Response to Consultants' Reports on Economic Benchmarking of Electricity DNSPs

Report prepared for
Australian Energy Regulator

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CONTENTS

DNSP NAME ABBREVIATIONS

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

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

EXECUTIVE SUMMARY

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

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

b) the productivity change to be applied to forecast opex for the NSW, ACT and Queensland DNSPs.

Economic Insights (2014) presented the results of our analysis for the NSW and ACT DNSPs based on a range of economic benchmarking techniques including stochastic frontier analysis (SFA), least squares econometrics (LSE) and opex multilateral partial factor productivity (MPFP) indexes. After choosing a conservative efficiency target based on the weighted average performance of the five top performing DNSPs and making additional allowance for factors not included in the econometric models, downwards adjustments were recommended for the base year opex of each of the NSW and ACT DNSPs.

The NSW and ACT DNSPs' revised regulatory proposals included a number of supporting consultants' reports critiquing the analysis in Economic Insights (2014). These included reports by Pacific Economics Group Research, Frontier Economics, Cambridge Economic Policy Associates (CEPA), Advisian and Huegin. A number of consultants' reports were also submitted by the Queensland DNSPs including ones by Frontier Economics, Huegin and Synergies.

We have reviewed both the critiques presented by the consultants and the alternative models presented in detail and have found no reason to change the approach adopted in our 2014 benchmarking analysis. We do, however, consider there is a case for revising the opex efficiency target. And updated and more detailed information on the impact of operating environment factors not explicitly included in the opex cost function model is now available.

We provide detailed responses to all the technical arguments raised by the DNSPs' consultants in the body of this report and also review their alternative models in detail. In this summary we respond to 10 high level issues raised by a number of the consultants.

Issue raised: *The Economic Benchmarking Regulatory Information Notice (EBRIN) data are not sufficiently mature and not fit–for–purpose.*

Response: The AER's EBRIN data are considerably more detailed, comprehensive and consistent than regulatory data in comparable countries, including the United States. The AER's economic benchmarking RIN data have been supplied using a consistent set of definitions and coverage both over time and across jurisdictions. The EBRIN data have undergone a more extensive checking, cross–checking and auditing process than regulatory benchmarking data in most other countries.

Many of the DNSPs' consultants' comments criticise the disaggregated opex data presented in the EBRIN but fail to understand the evolution of the Australian data. The EBRIN's aggregate and network services opex are quite consistent but the DNSPs were requested to provide categorisation based on their legacy state reporting classifications for the purpose of 'sense checking' the time series of opex for each DNSP. The disaggregated opex data were not intended to be used as a basis for comparing opex components across DNSPs.

Some DNSP consultants criticise the requirement for DNSPs to estimate some data points in the EBRIN. However, estimation by DNSPs is relatively minor and they are the ones best placed to fill in the very few gaps – which often exist due to changes in DNSP reporting systems in any case.

We acknowledge that no database will ever be perfect and, in the case of the EBRIN, more work is required on developing some of the lesser operating environment variables requested (eg standard vehicle access) to allow incorporation of more refined treatment in future. However, the output and input data and the material operating environment variable data used in Economic Insights (2014) are considered to be quite robust and to compare more than favourably with overseas datasets used in previous regulatory benchmarking studies. They are thus fit for the purpose of economic benchmarking.

Issue raised: *The DNSPs' consultants have submitted econometric models using Australian only data claiming to show smaller efficiency gaps.*

Response: While the EBRIN data are robust, they show little time–series variability for each DNSP. This is not an uncommon situation for infrastructure industries which are characterised by being relatively stable and 'steady as she goes' in nature. This means the 104 observations available in the EBRIN (for 13 DNSPs over 8 years each) are more akin to 13 observations for econometric estimation purposes. To be able to estimate models with sufficiently good precision in parameter estimates requires the addition of more cross–sectional observations – a point noted by Pacific Economics Group Research.

As a result, little weight can be placed on the models of CEPA and Frontier given the data characteristics. Rather, the models submitted support the case for including overseas DNSP data to increase the number of available cross–sectional observations. Similarly, attempts to test for differences in slope coefficients across countries are flawed because there is inadequate variation in the Australian data (given the relatively small number of Australian DNSPs) to obtain sufficiently accurate parameter estimates to support such tests.

And an important flaw in the DNSPs' consultants' models is that most include a variable that measures the proportion of network length above 66kV. While this is claimed to allow for the higher opex associated with high voltage lines, only the NSW, ACT and Queensland DNSPs have lines of above 66kV. This variable will hence also pick up other effects common to NSW, ACT and Queensland DNSPs, including possible higher levels of inefficiency.

The NSW DNSPs have themselves flagged that their ability to improve efficiency has been hindered by inefficient work practices and this has been confirmed by the Deloitte Access Economics (2014b) review of NSW and ACT DNSP work practices. In Queensland a state government review found Energex and Ergon could together achieve an estimated $1.4 billion reduction in operational costs over the 2015–20 regulatory control period (IDCESR 2013, p.49). And an independent review of ActewAGL's labour costs and vegetation management practices in 2013 commissioned by the AER has found considerable evidence that 'systemic issues have resulted in a material level of inefficiency' (EMCa 2015b, p.i).

The impact of including the above 66kV network variable in the DNSPs' consultants' models can be seen from the estimates it implies of the DNSPs' per kilometre costs of operating high voltage lines. These estimates are several times higher than the DNSPs reported per kilometre costs of operating these lines derived from regulatory accounts. This discrepancy arises because the variable is instead picking up other effects, including the costs of DNSP inefficiency. The smaller efficiency gaps shown by these models are thus false.

Pacific Economics Group Research reports a model using EBRIN and US data. However, the use of US data is problematic given the lack of key variables available in US reporting, the widely unbalanced panel used and the way US data are collected for largely financial reporting purposes.

Some of the DNSPs' consultants argue that the results in Economic Insights (2014) are driven by the inclusion of data from New Zealand and Ontario. This is incorrect. Our EBRIN–only results are consistent with our three country results – the benefit of including the overseas data is to improve the precision of our parameter estimates but it does not change the pattern of results.

Issue raised: *The New Zealand and Ontario data are not sufficiently comparable with the EBRIN data.*

Response: Economic benchmarking used to support regulatory decisions needs to be based on robust parameter estimates and robust parameter estimates cannot be obtained using only the EBRIN data. The DNSPs' consultants' reports generally fail to recognise that the purpose of our study was <u>not</u> to undertake international benchmarking but rather we included overseas DNSPs to improve the precision of our parameter estimates. More precise parameter estimates increase confidence in model accuracy and allow more accurate accounting for output change in forecasts of future opex productivity growth. For this purpose, the inclusion of country dummies to allow for systematic differences in operating environments, coverage and reporting regimes is appropriate. But it means that efficiency scores cannot then be compared across countries – even though the DNSPs' consultants incorrectly go on to do so.

We agree that were an international benchmarking study to be undertaken, then it would be important to ensure maximum comparability across opex and output categories. However, for the purpose at hand, the inclusion of country dummy variables provides adequate allowance for systematic differences. This is evidenced by the similarity in our efficiency results using the EBRIN data only and using the three country database.

We have opted to use purpose–built economic benchmarking databases used in recent regulatory decisions which have used a similar model specification. Such databases are available for New Zealand and Ontario which also have the benefit of having similar governance structures to Australia.

Issue raised: *The Economic Insights (2014) economic benchmarking results for Ontario DNSPs are different to those reported in the Pacific Economics Group (2013) report for the Ontario Energy Board.*

Response: It is not surprising that the two sets of efficiency score rankings differ given that those derived from (but not presented) in Economic Insights (2014) relate to *opex* efficiency while those in Pacific Economics Group Research (2013) relate to *total cost* efficiency.

Given that capital plays a major role in the total cost efficiency scores and given the long lived nature of capital in this industry, capital efficiency is much slower to adjust. Given the degree of capital intensiveness of the industry, this means total cost efficiency is also slow to adjust compared to opex efficiency. Hence, there is no expectation that a DNSP that is inefficient in its use of capital inputs will also be inefficient in its use of opex inputs and vice versa. Differences in work practices can account for a substantial proportion of differences in observed opex efficiency, regardless of whether or not the DNSP is efficient in its use of capital.

It is not unusual to see marked differences in the pattern of opex efficiency score rankings and total cost efficiency score rankings in energy distribution businesses. Highlighting the differences in rankings across studies when like is not being compared with like is, in our view, misleading.

Issue raised: *Most NZ and Ontario DNSPs are smaller than Australian DNSPs.*

Response: New Zealand and Ontario both have a small number of larger DNSPs and a large number of smaller DNSPs. The larger Ontario DNSPs are broadly comparable in size to the larger Australian DNSPs, except on line length for Essential Energy and Ergon Energy.

While New Zealand and Ontario DNSPs are smaller than Australian DNSPs on average, there are advantages in having a heterogeneous dataset with numerous observations to support precision in econometric estimates, as noted by Pacific Economics Group. The objective for this exercise is, therefore, getting more cross–sectional variability into the sample.

We have removed very small DSNPs with less than 20,000 customers from the New Zealand and Ontario databases to minimise the scope for very small DNSPs to exert undue influence on the results. Sensitivity analysis was undertaken of the effects of using different minimum DNSP sizes (in terms of customer numbers) in the database and the efficiency results were largely insensitive to the different options examined. In terms of the technical properties of the model, however, the medium database used provides the optimum trade–off between DNSP numbers and size.

We agree it would be nice to have more larger DNSPs in the sample, particularly large rural DNSPs. However, there are very few such DNSPs world–wide and none with the necessary comparable data. For the purposes of the current exercise – which is to improve the precision of our parameter estimates and not to undertake international benchmarking – the database we have used is the best available.

Issue raised: *The Economic Insights (2014) economic benchmarking does not sufficiently allow for differences in operating environments.*

Response: We allowed for differences in network densities and undergrounding in our econometric models and differences in subtransmission intensity, regulations, bushfire requirements and ActewAGL's unique features in ex post adjustments. These are the material operating environment factors that affect a DNSP's efficient level of opex. Our inclusion of country dummy variables in the econometric models allow for systematic differences in operating environments between countries.

Frontier Economics, CEPA and Pacific Economics Group Research attempt to include a variable for 132kV lines in their modelling. However, as noted, only NSW, ACT and Queensland DNSPs have significant lengths of 132 kV line and so this variable will pick up effects common to these states, including inefficiency. Our analysis of the DNSPs' consultants' results shows this is indeed the case with their model producing estimates of the opex cost for 132 kV lines several times higher than those reported by the DNSPs. Their modelling thus overstates operating environment effects and understates efficiency gaps.

Frontier Economics also attempts to include a second order density variable in its modelling. However, this approach is inferior to using the more general translog opex cost function which produced similar results to our preferred opex cost function model. Frontier also argues for spatial density measures. However, the calculation of such measures is problematic and they have not been used in previous economic benchmarking studies.

CEPA presents a number of regressions using EBRIN data only. However, given the limited variability of the EBRIN data, these regressions use up the effective degrees of freedom available and, hence, are not reliable.

Issue raised: *The Economic Insights (2014) economic benchmarking should have used the new 'latent heterogeneity' models.*

Response: The latent heterogeneity and related models are claimed to allow for inherent differences in operating environments. They attribute systematic differences in performance to latent (or unidentified) differences in operating environments. These methods, hence, all tend to overestimate efficiency scores because they do not allow for ongoing differences in efficiency levels over the sample period and they have not been used by other regulators.

Huegin claims to have found 4 'latent classes' but does not include country dummy variables and uses criterion biased to finding more rather than fewer classes. And Huegin's 'k–means clustering' simply identifies clusters of DNSPs that are similar to each other in terms of closeness of their means. It does not provide evidence that the DNSPs in these clusters are significantly different from each other nor that they belong to separate cost functions.

We believe our approach of estimating models which take account of the key density and undergrounding variables for all DNSPs in the sample and then making additional adjustments for identified additional material operating environment factors for the Australian DNSPs is a superior approach.

Issue raised: *The Economic Insights (2014) economic benchmarking does not include any peers for the relatively sparse networks of Essential Energy and Ergon Energy in its frontier group and so tends to underestimate their efficiency.*

Response: There are three rural DNSPs in the Economic Insights (2014) top quartile group of possible opex efficiency scores – Powercor, SA Power Networks and AusNet Distribution. If Essential Energy and Ergon Energy were genuine outliers, we would expect the flexible translog opex cost function to give them much higher opex efficiency scores than the less flexible Cobb–Douglas opex cost function. This is because the outlier points would exert more influence on the shape of the efficient cost frontier in the more flexible model and hence appear to be more efficient (albeit possibly by default). However, our results for the two different types of opex cost function are very similar suggesting the relatively low customer density of Essential Energy and Ergon Energy are not special factors.

The AER also sought an engineering view on the relationship between opex and customer density changes at the low densities of Essential Energy and Ergon Energy relative to other rural DNSPs. EMCa found that the relationship between maintenance opex and line length is approximately linear over the relevant range and the relationship between non–maintenance opex and customer numbers is also approximately linear. Since the logarithmic form of the Cobb–Douglas model mirrors approximately linear relationships over the relevant variable ranges, no special treatment is required for Essential Energy and Ergon Energy.

Issue raised: *The opex MPFP results show the performance range narrows over the second half of the period so NSW/ACT inefficiency is overstated.*

Response: The opex data used in the Economic Insights (2014) modelling include changes in provisions and the NSW DNSPs have timed negative changes in provisions for 2013. One therefore has to be aware of the optical illusion caused by the NSW 'increase' in opex MPFP in 2013 due to negative changes in provisions. This particularly applies to Huegin's stylised graphs using only three data observations per DNSP.

However, we note that the Victorian DNSPs received a 10 per cent opex step change increase in 2011 due to new requirements introduced following the Victorian Bushfires Royal Commission (VBRC). The negative technical change term in our estimated opex cost function model will, in part, result from the effect of the Victorian DNSPs' higher opex due to higher bushfire regulation requirements in the latter years. If the NSW/ACT DNSPs have not experienced the same extent of step change (eg because there has been no change in their bushfire regulation requirements), then their average relative efficiency for the period may be over–estimated.

Detailed analysis in AER (2015a,b,c) indicates that pre–VBRC Victorian DNSP bushfire–related opex would have been at least as high as in NSW when differences in the nature of the regimes are taken into account. And post–VBRC Victorian DNSP bushfire–related opex increased due to the more stringent and onerous explicit requirements now imposed on the Victorian DNSPs in key areas. However, over time we would expect the NSW DNSPs to move to adopt some of the higher Victorian standards due to duty of care considerations even though they are not formally required to do so.

We are, therefore, of the view that no further changes are required to the general approach we have used to form base year opex recommendations despite an apparent narrowing of the opex performance gap from 2011 onwards.

Issue raised: *Other regulators are claimed to adopt a more conservative approach in setting efficiency targets.*

Response: Economic Insights (2014) took the customer–weighted average of opex efficiency scores of DNSPs in the top quartile of possible scores (ie greater than 0.75) from our opex cost function modelling which produced a target of 0.86 (before allowance for additional operating environment factors). Ofgem removes the gap relative to the 75th percentile DNSP in electricity and removes three quarters of this gap in gas. Applying Ofgem's electricity approach to our results would imply a target of 0.84, although Ofgem does also average results from different types of studies. However, Economic Insights (2014) then allowed for additional operating environment factors not included in the econometric modelling which further reduced our target to 0.78 for the NSW DNSPs and 0.66 for ActewAGL. While difficult to compare, we believe our approach was likely more conservative than Ofgem's.

Some of the consultant reports confuse options available under productivity–based regulatory regimes (eg the former NZ thresholds regime and Ontario) with those available under building blocks. Consequently, some quotes from those jurisdictions supporting slower adjustment paths are taken out of context since opex can be adjusted more quickly than total inputs given the long–lived and relatively immobile nature of DNSP capital.

Conclusions

We have previously noted that it is prudent to adopt a conservative approach to choosing an appropriate benchmark for efficiency comparisons. Adopting a conservative approach allows for general limitations of the models with respect to the specification of outputs and inputs, data imperfections and other uncertainties. While we have not found any of the criticisms made of our 2014 economic benchmarking study warrant changes to be made to our underlying approach, we are of the view there may be a case for setting an even more conservative target than that used in Economic Insights (2014). This is particularly the case given that this is the first time economic benchmarking is being used as the primary basis for an Australian regulatory decision.

We are of the view that instead of using the customer weighted average of efficiency scores in the top quartile of possible scores (being those of CIT, PCR, SAP, UED and AND), a more conservative approach of using the lowest of the efficiency scores in the top quartile of possible scores is appropriate. This would make the average efficiency score of 0.77 achieved by AusNet Distribution the appropriate opex efficiency target (before allowance for additional operating environment factors). Being a predominantly rural DNSP also makes choosing AusNet Distribution's score a relatively conservative choice for the efficiency target. This change represents a 9 percentage point reduction in the opex efficiency target (from 0.86 to 0.77) and so is a generous additional allowance for any remaining modelling limitations, data imperfections and other uncertainties. It also represents a target of the 62nd percentile DNSP compared to Ofgem's target of the 75th percentile DNSP. Allowance for the additional operating environment factors not included in the econometric modelling then further reduces this target again (to between 0.62 and 0.69, depending on the DNSP).

Table A **NSW, ACT and Queensland DNSP opex efficiency scores, adjusted efficiency targets and base year opex adjustments to reach the target**

DNSP	*Efficiency score*	*Target allowing for additional OEFs*	*Reduction to base year opex*
Ausgrid	44.7%	68.7%	24.0%
Endeavour	59.3%	68.0%	0.0%
Essential Energy	54.9%	69.4%	26.4%
ActewAGL	39.9%	62.4%	32.8%
Energex	61.8%	65.6%	15.5%
Ergon Energy	48.2%	61.7%	10.7%

Incorporating the more conservative efficiency target and updated information on the impact of operating environment factors not included in the econometric models produces the base year opex reductions listed in table A for the NSW, ACT and Queensland DNSPs. Since Endeavour Energy is already exceeding its (conservatively set) target, no adjustment to its base year opex is required.

