Jemena Electricity Networks (Vic) Ltd

2016-20 Electricity Distribution Price Review Regulatory Proposal

Attachment 8-5

Huegin report on benchmarking, rate of change and productivity

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Jemena Electricity Networks (Vic) Ltd Productivity Study

Efficiency and growth for the 2015-20 regulatory period

huegin

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www.huegin.com.au
Level 10, 2 Elizabeth Plaza, North Sydney, NSW 2060
02 9409 2400

Executive summary

Recent changes to the National Electricity Rules (NER) and the efforts of the Australian Energy Regulator (AER) to improve electricity network regulation (through the Better Regulation Program) have led to the development of the Expenditure Forecast Assessment Guideline; a document that outlines the AER approach to evaluating the expenditure forecasts of network service providers. The changes mark a significantly more prescriptive approach to expenditure benchmarking than has existed in the past.

In this report, Huegin has analysed the data and models that have become available through the instalment of the Expenditure Forecast Assessment Guideline, the release of the first Annual Benchmarking Report and the first regulatory determination to use the new framework (the draft decision in NSW and ACT). We have used the information and various approaches and techniques to determine:

1. The extent to which Jemena Electricity Networks (JEN) can be considered an efficient total and operating expenditure performer; and
2. An appropriate forecast opex partial factor productivity relevant to JEN in the next regulatory control period.

MEASURING PRODUCTIVITY

Economic benchmarking for the purposes of efficiency evaluation of electricity network costs has always been beset with analytical challenges. Most significantly, specification of the input and output variables for benchmarking models has not reached consensus despite decades of research and debate across international jurisdictions.

Importantly, therefore, undue reliance on any particular technique or model should be avoided. Each model will exhibit its own bias and potential for error. As such, more than one model and approach should be considered and the limitations of each should be recognised. Caution must be exercised in the application of benchmarking models, particularly in the infancy of the approach and model specification in the current environment.

Deterministic application, particularly for developing substitute expenditure forecasts (as undertaken in the recent NSW and ACT draft decision) is an endeavour warned against by several stakeholders (see below, for example) leading up to and during the consultation period for the AER's Expenditure Forecast Assessment Guideline.

BENCHMARKING FOR EFFICIENCY COMPARISONS

Using a number of models and techniques, we find that JEN achieves similar cost performance to its most relevant peers, and favourable performance compared to the entire sample (13 Australian DNSPs). Signals from total expenditure, opex econometric models and common cost ratios indicate top quartile performance. Opex partial factor productivity results indicate lower efficiency scores for JEN, however we find that this is an anomaly of the specific combination of variables (physical asset vs opex) for JEN compared to other networks. This is a commonly recognised limitation of index partial factor productivity approaches and is supported by the observation of JEN's superior capital partial factor productivity performance relative to its opex performance.

IDENTIFYING AN APPROPRIATE PRODUCTIVITY GROWTH RATE

Notwithstanding the limitations of econometric models to inform absolute comparisons of efficiency between DNSPs, they can be utilised to determine rates of change over time. Huegin has tested a number of models and chosen an opex cost function appropriate for determining the applicable opex partial factor productivity rate for JEN. We believe that the significant amount of change in the industry inherent in the historical data negates the efficacy of the technology component of productivity growth and that change in business conditions over time is negligible. Our recommended rate of change for JEN is therefore based on output growth and returns to scale. This rate of change would see JEN continue to perform at an opex change rate over time lower than its peers (Victoria and the wider industry total) as well as its own historical trend.

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Benchmarking is not about identifying a single number denoting the efficiency of a business, but rather the potential range of likely numbers.

- Productivity Commission, p147, “Electricity Network Regulatory Frameworks”, Inquiry Report Volume 1, April 2013

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Introduction

Huegin was asked by Jemena Electricity Networks (JEN) to consider whether JEN, relative to other businesses, was an efficient total and operating expenditure performer and to determine an appropriate productivity growth rate for its upcoming regulatory period. This chapter outlines the context for this report, our terms of reference and our credentials relevant to the provision of such advice.

1

1.1 Background and Context

In November 2012 the Australian Energy Market Commission (AEMC) completed the Economic Regulation of Network Service Providers Rule Change[1]. This rule change required the Australian Energy Regulator (AER) to develop and publish a series of guidelines on its approach to regulating network service providers (NSPs), including the approach the AER will use to assess the efficiency of operating expenditure (opex) forecasts.

The AER is required to accept a Distribution Network Service Provider's (DNSP's) forecast opex where it is satisfied that the forecast opex for the regulatory control period reasonably reflects the criteria (the opex criteria) in clause 6.5.6(c) of the National Electricity Rules (NER), being:

- the efficient costs of achieving the opex objectives in clause 6.5.6(a) of the NER (opex objectives);
- the costs that a prudent operator would require to achieve the opex objectives; and
- a realistic expectation of the demand forecast and cost inputs required to achieve the opex objectives.

In deciding whether or not it is satisfied that the forecast opex for the regulatory control period reasonably reflects the opex criteria, the AER must have regard to certain factors specified in clause 6.5.6(e) of the NER, including, relevantly:

- the most recent annual benchmarking report that has been published under clause 6.27 of the NER and the benchmark opex that would be incurred by an efficient DNSP over the relevant regulatory control period (clause 6.5.6(e)(4)). Under clause 6.27 of the NER, the AER must prepare and publish an annual benchmarking report which should describe the relative efficiency of each DNSP in providing direct control services over a 12 month period;
- the actual and expected operating expenditure of the DNSP during any preceding regulatory control periods (clause 6.5.6(e)(5));
- the relative prices of operating and capital inputs (clause 6.5.6(e)(6));
- the substitution possibilities between opex and capital expenditure (capex) (clause 6.5.6(e)(7)); and
- any other factor the AER considers relevant and which the AER has notified the DNSP in writing, prior to the submission of its revised regulatory proposal under clause 6.10.3 is an operating expenditure factor (clause 6.5.6(e)(12).

The annual benchmarking report referred to by clause 6.27 of the NER uses various benchmarking techniques to compare the historical expenditure of the DNSPs. Those techniques are outlined in the AER's Expenditure Forecast Assessment Guideline[2]. The historical expenditure is also important in the context of a regulatory determination. The Expenditure Forecast Assessment Guideline outlines the intent of and process for the AER to develop its own alternative estimate of a DNSP's forecast expenditure.

> ***We will typically compare the DNSP's total forecast with an alternative estimate that we develop from relevant information sources. To calculate this alternative estimate we will consider a range of assessment techniques. Some of our techniques will assess the DNSP's forecast at the total level; others will assess components of the DNSP's forecast. Our estimate is unlikely to exactly match the DNSP's forecast. However, by comparing it to the DNSP's forecast, we can form a view as to whether or not we consider the DNSP's forecast reasonably reflects the expenditure criteria.***
>
> ***Therefore, if a DNSP's total capex or opex forecast is greater than the estimates we develop using our assessment techniques, and there is no satisfactory explanation for this difference, we will form the view that the DNSP's estimate does not reasonably reflect the expenditure criteria. In this case, we will substitute our own estimate that does reasonably reflect the expenditure criteria.***
>
> - AER, Better Regulation, p7, "Expenditure Forecast Assessment Guideline for Electricity Distribution", November 2013

[1] AEMC, Economic Regulation of Network Service Providers and Revenue Regulation of Gas Services, Final Position Paper, 2012

[2] AER, Better Regulation, "Expenditure Forecast Assessment Guideline for Electricity Distribution", November 2013

In terms of operating expenditure, examination of historical costs is relevant to the consideration of forecast cost through an assessment of whether the base year opex - the starting point of the forecast - reflects efficient expenditure of a DNSP that has appropriately responded to the incentive mechanisms in place.

> ***While we examine revealed costs in the first instance, we need to test whether DNSPs responded to the incentive framework in place. For this reason, we will assess the efficiency of base year expenditures using our techniques, beginning with the economic benchmarking and category analysis, to determine if it is appropriate for us to rely on a DNSP's revealed costs. That is, whether the DNSP's past performance was efficient relative to its peers and consistent with historical trends.***
>
> - AER, Better Regulation, p8 "Expenditure Forecast Assessment Guideline for Electricity Distribution", November 2013

The objective of the AER's benchmarking is therefore two-fold:

1. To determine whether historical expenditure is efficient; and
2. To facilitate the development by the AER of an alternative forecast of expenditure (by setting a base year and determining growth rates).

The Explanatory Statement for the Expenditure Forecast Assessment Guideline outlines economic benchmarking's role in the dual purpose of assessing historical expenditure and developing an alternative forecast.

> ***We are likely to use economic benchmarking to (among other things):***
>
> 1. ***Measure the rate of change in, and overall efficiency of, NSPs. This will provide an indication of the efficiency of historical expenditures and the appropriateness of their use in forecasts;***
> 2. ***Develop a top down total forecast of total expenditure;***
> 3. ***Develop a top down forecast of opex taking into account:***
>   - ***the efficiency of historical opex***
>   - ***the expected rate of change for opex***
>
> - AER, Better Regulation, Explanatory Statement, p78-9, "Expenditure Forecast Assessment Guideline for Electricity Distribution", November 2013

The Annual Distribution Benchmarking Report provides information on the ongoing benchmarking analysis by the AER of industry and individual DNSP costs. The regulatory determination for each individual DNSP is the point at which the AER uses the benchmarking information as an input into their own forecasting models.

The expenditure forecast that the DNSPs propose for the upcoming regulatory period is presented to the AER through their regulatory Proposal. This forecast is based on the DNSP's view of the efficiency of its historical expenditure and assumptions about the growth rate of future expenditure required to meet the objectives and criteria of the NER.

1.2 Terms of Reference

Huegin has been engaged to prepare this report by Jemena Electricity Networks (Victoria) Ltd (JEN). The subject of this report is productivity analysis applicable to JEN's current and recent performance and how that pertains to the upcoming regulatory control period, applicable from 1 January 2016 to 31 December 2020 (January to December calendar years).

Specifically, we have been asked to address two questions, these are:

1. Provide a forecast of the opex partial factor productivity growth rate that applies to the JEN network for the period 1 January 2014 to 31 December 2020 period, taking into account the following factors:
   - historical operating expenditure performance;
   - benchmark operating expenditure level;
   - business conditions;
   - relevant output and input variables;
   - operating environment features;
   - rate of technological change; and
   - any other factors the Expert considers relevant in this assessment.
2. Assess whether JEN, relative to other electricity distribution businesses, is considered to be an efficient total and opex cost performer using relevant benchmarking techniques.

Our complete terms of reference from JEN are attached as Annex A to this report.

1.3 Structure of this Report

There are four main chapters (including this one) in this report. A brief overview of each is presented below:

1. **Chapter 1: Introduction**. Sets out the context, terms of reference and establishes the authority to comment on the matters based on the experience and credentials of the report authors.
2. **Chapter 2: Measuring Productivity**. Defines key concepts, explains common benchmarking techniques and sets the context for benchmarking in regulatory evaluation of network service provider expenditure.
3. **Chapter 3: Comparative Efficiency Benchmarking**. The second question from the terms of reference is the subject of this chapter. We outline our approach (the techniques, models used and data relied upon), consider environmental variables[3], analyse total and partial factor productivity and present our conclusions on whether we consider JEN to be an efficient total and opex cost performer relative to other DNSPs.
4. **Chapter 4: Productivity Analysis**. The first question from the terms of reference is the subject of this chapter. We outline our approach (the techniques, models used and data relied upon), select an opex cost function, calculate rates of growth for JEN's forecast period and present our conclusions on what we consider an appropriate opex productivity growth rate applicable to JEN in the forecast regulatory period.

1.4 Huegin Experience and Credentials

Huegin focuses on providing analytical decision support which requires a knowledge of the way in which complex systems, such as electricity networks, work. Our team has significant experience in, and ongoing exposure to, operations improvement across many sectors including the electricity distribution sector. Given the ongoing drive for performance improvement in the electricity industry, a key focus in recent years has been understanding and modelling the drivers of performance and cost, as well as the degree to which businesses can influence these.

[3] Environmental variables refer to those factors that influence the cost outcomes but are caused by the operating conditions, exogenous factors or other aspects of the physical and non-physical environment in which the entity under study operates.

- Understanding and modelling the drivers of performance: The drivers of performance were first presented in the Australian DNSP benchmarking report in 2012. Since that time Huegin has continued to refine an explanatory model addressing the different drivers affecting Australian DNSPs. The effect of these eight drivers has been quantified and shown to significantly influence the results of benchmarking analysis.
- Understanding the degree to which drivers can be influenced: Huegin has developed a framework for explaining the degree to which organisations can influence the drivers of performance and cost. This framework highlights the need to understand the degree to which businesses can manage costs and performance when looking to assess relative performance and efficiency.

In addition to understanding and applying the benchmarking techniques as favoured by the AER, Huegin has focussed on the utility of benchmarking for supporting performance improvement decisions in the context of the Australian electricity industry.

The Huegin approach to benchmarking continues to evolve through the continued accumulation of this operational experience, application of specialist skills and research on the approaches and outcomes of benchmarking in other jurisdictions and industries.

This experience includes many benchmarking investigations on behalf of Australian DNSPs, notably a 2012 report of the costs and differences between many of the Australian networks and selected international networks. The purpose of that report was to provide a basic analysis of key issues in benchmarking and to share information amongst the businesses that was not available to them prior to the AER's publication of the data collated in the Regulatory Information Notices (RINs).

Successful application of benchmarking techniques for the purposes of performance comparison and decision making requires fluency in specialist techniques. The techniques regularly used by Huegin include econometric analysis, statistical analysis and advanced mathematical techniques.

Despite benchmarking being relatively new in the context of revenue setting in Australia, it has been applied in various ways in a number of industries and jurisdictions. Huegin continues to critically review the approaches and outcomes of benchmarking as applied by organisations such as the Office of Gas and Electricity Markets (OFGEM) in the United Kingdom.

Ongoing knowledge is developed, applied and tested by Huegin in various ways including:

- The development of reports and submissions
- The completion of investigative analyses
- The ongoing development of the Conduit benchmarking portal
- Ongoing participation in industry forums

Based on the specialist knowledge developed, Huegin is able to comment authoritatively on the application and utility of benchmarking in the context of regulating Australian DNSPs operating in the National Electricity Market (NEM).

1.4.1 Key Huegin Contributors to this Report

Huegin is a significant contributor to the body of knowledge for benchmarking as applied to businesses in the National Electricity Market (NEM). Huegin is also the benchmarking partner to the majority of businesses in the NEM.

The Huegin team has an appropriate mix of tertiary education and professional experience commensurate with the requirements of the task to determine an appropriate forecast of the opex partial factor productivity growth rate that would be applicable to JEN and to consider JENs level of efficiency using relevant benchmarking techniques such as those relied upon by the AER in the NSW and ACT draft decision. Qualifications and headline experience of those members who have contributed to this report include:

- Jamie Blair. BEng (Chem): Jamie is a Director in our Sydney office. Jamie is the lead author of major domestic and international benchmarking studies for the electricity industry. Jamie provides regulatory support to numerous Distribution Network Service Providers (DNSPs) throughout Australia.
- Oliver Skelding. BA (Economics), MEc: Oliver is a Senior Analyst in our Sydney Office. Oliver has a Masters of Economics, specialising in Econometrics and is a major contributor to both the analysis and written articles on economic benchmarking relied upon by most of the DNSPs operating in the NEM.
- Dr Ben Petschel. BSc (Mathematics) hons, PhD (Mathematical Finance): Ben is a Senior Analyst in our Sydney office. Ben has developed numerous models to provide analytical decision support within the electricity industry. These include models covering the drivers of cost and performance of wood pole populations throughout the NEM.
- Naomi Donohue. BBus (Accountancy and Computer Applications), CPA: Naomi is a Manager based in Brisbane. She worked for eight years in the regulatory and finance areas of a large DNSP, developing an in-depth understanding of cost structures and drivers within the regulatory construct.

Full profiles of team members are included at Annex B.

All contributors have read and understood the Practice Note CM7: Expert witnesses in proceedings in the Federal Court of Australia, June 2013. As lead author, Jamie Blair certifies that this report complies with Practice Note CM7. In accordance with the Guidelines, I confirm that I have made all inquiries that I believe are desirable and appropriate, and that no matters of significance that I regard as relevant have, to my knowledge, been withheld.

Signed	29 January 2015
	Date

Measuring Productivity

In this chapter, we outline briefly the concepts of productivity and efficiency, and consider the AER benchmarking in this context.

We also present some of the most common methods and techniques in electricity distribution regulation benchmarking and consider the current Australian electricity network regulation landscape.

2

2.1 Measuring Productivity and Efficiency

Productivity and efficiency are related, but separate concepts. Broadly speaking productivity measures the ratio of the outputs to inputs for a transformation process. Where a business produces multiple outputs from multiple inputs, the inputs must be aggregated as must the outputs.

Efficiency is the comparison of the actual and optimal values of input and output. There are many types of efficiency, the most relevant in this context are:

- Technical efficiency is the observation of achieving the maximum potential output with the measured input (or the minimum potential input with measured output). The challenge in determining technical efficiency is that for many processes, the theoretical maximum output is unknown.
- Productive efficiency requires technical efficiency, but also includes the requirement to achieve the outputs at minimum cost of inputs.
- Allocative efficiency requires that resources (inputs) are allocated to the goods and services (outputs) that produce the greatest benefit or return to the users.
- Dynamic efficiency introduces the concept of efficiency over time, whereby improvements in production technology, growth or innovation lead to improvements in productive and/or allocative efficiency over time. This involves a shift in the production frontier (the line of maximum output for given input).

Economic efficiency measurement works best in industries where outputs are physically tangible, easily quantified and have an intrinsic value to the consumer which can be measured by price (such as manufacturing). Complications arise when applied to an electricity distribution businesses, where regional monopolies exist and inputs and outputs are not so neatly defined, nor is the theoretical maximum output known.

The AER is primarily concerned with productive efficiency (see quote at bottom right of page) when benchmarking DNSPs. However using benchmarking models to measure productive efficiency invokes the risk of false signals of change in productive efficiency due to mis-specification of what are very simplified models (spend input for two or three simple outputs) of what is in reality a very complex production model (an electricity network). For example, if the benchmarking model adopted has expenditure as an input and customer numbers, line length and the peak demand over a period (as the AER’s currently preferred model does), any expenditure that does not result in an increase in one of those three attributes will be considered inefficiency. For example, the step change in vegetation management costs caused by the breaking of the drought and increased obligations in response to fires are not reflected as a change in the chosen outputs, and the spend is therefore recorded as declining productive efficiency. As another example, demand management expenditure is reflected in opex, however not only do the three aforementioned outputs fail to reflect the outputs of this expenditure, where such expenditure results in a reduction in demand and/or avoidance of growth in the asset, signals of decreasing productivity will appear in both the input and output index.

“

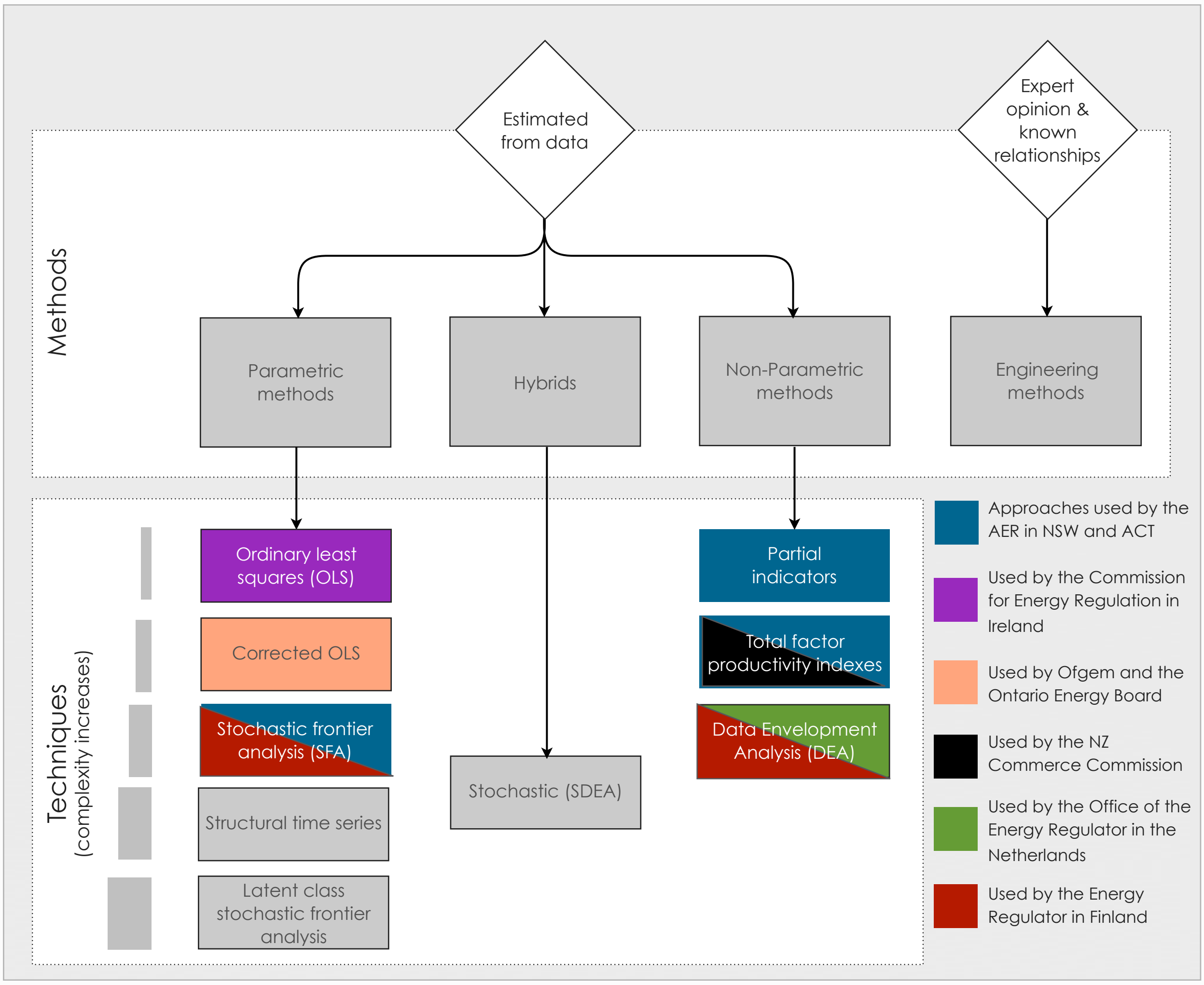
We consider that the benchmarking techniques in this report primarily assist us in forming a view on the productive efficiency of distributors. However measuring productive efficiency will assist us in assessing whether distributors are allocatively and dynamically efficient. Measuring productive efficiency will assist us in determining the efficient prices/ revenues for services promoting allocative efficiency. Measuring productive efficiency over time provides an insight into the dynamic efficiency of distributors.

- AER, Annual Distribution Benchmarking Report, November 2014

2.2 Methods, Techniques and Models

This section describes some common benchmarking techniques that have been used in electricity network regulation. Some of these have been adopted by the AER in theory through the Expenditure Forecast Assessment Guideline and in practice through the recent NSW and ACT distribution draft decision. Figure 1 shows the more common techniques, with an indication of those employed by the AER in the NSW and ACT distribution draft decisions and examples of use of some of the techniques in other jurisdictions.

Figure 1: Benchmarking methods and techniques. *Benchmarking methods are categorised mainly as parametric or non-parametric. These are then broken down further into techniques which describe the basis of combining variables and the reference point of measurement.*



The increasing complexity highlighted above is in regard to the assumptions and techniques that are required to produce estimates of efficiency. For example, partial indicators (such as opex per customer) require very few data points and are easy to compute. In comparison, Data Envelopment Analysis requires a larger dataset, returns to scale assumptions and uses algorithms to compute results. The benefits of this increased complexity are the ability to consider more combinations of outputs, inputs and environmental variables.It is the parametric and non-parametric methods that are of the subject of the approach outlined in the AER's Better Regulation program. The techniques of each of these are briefly described in the following paragraphs.

2.1.1 Benchmarking techniques - parametric

Parametric methods rely on assumptions about the distribution of the underlying population to provide estimates of the parameters of a cost function (i.e using mean values and standard distributions to make estimates regarding the underlying population). Common benchmarking techniques that are incorporated within the parametric method include the following.

Ordinary Least Squares (OLS) and Corrected Ordinary Least Squares (COLS)

These techniques seek a line of best fit between the observed data set in order to estimate a relationship between outputs, inputs and environmental variables. Corrected Ordinary Least Squares adjusts this line (to the best performing firm) to form a frontier from which to compare businesses in the sample.

For example, when benchmarking using an industry cost function the line may be shifted down to the firm with the largest negative residual (that is the business that has an actual cost that is the furthest below the predicted cost) and then other firms can be compared to this line. A common criticism of OLS and COLS is that it assumes that the whole distance between the industry line of best fit and a business's actual costs is inefficiency when it could actually result from model misspecification, omitted variables or data errors. The UK regulator, OFGEM, uses this approach to benchmark UK networks. However instead of moving the frontier line to the business that is furthest from the cost line, they use the upper quartile of businesses that appear efficient using the modelling technique.

Stochastic Frontier Analysis (SFA)

Stochastic Frontier Analysis (SFA) is similar to OLS in that it attempts to model the relationship between costs, outputs, inputs and environmental variables. The key difference between SFA and OLS is that it estimates DNSP efficiency by separating the error term (which is assumed to be inefficiency in COLS) into an inefficiency component and a random error component. Whilst SFA is favoured to OLS and COLS because of this adjustment to the error term, it requires a much larger data set and requires additional assumptions about the distribution of the inefficiency term. Regulators in Sweden, Germany and Finland have used this approach in conjunction with other approaches such as DEA. These jurisdictions have many more networks than Australia and benchmark total expenditure (to avoid issues with differences in capitalisation policies affecting efficiency scores).

