share Underground	1.96%	1.92%	1.83%	1.76%	1.70%	1.64%	1.77%
PP Opex Growth Rates Forecast							
Technology (A)	–1.79%	–1.79%	–1.79%	–1.79%	–1.79%	–1.79%	–1.79%
Returns to Scale (B)	0.02%	0.02%	0.01%	0.01%	0.01%	0.02%	0.02%
Business Conditions (C)	–0.26%	–0.25%	–0.24%	–0.23%	–0.22%	–0.22%	–0.23%
Growth Rates (=A+B-C)	–1.51%	–1.52%	–1.53%	–1.54%	–1.55%	–1.55%	–1.54%

Table 6.4 Annual opex partial productivity forecasts – Essential Energy, 2014–2019

	2014	*2015*	*2016*	*2017*	*2018*	*2019*	*Average*
Forecast changes							
Customer numbers	0.83%	0.82%	0.58%	0.50%	0.53%	0.60%	0.60%
Circuit Length	0.32%	0.32%	0.19%	0.26%	0.21%	0.21%	0.24%
R'd Maximum Demand	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Weighted Average Output Growth	0.59%	0.59%	0.41%	0.36%	0.38%	0.42%	0.43%
Share Underground	3.04%	2.95%	3.06%	4.76%	3.74%	3.61%	3.62%
PP Opex Growth Rates Forecast							
Technology (A)	–1.79%	–1.79%	–1.79%	–1.79%	–1.79%	–1.79%	–1.79%
Returns to Scale (B)	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
Business Conditions (C)	–0.40%	–0.39%	–0.40%	–0.63%	–0.49%	–0.47%	–0.48%
Growth Rates (=A+B-C)	–1.38%	–1.39%	–1.38%	–1.16%	–1.29%	–1.31%	–1.30%

For ActewAGL, Ausgrid and Endeavour, the forecast average annual opex partial productivity growth rates are all around –1.6 per cent. That is, based on the opex cost function analysis, opex partial productivity is forecast to continue to decline, extending the period of partial productivity decline observed in table 3.1 which reports the index number analysis of the historic RIN data. A slightly smaller negative average annual opex partial productivity growth rate of –1.3 per cent is forecast for Essential Energy using the opex cost function analysis. It should be noted the forecast methodology uses opex cost function parameter estimates based on recent business conditions – in this case those of the last 8 years. It is necessary to examine whether business conditions are likely to change significantly going forward and the impact of other factors before finalising the opex partial productivity forecast.

6.3 Step changes and measured opex productivity

As noted in section 1, the rate of change method for calculating the future opex allowance takes efficient opex for a base year (usually taken to be the second last year of the preceding regulatory period) and rolls it forward each year by the forecast rate of change in opex input prices plus the forecast rate of change in output minus the forecast rate of change in opex partial factor productivity (PFP). The idea is that over time more real opex allowance will be required if opex input real prices increase and if output increases (as more inputs are required to supply more output). But increases in opex partial productivity over time will normally reduce the quantity of opex required per unit of output, all else equal, and so this also has to be allowed for.

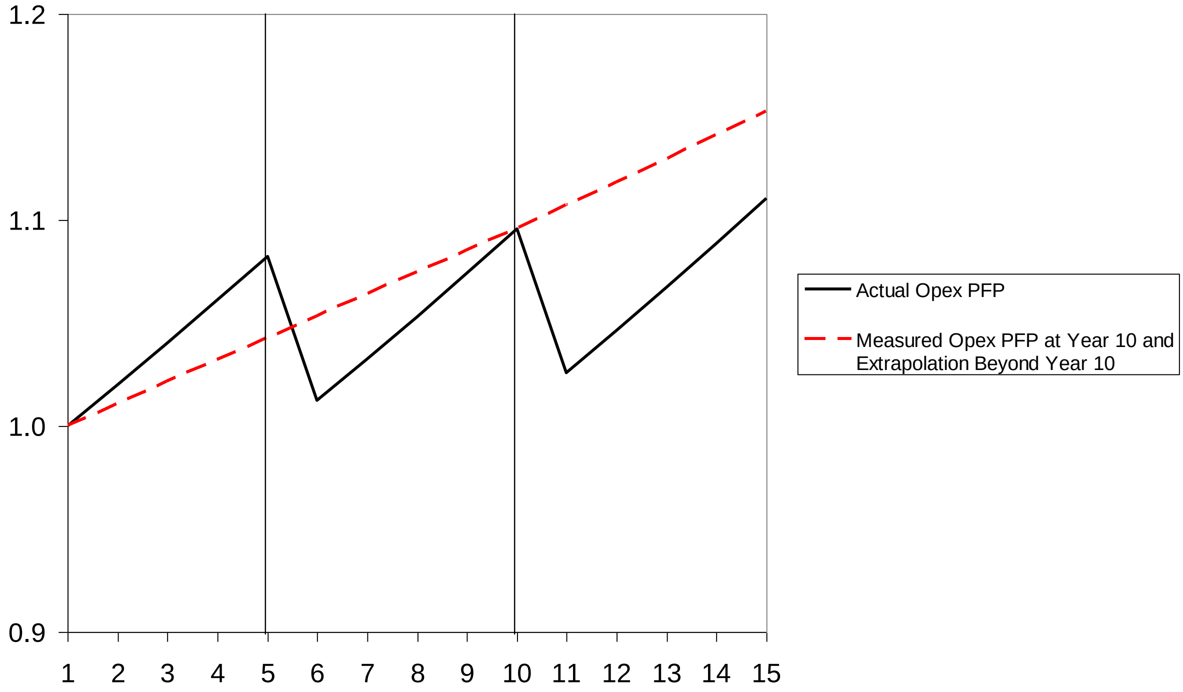
The base/step/trend method extends the rate of change method to allow for step changes which may be added to the efficient base year opex to reflect changes in NSPs' recognised responsibilities over time. For example, in the last Victorian reset conducted by the AER, the five Victorian DNSPs were allowed average step change increases in opex of just under 10 per cent, mainly in recognition of increased regulatory obligations following the February 2009 Victorian bushfires. Ausgrid was also granted an opex step change of over 6 per cent at its last reset while SA Power Networks was granted a step change of just over 1 per cent.

Step changes are likely to have significant implications for measured productivity growth as, without specific allowance for the step changes, they will make measured opex PFP look worse than what it would be for more like–with–like comparisons over time which removed the step change from reported historic opex. Without allowance for past step changes, there is a risk that DNSPs could potentially get a double benefit – once from a lower opex PFP growth rate in the roll forward plus full allowance for subsequent step changes as well.