None of the DNSP consultant reports challenged our view that a zero opex partial productivity growth rate should be used in the rate of change formula used to form the forecast of future opex requirements. The case for adopting a zero forecast opex partial productivity growth rate is, in fact, further strengthened by the adoption of a more conservative opex efficiency target in calculating the adjustment required to base year opex. We, therefore, remain of the view that a zero forecast opex partial productivity growth rate is appropriate.

1 INTRODUCTION

The Australian Energy Regulator (AER) is currently reviewing the expenditure proposals of electricity distribution network service providers (DNSPs) in New South Wales (NSW) and the Australian Capital Territory (ACT) for the five year regulatory period commencing on 1 July 2014. It is also reviewing the expenditure proposals of electricity DNSPs in Queensland for the five year regulatory period commencing on 1 July 2015.

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

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

b) the productivity change to be applied to forecast opex for the NSW, ACT and Queensland DNSPs.

Economic Insights (2014) presented the results of our analysis for the NSW and ACT DNSPs based on a range of economic benchmarking techniques including stochastic frontier analysis (SFA), least squares econometrics (LSE) and opex multilateral partial factor productivity (MPFP) indexes. Downwards adjustments were recommended for the base year opex of each of the NSW and ACT DNSPs based on the results of the economic benchmarking analysis.

On 20 January 2015 the three NSW DNSPs (Ausgrid, Endeavour Energy and Essential Energy) and the ACT DNSP (ActewAGL) submitted their revised regulatory proposals. The DNSPs' revised proposals included a number of supporting consultants' reports critiquing the analysis in Economic Insights (2014). These included Pacific Economics Group Research (PEGR 2015), Frontier Economics (FE 2015a), Cambridge Economic Policy Associates (CEPA 2015a,b), Advisian (2015) and Huegin (2015a). A number of consultants' reports were also submitted by the Queensland DNSPs on 13 February2015 including FE (2015b), Huegin (2015b,c) and Synergies (2015a,b). And a previously published benchmarking study was submitted by the McKell Institute (2014).

The AER has requested Economic Insights to respond to four subject areas raised in the consultants' reports as follows:

- model specification
- modelling issues
- incorporation of overseas DNSP data, and
- the appropriate benchmark frontier.

Other subject areas raised in the consultants' reports, the DNSPs' proposals and submissions are addressed in AER (2015a,b,c,d,e), including Regulatory Information Notice (RIN) data issues.

Each of the four subject areas listed above are addressed in the following sections of this report. Updated recommendations for base year opex adjustments and the opex partial productivity growth rate to be included in opex forecasts are presented in section 5.

2 MODEL SPECIFICATION

The consultants' reports raise a range of issues surrounding the outputs included in the economic benchmarking models, the measurement of inputs and the extent of, measurement of and relative importance of operating environment factors.

2.1 DNSP output specification

In this section we review the following output specification issues raised in the DNSPs' consultants' reports:

- approach adopted to choosing the output specification used
- the use of functional outputs versus opex–specific outputs
- issues with regard to specific outputs, and
- alternative output models advanced.

After a detailed review of the output–related issues raised in the consultants' reports, we are of the view that no modifications are required to our economic benchmarking analysis.

2.1.1 Approach to choosing output specification

We set out the criteria and rationale for choosing outputs to be included in an economic benchmarking study in Economic Insights (2013c). Under building blocks regulation there is typically not a direct link between the revenue requirement the DNSP is allowed by the regulator and how the DNSP structures its prices. Rather, the regulator typically sets the revenue requirement based on the DNSP being expected to meet a range of performance standards (including reliability performance) and other deliverables (or functional outputs) required to meet the expenditure objectives set out in clauses 6.5.6(a) and 6.5.7(a) of the National Electricity Rules (NER). DNSPs then set prices that have to be consistent with broad regulatory pricing principles.

In the case of building blocks, it will be important to measure output (and hence efficiency) in a way that is broadly consistent with the output dimensions implicit in the setting of DNSP revenue requirements. The regulator will generally focus on functional outputs in setting the DNSP revenue requirements. These are the key dimensions of DNSP output valued (but not necessarily explicitly paid for) by customers.

It is also important to distinguish between outputs and operating environment variables as both will directly affect DNSP costs. The distinction we draw between outputs and operating environment variables is that outputs reflect services directly provided to customers whereas operating environment variables do not. It is important to note that economic benchmarking focuses on the outputs provided to and valued by customers whereas engineering studies tend to focus more on 'cost drivers' such as the quantity of assets the DNSP may have in place. With the latter there is a risk of delinking the efficiency assessment of DNSPs from the provision of outputs actually valued and demanded by customers (see Huegin 2015a, p.40, for an example of the engineering approach).

Economic Insights' approach to choosing the output specification has been structured and has involved widespread consultation with stakeholders. Contrary to PEGR's (2015, p.51) claim that it involved 'assuming at the outset that the scale index would include a particular set of scale variables', the approach to output measurement for economic benchmarking was the subject of two workshops with stakeholders during 2013. Prior to these workshops, we circulated Economic Insights (2013a,b) reports outlining the range of options available for measuring DNSP outputs, including many of the output measures used by the British regulator, Ofgem. There was general agreement that the measure of output to be used in economic benchmarking should cover 'functional' rather than 'billed' outputs given the building blocks form of regulation used in Australia.

As a result of a structured process based on consideration of the composition of functional outputs, practice adopted in previous economic benchmarking studies used in regulatory determinations and on extensive consultation with stakeholders, we developed an initial output specification covering: energy delivered, customer numbers, system capacity and reliability.

Energy delivered was included as a functional output because it is what customers consume directly, throughput data are relatively robust and it has been included in nearly all previous economic benchmarking studies. Customer numbers was included as a functional output because customers typically face some fixed charges on their energy distribution bills. These charges are related to activities the DNSP has to undertake regardless of the level of energy delivered which include connection related infrastructure (eg having more residential customers may require more local distribution transformers and low voltage mains) and customer calls.

System capacity is clearly required to meet expected demand for distribution services and to maintain the quality, reliability and security of supply and the distribution system itself and so is a key functional output. The initial measure of system capacity was the product of line length and transformation capacity (at the distribution transformer level to avoid double counting). Upon review in an economic benchmarking context, this measure of system capacity had limitations in comparing DNSPs of differing sizes given its non–linear nature which provided an artificial advantage to larger DNSPs. The specification used in PEGR (2013) of separately including line length and ratcheted maximum demand was preferred.

This specification also addressed a key concern of user groups and some DNSPs who argued for the inclusion of demand side functional outputs so that the DNSP is only given credit for network capacity actually used and not for capacity that may be installed but excess to users' current or reducing requirements (Economic Insights 2013c, pp.11–12). Including observed maximum demand instead of network capacity was argued to be a way of achieving this. However, this measure would fail to give the DNSP credit for capacity it had been required to provide to meet previous maximum demands which may have been higher than those currently observed. The ratcheted maximum demand variable thus acts as a proxy for the transformer capacity the DNSP has had to install to meet actual demand and which it has to maintain on an ongoing basis, given the long–lived and immobile nature of DNSP assets.

Finally, reliability is an important dimension of DNSP output and receives some prominence in the NER expenditure objectives where maintaining the reliability of both supply and the system itself are explicitly mentioned. Improving (or maintaining) reliability is generally an important part of the service directly provided to customers (although customers are not typically charged for reliability explicitly) and so reliability is another important functional output to consider including.

Instead of adopting the structured and consultative approach to output specification outlined above – which is similar to the approach adopted by PEGR's Dr Kaufmann in PEGR (2013) – PEGR (2015) argues instead that 'a sound specification is best achieved by an econometric opex study that considers numerous candidate scale variables'. We disagree with the suggested approach which could involve randomly trying 'numerous candidate scale variables'. This risks divorcing the economic benchmarking study from assessing the efficiency with which the key functional outputs valued by customers are supplied.

Huegin (2015a, p.24) states that 'dozens' of variables have been considered and 'abandoned' during the benchmarking process. A similar claim is made in Huegin (2015c, p.15). This is not correct. As noted above, we have followed a structured process based on consideration of the composition of functional outputs, practice adopted in previous economic benchmarking studies used in regulatory determinations and on extensive consultation with stakeholders. The manageable number of output variables (not 'dozens') have been discussed with stakeholders and narrowed down to the key functional output variables listed above plus four disaggregated customer number variables. Our memo of 25 July 2014[1] described the examination of different combinations of the shortlisted variables in productivity indexes. Some of these such as the use of disaggregated customer numbers variables clearly favoured one type of DNSP (eg large urban DNSPs in this case) and were not pursued as they provided no recognition of other key functional outputs. The five variable specification chosen covered all key DNSP functional outputs, was clearly not biased to favour of any particular type of DNSP and a similar specification had recently been used by regulators in New Zealand and Ontario in arriving at regulatory reset parameters. This specification thus met all necessary requirements and also had considerable regulatory precedent.

We also note that our preferred output specification is relatively robust to changes in the outputs included. For example, the addition or exclusion of energy delivered and reliability do not fundamentally change the efficiency results obtained. Synergies (2015a, p.10) listed this as a key requirement for the use of economic benchmarking in a regulatory context.

Huegin (2015a, p.30) states that it 'cannot find evidence of robust engineering review of the model and its mechanics in the draft decision'. This statement reflects a misunderstanding of economic benchmarking models which are 'tops–down' models based on key functional outputs and key inputs. They are distinct from the 'bottoms up', detailed engineering assessments which have been used in previous reviews. We do note, however, that the economic benchmarking models have benefitted from extensive input from DNSP staff – many of whom were from engineering and operational backgrounds – during the 2013 workshops. DNSPs have also had ample opportunity to comment on economic benchmarking specification issues over an extended period in response to the ACCC/AER (2012) issues paper, to the briefing papers for the 2013 workshops, to the progress report on the AER's benchmarking reporting, to the AER's draft guidelines and to the AER's information

[1] Economic Insights Memo titled 'DNSP MTFP Results', 25 July 2014, circulated to stakeholders.

requirements. Furthermore, one of the co–authors of our report is an electrical engineer who has served as Chief Engineer of a DNSP. The economic benchmarking has thus been undertaken drawing on engineering and DNSP operational knowledge and experience in conjunction with experience in the application of economic benchmarking methods.

2.1.2 Functional outputs versus opex–specific outputs

PEGR (2015, p.51) goes on to argue that, with regard to productivity measures, a different output index should be used for partial productivity measures compared to that used for total factor productivity (TFP) measures. We disagree with this and are not aware of any index–based economic benchmarking study that adopts this approach. Rather, adopting such an approach would break the internal consistency of the productivity index measures whereby the TFP index is effectively a weighted average of the relevant partial productivity indexes (where the weights are shares in total cost). The approach we have adopted to opex partial productivity measurement is the same as that used by PEGR's Dr Kaufmann in PEG (2004) and numerous other reports. The output specification used in PEGR (2013) is thus equally applicable for the economic benchmarking of opex using productivity index measures as it is in a TFP study.

PEGR (2015) appears to be confusing the approach adopted in productivity index measurement with that adopted in estimating an opex cost function where opex–specific output parameters are estimated and this is indeed what we do in our cost function analysis. However, the starting point for included outputs should be the same group of key functional outputs valued by customers.

2.1.3 Issues with specific outputs

PEGR (2015, p.51) claims that 'substation capacity is likely to be a more important opex cost driver than ratcheted peak demand'. Huegin (2015a, p.22) go further and claim 'the incremental opex costs of increasing ratcheted peak demand is negligible'. These comments fail to recognise the role of ratcheted peak demand as a proxy for the transformer and other capacity that has had to be installed by the DNSP in the past to meet actual peak demand. Contrary to the PEGR and Huegin claims, the combination of the ratcheted peak demand variable and the line length variable provide a good proxy for the quantity of assets the DNSP has to maintain and, thus, the amount of opex it has to expend to do this to meet customers' requirements. Note this may differ from the amount of installed capacity if the DNSP has previously installed capacity in excess of customers' needs. PEGR's concentration on a substation capacity variable appears to be influenced by the fact that substation capacity is the only transformer variable currently available in the US where there is also no consistent maximum demand data available.

PEGR (2015, p.52) also questions our method of inclusion of a reliability measure in the index–based output variable. Again, the key consideration here is what the relevant functional output is and it is the reliability actually experienced by customers. For reasons that are not clear, PEGR argues that inclusion of reliability favours 'urban utilities in Victoria and ACT since these utilities enjoy favourable reliability operating conditions'. No explanation is given of how these DNSPs differ from the NSW urban DNSPs which face broadly similar ‘reliability operating conditions’. Rather, it is likely that the Victorian and ACT DNSPs have focussed more on improving their reliability. Under our output specification, where minutes off–supply enters as a negative output, these DNSPs get credit for this by having their output reduced less compared to DNSPs with low levels of reliability, to the extent that consumers value reliability as reflected in the value of consumer reliability (VCR). However, we note that there is general consistency between the econometric results (which do not include reliability) and the opex MPFP results (which do include reliability as an output). We therefore do not agree with Synergies (2015b, p.12) that our econometric results are not sufficiently robust to base regulatory decisions on because they do not include reliability as an output.

2.1.4 Alternative output models

Huegin (2015a, p.35) claims ‘there has been insufficient consideration of alternative methods and model specifications’. However, as noted above, we have undertaken a structured process considering the composition of functional outputs, previous regulatory practice and an extensive consultation process with stakeholders involving 8 separate workshops conducted by the AER during 2013. These workshops focussed on model specification issues and alternative economic benchmarking methods. DNSPs were also kept informed of model development during 2014 in the lead–up to the completion of the AER’s initial benchmarking report.

Huegin (2015a, p.35) also claims that ‘the chosen model, its variables and the coefficients reflect a model that has poor explanatory power of the real operating costs of an electricity network’. A similar statement is made on page 40 of the report that the output variables are ‘not strongly representative of the drivers of operational expenditure’. These statements are not correct. As noted above, the specification of the model has been developed using a structured approach based on consideration of key functional outputs, previous regulatory studies and extensive consultation with DNSPs and other stakeholders. It has drawn on engineering and DNSP operational experience as well as economic benchmarking expertise. The econometric models all have high explanatory power and perform to a high statistical standard. Furthermore, the Huegin statement quoted above regarding a ‘negligible’ incremental cost of ratcheted peak demand reflects a misunderstanding of this variable’s role as a proxy for transformation capacity the DNSP has had to install to meet the highest past maximum peak demands. Similarly, the customer numbers variable will reflect the high fixed costs of operating a network and not just the marginal cost of connecting an extra customer. The output specification is consistent with current best practice in regulatory economic benchmarking studies.

Advisian (2015, p.53) argue that the model does not ‘reflect the underlying opex cost drivers of Australian electricity networks, which primarily relate to the volume, configuration and geographical distribution of networks’. Advisian goes on to argue that total installed zone and distribution transformer capacity should be used instead of ratcheted maximum demand to ‘recognise differences in security requirements, utilisation and load distribution across the network’. The difficulty with this approach of looking at a ‘cost driver’ of installed capacity rather the functional output of previous realised maximum demand is that it will be very slow to recognise DNSP inefficiency and gold plating. That is, if a DNSP continues to install capacity in excess of that required to meet customers' requirements then it will not be penalised under this approach because it may be deemed to be efficient at servicing the assets it continues to build but, at the same time, be increasingly inefficient in meeting customers' requirements. This was recognised by CEPA (2015a, p.24) which states 'RAB additions is not an ideal driver as it may mean that inefficient spending on capex is rewarded'. Despite this obvious limitation, CEPA (2015a) includes this variable in its regressions which will act as an inappropriate measure of output (rather than capturing opex/capex trade–offs as intended).

This shortcoming is further reflected in Advisian's (2015, p.2) support for revealed base year cost as a starting point because it represents the 'most appropriate and robust means of accounting for the differences in spatial density and all other network specific factors'. This approach would effectively attribute all differences in DNSP performance to operating environment differences and unnecessarily burden consumers with paying for the cost of a DNSP's ongoing inefficiency.

CEPA (2015a, p.26) presents the results of a number of econometric models run using modified Australian RIN data. These models all include only one primary output[2] – circuit length – and varying numbers of claimed operating environment factor variables. We do not consider these models to be either credible or reliable for a number of reasons. To adequately model the cost characteristics of DNSPs, we believe several output variables are required to adequately represent the functional outputs of a DNSP. Key candidates include energy delivered, customers served, line length, transformer capacity or actual demand and reliability.

Furthermore, the characteristics of the Australian data are such that the small amount of additional variation provided by time–series data for each DNSP render econometric estimation using only the Australian data relatively fraught and likely to produce sensitive results, as acknowledged by CEPA (2015b, p.22). Given the limited variation in the Australian RIN data, it is not surprising that including a relatively large number of claimed operating environment factor variables will tend to eliminate residual variation and lead to a smaller range of estimated efficiency scores. However, another significant problem is the inclusion of a share of 132kV lines in circuit length variable since only DNSPs in NSW, ACT and Queensland have lines of this voltage. This means this variable will pick up effects common to these states, including the costs of inefficiency. The impact of including this variable in the DNSPs' consultants' models can be seen from the estimates it implies of the DNSPs' per kilometre costs of operating high voltage lines. These estimates are several times higher than the DNSPs' reported per kilometre costs of operating these lines derived from regulatory accounts. This leads to the models significantly underestimating inefficiency for DNSPs in these states. Given these problems, we are of the view no weight can be placed on the CEPA results. The characteristics of the Australian data will be examined in further detail in section 3 and the CEPA models will be reviewed in more detail in section 3.10.

[2] Customer numbers are also effectively included in those models which include a customer density variable.

2.2 DNSP input specification

In this section we review the following input specification issues raised in the DNSPs' consultants' reports:

- the need to 'levelise' opex input prices, and
- consistency of disaggregated opex data.

After a detailed review of the input–related issues raised in the consultants' reports, we are of the view that no modifications are required to this aspect of our economic benchmarking analysis.

2.2.1 'Levelisation' of opex input prices

PEGR (2015, p.52 and p.55) criticise the opex input price specification used in Economic Insights (2014) for not 'levelising' prices across the included Australian DNSPs. By not 'levelising' prices PEGR means that a common opex price index is used for all the DNSPs and no allowance is made for possible different price levels across DNSPs. We have considered this topic and do not believe it is a significant issue. With the advent of the mining boom in Australia there has been a high demand for field staff of the type employed by DNSPs right across Australia over the last several years (Deloitte Access Economics 2014a, p.30). This has had the effect of greatly reducing any pre–existing labour price differences for field staff across the country. Consequently, we are of the view that using a common opex price index across the Australian DNSPs is a reasonable assumption for the period used in the study of 2006 onwards.