Latent Class Stochastic Frontier Analysis (SFA)

Latent class SFA builds on the SFA technique but assumes that firms within an industry are likely to operate using different technologies (different parameter estimates) and should therefore be split into different groups for the purposes of benchmarking. These groups can then be used to benchmark DNSPs against other DNSPs within their group (an example in the Australian context might be groupings based on rural and urban businesses). Latent class SFA has the advantage that it allows for greater heterogeneity between businesses and therefore is likely to provide more accurate estimates of efficiency between businesses. A disadvantage of this approach is that it requires a large amount of data to both identify the different groups accurately and perform SFA on these different groups. To date, latent class SFA modelling of electricity distribution networks has been explored through academic channels more than regulatory; however the utility of this extension of SFA models has been found to be high[4].

Structural Time Series

Structural time series models are regression models that incorporate greater flexibility in terms of modelling cost or production functions as they allow for parameter estimates that can vary over time. That is, the regression model parameters are functions of time rather than constants.

2.1.2 Functional form of parametric models

Parametric models are used to estimate the relationship between inputs and outputs. In the context of modelling an opex cost function, modelling will attempt to identify the relationship between operating costs and different cost drivers. A benefit of using econometric modelling to estimate an industry cost function is that it can produce statistical results that can be used to infer which variables have a significant effect on operating expenditure and how well the proposed model explains variation in DNSP expenditure. When modelling operating costs, the form

4 See, for example: Agrell, Farsi, Fillippini & Koller, "Unobserved heterogeneous effects in the cost efficiency analysis of electricity distribution systems", January 2013 and Llorca, Orea & Pollitt, "Using the latent class approach to cluster firms in benchmarking: An application to the US electricity transmission industry", March 2014

of the relationship between costs and cost drivers needs to be assumed. The two most common functional forms are the Cobb-Douglas cost function and the Translog cost function which are displayed below.

Cobb-Douglas

$$\ln Opex = b_0 + b_1 \ln Y_1 + b_2 \ln Y_2 + b_3 \ln X_k + b_4 T + b_5 \ln Z_1$$

In this example of a Cobb-Douglas model, there are two outputs (Y1 and Y2), one measure of capital (Xk), a time variable (T) and an environmental variable (Z1).

Translog

$$\ln C = b_0 + b_1 \ln Y + b_2 \ln X + 0.5 b_3 \ln Y \ln Y + 0.5 b_4 \ln X \ln X + b_5 \ln X \ln Y + b_6 T$$

The Translog model builds upon the Cobb-Douglas model by introducing interaction terms into the model - in this case lnXlnY is included as well as squared terms for outputs (Y) and an inputs (X). The Translog functional form is often preferred to the Cobb-Douglas because it imposes less restrictions on the production and substitution elasticities (i.e one does not have to assume constant returns to scale as imposed with a Cobb-Douglas functional form). One difficulty with using the Translog functional form, particularly within the context of electricity distribution is that electricity distribution tends to have highly correlated variables that exhibit little intra-group variation. This is known as multicollinearity, and it can result in unstable estimates that can change significantly given minor changes in the model specification or underlying data.

2.1.3 Benchmarking techniques - non-parametric

Non-parametric methods do not require the same assumptions regarding the underlying distribution of the population and therefore require smaller amounts of data for use in benchmarking analysis. Common non-parametric techniques are discussed below.

Partial Indicators

Partial indicators are the ratio of a single input and output, for example opex/customer. Whilst this technique is relatively simple in comparison to other benchmarking techniques it does not account for the different factors beyond the control of businesses that influence the ratios.

Total Factor Productivity (TFP)

Total factor productivity incorporates multiple outputs and inputs by using different weights derived from revenue and cost shares to aggregate them into a single output and input index. Total factor productivity is generally preferred to partial indicators because it is able to include more outputs and inputs through which to benchmark businesses, a criticism is that it is unable to account for environmental differences that can influence the productivity results. TFP has been utilised in electricity network regulation in New Zealand, Canada and the United States.

Data Envelopment Analysis (DEA)

Data Envelopment Analysis uses linear programming to compare businesses with others in its industry. Essentially DEA takes components of multiple businesses in the industry to build a hypothetical firm that produces the same amount of outputs with less inputs (or more outputs for the same amount of inputs). Businesses are then compared to this hypothetical firm and efficiency estimates obtained. Similarly to partial indicators and TFP, DEA uses the combination of outputs and inputs to determine the relative efficiency between businesses. This means that if there are some businesses that have environmental factors that affect their ability to convert inputs into outputs they are likely to appear inefficient compared to businesses operating in more favourable environments. OFGEM has utilised DEA in previous regulatory frameworks, however it is often only used in support of other techniques.

2.3 Productivity and Efficiency in the Regulatory Context

There are three important documents (aside from the NEO, NEL and NER) that shape the context of productivity and efficiency evaluation of electricity distribution networks, namely:

1. The AER's Better Regulation Expenditure Forecast Assessment Guideline (the Guideline) of November 2013 and its associated documents (Explanatory Statements, Technical Notes, etc);
2. The AER's Annual Distribution Benchmarking Report of November 2014; and
3. The AER's Draft Decision for the NSW and ACT Distribution Determination of November 2014.

Each of these three documents provide guidance and precedent in the application of productivity analysis and efficiency assessment of Distribution Network Service Providers by the AER.

2.3.1 The Expenditure Forecast Assessment Guideline

The Expenditure Forecast Assessment Guideline states that if the AER considers that the DNSP forecast does not meet the Rules objectives and criteria, the AER must establish an appropriate alternative forecast. The AER must establish if base year opex is efficient and then apply a rate of change to the base year and account for step changes to determine an appropriate alternative forecast. Rate of change includes:

- Output growth;
- Real price growth; and
- Productivity.

To determine forecast productivity the AER will consider non-recurrent efficiency gains/losses in the base year. Then, using various assessment techniques the AER will also determine or consider:

- Forecast output growth;
- Expected changes in the DNSP's specific business conditions;
- Expected technological change;
- The efficiency gap of the DNSP under consideration (to the efficient frontier in the benchmarking analysis);
- Historical productivity performance; and
- Any difference between industry average productivity change and the rate of productivity change at the efficient frontier.

Assessment techniques specified in the Guideline are:

- Benchmarking (economic techniques and category analysis);
- Methodology review;
- Governance and policy review;
- Predictive modelling;
- Trend analysis;
- Cost benefit analysis; and
- Detailed project reviews (including engineering review).

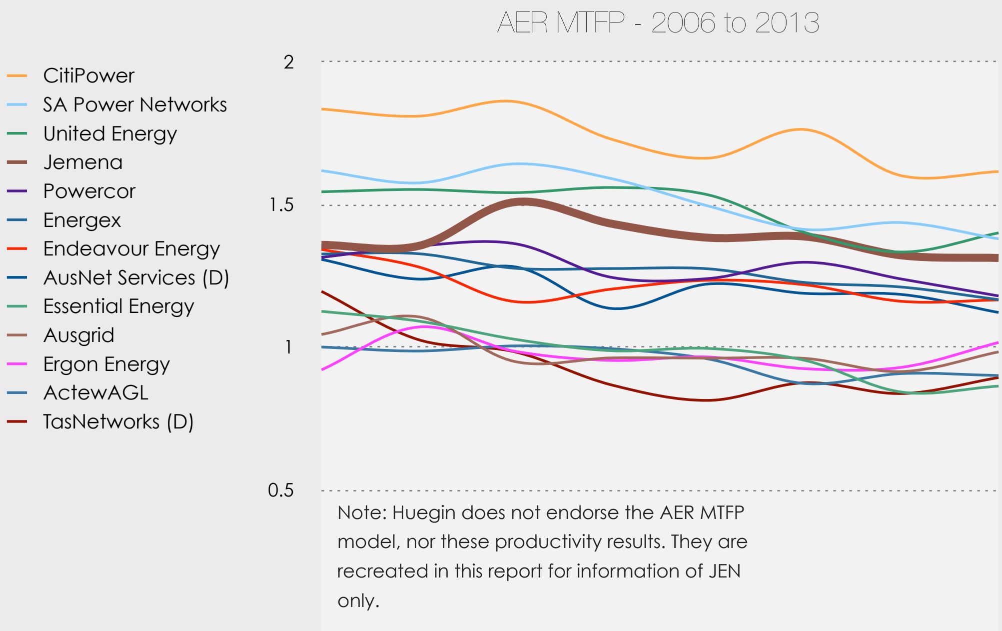
The focus of this report is the first of these techniques, benchmarking to establish comparative efficiency and applicable productivity change.

2.3.2 The Annual Distribution Benchmarking Report

The first Annual Distribution Benchmarking Report, released in late November 2014, provides a high level view of the benchmarking analysis conducted by the AER. The scope of the report includes some MTFP analysis and simple cost ratio comparisons. The MTFP results are based on the analysis of the AER's consultant, Economic Insights. These results are presented in figure 2 below. JEN ranks fourth in the AER's analysis of MTFP, based on the average of 2006 to 2013 data.

Figure 2: The AER's Multilateral Total Factor Productivity Results. *The AER produced time series MTFP results for individual DNSPs in its annual benchmarking report. The model and results are shown below.*

Economic Insights MTFP model	Variables
Input Specification (#2a)	Opex, Overhead Subtransmission MVAkms, Overhead Distribution MVAkms, Underground Subtransmission MVAkms, Underground Distribution MVAkms, Transformers and Other MVA (excl first stage of two stage zone subs)
Output Specification (#4a)	Energy, Ratcheted Maximum Demand, Customer Numbers, Circuit kms, Minutes off Supply (using Sep 2014 Value of Customer Reliability)



DNSP	2006	2007	2008	2009	2010	2011	2012	2013	Average
CitiPower	1.834	1.809	1.860	1.728	1.662	1.762	1.600	1.615	1.734
SA Power Networks	1.618	1.575	1.642	1.590	1.494	1.412	1.436	1.379	1.518
United Energy	1.544	1.552	1.541	1.559	1.533	1.401	1.333	1.400	1.483
Jemena	1.358	1.354	1.508	1.432	1.383	1.387	1.321	1.312	1.382
Powercor	1.314	1.354	1.362	1.244	1.240	1.297	1.238	1.179	1.278
Energex	1.326	1.327	1.276	1.275	1.274	1.226	1.210	1.166	1.260
Endeavour Energy	1.342	1.281	1.159	1.203	1.234	1.218	1.160	1.165	1.220
AusNet Services (D)	1.307	1.238	1.281	1.135	1.221	1.188	1.184	1.121	1.209
Essential Energy	1.125	1.091	1.027	0.987	0.995	0.953	0.842	0.863	0.985
Ausgrid	1.044	1.106	0.949	0.962	0.961	0.960	0.914	0.983	0.985
Ergon Energy	0.920	1.070	0.985	0.953	0.965	0.924	0.929	1.016	0.970
ActewAGL	1.000	0.986	1.004	0.994	0.958	0.872	0.907	0.900	0.953
TasNetworks (D)	1.195	1.026	0.983	0.867	0.813	0.875	0.837	0.893	0.936

2.3.3 The AER's Draft Decision for the NSW and ACT Distribution Determination

The recent AER Draft Decision for NSW and ACT Distribution marks the first occasion that the AER has applied their new benchmarking approach in a regulatory determination. It is also the first time such an approach has been applied in Australian electricity network regulation (productivity benchmarking has been employed by state based regulators previously, but not as a deterministic tool to set expenditure allowances). The AER did not consider any of the NSW or ACT DNSPs' base year opex reflected efficient expenditure levels. The AER relied upon the MTFP results as an indication that the DNSPs were inefficient in its opinion and adopted the recommendations of Economic Insights for the prediction of a substitute estimate of efficient base year opex based on a Stochastic Frontier Analysis (SFA) Cobb-Douglas model. All four DNSPs had their 2013 base year opex reduced by an amount informed by SFA model results produced by Economic Insights. The AER then used this reduced "efficient" base year opex value to forecast forward projections of opex. Important observations from the Draft Decision include:

1. The AER applied a 0% productivity rate to the forecast, as their models indicated a negative productivity shift for industry. The AER substitute forecasts are therefore reflective of output and price growth only, however,
2. The efficiency gap assumed by the AER (based on their econometric model) was applied immediately to the base year, with no allowance or glide path for change over time.

The relevance of the NSW and ACT Draft Decision to JEN includes the econometric model specification and results, as well as the AER's approach of applying those results in determining an alternative forecast of operating expenditure.

We include consideration of the AER approach in NSW and ACT within this report for JEN, however Huegin and others have provided submissions[5] outlining several concerns with the AER's current model, use of data and application of the results in the NSW and ACT draft decision. We have also considered those concerns in this report where relevant. Of particular concern to Huegin is:

1. Economic Insights introduced international data (from New Zealand and Ontario) to facilitate the use of SFA models (which require much more data than available in Australia). This raises issues such as:
    a. The data has been collected for the purposes of regulation in those jursidictions. Whilst it is openly available on the websites of the respective regulators, Economic Insights and the AER have no insight into the provenance of the data nor the basis of preparation of that data.
    b. The use of the data does not comply with the data validation process outlined in the Expenditure Forecast Assessment Guideline Explanatory Statement[6], where the AER states that it will identify anomalies, correct errors and consult with relevant network service providers.
    c. The introduction of the international data significantly undermines the model specification process as only combinations of the available variables are possible to test. This negates any benefit of the collection of the vast amount of data through the Regulatory Information Notices (RINs) from the Australian businesses by the AER. Economic Insights acknowledged that the consideration of environmental variables in their econometric model was limited to the share of underground only due to the lack of data available from Ontario[7].
    d. The data for Ontario is only published in the format relied upon to the year 2012. To Huegin's knowledge, the AER has no mechanism in place to collect data of the same format from the same networks for time periods beyond 2012. Hence the efficacy of the econometric models diminish rapidly over time, given that the form of the AER's SFA model is so heavily dependent on the greater volume of old data available from Ontario networks.

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[5] See, for example, Attachments 1.05, 1.06, 1.07, 1.08 and 1.09 of the Ausgrid Revised Regulatory Proposal, January 2015 (http://www.aer.gov.au/node/11483)

[6] AER, page 161, "Expenditure Forecast Assessment Guideline Explanatory Statement", Nov 2013

[7] Economic Insights, p32, "Economic Benchmarking of NSW and ACT DNSP Opex", 17 November 2014

2. Given the infancy of the approach, Huegin believes that the AER has placed undue reliance on the efficacy of the models. In particular, the weight of reliance placed on a single econometric model that has limitations acknowledged by its author (for example, the limited consideration of environmental variables) is disproportionate with the confidence that one can have in such models to accurately predict efficient levels of opex for an individual network.

3. In Huegin's opinion, the application of the approach by the AER in the NSW and ACT draft decision reflects a decision that is not in the long-term interest of consumers, nor does it consider the circumstances of the individual DNSP. Each of these views is explained below:

    a. In our experience, no business is capable of making immediate cuts to operating expenditure of the magnitude of that reflected in the NSW and ACT decision. As such, businesses must react with cost-cutting exercises, focusing on the areas of the business where the biggest impact can be made most quickly. This does not encourage efficiency or productivity improvement, it merely promotes doing less of what was historically done - resulting in short term cost savings but perhaps invoking future issues that are not in the long-term interest of consumers. For example, increasing maintenance or pole inspection intervals will result in immediate cost savings, but perhaps at the expense of longer term DNSP reliability.

    b. The current circumstances of a DNSP include the legacy of decisions made that have shaped the current cost basis. Whilst consumers should not shoulder the costs of historical decisions if they have been made within an environment of managerial inefficiency, the circumstances of the DNSP must include the expenditure allowance set for them at the previous regulatory determination. We note that even where a DNSP has underspent against the allowance deemed efficient in accordance with the NER in the previous determination (for example, Ausgrid in 2013), the AER still considers the base year opex inefficient.

Economic benchmarking models are more reliable at measuring rates of change over time or the productivity at an industry level than they are at measuring relative efficiency between businesses within the industry. This is because the residuals of the models that are relied upon to provide the relative scores and rankings cannot be accurately divided into the constitute components of efficiency, heterogeneity and noise/error. Other regulators acknowledge the weakness inherent in using these models for inferring relative efficiency between businesses and thus avoid applying them deterministically. Examples include:

1. The Ontario Energy Board uses econometric analysis to arrange networks into five efficiency performance cohorts. Depending on the cohort, each business is set a stretch factor for future productivity of between 0% and 0.6%. That is, regardless of the econometric model scores are only used to assign the cohort, after which future rates of change are set based on the cohort the network falls in[8].

2. The German energy regulator uses four efficiency benchmarks (two from DEA and two from SFA) and sets the efficiency score for each business as the maximum score from the four models or 60%, whichever is the highest.

In summary, Huegin believes that economic benchmarking models can provide insight into differences between businesses and changes over time, but this is an input into the consideration of historical efficiency of a business, rather than the determinant. As such, in considering whether JEN is an efficient total and opex cost performer, we use a number of techniques in chapter 3 and observe the results and consider other influences when forming our view. In chapter 4 we consider a number of econometric models and form a view on the most appropriate model and assumptions for determining the future growth rate of productivity for JEN. Our view is that in the circumstances of a DNSP that cannot be categorically defined as materially inefficient historically, yet some form of future productivity improvement is warranted (e.g. through economies of scale), then a glide path for transition to the future cost base is appropriate in the context of the Rules and the long-term interests of consumers.

[8] The choice of 0% for DNSPs in the top cohort is to "strengthen the efficiency incentives inherent in the rate-adjustment mechanism and in doing so reward the top performers" pg1 Ontario Energy Board Letter, August 14, 2014

Comparative Efficiency Benchmarking

Huegin was asked to assess whether JEN, relative to other electricity distribution businesses, is considered to be an efficient total and opex cost performer using benchmarking techniques.

This chapter presents a view of comparative productivity, productivity growth and total and partial factor productivity analysis of JEN and other electricity distribution businesses.

3

3.1 Comparative Efficiency Benchmarking Approach

To understand whether JEN is an efficient total and opex cost performer, we must compare JEN's cost performance against a number of reference points, most significantly:

- JEN's peer networks and the wider industry; and
- JEN's own performance over time.

Unfortunately, many productivity comparison methods are distorted by the unobserved heterogeneity inherent in the variables chosen to compare productivity performance. That is, each method is restricted to a limited number of variables and none can explain the influence of all variables on cost at once, so apparent productivity differences between businesses often also include the impact of different operating environments. To overcome this limitation, we utilise multiple techniques, recognise the sensitivity of the results to changes in the assumptions and consider environmental variable differences where possible. Most importantly, we understand that the limitations of the techniques largely prohibit definitive, quantitative estimates of efficiency, and therefore we look for indications of sufficient evidence within the results to either support the hypothesis that JEN is an efficient business or alternatively to support the hypothesis that JEN's historical costs cannot be considered inefficient.

3.1.1 Techniques

For the purposes of this chapter, we define techniques as the productivity modelling methodology, be it:

1. Total or partial factor productivity analysis; and
2. An index or econometric method.

MTFP - consistent with the AER's approach

For investigating total factor productivity, we utilise the multilateral Tornqvist index method adopted by the AER. The MTFP method adopted by the AER is described below:

The multilateral Tornqvist index proposed by the AER

$$\ln(MTFP_{st}^{T*}) = \ln(Y_{st}^{T*}) - \ln(X_{st}^{T*})$$

$$= \left[\sum_{i=1}^{N}\left(\frac{\omega_{it}+\overline{\omega}_i}{2}\right)(\ln y_{it} - \overline{\ln y_i}) - \sum_{i=1}^{N}\left(\frac{\omega_{is}+\overline{\omega}_i}{2}\right)(\ln y_{is} - \overline{\ln y_i})\right]$$

$$- \left[\sum_{j=1}^{M}\left(\frac{\omega_{jt}+\overline{\omega}_j}{2}\right)(\ln x_{jt} - \overline{\ln x_j}) - \sum_{j=1}^{M}\left(\frac{\omega_{js}+\overline{\omega}_j}{2}\right)(\ln x_{js} - \overline{\ln x_j})\right]$$

Where;

Y_{st}^{T*} = an index of outputs

X_{st}^{T*} = an index of inputs

ω_{it} = weighting of inputs/outputs

$\overline{\ln y_i}$ = industry average (a bar above any variable indicates the industry average)

We have used the same MTFP approach as the AER as we have no particular preference amongst the alternative forms of productivity index methods available[9], therefore alignment with the AER approach is considered practical and more informative for JEN than an alternative model. Further, the materiality of debate over alternative forms of the model is low given the limited application of the MTFP model (that is, to provide an indication of efficiency only, rather than a determination of efficient expenditure). We have, however, employed more than one MTFP model to test the sensitivity of the results to changes in the specification (see figure 13).

Advantages of using MTFP models include:

- As a non-parametric approach, an industry cost function does not need to be assumed;
- DNSPs are directly compared to other DNSPs within the industry and not a regression line (econometric modelling) or a hypothetical frontier business that is a combination of different businesses (DEA);
- The amount of data required is less exhaustive than for other benchmarking techniques; and
- MTFP benchmarking is transparent and easy to replicate.

There are also a number of disadvantages to using MTFP to infer relative efficiency between DNSPs, these include:

- MTFP does not take into account environmental variables. This means that it is difficult to interpret whether the results are due to inefficiency or different operating environments;
- MTFP does not take into account economies of scale. As is the case with operating environments, this makes it difficult to distinguish between inefficiency and different levels of expenditure that are the result of scale differences between DNSPs;
- MTFP scores can change significantly depending on the choice of inputs and outputs; and
- MTFP does not produce any statistical results which makes it difficult to determine if the results are valid and indicative of true efficiency differences between DNSPs.

MTFP can also be disaggregated into opex and capex partial factor productivity results by omitting the capital or operating expenditure inputs respectively to determine the output index relative to opex or the capital inputs. We use this method to analyse opex productivity in isolation of the capital inputs. We also use econometric techniques to evaluate opex partial factor productivity.

Econometric Modelling - modifications to the AER's approach

Econometric modelling is a parametric approach used to estimate the relationship between inputs and outputs. In the context of benchmarking opex, this means estimating a relationship between opex (the dependent variable) and a number of different inputs (independent variables) that are both measurable and have an impact on opex, either directly or indirectly.

Advantages of using econometric modelling include:

1. Econometric modelling estimates the relationship between different inputs and operational expenditure and can therefore predict opex for known inputs; and
2. Econometric modelling produces statistical results that can be used to infer which variables have a significant effect on DNSP expenditure and how well the proposed model explains variations in DNSP expenditure.

Disadvantages of using econometric modelling are:

1. The technique requires more data than DEA and MTFP;
2. In the presence of multicollinearity, coefficients can be unstable;
3. A relationship between inputs and operational expenditure needs to be assumed; and

[9] Given the insoluble difficulties with defining clear inputs and outputs for the industry it is easy, and not particularly informative, to champion one model over another. Huegin believes the best approach is to look at a number of different models recognising that output/input selection will bias some DNSPs at the expense of others. We believe the important step is to make adjustments where results are biased due to model specification – one example of this is to remove the effects of transmission assets for NEM DNSPs that we believe skews the results in favour of DNSPs that operate at lower voltages.

4. With a wide range of functional forms and input variables to choose from there may be a number of different models that are statistically valid but produce different estimates.

In this chapter we use a number of variable combinations in the econometric cost function and also investigate different forms of the cost function when estimating historic opex efficiency.

3.1.2 Data

The data relied upon for the modelling conducted in support of our analysis of comparative productivity is sourced from the Economic Benchmarking RINs, Annual RINs and Category Analysis RINs published by the AER. Adjustments made to, and assumptions made about, the source data are outlined in annex C.

3.1.3 Models

We have employed a number of models to investigate benchmark efficiency of JEN relative to its peers. The model specifications employed in this chapter are described in table 1 below.

Table 1: Productivity model specifications

Specification		Model													
		MTFP				Opex PFP				Econometric (opex)					
		1	1A	2	2A	3	3A	4	4A	5	6	7	8	9	10
Inputs/ Dependent Variable	*Opex*	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	OH MVA-km	x	x												
	UG MVA-km	x	x												
	Transformer Capacity	x	x	x	x										
	OH Subtransmission MVA-km			x	x										
	OH Distribution MVA-km			x	x										
	UG Subtransmission MVA-km			x	x										
	UG Distribution MVA-km			x	x										
Outputs/ Independent Variables	*Customer Numbers*	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	System Capacity	x	x			x	x			x	x	x	x		x
	Customer Minutes off Supply	x	x	x	x	x	x	x	x						
	Energy			x	x			x	x						
	Ratcheted Peak Demand			x	x			x	x					x	
	Circuit Length			x	x			x	x			x		x	
Environmental Variables and/or Adjustments	*Remove assets & opex at or above 110kV*		x		x		x		x						
	Share of Single Stage Transformation									x			x		x
	RAB									x	x				
	Demand Density									x			x		x
	Capacity Intensity										x	x	x		
	Share of Underground Network											x		x	
Technology Variable	*Year*									x	x	x	x	x	x

Notes:
1. Models 1 and 2 are the preferred specification from the AER's Expenditure Forecast Assessment Guideline and Annual Benchmarking Report respectively.
2. Models 3 and 4 are the opex PFP models associated with the MTFP models 1 and 2 respectively.
3. Models 1A, 2A, 3A and 4A are adjusted to exclude assets above 110kV from physical measures and opex associated with these assets, as only NSW, ACT and QLD have assets at this voltage level. Opex has also been adjusted; where the DNSP reports opex at the voltage level it has been subtracted from the RIN total opex figure, where the DNSP does not report opex at the voltage level an average cost per km from the other DNSPs has been assumed.
4. Models 5 to 10 are variations of econometric models.
5. Models 2, 4 and 9 are those relied upon by the AER in the NSW and ACT draft decisions.
6. Demand density is the peak demand per customer.
7. Capacity intensity is the total MVAkm of line capacity per km of network.