To illustrate this consider the case where there has been ongoing regulatory and/or obligation 'creep' over a number of regulatory periods and certainly over the length of historic data. Assume that each of the previous changes occurred at the beginning of each regulatory period and then the productivity growth rate within each period was the same as it would have been in the absence of the series of increased obligations. If we do not explicitly allow for the impact of past step changes when we calculate productivity growth over the historic period spanning more than one regulatory period, we will have a lower productivity growth rate than the within period productivity growth rate going forward as illustrated in figure 6.1 using a stylised example.

In figure 6.1 the within–period annual opex PFP growth rate is 2 per cent in all three 5–year regulatory periods. There is a step change of 10 per cent of base opex at the start of the second regulatory period and a further proposed step change of 10 per cent for the start of the third regulatory period. If the step change at the start of the second regulatory period is not allowed for when calculating the opex partial productivity growth rate at the reset at the end of the second period – and assuming that data are available for both the first and second regulatory periods and as long a time period as available is used to calculate the trend, as would be normal practice – then the measured opex PFP growth rate will underestimate the actual opex PFP growth rate. In this example the measured annual opex PFP growth rate is only 1 per cent instead of the actual within–period growth rate of 2 per cent. Similarly, failure to allow for step changes at a time of declining measured opex productivity will make the measured opex PFP growth appear more negative than it should be.

Figure 6.1 **Illustrative impact of step changes on measured productivity growth**



If the first step change is not allowed for in calculating the opex PFP growth rate (assuming simple extrapolation is used for the opex PFP growth rate to be used in the rate of change formula for the third period opex allowance[13]), the DNSP will be overcompensated if it is also allowed the proposed 10 per cent step change at the start of the third period.

There would appear to be two possible solutions to this – either base the opex PFP growth rate for the third period on the within–period opex PFP growth rate for the second period (and possibly the first period if the size of the step change is known) or else use the measured opex PFP growth rate from the longer period and reduce the size of the step change allowed at the start of the third period. The advantage of the first method is that it attempts to obtain a measure of underlying opex PFP growth. But the disadvantages are that it may be more reliant on short time periods which tend to produce more volatile and less accurate measures of trend growth rates and the size of step changes may not be known for all DNSPs (given the way past resets have been done). This makes the second option the likely more tractable approach.

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[13] A broadly similar result would apply if the opex cost function method was used instead of simple extrapolation.

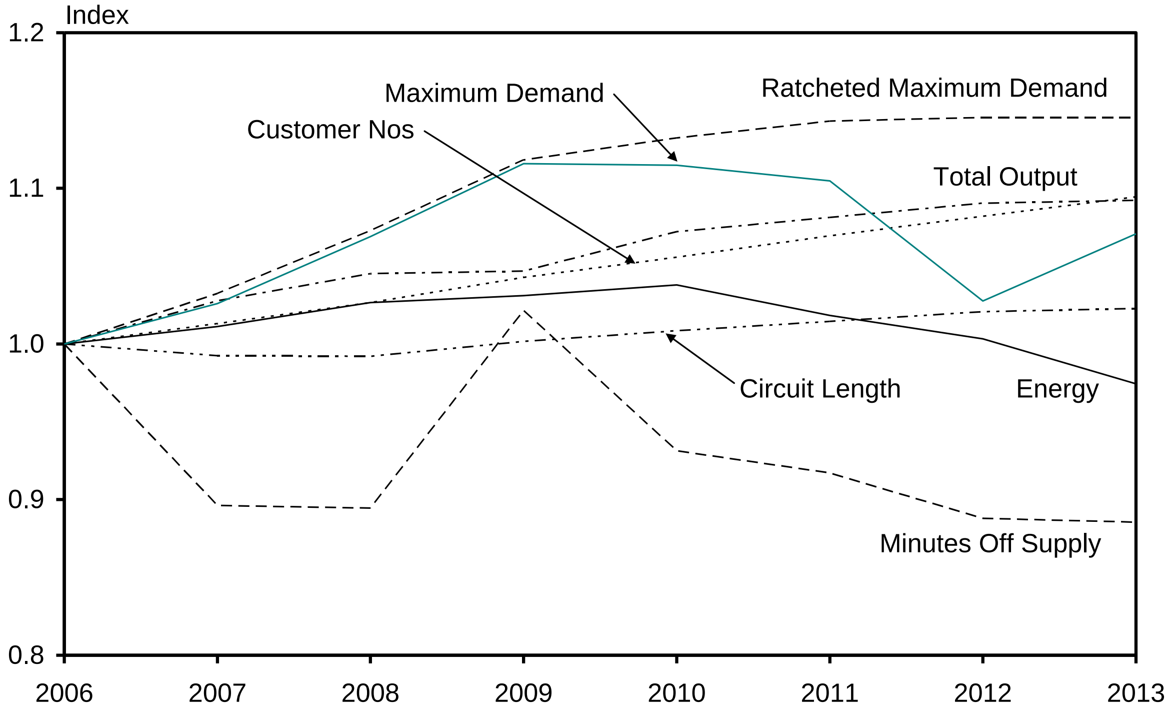
A number of complications need to be recognised in practical applications. The principal of these is that in practice the opex PFP growth rate is usually measured based on a wider sample of DNSPs and not all of those DNSP will have had the same experience with step changes. The size of step changes allowed may have varied considerably across jurisdictions with some DNSPs not having been allowed any step changes while others may have been granted relatively generous step changes. The measured opex MPFP growth rate will reflect a weighted average of these various step change experiences. A further practical difficulty is that past resets for some NSPs may have been reported in such a way that step changes are not separately identified. And resets for different jurisdictions have, of course, occurred at different times which further complicates the situation.

6.4 Outlook for future output growth

Opex partial productivity growth going forward will be driven by the overall growth rate in DNSP outputs and the overall growth rate in DNSP opex inputs. We thus need to examine these components to gain a fuller understanding of the likely scope for opex productivity growth to improve going forward.

The five individual output components used in the MPFP analysis presented in section 4 are graphed in figure 6.2 for the period 2006 to 2013 at the overall DNSP industry level. Customer numbers can be seen to have increased steadily over the period with an average annual growth rate of 1.3 per cent. Line length has also grown but more modestly with an average annual growth rate of 0.3 per cent. And, apart from a one year upwards spike in 2009 – mainly due to the Victorian bushfires – minutes off supply has generally declined, which is equivalent to an increase in output.