We also have concerns with the potential incentive effects of using different price levels for different DNSPs. This would be akin to allowing a 'cost pass through' and reduce the incentive for DNSPs to negotiate the best prices with employees, contractors and other suppliers.

There is furthermore inadequate information available to allow fine–tuning of the available price indexes to account for regional differences in price levels, should they exist. This is illustrated by the very indirect approach PEGR (2014) adopted to attempt to 'levelise' Australian DNSP opex prices. As noted by PEGR (2014, p.11), while both the Australian Bureau of Statistics (ABS) and the national statistical agency in the US produce national level Electricity, gas, water and waste (EGWW) sector Wages price indexes (WPI), neither agency publishes these indexes at the state level. PEGR (2014) attempts to introduce labour price level differences using information on gross weekly personal income by wide bracket range from the 2011 ABS Census data. These data use a completely different basis for calculating labour prices than the WPI – for instance, gross personal income includes differences in hours worked, labour quality and overtime rates whereas the WPI is the price for a standard basket of labour services. Use of the gross weekly personal income data to introduce differences in levels of the WPI across states is thus likely to introduce a number of sources of error. It would also be less transparent.

PEGR (2014) further compounds these sources of error by using differences in movements between the all industries WPIs at the state and national levels to construct estimated state level EGWW WPI growth rates. Given the demand for field staff with engineering skills generated by the mining boom, there is no reason to expect movements in the EGWW WPI in each state to mirror movements in that state's all industries WPI. PEGR (2014) then further attempts to introduce variation in the materials and services component of opex by assuming that 25 per cent of materials and services are made of labour costs and should be 'levelised' using a similar process to that used for the labour component of opex.

We believe PEGR's attempts to introduce differences in opex price levels and price growth rates across DNSPs is misguided and likely to introduce a number of sources of error which then have the potential to compound through time. Rather, assuming a common annual opex price level and growth rate across DNSPs as done in Economic Insights (2014) provides a more accurate and unbiased approach, particularly given the influence of the mining boom on Australian labour prices in recent years.

PEGR (2015, p.55) also criticises the opex price index used in Economic Insights (2014) for not using DNSP–specific weights for the labour, materials and services components. Rather, our study used the opex cost shares reported in PEG (2004) of 62 per cent for labour and an aggregate of 38 per cent spread across five different types of materials and services (with a different Producer price index used for each of the five components). Given the high degree of contracting out used in Australian DNSPs, the information required to construct DNSP–specific opex component weights is not readily available. We note that PEGR (2014) adopted the same approach we have used regarding opex price component weights, as did the PEGR (2013) study for the Ontario Energy Board. This criticism is, therefore, not relevant.

2.2.2 Consistency of disaggregated opex data

FE (2015a, p.xiv) criticise the RIN data for not having vegetation management expenses reported for all DNSPs. This reflects FE's lack of familiarity with the evolution of the Australian DNSP data. The Australian DNSPs have individual categorisation of opex in their Annual Reporting Requirements based on legacy state reporting systems which existed prior to the AER taking over regulation. The RIN opex data are consistently reported at the aggregate opex level, which is what is used in economic benchmarking. Any scope for differences in coverage of activities between states is removed by utilising the narrow coverage of network services opex which concentrates on poles and wires–related activities.

DNSPs were asked to provide disaggregation of opex for the EBRIN based on their Annual Reporting Requirements for the relevant regulatory year[3]. It is, therefore, not surprising that different categories are reported by different DNSPs and there is no consistent 'vegetation management' category. Categorisation of opex was requested to allow consistency checking for each DNSP's data, and not with the intention of undertaking economic benchmarking at a disaggregated opex level. Since the disaggregated opex data the RIN data were being cross–checked against were those previously reported to state regulators in accordance with their audit and sign–off requirements, the disaggregated RIN data needed to be presented on the same basis. This process provided the AER with greater confidence that the RIN data were

[3] The AER undertook a separate Category Analysis RIN data collection process aimed at obtaining consistent disaggregated information.

accurate. The comparisons with the procedures adopted by the British regulator, Ofgem, and its evolution are, therefore, not relevant in the context of the evolution of regulatory reporting in Australia.

Although it does not relate to economic benchmarking of opex, PEGR (2015, p.53) criticise the use of physical proxies for the capital input quantity in Economic Insights' (2014) Multilateral TFP indexes on the grounds that 'it does not consider important dimensions of capital cost management'. This criticism is unfounded because physical quantity measures provide the most accurate representation of the assets the DNSP actually has on the ground and their contribution to the production process. Differences in the cost of assets (eg running old assets for longer before replacement) are reflected in differences in the annual user cost of capital in Economic Insights (2014). This will affect the weight given to capital in forming the Multilateral TFP index and the total cost of the DNSP in total cost comparisons. These cost differences should not be confused with differences in the quantity of capital input used given the relatively one–hoss–shay characteristics of assets in the industry, as PEGR (2015) appears to do.

Finally, we note that PWC (2015) have criticised the use of the Regulated Asset Base (RAB) in benchmarking measures. The RAB is not used in our preferred Cobb Douglas SFA opex cost function nor our other econometric opex cost function models. And it only has a very indirect role in our opex MPFP indexes in the estimation of output cost shares. The impact of the RAB on our opex MPFP results is thus not likely to be material and it has no impact on our preferred econometric efficiency measures.

2.3 DNSP operating environment factors

In this section we review the operating environment factor issues raised in the DNSPs' consultants' reports:

- the extent and adequacy of operating environment factors examined
- across–country operating environment differences
- customer density measures
- capital intensiveness differences, and
- methods of allowing for operating environment differences.

After a detailed review of the operating environment factor–related issues raised in the consultants' reports, we are of the view that the approach we have used to incorporate operating environment factors in our economic benchmarking analysis is sound. This involves incorporating network density differences and undergrounding differences directly in our econometric models and making ex post allowance for other operating environment differences identified as being material among the Australian DNSPs. Some minor adjustments will be made to incorporate updated and more detailed information now available on operating environment factors not explicitly included in the opex cost function models.

2.3.1 Extent and adequacy of operating environment factors examined

PEGR (2015, p.51) argues that 'productivity indexes do not account for the cost impacts of miscellaneous Z [operating environment factor] variables directly'. As noted in Economic Insights (2014, p.14), however, our index number analysis allows for three types of operating environment factors: density differences, undergrounding and system complexity. By including customer numbers, network length, energy throughput and ratcheted peak demand as outputs we effectively allow for differences in customer density (customers per line/cable kilometre), energy density (energy delivered per customer) and demand densities (peak demand per customer and peak demand per line/cable kilometre) in the analysis. This is because a DNSP with a low customer density, for example, will receive output credit for having a longer line and cable length than an otherwise similar–sized DNSP that has high customer density and, hence, shorter line length. By including these important density impacts in our output specification, we allow for many of the operating environment factor effects that have been raised in the five DNSP consultants' reports.

The second operating environment factor we allow for in our econometric modelling is undergrounding by including an operating environment variable for the proportion of underground cables in total line and cable length in our cost functions. Synergies (2015b, p.5) notes that Ergon Energy has the lowest proportion of underground cables in the sample – the effect of this on opex will thus be captured by our econometric models.

Furthermore, by excluding the first stage of two stage transformation at the zone substation level from our productivity analysis we put DNSPs on a more comparable footing with regard to system complexity. In our econometric analysis, we make ex post allowance for this effect by adjusting for the higher cost of maintaining subtransmission lines before forming our recommendations. We, thus, do already allow for this operating environment factor which PEGR (2015) argues to be important.

To test the adequacy of our allowance for operating environment factors, we performed a second stage regression analysis of our opex MPFP scores. We regressed our opex MPFP indexes against the following 7 operating environment factors:

- customer numbers (to check whether additional scale effects are significant)
- customer, energy and demand network densities
- the share of underground cable length in total circuit kilometres
- the share of single stage transformation capacity in single stage plus the second stage of two stage transformation capacity at the zone substation level, and
- system average interruption duration index (SAIDI).

The results of the second stage regression analysis are reproduced in table 2.1. None of these factors were individually significant indicating that no additional adjustment for operating environment factors beyond those already included in the model was required. PEGR (2015, p.52) questions our results on the grounds that the three density measures have pair–wise correlations in the range of 0.90 to 0.96 and so multicollinearity in the regression may be masking more significant impacts. PEGR goes on to state that we 'should have tested the joint significance of the parameter estimates'. CEPA (2015a, p.23) also notes a likely high correlation of the variables included in the second stage regression analysis and questions its merit.

In response to these comments we have undertaken a joint test of the significance of the included operating environment factor variables using an F test[4]. The F–test value for the joint insignificance of the seven included operating environment factor variables is 1.21. This compares to an F–test critical value with 7 and 95 degrees of freedom at the 1 per cent level of 2.1 indicating that the seven variables are jointly quite insignificant, as well as individually insignificant. We therefore reject the claims by PEGR, CEPA and the other consultant reports that our model does not allow sufficiently for operating environment differences.

Table 2.1 **DNSP opex MPFP second stage regression results**

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

PEGR (2015, pp.52, 54) and Huegin (2015a, p.47) also argue that our analysis should have included other operating environment variables such as climate and forestation. It is not possible, at this stage, to adequately include operating environment factor variables for these effects in our econometric model. Although the AER has commenced collecting information on which weather stations are in each DNSP's service area and which ones the DNSPs view as being material, and on the number of trees per span, this information is not available for the whole period and is not yet at a sufficiently developed stage. We note that most Australian DNSPs include a range of climatic conditions and forestation conditions within their service area. While we view these effects as being less important than the operating environment factors included in the second stage regression analysis such as those relating to network density and system structure, they are considered as part of our ex post adjustment for additional operating environment factors based on the detailed analysis in AER (2015a,b,c,d,e).

We also note that the AER (2014a,b,c,d) reviewed a number of related operating environment factors such as prevalence of natural disasters and corrosive environments and the relevant differential effects were included in the respective input allowances in Economic Insights (2014), were the top quartile DNSPs operating under the same conditions as the NSW and ACT DNSPs. Since only a limited number of operating environment factor variables can be included in economic benchmarking analyses, we consider we have included the most

[4] An F test is a statistical test that allows one to test whether a group of variables in a regression jointly make a significant contribution to explaining the variation in the regression's dependent variable. The more commonly reported t–statistic, on the other hand, only allows the contribution of an individual variable to be tested.

important variables directly – and the second stage regression analysis indicates that no additional allowance for these variables is required – and we have included other relevant variables in the input allowance allowed between the top quartile DNSPs and the NSW and ACT DNSPs. This analysis is updated in the current report based on the updated and more detailed analysis in AER (2015a,b,c,d,e) and is extended to include the Queensland DNSPs.

FE (2015a, p.98) criticised our allowance of 10 per cent for 'factors not controlled for in the modelling' as being 'incomplete, inadequate and arbitrary'. It is not clear whether FE is referring here to our adoption of the weighted average of the DNSPs in the top quartile of possible efficiency scores instead of the frontier performer's efficiency score (which reduces the initial target by 9 percentage points) or our allowance of 10 per cent additional input use by the most efficient DNSPs for operating environment factors not explicitly included in the SFA model. Either way, we reject this criticism. The adoption of a more conservative target rather than the frontier DNSP's efficiency score is standard practice among regulators using economic benchmarking and is broadly similar to the approach adopted by Ofgem. And the additional 10 per cent input allowance used in calculating adjusted targets for the NSW DNSPs was based on a detailed and extensive assessment of the relative importance of 33 separate operating environment factors identified by DNSPs, the AER and other stakeholders. The AER's detailed analysis was presented in section A5 of Attachment 7 to each of the NSW and ACT DNSPs' draft decisions. In this report the DNSP–specific input margins allowed are updated based on the more detailed analysis in AER (2015a,b,c,d) and extended to the Queensland DNSPs based on AER (2015e). Among other things, a more detailed approach is now adopted to allowing for operating environment factors having a small effect.

In its draft decision, the AER found no grounds for allowing an additional margin for most of the examined operating environment factors. However, four factors were found to have a material impact as follows:

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

The first three were found to put the most efficient firms at an advantage relative to the NSW and ACT DNSPs while the fourth was found to put them at a disadvantage relative to the NSW DNSPs. Based on the AER's detailed analysis, a 10 per cent margin for the NSW DNSPs and a 30 per cent margin for the ACT DNSP were included to cover these factors. The FE criticism is, therefore, not accurate. In this report we update the size of the margins allowed in light of subsequent more detailed analysis and more up–to–date information, including that from the DNSPs' revised regulatory proposals, and extend the analysis to include the Queensland DNSPs.

CEPA (2015b, pp.16–18) makes a similar criticism to that of FE discussed above. For the same reasons as listed above, we also reject the CEPA criticism.

And Synergies (2015b, p.37) claims:

> 'The models developed by Economic Insights include few environmental factors, taking no account of, inter alia, climate, terrain, vegetation, bush fire mitigation, age of assets, network complexity and design, all of which can be expected to influence operating costs.'

This statement fails to recognise that all of the factors listed by Synergies are considered as part of our ex post adjustment for additional operating environment differences between the DNSPs being reviewed and those forming the target top quartile group. The Synergies statement is therefore incorrect.

2.3.2 Across–country operating environment differences

CEPA argues that insufficient allowance has been made for operating environment differences between Australian, New Zealand and Ontario DNSPs. Because we are not doing international benchmarking but rather including overseas data to help improve the precision of parameter estimates, we include dummy variables for the overseas jurisdictions to pick up a range of factors, including operating environment differences across countries. CEPA (2015b, p.17) argues that while our approach will control for level differences across countries, it does not control for 'cost relationship differences' (ie differences in exogenous variable coefficients). For there to be significant differences in these coefficients across countries would require there to be significant differences in the fundamental technology used in electricity distribution across countries. CEPA provide no evidence to support there being such a fundamental difference in technologies used. The three countries all use poles, wires and cables to distribute electricity to customers. Voltage differences and differences in the degree of undergrounding are unlikely, in our view, to be sufficient to change these underlying relationships between individual functional outputs and opex.

Operating environment differences between countries may, however, lead to differences in opex levels, all else equal. An example of this would be Ontario's considerably harsher winter conditions which require more to be spent on clearing lines of ice and snow and keeping access to customers open. This would be likely to increase opex for an Ontario DNSP that was otherwise of similar size to an Australian DNSP. And we do indeed find that the country dummy variable for Ontario indicates that Ontario opex is around 15 per cent higher, all else equal – while part of this may be explained by differences in coverage and reporting, we would expect the major part to reflect the higher cost of operating in Ontario's harsher climate.

We also note that the relative lack of time–series variation in the Australian data (which will be illustrated further in the following section) would make allowance for possible variation in parameter coefficients problematic and unreliable. We are therefore of the view that allowance for differences in cost levels across countries is the most appropriate method of allowing for differences in operating environment conditions across countries.

Synergies (2015a, pp.34–37) compare the range of efficiency scores reported in Economic Insights (2014) with those obtained in a FE (2013) study undertaken for Ofgem and criticise our range of efficiency scores as being 'excessive' compared to that found in the UK study. However, the Synergies comparison uses our model scores before adjustment is made for operating environment factors not explicitly included in the econometric models. The Synergies comparison is thus not comparing like–with–like and it is the narrower range of efficiency scores after these adjustments are made that forms the basis for our recommended adjustments to base year opex. It is furthermore not comparing like–with–like since the FE (2013) study analysed so–called 'totex' (the sum of opex and capex) rather than opex.

2.3.3 Customer density measures

CEPA (2015a, p.24), Advisian (2015, pp.29–39) and Huegin (2015a, pp.45–46) argue that a measure of customer density taken as customers per kilometre of line fails to adequately capture the cost disadvantages faced by rural networks. They argue that the DNSP's service area is a better guide to the requirement for the number of separate depots the DNSP has to maintain to manage the constraints imposed by travel times from any particular depot. While we acknowledge there are multiple dimensions of network density – including more than one concept of customer density – we are not convinced that the proposed alternative customer density measure of customers per square kilometre is a sufficiently robust measure to be used in an economic benchmarking study. This is particularly the case in Australia where many outback areas are larger than some European countries while being very sparsely populated. And, it remains the case that DNSP decision–making and operational activities are based on the length of line the DNSP has deployed, not its service area.

The difficulty with specifying customer density in terms of customers per square kilometre in Australia is the arbitrariness involved in specifying exactly what constitutes the area 'serviced' given the sparseness with which outback areas are populated. Consider the Northern Territory as an example where the DSNP services Darwin and Katherine (with a line between the two) on its main network and then there are outposts around the Territory serviced by isolated, diesel generator–based systems. It is problematic to determine the DNSP's service area in this case. It is clearly not the whole Northern Territory. The network service area could include Darwin and Katherine plus an area of, say, 50 kilometres either side of the line connecting them but this would be entirely arbitrary.

Similar issues apply to large parts of Queensland, NSW, South Australia and Victoria. Indeed, data provided in response to information requests regarding CEPA (2015a,b) showed that an area of 1.7 million square kilometres had been used as Ergon Energy's service area when the total area of Queensland as a whole is only is only 1.72 million square kilometres (Geoscience Australia 2015). The service area CEPA (2015a,b) has used therefore significantly overstates Ergon Energy's actual service area. In our view the line length based customer density measure used in our study is the only objective and verifiable measure available and captures the most important dimensions of customer location affecting DNSP costs.

We disagree with the Huegin (2015a, p.46) statement that our analysis 'fails to recognise that electricity is transported further across the state to more premises in NSW and QLD'. Examination of figure 8 in AER (2014e) indicates that Ergon Energy and Essential Energy have by far the lowest customer densities in terms of customers per kilometre while the predominantly urban DNSPs of Ausgrid, Endeavour Energy and Energex have much lower customers per kilometre values than the purely urban networks of CitiPower, Jemena and

United Energy. And the other rural DNSPs in the sample (such as Powercor and AusNet Distribution) have densities between those of the remote area DNSPs and the mixed urban/rural networks. Since customer density is captured in our output specification which includes both customer numbers and line length, networks with low customer density receive credit for their relatively longer line lengths compared to otherwise similar networks. We note that there is no correlation between customer density and either our opex efficiency scores nor our MTFP scores. We, therefore, reject the Huegin proposition that differences in the product of dwelling numbers and distance determine our state–wide MTFP rankings. And we reject the analogous claim by FE (2015b, p.19) regarding a relationship between opex efficiency rankings and customer density which is clearly contradicted by FE's (2015b, p.18) own table 2.