Our view on productivity evaluation models (index or econometric) is that any specified model will exhibit a level of bias against certain networks - particularly in a diverse environment such as Australia. The selection of a few common input and output variables, and the simplicity of electricity distribution production functions that such an approach implies, further contributes to the potential for error when these models are used to calculate efficiency differences between businesses. This is due to:

1. The fact that the variables are often only proxies for differences in scale between networks, rather than drivers of cost;
2. The influence of omitted variable bias, where the impact of actual cost drivers that are not included in the model are interpreted as inefficiency; and
3. The potential for error is increased when the models are used to compare businesses within the sample, rather than measure overall industry productivity (as the models have varying degrees of suitability based on the individual circumstances of each network). This is largely due to the impacts of latent heterogeneity [10] between NEM DNSPs. Given that this heterogeneity (such as customer demographics, network design, state specific legislation, climate and topographical differences etc.) is likely to be fairly constant over time then it is easier to benchmarks DNSPs between time periods (where environmental factors and their impact on opex are fairly constant) than between businesses (where the impact of environmental differences on opex are varied). This difficulty in quantifying efficiency levels between DNSPs is particularly troublesome when being used to set expenditure allowances because it is virtually impossible using high level economic models to distinguish between efficiency (much of which is time-invariant) and heterogeneity.

In recognition of these limitations and risks of using a single model to infer relative efficiency, we have considered all 14 models in our analysis throughout this report. Whilst we consider some models to be more relevant, accurate and/or generally more suitable than others, we considered the balance of the results when forming our views on the evaluation of efficiency of JEN's historical total and operating costs to mitigate the potential for model bias as much as possible. To inform our view of an appropriate productivity growth rate, however, we must consider the most suitable econometric model. For this purpose we use statistical testing and observation to select an appropriate model (model 10 is our preferred model), which is discussed further in the next chapter.

Further discussion on the models and the rationale for their inclusion in our analysis is included at annex D.

The methods applied and scope of expenditure included for each model specification described in table 1 is shown in table 2.

Table 2: Methodological application of models

Productivity Models Used	Index Method Models	Econometric Method Models
Total Expenditure	Models 1, 1A, 2 & 2A	N/A
Operating Expenditure	Models 3, 3A, 4 & 4A	Models 5, 6, 7, 8, 9 & 10

3.2 Consideration of Environmental Variables

Unobserved heterogeneity - differences between networks that are not included in economic benchmarking model specifications, yet have a material impact on the results - is an ongoing challenge to the efforts to measure relative efficiency of network businesses. The consideration of environmental variables and the degree to which each network is exposed to their effect is critically important in any benchmarking study. Whether by observation or more sophisticated analytical techniques, allowance for differences in exogenous factors must be present if benchmarking results are to be considered credible. For index models, this allowance is often provided by second stage regression, where raw results are regressed against the variable in question and adjusted accordingly. For econometric methods, the variable can be included within the opex cost function itself. In any

[10] Latent heterogeneity refers to factors known to be relevant to the variable under study, but unable (or at least very difficult) .to be measured from the data available.

case, the absence of appropriate consideration of network differences will render relative comparison of efficiency scores meaningless.

3.2.1 Identifying peer networks

Electricity distribution networks differ through the legacy of their design, topographical and geographical attributes of their location and regulatory and legislative requirements associated with the local jurisdiction. Section 2.1.1 described a number of techniques including latent class modelling where algorithms classify groups or clusters of networks by categories defined by characteristic similarities within the group and differences between groups. Latent class modelling requires reasonably large datasets, and dividing networks in Australia into classes would tend to produce several groups of very small membership. However failure to recognise that there are legitimate differences between the networks renders the measurement of relative efficiency unreliable when efficiency scores are generated from a single model. Comparing Ergon Energy or Essential Energy to CitiPower, for example, on the basis of the raw MTFP results included in figure 2 would not provide a meaningful assessment of relative productivity. This is because Ergon Energy, with sparsely distributed customers and much higher consumption and demand per customer has a network designed to meet these conditions. This design includes long, radial feeders with high levels of Single Wire Earth Return (SWER) but also much higher voltage subtransmission cables and transformers to transport electricity over long distances. CitiPower, on the other hand, has a very small, densely populated network area. Much of its network is underground and it operates at generally lower voltages than Ergon Energy. Due to these differences, the cost drivers of each network would vary significantly. For this reason, productivity results based on the assumption of common weightings and combinations of input and output variables are unlikely to provide reliable comparisons of efficiency without consideration of the impact of the different operating conditions[11].

Huegin have in the past tested the sensitivity of individual DNSP scores to changes in the weightings on the variables in the AER models. That analysis demonstrated that not only are the results very sensitive to such changes, but it also showed that the magnitude and direction (i.e. negative or positive) of the change in the productivity score was similar for certain groups of businesses. That is, small groups of businesses exhibited similar patterns of change in the results with variations in the weightings, and these groups exhibited very different patterns from other groups. This is an indication of the existence of attribute based classes in the data. That is, the relationship between the combination of inputs and outputs is similar for certain businesses. One way of analysing the existence of classes in a data set is through clustering algorithms. These are computational methods capable of segmenting entities in a data set into classes of similar attributes. The advantage that this statistical technique poses over economic models is that many more variables can be considered in much smaller data samples. Table 3 on the following page shows the 17 network variables used in the analysis and figure 4 illustrates the hierarchy of classes and membership of each group or cluster.

Table 3: Network variables used in cluster analysis

Electricity Supply	Physical Network Attributes	Performance	Density
Customer numbers	Overhead lines	Customer minutes off supply	Customer density
Maximum demand	Underground cables	SAIDI	Demand density
Energy distributed	Zone transformers	SAIFI	Energy density
	Distribution transformers		
	Circuit length		
	Share of single stage transformation		
	Transformers excluding first stage		
	System capacity		

[11] See for example: Agrell, Farsi, Filippini and Koller, "Unobserved heterogeneous effects in the cost efficiency analysis of electricity distribution systems", January 2013

Figure 4: DNSP class hierarchy

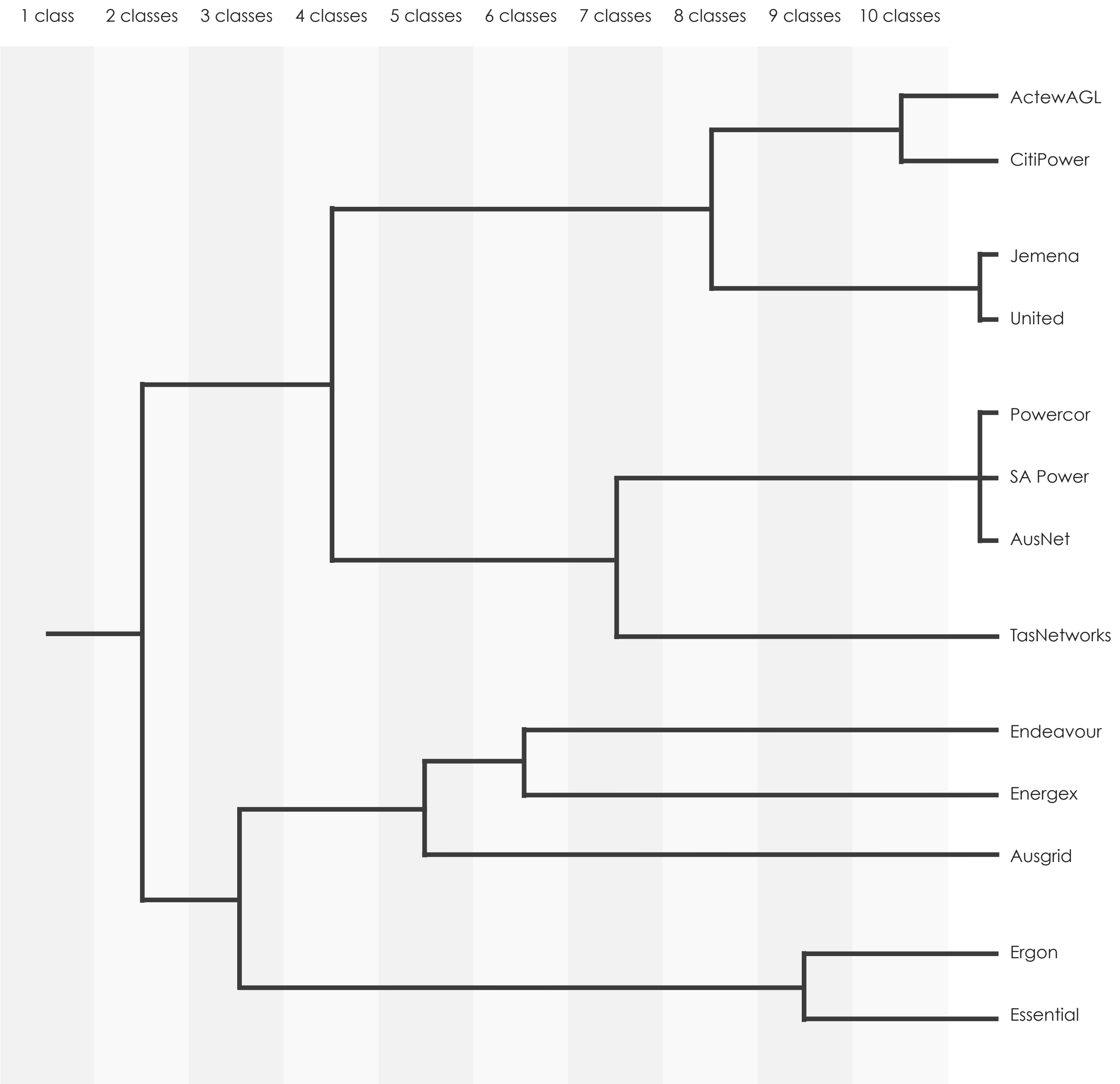


Figure 4 has been constructed through the iterative application of a clustering algorithm (more information on clustering algorithms is included at annex E) using k-means analysis[12]. Clustering algorithms require an assumption of the number of classes inherent in the sample. To create the hierarchy shown in figure 4, we ran analysis on the range of assumptions from two classes to ten classes (whilst ten classes is not an assumption that we would use, the analysis has been extended to that level to highlight the endurance of certain groupings). That is, we ran the clustering algorithm on the basis of an assumption that there are two classes of asset type amongst the 13 DNSPs, then an assumption of three classes and so on until the final run at the assumption of ten individual classes of DNSP. The result is the segmentation of businesses in clusters at each assumption, showing the nature and enduring strength of the similarities between networks based on the variables identified in table 3.

There are several observations of note in figure 4:

- At the first division (the two class assumption), the networks separate into the Queensland and New South Wales businesses in one class and all other networks (Tas, Vic, SA) in the other class.

[12] K-means clustering uses different business characteristics to put businesses in groups based on distances between these observed characteristics.

- At the second division (three class assumption), Ergon Energy and Essential Energy separate from the first group.
- At the third division (four class assumption) the predominately rural/regional southern networks (Powercor, AusNet Services, SA Power Networks and TasNetworks) split from the four networks that are fully enclosed within a single metropolitan area (ActewAGL, CitiPower, JEN and United Energy).
- Beyond four classes:
  - Ausgrid forms a class of which it remains the only member.
  - Powercor, AusNet Services and SA Power Networks endure as a group all the way to the ten class assumption.
  - ActewAGL, CitiPower, JEN and United Energy remain in a common class until the assumption of eight classes (at which point JEN and United Energy remain paired through to the ten class assumption, and ActewAGL and CitiPower remain paired until the nine class assumption).
  - At ten classes, there are only two classes that continue to include more than one business - the pair of JEN and United Energy and the group of Powercor, SA Power Networks and AusNet Services.

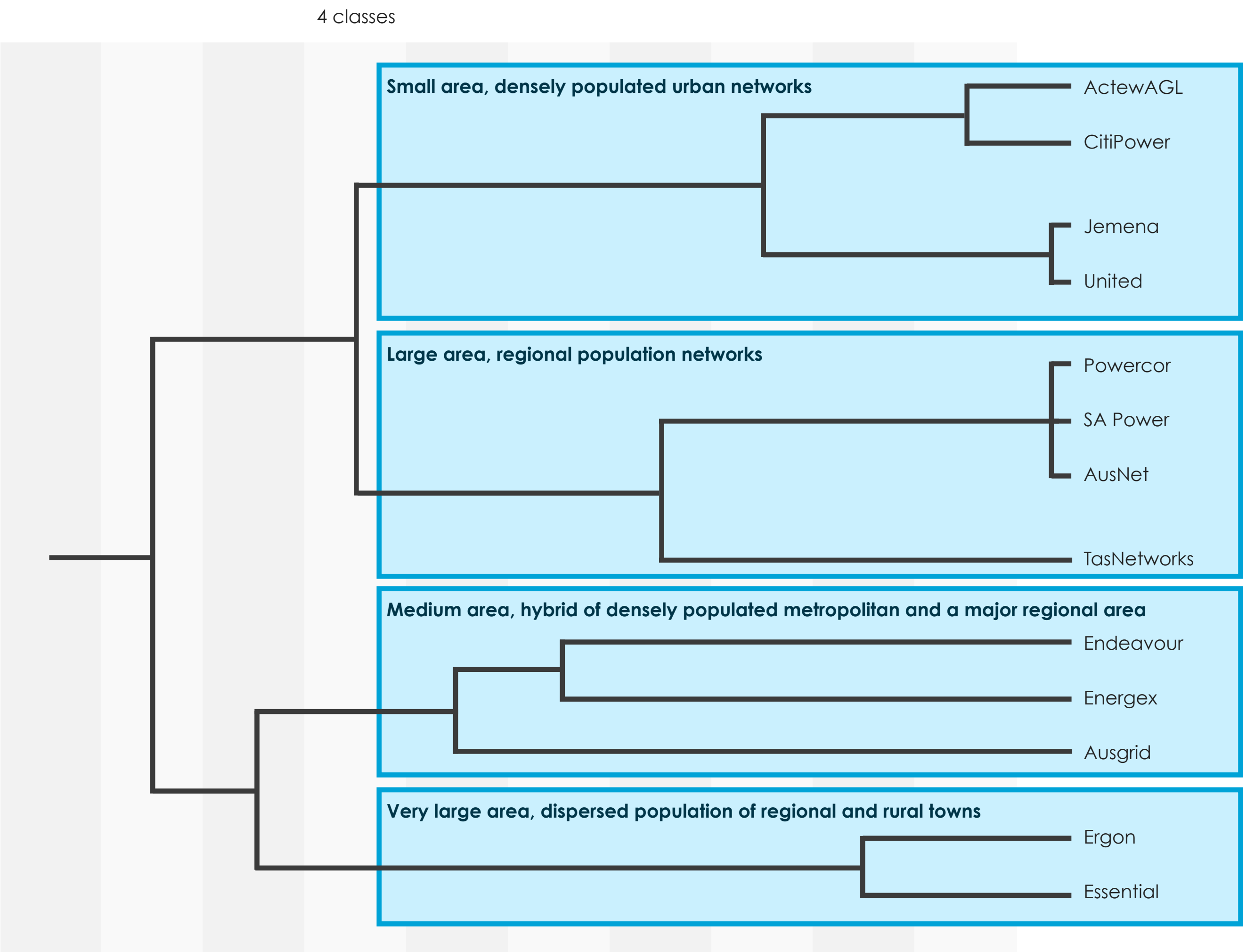
Statistical testing can be used to determine the optimal number of classes, however the answer is dependent on the actual variables chosen and the networks included in the sample. For example, during the recent NSW and ACT draft determination, Huegin ran latent class model analysis over the 68 Australian, New Zealand and Ontario networks in the AER's data sample. This analysis using latent class modelling found that the four class assumption is the optimal split of businesses into similar clusters for benchmarking purposes[13].

Considering both latent class modelling and k-means clustering analysis, we consider that 2, 3 or 4 classes are the strongest clustering of networks. Four classes is more informative, as the networks become more closely aligned within their groups the more granular the assumption becomes. However if the clustering analysis was used to apply different productivity models for each group, this level of classification is impractical because the membership of the groups is too small to produce statistically significant results. Our intent for this study is to determine the most appropriate networks to compare to JEN when observing productivity results, particularly for cost ratios. As such, the unsuitability of the cluster sizes for modelling purposes is irrelevant.

At the four class assumption level, we find that JEN is more closely paired to United Energy (a pairing that endures beyond the ten class assumption) than it is to ActewAGL or CitiPower (which split away as a pair at the eight class assumption). Figure 5 on the next page highlights the four class assumption groups.

[13] In latent class modelling, the Akaike Information Criterion (AIC) can be used to test the relative strength of each assumption. In work completed during the NSW revised regulatory proposal (Huegin, "Response to the Draft Determination on behalf of NNSW and ActewAGL: Technical Response to the application of benchmarking by the AER", 16 January 2015), Huegin found that the four class assumption was strongest. See annex E for more detail.

Figure 5: DNSP optimal class consideration



The significance of the segmentation of the networks into clusters manifests in the interpretation of productivity or efficiency scores in the context of a single industry model, such as those employed by the AER. Multiple classes means either separate models, or multiple frontiers, should be considered. When reviewing productivity model scores, it is misleading to compare results across class clusters. However even within groups, the eventual split into more granular clusters demonstrates the caution that must be taken in comparing efficiency scores between networks - which is why consideration of environmental variables and differences in operating conditions is critical.

3.2.2 Defining and measuring environmental variables

Using network attributes to group or pair similar networks is useful, however understanding the relevance and influence of such groupings on cost depends upon the nature and magnitude of the relationship between common attributes and cost. In our work we have found that many of the physical and jurisdictional differences between networks, commonly classified as environmental variables or factors, are important drivers of cost variations across the networks. These variables are within or outside the control of management to varying degrees. If left unaccounted for, their influence is often erroneously interpreted as inefficiency. Care must be taken in how they are considered, however.

In the presence of different classes of networks, as demonstrated in the previous pages, inclusion of a specific variable in the productivity model or even adjustment of the results from the model, will not produce valid efficiency score results. This is because the influence and materiality of the variable will differ for the different classes. Another complicating factor of environmental variables is that there is rarely a simple measure or adjustment that can be made. The influence of the variable will vary across a single network, as well as between networks. For example, climate is difficult to incorporate because there is no single measure of climatic impact that describes its effect on network costs and for large networks such as Ergon Energy, the effect varies by location. For the purposes of our exercise, we consider the efficiency results in concert with an understanding of the materiality of environmental variables in contributing to the differences in efficiency scores between DNSPs. Table 4 below describes some of the more material environmental variables that must be considered for any efficiency comparison - both within class groups and across them.

Table 4: Environmental variables relevant to electricity distribution costs

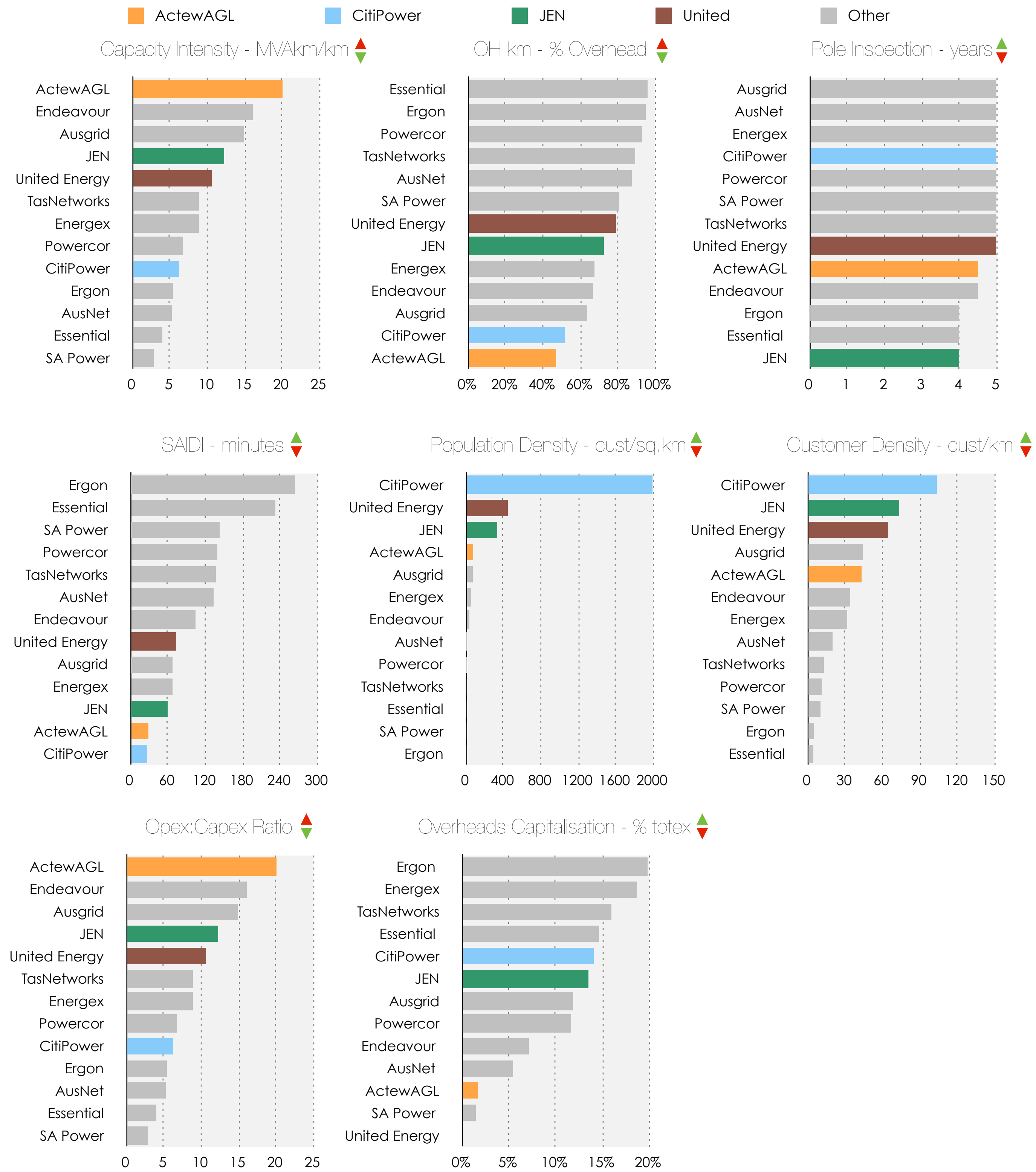
Environmental Variables Material to Total and Partial Factor Analysis			
Group	Variable	Direction	Description
Material to Total and Partial Factory Analysis			
Design	Capacity Intensity	Red ▲ Green ▼	The type and number of assets required to transport electricity between transmission points and the customer is a legacy of the original design and decisions since then.
	Overhead Network	Red ▲ Green ▼	High proportions of overhead network decrease the resilience of the network and also increase costs such as vegetation management.
Work Practices	Inspection Frequency	Green ▲ Red ▼	A significant proportion of electricity network costs are maintenance costs, and much of this cost is driven by asset inspections. The inspection cycle of assets therefore has a material impact on costs.
Service Standards	SAIDI	Green ▲ Red ▼	The latent level of reliability of a network is a function of its original design and management. SAIDI improvements generally require capital expenditure, however maintenance of SAIDI at a particular level requires opex.
Demographics	Population Density	Green ▲ Red ▼	Population density (customers per square km of service territory) differs from customer density (see below). Population density provides an indication of the dispersion of customers and relative distance between them. High population densities generally facilitate a more meshed network, whilst low densities require radial network designs.
	Customer Density	Green ▲ Red ▼	Customer density (customers per km line) is an indication of the distribution of customers along the network feeders.
Material to Partial Factor Analysis Only			
Cost Allocation and Accounting	Opex to Capex Ratio	Red ▲ Green ▼	Higher allocation of expenditure to operating expenses rather than capital will drive poorer results in efficiency measurement for opex partial factor or econometric models. Leasing costs and labour provisions are two common causes of high opex to capex ratios.
	Overhead Capitalisation	Green ▲ Red ▼	Low levels of overhead capitalisation will "strand" costs in opex and lead to poorer results in efficiency measurement for opex partial factor or econometric models.

Notes:

1. Direction indicates the relationship between the value of the variable and the relative advantage afforded by it. That is, a red arrow up indicates that as the variable value increases, the cost disadvantage increases, and vice versa for a green arrow up.
2. Not all environmental variables have a constant, linear relationship between their value and the advantage or disadvantage. For example, low customer density has a cost disadvantage associated with longer travel time and more support infrastructure, however higher customer density will eventual lead to cost disadvantages associated with congestion.

Figure 6 depicts the comparison of JEN to its peers and to the wider group on a range of variables that have influence on cost.

Figure 6: Environmental variable comparison - JEN, peers and broader group



In summary:

1. JEN occupies a generally neutral position in its peer group, with attributes similar to United Energy and "between" ActewAGL and CitiPower.
2. The least favourable attributes for JEN within its peer group are the percentage of overhead line and population density.

3. Within the broader group JEN also occupies a relatively neutral position (i.e. neither considerably favourable or unfavourable) on most attributes, with the exception of:
    1. SAIDI, where JEN has a higher level of network reliability than many of the other DNSPs; and
    2. Customer density, where JEN has more favourable conditions than many of the other DNSPs (although this is not a factor within its smaller peer group).

3.3 Total Factor Productivity Index

The AER's Expenditure Forecast Assessment Guideline Explanatory Statement states that MTFP will be used primarily to measure the overall efficiency and productivity of the network service providers[14]. In the Annual Distribution Benchmarking Report, the AER published results from its MTFP analysis of industry, state and individual DNSP productivity [15]. As shown in figure 2 of this report, JEN ranks fourth in the AER's MTFP model of individual DNSP productivity. Under the AER approach to determining an efficient frontier outlined in the recent NSW and ACT Draft Decision for Distribution Determination, whereby any DNSP with an efficiency score above 75% was deemed on the frontier, JEN would be considered efficient on the basis of the MTFP result.

3.3.1 Industry productivity appears to be declining

Industry productivity was shown to have declined over the measurement period (2006 - 2013) based on the AER's MTFP analysis in the Annual Distribution Benchmarking Report [16].

It is important to understand the inference that this signal of declining total factor productivity represents. So long as the output index of a total (or partial) factor productivity model is based on physical attributes of the networks, moderate increases in cost will cause a downturn in productivity. Outputs such as customer numbers, line length and system capacity are very large numbers that change in small increments. High output index values and growth rates are therefore very difficult to achieve.