Figure 6.2 **DNSP output component indexes, 2006–2013**



Energy throughput, however, increased up to 2010 and has subsequently declined with an average annual growth rate of –2.1 per cent since 2010. Maximum demand also increased up to 2009 but declined since with an average annual growth rate of –1.3 per cent since 2010. Maximum demand did, however, increase in 2013 and the ratcheted maximum demand output continued to increase up to 2011 before levelling off.

Australia did not experience an immediate downturn due to the global financial crisis of 2008. Instead, the AER (2013b, p.20) attributes the ongoing decline in electricity demand to:

- commercial and residential customers responding to higher electricity costs by reducing energy use and adopting energy efficiency measures such as solar water heating – new building regulations on energy efficiency reinforce this trend
- subdued economic growth and weaker energy demand from the manufacturing sector, and
- the continued rise in rooftop solar photovoltaic (PV) generation (which reduces demand for electricity supplied through the grid).

The AER (2013b, p.21) stated that it expected growth in electricity demand to resume ‘in the longer term’ with a rising population, moderation of growth in electricity prices and the development of liquefied natural gas (LNG) projects in Queensland. AEMO (2014a, p.ii) states that it expects residential and commercial electricity consumption to grow at an average annual rate of –0.5 per cent through to 2016 and for electricity consumption to be relatively flat after that. AEMO (2014a, p.iv) also expects that only Queensland and NSW will return to their historic maximum demand levels within the next decade while the southern states may take two decades to return to their historic maximums.

It thus looks likely that the main source of output growth for DNSPs over the next regulatory period will be from ongoing increases in customer numbers resulting from population growth.

On the opex input side, opex quantities increased at a relatively high average annual growth rate of 3.5 per cent over the 8–year period. Step change increases in opex allowances for the Victorian DNSPs in the order of 10 per cent in the 2010 reset to address new requirements following the 2009 Victorian bushfires are likely to have been a significant contributor to the relatively high growth in opex over the period as a whole. However, capital input quantities also grew strongly at an average annual rate of 3.3 per cent over the 8–year period, despite the reduction in output growth.

Average annual growth in total input quantity of 2.8 per cent since 2010 at a time when average annual total output quantity growth has been only 0.6 per cent and is expected to remain relatively flat for the next decade would indicate that DNSPs are likely to be carrying excess capacity for the next several years at least. This would indicate that there should be considerable scope to achieve economies on opex input use. Thus, while continued reduction in opex partial productivity is consistent with current market conditions in the short term, in the medium term we would expect that opex partial productivity growth would be relatively flat for a period before returning to positive growth.

7 FINDINGS AND CONSIDERATIONS

Economic Insights has been asked to provide advice on:

a) whether the AER should make adjustments to base operating expenditure (opex) for the NSW/ACT DNSPs based on the results from economic benchmarking models, and

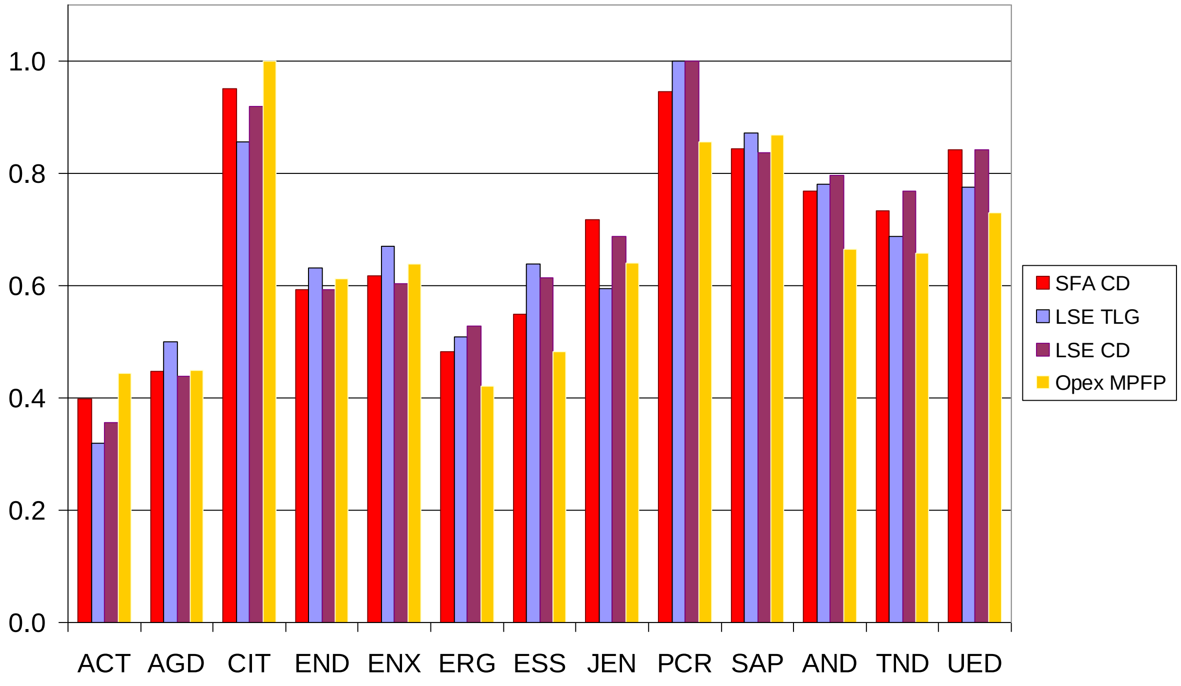
b) the productivity change to be applied to forecast opex for the NSW/ACT DNSPs.

In this section we consider each of these issues in turn.

7.1 Base year opex adjustments

In this report we have used a range of economic benchmarking methods to assess the relative opex cost efficiency of Australian DNSPs. The methods include a Cobb Douglas stochastic frontier analysis (SFA) opex cost function model, Cobb Douglas and translog least squares econometrics (LSE) opex cost function models and opex multilateral partial factor productivity (MPFP) indexes. The resulting average opex cost efficiency scores for 2006–2013 are presented in figure 7.1. Opex MPFP index values and LSE dummy variable coefficients are converted to efficiency scores so that the most efficient DNSP's score is one. Efficiency scores are calculated directly in SFA with the highest score generally being somewhat less than one due to allowance for white noise, averaging and other statistical effects. DNSPs with scores less than one are progressively less efficient.