We also note that the benchmarking analysis has received support from within the industry. The Energy Supply Association of Australia (ESAA 2014), for example, states:

> 'the benchmarking is a thorough piece of analysis. On many comparisons, the same businesses come out at or near the efficiency frontier … while another group of businesses are well behind this frontier. It is hard to avoid the conclusion that some businesses could be run much more efficiently …. One example is the total factor productivity comparison in the benchmarking report'.

2.3.4 Capital intensiveness differences

Huegin (2015a, pp.42–44) argues that we have made inadequate allowance for the 'capacity intensity' of DNSPs in our modelling. That is, Huegin claims that DNSPs that have 132 kV lines appear to be inefficient in our analysis because costs associated with high voltage lines are not sufficiently recognised. Huegin firstly argues that our decision to split overhead lines and underground cables into distribution (below 33 kV) and subtransmission (33 kV and above) components does not 'mitigate' this issue in the MTFP analysis. This is incorrect. By making this change we explicitly recognise that although high voltage lines can contribute a significant proportion of overall MVAkms, they represent a much smaller proportion of overall lines and cables annual user costs. This has the effect of significantly reducing the weight given to the high voltage lines in measuring DNSP MTFP levels. Despite this change, changes in overall MTFP rankings were relatively minor, indicating that the issue raised by Huegin is not material.

As well as not being a significant driver of the MTFP results, it should be recognised that the MTFP results themselves are not relevant to the opex modelling and opex recommendations. What is relevant to the opex modelling and recommendations is the potentially higher opex per kilometre of operating high voltage subtransmission lines compared to lower voltage lines. Based on the AER's detailed examination of operating environment factors referred to above, we recognised the higher opex requirement of very high voltage lines as part of the input margin applied to the top quartile Victorian and South Australian DNSPs in recognition of the fact that they do not operate with the very high voltage subtransmission lines found in NSW and the ACT. In fact, based on Ausgrid's Regulatory Accounts, we recognise that the per kilometre opex requirement for lines of 66 kV and above is approximately twice that of distribution lines (AER 2014a, p.7–133). This factor is applied to all subtransmission lines in forming our ex post adjustment for operating environment factors not explicitly included in our econometric models. We therefore reject the Huegin assertion that inadequate allowance has been made for 'capacity intensity'.

Huegin (2015a, pp.48–50) argues that our economic benchmarking results penalise DNSPs 'that have a more opex intensive network and business than capex intensive'. This is not correct. Figure A28 in AER (2014e) shows opex as a proportion of totex (where totex is the sum of opex and capex) for the Australian DNSPs for the average of the period 2006 to 2013. Ausgrid and Energex have the lowest opex shares of totex at around 30 per cent, followed by CitiPower and Endeavour Energy at around 31 per cent and Essential Energy at around 34 per cent. The other four DNSPs that are top quartile opex efficiency performers all have opex shares of totex of between 38 and 48 per cent. The NSW DNSPs are thus all less 'opex intensive' (relative to totex) than all but one of the five top quartile opex efficiency performers and that DNSP has opex intensive similar to Ausgrid and Endeavour Energy. The Australian DNSP with the highest historical 'opex intensiveness' at around 53 per cent is ActewAGL and we made a generous allowance for ActewAGL's different capitalisation policy as part of the input margin applied to the top quartile DNSPs in assessing ActewAGL's historical opex efficiency in Economic Insights (2014)[5]. Thus, within the Australian DNSPs, Huegin's argument clearly does not hold water.

And, it is not valid to compare the Australian and overseas DNSPs' opex intensiveness with the spread of efficiency scores derived from the econometric models. This is because the models are not designed to undertake international benchmarking as such. Because we are using the overseas data to improve the precision of parameter estimates, we include dummy variables for the overseas jurisdictions which allow for systematic differences in opex coverage and reporting. No conclusions can therefore be drawn regarding differences in opex intensity between Australian and overseas DNSPs and relative opex efficiency of Australian DNSPs compared to the overseas DNSPs.

We also note that Huegin (2015a, p.48) argues that DNSPs that achieve high opex efficiency scores would also be likely to be efficient capex efficiency performers. Huegin present a graph comparing opex MPFP with capital MPFP but then try to draw conclusions regarding capex and opex levels. This confuses capital efficiency (which includes all the DNSP's existing assets and is a stock concept) with capex (which only includes assets installed in the current year and which is a gross flow concept). It also fails to recognise that the capital input quantity measure used in Economic Insights (2014) is based on an aggregation of physical measures whereas capex is a dollar value–based measure. We also note that there is no reason to expect a DNSP which is an efficient opex performer to also be an efficient capital performer. This is because capital efficiency is influenced by a much wider range of factors and the long–lived nature of DNSP assets means capital efficiency levels are usually slower to change than opex efficiency levels. The Huegin analysis is, therefore, misguided for a number of reasons.

[5] In this report we consider subsequent information from ActewAGL's revised regulatory proposal in forming the ex post adjustment for additional operating environment factors for ActewAGL.

2.3.5 Methods of allowing for operating environment differences

Huegin (2015a, pp.51–52) argue that our allowance for operating environment factors affecting the NSW DNSPs is inadequate and the adjustment itself is applied inappropriately. As noted above, the Economic Insights (2014) allowance of an input margin on the target DNSP efficiency score was based on detailed and extensive analysis by the AER (2014a,b,c,d, section A5). It includes recognition of the considerably higher opex cost associated with very high voltage lines and a generous allowance for factors that were identified as not being individually material but which may be collectively material.

Huegin goes on to mount an incorrect argument regarding the way we apply the input margin. Firstly, Huegin argue that it is not correct to adjust 'the frontier' as this is 'a number with no absolute meaning'. Huegin is incorrect on a number of grounds here. We do not adjust the frontier as such but rather the weighted average efficiency score of the target DNSPs which are those with efficiency scores in the top quartile of possible scores. To argue this is a number 'with no absolute meaning' reflects a lack of understanding of economic benchmarking concepts. It is common practice for regulators to moderate adjustments based on economic benchmarking. Most aim to be conservative but moderation is done in different ways by different regulators and in different applications. This generally involves not setting an efficiency target of 100 per cent but rather a lower score such as the weighted average of efficiency scores of DNSPs with scores in the top quartile of possible scores or, say, the efficiency score of the 75th percentile firm.

Huegin (2015a, p.52; 2015c, p.17) also appears to argue that the input margin we have applied to the opex of the target DNSP in arriving at the target efficiency score for the DNSP being reviewed adjusted for additional operating environment factors it faces is calculated incorrectly. Huegin appears to argue that the input margin should be calculated as the ratio of the dollar amount of the extra costs of the DNSP being reviewed associated with its less advantageous operating environment relative to the target DNSP's opex. Instead, in calculating the adjusted efficiency target, we have applied a percentage increase to the target DNSP's opex based on the best information available on the efficient cost of operating under the additional operating environment condition. The approach suggested by Huegin is incorrect as it would overestimate the input margin for the target DNSP and hence underestimate the efficiency target for the DNSP being reviewed. Using the Huegin approach would impose a further unnecessary inefficient cost burden on the consumers of the DNSP being reviewed.

CEPA (2015b, p.18) also argues that our approach of adjusting for identified operating environment factors not explicitly included in the econometric models is 'not in line with the approach used by Ofgem'. Given the purpose of the study, adjustment for operating environment factors can be done either as part of the modelling (assuming sufficient information is available for all included DNSPs across all jurisdictions) or, where data for particular variables are not universally and consistently available across countries but are available for Australian DNSPs, it can be done as an adjustment when comparing Australian DNSP performance to the most efficient Australian firms. We adopt a combination of both approaches.

It should also be noted that degrees of freedom considerations and correlation among exogenous variables in regressions limit the number of operating environment variables that can usefully be included directly in economic benchmarking models, making the use of subsequent adjustment the only way of allowing a fuller treatment of operating environment factors. Thus, while our approach may be different to that adopted by Ofgem (although we note that Ofgem does also make additional adjustments for some DNSPs as will be discussed later in this report), it is a completely valid approach and one that makes optimal use of the information available to us. By adopting the two step approach our study includes allowance for the impact of many more operating environment factors than have earlier economic benchmarking studies and the alternative models advanced by the DNSPs' consultants.

We also note that CEPA (2015a,b) do not acknowledge the adjustments that we have made to the opex data before estimation – these include removing feed–in tariffs, costs associated with metering services, public lighting services, etc. And broadly similar two stage adjustment approaches are adopted by overseas regulators as illustrated by FE (2015b, section 5). In particular, Ofgem does make ex post adjustments by using DNSP–specific 'special factors' for some DNSPs and the Norwegian regulator (NVE) makes post modelling adjustments using second stage regressions before arriving at its decision. We note that FE (2015b, p.77) arrive at the following conclusion:

> 'AER may need to adopt a hybrid of the Ofgem approach (which involves more direct and bespoke scrutiny of the companies), but taking account of a broader range of factors, as does NVE.'

This is precisely consistent with the approach adopted in Economic Insights (2014) and AER (2014a,b,c,d).

Finally, as will be discussed in section 3.5, the challenge with economic benchmarking for regulatory purposes is to determine how much of the unexplained residual from modelling to allocate to DSNP inefficiency and how much to latent (or unobservable) heterogeneity among the included DNSPs. Assuming all is inefficiency likely provides an upper bound for base year cost adjustments while assuming it is due to latent heterogeneity will provide a lower bound for base year adjustments. The former may produce too large an adjustment while the latter will almost certainly produce too low an adjustment. Our use of the two step process for calculating the overall adjustment for operating environment differences provides a means of reaching the most appropriate point within this range of possible base year adjustments.

3 MODELLING ISSUES

In this section we respond to the following issues raised in the DNSPs' consultants' reports:

- reasons for including overseas data
- approach to including overseas data
- Australian DNSP peers
- methodology issues
- latent heterogeneity
- claimed correlation between opex and capital MPFPs
- use of data envelopment analysis
- requirements for regulatory benchmarking
- comparing Ontario results, and
- the consultants' alternative benchmarking models.

After a detailed review of the modelling issues raised in the consultants' reports, we are of the view that no modifications are required to the approach we have adopted in our economic benchmarking analysis.

3.1 Reasons for including overseas data

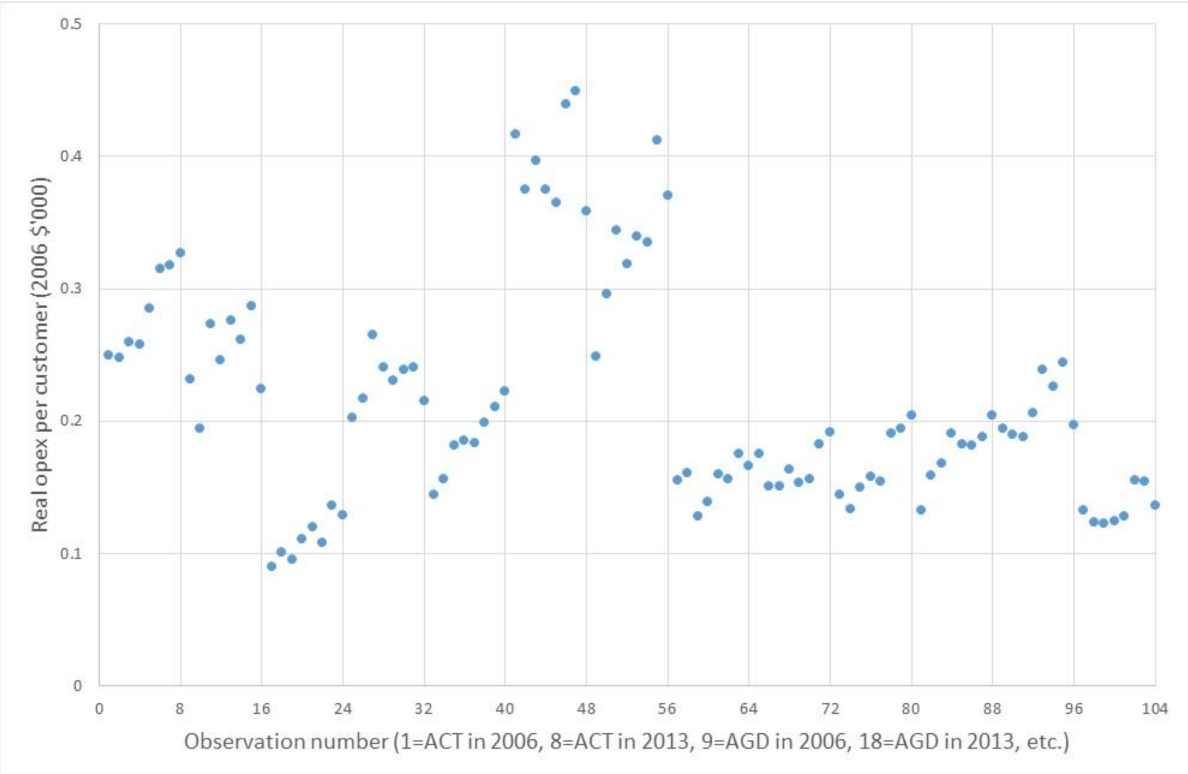
At the outset it is important to note that the purpose of the modelling contained in Economic Insights (2014) was <u>not</u> to undertake international benchmarking. Rather, the objective was to supplement the observations available to improve the precision with which key parameters can be estimated. More precise parameter estimates increase confidence in model accuracy and allow more accurate accounting for output change in forecasts of future opex productivity growth. This objective has determined the modelling strategy adopted. Several of the DNSPs' consultants' reports have misinterpreted the purpose of the study and made comments regarding comparisons of results across countries which are incorrect and incompatible with the modelling approach adopted. Before addressing these comments, we first review the characteristics of the Australian DNSP RIN data and the results of models using only the Australian data.

3.1.1 Characteristics of the Australian DNSP RIN data

As noted in Economic Insights (2014, p.28), after a careful analysis of the economic benchmarking RIN data we concluded that there was insufficient variation in the DNSP RIN data set to allow us to reliably estimate even a simple version of an opex cost function model (eg a Cobb–Douglas LSE model with three output variables and two operating environment variables) using only the Australian data. A sample data plot is reproduced in figure 3.1 and provides an illustration of the limitations of the data from an econometric perspective. In essence, the time series pattern of the data is quite similar across the 13 DNSPs. Hence, in this case, there is little additional data variation supplied by moving from a cross–sectional data set of 13 observations to a panel data set of 104 observations. As a consequence, while the Australian DNSP RIN data are perfectly capable of supporting index number–based economic benchmarking methods, more complex econometric models require a larger data set with more than what is essentially 13 different observations to allow estimation with a high degree of confidence. Unless the RIN data are supplemented with additional cross–sectional observations, the 'implicit' degrees of freedom would be near zero or even negative in some cases.

The impact of this characteristic of the RIN data can be further illustrated by comparing the parameter estimates of a simple cost function using the full RIN database with 104 observations with the parameter estimates of a similar regression using only the 13 cross–sectional observations obtained by averaging the 8 years of data for each DNSP. The estimates are presented in table 3.1.

Figure 3.1 **Real Opex per Customer for Australian DNSPs, 2006–2013**



The coefficients for the output and operating environment factor parameters can be seen to be very similar in table 3.1 indicating that little additional explanatory power is obtained from including additional time–series data. Hence, there are likely to be inadequate degrees of freedom in the Australian panel data to form robust parameter estimates. This could manifest itself as a lack of significance for the included output parameters or, alternatively, as spurious precision for additional operating environment factors if included as the limited variation is quickly (but inappropriately) explained (as is the case in CEPA 2015a,b) – see Halcoussis (2005, Cht13) for a discussion of the misleading results small samples are prone to producing. Rather, additional cross–sectional observations are required to introduce more variation into the data and obtain more robust estimates.

Table 3.1 **Opex cost function estimates using full RIN sample and DNSP averages**

Parameter	Full RIN sample	RIN DNSP averages sample
Log(customer numbers)	0.4908	0.5089
Log(circuit length)	0.4118	0.4173
Log(ratcheted max demand)	0.0826	0.0527
Log(share of underground)	0.1818	0.1921
Log(time)	0.0227	
Constant	–33.4415	12.0370
R squared	0.8764	0.8900
No of observations	104	13

The difficulties of using only the RIN data for econometric studies is noted in two of the DNSPs' consultants' reports. PEGR (2015, p.37) observe:

> 'In Australia, standardized data are available for only thirteen distributors for the 2006–2013 sample period. A sample with only 104 observations greatly limits the sophistication of econometric cost models that can be developed: it may be impossible to obtain accurate estimates of the cost impact of certain business conditions, or to properly model scale and scope economies.'

Based on using the RIN data only, CEPA (2015a, p.24) also observes:

> 'I have been unable to estimate SFA models on a robust and consistent basis. In most cases the SFA models will not converge and results are not produced. In cases where the models do converge a small change to the specification (i.e. additional variable included) would result in non–convergence, thus indicating the lack of robustness in the models.'

CEPA (2015b, p.22) also notes 'I found that the modelling was very sensitive to the inclusion of operating environment variables'.

Furthermore, given the characteristics of the RIN data, it is simply not possible to compare model 'slope' coefficients across the three jurisdictions with any degree of confidence (as CEPA 2015a, p.ix, and FE 2015a, p.24, claim to do).

This is also the reason that FE (2015a, p.75) obtains opex efficiency scores of 100 per cent for 10 of the 13 Australian DNSPs in its data envelopment analysis (DEA) application – there is simply not enough cross–sectional observations to sensibly support this technique using only the RIN data. It is, therefore, rather perplexing that FE (2015a, p.101) goes on to recommend that the AER 'discard the international data from its sample', 'rely only on Australian data' and 'rely on most recent evidence from 2013'. This again reflects FE's apparent lack of familiarity with the Australian electricity distribution industry.