Of course, costs that increase at a greater rate than the output index may be legitimate productivity decline, however this does not automatically equate to decreasing efficiency. This is especially the case if the output index specification fails to capture the cause of the increase in cost. For example, a significant contributor to the productivity change in the AER MTFP model is the increase in opex, which in turn is materially driven by an increase in vegetation management costs.

The sharp increase in vegetation management cost:

1. Does not cause an associated increase in any of the output variables (as the outputs do not include the output of vegetation management activities); and
2. Is related to the change in obligations to do more vegetation management after fire-related events, rather than the onset of inefficient practices.

Therefore inferences of productivity and efficiency performance based on models that do not isolate the influence of such changes must be treated with caution.

Further, where output variables may change over long-run time in a similar pattern to cost, there may appear to be a high correlation of productivity and change in those variables. However if those variables are included in the output specification on the assumption that such correlation is actually a causal relationship, occasional short-run fluctuations in those variables can give false signals of productivity change. For example, steady increases in demand and consumption over a long period appear correlated to changes in cost. However in a period of falling or stagnant demand and/or consumption, productivity change will appear negative because

[14] AER, page 124, Better Regulation - Explanatory Statement - Expenditure Forecast Assessment Guideline, November 2013

[15] AER, pages 30-32, Annual Distribution Benchmarking Report, 27 November 2014

[16] Ibid, page 30

costs will not decrease in a causal response to the drop-off in demand or consumption. There are two reasons for this:

1. Assets are not removed in response to falling demand or consumption; and

2. Assets (and therefore costs) are added to the network in anticipation of demand, not in response to it, and therefore the change in cost and demand are separated in time (and therefore so are the respective changes in the input and output indices of an MTFP model).

3.3.2 Results are sensitive to model specification

As discussed in this report, MTFP results are sensitive to the model specification and also cannot account for environmental variables. As such, Huegin tested a number of MTFP model specifications to examine the hypothesis that JEN can be considered to be an overall efficient DNSP.

Time series MTFP results for each model specification outlined in tables 1 and 2 are included below and plotted on the following page.

Table 5: Time series MTFP results - Models 1, 1A, 2 & 2A

	Model 1										
	2006	2007	2008	2009	2010	2011	2012	2013	Ave	Rank	Score
ActewAGL	1.00	1.00	1.01	1.01	0.98	0.92	0.92	0.92	0.97	13	44%
Ausgrid	1.18	1.28	1.09	1.12	1.13	1.13	1.12	1.22	1.16	11	53%
CitiPower	2.21	2.18	2.25	2.12	2.05	2.20	1.99	2.03	2.13	3	97%
Endeavour Energy	1.32	1.27	1.15	1.20	1.24	1.24	1.18	1.19	1.23	10	56%
Energex	1.70	1.72	1.66	1.68	1.70	1.63	1.57	1.43	1.64	7	74%
Ergon Energy	1.07	1.27	1.15	1.11	1.12	1.12	1.10	1.15	1.14	12	52%
Essential Energy	1.55	1.56	1.50	1.44	1.52	1.47	1.33	1.37	1.47	8	67%
Jemena	1.73	1.71	1.93	1.83	1.76	1.80	1.71	1.72	1.78	6	81%
Powercor	2.03	2.08	2.12	1.89	1.93	2.04	1.94	1.87	1.99	4	90%
SA Power Networks	2.30	2.24	2.35	2.27	2.12	2.07	2.17	2.08	2.20	1	100%
AusNet Services	2.05	1.94	2.02	1.78	1.94	1.92	1.93	1.86	1.93	5	88%
TasNetworks	1.47	1.46	1.46	1.36	1.28	1.37	1.32	1.43	1.39	9	63%
United Energy	2.19	2.20	2.20	2.21	2.20	2.01	1.94	2.08	2.13	2	97%

	Model 1A										
	2006	2007	2008	2009	2010	2011	2012	2013	Ave	Rank	Score
ActewAGL	1.00	1.01	1.02	1.02	1.00	0.92	0.95	0.96	0.99	11	67%
Ausgrid	1.06	1.15	0.97	0.99	1.00	1.01	1.01	1.12	1.04	9	71%
CitiPower	1.41	1.38	1.43	1.35	1.30	1.38	1.26	1.28	1.35	3	92%
Endeavour Energy	1.21	1.16	1.06	1.11	1.14	1.13	1.09	1.11	1.13	7	77%
Energex	1.49	1.51	1.45	1.46	1.47	1.44	1.46	1.41	1.46	1	100%
Ergon Energy	0.77	0.92	0.83	0.81	0.82	0.82	0.84	0.90	0.84	13	57%
Essential Energy	1.12	1.11	1.05	1.01	1.07	1.03	0.92	0.97	1.04	10	71%
Jemena	1.05	1.05	1.16	1.11	1.06	1.09	1.04	1.05	1.08	8	74%
Powercor	1.25	1.28	1.30	1.16	1.18	1.25	1.20	1.16	1.22	5	84%
SA Power Networks	1.44	1.41	1.48	1.43	1.34	1.31	1.37	1.33	1.39	2	95%
AusNet Services	1.26	1.21	1.24	1.11	1.19	1.19	1.19	1.15	1.19	6	82%
TasNetworks	0.91	0.90	0.90	0.83	0.79	0.84	0.81	0.87	0.86	12	59%
United Energy	1.37	1.37	1.35	1.37	1.34	1.22	1.19	1.27	1.31	4	90%

	Model 2										
	2006	2007	2008	2009	2010	2011	2012	2013	Ave	Rank	Score
ActewAGL	1.00	0.99	1.00	0.99	0.96	0.87	0.91	0.90	0.95	12	55%
Ausgrid	1.04	1.11	0.95	0.96	0.96	0.96	0.91	0.98	0.98	10	57%
CitiPower	1.83	1.81	1.86	1.73	1.66	1.76	1.60	1.61	1.73	1	100%
Endeavour Energy	1.34	1.28	1.16	1.20	1.23	1.22	1.16	1.16	1.22	7	70%
Energex	1.33	1.33	1.28	1.27	1.27	1.23	1.21	1.17	1.26	6	73%
Ergon Energy	0.92	1.07	0.98	0.95	0.96	0.92	0.93	1.02	0.97	11	56%
Essential Energy	1.13	1.09	1.03	0.99	1.00	0.95	0.84	0.86	0.99	9	57%
Jemena	1.36	1.35	1.51	1.43	1.38	1.39	1.32	1.31	1.38	4	80%
Powercor	1.31	1.35	1.36	1.24	1.24	1.30	1.24	1.18	1.28	5	74%
SA Power Networks	1.62	1.57	1.64	1.59	1.49	1.41	1.44	1.38	1.52	2	88%
AusNet Services	1.31	1.24	1.28	1.13	1.22	1.19	1.18	1.12	1.21	8	70%
TasNetworks	1.20	1.03	0.98	0.87	0.81	0.88	0.84	0.89	0.94	13	54%
United Energy	1.54	1.55	1.54	1.56	1.53	1.40	1.33	1.40	1.48	3	86%

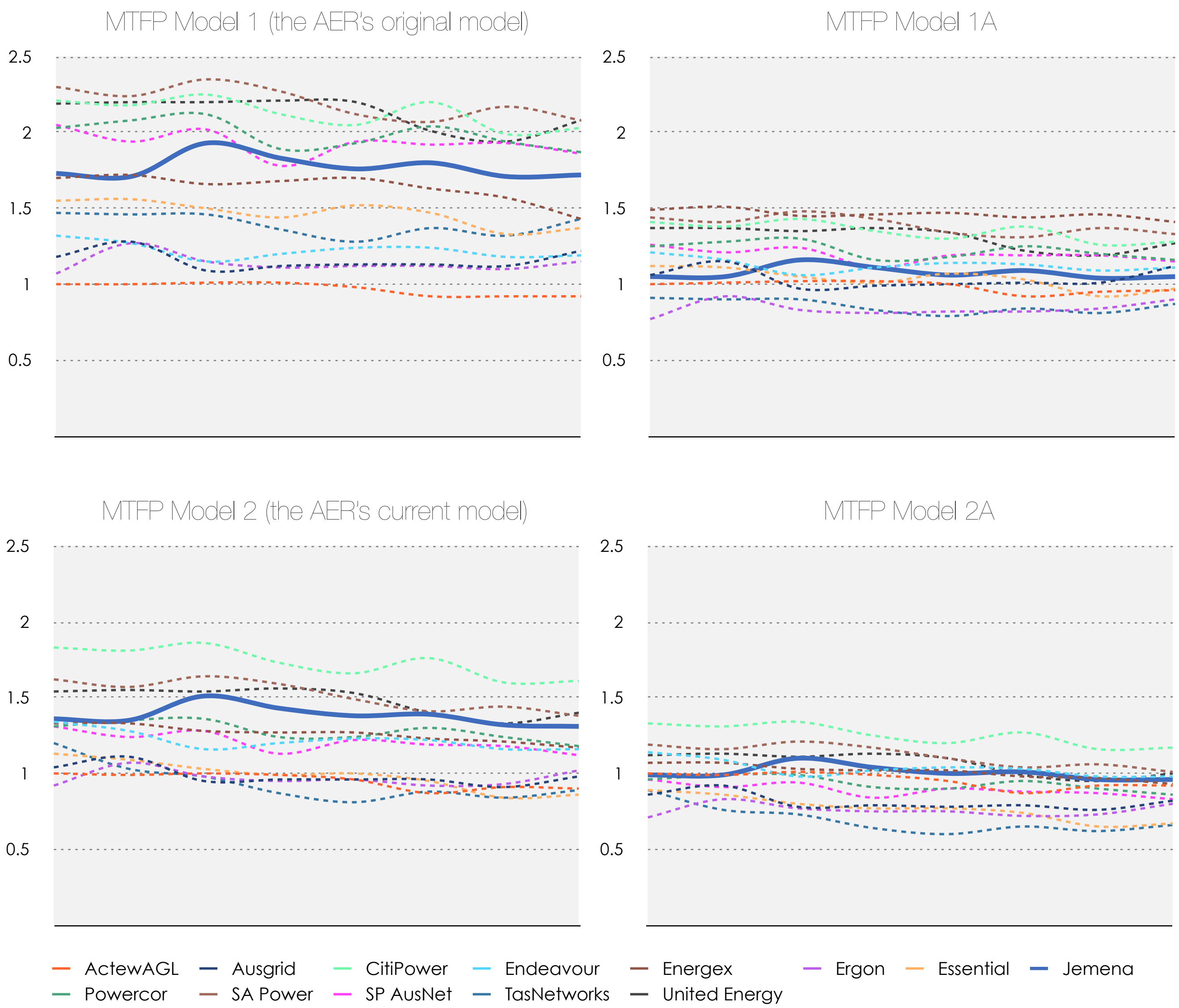
	Model 2A										
	2006	2007	2008	2009	2010	2011	2012	2013	Ave	Rank	Score
ActewAGL	1.00	0.99	1.01	0.99	0.95	0.87	0.92	0.92	0.96	7	76%
Ausgrid	0.86	0.92	0.78	0.79	0.78	0.79	0.76	0.82	0.81	10	65%
CitiPower	1.33	1.31	1.34	1.25	1.20	1.27	1.16	1.17	1.25	1	100%
Endeavour Energy	1.14	1.09	0.98	1.02	1.04	1.03	0.98	0.98	1.03	4	82%
Energex	1.07	1.07	1.03	1.02	1.02	0.98	0.97	0.93	1.01	5	80%
Ergon Energy	0.71	0.83	0.77	0.75	0.75	0.72	0.73	0.80	0.76	12	61%
Essential Energy	0.89	0.86	0.80	0.77	0.77	0.74	0.65	0.67	0.77	11	61%
Jemena	0.99	0.99	1.10	1.04	1.00	1.01	0.96	0.96	1.01	6	80%
Powercor	0.96	0.99	0.99	0.91	0.90	0.95	0.90	0.86	0.93	8	74%
SA Power Networks	1.19	1.16	1.21	1.17	1.10	1.04	1.06	1.01	1.12	2	89%
AusNet Services	0.96	0.91	0.94	0.84	0.90	0.88	0.87	0.83	0.89	9	71%
TasNetworks	0.89	0.76	0.73	0.64	0.60	0.65	0.62	0.66	0.69	13	55%
United Energy	1.12	1.13	1.11	1.13	1.10	0.99	0.95	1.00	1.06	3	85%

The AER did not use their MTFP model as a means of determining potential inefficiency quantitatively in the NSW and ACT Draft Decisions. The AER did, however, acknowledge the inherent error and inability of these models to inform precise efficiency evaluations by adjusting their econometric opex (SFA Cobb Douglas) model frontier to the customer-weighted average of the efficiency scores of all businesses at or above an efficiency score of 75%. Taking the same approach, JEN would be:

- On the frontier for three of the four MTFP models (1, 2 and 2A) based on the results in table 5 for both average efficiency over the period and the 2013 efficiency score;
- Only 1% off the frontier for the other MTFP model (1A) for both average efficiency over the period and the 2013 efficiency score; and
- Within a range of 3% to 17% below the MTFP efficiency scores of United Energy, depending on which model is used.

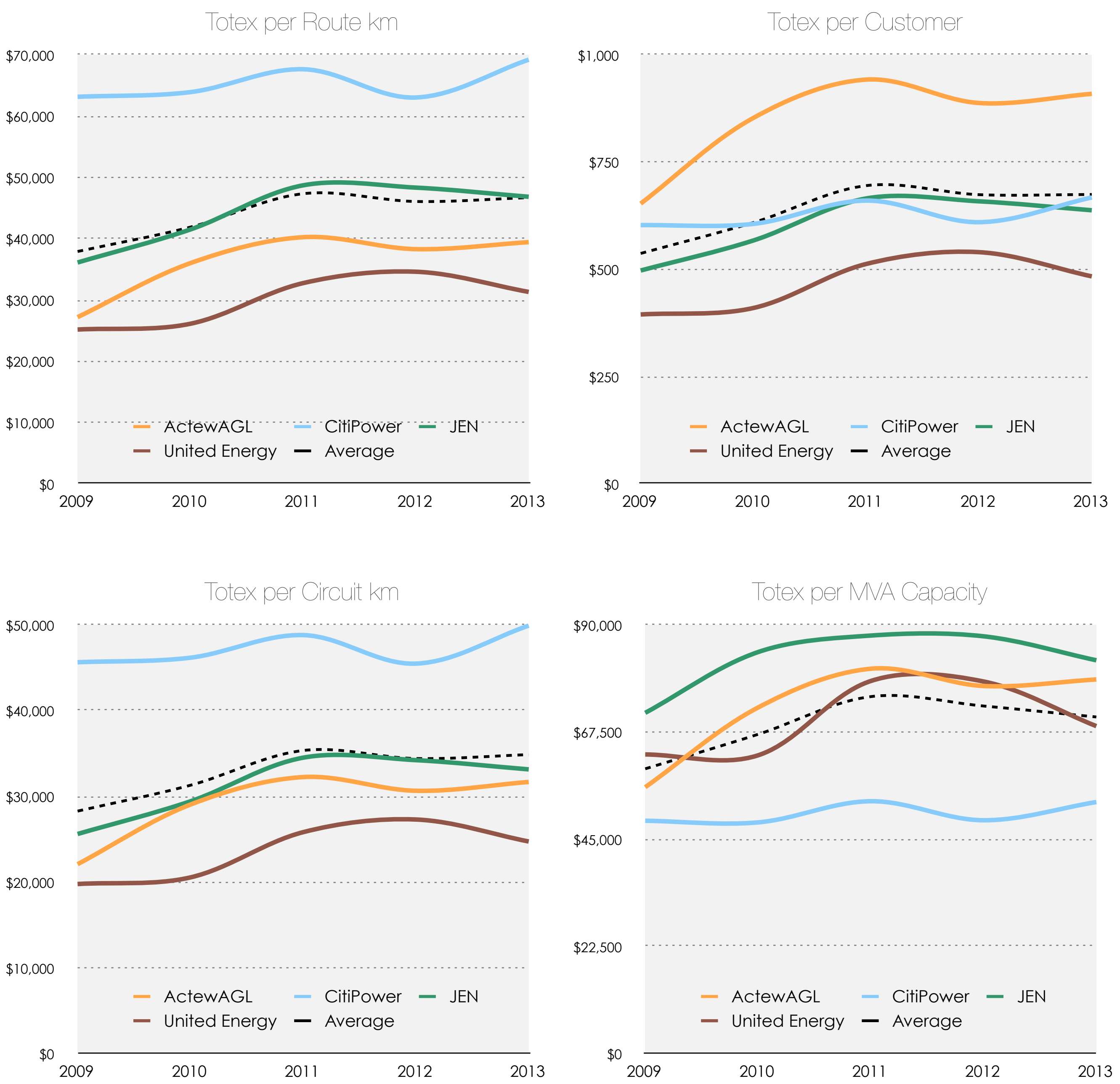
Figure 7 also shows that the gap between JEN and the frontier firm has closed between the start (2006) and end points (2013) of the analysis period.

Figure 7: Time series MTFP results - Models 1, 1A, 2 & 2A



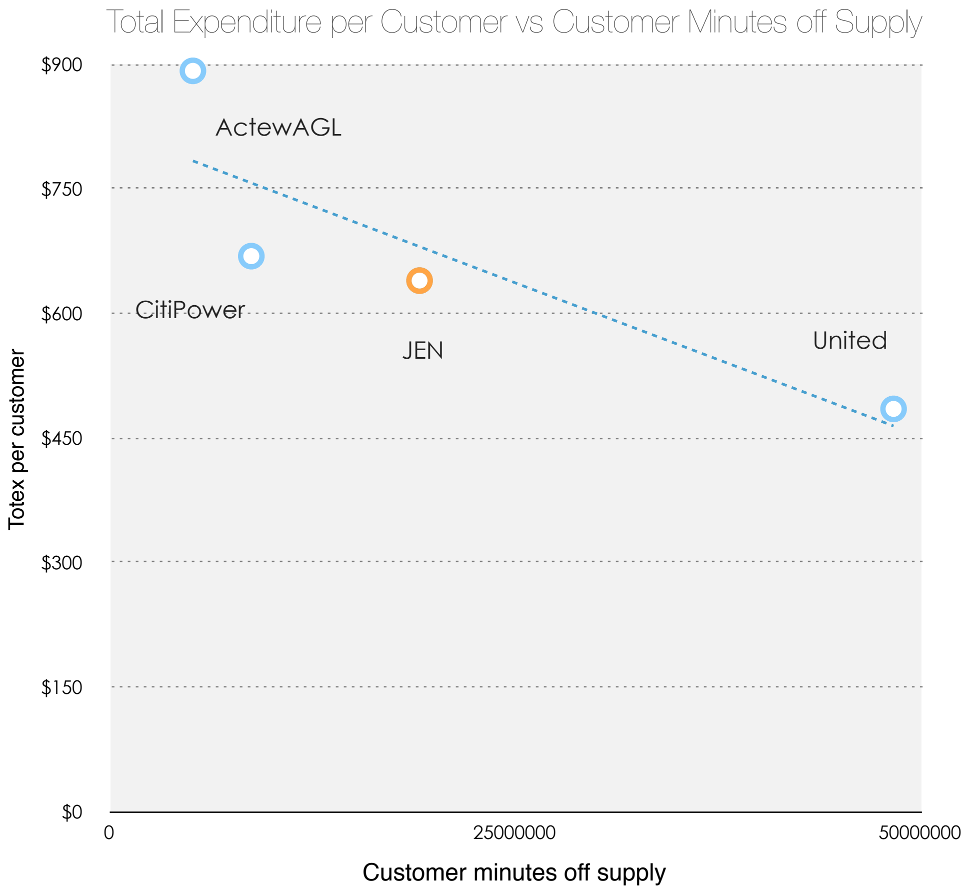
Based on the above, and in recognition of the limitations of TFP models (specifically due to mis-specification and omitted variable bias in a diverse environment) to provide quantitative estimates of inefficiency, we cannot consider that JEN is inefficient at a total expenditure level. We analysed some high level total expenditure cost ratios within the JEN peer group to further test the performance of JEN on a total expenditure basis. Figure 8 shows the comparison of common total expenditure ratios over time. When we consider JEN's total expenditure performance against its peers using simple ratio analysis, we find that JEN is operating around or just better than the group average on most cost ratios. As a small, densely populated network, CitiPower is disadvantaged by network length denominators in this peer group. As a larger, more sparsely populated network, ActewAGL is disadvantaged by ratios with a customer number denominator. JEN and United Energy compare more consistently, both to each other and the group average.

Figure 8: Totex ratios - peer group ($2014)



The importance of environmental variables can be illustrated through the consideration of cost differences above in the context of a particular factor. For example, when adjusted for scale JEN shares many characteristics with United Energy's network, however its total expenditure per customer is higher. But when total expenditure per customer is viewed in conjunction with customer minutes off supply, a more complete picture emerges of the multi-dimensional nature of performance. Figure 9 on the following page shows the relationship between total expenditure per customer and customer minutes off supply for the JEN peer group. Whilst there appears to be a reasonable variation in total expenditure per customer within the peer group (as shown by the top right graph in figure 8 above), this variation can be shown relative to the reliability performance of each network. Figure 9 shows that as the customer minutes off supply decreases, the total expenditure per customer increases. This demonstrates that at least some of the variation in expenditure per customer between the four businesses is due to the inherent reliability of the networks and the expenditure associated with maintaining the service standard of each network.

Figure 9: Cost performance vs reliability performance (2009-13 average)



Whilst this analysis is not definitive proof of the relationship between expenditure and performance outcomes, it does highlight the risks associated with comparing costs across businesses without considering salient factors that influence the cost of each individual network.

3.4 Opex Partial Factor Productivity

As discussed in section 3.1.1, we have employed both index and econometric techniques to investigate opex partial factor productivity. The results and discussion of the relevance to JEN and what information they provide about JEN's opex performance are presented below.

3.4.1 Index method

The index methods applied for opex analysis are based on the MTFP models used in section 3.3 with omission of the physical input variables. That is, the input index includes opex only. The opex partial factor productivity measure is subject to the same influence of environmental variable differences as the MTFP measure, however the last two factors at the bottom of table 4 (opex:capex ratio and overheads capitalisation) also influence the opex partial factor productivity results.

Table 6 below shows the Opex PFP results for the four models tested (3, 3A, 4 and 4A) and figure 10 on the following page shows the plots of partial productivity results for each model.