Figure 7.1 **DNSP average opex cost efficiency scores, 2006–2013**



The efficiency scores across the three econometric models are relatively close to each other for each DNSP and they are, in turn, relatively close to the corresponding MPFP score. This similarity in results despite the differing methods used and datasets used reinforces our confidence in the results.

For the reasons outlined in section 5, our preferred results are those from the SFA Cobb–Douglas model due to its direct estimation of the efficiency score and superior statistical properties. Consequently, subsequent discussion will focus on the SFA Cobb–Douglas results although there is generally not much difference in the results across the four methods used.

The opex efficiency scores indicate very large efficiency gaps for the NSW/ACT DNSPs relative to the best performers on opex efficiency, CitiPower and Powercor. These two Victorian DNSPs have contrasting metropolitan and rural coverage and share common ownership with SA Power Networks which is the third best performer. Relative to the two best performers, there are estimated efficiency gaps of around 58 per cent for ActewAGL, 53 per cent for Ausgrid, 42 per cent for Essential Energy and 38 per cent for Endeavour. However, before presenting our findings on indicative base year opex adjustments from the model results, we need to consider three issues as follows:

1) choice of the appropriate benchmark and allowance for modelling limitations
2) allowance for operating environment factors not explicitly included in the models, and
3) how to move from average results for the period to base year (2013) results.

We now examine each of these in turn.

7.1.1 Choice of the appropriate benchmark

The frontier benchmark for the NEM DNSPs is CitiPower which has an efficiency score of 0.95. CitiPower is closely followed by Powercor with an efficiency score of only slightly less than 0.95. Although these two DNSPs have contrasting metropolitan and rural coverage, as noted above, they do share common ownership.

Although the output specification used appears to perform well, we are taking an average result which reduces the impact of year–to–year fluctuations and abnormalities, and our opex cost function models perform well statistically, we are of the view that it is prudent to adopt a conservative approach to choosing an appropriate benchmark for efficiency comparisons. Adopting a conservative approach allows for general limitations of the models with respect to the specification of outputs and inputs, data imperfections and other uncertainties. This is because all models are by definition a simplification of reality and may not capture all relevant effects. That said, however, it should be noted that the country–specific dummies we have included in the opex cost functions do allow for any systematic differences between countries.

Rather than adopt the frontier DNSP as the benchmark for efficiency comparisons, we are of the view that it would be prudent to instead adopt a weighted average of the efficiency scores in the top quartile of the efficiency score range in calculating the cost efficiency target for the NSW/ACT DNSPs. That is, we take a weighted average of the efficiency scores greater than or equal to 0.75, where customer numbers are used as the basis for forming the weighted average. There are five DNSPs with efficiency scores greater than or equal to 0.75 comprising CitiPower, Powercor, SA Power Networks, United Electricity Distribution and AusNet

Distribution. The weighted average efficiency score of these five Victorian and South Australian DNSPs is 0.86. By taking the weighted average of efficiency scores in the top quartile, we thus reduce the efficiency benchmark by 9 percentage points compared to the frontier DNSP efficiency score. This is equivalent to allowing an additional margin on the frontier DNSP's input use of 10 per cent in calculating the benchmark for the NSW/ACT DNSPs (0.95/1.1 = 0.86) and is thus a relatively generous allowance.

7.1.2 Operating environment factors not explicitly included

The economic benchmarking models used already include adjustment for a number of key operating environment factors.

All of the models already include adjustment for network density effects through the specification of outputs. The inclusion of energy delivered, ratcheted maximum demand, customer numbers and line length in the opex MPFP measure and the inclusion of the latter three of these in the opex cost function models (along with the very high correlation observed between the energy and maximum demand outputs) mean that differences in customer density, energy density and demand density are all implicitly incorporated. The second stage regression analysis reported in section 4.1 indicated no significant network density effects remained beyond those captured by the output specification.

The opex cost function models include explicit adjustment for the proportion of underground lines.

The second stage regression analysis of the opex MPFP measure reported in section 4.1 indicates no additional significant effects were detected for differences in the share of single stage transformation, scale effects or reliability differences.

We recognise, however, that there may be a number of additional operating environment factors whose effects may not have been fully included in the models and which warrant further consideration. In this section we look at the potential effects of an additional four factors identified in AER (2014a,b,c,d)[14] as follows:

- differences in the relative importance of subtransmission
- jurisdictional differences in regulatory and legislative requirements
- ActewAGL's small scale and special characteristics, and
- Victorian bushfire aftermath.

Differences in subtransmission intensiveness

The three NSW DNSPs have relatively 'upstream' boundaries with transmission compared to DNSPs in Victoria and South Australia. As a result they are relatively more 'subtransmission intensive' than the Victorian and South Australian DNSPs in that, all else equal, they will have longer lengths of subtransmission lines than an otherwise equivalent DNSP that was located in Victoria or South Australia. AER (2014) indicates that subtransmission lines over 66 kV are likely to have opex requirements per kilometre that are around twice as high as

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[14] Hereafter referred to as 'AER (2014)'.

other DNSP lines. An estimate of the additional opex requirement for each NSW DNSP resulting from network boundary differences between NSW and Victoria/South Australia can therefore be formed by finding the difference in the percentage of total line length accounted for by subtransmission lines between the NSW DNSP and the weighted average benchmark Victorian and South Australian DNSPs.

Undertaking this calculation indicates that subtransmission lines (defined as lines and cables of 33 kV and above) account for around 10.8 per cent of Ausgrid's line and cable length, 10.3 per cent of Endeavour's, 7.8 per cent of Essential Energy's and 5.3 per cent of the weighted average Victorian and South Australian benchmark. Also allowing for the higher opex cost per kilometre associated with subtransmission lines leads to the finding that the weighted average Victorian and South Australian benchmark DNSP would incur additional opex costs equivalent to around 5.5 per cent if it had the same subtransmission intensiveness as Ausgrid, 5.0 per cent it was the same as Endeavour's and around 2.5 per cent if it was the same as Essential Energy's. It should be noted that this implicitly assumes that all opex is line–related and will therefore likely over–estimate the impact of higher subtransmission intensiveness on the NSW DNSPs' opex.

Regulatory and legislative requirements

There has been a concerted effort over recent years to harmonise Australia's legislative requirements and reduce the regulatory 'red tape' burden on businesses. For example, all jurisdictions in the NEM, except Victoria, have enacted the Work Health and Safety Act and Work Health and Safety Regulations. AER (2014) does not consider there to be a material cost difference between jurisdictions that have enacted the model laws.