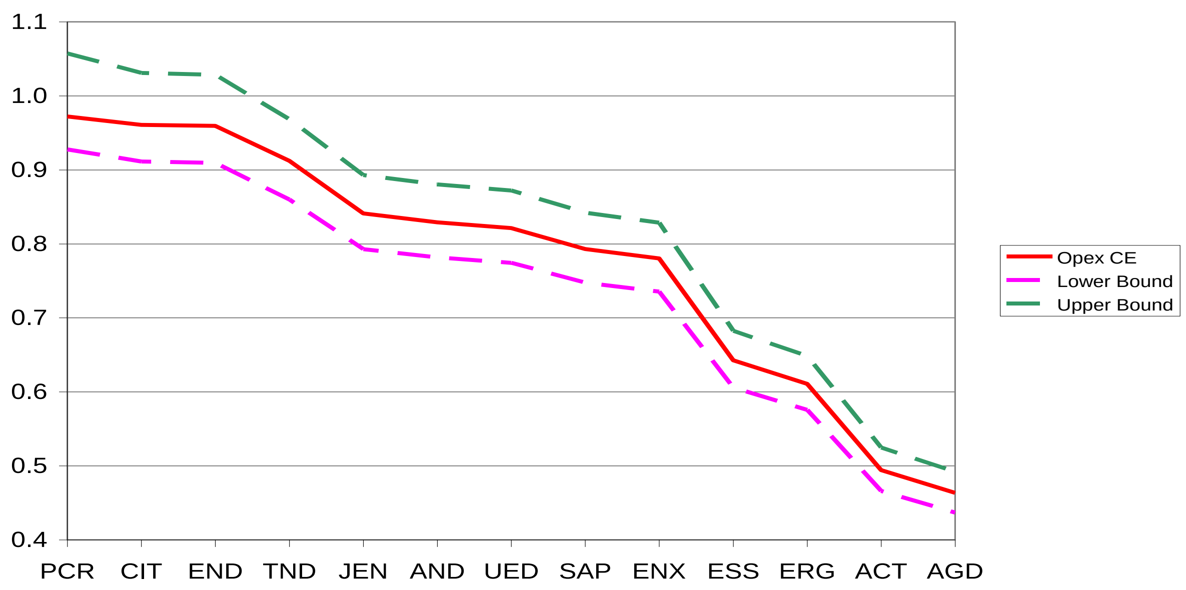
3.1.2 Australian DNSP RIN data econometric results

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

Table 3.2 **SFA Cobb–Douglas opex frontier estimates using RIN dataset**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(DistributionTrans)	–0.018	0.120	–0.150
ln(Custnum)	0.559	0.332	1.680
ln(CircLen)	0.124	0.183	0.680
ln(ShareUGC)	–0.162	0.164	–0.990
ln(ShareSingleStage)	–0.421	0.117	–3.610
ln(CMoS):	0.043	0.061	0.700
Year	0.046	0.009	5.120
Constant	–81.588	17.810	–4.58
Variance parameters:			
Mu	–0.585	2.322	–0.250
SigmaU squared	0.300	0.649	
SigmaV squared	0.007	0.001	
LLF			83.103

Figure 3.2 **SFA Cobb–Douglas opex efficiency scores using RIN dataset**



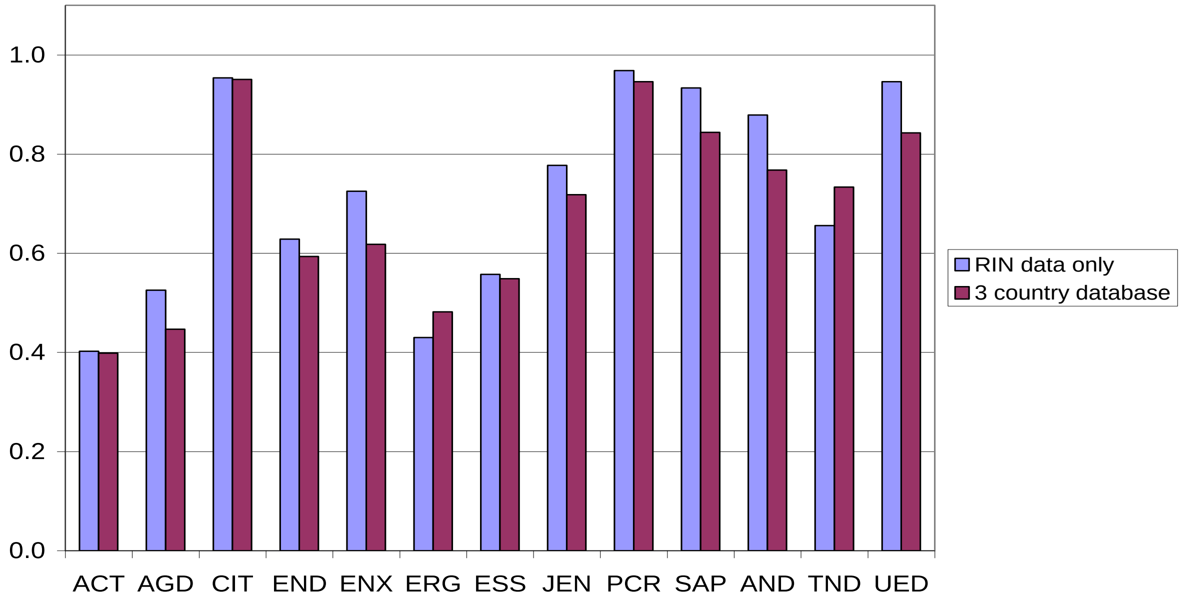
The most comprehensive opex cost function model we derived from using the RIN data only involved two outputs (customer numbers and circuit length), three operating environment factors (share of underground, share of single stage transformation and minutes off supply), distribution transformer MVA as the quantity of capital (to allow for opex/capital interaction) and a time trend. Estimating a Cobb–Douglas opex cost function using the SFA method produced the estimates shown in table 3.2 and the efficiency scores and confidence intervals shown in figure 3.2.

From table 3.2 we see that the estimated coefficients are all of the expected sign but the significance levels of the parameter estimates are relatively low. The spread and ranking of opex efficiency scores in figure 3.2 are relatively similar to those reported in Economic Insights (2014) using the three country database. The one exception is Endeavour Energy which ranks third best in the RIN data only model compared to ninth best using the broader data set.

Table 3.3 **SFA Cobb–Douglas cost frontier estimates using RIN data only and preferred 3–country specification**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	1.106	0.230	4.810
ln(CircLen)	0.126	0.087	1.450
ln(RMDemand)	–0.164	0.240	–0.690
ln(ShareUGC)	–0.030	0.088	–0.340
Year	0.034	0.005	6.260
Constant	–55.976	10.849	–5.160
Variance parameters:			
Mu	–0.283	1.402	–0.200
SigmaU squared	0.326	0.523	
SigmaV squared	0.008	0.001	
LLF			78.190

Figure 3.3 **Preferred 3–output SFA Cobb–Douglas efficiency scores – RIN only data versus 3 country data**



To further illustrate the impact of using Australian only data versus data from the three countries, in table 3.3 we present regression results for our preferred three–country CD SFA model using only the RIN data. It does not perform well in terms of the signs and magnitudes of the estimated coefficients as can be seen in table 3.3, but it does produce very similar efficiency scores as can be seen in figure 3.3.

In response to the question raised in PEGR (2015, pp.65–66) – and contrary to the assertions in FE (2015a, p.xi), CEPA (2015a, pp.16–18) and Huegin (2015c, pp.13,15) – the results in Economic Insights (2014) are thus consistent with those obtained using Australian RIN data only and are not 'driven' by the larger number of observations from the overseas jurisdictions. Rather, the addition of the international data simply improves the precision of the parameter estimates, as intended, while providing only minor refinements to the efficiency scores.

Finally, it is important to recognise that the characteristics of the Australian RIN data make any econometric model estimated using only the RIN data insufficiently robust to support regulatory decisions. In particular, Huegin's (2015a, p.13) claim that international data are introduced because 'the imperative is to facilitate a specific model type' (meaning SFA) is incorrect. Rather, more data are required to facilitate the robust estimation of any type of econometric model.

3.2 Approach to including overseas data

Economic benchmarking used to support regulatory decisions generally needs to be based on robust parameter estimates so that all stakeholders can have confidence in the results. Having more precise parameter estimates also supports more accurate forecasting of the opex productivity growth rate to be included in the rate of change method. Given the difficulty of estimating a robust model from the relatively small EBRIN database that contains limited time–series variation, we next sought to expand the database to include more cross–sectional observations. This approach is supported by the following from PEGR (2015, p.18):

> 'econometric benchmarking will in general be more accurate to the extent that it is based on a large, varied sample of good operating data. In cost research most variation in the values of business conditions occurs between companies rather than within companies over time. It is thus especially desirable for the sample to include data for numerous companies. When the sample is small, it will be difficult to identify all of the relevant cost drivers and accommodate the appropriate functional form.'

3.2.1 Process used to include overseas data

Increasing the number of cross–sectional observations required us to look at available overseas databases. An important consideration then becomes the availability of comparable overseas databases. As PEGR (2015, p.54) notes, there is a large volume of data available for US electric utilities. However, despite the large quantity of US data, it is generally not of consistent quality as it has been assembled for purposes other than economic benchmarking and US DNSP data is further compromised by being derived from vertically integrated utilities in many cases with all the ensuing cost allocation issues. US data is also quite incomplete as regards variables required for robust economic benchmarking. Fundamental variables such as line length, maximum demand and reliability are not consistently reported, if reported at all.

Rather than trying to obtain data from a jurisdiction such as the US that has very disparate and inconsistent reporting systems, we sought out jurisdictions where largely similar economic benchmarking datasets to the RIN data were already available, had undergone extensive checking and development and had been used by regulators in price resets. New Zealand and Ontario both had economic benchmarking datasets available in the public domain which were largely consistent with the RIN data and met these criteria. The Ontario database's capital component is largely derived from historic cost information and contains less detailed physical data but it contains detailed output and consistent opex data which are the main items required in estimating opex cost functions. Furthermore, recent regulatory decisions in both these jurisdictions had drawn on economic benchmarking models very similar to those used in Economic Insights (2014).

While New Zealand and Ontario DNSPs are smaller than Australian DNSPs on average, consistent with the quote above from PEGR (2015) there are advantages in having a heterogeneous dataset with numerous observations to support precision in econometric estimates. As PEGR (2015, p.54) notes, we have removed very small DSNPs with less than 20,000 customers from the New Zealand and Ontario databases to minimise the scope for very small DNSPs to exert undue influence on the results. Sensitivity analysis was undertaken of the effects of using different minimum DNSP sizes (in terms of customer numbers) in the database and the results were largely insensitive to the different options examined. However, the models had the least number of violations of monotonicity conditions (the requirement that an increase in any output involves an increase in cost) for the medium size database indicating this was the optimal choice allowing a large number of DNSPs to be included while not being unduly influenced by very small DSNPs.

FE (2015a, p.vii) claims that we have 'failed to apply suitable due diligence to the data'. A similar claim is made by Huegin (2015a, p.15). FE (2015a, p.xiv) also states:

> 'The serious difficulties inherent in the data preparation – and the amount of work that is required to create a consistent dataset – are simply not acknowledged in the AER's benchmarking analyses.'

We reject these statements. The AER data collection and verification process has been long and detailed, ranging from extensive consultation with stakeholders during 2013 in the development of data requirements and specifications, onerous auditing and verification requirements built into the supply of the initial data and then extensive consistency checking and cross–checking of submitted data during 2014.

Similar processes have been applied by the New Zealand and Ontario regulators to the development and verification of their databases over an even longer period. In fact, both these databases were first put in place in the mid–1990s and have been used in economic benchmarking since the early 2000s. The long history of these databases and the extent of checking undertaken by the respective regulators is one of the key reasons we decided to use these databases in preference to data from the US where there is far less consistency and no systematic data checking process.

FE (2015a, p.xiii) and Synergies (2015b, p.33) also question the backcasting of the RIN data and whether this will have been done consistently across DNSPs. We again note the extensive specification, auditing and checking process the AER has undertaken in forming the RIN database which make it is as accurate as it possibly can be and superior to most economic benchmarking databases used to support regulatory decisions in other countries.

FE (2015a, p.xii) also notes the differences in geographic characteristics across countries (including European countries) and claims we do not control for these adequately. Huegin (2015a, p.16) also notes the spread of DNSP sizes across jurisdictions. As noted above in the quote from PEGR (2015), heterogeneity in characteristics is actually required to produce more robust parameter estimates and so we reject the FE and Huegin criticisms. Furthermore, as discussed in section 2.3, we have undertaken a detailed process to assess the importance of operating environment factors and to allow for them as appropriate.

3.2.2 Role of dummy variables

Having identified the New Zealand and Ontario DNSP economic benchmarking databases as the best candidates for extension of our econometric modelling database, the next task was to allow for differences in coverage, definitions and reporting conventions across the three jurisdictions. Because our objective was not to undertake international benchmarking as such but, rather, to improve the precision of parameter estimates to facilitate opex efficiency measurement across the Australian DNSPs only, there is no need for the coverage of opex in each jurisdiction to be identical nor for operating environment conditions to be identical. By including country dummy variables for New Zealand and for Ontario, we are able to allow for systematic differences in opex coverage and operating environment conditions across countries. That is, we are not interested in absolute levels of opex in the other two jurisdictions but rather in relationships between opex and outputs and operating environment factors. Correspondingly, it is then invalid to compare the SFA efficiency scores across countries.

Most of the DNSPs' consultants' reports fail to grasp this distinction. For example, FE (2015a, p.12) refer to an Ontario firm as being the overall 'frontier firm' when it is not possible to draw this conclusion. Rather, scores can be compared within each jurisdiction but not across jurisdictions because of the use of the country dummy variables. For this reason figure 3 in FE (2015a, p.17), which graphs the raw opex efficiency scores across the entire three country sample, is invalid and reflects a misunderstanding of the analysis, as does Synergies (2015b, p.36) comparison of efficiency scores across countries. Similarly, the FE (2015a, pp.42–43) comments regarding 'international benchmarking' are misguided and not relevant. Huegin (2015a, p.26) makes a similar mistake by referring to an Ontario DNSP as 'the best performing network … amongst the entire sample'.

FE (2015a, p.16) also makes a similar misinterpretation by attempting to interpret the country dummies as reflecting the extent to which an Australian DNSP would have to have lower opex than a New Zealand or Ontario DNSP to be 'fully efficient'. And Synergies (2015b, p.37) also attempts to interpret the country dummies as reflecting the extent of 'cost disadvantage' across countries due to 'latent heterogeneity'. Again, the country dummies are designed to pick up a range of influences including operating environment differences, unaccounted for currency conversion differences, coverage differences and accounting differences. It is hence invalid to interpret the country dummy coefficients as differences in efficiency levels as FE has done or reflections of cost disadvantages as Synergies has done.

Similarly, the need for reporting 'standardisation' across countries referred to in CEPA (2015b, p.18) is less necessary with the more limited objective we have for including overseas data than would be the case were we doing international benchmarking. Consequently, the comments in PEGR (2015, p.53), Synergies (2015b, pp.33–34) and FE (2015a, p.x) regarding differences in opex coverage between the RIN, New Zealand and Ontario reporting are not an issue for the more limited exercise we are undertaking. Similarly, CEPA (2015b, p.16) comments regarding differences in operating environment conditions across countries are misplaced as these differences are accounted for by the country dummy variables.

A number of the consultants' reports argue that the incorporation of country dummy variables only allows for differences in underlying cost levels between countries (ie differences in the constant term of the opex cost function between countries), but not differences in 'cost driver' relationships (ie differences in the 'slope' coefficients of the cost function across countries). For example, PEGR (2015, p.55), FE (2015a, p.x) and CEPA (2015a, p.16) all make this argument. As noted in the preceding section, none of the consultants attempt to mount an argument as to why the technology used in electricity distribution might be significantly different across the three countries. We are of the view that the inclusion of country dummies represents the most tractable and accurate way of allowing for differences in underlying opex cost conditions and reporting between countries.

We further note that inclusion of additional country dummies to allow for differences in exogenous variable coefficients across countries would be equivalent to running individual opex cost function regressions for each country. Given the lack of time–series variability in the Australian RIN data, this exercise would be problematic and produce unreliable results. We thus reject the FE (2015a, pp.24–25) attempt to test for such differences. Indeed, the incorrect negative sign on the ratcheted maximum demand output variable for the Australian sample reported in FE's table 7 reflects this very problem. It is precisely for this reason that we supplement the RIN data with the New Zealand and Ontario data so that we can obtain more robust and reliable parameter estimates.

Although minimal details are presented, the attempt by Huegin (2015c, p.13) to estimate a model using data from only three DNSPs is, needless to say, completely unreliable as reflected in the incorrect signs of the reported coefficients.

3.2.3 Apparent anomalies in the overseas data

FE (2015a, pp.55–56) list what they claim to be 'several large inconsistencies' in the Ontario and New Zealand DNSP data used in Economic Insights (2014). As noted above, our approach has been to use databases that have been used by the electricity regulators in recent regulatory decisions. Similar processes have been applied by the New Zealand and Ontario regulators to the development and verification of their databases over a long period. While no database will likely ever be perfect and there will always be room for further improvement in any database, many of the 'large inconsistencies' claimed by FE (2015a) are likely to reflect the operations of smaller DNSPs.

For example, FE (2015a, p.55) lists what appears to be large movements upwards and downwards from year–to–year in the reported opex of Greater Sudbury Hydro Inc. This is a relatively small DNSP operating in an industrial part of Ontario. It is not unusual for small DNSPs to exhibit significant changes in opex from year–to–year as many changes to DNSP operations will have a 'fixed cost' element (eg staff training for the introduction of new systems) and be characterised by lumpiness. For smaller DNSPs these 'fixed cost' elements will represent a larger proportion of opex. What is important in these instances is the trend of opex over time rather than year–to–year movements. These characteristics are also better handled by the econometric methods we use compared to non–parametric methods such as DEA.

FE (2015a, p.56) goes on to list a small number of DNSPs that exhibit large step increases in energy delivered and/or maximum demand. Again, with the smaller regional Ontario and New Zealand DNSPs it is not uncommon to find a larger industrial plant in the DNSP's service area. If these plants start up – or shut down – during the sample period, then there can be sizable steps up or down in energy delivered or maximum demand.