Table 6: Time series Opex PFP results - Models 3, 3A, 4 & 4A

	Model 3										
	2006	2007	2008	2009	2010	2011	2012	2013	Ave	Rank	Score
ActewAGL	1.00	1.01	0.99	0.99	0.90	0.79	0.80	0.78	0.91	13	40%
Ausgrid	1.24	1.50	1.04	1.14	1.10	1.14	1.08	1.41	1.21	11	54%
CitiPower	2.66	2.40	2.62	2.19	2.02	2.32	1.82	1.91	2.24	1	100%
Endeavour Energy	1.43	1.35	1.11	1.24	1.35	1.31	1.28	1.41	1.31	9	58%
Energex	1.84	1.79	1.73	1.77	1.81	1.61	1.39	1.11	1.63	6	73%
Ergon Energy	0.83	1.06	0.94	0.93	0.97	0.86	0.82	0.95	0.92	12	41%
Essential Energy	1.46	1.38	1.20	1.23	1.30	1.29	1.06	1.21	1.27	10	56%
Jemena	1.37	1.33	1.72	1.59	1.38	1.46	1.31	1.36	1.44	8	64%
Powercor	2.02	2.27	2.35	2.01	2.21	2.24	1.91	1.81	2.10	3	94%
SA Power Networks	2.42	2.54	2.48	2.31	2.21	1.87	1.96	1.84	2.20	2	98%
AusNet Services	2.10	1.81	1.82	1.53	1.71	1.70	1.68	1.54	1.74	5	77%
TasNetworks	1.37	1.54	1.61	1.49	1.28	1.43	1.31	1.65	1.46	7	65%
United Energy	1.78	1.88	1.90	1.92	1.89	1.55	1.53	1.76	1.78	4	79%

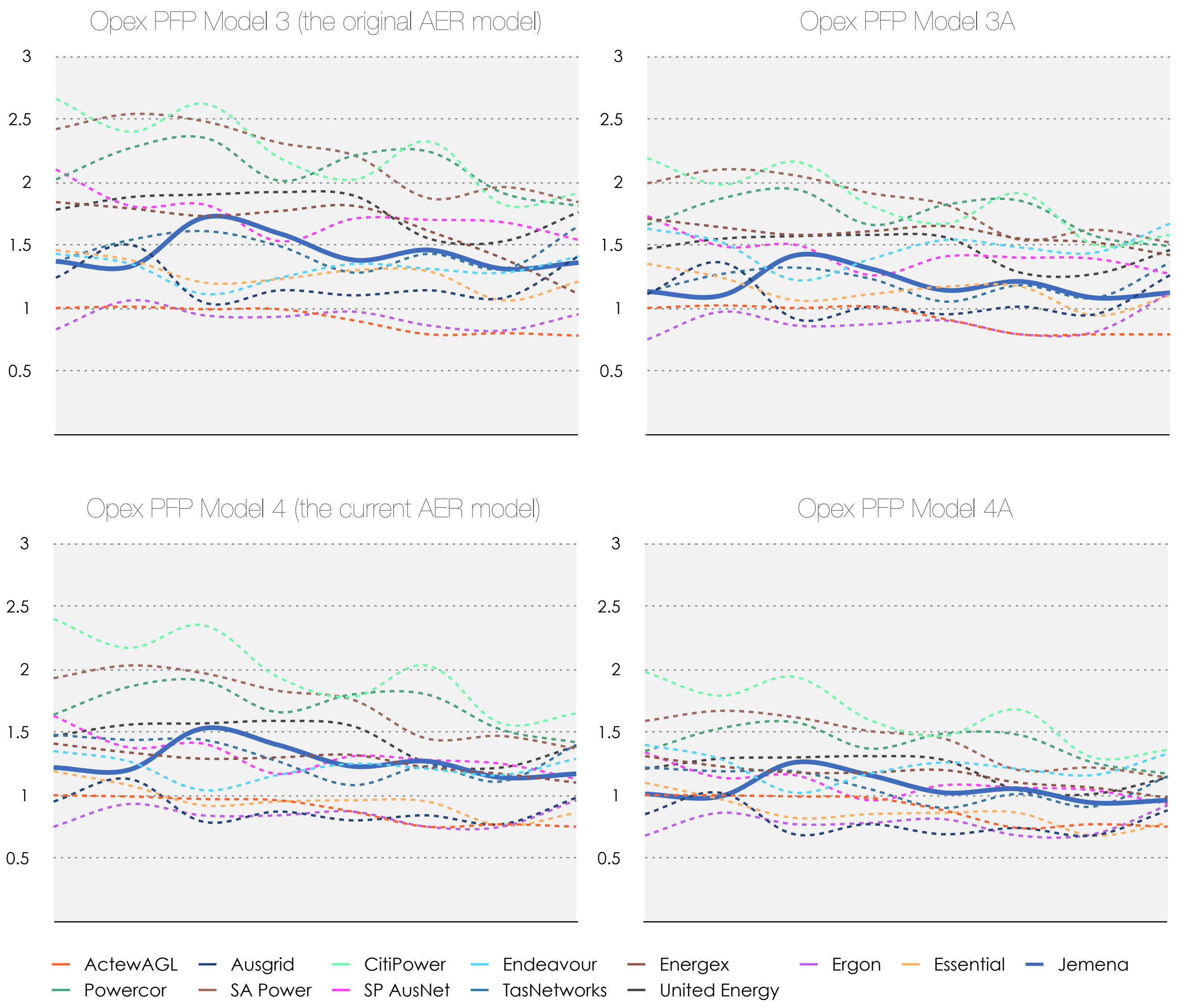
	Model 3A										
	2006	2007	2008	2009	2010	2011	2012	2013	Ave	Rank	Score
ActewAGL	1.00	1.02	1.00	1.01	0.91	0.79	0.79	0.79	0.91	12	49%
Ausgrid	1.11	1.36	0.91	1.01	0.95	1.01	0.95	1.26	1.07	11	58%
CitiPower	2.19	1.98	2.16	1.81	1.67	1.91	1.50	1.58	1.85	1	100%
Endeavour Energy	1.63	1.52	1.22	1.39	1.54	1.48	1.44	1.67	1.49	5	80%
Energex	1.71	1.64	1.58	1.61	1.65	1.55	1.52	1.42	1.58	4	86%
Ergon Energy	0.75	0.97	0.86	0.87	0.90	0.79	0.81	1.12	0.88	13	48%
Essential Energy	1.35	1.24	1.06	1.11	1.17	1.17	0.94	1.10	1.14	10	62%
Jemena	1.13	1.10	1.42	1.31	1.14	1.21	1.08	1.12	1.19	9	64%
Powercor	1.66	1.87	1.94	1.66	1.82	1.85	1.57	1.49	1.73	3	94%
SA Power Networks	1.99	2.10	2.05	1.91	1.82	1.54	1.62	1.52	1.82	2	98%
AusNet Services	1.73	1.49	1.50	1.26	1.41	1.40	1.39	1.27	1.43	7	77%
TasNetworks	1.13	1.27	1.32	1.23	1.05	1.18	1.08	1.36	1.20	8	65%
United Energy	1.47	1.55	1.57	1.58	1.56	1.28	1.27	1.46	1.47	6	79%

	Model 4										
	2006	2007	2008	2009	2010	2011	2012	2013	Ave	Rank	Score
ActewAGL	1.00	0.99	0.97	0.96	0.87	0.75	0.77	0.75	0.88	12	44%
Ausgrid	0.95	1.13	0.79	0.87	0.80	0.84	0.77	0.98	0.89	11	45%
CitiPower	2.40	2.17	2.35	1.94	1.78	2.03	1.57	1.65	1.99	1	100%
Endeavour Energy	1.35	1.27	1.04	1.16	1.25	1.21	1.16	1.29	1.22	9	61%
Energex	1.41	1.34	1.29	1.30	1.32	1.22	1.17	1.10	1.27	8	64%
Ergon Energy	0.75	0.93	0.84	0.84	0.87	0.75	0.75	0.96	0.84	13	42%
Essential Energy	1.19	1.08	0.92	0.95	0.96	0.95	0.76	0.86	0.96	10	48%
Jemena	1.22	1.20	1.53	1.40	1.23	1.27	1.14	1.17	1.27	7	64%
Powercor	1.64	1.86	1.91	1.66	1.80	1.80	1.52	1.42	1.70	3	86%
SA Power Networks	1.93	2.03	1.97	1.83	1.76	1.45	1.47	1.37	1.73	2	87%
AusNet Services	1.63	1.38	1.41	1.17	1.31	1.28	1.25	1.13	1.32	5	66%
TasNetworks	1.48	1.44	1.44	1.27	1.08	1.23	1.11	1.40	1.31	6	66%
United Energy	1.47	1.56	1.57	1.59	1.55	1.26	1.22	1.39	1.45	4	73%

	Model 4A										
	2006	2007	2008	2009	2010	2011	2012	2013	Ave	Rank	Score
ActewAGL	1.00	1.00	0.99	0.98	0.88	0.74	0.77	0.75	0.89	10	54%
Ausgrid	0.85	1.02	0.69	0.77	0.69	0.74	0.68	0.88	0.79	12	48%
CitiPower	1.98	1.79	1.94	1.60	1.47	1.68	1.30	1.36	1.64	1	100%
Endeavour Energy	1.40	1.29	1.02	1.17	1.26	1.21	1.16	1.33	1.23	4	75%
Energex	1.31	1.23	1.18	1.18	1.20	1.10	1.06	0.98	1.16	6	70%
Ergon Energy	0.68	0.86	0.77	0.78	0.81	0.68	0.69	0.92	0.77	13	47%
Essential Energy	1.10	0.97	0.82	0.85	0.86	0.86	0.68	0.78	0.87	11	53%
Jemena	1.01	0.99	1.26	1.16	1.02	1.05	0.94	0.96	1.05	9	64%
Powercor	1.35	1.53	1.58	1.37	1.49	1.48	1.26	1.17	1.41	3	86%
SA Power Networks	1.59	1.67	1.62	1.51	1.45	1.20	1.22	1.14	1.43	2	87%
AusNet Services	1.34	1.14	1.16	0.96	1.08	1.06	1.04	0.93	1.09	7	66%
TasNetworks	1.22	1.19	1.19	1.05	0.90	1.01	0.91	1.15	1.08	8	66%
United Energy	1.21	1.29	1.30	1.31	1.28	1.04	1.01	1.14	1.20	5	73%

As with the MTFP models, the AER did not rely upon the opex PFP models in their recent draft decisions for the NSW and ACT businesses to determine substitute forecasts of expenditure. The AER did, however, use it to support their claims of the level of inefficiency in the NSW and ACT networks, as predicted by their opex econometric model. This position has important implications for JEN. As shown above, the opex PFP scores for JEN using the model preferred by the AER and the others tested by Huegin are lower than those of the MTFP models. In the NSW and ACT Draft Decision, the AER did not give appropriate consideration to the significance of different cost allocation and capitalisation policies of the businesses. JEN is one of the businesses that will be disadvantaged by this approach. This is explored further in the following pages.

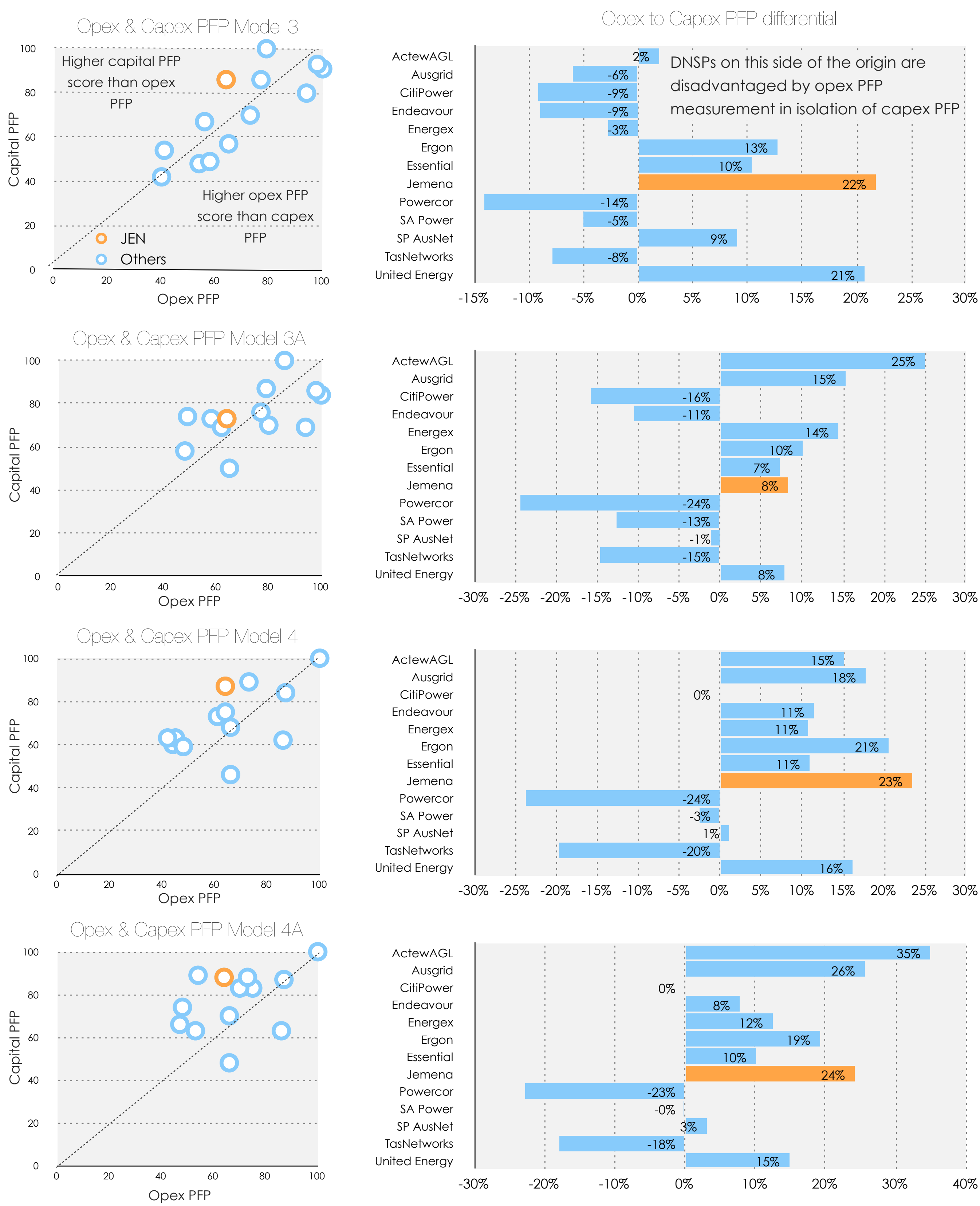
Figure 10: Time series Opex PFP results - Models 3, 3A, 4 & 4A



The immediate observation from the comparison of the graphs above with those in figure 7 are that the opex PFP scores (figure 10) are much more volatile over time than the MTFP scores (figure 7). This is due to the fact that opex varies over time to a much greater degree than the physical network measures that dominate the input index in the MTFP models.

Another key observation is that the rankings between MTFP and opex PFP change quite significantly. Intuitively, one would expect that material and systemic inefficiency would be reflected in both opex PFP and MTFP results - as managerial inefficiency would pervade both capital and operating expenditure. However there are many instances in the PFP benchmarking where the discrepancy between the capital and operating PFP for individual businesses using the same model specification is considerable. This is a reflection of the variation in operating or capital intensity of each of the networks, and without considering both simultaneously, erroneous assumptions of partial factor productivity will be made using index methods. This is particularly important for JEN, which is one of the networks affected most by the consideration of opex PFP in isolation of capital PFP. Figure 11 demonstrates the networks most exposed to biased efficiency scores through the consideration of opex PFP in isolation of capital. Across all four models ActewAGL and JEN average 19% differential between opex and capex PFP, the most disadvantaged of all the DNSPs.

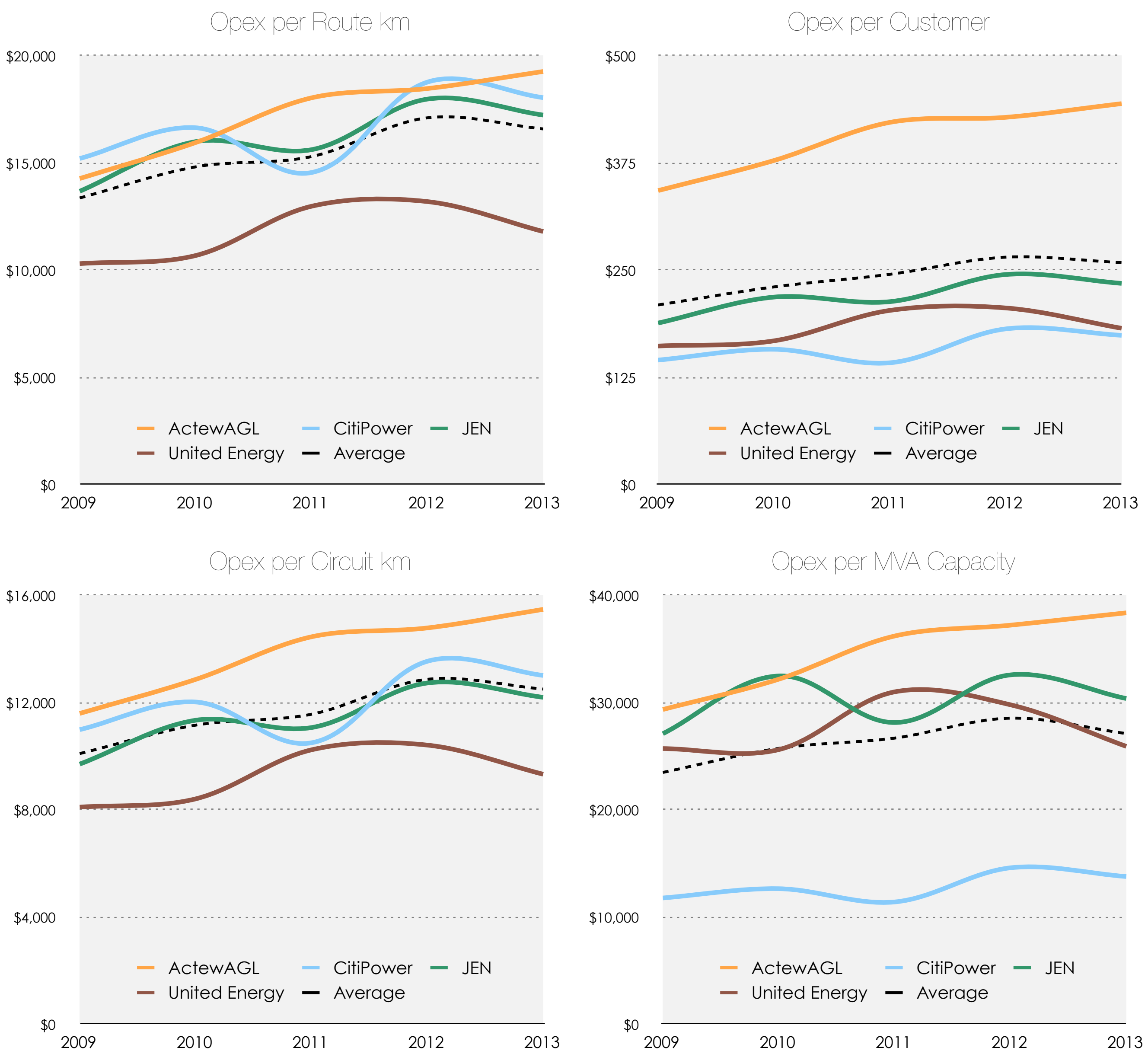
Figure 11: The consequence of partial productivity consideration



It is important to note that disparity between capital and operating PFP is not necessarily driven by variation in the allocation of opex and capex. In the AER's models, capital PFP is measured using physical assets, not expenditure. So variation in capital and operating PFP is a result of different combinations of the inputs of assets and opex between businesses. In the four MTFP models analysed, JEN consistently has a higher opex to output index ratio relative to the industry and a consistently lower asset to output index ratio. This observation offers no information about relative efficiency, rather it highlights the limitation of using partial factor productivity indices to infer managerial inefficiency. Such analysis also ignores the fact that an efficient business will make capital and operating cost allocation decisions over time which may change the partial productivity of each measure, but reflect business conditions rather than shifting efficiency.

To further examine JEN's historical opex performance, we compared JEN to its peers on the basis of some common opex ratios (figure 12). Similar to total expenditure ratios, JEN is generally around or below the group average and relatively close to United Energy in performance.

Figure 12: Opex ratios - peer group ($2014)



Based on the comparison of simple and index ratios, we cannot conclude that JEN is an inefficient opex performer. When we consider:

- the limitations of economic benchmarking,

- the level of error inherent in the data source,
- the influence of environmental variables that are not accounted for, and
- the disparity between JEN's capex and opex PFP performance (indicating model bias, rather than systemic managerial inefficiency),

we conclude that there is no evidence to suggest that JEN does not perform close to its peer group.

When we consider the analysis of total and partial index productivity, we conclude:

1. For three of the four total expenditure models tested, JEN is in the upper quartile of efficiency scores. For the fourth JEN is only 1% away from the upper quartile. We therefore consider that JEN is historically an efficient total expenditure performer relative to its peers.
2. For the four opex PFP models, JEN is 11% away from the upper quartile of efficiency scores. However we find that JEN's opex PFP performance is influenced by the asymmetric opex intensity of its network - that is, comparison of opex PFP to capex PFP performance suggests that JEN's opex PFP results are reflective of the risk of using partial productivity indicators, rather than systemic managerial inefficiency.
3. The comparison of simple cost ratios within the smaller peer group demonstrates JEN operates at around the average of the four DNSPs, and close to United Energy's level of opex performance.
4. Based on the observations at points 2 and 3 above, we conclude that JEN's historical opex reflects relatively efficient opex performance.

We have used econometric modelling to further explore the historical opex performance of JEN relative to its peers.

3.4.2 Econometric method

The AER's Expenditure Forecast Assessment Guideline Explanatory Statement states that econometric modelling will be used to develop a "top down forecast of opex" [17]. The AER does not employ econometric modelling in the Annual Distribution Benchmarking Report, as the technique is used to test the revealed costs and forecasts in the DNSP regulatory proposal, and is therefore conducted only during the determination. The AER introduced data from Ontario, Canada and New Zealand to facilitate the adoption of an SFA econometric model for the NSW and ACT Draft Decision. In the AER's analysis for the NSW and ACT Draft Decision, JEN's opex score was 24% from the frontier Australian network (CitiPower). We consider the introduction of international data to be of sufficient concern that we do not believe it reasonable to rely upon the results. Specifically:

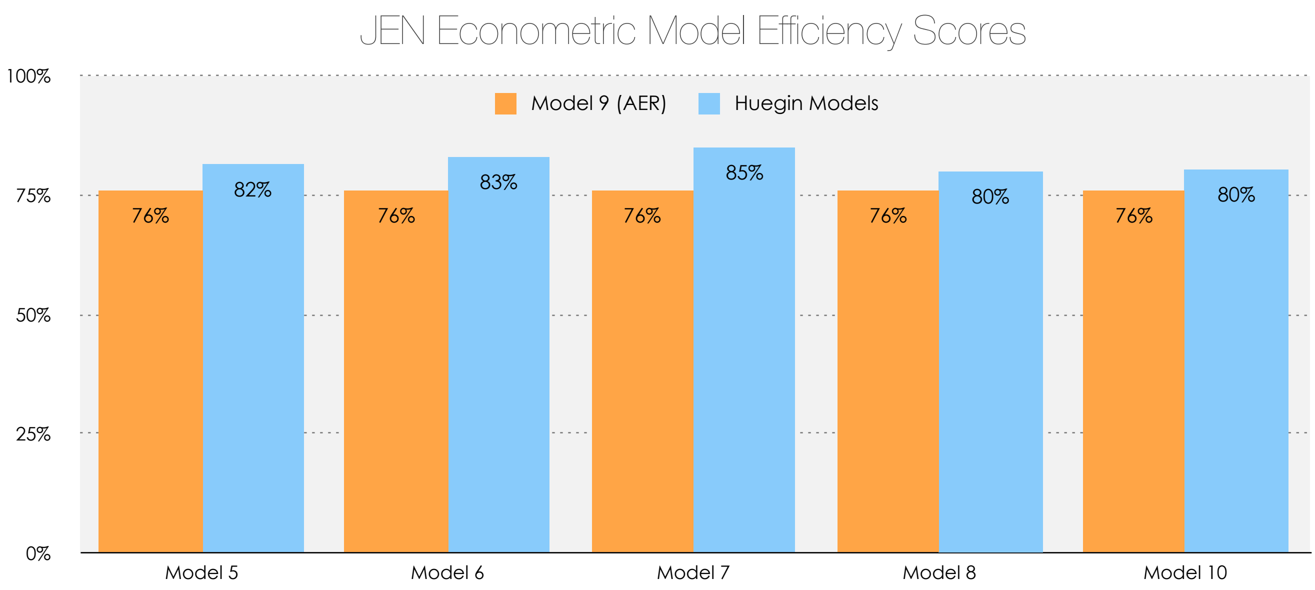
1. There is insufficient knowledge of the provenance of the data (the data has been sourced from the internet, with no means of validating it or scrutinising the basis of preparation);
2. The motivation to introduce the international data was to faciliate SFA, rather than add any analytical value to the benchmarking models; and
3. The introduction of the data has limited the consideration of environmental variables to the share of underground network only, as no other data is available from New Zealand or Ontario.

We employed six econometric models (Models 5 to 10 in Table 1) to test the reasonableness of JEN's historical opex and assess the efficiency of its most recent costs (calendar year 2013 costs are the most recent available for all Victorian businesses and financial year 2013 for the other states). The AER model specification (Model 9) is included as a measurement reference against the other five econometric models. It should be noted that the purpose of the econometric modeling was to provide accurate estimates for use in calculating a growth rate of opex over the next five years. Whilst we have used the residual to infer efficiency between businesses we remain skeptical of the ability of top down econometric models to separate inefficiency from DNSP heterogeneity.

The description of the econometric models, the statistics, form and associated assumptions with each is included in annex D. The results are summarised in figure 13.

[17] AER, page 124, Better Regulation - Explanatory Statement - Expenditure Forecast Assessment Guideline, November 2013

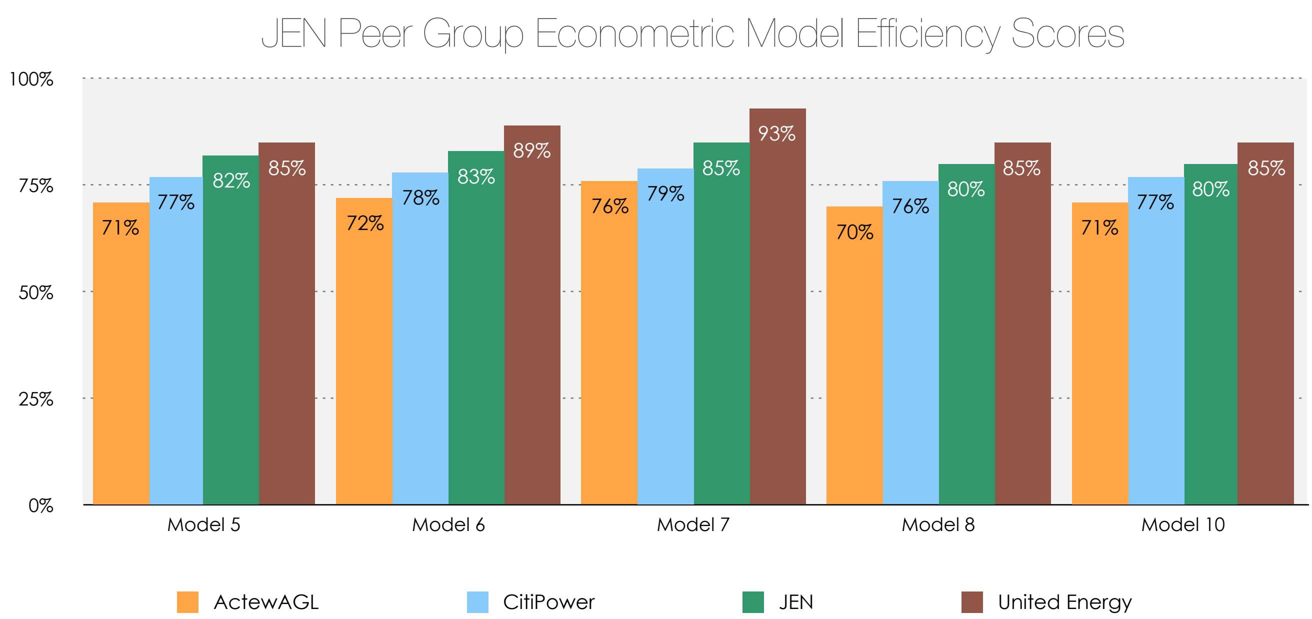
Figure 13: JEN 2013 opex efficiency relative to frontier DNSP



* The AER model specification has been used as a comparison basis (and included here as a ratio of the JEN score to the frontier firm - CitiPower - score from the AER analysis), however Huegin does not believe that international data (which the AER model is critically reliant upon) is appropriate for calculating substitute opex of an Australian network. Note that the maximum efficiency score that these percentages are calculated against is 95% (CitiPower score), not 100%.