The Victorian government employed PricewaterhouseCoopers (2012) to estimate the costs implementing the new occupational health and safety laws would impose on doing business in Victoria. It was found the cost burden that would be imposed on Victoria would be equivalent to around 0.25 per cent of Gross State Product. Since DNSP work environments may be more dangerous than the average work environment across the economy, AER (2014) suggests a conservative approach would be to assume that a Victorian DNSP would face just over twice the amount of costs due to a change in occupational health and safety laws compared to the average firm. On this basis, Victorian DNSPs would incur a 0.6 per cent opex increase if they had to operate under the same occupational health and safety laws as DNSPs in other states.

AER (2014) was unable to identify any impacts of differences in environmental and planning regulations across different jurisdictions. AER (2014) could also find no evidence that Victorian DNSPs face a cost advantage on building requirements.

Overall, Victorian DNSPs may thus require an increase of 0.6 per cent in their opex if they had to operate under the same regulatory and legislative requirements as NSW/ACT DNSPs. Taking the weighted average across the benchmark Victorian and South Australian DNSPs, it would thus be appropriate to increase the benchmark's input use by 0.5 per cent to allow for differences in regulatory and legislative requirements relative to the NSW/ACT DNSPs.

ActewAGL's small scale and unique features

Being the smallest of Australia's DNSPs with around 177,000 customers could account for some of the very large cost efficiency gap found for ActewAGL if it faced substantial diseconomies of size. However, the dataset used in the opex cost function analysis contains 88 DNSPs with less than 100,000 customers compared to 25 DNSPs with more than 100,000 customers. The smallest DNSPs in the sample have just over 20,000 customers. Despite including many DNSPs considerably smaller than ActewAGL, the opex cost function analysis found negligible evidence of the existence of diseconomies of scale at the sample mean, which is relatively close to ActewAGL's size.

ActewAGL (2014) has argued that it faces opex cost disadvantages from the practice of backyard reticulation of overhead lines which is unique to the ACT and from having different capitalisation policies to other NEM DNSPs. The latter are argued to lead to ActewAGL allocating some expenses to opex which other NEM DNSPs allocate to capital costs. Leasing practices employed by ActewAGL for cars and computers are also argued to lead to more costs for these items being allocated to opex by ActewAGL than other NEM DNSPs.

AER (2014) has undertaken a detailed analysis of ActewAGL's operating environment. Over 35 separate operating environment factors were examined. Of these, only five factors were identified as potentially requiring additional allowance for in the economic benchmarking analysis because they were not explicitly included in the modelling or impacted ActewAGL in a materially different manner than other included DNSPs. These were:

- ActewAGL's capitalisation policy
- standard control services connections
- backyard reticulation
- taxes and levies, and
- occupational health and safety regulations.

ActewAGL expenses a higher proportion of its costs than any of the other DNSPs included in the economic benchmarking analysis. It was estimated the adoption of practices used by ActewAGL such as the use of operating leases for vehicles and computers (rather than finance leases used by other DNSPs) would increase the benchmark Victorian and South Australian DNSP's opex by around 17.5 per cent.

ActewAGL's standard control services include some connection services which are not included in other DNSPs' standard control coverage. AER (2014) estimated these connection services would increase the benchmark Victorian and South Australian DNSPs' opex by around 4.5 per cent if they had similar standard control coverage.

AER (2014) estimated that backyard reticulation, which is unique to the ACT, would increase the benchmark DNSPs' opex by just under 3 per cent if they had to operate under the same access to lines conditions as ActewAGL.

ACT jurisdictional taxes and levies (such as the Energy Industry Levy) were estimated by the AER (2014) to increase the benchmark DNSPs' by around 2.5 per cent, were they to face the same taxes and levies as ActewAGL.

Combined with the weighted average allowance of 0.5 per cent of opex (discussed above) if the benchmark DNSPs faced the same occupational health and safety regulations as those applying in the ACT and NSW, the total increase in opex for the benchmark DNSPs from the five factors identified by AER(2014) comes to around 27.5 per cent if they were to face the same operating environment factors as ActewAGL. It should be noted that ActewAGL has a lower subtransmission intensiveness than the weighted average Victorian and South Australian benchmark DNSP and so no allowance is made for this factor. However, AER (2014) noted that an additional allowance should be made for factors which, while not individually material, may be collectively material. Consequently, we consider it would be prudent to assume that the opex use of the benchmark weighted average Victorian and South Australian DNSP would be up to 30 per cent higher if it faced the same operating environment conditions as ActewAGL.

Victorian bushfire aftermath

Following the Victorian bushfires of February 2009, the Victorian DNSPs received step change increases in their opex requirement for the 2011–2015 regulatory period totalling 8.4 per cent of the approved opex requirement. Much of this was related to temporary opex increases to cover Victorian–specific requirements in response to the fires and associated Royal Commission recommendations which exceed requirements in other States.

AER (2014) estimates that the effect of these temporary opex increases has been a cost *disadvantage* to the Victorian DNSPs of just over 10 per cent for the period from 2011 onwards (ie their opex costs were increased by just over 10 per cent for this period compared to what they otherwise would have been). Taking the weighted average Victorian and South Australian benchmark, this would be a cost disadvantage to the benchmark of 7.8 per cent from 2011 onwards.

Conclusion

Based on the available evidence, we are of the view that it is reasonable to assume that the opex of the benchmark Victorian and South Australian DNSPs would be considerably less than 10 per cent higher if they had to operate under the same system subtransmission intensiveness as the NSW DNSPs and if they faced the same occupational health and safety regulations as the NSW DNSPs. Nonetheless, we propose to make a conservative allowance of a 10 per cent input margin on the benchmark Victorian and South Australian DNSPs to cover these factors. This includes allowance for a number of factors that, while individually not significant, may collectively be significant.

In the case of ActewAGL, five factors have been identified which impact ActewAGL's reported opex differently to the other DNSPs in the sample. The most important of these is the different capitalisation policy employed by ActewAGL. Consequently, we propose to make an allowance of a 30 per cent input margin on the benchmark Victorian and South Australian DNSPs to cover these factors. Again, this also includes allowance for a number of factors that, while individually not significant, may collectively be significant.