We note that one Ontario DNSP – Welland Hydro Electric System Corp (NB not 'Wheland' as incorrectly listed by FE) – does appear to have made a reporting error for maximum demand in 2012 but this does not affect the ratcheted maximum demand measure used in our economic benchmarking models.

We also note that a few Ontario DNSPs do report large changes in line length in one year for this to be reversed the following year. Again, what is important in these instances is the trend of line length over time rather than year–to–year movements because regression methods fit lines of best fit based on variable trends. And, FE (2015a, p.56) note that in New Zealand, Counties Power's reported line length over 66kV increased by 146 per cent between 2006 and 2007. However, the relevant line lengths are 17 and 43 kilometres which is an entirely plausible change and, in any case, this variable is not used in our modelling.

Given the nature of smaller DNSPs, a number of the changes identified by FE (2015a) are likely to reflect actual operations. While we could have smoothed the data to remove apparently anomalous changes in particular years for a small number of DNSPs before undertaking our modelling, we are of the view that it is better to use the data actually used by the relevant regulators in their most recent decisions. These data have been the subject of extensive checking by the regulators and it is not clear that the data movements identified by FE (2015a) are necessarily incorrect. Given the small number of observations involved out of our 440 overseas observations, the effect of smoothing the data would not be material in any case.

3.3 Peers for Australian DNSPs

FE (2015a, pp.25–31) and Synergies (2015b, pp.4–5) note that some of the Australian DNSPs are larger than many of the New Zealand and Ontario DNSPs in some output dimensions. In particular, Hydro One Networks from Ontario is the only overseas DNSP that comes close to

Ergon Energy and Essential Energy in terms of circuit length. The circuit length of these two DNSPs is also considerably longer than for the other Australian DNSPs and they have the lowest customer densities.

In terms of customer numbers, Ausgrid and Energex come first and second in the overall sample while Hydro One Networks from Ontario is third and Toronto Hydro–Electric System has customer numbers comparable to several Australian DNSPs. With regard to energy delivered, these two Ontario DNSPs deliver more electricity than all Australian DNSPs except Ausgrid. Likewise, the ratcheted maximum demand of these two Ontario DNSPs is comparable to the larger Australian DNSPs of Ausgrid and Energex. Ausgrid and Energex both have key network densities that are similar to other Australian DNSPs that are predominantly urban but which also supply some rural areas. They can therefore not be considered to be outliers.

Huegin (2015a, pp.58–59) also claim that 'Essential Energy has no peers in the frontier group'. Although the top quartile group contains three rural DNSPs (SA Power Networks, Powercor and AusNet Services) and these DNSPs have similar customer numbers to Essential Energy and Ergon Energy, they only have half the circuit length or less.

While it would be desirable to have more rural DNSPs with line lengths similar to Essential Energy and Ergon Energy, these two Australian DNSPs are unusual with no DNSPs we are aware of in comparable countries with accessible data having their extent of lines. There is a risk that the Essential Energy and Ergon Energy data points could have a sizable effect on the frontier shape in this part of the data space if flexible models such as the translog are used. However, this will then often tend to favour these points because the frontier bends to meet them and hence, in most cases, they are likely to have higher efficiency scores (ie the model may find them efficient by default). If more rigid frontier methods (such as the Cobb–Douglas) are used, these points can exert some leverage on the general shape of the estimated function but the frontier shape will be largely determined by the smaller data points when there are a majority of smaller points. Hence, if the Cobb–Douglas and translog opex cost functions give similar efficiency scores – as they do in Economic Insights (2014) – then there is less chance that the large DNSPs such as Essential Energy and Ergon Energy are outliers that require special treatment.

This is supported by the EMCa (2015a) engineering review commissioned by the AER which indicates the relationship between maintenance opex and line length and between non–maintenance opex and customer numbers can be expected to be approximately linear for rural and remote DNSPs. Since the CD model implies approximately linear relationships over the variables' relevant ranges, no additional allowance for the characteristics of the remote DNSPs is required. Furthermore, plotting predicted efficient opex per customer from our CD model against customer density produces a graph almost identical to figure 13 in EMCa (2015a, p.32)

Huegin (2015c, p.20) claims that certain opex components including costs associated with high voltage lines should be removed in index number comparisons of Ergon Energy's opex efficiency while certain 'capacity' components should also be removed to enable like–with–like comparisons with other DNSPs. However, Huegin provides no details of its adjustments so we are unable to consider them. Huegin claims the costs it has removed from Ergon

Energy's opex would be treated as capex by other DNSPs. However, we note that Ergon does not have a high opex share of totex (the sum of opex and capex) compared to other Australian DNSPs and its share is considerably lower than all of our top quartile target DNSPs with the exception of CitiPower (AER 2014e, figure A.28). Generally, we consider the two stage allowance for operating environment differences we incorporate in our economic benchmarking to be superior to selectively adjusting data used in index number comparisons as the latter is more information intensive and prone to error or subjectivity.

Synergies (2015b, p.5) notes that Ergon Energy has the worst reliability performance (measured as unplanned outage minutes per customer) of the Australian DNSPs and appears to attribute this to Ergon Energy having the highest proportion of single wire earth return (SWER) line length. Synergies and Advisian (2015, pp.50–52) both note that no allowance is made for the proportion of SWER in Economic Insights (2014). However, while Synergies appear to imply that having more SWER lines will lead to higher opex, all else equal, due to SWER's lesser reliability, Advisian (2015, p.50) argue that having more SWER lines will lead to lower opex, all else equal, because 'its long span lengths lead to fewer poles per circuit km and its limited pole top hardware should result in lower Opex costs on a line kilometre basis than conventional two, three or four wire line construction'.

We note that of our top quartile rural DNSPs, Powercor and SA Power Networks have broadly similar proportions of SWER compared to Ergon Energy while AusNet Distribution has a similar proportion compared to Essential Energy (Advisian 2015, p.51). Furthermore, we note that Ergon Energy and Essential Energy both do somewhat worse on our opex MPFP efficiency measure compared to how they do using both our SFA and LSE econometric models' efficiency measures. This is because reliability performance is included as a (negative) output in the opex MPFP analysis but is not included in the econometric analysis. The treatment of reliability and SWER lines in our preferred SFA model is, therefore, likely to overstate the opex efficiency performance of both Ergon Energy and Essential Energy.

Advisian (2015, pp.50–52) also argues that not allowing for what they claim to be the lower opex requirements of SWER lines leads to the NSW urban DNSPs being relatively disadvantaged. Advisian includes ad hoc calculations of what they claim the effects of this are by reducing SWER line circuit lengths by 50 per cent. However, there is no robust justification given for the magnitude of this reduction and no consideration appears to have been given to the increased opex requirements of SWER's lesser reliability (as noted by Synergies 2015b, p.5). We also do not accept the ad hoc recalculation of efficiency scores based on the estimated circuit length coefficient as indicative of efficiency outcomes were such a change to be consistently made across all DNSPs in the database. We furthermore note that the two urban DNSPs in our top quartile, CitiPower and United Energy, also have negligible proportions of SWER line (in common with Ausgrid and Endeavour Energy). We are, therefore, of the view that no additional allowance needs to be made for SWER lines.

3.4 Methodology issues

Huegin (2015a) and PEGR (2015) raise a number of methodological issues. We note firstly that the Huegin report contains a number of errors. For example, the diagram in Huegin (2015a, p.11) illustrating different approaches to forming an efficient production frontier has the SFA line to the south–east of the ordinary least squares (OLS) line when it should be to the north–west of the OLS line. This is because OLS effectively fits a line of best fit through the overall sample whereas SFA estimates a frontier using statistical methods which allow for some outlier observations. The SFA frontier will thus normally lie between the COLS (which does not allow for outliers) and OLS lines and not below the OLS line as plotted by Huegin. Huegin (2015a, p.35) also describes the model used by PEGR (2014) as being 'COLS' (corrected ordinary least squares) when it is in fact an FGLS model (feasible generalised least squares which is an OLS–type method whereas COLS involves moving the OLS surface to encompass the most efficient observation within a de facto frontier).

Huegin (2015a, p.12) also claims that the data requirements for the data envelopment analysis (DEA) technique are 'less exhaustive than for other benchmarking techniques such as SFA'. We disagree with this statement. While a technical efficiency–only version of DEA can be calculated with only quantity information, for DEA to produce the same information on the more comprehensive measure of cost efficiency as index number and econometric methods, it requires the same range of variables. And there is little difference in the number of observations required by DEA and econometric methods to produce robust estimates. Only index number methods can produce robust results with few observations.

We also disagree with Huegin's (2015a, p.12) claim that 'MTFP does not take into account environmental variables'. As discussed in section 2, an appropriate choice of output variables can incorporate the major operating environment considerations of various aspects of network density. And, as also noted above, there is no reason to expect that the opex efficiency rankings derived from our model for Ontario in Huegin (2015a, p.14) should match those presented for total cost efficiency in PEGR (2013). This is because total cost efficiency is more dependent on capital inputs which are slower to adjust in the DNSP industry given their long–lived nature than opex inputs. The Huegin graph is thus not comparing like with like.

PEGR (2015, p.55) questions our presentation of the Cobb–Douglas SFA model as our preferred set of results as 'a statistical test revealed that these [second order] parameters were also significant as a group in the translog SFA model'. PEGR goes on to argue that 'the model used in the featured SFA benchmarking was misspecified with respect to functional form'. However, as noted in Economic Insights (2014, p.33) the translog SFA model had violations in monotonicity conditions (the requirement that an increase in any output involves an increase in cost) for 7 of the 13 Australian DNSPs using the medium data set, making it unsuitable for efficiency measurement. By contrast, the least squares econometrics (LSE) translog model suffered no monotonicity violations for the Australian DSNPs and the Cobb–Douglas SFA model also performed very well. We thus presented results for these two models (along with the Cobb–Douglas LSE model). Given the superior efficiency measurement properties of the SFA model, we presented the Cobb–Douglas SFA results as our preferred set. However, there is little difference in efficiency scores across the three sets of econometric results in practice.

PEGR (2015, p.55) also criticise our preferred Cobb–Douglas SFA model not correcting for heteroskedasticity or autocorrelation. The already complicated error structure included in SFA models makes it difficult to include additional adjustments and this is not normally done in SFA models. However, we do include allowance for heteroskedasticity or autocorrelation in our LSE models. The minimal difference in results between the models indicates that these effects are likely to be minimal.

PEGR (2015, pp.55–56) criticise our LSE models because they use Australian DNSP–specific dummy variables to measure efficiency. PEGR argues that these dummy variables are ‘incidental’ variables rather than ‘structural’ variables and many studies reporting general regression results do not report the dummy variable parameters but simply note that the model included ‘subject fixed effects’ because it is difficult to interpret the dummy variable parameters. However, this problem is more specific to panel–data models with a large number of individual dummies relative to the size of the panel. Many efficiency studies use dummy variables to measure efficiency levels and the interpretation of their parameter estimates is clear cut in this context (namely indicating different levels of cost once the included exogenous variables are allowed for – see Lawrence 2005, 2007).

Finally, PEGR (2015, p.56) questions our use of the Horrace and Schmidt (1996) method for calculating confidence intervals for our efficiency scores. PEGR argue that the confidence intervals are only intended to present a range of values for a specific estimate considered in isolation and that ‘in order to rank the companies in the population, joint confidence intervals that consider error in all the estimated firm inefficiencies should have been used’. We are not aware of any regulatory efficiency measurement studies that have used the approach suggested by PEGR. In any case, it should be noted our aim is not actually to produce DNSP rankings. Rather, we are establishing a benchmark frontier and then estimating the distance each firm lies below the frontier – each firm is treated individually in this respect.

3.5 Latent heterogeneity

In reports prepared for the NSW DNSPs, FE (2015a) and Huegin (2015a) both claim that the opex cost function modelling in Economic Insights (2014) has not taken sufficient account of heterogeneity in the sample observations. We do not agree with this. As already discussed in section 2, we have included a range of output measures in our model which have captured a large part of the heterogeneity in these firms, relating to the key operating environment factors of customer density, energy density and demand density. We have also included an environmental measure to capture the effects of undergrounding and we have dealt with a number of other operating environment factors which could not be explicitly included in the modelling by using ex post adjustments.

Thus, we are of the view that no further modelling refinements are needed regarding heterogeneity. However, FE (2015a) and Huegin (2015a) have chosen to investigate additional modelling options. Additional modelling of heterogeneity was later undertaken in the FE (2015b) and Huegin (2015b) reports prepared for and submitted by Ergon Energy.

3.5.1 Heterogeneity modelling

We first consider FE (2015a, p.18) who have argued that there is additional ‘latent heterogeneity‘ and have chosen to estimate the models of Greene (2005) which are known as True Random Effects (TRE) and True Fixed Effects (TFE). These models assume that heterogeneity is time–invariant and that inefficiency varies randomly over time. This is clearly a very controversial assumption which has been widely commented upon at many conferences and in journal articles since these models were first proposed (eg Farsi, Filippini and Greene 2006 and Agrell et al 2013). In essence, if inefficiency does not vary substantially over time, this time–invariant inefficiency will be incorrectly labelled as latent heterogeneity and hence actual inefficiency will be underestimated. In infrastructure industries, such as electricity distribution, where assets are long lived and previous methods of price regulation may have entrenched inefficiency, the assumptions inherent in these TRE and TFE models are unlikely to be appropriate.

FE (2015a, p.21) estimate these models and, unsurprisingly, find very large mean efficiency scores of approximately 96 per cent, which would appear to be unreasonably high given what is known about the relative performance of firms in this sample from other sources, including public comments from the least efficient DNSPs themselves (see Graham 2014) and detailed independent analysis of work practices in Deloitte Access Economics (2014b).

Agrell et al (2013, p.8) sum up the clear problems with these TRE and TFE models as follows:

> 'Assuming that physical network and environmental characteristics do not vary considerably over time and that the inefficiency is time–varying, these models help to separate unobserved time–invariant effects from efficiency estimates. However, if inefficiency is persistent over time, these models underestimate the inefficiency systematically, e.g. if managers take wrong decisions in every period or make the same mistakes again and again, the corresponding consequences in terms of inefficiency are detected as time–invariant unit–specific heterogeneity and not as inefficiency. As noted in Greene (2008), the 'truth' doubtless lies somewhere between the two strong assumptions.'

To our knowledge no regulator in any country has ever used TRE and TFE models in regulatory decisions because of the inherent problems with the underlying assumptions in these models. We furthermore note that in Economic Insights (2014) we made ex post adjustments to our model results to account for operating environment factors not explicitly included in the econometric model. These adjustments were based on detailed analysis reported in AER (2014a,b,c,d) of 33 possible factors raised by stakeholders. We are of the view this represents a more robust approach than use of the TRE and TFE models reported in FE (2015a) and supported in Synergies (2015b, pp.37–38) which clearly overstate efficiency scores.

FE (2015b) attempt to explicitly model some additional heterogeneity in the cost frontier modelling process described in Economic Insights (2014). They suggest the use of a one stage model and a two stage model.

The one stage model involves the inclusion of two extra variables in the Economic Insights (2014) SFA Cobb–Douglas model, namely, the (unlogged) share of circuit length that is above 66kV and the square of the logarithm of customer numbers divided by circuit length. After estimating this revised model FE find that these variables are observed to be statistically significant at the 1 per cent and 10 per cent levels, respectively. They are also estimated to have approximately 15 per cent and 4 per cent positive effects, respectively, on the efficiency score of Ergon Energy.

There are, however, some significant problems with the analysis reported in FE (2015b). Firstly, only the NSW, Queensland and ACT DNSPs report any line lengths over 66 kV in Australia[6]. It is, therefore, likely that this variable will simply pick up other characteristics that are shared by DNSPs in these states relative to DNSPs in the other states. Among other things, it will pick up inefficiency costs for the DNSPs in these states and lead to the efficiency scores for the NSW, ACT and Queensland DNSPs being substantially overstated as will be shown in section 3.10. This effect is similar to the 'efficient by default' problem which characterises the TRE and TFE models reported in FE (2015a) and which leads to them overstating efficiency scores.

A second problem with the FE (2015b) analysis is that the variable line length over 66kV for Ergon Energy – which starts off nearly three times the next highest Australian value – shows a decline of around 38 per cent between 2010 and 2013. When queried about this during data verification, Ergon Energy indicated that the very high voltage lines in question had been 'returned back' to the TNSP, Powerlink. This makes reliance on this variable in econometric modelling adjustments for Ergon Energy questionable. By contrast, our ex post adjustment for subtransmission intensiveness uses data for 2013 which will more accurately capture the current situation with regard to high voltage lines for Ergon Energy.

Economic Insights (2014, p48) describes how we drew on AER (2014a,b,c,d) calculations of opex efficiency adjustments for high voltage lines in the case of the NSW and ACT DNSPs based on relative shares of overall line lengths across states accounted for by subtransmission, where subtransmission comprises lines of 33kV and above. Ergon Energy also has the highest proportion of line length accounted for by subtransmission lines, followed by Ausgrid, Endeavour Energy, Energex and Essential Energy. The other states have smaller (but positive) proportions of subtransmission lines making this a more reliable and robust way of adjusting for the higher opex per kilometre required to maintain high voltage lines.

The inclusion of the square of the logarithm of customer numbers divided by circuit length appears to be a rather ad hoc way to deal with potential second–order model non–linearity in FE (2015b). As noted in FE (2015b, p.39) the output specification used in Economic Insights (2014) is equivalent to including a separate customer density variable in the opex cost function (as the numerator component of customer numbers and denominator component of line length are included as separate outputs). Furthermore, the translog model reported in Economic Insights (2014) also includes squared and cross product terms for these outputs. We note that in the results reported in figure 7.1 in Economic Insights (2014) the Ergon Energy opex efficiency score for the translog model (LSE TLG) is quite similar to the efficiency scores obtained from the two Cobb–Douglas models (SFA CD and LSE CD). The translog model is a much more comprehensive way of dealing with potential second–order non–linearity, because it allows for this effect on all variables in the model, not just one hand–picked variable. We are therefore of the view that including this variable as an ad hoc add–on to the SFA CD model adds nothing compared to the translog model reported in Economic Insights (2014) which produces similar opex efficiency scores to the SFA CD model.