The econometric model scores for JEN in Figure 13 have been calculated as the JEN efficiency score divided by the frontier firm for each model. As shown, for each of our econometric model specifications, JEN's opex efficiency in 2013 is around or above 80% of the maximum for Australian DNSPs. Each model also provides a result of up to 10% higher for JEN than the AER SFA model that uses international data. As discussed in this report, some networks are more appropriate comparators for JEN than others. To provide more context to the econometric efficiency results, we analysed the results for the four-DNSP peer group identified earlier in this report (JEN, United Energy, CitiPower and ActewAGL). Figure 14 shows the econometric model efficiency scores for the four DNSPs.

Figure 14: JEN 2013 opex efficiency relative to peer group



As with the index methods, there is no evidence to suggest from econometric modelling that JEN's historical opex is inefficient. The majority of the models indicate that JEN's historical opex is in the upper quartile of efficiency scores and is close to that of its most appropriate peers. There is no evidence to suggest that it's base year should not be considered representative of its true revealed costs.The econometric models tested in this chapter will be evaluated for their suitability to set a forecast productivity rate of growth in the next chapter.

3.5 Conclusions on Total and Opex Partial Factor Productivity

JEN is in the group of businesses that are most productive based on most MTFP models. Its opex PFP performance is moderately lower, but this is clearly influenced by a mix of inputs skewed more toward operating expense versus physical assets than many of its peers. This is reflected in JEN's superior capital PFP performance using the same model specifications as those used to determine opex PFP. Econometric modelling of JEN's historical opex is more consistent with the MTFP results.

JEN's total and operating expenditure efficiency is consistently close to United Energy using most models and approaches. Across all 14 models tested, JEN's efficiency scores are an average of 7.5% lower than United Energy. We consider that this is reasonable given the scale and customer density advantages that United Energy has over JEN and the lower levels of SAIDI that JEN must and is maintaining.

Importantly, based on the evidence available from the models and analysis, and acknowledging the limitations of productivity score comparisons, JEN cannot be considered to be inefficient. We note that a finding of inefficiency is a requirement of the Expenditure Forecast Assessment Guideline if the AER is to consider that the historical expenditure of the DNSP is not reflective of the true revealed costs of the network. We also note the AER's finding for Transgrid in its recent draft decision for transmission, where it found no evidence to suggest the revealed base year was materially inefficient[18].

Comparative Efficiency Benchmarking Key Points

Total Factor Productivity

- JEN's historical total expenditure is around or above the threshold for the top quartile efficient frontier for the majority of MTFP models considered by the AER and tested by Huegin.
- Within the limitations of MTFP modelling, JEN cannot be considered to be an inefficient total expenditure performer in the context of the Australian DNSP environment.

Opex Partial Factor Productivity

- JEN's opex PFP results are lower than its MTFP results for most model specifications.
- Consideration of both opex and capex PFP suggests that JEN's opex PFP performance is not symptomatic of managerial inefficiency. The econometric modelling illustrates this further.

Opex Econometric Modelling

- JEN's opex econometric modelling results are more indicative of its MTFP results - at or above the threshold for top quartile efficiency across the industry.

Signals of Efficiency

- Amongst its peers, JEN is naturally above efficiency levels of ActewAGL (which has less favourable environmental conditions) below CitiPower (which has more favourable conditions) and similar, if slightly below United Energy (which operates in similar conditions, yet has greater scale and customer density).
- JEN's opex efficiency results must be considered in the context of its high opex to capex ratio. High opex to capex ratios disadvantage firms in opex benchmarking and can be driven by lower overhead capitalisation and also expensing of items rather than capitalising (lease versus buy, etc).

[18] AER, page 7-33, TransGrid transmission determination 2015-18 | Attachment 7 – Operating expenditure, November 2014

Productivity Growth Rate

Huegin was asked to provide a forecast of the opex partial factor productivity growth rate that applies to the JEN network for the period 1 January 2014 to 31 December 2020.

This chapter outlines our view on the most appropriate opex cost function for Australian electricity distribution. Based on this, we propose a suitable growth rate for productivity for JEN to include in its forecast of opex.

4

4.1 Productivity Growth Rate Approach

In this chapter we use econometric modelling to find an appropriate cost function for opex and for identifying an appropriate opex partial productivity growth rate for JEN networks future opex. As discussed earlier, econometric modelling is one of the techniques in the AER's benchmarking framework. By estimating an industry opex cost function the AER could compare a DNSP's modelled opex with their actual opex to determine whether a revealed cost approach is appropriate or whether a base year adjustment is necessary. This means that if a DNSP's actual opex is below that predicted by an industry opex cost function then the base year can be used as the starting point from which an annual rate of growth can be applied. Our approach to finding an appropriate productivity growth rate for JEN is to test a number of models for suitability as an opex cost function, and then applying that cost function to estimate rates of growth.

4.1.1 Technique

In the previous chapter we discussed the use of econometric models to evaluate the efficiency of a DNSP's historical opex and the suitability of using a DNSP's revealed opex costs as a starting point from which to forecast future opex. Econometric modelling can also be used to forecast a feasible opex growth rate by estimating a partial productivity growth rate. This technique, using an econometric model to estimate a productivity growth rate, is illustrated below.

Estimating opex partial productivity growth

$$P\dot{F}P_{Opex} = \left(1 - \sum_i \varepsilon_{Y_i}\right) \cdot \dot{Y}^{\varepsilon} - \varepsilon_{X_k} \cdot \dot{X}_k - \varepsilon_{Z_1}\dot{Z}_1 - \dot{g}$$

Where;

$P\dot{F}P_{Opex}$ = opex partial productivity growth

ε_{Y_i} = effect of a change in output on opex, estimated using an econometric model

ε_{X_k} = effect of a change in capital on opex, estimated using an econometric model

ε_{Z_1} = effect of a change in an environmental variable on opex, estimated using an econometric model

$\dot{g}$ = change in opex over time, estimated using an econometric model

The opex productivity growth rate can then further be considered to be comprised of as a combination in technology change, returns to scale and business conditions.

4.1.2 Data

The data relied upon for the modelling conducted in support of our analysis of comparative productivity is sourced from the Economic Benchmarking RINs, Annual RINs and Category Analysis RINs published by the AER.

4.1.3 Models

The functional form chosen by the AER in the NSW and ACT Draft Decision (the SFA Cobb Douglas model) was the result of running a number of different models and choosing one the AER (through their consultants) believed was most reflective of the industry opex cost function. A major consideration in econometric model selection is the stability of each model. Models become unstable where two or more of the variables are highly correlated with each other - an issue known as multicollinearity.

SFA models require much more data than is available in the Australian industry. As such, the AER's model selection was predicated on the assumption that international data was appropriate to use in the analysis. Whilst the AER's model is statistically stable, testing and analysis was significantly limited as only a narrow scope of data was available from the other jurisdictions. We believe the opex function of the AER's SFA Cobb Douglas model is not appropriate for the context of predicting opex or setting productivity growth rates. We have provided our view of the AER's SFA model and the reliance on international data earlier in this report. For the purpose of the analysis of an appropriate productivity growth rate for JEN, we tested five econometric opex models - Models 5, 6, 7, 8 and 10 in table 1.

4.2 Selecting an Opex Cost Function

We have selected a Cobb-Douglas expenditure function and used the random effects technique to estimate the model. Statistical testing results are presented in annex D. We have selected Model 10 as our preferred econometric model. Summary results for Model 10 are presented below.

Table 7: Model 10 statistical results

	Estimate	Std. Error	t-value	Pr(>|t|)
(Intercept)	2.9866449	2.2423097	1.332	0.185966
log(System Capacity)	0.1874679	0.0625439	2.9974	0.00345
log(Customers)	0.4482056	0.2101814	2.1325	0.035467
Share of Single Stage Transformation	-0.7802683	0.2957404	-2.6384	0.009691
log(Demand density)	-0.2794215	0.122315	-2.2844	0.024503
Year	0.0288561	0.0047306	6.0999	0.00000002116

In line with the outputs selected by the Australian Energy Regulator in the Expenditure Forecast Assessment Guideline[19] we have included system capacity (kVA*kms) and customer numbers as outputs for the electricity distribution industry. The results from the econometric model suggest that as system capacity increases by 1% opex increases by around 0.19% and as customer connections increase by 1% opex increases by around 0.45%.

One difficulty with using a single econometric model to benchmark NEM DNSPs is that there are a number of different cost drivers that influence businesses differently. Huegin believes one of the most material environmental variables that influences cost differences between DNSPs is network design. We believe that the share of single stage transformation and demand density are useful proxies for these physical network differences. The results suggest that both have a significant influence on changes in opex between DNSPs.

The coefficient on Year suggests that operating expenditure, after accounting for the variables included in the model, has been increasing at a rate of around 2.9% since 2006.

Huegin believes that given the shortcomings of using a single econometric model to benchmark efficient opex within such a heterogeneous industry, efficiency estimates using any model are unlikely to truly reflect accurate efficiency differences between DNSPs[20]. We have therefore sought a model that provides consistent estimates for use in identifying an output growth rate and associated opex partial productivity growth rate for use in forecasting an opex growth rate for JEN.

4.2.1 Choosing the method

When choosing an estimation method we considered Stochastic Frontier Analysis (SFA), Pooled Ordinary Least Squares (OLS), Random Effects (RE) and Fixed Effects (FE).

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[19] AER, Pg 142, "Expenditure Forecast Assessment Guideline Explanatory Statement, November 2013

[20] The greatest shortcoming being the difficulty in distinguishing between the effects of variables that are effectively constant over the benchmark period on opex – i.e if we suspect inefficiency to be systemic and inherent network heterogeneity exists between DNSPs then it is impossible to disentangle the effects of inefficiency and heterogeneity using econometric methods.

SFA was the technique employed to estimate an opex cost function in the NSW and ACT draft decisions. Huegin believes that whilst SFA is a benchmarking technique that has desirable properties in terms of the direct estimation of a cost frontier from which DNSPs can be measured, the need to include data from international distributors introduces its own difficulties that outweigh the benefits of using SFA.

With this in mind, Huegin has considered Ordinary Least Squares and Generalised Least Squares (Random Effects and Fixed Effects) estimation techniques to compare JEN's operating expenditure relative to other DNSPs in the NEM.

Pooled OLS ignores the panel nature of the data (equivalent to 104 DNSPs over one year) as opposed to random and fixed effects which incorporate information about the panel structure of the data (13 DNSPs over eight years). It is for this reason that we are inclined to consider random and fixed effects to be more favourable than using pooled OLS[21].

The Random Effects estimation technique was chosen ahead of fixed effects for the following reasons.

1. Given the small changes in outputs and environmental variables over time, fixed effects (which uses the intra-DNSP variation to produce estimates) results in large standard errors making efficiency and coefficient inferences difficult
2. Random effects produces more efficient estimates than fixed effects. The use of random effects is predicated on the assumption that the error term (DNSP specific effect and white noise) is uncorrelated with the variables included in the model. This assumption was tested using the Hausman test, the results of which suggested that random effects was the preferred model.

After using the random effects technique to model DNSP operating expenditure, relative efficiency scores were obtained relative to a frontier firm (the frontier firm being the DNSP with the greatest difference between actual estimated opex).

The Breusch Pagan Lagrange Multiplier Test and the Hausman Tests are summarised in the following sections.

4.2.2 Testing for individual heterogeneity

We used a Breusch Pagan Lagrange Multiplier Test[22] to detect the presence of individual heterogeneity within the preferred model and therefore the suitability of random and/or fixed effects models over pooled OLS. The null hypothesis is that there are no individual effects (and pooled OLS is suitable). The results of this testing are as follows:

- Chi squared = 245.4906
- Degrees of Freedom = 1
- p-value < 2.2e-16
- Alternative hypothesis: there are significant individual effects

The decision was to **reject the null hypothesis** and use random or fixed effects estimators. That is, the test supports the alternative hypothesis that there are significant individual effects.

4.2.3 Random or fixed effects

We used a Hausman Test[23] as a guide on whether fixed effects or random effects should be used to model the opex cost function. The null hypothesis is that both fixed and random effects are consistent and therefore random effects should be used as it is the most efficient. The results of this testing are as follows:

[21] Although pooled OLS models were estimated and the Breusch Pagan Lagrange Multiplier Test used as an indication of whether pooled OLS was more appropriate than random or fixed effects.

[22] See Annex D for detail

[23] See Annex D for detail

- Chi squared = 5.8861
- Degrees of Freedom = 5
- p-value = 0.3175
- Alternative hypothesis: one model is inconsistent

The decision was to **not reject the null hypothesis (both estimators are consistent)** and use a random effects estimator.

4.3 Calculating the Rates of Growth

Using Model 10, we can forecast rates of growth for the period 2014 to 2020. Table 8 below shows the components of productivity change estimated by the model.

Table 8: Model 10 forecast rates of change

	2015	2016	2017	2018	2019	2020
Technology	-2.89%	-2.89%	-2.89%	-2.89%	-2.89%	-2.89%
Output growth	2.33%	2.57%	2.56%	2.39%	2.37%	2.28%
Returns to scale	0.85%	0.94%	0.93%	0.87%	0.86%	0.83%
Business conditions	1.47%	0.08%	-0.04%	-0.04%	-0.02%	-0.11%

The technology rate of change is negative of the "Year" estimate in table 7. Output growth is the sum of the JEN forecast of system capacity and customer numbers, weighted by the respective cost elasticities for those variables shown in table 7. Returns to scale is the forecast impact on opex in accordance with the cost elasticities in response to the growth of outputs. Business conditions reflects the forecast change in demand density (based on JEN forecast of peak demand and customer numbers); share of single stage transformation is assumed constant.

We have excluded business conditions as a component of future growth rate. Our reason for this omission is that in our chosen opex cost function we have included demand density and the share of single stage transformation as environmental variables. In a number of previous benchmarking reports[24], Huegin has referred to the inherent, inherited and incurred costs associated with exogenous factors that impact DNSPs. The inclusion of these two explanatory variables acts as a mechanism for treating the heterogeneity across networks with:

1. Share of single stage transformation as a proxy for network design; and
2. Demand density as a proxy for the impact of customer demographics on network design (reflecting the demand customers place on the network and the design requirements this places on assets).

We do not believe that it is appropriate to use them to estimate the growth rate of opex within a single DNSP as the purpose of their inclusion in the cost function is to model the differences between the DNSPs.

We have also assumed that, despite a forecast technology growth rate of -2.89%, that this is excluded from the annual growth rate for the future period. When deciding whether to include a technology component in the opex rate of change estimates there are two factors we have considered, namely:

1. Whether historic changes in operating expenditure (which have been used as a proxy for technology change) are reflective of future operating expenditure; and

[24] For example, Huegin, "Distribution Benchmarking Study", 2012

2. Whether this historic rate of change for the industry is reflective of JEN's changes in operating expenditure.

Huegin's econometric estimates of technology change using only NEM DNSPs ranged from 3.45% to 1.8% whilst Economic Insights estimates from their stochastic frontier analysis model using New Zealand, Ontario and NEM DNSPs gave an estimate of 1.8%. These results indicate that after including the effects of the different outputs and environmental variables, DNSP opex (in real terms) has been increasing across the National Electricity Market. Huegin is of the opinion that these historical increases in opex are not likely to be reflective of future operating expenditure changes. Our reasons for this position are:

1. There have been increased costs for Victorian DNSPs due to increased regulatory requirements emerging from the 2009 Victorian Bushfires Royal Commission.
2. SA Power Networks has incurred large increases in vegetation management costs since 2006 resulting in a $35.1 million ($2009-10) pass through.
3. Ausgrid's opex increased between 2006 and 2012 as a result of large increases in repex and augex projects.
4. Energex's historical opex includes significant costs associated with corporate restructuring (around $61 million) in 2012 and 2013.

Given that these costs, which combined have a significant impact on the rate of change of historical industry operating expenditure, are unlikely to continue to increase we believe that historical annual changes in opex after excluding the impacts of changing outputs and environmental variables are unlikely to be reflective of future changes.

In addition, JEN's historical annual opex growth rate ($ real) since 2006 has been around 2.2% whilst JEN's system capacity has increased over the same period by around 5% per annum, customer connections have increased by 1.2% per annum and peak demand has increased by 2.2% per annum. These growth rates suggest that JEN's increasing opex has been roughly in line with its increasing outputs. With this in mind, Huegin believes that the average technology growth rate for the industry (as measured by the coefficient for Year in the econometric models) would not be appropriate for estimating JEN's future operating expenditure.

The opex annual growth rate is calculated through the formula:

Opex annual growth rate = (1+Output growth rate)x(1+Input price growth rate)x(1-Opex partial productivity growth rate) -1

For the purposes of modelling and assessing the reasonableness of JEN's forecasts in this report, opex price escalation has not been estimated. Opex price escalation is the result of inflation and real price increases. Neither of these values can be found through the econometric model. Instead, the JEN forecast growth rate has been calculated in real terms, based on an output growth rate and productivity improvement only.

With business conditions and technology growth excluded from the future productivity assumptions, the opex annual growth rate (in real terms) can be calculated through the formula:

Opex annual growth rate = (1 + Output growth rate) x (1 - Returns to scale) - 1

The results of this analysis are presented in Table 9.

Table 9: Model 10 opex annual growth rate

	2015	2016	2017	2018	2019	2020
Output growth	2.33%	2.57%	2.56%	2.39%	2.37%	2.28%
Returns to scale	0.85%	0.94%	0.93%	0.87%	0.86%	0.83%
Opex Annual Growth	**1.46%**	**1.61%**	**1.61%**	**1.50%**	**1.49%**	**1.43%**

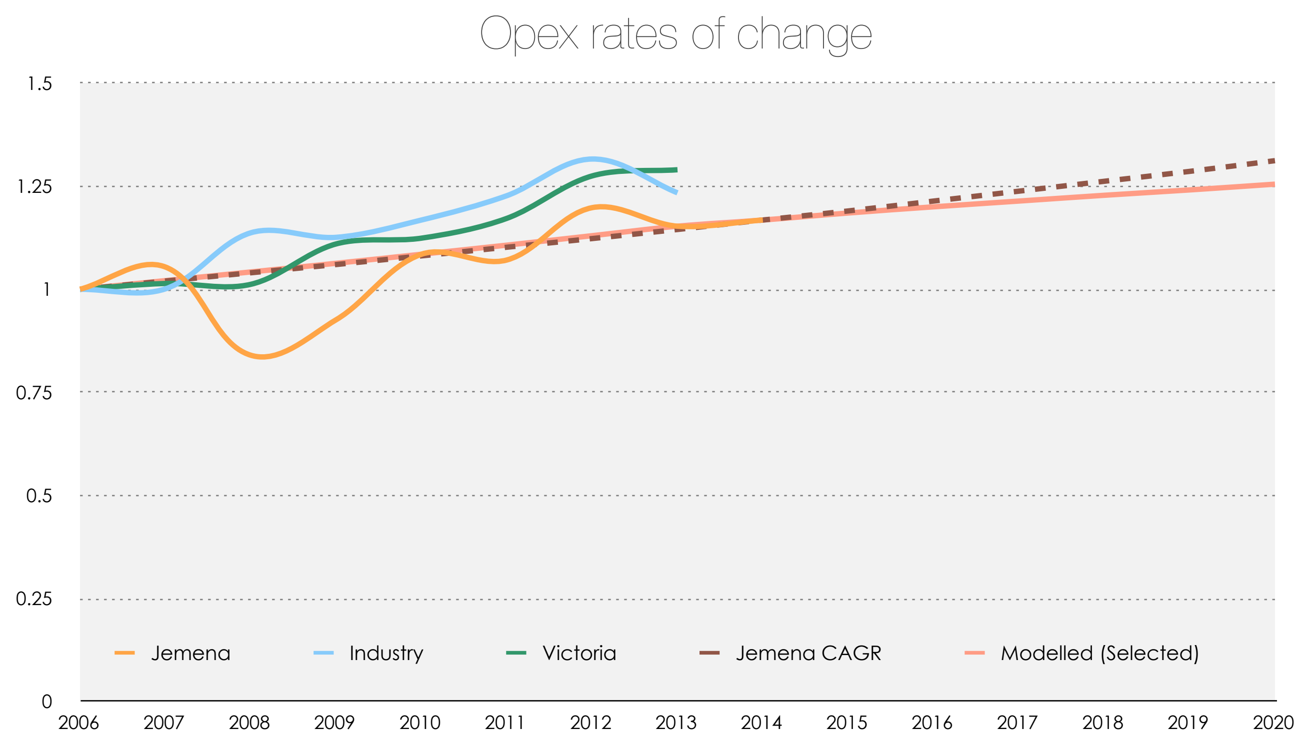
4.4 Testing the Reasonableness of the Forecast

To test the reasonableness of our assumptions on opex growth we analysed a number of opex rates of change, both historical and forecast. Specifically, we compared:

- The change in JEN's actual opex over the period 2006 to 2013.
- The change in total actual opex for all Victorian DNSPs between 2006 and 2013.
- The change in total actual opex for all DNSPs between 2006 and 2013.
- The trend of JEN's opex over the 2014 to 2020 period based on extrapolation using the historical rate of change in JEN's actual opex.
- The change in opex from 2006 to 2020 using our econometric model to predict opex.

The results are shown in figure 15 below.

Figure 15: Comparison of opex change over time - actual, forecast, predicted



Our observations from the analysis above are:

- JEN's historic opex rate of change is lower than the Victorian rate of change;
- JEN's historic opex rate of change is lower than the industry rate of change; and
- The forecast rate of change for JEN's opex using our econometric model is lower than the forecast based on extrapolation of JEN's actual opex historic rate of change.

We believe that based on the collective analysis throughout this report that our recommended productivity growth rate for JEN is a reasonable basis for JEN to incorporate productivity change in their opex forecast.

4.5 Conclusions on the Productivity Growth Rate

Econometric modelling is sensitive to the assumptions of the functional form, variable selection and source data error. Models can be tested for statistical strength, however mis-specified cost functions will still have the potential to produce misleading results. As such, we have tested a number of econometric models and selected the model we believe most appropriate for the task of calculating forecast productivity growth rates for JEN. We believe the resultant productivity growth rate is appropriate for JEN to use in its forecast and we also believe that it produced reasonable results when compared to a number of opex reference points.

Productivity Growth Rate Key Points

Real Opex Growth Rate

- We have estimated real opex growth rates based on forecast output growth and productivity change represented by the returns to scale component of growth.

Reasonableness of Growth Rate

- We believe that the incremental improvement in JEN opex relative to its own historical rate of change (which is lower than the Victorian and industry rate) is a reasonable assumption for JEN based on its benchmark position amongst its peers.

Terms of Reference

This annex includes the Terms of Reference for the Productivity Study conducted by Huegin at the request of JEN.

A

Jemena Electricity Networks (Vic) Ltd

Expert Terms of Reference - Productivity Study

Confidential

1 August 2014

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Contact Person

Eli Grace-Webb
Manager Regulatory Analysis and Strategy
Ph: (03) 8544 9164
eli-grace-webb@jemena.com.au

Jemena Electricity Networks (Vic) Ltd

ABN 82 064 651 083
321 Ferntree Gully Road
Mount Waverley VIC 3149

Postal Address

Locked Bag 7000
Mount Waverley VIC 3149
Ph: (03) 8544 9000
Fax: (03) 8544 9888

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List of appendices

1. BACKGROUND

Jemena Electricity Networks (Vic) Ltd (**JEN**) is one of five licensed electricity distribution networks in Victoria. JEN distributes electricity to over 319,000 customer sites via approximately 11,000km of distribution system and over 950 square kilometres of north-west greater Melbourne. The network footprint incorporates a mix of major industrial areas, residential growth areas, established inner suburbs and Melbourne International Airport.

JEN is currently preparing its Electricity Distribution Price Review (**EDPR**) proposal with supporting information for the consideration of the Australian Energy Regulator (**AER**). The revised EDPR will cover the period 1 January 2016 to 31 December 2020 (January to December calendar years). JEN must submit its EDPR proposal to the AER by 30 April 2015.

When considering JEN's EDPR proposal, the AER must have regard to the National Electricity Objective (**NEO**) as stated in the National Electricity Law (**NEL**), which is:

> *to promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to – price, quality, safety, reliability, and security of supply of electricity; and the reliability, safety and security of the national electricity system.*

The National Electricity Rules (**NER**) outline specific requirements to assess and determine expenditure proposals in accordance with the NEL, and therefore give effect to the NEO. Clauses 6.5.6(a) and 6.5.7(a) specify the expenditure objectives to be achieved by

The AER, when making a distribution determination, will decide whether it is satisfied that a DB's proposed total capex forecast and total opex forecast reasonable reflect the expenditure criteria, which are set out in clauses 6.5.6(c) and 6.5.7(c) as follows:

1. The efficient costs of achieving the capex and opex objectives
2. The costs that a prudent operator would require to achieve capex and opex objectives
3. A realistic expectation of the demand forecast and cost inputs required to achieve the capex and opex objectives.

Rule 6.5 of the NER outlines the expenditure objectives to be achieved by an electricity distribution business (**DB**) and expenditure factors which the AER will consider in deciding whether or not it is satisfied with a DB's proposed expenditure forecasts. These are set out in Attachment A.

The AER prefers a 'base-step-trend' approach to assessing most opex categories as follows:

$$Opex_t = \prod_{i=1}^{t} \left(1 + rate\ of\ change_i\right) \times \left(A^*_f - efficiency\ adjustment\right) \pm step\ changes_t$$

$$Rate\ of\ change_i = output\ growth_i + real\ price\ growth_i - productivity\ growth_i$$

where:

- $rate\ of\ change_i$ is the annual percentage rate of change in year i
- A^*_f is the estimated actual opex in the final year of the preceding regulatory control period
- $efficiency\ adjustment$ is the difference between efficient opex and deemed final year opex

- $step\ changes_t$ is the determined step change in year t

Accordingly, JEN seeks the independent opinion of a suitable consultant, as a suitably qualified expert (**Expert**) on efficiency measurement and benchmarking in the electricity distribution sector, as outlined below. This opinion will facilitate JEN's development and justification of expenditure forecasts to be included in its EDPR proposal.