7.1.3 Moving from average 2006–2013 results to 2013 network services results

The efficiency results discussed up to now in this section are an average for the 8 years from 2006 to 2013 for each DNSP. The results obtained from the econometric opex cost function models are ‘time invariant’ or average results for the 8 years for each DNSP and the index number–based opex MPFP scores have been presented on a similar basis for consistency. While using average results is a constraint of the econometric methods used, it has the benefit of reducing the effects of anomalous years and reducing the impact of any gaming DNSPs may have engaged in to affect their base year opex levels. However, the base year for the application of the AER’s base/step/trend assessment method is 2013 rather than the average of the 8 year period, 2006–2013.

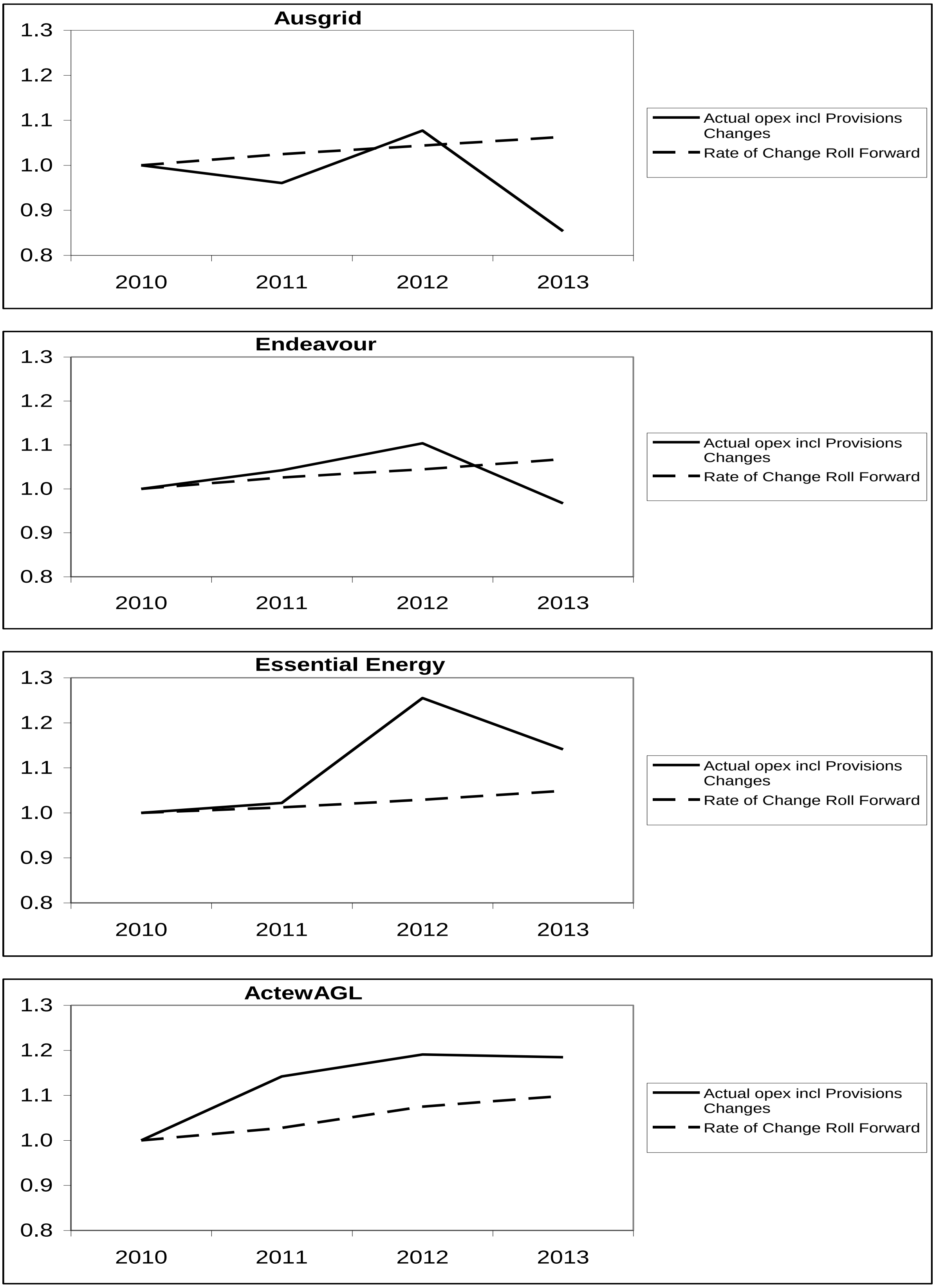
Rather than simply applying the average 2006–2013 efficiency results to data for 2013, we need to allow for opex movements between the average (approximately midpoint) of the period and 2013. Some DNSPs’ opex growth has increased rapidly over the period, some have declined somewhat and some DNSPs appear to have anomalous opex reductions in 2013, in some cases due to provisions changes. We therefore need to roll forward the efficient opex target for each DNSP from the average–of–the–period result obtained from the opex cost function model (and including the adjustments discussed above) to 2013.

The most logical and consistent method to use to roll forward the target efficient opex for each DNSP from the average–of–the–period result to 2013 is the same rate of change method as used to roll forward base year efficient opex to forecast opex in the out–years. That is, we use the rate of change method presented in equation (2) which rolls opex forward by the sum of growth in output less the growth in opex PFP. Since the model uses constant price opex, we do not need to include the change in opex prices in the rate of change formula. Rather, all calculations are undertaken using the constant price opex series.

DNSPs whose opex has increased faster over the second half of the period than the rate of change indicates will get larger cuts to their base year opex than those suggested by their average score while those DNSPs whose opex has increased less than the rate of change will get lower cuts to their base year opex than those suggested by their average score.

In figure 7.2 we present two indexes of opex quantities between 2010 and 2013 for each of the NSW/ACT DNSPs. One index is that of actual network services opex quantity (including changes in provisions) while the other is that of the rate of change rolled forward network services opex quantity (without the opex efficiency reduction included). For Ausgrid and Endeavour we see that actual opex quantity increased less between 2010 and 2013 than did their rate of change rolled forward opex quantity – although in both cases this was due to a relatively large fall in opex quantity in 2013. In both cases this was largely attributable to the change in provisions in 2013. This means that 2013 network services opex reductions for Ausgrid and Endeavour will both be somewhat smaller than those indicated by their average efficiency performance.

Figure 7.2 **Indexes of actual opex quantity (including changes in provisions) and rate of change rolled forward opex quantity, 2010–2013**



For both Essential Energy and ActewAGL we see that actual network services opex quantity increased more between 2010 and 2013 than did their rate of change rolled forward opex quantity. This means that 2013 network services opex reductions for Essential Energy and ActewAGL will both be somewhat larger than those indicated by their average efficiency performance.