[6] Two of the 18 included New Zealand DNSPs report very short lengths of line over 66 kV and no Ontario DNSPs have lines of these voltages.

Despite the shortcomings identified with the FE models, we note that FE (2015b, p.x) indicates that ActewAGL, Ausgrid and Essential Energy rank towards the lower end of opex efficiency scores for all variants presented.

FE (2015b) also estimate two second stage models, where they take the efficiency scores of the Australian DNSPs from the Economic Insights (2014) preferred model and FE's first stage modification of our model to include variables for above 66kV lines and second order customer density and regress the two sets of efficiency scores individually on a range of 16 different additional potential explanatory factors comprising various climatic and density variables. Since there are only 13 observations in these regressions, they are, by definition, unlikely to produce reliable results.

In FE's second stage regression of the Economic Insights (2014) results, the above 66kV variable is found to be highly significant. However, as discussed above, no weight can be placed on this finding because the above 66kV variable, among other things, picks up inefficiency costs given that only the NSW, ACT and Queensland DNSPs have lines of these voltages. This will be discussed further in section 3.10 but the effect is again similar to the 'efficient by default' problem which characterises the TRE and TFE models reported in FE (2015a) and which leads to them overstating efficiency scores.

The FE (2015b) second stage regression of its modification of our model to include variables for above 66kV lines and second order customer density finds that not even one of these 16 variables is statistically significant at the 10 per cent level. However, FE do identify two variables with p–values of 13 per cent and 11 per cent, namely, customers per square kilometre of service area and the 90th percentile of annual maximum wind gust speed in kilometres per hour and go on to discuss their impact on the results. Again, no weight can be placed on the adjusted efficiency scores FE (2015b) present in their table 11 because the inclusion of the above 66kV lines variable in their first stage model picks up inefficiency costs and leads to their resulting efficiency scores being substantially overstated.

We note from their table 11 that the customers per square kilometre of service area variable has a very small effect (less than 2 per cent) on the Ergon Energy efficiency score, lending weight to our view that the variables included in our model are capturing the main effects of customer density quite well.

Also reported in table 11, FE (2015b) finds that the 90th percentile of annual maximum wind gust speed in kilometres per hour variable has a larger 6 per cent effect on the Ergon Energy efficiency score. However, it should be noted that neither of these two variables are significant at the 10 per cent level and the remaining 14 variables were even more insignificant in this exercise.

Finally, we note that FE (2015b, p.44) cite Coelli et al (2005, p.194) as providing support for using a second stage regression in their SFA analysis. However, the text they cite is in relation to DEA models, which are deterministic models. In the case of stochastic models, the advice differs. For example, Coelli et al (2005, pp.281–2), in a chapter on SFA, expresses a clear preference for the use of single stage analysis in the case of SFA models:

> 'Some authors (eg., Pitt and Lee, 1981) explore the relationship between environmental variables and predicted technical efficiencies using a two–stage

> approach. The first stage involves estimating a conventional frontier model with environmental variables omitted. Firm–specific technical efficiencies are then predicted using formulas such as 9.24. The second stage involves regressing these predicted technical efficiencies on the environmental variables. One problem with this approach is that predicted technical inefficiencies are only a function of environmental variables if the latter are incorporated into the first stage, and doing so makes the second stage unnecessary, because the relationship between the predicted inefficiency effects and the environmental variables is known (it is given by equations such as 9.24).'

Battese and Coelli (1995, pp.325–6) also criticised the use of two–stage models on SFA efficiency scores as follows:

> 'Pitt and Lee (1981) and Kalirajan (1981) … adopted a two–stage approach, in which the first stage involves the specification and estimation of the stochastic frontier production function and the prediction of the technical inefficiency effects, under the assumption that these inefficiency effects are identically distributed. The second stage involves the specification of a regression model for the *predicted* technical efficiency effects, which contradicts the assumption of identically distributed inefficiency effects in the stochastic frontier.'

While we reject the modelling reported in FE (2015b), we note that section 2 on the unusual conditions Ergon Energy faces – particularly with regard to climatic conditions – is noteworthy. Indeed, all the operating environment factors affecting Ergon Energy nominated by FE (2015b) have been considered in the detailed AER (2015e) assessment of the conditions Ergon Energy faces. And we incorporate the relevant disadvantages Ergon Energy faces in our ex post adjustment of the target DNSP's input use in calculating Ergon Energy's adjusted efficiency target in section 5. This provides a better way of addressing these issues than attempting to incorporate them directly within the econometric modelling or problematic second stage regressions. And, as noted in section 2.3, it is also consistent with FE's (2015b, p.77) own recommendation for the best way of dealing with these issues.

3.5.2 'Latent class' modelling

We next consider the proposal of Huegin (2015a) to use Latent Class SFA models to identify 'heterogeneity'. These methods have been used by Agrell et al (2013) and Llorca et al (2014), among others. In this methodology, clustering methods are used to identify subsets of the sample data so that separate frontiers can be estimated for each subset.

In Huegin (2015a) the Akaike Information Criteria (AIC) is used to identify the number of subsets (classes) in the model. It is well known, for example see Greene (2003, p.160), that the AIC tends to over fit models relative to other model selection criteria such as the Schwartz or Bayesian Information Criteria (BIC). That is, in a Latent Class model the AIC will tend to favour models with more classes rather than less classes.

Huegin (2015a, p.55–56) estimate their Latent Class SFA model and report that they have identified four different classes in the sample data. The results reported were very brief and hence a number of aspects of their analysis warranted further questions.

First, Huegin chose to drop the country level dummies from the model in their analysis, which would be expected to encourage the method to find more classes than actually existed. When we asked why this was done, Huegin stated in their response dated 6 February 2015 that:

> 'The model was designed to investigate whether using the medium dataset from which the AER's SFA results were obtained there was an indication of different technological classes within the dataset – i.e heterogeneity in the parameters of the model.
>
> 'Country dummies are a useful indicator of the different levels of opex between DNSPs but do not control for the impact of different explanatory variables on opex between countries and technological classes. That is, the inclusion of country dummies assumes there are differences in the intercept between countries but not in the elasticities of the dependent variables used.
>
> 'Our latent class modelling also excluded a variable for time because the analysis was to determine whether different latent classes existed within the dataset and not to estimate relative levels of efficiency between the 68 distributors used in the dataset.'

This response is not satisfactory. By dropping these important variables Huegin are introducing misspecification into the model. One would expect the three countries to show as separate classes when no adjustment is made for cross–country differences – our econometric models, on the other hand, do include such an adjustment. And one would expect conditions to change over time. By not including allowance for time effects, Huegin is again biasing its analysis towards (incorrectly) finding more groups. Huegin then take a misspecified model and look for latent classes in order to show that our correctly specified model is faulty. Such an approach is clearly questionable at best. In their response we also note that Huegin chose to not repeat their analysis with the dummies included. It is likely that these country level dummy variables may actually have had a large effect on the results Huegin obtained.

Second, Huegin (2015a) did not report any of the efficiency scores obtained from their model. When questioned about this Huegin again chose to not report their efficiency scores and instead argued in their response dated 6 February 2015 that:

> 'We do not agree with the AER's model specification, in particular we consider ratcheted maximum demand to be a poor explanatory variable for opex. We did not provide the efficiency scores because we believe that whilst the analysis demonstrates the presence of multiple classes within the data set, the model specification and source data are unable to provide meaningful indications of relative efficiency. Latent class modelling provides more realistic estimates of relative efficiency by ensuring comparisons are only made within classes, however a weak explanatory model and/or spurious input data will still produce unreliable results.'

We consider this response to be not satisfactory. For the reasons outlined in section 2 we consider our output specification to be well justified and similar to that used in economic benchmarking studies used in regulatory determinations in other jurisdictions. Without additional information, it may well be the case that the scores Huegin obtained were less favourable to the NSW/ACT DNSPs relative to the (ex post) adjusted efficiency scores reported in Economic Insights (2014).

Third, Huegin (2015a) did not report any parameter estimates from their model. After a request was made for further detail, some computer output was provided on 30 January 2015 which illustrated that some of the estimated coefficients in the Huegin model had incorrect signs. For example, for one class an increase in ratcheted maximum demand output leads to a decrease in opex costs in the model. This further draws into question the validity of this modelling exercise.

Overall, we find the latent class SFA modelling by Huegin (2015a) to be not convincing. Again, to our knowledge, no regulatory authority has used this approach in a regulatory setting. This is likely to be in part because of some of the abovementioned issues and also because it is widely known that by dividing any data set into subsets the mean efficiency score will almost invariably increase as the sample size decreases. For example, see Zhang and Bartels (1998) for an often cited paper illustrating this in the context of DEA efficiency measures.

In their subsequent report for Ergon Energy, Huegin (2015b) use k–means clustering to look for clusters (classes) in the sample data presented in Economic Insights (2014). They first use a group of 18 variables and cluster the 13 Australian DNSPs into between 2 to 10 clusters. Then, in a second exercise, they use the set of variables from the preferred model in Economic Insights (2014) to cluster all 68 DNSPs into up to 4 classes.

The general thrust of the report is that Huegin wish to argue that Ergon is not comparable to some of the best performing Australian DNSPs but neither details nor references are provided. Huegin (2015b, p.5) conclude by stating that: ‘The exercise of testing for clusters within the data demonstrates that the AER has erred in selecting a single cost function for all 68 businesses’. This statement is not correct. First, the Huegin (2015b) clustering exercise involves a simple comparison of means, which is a linear analysis. The Economic Insights (2014) models are non–linear economic cost function models (Cobb–Douglas and translog) which are used to capture the classic diminishing marginal returns nature of economic cost structures. Second, as was the case in Huegin (2015a), Huegin (2015b) have again chosen to exclude the country–level dummy variables from the analysis, which introduces misspecification. Third, the use of the word ‘testing’ is misleading, since no statistical tests are conducted for the number of classes in Huegin (2015b). These clustering methods identify clusters of DNSPs that are similar to each other in terms of closeness of their means. They do not provide evidence that the DNSPs in these clusters are significantly different from each other nor that they belong to separate cost functions.

3.6 Claimed correlation between opex and capital MPFPs

Synergies (2015b, pp.38) regresses the Australian DNSPs’ opex MPFP indexes against their capital MPFP indexes for 2013 and claim:

> ‘It is apparent that there is a strong relationship between capital and operating cost MTFP (sic). One might say that capital MTFP (sic) ‘explains’ 43% (the R^2 of the

> linear relationship between them in 2013) of the observed variation in operating cost MTFP (sic)'.

It is important to note in the first instance that there is no significant correlation between the Australian DNSPs' opex MPFP and capital MPFP index values in 2013. The Spearman correlation coefficient between the two variables is 0.35 whereas the critical value for significance at the 10 per cent level is 0.48 and at the 5 per cent level is 0.56 with 13 observations. And, even if there were correlation between the two, it would be misleading to say this implied causation.

Synergies claims that opex efficiency will be constrained by the volume of assets that a DNSP has. Thus, it argues that a DNSP with more assets (and hence lower capital MPFP, all else equal) will also have low opex efficiency since 'the nature of the capital stock limits the extent to which operating costs can be reduced to the rate at which excessive capital can also be reduced' (Synergies 2015b, p.39). However, apart from the fact that the two partial productivities are not significantly correlated as noted above, this argument fails to recognise that the efficiency of work practices and staffing levels may vary substantially across DNSPs. Thus, for two otherwise identical DNSPs, if one has inefficient work practices and the other has efficient work practices, there will be scope for the one with inefficient work practices to increase its opex efficiency quickly relative to the other.

To put this another way, it is possible that poor managers can inefficiently use both too much opex and too much capital. But, if the DNSP has overinvested in assets then there would be likely to be less strain on those assets with consequently reduced chance of failure and need for repair. This could actually reduce the need for opex rather than increase it as claimed by Synergies.

We note that the calculation of capital input quantity proxies based on asset values (as Synergies says it has done) is fraught with difficulty, quite apart from the numerous 'strong' assumptions reported in Synergies (2015b, p.40). The principal of these is the tendency of this approach to imply physical depreciation of the asset of the same type as used in regulatory reporting. This typically involves straight–line depreciation rather than the one–hoss–shay characteristics these assets display in physical terms. To provide a sufficiently robust measure of the quantity of capital input for efficiency measurement purposes, the variable used needs to reflect physical depreciation properties rather than those of financial depreciation. We can thus place no weight on the Synergies extended analysis.

3.7 Use of data envelopment analysis

Synergies (2015b, pp.41–43) claims that:

> 'There are other economic measures of efficiency that are better able to take account of the characteristics of the DNSPs in assessing controllable efficiency. DEA, which the AER appears to have rejected due to the data intensity of the approach, effectively derives the production technology or production function from that which is observed in the sample of businesses or firms that are examined.'

It should be noted that DEA is a non–parametric method (as is index number analysis) so it provides no statistical information on confidence levels but it does provide some more detailed results than can index number analysis. However, given its reliance on linear programming methods (which place the frontier around all observations, including outliers), DEA is more prone to providing distorted results if there are data issues with firms it puts on the frontier. Econometric methods such as SFA, on the other hand, reduce the impact of outlier observations (because the statistical method used will place the frontier inside of the outlier observations).

DEA is often used in a quantities–only version which requires considerably fewer variables but only produces information on technical efficiency and not cost efficiency. To provide information on cost efficiency DEA requires the same range of variables as index number methods and will generally produce similar results to index number methods.

The AER (2013) flagged the possible use of DEA in addition to index number methods. However, DEA requires a large number of observations to implement satisfactorily, as do econometric methods including SFA. Early analysis of the Australian–only data indicated that DEA would not be a robust technique for the Australian data set due to the limited number of cross–sectional observations. The international dataset we have used requires the use of country dummy variables which cannot readily be accommodated within DEA but which can be readily accommodated in econometric models. SFA is a preferable form of econometric model because it separates out the inefficiency component from the random noise component of the error term.

DEA is also exposed to a self–identification or 'efficient by default' problem. That is, some firms are identified as efficient solely because DEA is not able to compare them with other sampled firms and it is not possible to know what sample size is required to obtain a reasonable estimate of relative efficiencies within the sample. This also leads to the inclusion of more outputs and inputs for a given sample size in DEA producing higher efficiency scores simply because the method has difficulty finding similar combinations of outputs and inputs so more firms become efficient by default, regardless of whether they are truly efficient or not.

The smaller the sample size is, the more acute this 'efficient by default' problem is as graphically illustrated by the FE (2015a, pp.72–76) attempt to apply a DEA model to Australian data for 2013, ie to a sample of only 13 observations. Increasing the number of outputs from three to four increases the number of DNSPs with scores above 0.95 from two to seven, while also introducing variable returns to scale further increases the number with scores above 0.95 to 10 – simply because the sample is not large enough to support sensible efficiency analysis using this method.

Huegin (2015a) also applied DEA models to examine the effects of including alternative outputs and alternative scale assumptions. NZ and Ontario observations were included in determining the cost frontier, against which relative efficiencies of the Australian DNSPs are measured. As noted in section 3.5, not including country dummy variables is likely to fail to take account of systematic operating environment, coverage and reporting differences across countries. In each of the four models, ActewAGL is found to be the least efficient Australian DNSP. This appears to be broadly consistent with the findings of our econometric models.

But by contrast, Ausgrid in some years (eg 2007 and 2013) appear to be efficient under Huegin's two variable returns–to–scale DEA models. This again illustrates the self–identification problem of DEA since Ausgrid has the largest customer base in the sample, 20 per cent higher than the DNSP with the next most customers. It is thus self–identified as efficient due to the model finding it non–comparable with other included DNSPs on this output dimension.

We thus disagree with Synergies' claim that DEA is 'better able to take account of the characteristics of the DNSPs'. Index number methods can be implemented with a minimal number of observations. If additional data can be incorporated to support either DEA or econometric methods, it is better to use one of the parametric methods, rather than another non–parametric method such as DEA.

With regard to the specific application of DEA reported in Synergies (2015b), it is important to note that it includes three inputs – opex and two capital inputs. The results from this application can thus not be compared with the opex efficiency scores reported in economic Insights (2014) as it is not comparing like with like.

One would also expect higher observed efficiency scores in the Synergies application simply because of the inclusion of more input dimensions (ie more DNSPs become efficient by default).

A further significant problem with Synergies' DEA application is its specification of capital inputs. While its use of MVA of transformer capacity for the quantity of one of the capital inputs is appropriate, Synergies' (2015b, p.42) use of the 'user cost of capital associated with distribution lines' to measure the quantity of the other capital input is incorrect. The user cost of capital is a measure of the annual cost of using capital inputs and does not necessarily bear a close relationship to the quantity of capital inputs being used. For the same reasons as described in the previous section, using the depreciated asset value as a proxy for the quantity of capital input (which forms the basis of the return on capital component of the annual user cost) will reflect financial depreciation properties rather than the physical characteristics of the asset required for efficiency measurement. This problem is exacerbated in using the annual user cost because the return of capital component of the annual user cost directly reflects financial depreciation.

We also note that Synergies (2015b, p.42) states that it uses 'Peak MW' as one of its three outputs rather than the ratcheted maximum demand variable used in Economic Insights (2014). This will again make the Synergies specification less comparable with that used in Economic Insights (2014) and somewhat difficult to justify as being a reflection of functional outputs for the reasons discussed in section 2 with regard to system capacity measures.

Finally, it also appears that the Synergies (2015b) DEA application relates only to technical efficiency and not cost efficiency as calculated in Economic Insights (2014).

We also note that in Synergies' (2015b, p.42) figure 21, 10 of the 13 Australian DNSPs are reported as exhibiting decreasing returns to scale while the remaining three exhibit constant returns to scale. The implication of this is that most of the Australian DNSPs are found to be inefficiently large and so should be split up into smaller entities. This would appear to run counter to engineering logic.

In Synergies' (2015b, p.42) figure 21 it is also not clear what the column headed 'controllable efficiency' relates to. The normal disaggregation of technical efficiency scores in DEA models is into measures of congestion efficiency (the ability to dispose of 'surplus' inputs), pure technical efficiency and scale efficiency with the product of these three measures equalling the technical efficiency score. The Synergies table does not conform with this normal disaggregation and associated consistency properties.

For the reasons outlined above, we are of the view that no weight can be placed on the Synergies (2015b), FE (2015a) or Huegin (2015a) DEA applications and they have no implications for the opex efficiency results presented in Economic Insights (2015b).