2. SCOPE OF WORK

The Expert will provide a two-part opinion report detailing:

Part A—forecast opex partial factor productivity

Provide a forecast of the opex partial factor productivity growth rate that applies to the JEN network for the period 1 January 2014 to 31 December 2020 period, taking into account the following factors:

1. historical operating expenditure performance
2. benchmark operating expenditure level
3. business conditions
4. relevant output and input variables
5. operating environment features
6. rate of technological change, and
7. any other factors the Expert considers relevant in this assessment.

The forecast of the overall opex partial factor productivity growth rate should also be split into three components; namely technology, returns to scale and operating environment.

The Expert is to look at historical and forecast changes in operating expenditure, covering the period from 1 January 2011 to 31 December 2020, as required for the JEN EDPR submission. The Expert is to determine the appropriate opex partial factor productivity, and substantiate this factor to a standard capable of satisfying the AER when it applies the NER criteria to assess operating expenditure forecasts.

The Expert should provide its estimate of the opex cost function and forecast opex partial productivity growth rate for JEN, in a form that is suitable for incorporation into the rate of change approach for forecasting opex in JEN's EDPR proposal.

Part B—provide a report detailing its analysis of Time Series and Multilateral Total Factor Productivity (**TFP**) efficiency estimates, and Partial Factor Productivity (**PFP**) estimates, that is suitable for validating JGN's opex and capex forecasts and use in support of statements about JEN's relative cost performance

The Expert is to assess whether JEN, relative to other electricity distribution businesses, is considered to be an efficient total and opex cost performer using relevant benchmarking techniques. This assessment should consider the use of benchmarking in previous regulatory decisions and the AER's consultation on the Expenditure Assessment Guideline for electricity networks, to the extent that this is relevant.

This analysis should be suitable for comparing JEN's productivity level and productivity growth rate performance with the Victorian, South Australian and Queensland DBs for which similar analysis has previously been undertaken.

2.1 INFORMATION TO BE CONSIDERED

The Expert is expected to draw upon the following information:

- historical and forecast cost, input and output data provided by JEN

- the publicly available data sets of DBs submitted for economic benchmarking regulatory information notices
- the publicly available data sets of DBs submitted for category analysis regulatory information notices
- relevant published research literature
- relevant government decisions on energy policy and policy implementation
- factors such as the scale, topography and configuration of the JEN network, that may contribute to or explain observed differences between the results obtained for JEN and for other DBs in the data set on which the analysis is based
- recent regulatory reviews for electricity that have considered efficiency measures within the context of establishing cost forecasts, and
- such other information that, in the Expert's opinion, should be taken into account to address the Scope of Work.

3. DELIVERABLES

At the completion of its review the Expert will provide an independent expert report which addresses the Scope of Work and:

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

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

3.1 USE OF THE REPORT

JEN expects to submit the Expert's report to the AER as part of JEN's EDPR proposal for the period from 1 January 2016 to 31 December 2020. The AER may provide the report to its own advisers. The report must be expressed so that it may be relied upon by both JEN and the AER.

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

The Expert must be available to assist JEN in connection with the work defined in the Scope of Work, until such time as JEN has responded to the AER's draft decision on JEN's EDPR proposal.

[1] Available at: http://www.fedcourt.gov.au/law-and-practice/practice-documents/practice-notes/cm7.

3.2 COMPLIANCE WITH THE CODE OF CONDUCT FOR EXPERT WITNESSES

Attachment B is a copy of the Federal Court's Practice Note CM 7, entitled "Expert Witnesses in Proceedings in the Federal Court of Australia", which comprises the code of conduct for expert witnesses in the Federal Court of Australia (the **Code of Conduct**).

The Expert is required to be familiar with the Code of Conduct and comply with it at all times in the course of the engagement by JEN. In particular, the expert report prepared for JEN should contain a statement at the beginning of the report to the effect that the author of the report has read, understood and complied with the Code of Conduct.

In particular, the report should contain particulars of the timing, study or experience by which the Expert has acquired specialised knowledge. The report should also state that each of the Expert's opinions is wholly or substantially based on the Expert's specialised knowledge.

It is also a requirement that the report be signed by the Expert and a declaration that:

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

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

4. TIMETABLE

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

- analysis of time series and multilateral TFP estimates and PFP estimates; estimate of the opex cost function and forecast opex partial productivity growth rate; and draft written report, by 30 September 2014, and
- final written report by 31 October 2014.

Attachment A
Expenditure Objectives and Factors

A1. EXPENDITURE OBJECTIVES AND FACTORS

A building block proposal must include the total forecast operating expenditure for the relevant control period which the Distribution Network Service Provider considers is required in order to achieve each of the following (expenditure objectives):

- 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:
  - the quality, reliability or security of supply of standard control services, or
  - the reliability or security of the distribution system through the supply of standard control services

  to the relevant extent:

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

In deciding whether or not the AER is satisfied that the total of a Distribution Network Service Provider's forecast expenditure for the regulatory control period reasonable reflects the expenditure criteria, the AER must have regard to the following (the expenditure factors):

- The most recent annual benchmarking report that has been published under rule 6.27 and the benchmark expenditure that would be incurred by an efficient Distribution Network Service Provider over the relevant regulatory control period
- the actual and expected expenditure of the Distribution Network Service Provider during any preceding regulatory control periods
- the extent to which the expenditure forecast includes expenditure to address the concerns of electricity consumers as identified by the Distribution Network Service Provider in the course of its engagement with electricity consumers
- the relative prices of operating and capital inputs
- the substitution possibilities between operating and capital expenditure
- whether the expenditure forecast is consistent with any incentive scheme or schemes that apply to Distribution Network Service Provider under clauses 6.5.8 or 6.6.2 to 6.6.4
- the extent the expenditure forecast is referrable to arrangements with a person other than the Distribution Network Service Provider that, in the opinion of the AER, do not reflect arm's length terms
- whether the expenditure forecast includes an amount relating to a project that should be more appropriately to be included as a contingent project under clause 6.6A.1(b)
- the extent the Distribution Network Service Provider has considered, and made provision for, efficient and prudent non-network alternatives

- any relevant final project assessment report (as defined in clause 5.10.2) published under clause 5.17.4(o), (p) or (s), and
- any other factor the AER considers relevant and which the AER has notified the Distribution Network Service Provider in writing, prior to the submission of its revised regulatory proposal under clause 6.10.3, is an operating expenditure factor.

Attachment B
Federal Court Practice Note

Jemena

B1. FEDERAL COURT PRACTICE NOTE

FEDERAL COURT OF AUSTRALIA

Practice Note CM 7

EXPERT WITNESSES IN PROCEEDINGS IN THE FEDERAL COURT OF AUSTRALIA

Commencement

1. This Practice Note commences on 4 June 2013.

Introduction

2. Rule 23.12 of the Federal Court Rules 2011 requires a party to give a copy of the following guidelines to any witness they propose to retain for the purpose of preparing a report or giving evidence in a proceeding as to an opinion held by the witness that is wholly or substantially based on the specialised knowledge of the witness (see **Part 3.3 - Opinion** of the *Evidence Act 1995* (Cth)).

3. The guidelines are not intended to address all aspects of an expert witness's duties, but are intended to facilitate the admission of opinion evidence[2], and to assist experts to understand in general terms what the Court expects of them. Additionally, it is hoped that the guidelines will assist individual expert witnesses to avoid the criticism that is sometimes made (whether rightly or wrongly) that expert witnesses lack objectivity, or have coloured their evidence in favour of the party calling them.

<u>**Guidelines**</u>

1. General Duty to the Court[3]

1.1 An expert witness has an overriding duty to assist the Court on matters relevant to the expert's area of expertise.

1.2 An expert witness is not an advocate for a party even when giving testimony that is necessarily evaluative rather than inferential.

1.3 An expert witness's paramount duty is to the Court and not to the person retaining the expert.

2. The Form of the Expert's Report[4]

2.1 An expert's written report must comply with Rule 23.13 and therefore must

(a) be signed by the expert who prepared the report; and

(b) contain an acknowledgement at the beginning of the report that the expert has read, understood and complied with the Practice Note; and

(c) contain particulars of the training, study or experience by which the expert has acquired specialised knowledge; and

(d) identify the questions that the expert was asked to address; and

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[2] As to the distinction between expert opinion evidence and expert assistance see *Evans Deakin Pty Ltd v Sebel Furniture Ltd* [2003] FCA 171 per Allsop J at [676].

[3] The "*Ikarian Reefer*" (1993) 20 FSR 563 at 565-566.

[4] Rule 23.13.

(e) set out separately each of the factual findings or assumptions on which the expert's opinion is based; and

(f) set out separately from the factual findings or assumptions each of the expert's opinions; and

(g) set out the reasons for each of the expert's opinions; and

(ga) contain an acknowledgment that the expert's opinions are based wholly or substantially on the specialised knowledge mentioned in paragraph (c) above[5]; and

(h) comply with the Practice Note.

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

2.3 There should be included in or attached to the report the documents and other materials that the expert has been instructed to consider.

2.4 If, after exchange of reports or at any other stage, an expert witness changes the expert's opinion, having read another expert's report or for any other reason, the change should be communicated as soon as practicable (through the party's lawyers) to each party to whom the expert witness's report has been provided and, when appropriate, to the Court[6].

2.5 If an expert's opinion is not fully researched because the expert considers that insufficient data are available, or for any other reason, this must be stated with an indication that the opinion is no more than a provisional one. Where an expert witness who has prepared a report believes that it may be incomplete or inaccurate without some qualification, that qualification must be stated in the report.

2.6 The expert should make it clear if a particular question or issue falls outside the relevant field of expertise.

2.7 Where an expert's report refers to photographs, plans, calculations, analyses, measurements, survey reports or other extrinsic matter, these must be provided to the opposite party at the same time as the exchange of reports[7].

3. Experts' Conference

3.1 If experts retained by the parties meet at the direction of the Court, it would be improper for an expert to be given, or to accept, instructions not to reach agreement. If, at a meeting directed by the Court, the experts cannot reach agreement about matters of expert opinion, they should specify their reasons for being unable to do so.

J L B ALLSOP
Chief Justice

4 June 2013

[5] See also *Dasreef Pty Limited v Nawaf Hawchar* [2011] HCA 21.

[6] The *"Ikarian Reefer"* [1993] 20 FSR 563 at 565

[7] The *"Ikarian Reefer"* [1993] 20 FSR 563 at 565-566. See also Ormrod *"Scientific Evidence in Court"* [1968] Crim LR 240

Team member CVs

CVs of Huegin team members that contributed to this report are contained within this annex.

B

Jamie **Blair,** B.Eng (Chem)

Role: Project Lead

Jamie is a Director of Huegin Consulting Group and our project lead and electricity benchmarking expert. Jamie has significant experience in cost analysis and benchmarking in the electricity industry and often presents Huegin's work at industry conferences and academic forums. Jamie has extensive asset management experience, both in industry and consulting.

Relevant Skills

Industry benchmarking
Performance assessment
Regulatory supporting, including revenue proposal analysis and review
Risk management
Safety reporting
Maintenance and cost modelling
Analytical decision support and statistical analysis

Relevant Experience

Jamie is an experienced engineer and consultant with specific expertise in the areas of investment analysis, cost analysis and performance benchmarking. His work is primarily for clients who own, manage or operate large physical assets. Relevant experience includes:

- Led over twenty independent benchmarking studies of domestic and international electricity networks.
- Facilitated the corporate strategic planning of an electricity distribution business and a utilities maintenance organisation.
- Developed the asset management frameworks for a major transport infrastructure manager and a large Defence weapons logistics management organisation.
- Led the analytical review of five recent regulatory determinations on behalf of network service providers.
- Developed and implemented the investment decision support framework and systems of a large network operator.
- Developed and implemented the investment decision support framework and systems of a ports operator.

Professional Summary

Jamie Blair is a Director of Huegin Consulting. Jamie has 20 years of management and consulting experience across a number of industries including utilities, construction, military aviation, banking and finance and fast moving consumer goods.

Prior to joining Huegin in 2008, Jamie has worked in industry specialist consultancies, management consultancies, military engineering and mining. His industry experience includes engineering, maintenance and logistics management of high value fleets of equipment and assets and his consulting experience spans all phases of the asset management lifecycle from investment planning and strategy to operations and maintenance and disposal and divestment.

Oliver **Skelding,** B.A.(Economics), M.Ec (Econometrics)

Role: Econometrician

Oliver is a senior analyst in our Sydney office who has experience in the regulation of monopoly industries, economic benchmarking and the application of econometric techniques.

Relevant Skills

	Knowledge of the regulatory framework within the National Electricity Market
	Knowledge of Australian DNSP cost structures
	Total factor and partial productivity analysis
	Econometric modelling

Relevant Experience

Oliver has worked with a number of Australian DNSPs to identify expenditure outcomes relative to other operators within the Australian electricity supply industry. Recent engagements include;

- Working with a Victorian DNSP to benchmark expenditure relative to other businesses in the NEM. This project involved using both the AER's benchmarking techniques and other available benchmarking techniques such as Data Envelopment Analysis.
- Assisting an Australian TNSP with benchmarking in preparation for its revenue proposal to the Australian Energy Regulator.
- Working with a number of DNSPs to highlight possible outcomes of the application of the AER's preferred benchmarking techniques.
- Developed performance reports and conducted performance analysis for a number of functions for a large infrastructure manager.
- Developed safety and risk analysis and reports for electrical safety incidents for a state safety regulator.

Professional Summary

Oliver has completed a Master of Economics, specialising in Econometrics. Prior to working with Huegin he worked for the NSW Department of Finance and Services.

At Huegin, Oliver has responded on behalf of Australian DNSPs to the Australian Energy Regulator's Better Regulation Paper regarding the difficulties of using econometric benchmarking techniques within the context of Australian DNSPs and TNSPs. Oliver has also assisted with the benchmarking of Australian DNSPs and TNSPs in preparation for revenue proposals to the Australian Energy Regulator.

Dr Ben **Petschel,** B.Sc.(Mathematics), PhD (Mathematical finance)

Role: Mathematician

Ben has extensive experience in mathematical modelling for cost optimisation and risk management for both multi-national organisations and academic institutions. Ben is highly experienced in benchmarking methodologies, techniques and analysis. He has worked in projects in the energy, transport, mining and financial services industries.

Relevant Skills

	Knowledge of regulatory requirements for electricity networks
	Financial services risk and governance
	Safety risk modelling expertise
	Fault tree analysis
	Complex mathematical modelling
	Statistical and mathematical analysis

Relevant Experience

Ben is an experienced mathematician who has worked in industry applying his skills to various cost, risk and asset management problems. In the past three years Ben has worked extensively in electricity and transport infrastructure management. His experience includes:

- Capital works program simulation for a large electricity network, where Ben modelled and analysed the workforce demand associated with various .
- Capital project portfolio optimisation, where Ben has built and deployed investment decision support models that allocate capital across projects based on advanced, complex decision algorithms for electricity and transport industry asset managers. .
- Post tax revenue model scenario modelling, where Ben has built and analysed probabilistic capital and operating expenditure profiles associated with various x-factor and consumer behaviour scenarios.
- Asset replacement forecasting for a large electricity distribution network.
- Developed and implemented a model for wooden electricity pole maintenance for the purposes of risk management and consideration of impacts to changes in inspection and maintenance programs of an electricity distributor

Professional Summary

Ben studied applied mathematics and mathematical finance at the University of Queensland. He has worked in Operational Risk modelling for St. George Bank and Westpac, and Risk Model Validation for ANZ Bank. His PhD thesis was on the weather impacts on derivatives trading prices. Since joining Huegin, Ben has designed and built many electricity industry investment and cost models, analysed asset forecasts and provided mathematical and analytical support to many distribution businesses.

Naomi **Donohue,** B.Bus (Accountancy and Computer Applications), CPA

Role: Regulatory Expert

Naomi is our Brisbane based senior manager. Naomi was involved in the AER's Better Regulation process and has expertise in distribution network service provider regulation and cost constructs. Naomi was key in unpacking the regulatory environment and cost breakdowns examined in the report.

Relevant Skills

	Regulatory Determination knowledge and experience
	Industry Operational knowledge
	Industry Regulation knowledge
	Benchmarking experience

Relevant Experience

Naomi is a qualified CPA with extensive experience in regulation and finance of electricity energy distributors. Naomi has specific expertise in the areas of regulatory determinations and national electricity market rule changes.

- Management and co-ordination of the financial related components of the revenue determination for an electricity distribution network service provider.
- Participation and involvement in the AER's Better Regulation program.
- In-depth understanding and knowledge of the energy regulation environment in Australia..
- Identification and strategic management of regulated and non-regulated revenue risks and opportunities, collation and presentation of expected costs for operations and infrastructure investment, and compliance with relevant national electricity law and regulatory requirements.
- Responsible for compilation and AER approval of a network service providers' Cost Allocation Model.
- Completion of all financial modelling to a support a network service providers' Regulatory proposal utilising AER models without any compliance or regulatory issues.

Professional Summary

Naomi has significant experience working in the regulated electricity sector, having worked in a distribution network service provider's regulatory and financial departments for over 8 years prior to joining Huegin. She is also experienced working with government agencies to achieve both commercial and social outcomes. Naomi is a qualified CPA with over 20 years experience in management accounting, strategic planning, process improvement and regulation.

Information Relied Upon

The information relied upon throughout this report and details of amendments made to source data is included in this annex.

C

The source data relevant to the analysis and results presented in this report is identified in the following table.

Figure or Table	Data Source	Notes
Figure 2: AER Annual Benchmarking Report Results	Economic Insights AER DNSP MTFP & MPFP 10 Nov 2014.xls	
Figure 4: DNSP class hierarchy	Economic Benchmarking RINs	
Figure 6: Environmental variable comparison	Category Analysis RINs and Economic Benchmarking RINs	Solar Feed-in Tariffs excluded from opex
Table 5 and Figure 7: Time series MTFP results	DNSP Data MTFP.txt, DNSP Productivity Files 17 Nov 2014, www.aer.gov.au	Data for adjustments for exclusion of 110kV and above assets sourced from Economic Benchmarking RINs
Figure 8: Totex ratios	Category Analysis RINs and Economic Benchmarking RINs	Solar Feed-in Tariffs excluded from opex
Table 6 and Figure 10: Time series opex PFP results	DNSP Data MTFP.txt, DNSP Productivity Files 17 Nov 2014, www.aer.gov.au Category Analysis RINs and Economic Benchmarking RINs	Data for adjustments for exclusion of 110kV and above assets sourced from Economic Benchmarking RINs
Figure 11: The consequences of partial productivity consideration	DNSP Data MTFP.txt, DNSP Productivity Files 17 Nov 2014, www.aer.gov.au Category Analysis RINs and Economic Benchmarking RINs	Data for adjustments for exclusion of 110kV and above assets sourced from Economic Benchmarking RINs
Figure 12: Opex ratios	Category Analysis RINs and Economic Benchmarking RINs	Solar Feed-in Tariffs excluded from opex
Figure 13 and Figure 14: Econometric model efficiency scores	Economic Benchmarking RINs Economic Insights, "Economic Benchmarking Assessment of Operating Expenditure for NSW and ACT Electricity DNSPs", Nov 2014	
Table 7: Model 10 statistical results	Economic Benchmarking RINs	Huegin Analysis
Table 8: Model 10 forecast rates of change	Economic Benchmarking RINs	Huegin Analysis
Table 9: Model 10 opex annual growth rate	Economic Benchmarking RINs	Huegin Analysis
Figure 15: Comparison of opex change over time	Economic Benchmarking RINs	Huegin Analysis

Model Details

Model specifications, statistical results and other model information is contained within this annex.

D

Multilateral Total Factor Productivity

As discussed in section 3.1.1, MTFP has advantages and disadvantages as a technique for measuring the productivity of an industry and businesses within that industry. In an industry with diverse operating conditions, such as the Australian electricity distribution industry, any particular MTFP model will present some level of bias against some networks and advantage to others. This is important to acknowledge, as MTFP cannot account for environmental differences in the model itself.

Given that the role of MTFP in the AER's benchmarking approach is to make a first pass assessment of the likelihood of inefficiency in a business' historical expenditure, the selection of the model specification is only important to the extent that it can differentiate inefficiency from statistical noise and heterogeneity. The latter can be corrected (to some extent) through consideration of environmental variables either through adjustment of the input data and/or second stage regression of the MTFP results.

The ongoing debate on the appropriate inputs and outputs of production for an electricity network show no signs of consensus on the "correct" specification. We have therefore included both the originally preferred specification from the AER Expenditure Forecast Assessment Guideline and the recently preferred specification from the NSW and ACT draft decisions.

As a service delivery infrastructure, the outputs of an electricity network are difficult to define from a production perspective. As such, we do not advocate or endorse any particular MTFP model specification, but we do support the view that multiple models should be used and examined for the existence of bias. We have included four MTFP model specifications in our analysis. These are:

- Model 1 - The AER's preferred model from the Expenditure Forecast Assessment Guideline of November 2013.
- Model 1A - Model 1 with the exclusion of assets (and costs) of 110kV and above.
- Model 2 - The AER's most recently preferred model from the NSW and ACT draft decisions.
- Model 2A - Model 2 with the exclusion of assets (and costs) of 110kV and above.

The rationale of including the above models is based on:

1. Given the purpose of the MTFP modelling (to test for the signals of potential inefficiency in historical expenditure), we find it useful to use models used or endorsed by the AER - as these may be applied to JEN in its regulatory determination.
2. Our view is that each of the AER's models (previously and currently preferred - 1 and 2 respectively) exhibit bias through the lack of recognition of the increased costs associated with very high voltage assets that are not present in all networks, hence we have included Models 1A and 2A.

Regarding point 2 above, the measurement of physical assets in the MTFP models (by capacity) inflates the inputs for networks with very high voltage assets. Removal of system capacity as an output compounds the issue for those networks as the effect remains in the inputs but without an appropriate "balancing" factor in the outputs.

JEN's performance across all four models remains relatively stable. Importantly, correcting for the asset related bias does not materially move JEN from the frontier.

Model 1 Specification and Time Series Results

Model 1 is a replication of the AER originally preferred specification from the Expenditure Forecast Assessment Guideline. The output and input specification and time series results are shown below.

Outputs: Customer Numbers, System Capacity, Customer Minutes off supply
Inputs: OH MVA-kms, UG MVA-kms, Transformer Capacity, Opex

	2006	2007	2008	2009	2010	2011	2012	2013
ActewAGL	1.00	1.00	1.01	1.01	0.98	0.92	0.92	0.92

Ausgrid	1.18	1.28	1.09	1.12	1.13	1.13	1.12	1.22
CitiPower	2.21	2.18	2.25	2.12	2.05	2.20	1.99	2.03
Endeavour	1.32	1.27	1.15	1.20	1.24	1.24	1.18	1.19
Energex	1.70	1.72	1.66	1.68	1.70	1.63	1.57	1.43
Ergon	1.07	1.27	1.15	1.11	1.12	1.12	1.10	1.15
Essential	1.55	1.56	1.50	1.44	1.52	1.47	1.33	1.37
Jemena	**1.73**	**1.71**	**1.93**	**1.83**	**1.76**	**1.80**	**1.71**	**1.72**
Powercor	2.03	2.08	2.12	1.89	1.93	2.04	1.94	1.87
SA Power	2.30	2.24	2.35	2.27	2.12	2.07	2.17	2.08
SP AusNet	2.05	1.94	2.02	1.78	1.94	1.92	1.93	1.86
TasNetworks	1.47	1.46	1.46	1.36	1.28	1.37	1.32	1.43
United Energy	2.19	2.20	2.20	2.21	2.20	2.01	1.94	2.08

Model 1A Specification and Time Series Results

Model 1A is a replication of the AER originally preferred specification from the Expenditure Forecast Assessment Guideline, however the input data has been amended to exclude assets and expenditure associated with assets at 110kV or above. The output and input specification and time series results are shown below.

Outputs: Customer Numbers, System Capacity (minus assets greater than or equal to110), Customer Minutes off supply
Inputs: OH MVA-kms (>=110kv assets excluded), UG MVA-kms (>=110kv assets excluded), Transformer Capacity, Opex (dual function asset opex excluded)

	2006	2007	2008	2009	2010	2011	2012	2013
ActewAGL	1.00	1.01	1.02	1.02	1.00	0.92	0.95	0.96
Ausgrid	1.06	1.15	0.97	0.99	1.00	1.01	1.01	1.12
CitiPower	1.41	1.38	1.43	1.35	1.30	1.38	1.26	1.28
Endeavour	1.21	1.16	1.06	1.11	1.14	1.13	1.09	1.11
Energex	1.49	1.51	1.45	1.46	1.47	1.44	1.46	1.41
Ergon	0.77	0.92	0.83	0.81	0.82	0.82	0.84	0.90
Essential	1.12	1.11	1.05	1.01	1.07	1.03	0.92	0.97
Jemena	**1.05**	**1.05**	**1.16**	**1.11**	**1.06**	**1.09**	**1.04**	**1.05**
Powercor	1.25	1.28	1.30	1.16	1.18	1.25	1.20	1.16
SA Power	1.44	1.41	1.48	1.43	1.34	1.31	1.37	1.33
SP AusNet	1.26	1.21	1.24	1.11	1.19	1.19	1.19	1.15
TasNetworks	0.91	0.90	0.90	0.83	0.79	0.84	0.81	0.87
United Energy	1.37	1.37	1.35	1.37	1.34	1.22	1.19	1.27

Model 2 Specification and Time Series Results

Model 2 is a replication of the AER currently preferred specification from the 2014 AER Annual Benchmarking Report. The output and input specification and time series results are shown below.