To summarise, there are three steps in calculating the adjustments to base year opex required to reach the relevant efficiency target. These are:

1) Calculate the average efficient opex quantity for each DNSP taking account of the relevant benchmark and allowance for relevant operating environment factors not included in the modelling
2) Roll forward the average efficient opex quantity for each DNSP to 2013 using the rate of change method, and
3) Compare the actual 2013 opex quantity for each DNSP to its rolled forward efficient quantity to calculate the adjustment required to the DNSP's 2013 network services opex.

We conclude that the relevant benchmark for the NSW/ACT DNSPs should be the weighted average efficiency score of the five top quartile Victorian and South Australian DNSPs. We believe it is prudent to adopt this conservative approach to choosing an appropriate benchmark for efficiency comparisons as it allows for general limitations of the models with respect to the specification of outputs and inputs, data imperfections and other uncertainties. We are also of the view that the benchmark should be set uniformly for the NSW/ACT DNSPs rather than being tailored to each of the DNSPs. The results are relatively insensitive in any case in this instance to the choice of urban, suburban or rural benchmarks.

After considering the likely effects of operating environment factors not explicitly included in the model, we conclude that an opex efficiency target for the NSW DNSPs should be set based on increasing the weighted average Victorian and South Australian benchmark's opex input use by 10 per cent. For ActewAGL the input margin on the benchmark DNSP should be conservatively set at 30 per cent.

The weighted average Victorian and South Australian benchmark efficiency score in the SFA Cobb Douglas model is 0.86. Allowing for a 10 per cent increase in input use by the best performers before setting the efficiency target would see an increase of 10 per cent in the denominator of the best performers' efficiency score. This leads to the target being 0.78 (=0.86/1.1) for the NSW DNSPs. It should be noted that this is actually equivalent to increasing the frontier DNSP's input use by 20 per cent overall (ie 0.78 = 0.95/1.2).

For ActewAGL allowing a 30 per cent increase in input use by the best performers before setting the efficiency target would see an increase of 30 per cent in the denominator of the best performers' efficiency score. This leads to the target being 0.66 (=0.86/1.3) for ActewAGL. It should be noted that this is actually equivalent to increasing the frontier DNSP's input use by around 43 per cent overall (ie 0.66 = 0.95/1.43).

Even after making these relatively generous allowances, the resulting adjustments to the average opex quantity for each of the NSW/ACT DNSPs are quite large as listed in table 7.1

– over 40 per cent for Ausgrid, 40 per cent for ActewAGL, 30 per cent for Essential Energy and nearly a quarter for Endeavour.

Given differences in actual opex quantity growth rates across the four NSW/ACT DNSPs compared to their respective rate of change rolled forward opex quantity growth rates over the second half of the period, the size of these adjustments reduce for Ausgrid and Endeavour and increase for Essential Energy and ActewAGL for the 2013 base year.

In table 7.1 we list the NSW/ACT DNSPs' efficiency scores, efficiency targets and the adjustments to average network services opex and 2013 network services opex that would be required to reach this target.

Table 7.1 **NSW/ACT DNSP opex efficiency scores, efficiency targets and average and 2013 network services opex adjustments to reach the target**[a]

DNSP	*Efficiency score*	*Efficiency Target*	*Implied opex reduction to reach average efficiency target*	*Reduction to 2013 network services opex*
Ausgrid	45%	78%	43%	33%
Endeavour	59%	78%	24%	13%
Essential Energy	55%	78%	30%	35%
ActewAGL	40%	66%	40%	45%

[a] Based on Economic Benchmarking RIN data including changes in provisions

It can be seen that substantial 2013 network services opex reductions are required for three of the four NSW/ACT DNSPs to reach the relatively conservatively set efficiency targets. Network services opex reductions in the order of 45 per cent would be required for ActewAGL and around one third for Ausgrid and Essential Energy. A smaller reduction of around 13 per cent would be required for Endeavour.

The results reported in table 7.1 use network services opex as reported in the DNSPs' Economic Benchmarking RINs and include changes in provisions. In some cases there may be a need to make minor adjustments to ensure like–with–like comparisons by allowing for differences between the Economic Benchmarking RIN–based network services opex used in this report and the basis used to report opex in the DNSPs' proposals for the next regulatory period.

7.2 Opex productivity growth forecast to include in the rate of change

In section 6.2 we presented the results of opex partial productivity forecasts formed from the SFA Cobb–Douglas opex cost function estimated parameters and the forecast output and operating environment factor changes included in the NSW/ACT DNSPs' reset RINs. These forecast opex partial productivity growth rates were around –1.6 per cent for Ausgrid and ActewAGL, –1.5 per cent for Endeavour and –1.3 per cent for Essential Energy, implying ongoing increases in opex, all else equal.

In section 6.3 we noted the impact of step changes in opex allowances made in a number of recent resets – particularly those in Victoria – and their consequent depression of measured opex productivity growth rates. All else equal, failure to allow for the effect of past reset opex step changes in subsequent resets will lead to DNSPs being over–renumerated as the measured opex productivity growth rate will underestimate the actual opex productivity growth rate. The opex partial productivity growth rate used in the rate of change formula needs to reflect productivity growth excluding step changes or else, if measured opex productivity is used, negative step changes may be required to equate the net present value of the actual opex requirements and the allowance resulting from application of the rate of change formula. To avoid negative step changes, this points to the use of a forecast productivity growth rate higher than measured from historic data spanning more than one regulatory period.

We also examined the outlook for future DNSP output growth in section 6.4. Currently available forecasts from AEMO (2014a) indicate that residential and commercial energy deliveries are likely to decline modestly for the next few years before remaining flat for several years after that. This is mainly due to the effect of increased solar PV uptake and improved energy efficiency of appliances and buildings. NSW is not expected to surpass the highest historic maximum demand level for another decade. Despite this, network input use over the last 8 years has grown strongly pointing to the likely emergence of excess capacity in the short to medium term. This should pave the way for a return to flat and then increasing opex partial productivity levels going forward.

We also note that a situation of declining opex partial productivity is very much an abnormal situation as we normally expect to see a situation of positive technical progress rather than technical regress over time. While we acknowledge the distinction between the underlying state of technological knowledge in the electricity distribution industry and the impact of cyclical factors that may lead to periods of negative measured productivity growth, the latter would be expected to be very much the exception, step change issues aside.