Outputs: Energy, Ratcheted Maximum Demand, Customer Numbers, Circuit Length, Customer minutes off supply
Inputs: OH subtransmission, OH distribution, UG subtransmission, UG distribution, Transformer capacity, Opex

	2006	2007	2008	2009	2010	2011	2012	2013
ActewAGL	1.00	0.99	1.00	0.99	0.96	0.87	0.91	0.90
Ausgrid	1.04	1.11	0.95	0.96	0.96	0.96	0.91	0.98
CitiPower	1.83	1.81	1.86	1.73	1.66	1.76	1.60	1.61
Endeavour	1.34	1.28	1.16	1.20	1.23	1.22	1.16	1.16
Energex	1.33	1.33	1.28	1.27	1.27	1.23	1.21	1.17
Ergon	0.92	1.07	0.98	0.95	0.96	0.92	0.93	1.02
Essential	1.13	1.09	1.03	0.99	1.00	0.95	0.84	0.86
Jemena	**1.36**	**1.35**	**1.51**	**1.43**	**1.38**	**1.39**	**1.32**	**1.31**
Powercor	1.31	1.35	1.36	1.24	1.24	1.30	1.24	1.18
SA Power	1.62	1.57	1.64	1.59	1.49	1.41	1.44	1.38
SP AusNet	1.31	1.24	1.28	1.13	1.22	1.19	1.18	1.12
TasNetworks	1.20	1.03	0.98	0.87	0.81	0.88	0.84	0.89
United Energy	1.54	1.55	1.54	1.56	1.53	1.40	1.33	1.40

Model 2A Specification and Time Series Results

Model 2A is a replication of the AER currently preferred specification from the 2014 AER Annual Benchmarking Report, however the input data has been amended to exclude assets and expenditure associated with assets at 110kV or above. The output and input specification and time series results are shown below.

Outputs: Energy, Ratcheted Maximum Demand, Customer Numbers, Circuit Length (110kv assets removed), Customer minutes off supply
Inputs: OH subtransmission (>=110kv assets removed), OH distribution, UG subtransmission (>=110kv assets removed), UG distribution, Transformer capacity, opex (dual function asset opex removed)

	2006	2007	2008	2009	2010	2011	2012	2013
ActewAGL	1.00	0.99	1.01	0.99	0.95	0.87	0.92	0.92
Ausgrid	0.86	0.92	0.78	0.79	0.78	0.79	0.76	0.82
CitiPower	1.33	1.31	1.34	1.25	1.20	1.27	1.16	1.17
Endeavour	1.14	1.09	0.98	1.02	1.04	1.03	0.98	0.98
Energex	1.07	1.07	1.03	1.02	1.02	0.98	0.97	0.93
Ergon	0.71	0.83	0.77	0.75	0.75	0.72	0.73	0.80
Essential	0.89	0.86	0.80	0.77	0.77	0.74	0.65	0.67
Jemena	**0.99**	**0.99**	**1.10**	**1.04**	**1.00**	**1.01**	**0.96**	**0.96**
Powercor	0.96	0.99	0.99	0.91	0.90	0.95	0.90	0.86
SA Power	1.19	1.16	1.21	1.17	1.10	1.04	1.06	1.01

SP AusNet	0.96	0.91	0.94	0.84	0.90	0.88	0.87	0.83
TasNetworks	0.89	0.76	0.73	0.64	0.60	0.65	0.62	0.66
United Energy	1.12	1.13	1.11	1.13	1.10	0.99	0.95	1.00

Opex partial factor productivity results

For opex PFP we use the same model specifications as those tested for MTFP with modification of the input index to include opex only.

Model 3 Specification and Time Series Results

Model 3 is a replication of the AER originally preferred specification from the Expenditure Forecast Assessment Guideline. The output specification and time series results are shown below.

Outputs: Customer Numbers, System Capacity, Customer Minutes off supply

	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
ActewAGL	1.00	1.01	0.99	0.99	0.90	0.79	0.80	0.78
Ausgrid	1.24	1.50	1.04	1.14	1.10	1.14	1.08	1.41
CitiPower	2.66	2.40	2.62	2.19	2.02	2.32	1.82	1.91
Endeavour	1.43	1.35	1.11	1.24	1.35	1.31	1.28	1.41
Energex	1.84	1.79	1.73	1.77	1.81	1.61	1.39	1.11
Ergon	0.83	1.06	0.94	0.93	0.97	0.86	0.82	0.95
Essential	1.46	1.38	1.20	1.23	1.30	1.29	1.06	1.21
Jemena	**1.37**	**1.33**	**1.72**	**1.59**	**1.38**	**1.46**	**1.31**	**1.36**
Powercor	2.02	2.27	2.35	2.01	2.21	2.24	1.91	1.81
SA Power	2.42	2.54	2.48	2.31	2.21	1.87	1.96	1.84
SP AusNet	2.10	1.81	1.82	1.53	1.71	1.70	1.68	1.54
TasNetworks	1.37	1.54	1.61	1.49	1.28	1.43	1.31	1.65
United Energy	1.78	1.88	1.90	1.92	1.89	1.55	1.53	1.76

Model 3A Specification and Time Series Results

Model 3A is a replication of the AER originally preferred specification from the Expenditure Forecast Assessment Guideline, however the data has been amended to exclude assets and expenditure associated with assets at 110kV or above. The output specification and time series results are shown below.

Outputs: Customer Numbers, System Capacity (minus assets greater than or equal to 110), Customer Minutes off supply

	2006	2007	2008	2009	2010	2011	2012	2013
ActewAGL	1.00	1.02	1.00	1.01	0.91	0.79	0.79	0.79
Ausgrid	1.11	1.36	0.91	1.01	0.95	1.01	0.95	1.26
CitiPower	2.19	1.98	2.16	1.81	1.67	1.91	1.50	1.58
Endeavour	1.63	1.52	1.22	1.39	1.54	1.48	1.44	1.67
Energex	1.71	1.64	1.58	1.61	1.65	1.55	1.52	1.42
Ergon	0.75	0.97	0.86	0.87	0.90	0.79	0.81	1.12
Essential	1.35	1.24	1.06	1.11	1.17	1.17	0.94	1.10

Jemena	**1.13**	**1.10**	**1.42**	**1.31**	**1.14**	**1.21**	**1.08**	**1.12**
Powercor	1.66	1.87	1.94	1.66	1.82	1.85	1.57	1.49
SA Power	1.99	2.10	2.05	1.91	1.82	1.54	1.62	1.52
SP AusNet	1.73	1.49	1.50	1.26	1.41	1.40	1.39	1.27
TasNetworks	1.13	1.27	1.32	1.23	1.05	1.18	1.08	1.36
United Energy	1.47	1.55	1.57	1.58	1.56	1.28	1.27	1.46

Model 4 Specification and Time Series Results

Model 4 is a replication of the AER currently preferred specification from the 2014 AER Annual Benchmarking Report. The output specification and time series results are shown below.

Outputs: Energy, Ratcheted Maximum Demand, Customer Numbers, Circuit Length, Customer minutes off supply

	2006	2007	2008	2009	2010	2011	2012	2013
ActewAGL	1.00	0.99	0.97	0.96	0.87	0.75	0.77	0.75
Ausgrid	0.95	1.13	0.79	0.87	0.80	0.84	0.77	0.98
CitiPower	2.40	2.17	2.35	1.94	1.78	2.03	1.57	1.65
Endeavour	1.35	1.27	1.04	1.16	1.25	1.21	1.16	1.29
Energex	1.41	1.34	1.29	1.30	1.32	1.22	1.17	1.10
Ergon	0.75	0.93	0.84	0.84	0.87	0.75	0.75	0.96
Essential	1.19	1.08	0.92	0.95	0.96	0.95	0.76	0.86
Jemena	**1.22**	**1.20**	**1.53**	**1.40**	**1.23**	**1.27**	**1.14**	**1.17**
Powercor	1.64	1.86	1.91	1.66	1.80	1.80	1.52	1.42
SA Power	1.93	2.03	1.97	1.83	1.76	1.45	1.47	1.37
SP AusNet	1.63	1.38	1.41	1.17	1.31	1.28	1.25	1.13
TasNetworks	1.48	1.44	1.44	1.27	1.08	1.23	1.11	1.40
United Energy	1.47	1.56	1.57	1.59	1.55	1.26	1.22	1.39

Model 4A Specification and Time Series Results

Model 4A is a replication of the AER currently preferred specification from the 2014 AER Annual Benchmarking Report, however the data has been amended to exclude assets and expenditure associated with assets at 110kV or above. The output specification and time series results are shown below.

Outputs: Energy, Ratcheted Maximum Demand, Customer Numbers, Circuit Length (110kv assets removed), Customer minutes off supply

	2006	2007	2008	2009	2010	2011	2012	2013
ActewAGL	1.00	1.00	0.99	0.98	0.88	0.74	0.77	0.75
Ausgrid	0.85	1.02	0.69	0.77	0.69	0.74	0.68	0.88
CitiPower	1.98	1.79	1.94	1.60	1.47	1.68	1.30	1.36

Endeavour	1.40	1.29	1.02	1.17	1.26	1.21	1.16	1.33
Energex	1.31	1.23	1.18	1.18	1.20	1.10	1.06	0.98
Ergon	0.68	0.86	0.77	0.78	0.81	0.68	0.69	0.92
Essential	1.10	0.97	0.82	0.85	0.86	0.86	0.68	0.78
Jemena	**1.01**	**0.99**	**1.26**	**1.16**	**1.02**	**1.05**	**0.94**	**0.96**
Powercor	1.35	1.53	1.58	1.37	1.49	1.48	1.26	1.17
SA Power	1.59	1.67	1.62	1.51	1.45	1.20	1.22	1.14
SP AusNet	1.34	1.14	1.16	0.96	1.08	1.06	1.04	0.93
TasNetworks	1.22	1.19	1.19	1.05	0.90	1.01	0.91	1.15
United Energy	1.21	1.29	1.30	1.31	1.28	1.04	1.01	1.14

Econometric Modelling

Econometric modelling holds an advantage over index productivity modelling in that environmental variables are more readily incorporated into the model. However it often requires more data and the need to specify the functional form of the model invokes the potential for bias and error.

In electricity distribution cost efficiency benchmarking, the challenge of identifying the appropriate variables is significant. There is no consensus on the most appropriate model specification, yet the selection of a particular specification will determine the efficiency score results. The AER have adopted a Stochastic Frontier Analysis (SFA) Cobb-Douglas econometric model (referred to as Model 9 throughout this report). SFA models require more data than is available in Australia, therefore the AER have relied upon data from Ontario and New Zealand. Huegin disagrees with this approach. Our preferred econometric model is referred to as Model 10 throughout this report. The summary of the difference between Models 9 and 10 are shown below.

	Model 9 (AER preferred)	Model 10 (Huegin preferred)
Independent Variables	Customer Numbers, Ratcheted Peak Demand, Circuit Length	Customer Numbers, System Capacity
Environmental Variables	Share of Underground Network	Share of Single Stage Transformation, Demand Density
Technology Variable	Year	Year
Dummy Variable	Country	None
Data	All 13 Aust NEM DNSPs, 18 NZ networks and 37 Ontario networks	All 13 Aust NEM DNSPs

We prefer Model 10 over Model 9 because:

1. We believe the international data is not comparable to the Australian data. In particular:
    a. The Ontario data was collected for a specific benchmarking project, there is no assurance of the validity or provenance of the data and it only includes data up until 2012.
    b. The Ontario data has been manipulated to exclude costs associated with assets of 50kV or above - which has not been replicated for the NZ or Australian data.
2. We believe that the use of an SFA model, and therefore the necessity to expand the dataset, has undue influence on the model form. In particular, the only environmental variable able to be included is the share of underground cable (as a proportion of the total network length) as no other data is available that is common across all three jurisdictions.

Notwithstanding our preference to exclude international data (and therefore SFA), we did include the AER model specification as one of the econometric models we used for the Australian data. To accommodate its use for NEM data only, we used an Ordinary Least Squares model with Random Effects.

The statistical attributes of each of the econometric models used or referred to throughout this report are detailed over the following pages.

Model 10 - the Huegin preferred opex model

Random Effects

Balanced Panel: n=13, T=8, N=104

	Estimate	Std. Error	t-value	Pr(>|t|)
(Intercept)	2.987	2.242	1.332	0.186
log(System Capacity)	0.187	0.063	2.997	0.003

	Estimate	Std. Error	t-value	Pr(>ltl)
log(Customers)	0.448	0.210	2.133	0.035
Share of Single Stage Transformation	-0.780	0.296	-2.638	0.010
log(Demand density)	-0.279	0.122	-2.284	0.025
Year	0.029	0.005	6.100	0.000

Total Sum of Squares: 2.7783

Residual Sum of Squares: 0.76026

R-Squared : 0.72636

Adj. R-Squared : 0.68446

F-statistic: 52.0276 on 5 and 98 DF, p-value: < 2.22e-16

Effects:

	var	std. dev	share
idiosyncratic	0.007622	0.087303	0.109
individual	0.062454	0.249909	0.891

theta: 0.8774

Alternative models

Given the sensitivity of opex benchmarking to model specification a number of different models incorporating different explanatory variables where used to provide a sensitivity test for the partial productivity estimates obtained. Models used for the sensitivity testing are described in more detail below. As shown in figure 13 in the main report, Model 8 gave an identical result to the selected model (Model 10) for JEN, whilst Models 5, 6 and 7 gave slightly higher results. Model 9 (the AER's currently preferred specification, used in the NSW and ACT draft decision) produces a slightly lower result for JEN.

Model 5

Balanced Panel: n=13, T=8, N=104

	Estimate	Std. Error	t-value	Pr(>ltl)
Intercept	2.6476344	2.1942852	1.2066	0.23052
log(System Capacity)	0.1680468	0.0648411	2.5917	0.01103
log(Customers)	0.3647329	0.2153711	1.6935	0.09357
Share of Single Stage Transformation	-0.7356860	0.2892936	-2.5430	0.01257
log(Capital Stock)	0.1202914	0.1192853	1.0084	0.31576
log(Demand Density)	-0.2565571	0.1206574	-2.1263	0.03601
Year	0.0253051	0.0059267	4.2697	4.56E-05

Total Sum of Squares: 2.8731

Residual Sum of Squares: 0.76121

R-Squared   : 0.73506

Adj. R-Squared : 0.68558

F-statistic: 44.8532 on 6 and 97 DF, p-value: < 2.22e-16

Effects:

	var	std. dev	share
idiosyncratic	0.007711	0.087811	0.119
individual	0.057039	0.238828	0.881

theta: 0.8711

Model 6

Balanced Panel: n=13, T=8, N=104

	Estimate	Std. Error	t-value	Pr(>ltl)
Intercept	-0.7365127	1.2051497	-0.6111	0.5425232
log(System Capacity)	0.2346794	0.0648142	3.6208	0.0004671
log(Customers)	0.3418069	0.1600863	2.1351	0.0352426
log(Capital Stock)	0.1958642	0.1159654	1.6890	0.0944012
log(capacity intensity)	0.2403815	0.1054849	2.2788	0.0248475
Year	0.0178744	0.0053821	3.3211	0.0012607

Total Sum of Squares: 3.9126

Residual Sum of Squares: 0.87209

R-Squared   : 0.77711

Adj. R-Squared : 0.73227

F-statistic: 68.3342 on 5 and 98 DF, p-value: < 2.22e-16

Effects:

	var	std. dev	share
idiosyncratic	0.008331	0.091273	0.22
individual	0.029521	0.171816	0.78

theta: 0.8154

Model 7

Balanced Panel: n=13, T=8, N=104

	Estimate	Std. Error	t-value	Pr(>ltl)
Intercept	-2.1531631	1.7604268	-1.2231	0.22423
log(Customers)	0.7982547	0.1931738	4.1323	7.57E-05
log(Circuit Length)	0.2238110	0.1353316	1.6538	0.10137
log(Share of underground)	-0.1253476	0.1214766	-1.0319	0.30467
log(Capacity intensity)	0.2824548	0.1349090	2.0937	0.03887
Year	0.0345200	0.0054755	6.3045	8.32E-09

Total Sum of Squares: 2.8059

Residual Sum of Squares: 0.79919

R-Squared : 0.71517

Adj. R-Squared : 0.67391

F-statistic: 49.2136 on 5 and 98 DF, p-value: < 2.22e-16

Effects:

	var	std. dev	share
idiosyncratic	0.007702	0.087760	0.112
individual	0.061197	0.247381	0.888

theta: 0.8756

Model 8

Balanced Panel: n=13, T=8, N=104

	Estimate	Std. Error	t-value	Pr(>ltl)
Intercept	2.7612418	2.2135352	1.2474	0.215241
log(System Capacity)	0.2159281	0.0656745	3.2879	0.001407
log(Customer numbers)	0.4064103	0.1852443	2.1939	0.030630
Share of single stage transformation	-0.7004670	0.3190735	-2.1953	0.030526
log(Capacity intensity)	0.0589756	0.1397445	0.4220	0.673941
log(Demand density)	-0.2217639	0.1173935	-1.8891	0.061870
Year	0.0279709	0.0055382	5.0505	2.07E-06

Total Sum of Squares: 3.1908

Residual Sum of Squares: 0.79629

R-Squared : 0.75044

Adj. R-Squared : 0.69993

F-statistic: 48.6141 on 6 and 97 DF, p-value: < 2.22e-16

Effects:

	var	std. dev	share
idiosyncratic	0.007697	0.087732	0.152
individual	0.042866	0.207042	0.848

theta: 0.8518

Model 9 (the AER's preferred model, used in the NSW and ACT decision)

Balanced Panel: n=13, T=8, N=104

	Estimate	Std. Error	t-value	Pr(>ltl)
Intercept	-2.3995129	2.4179358	-0.9924	0.323456
log(Customers)	0.9981809	0.3149295	3.1695	0.002037
log(Circuit Length)	0.1254799	0.1569386	0.7995	0.425907
log(Ratcheted Peak Demand)	-0.1103074	0.2444282	-0.4513	0.652779
log(Share of underground)	-0.1098278	0.1318645	-0.8329	0.406936
Year	0.0369309	0.0058096	6.3569	6.54E-09

Total Sum of Squares: 2.4558

Residual Sum of Squares: 0.78565

R-Squared : 0.68009

Adj. R-Squared : 0.64085

F-statistic: 41.6671 on 5 and 98 DF, p-value: < 2.22e-16

Effects:

	var	std. dev	share
idiosyncratic	0.007671	0.087582	0.072
individual	0.098818	0.314353	0.928

theta: 0.902

Clustering Algorithms

Information on clustering algorithms used within this report are contained within this annex.

E

Context

Under the regulatory framework applied by the Australian Energy Regulator (AER) when evaluating electricity network expenditure forecasts, the AER must consider cost efficiency through benchmarking. The small sample size in Australia and diverse range of operating conditions provide significant challenges to this endeavour.

In its most recent decision - the draft decision for NSW and ACT distribution - the AER introduced data from Ontario, Canada and New Zealand to facilitate the utilisation of a Stochastic Frontier Analysis (SFA) econometric model of efficiency (SFA requires more data than is available in Australia alone). The SFA econometric model assumes a common opex cost function for the 68 networks in the sample population. Whilst some adjustments can be made to account for environmental factors that differ across the networks, unobserved heterogeneity remains perhaps the greatest challenge to the model efficacy.

In Huegin's opinion, latent classes exist in the data relied upon by the AER in the NSW and ACT draft decision. Our view is that the presence of these classes has led the AER to overestimate the efficiency gap of several Australian networks.

Latent Class Modelling

Recent research[25] in electricity network benchmarking suggests that in a population of electricity networks latent classes (groupings of networks with similar attributes within the group but differences to other groups) exist. The presence of these latent classes, if not recognised, leads to comparison of networks to an efficiency frontier that is not appropriate for its individual circumstances. This in turn leads to exaggeration of inefficiency.

It is important to recognise the potential for unobserved heterogeneity when using economic benchmarking techniques to compare the expenditure, and efficiency, of electricity network businesses. Unobserved heterogeneity occurs when variables other than those included in the econometric model specification have influence on the dependent variable under study (in this case, opex). The absence of these variables in the model specification can lead to erroneous inferences about efficiency. That is, differences in the observed and predicted level of opex will include the influence of these material, but unaccounted for, variables. Because the variables are unobserved, the influence is often translated as inefficiency.

To test the existence of latent classes in the AER dataset, Huegin ran analysis using the AER's SFA model and the data for the 68 networks used by the AER as the input to its model. The data file used for the analysis was the Economic Insights medium data set (within the file "AER Draft decision Ausgrid distribution determination - Ausgrid 2014 - Economic Insights DNSP productivity files - November 2014") downloaded from the AER's website. The only adjustments that have been made to this dataset are that a new column has been created and labelled DNSPID (for example ActewAGL will be 1 for all years, Ausgrid 2 etc). LIMDEP was selected as the statistical application for our latent class modelling as it is widely recognised as the preferred application for this type of analysis by researchers and academics. The LIMDEP code and process is provided below. User guides and instruction manuals on LIMDEP can be found on the web.

```
#Import data into LIMDEP 10#
        IMPORT; FILE="nameofdatafile.csv"$

# Create a dependant variable (opex real)#
        CREATE; y=log(OPEX/PROPEX)$

# Specify as panel data#
        SETPANEL; GROUP=DNSPID; PDS=YEARID$

# Run SFA model and then Latent class SFA Model#
        FRONTIER; Cost; Lhs = y ;  Rhs = one,log(CUSTNUM), log(CIRCLEN), log(RMDEMAND),
        log(SHAREUGC); Panel$

        FRONTIER; Cost; Lhs = y ;  Rhs = one,log(CUSTNUM), log(CIRCLEN), log(RMDEMAND),
        log(SHAREUGC); LCM;Pts=4;List;Panel$
```

[25] See, for example: Llorca, Orea & Pollit, p 15 "Using the latent class approach to cluster firms in benchmarking: An application to the US electricity transmission industry", March 2014

Latent class modelling requires an assumption of the number of classes before running the model. As such, Huegin ran analysis on the data set under the assumption of between one and five classes. The Akaike Information Criterion[26] was used to determine the optimal number of classes. The AIC is a model selection statistic that facilitates the comparison of econometric models based on their likelihood and number of parameters (more parameters resulting in a greater "penalty").

The results of the AIC analysis for the assumption of one to five classes are shown below. The lower the AIC, the stronger the preference for that model. The four-class assumption was strongest. These results suggest the presence of four distinct technological groups among the DNSPs in the dataset is a preferential assumption compared to the inference of a single, homogenous class. Importantly, all assumptions of multiple classes (two through five) are superior to the single class assumption based on the AIC.

1 Class

Latent Class / Panel Frontier Model
Dependent variable Y
Log likelihood function 81.18529
Restricted log likelihood .00000
Chi squared [1 d.f.] 162.37057
Significance level .00000
Estimation based on N = 544, K = 7
Inf.Cr.AIC = -148.4 AIC/N = -.273
68 individuals
Stochastic frontier (half normal model)

2 Classes

Latent Class / Panel Frontier Model
Dependent variable Y
Log likelihood function 245.58788
Restricted log likelihood .00000
Chi squared [9 d.f.] 491.17577
Significance level .00000
Estimation based on N = 544, K = 15
Inf.Cr.AIC = -461.2 AIC/N = -.848
68 individuals
Stochastic frontier (half normal model)

3 Classes

Latent Class / Panel Frontier Model
Dependent variable Y
Log likelihood function 320.45122
Restricted log likelihood .00000
Chi squared [17 d.f.] 640.90244
Significance level .00000
Estimation based on N = 544, K = 23
Inf.Cr.AIC = -594.9 AIC/N = -1.094
68 individuals
Stochastic frontier (half normal model)

4 Classes

Latent Class / Panel Frontier Model
Dependent variable Y
Log likelihood function 362.25186
Restricted log likelihood .00000
Chi squared [25 d.f.] 724.50372
Significance level .00000
Estimation based on N = 544, K = 31
Inf.Cr.AIC = -662.5 AIC/N = -1.218
68 individuals
Stochastic frontier (half normal model)

5 Classes

Latent Class / Panel Frontier Model
Dependent variable Y
Log likelihood function 347.50650
Restricted log likelihood .00000
Chi squared [33 d.f.] 695.01300
Significance level .00000
Estimation based on N = 544, K = 39
Inf.Cr.AIC = -617.0 AIC/N = -1.134
68 individuals

26 The Akaike Information Criterion is a measure of the statistical quality of a model relative to other models. The AIC has been used to examine class number assumptions in electricity networks previously, for example: Llorca, Orea & Pollit, p 15 "Using the latent class approach to cluster firms in benchmarking: An application to the US electricity transmission industry", March 2014

It should be noted that the latent class model results rely upon the actual model specifications - particularly the variables chosen - but importantly the analysis demonstrates that networks in the benchmarking data population should not be considered in a single class.

Confirming existence of classes - k-means clustering

A more simple means of analysing the existence of classes in a data set is through clustering algorithms. These are computational methods capable of segmenting entities in a data set into classes of similar attributes. This type of statistical analysis is used in data mining to segment large data sets into classes. Typical applications include:

- Customer base segmentation (on variables that may indicate product preferences or likelihood of repeat purchases, etc);
- Biological classification of organisms based on observed attributes;
- Classifying chemical compounds based on analysis of individual elements.

A common statistical clustering method is the k-means clustering technique which aims to partition *n* observations into *k* clusters in which each observation belongs to the cluster with the nearest mean, serving as a prototype of the cluster. The statistical process for k-means clustering is as follows:

1. Select the number of clusters, k.
2. Initialise the centre of the clusters.
3. Attribute the closest cluster to each data point.
4. Set the position of each cluster to the mean of all data points belonging to that cluster.
5. Repeat steps 3 and 4 until convergence occurs (i.e when the assignments at step 3 do not change with further iterations).

k-means clustering relies on the correct assumption of the number of clusters for the population. Like latent class modelling, there are statistical techniques that facilitate the identification of the optimal number of clusters. However we have not employed these techniques for the purposes of this report as:

1. The optimal number of clusters depends on the specific variables chosen;
2. The use of k-means in this context was merely to demonstrate the separation of the networks into groupings across a range of cluster number assumptions;
3. The objective was only to identify appropriate peer networks for JEN; and
4. The latent class modelling has already demonstrated that more than one class is preferable to a single class assumption.

Contact Details

Jamie Blair

Level 10, 2 Elizabeth Plaza, North Sydney, NSW 2060

t: +612 9409 2400
e: info@huegin.com.au

huegin