In New Zealand, the Commerce Commission (2014) used an opex partial productivity growth rate of zero in the rate of change component of its high level building blocks methodology used in its draft decision on electricity distribution in line with recommendations in Economic Insights (2014b). Applying similar output specifications to those considered in this project led to measured opex partial productivity growth rates of between –0.1 and –0.8 per cent per annum over the last decade.

There is also an interaction between decisions on base year adjustments and the opex partial productivity growth rate to be used in the rate of change formula that needs to be considered. As with all building blocks applications, the underlying objective is to equate the net present value of the opex allowance with the net present value of expected opex requirements over the upcoming regulatory period. Just as any number of P–zero and X factor combinations can be used at the price cap level to equate the net present values of forecast revenue and revenue requirements, then any number of combinations of base year adjustment and opex productivity growth rates used in the rate of change could be used to equate the net present values of the opex allowance and the expected efficient opex requirements. In particular, if base year opex adjustments are made to fully reach the target opex efficiency score, then there would be less scope to incorporate an onerous opex productivity growth rate than if base year adjustments were less onerous. For example, if base year adjustments only closed part of the gap relative to the efficiency target then there would be considerably more scope to adopt a more onerous forecast productivity growth rate in the rate of change.

We are of the view that a forecast opex productivity growth rate of zero should be used in the rate of change formula. There is a reasonable prospect of opex productivity growth moving from negative productivity growth towards zero change in productivity in the next few years as energy use and maximum demand stabilise, given the excess capacity that will exist in the short to medium term and as the impact of abnormal one–off step changes recedes. We have concerns with the incentive effects of including negative opex partial productivity growth rates in the rate of change formula – to some extent this would be akin to rewarding the DNSPs for having previously overestimated future output growth and now entrenching productivity decline as the new norm. If the effects of step changes can be clearly identified, the forecast opex growth rates should be adjusted to net these effects out.

7.3 Findings

Our findings on base year network services opex adjustments and forecast opex partial productivity growth rates to be included in the base/step/trend formula for the NSW/ACT DNSPs are presented in table 7.2. We have based these findings on the application of a range of economic benchmarking methods which have all produced broadly similar results despite differences in specifications and datasets used.

Table 7.2 **Findings on base year network services opex adjustments and forecast opex productivity growth rates**

DNSP	*Base year network services adjustment*	*Forecast opex productivity growth*
Ausgrid	–33%	0%
Endeavour	–13%	0%
Essential Energy	–35%	0%
ActewAGL	–45%	0%

Although the base year network services opex adjustments appear large, a number of conservative decisions in favour of the DNSPs have been made in arriving at these figures. These include conservative setting of the benchmark as the weighted average of top quartile DNSPs rather than the frontier DNSP and extra allowances for operating environment factors not explicitly included in the models.

There is a reasonable prospect of opex productivity growth moving from negative productivity growth towards zero change in productivity in the next few years as energy use and maximum demand stabilise, given the excess capacity that will exist in the short to medium term and as the impact of abnormal one–off step changes recedes. It should also be noted that recent historic negative measured opex productivity growth rates include the effects of some significant step changes included in previous resets.

APPENDIX A: DERIVING OUTPUT COST SHARE WEIGHTS

This study uses a multi–output Leontief cost function to estimate output cost shares, using a similar procedure to that used in Lawrence (2003). This functional form essentially assumes that DNSPs use inputs in fixed proportions for each output and is given by:

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

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:

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

where the i’s represent the M inputs, the j’s the N outputs and t is a time trend representing the 8 years, 2006 to 2013.

The input demand equations were estimated separately for each of the 24 DNSPs using the non–linear regression facility in Shazam (Northwest Econometrics 2007) and data for the years 2006 to 2013. Given the absence of cross equation restrictions, each input demand equation is estimated separately.

We then derive the output cost shares for each output and each observation as follows:

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

We then form 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:

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

APPENDIX B: MTFP AND MPFP SENSITIVITY ANALYSIS RESULTS

Table B1 **DNSP multilateral total factor productivity indexes and annual growth rates using all zone substation transformers, 2006–2013**

DNSP	*Average MTFP index level*	*Average annual MTFP growth rate*
CIT	1.718	–1.87%
SAP	1.512	–2.26%
UED	1.481	–1.47%
JEN	1.379	–0.45%
PCR	1.279	–1.54%
AND	1.210	–2.17%
ENX	1.152	–1.69%
END	1.108	–2.24%
ESS	0.964	–3.74%
ACT	0.953	–1.48%
TND	0.942	–4.27%
ERG	0.933	1.34%
AGD	0.921	–0.83%

Table B2 **DNSP multilateral total factor productivity indexes and annual growth rates using common MVA ratings, 2006–2013**

DNSP	*Average MTFP index level*	*Average annual MTFP growth rate*
UED	1.441	–0.82%
CIT	1.428	–1.86%
JEN	1.299	–0.52%
SAP	1.253	–2.17%
PCR	1.076	–1.55%
ENX	1.041	–1.68%
END	1.037	–1.65%
ACT	0.950	–1.61%
TND	0.939	–3.96%
AND	0.896	–2.18%
AGD	0.882	–0.84%
ERG	0.679	2.32%
ESS	0.673	–2.21%

Table B3 **DNSP multilateral opex partial factor productivity indexes and annual growth rates excluding changes in provisions, 2006–2013**

DNSP	*Average MTFP index level*	*Average annual MTFP growth rate*
CIT	2.171	–2.51%
SAP	1.934	–1.43%
PCR	1.831	0.67%
UED	1.570	–0.17%
TND	1.555	–3.18%
AND	1.424	–3.51%
ENX	1.419	–1.32%
JEN	1.386	0.50%
END	1.362	–3.11%
ESS	1.068	–3.22%
AGD	1.005	–3.48%
ACT	0.964	–0.52%
ERG	0.915	1.59%

Table B4 **DNSP multilateral opex partial factor productivity indexes and annual growth rates using AWOTE as the labour price, 2006–2013**

DNSP	*Average MTFP index level*	*Average annual MTFP growth rate*
CIT	2.014	–4.67%
SAP	1.748	–4.14%
PCR	1.729	–1.31%
UED	1.473	–0.14%
AND	1.340	–4.48%
TND	1.324	–0.13%
JEN	1.290	0.01%
ENX	1.287	–2.92%
END	1.236	0.03%
ESS	0.970	–3.97%
AGD	0.904	1.16%
ACT	0.894	–3.45%
ERG	0.851	4.32%

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