3.8 Requirements for regulatory benchmarking

In a report prepared for Ergon Energy, Synergies (2015a, pp.9–11) lists a number of detailed requirements that it considers should be met before benchmarking can form the basis of regulatory decisions. We note that an appropriate time for Ergon Energy to have presented such a list would have been during the AER's extensive workshop process in 2013 in the lead up to the issuance of the Expenditure Forecast Assessment Guidelines.

Synergies (2015a, pp.11–12) goes on to claim that the economic benchmarking results presented in Economic Insights (2014) do not meet the requirements it has set out. We disagree with Synergies' assessment. Without accepting the Synergies requirements as necessarily being appropriate, we are of the view that Economic Insights (2014) does meet all the requirements listed.

Focusing on Synergies' (2015a, pp.11–12) claims that our modelling does not meet key aspects of its stated requirements, we provide the following responses.

Claim: The stochastic frontier analysis ('SFA') upon which the AER places most reliance does not include reliability as an output, which is a known driver of operating costs.

Response: Reliability is included as a (negative) output in our index number model. The results obtained from the index number and the SFA models are similar. We note that the rural DNSPs with lower density (which also have the worst reliability) appear slightly less efficient in the index number results and would face slightly larger base year opex reductions if this model was used. The treatment of reliability thus does not affect the assessment of base year opex efficiency for most DNSPs and provides a relatively favourable treatment of low density rural DNSPs.

Claim: The inputs do not include a detailed breakdown of inputs such as high and low voltage lines, line capacities etc.

Response: Line voltage and capacity information is used in calculating the ex post adjustment for operating environment factors not directly included in the opex cost function models. It is therefore included in the analysis. And it is also included in the multilateral index number models.

Claim: It may not properly take account of production technologies in use by DNSPs that are somewhat extreme in character in terms of, for example, scale, customer density, climate etc.

By way of example, there are few examples of large DNSPs using SWER lines, so this technology is not accurately represented.

Response: There is no evidence that the SFA model in Economic Insights has been unable to appropriately accommodate ‘extreme in character’ production technologies such as the relatively low customer densities of Australia’s remote area DNSPs. On the contrary, comparing results from the Cobb–Douglas and translog SFA models suggests the model is handling these differences well. This is supported by the EMCa (2015a) engineering review commissioned by the AER which indicates the relationship between maintenance opex and line length and between non–maintenance opex and customer numbers can be expected to be approximately linear for rural and remote DNSPs. Since the CD model implies approximately linear relationships over the variables’ relevant ranges, no additional allowance for the characteristics of the remote DNSPs is required. And other extreme operating environment circumstances such as climatic conditions are accommodated through the ex post adjustment process. As discussed in section 3.3, there are DNSPs in the top quartile target group with SWER proportions similar to the remote area DNSPs and others with shares similar to the more urban DNSPs.

Claim: It may not properly take account of endogenous factors that affect costs which are specific to one or a small number of DNSPs.

Response: It is not clear what Synergies means by ‘endogenous’ factors. To the extent that an endogenous factor affects a DNSP’s efficiency score it is presumably under management control and can be changed. Because we get little difference in results between the more flexible translog LSE model and the somewhat more rigid Cobb–Douglas SFA model, we are confident the SFA model is accurately modelling the included DNSPs.

Claim: The preferred benchmarking approach only examines operating cost efficiency and does not examine capital cost efficiency, even though the two may be interdependent.

Response: As noted in section 3.6, opex MPFP and capital MPFP are not correlated in the 2013 RIN data. And even if they were, correlation does not imply causation. Inefficient work practices are one reason a DNSP could be expected to improve its opex efficiency level quickly, regardless of its capital efficiency level. We have concentrated on opex efficiency levels and their drivers as that was our brief from the AER.

Claim: Important determinants of costs (or factors that are likely to be important determinants of cost) are not consistently reported across the database used for the SFA estimates, and so are not included in the models.

Response: Relevant operating environment factors that could not be included in the modelling due to data limitations in New Zealand and Ontario are included in the ex post adjustment process for the Australian DNSPs where complete data are available. It is thus incorrect to say that these factors are not included in the analysis.

Claim: There is evidence that the Australian DNSPs are systematically different in their characteristics (scale etc.) from either the New Zealand or Ontario DNSPs, suggesting that the econometrically determined Cobb Douglas and translog cost functions are poor representations of Australian DNSPs.

Response: We include country dummy variables in our models to account for systematic differences between countries due to differences in operating environments, DNSP coverage, accounting conventions and currency conversion not covered by the purchasing power parities used. The DNSPs' consultants' reports have not put forward any arguments as to why technologies might differ across the three jurisdictions (and hence why regression slope coefficients might differ). There is insufficient time–series variation in the Australian DNSP data to test whether slope coefficients differ from those in the other jurisdictions and this is precisely why we need to include the overseas observations. We therefore reject the Synergies assertion.

Claim: It does not take into account a number of DNSP–specific characteristics that are likely to be important, such as climate and the age and condition of the capital stock.

Response: These operating environment factors are consider in detail in assessing the need for ex post adjustments to the results. We therefore reject the Synergies assertion.

Claim: The benchmarking also lacks consistency. For example, different but entirely reasonable benchmarking approaches give rise to very different estimates of controllable efficiency.

Response: We reject this proposition put forward by Synergies. Economic Insights (2014) presents results from four different modelling approaches, all of which produce very similar results. These results are also very stable when specification is changed or observations are added to or dropped from the database. The results are therefore very consistent. We note the DEA results reported by Synergies (2015b) are for all inputs, not opex, and contain specification flaws. And in section 3.5 we explain the flaws with the 'latent heterogeneity' models advocated in some of the consultants' reports and why our approach of making ex post adjustments for operating environment factors not explicitly included in the econometric models is superior.

3.9 Comparing Ontario results

A number of the consultants' reports argue that the efficiency results for the Ontario DNSPs differ markedly between those derived from (but not presented in) Economic Insights (2014) modelling and those presented in PEGR (2013) and subsequently used by the Ontario Energy Board in its latest regulatory determination. In particular, Huegin (2015a,c) and FE (2015a) raise this issue.

It is not surprising that the two sets of efficiency score rankings differ given that those in Economic Insights (2014) relate to *opex* efficiency while those in PEGR (2013) relate to *total cost* efficiency. The reason totally different efficiency measures were used in the two studies reflects the fundamentally different regulatory regimes – Australia uses building blocks regulation with its separate examinations of opex and capex whereas Ontario uses productivity–based regulation which focuses on total costs.

Given that capital plays a major role in the total cost efficiency scores and given the long lived nature of capital in this industry, capital efficiency is much slower to adjust. Given the degree of capital intensiveness of the industry, this means total cost efficiency is also slow to adjust compared to opex efficiency. As discussed in the preceding sections, there is no expectation that a DNSP that is inefficient in its use of capital inputs will also be inefficient in its use of opex inputs and vice versa. Differences in work practices can account for account for a substantial proportion of differences in observed opex efficiency, regardless of whether or not the DNSP is efficient in its use of capital.

It is not unusual to see marked differences in the pattern of opex efficiency score rankings and total cost efficiency score rankings in energy distribution businesses. Indeed, if opex efficiency score rankings and overall efficiency score rankings coincided, it would be a cause for concern with the analysis.

Highlighting the differences in rankings across studies when like is not being compared with like is, in our view, misleading.

3.10 Review of consultants' alternative benchmarking models

A number of the DNSPs' consultants' reports presented alternative benchmarking models using different datasets, estimation methods, and model specifications compared to Economic Insights (2014). We have already examined a number of these models in earlier sections – including those using latent heterogeneity approaches and DEA. In this section we review the consultants' models before presenting a summary of our assessment in table 3.4.

After a detailed review we have found that all the alternative models submitted by the DNSPs' consultants have serious flaws. In particular, all of the models have problems in at least one of the following six areas – and most have problems in several of these key areas:

- the Australian data has inadequate variation to support robust model estimation where it is the only data source used or where separate parameters are estimated for Australia
- use of a 132kV line variable inadvertently picks up other effects and leads to an understating of efficiency gaps
- latent heterogeneity models incorrectly allocate persistent inefficiency effects to operating environment differences
- inadequate observations numbers lead to some models misleadingly finding DNSPs to be 'efficient by default'
- some output and input specifications are inadequate and/or not relevant, and
- other overseas data sources unduly limit the range of variables that can be included.

We now examine each of these areas in turn.

3.10.1 Inadequate data variation in Australian data–only models

We demonstrated in section 3.1 that, while the EBRIN data are robust, they show little time–series variability for each DNSP. This is not an uncommon situation for infrastructure industries which are characterised by being relatively stable and 'steady as she goes' in nature as noted by PEGR (2015, p.18):

> 'econometric benchmarking will in general be more accurate to the extent that it is based on a large, varied sample of good operating data. In cost research most

> variation in the values of business conditions occurs *between* companies rather than *within* companies over time.'

We showed in figure 3.1 and table 3.1 that the 104 observations available in the EBRIN (for 13 DNSPs over 8 years each) are more akin to 13 observations for econometric estimation purposes and this makes estimation of robust econometric models using only this data problematic – a point noted by PEGR (2015, p.37):

> 'In Australia, standardized data are available for only thirteen distributors for the 2006–2013 sample period. A sample with only 104 observations greatly limits the sophistication of econometric cost models that can be developed: it may be impossible to obtain accurate estimates of the cost impact of certain business conditions, or to properly model scale and scope economies.'

To be able to estimate more robust models with good precision in parameter estimates thus requires the addition of more cross–sectional observations than are currently available within Australia. Again, PEGR (2015, p.18) notes:

> 'It is thus especially desirable for the sample to include data for numerous companies. When the sample is small, it will be difficult to identify all of the relevant cost drivers and accommodate the appropriate functional form.'

As also noted in section 3.1, the inadequate degrees of freedom to form robust parameter estimates using only the Australian panel data could manifest itself as a lack of significance for the included output parameters or, alternatively, as spurious precision for additional operating environment factors if included as the limited variation is quickly (but inappropriately) explained (as is the case in CEPA 2015a,b). CEPA (2015a, p.24) also noted that it had difficulty in getting models using only the Australian data to converge and that small changes in specification would lead to lack of stability in its estimates.

As a result, given the limited cross–sectional observations and limited time–series variation within the Australian data, little weight can be placed on the models of CEPA (2015a,b), FE (2015a,b), Huegin (2015a,b,c) and Synergies (2015b) and the illustrative model in PEGR (2014), all of which use or rely on Australian data only. Rather, the models submitted support the case for including overseas DNSP data to increase the number of available cross–sectional observations to improve the precision of parameter estimates. Similarly, attempts to test for differences in slope coefficients across countries in these reports are flawed because there is inadequate variation in the Australian data (given the relatively small number of Australian DNSPs) to obtain sufficiently accurate parameter estimates to support such tests.

3.10.2 132kV line variable inadvertently picks up other effects

A number of the DNSPs' consultants' models include a variable for operating environment factors associated with the operation of very high voltage lines (those above 66kV) by those DNSPs that have relatively 'upstream' boundaries with transmission. In some cases these variables measure the share of network length above 66kV in logged form (CEPA 2015a,b), the share of network length above 66kV in unlogged form (FE 2015b) or the log of kilometres of network above 66kV (PEGR 2014). In all cases where these variables are included, the range of efficiency scores is considerably less than in Economic Insights (2014) and the consultants claim that Economic Insights (2014) omits an important operating environment factor.

The network circuit length above 66kV was included as a variable in the Economic Insights (2014) database but was not used in Economic Insights (2014). After consideration of the variable we noted that it only included non–zero values for the NSW, ACT and Queensland DNSPs in Australia and was zero for all the Ontario DNSPs and all bar two of the included New Zealand DNSPs (and those two only recorded quite short line lengths above 66kV in any case). We were concerned, therefore, that by including this variable we may be inadvertently picking up other effects that may be common to the NSW, ACT and Queensland DNSPs (since the variable is effectively only non–zero for these DNSPs as they are the only DNSPs to have significant lengths of line above 66kV) and incorrectly attributing those effects to the above 66kV operating environment factor.

If, for example, efficiency levels of DNSPs in these three states are not high compared to other DNSPs, there is a risk that an above 66kV variable would pick up inefficiency costs rather than the costs of operating the above 66kV network. There has been considerable commentary regarding the efficiency levels in these states. These include commentary from senior management in the NSW DNSPs (see Graham 2014) citing investment processes and work practices. Detailed independent analysis of work practices in Deloitte Access Economics (2014b) also indicates that these DNSPs are not likely to be operating efficiently. In recognition of the need to improve efficiency levels of the NSW DNSPs, Networks NSW was formed in 2012 with the aim of providing major future efficiency gains across a number of business functions including customer value, asset management, investment governance, safety, finance, risk management, technology, and human resources (Networks NSW 2012).

Similarly, in Queensland a report by the Interdepartmental Committee on Electricity Sector Reform (IDCESR 2013, p.49) noted that the Independent Review Panel on Network Costs it had commissioned had found Energex and Ergon could together achieve an estimated $1.4 billion reduction in operational costs over the 2015–20 regulatory control period. The Panel made 45 recommendations to the IDC on ways that network costs can be reduced and found the DNSPs had ‘a corporate culture geared to expanding network infrastructure and enlarging the capital base of the businesses—driving inefficient expenditure’ (IDCESR 2013, p.48).

And an independent review of ActewAGL’s labour costs and vegetation management practices in 2013 commissioned by the AER has found considerable evidence that ‘systemic issues have resulted in a material level of inefficiency’ (EMCa 2015b, p.i). With regard to ActewAGL’s work practices EMCa (2015b, p.i) found that inefficiency is ‘characterised by duplication of effort in work planning and scheduling, loss of field productivity through ineffective works management and through ineffective data and information management’. Similarly, EMCa (2015b, p.ii) found ‘evidence of inefficient vegetation management costs in 2012/13 due to the manual processes between the office and field and the extent of clearance work that was deemed to be urgent, and which was therefore undertaken with a resultant higher cost’.

Rather than risk inadvertently confusing inefficiency effects and the impacts of having to operate very high voltage lines by including an above 66kV line variable in our econometric models, we opted instead to adjust for differences in relative subtransmission intensiveness as part of our ex post adjustment for additional operating environment factors using information on the actual costs of operating subtransmission lines.

CEPA (2015a,b), FE (2015b) and PEGR (2014) have, on the other hand, opted to include an above 66kV line variable in their econometric models. One way to assess whether this variable is accurately adjusting for the costs associated with operating high voltage lines or whether it is picking up other effects is to compare the implied costs per kilometre of operating these high voltage lines derived from the consultants' models with actual DNSP data.

Ausgrid's Regulatory Accounts separately provide the opex for operating the 66kV and 132kV component of its network and the opex of operating the rest of its network. The Regulatory Accounts indicate that, on a per kilometre basis, Ausgrid's 66kV and 132kV assets are up to twice as costly to operate as the remainder of their network. We assume this is representative of the cost relativity of operating the above 66kV network[7] and that Ausgrid's per kilometre cost relativity is representative of that applying to the other DNSPs with these assets.

Table 3.3 **Opex per km for above 66kV lines as a multiple of opex per km for the rest of the network implied by DNSPs' consultants' models**

DNSP	*DNSP Actual Data*[a]	*CEPA (2015a,b)*	*FE (2015b)*	*PEGR (2014)*
ACT	2	11.7	17.0	9.0
AGD	2	10.4	17.7	11.4
END	2	10.9	17.4	11.7
ESS	2	34.4	14.5	48.2
ENX	2	15.5	15.9	17.6
ERG	2	13.5	16.4	18.1
Average		16.1	16.5	19.3

[a] Based on Ausgrid Regulatory Accounts

The implied opex per kilometre for above 66kV lines relative to the rest of the DNSPs' networks derived from the three consultants' models are listed in table 3.3. The implied multiples from the consultants' reports range from 9 to 48 times compared to the 2 times based on actual DNSP data. The average multiple for CEPA (2015a,b) is 16 times, for FE (2015b) is 17 times and for PEGR (2015) is 19 times. These multiples are all several times higher than the 2 times multiple derived from actual DNSP data and confirm our concern that the above 66kV variable picks up effects other than the higher cost of operating these lines. It is likely the models are mistakenly misallocating inefficiency costs to the 132kV network variable[8]. In this sense the consultants' models suffer from a similar problem to the latent homogeneity models discussed in section 3.5 whereby persistent efficiency differences are mistakenly measured as differences in operating environments. The smaller efficiency gaps shown by these models are thus false.

[7] Ausgrid's 66kV line length comprised only 20 per cent of its 66kV and above line length in 2013.

[8] It should also be noted that correlation of the above 66kV variable with DNSP efficiency scores would violate a key assumption of the OLS and random effects models used by the consultants which require the error term(s) to be independent of included exogenous variables.

Another illustration of the impact of the above 66kV variable inadvertently picking up other effects, including inefficiency costs, can be seen by comparing the consultants' models' implied shares of above 66kV network opex in total opex for Ausgrid in 2013 with Ausgrid's actual data. In its Category Analysis RIN Ausgrid indicated that its 66kV and above network costs made up 7.5 per cent of its total opex in 2013. However, the CEPA (2015a,b) model results imply that the share of above 66kV network opex in total opex was 31 per cent in 2013, the FE (2015b) model results imply it was 44 per cent while the PEGR (2014) model results imply it was 34 per cent – and it should be noted that the consultants' models' coverage excludes 66kV network opex whereas it is included in the much smaller Category Analysis RIN figure. Again, the consultants' models' overestimates of this share by several fold illustrate that the model results are mistakenly misallocating inefficiency costs to the 132kV network variable and are substantially underestimating performance gaps.

Analysis of the consultants' models which incorporate the above 66kV variable vindicate our decision to adjust for differences in subtransmission intensiveness by way of ex post adjustment based on evidence of the actual relative costs per kilometre of operating subtransmission networks relative to the rest of the DNSP's network. This avoids the risk of mistaking inefficiency costs and other effects specific to the six DNSPs that operate lines above 66kV with the costs of operating those lines as the DNSPs' consultants' reports have done.

3.10.3 Latent heterogeneity models underestimate efficiency differences

As discussed in section 3.5, the latent heterogeneity and related models in FE (2015a) and Huegin (2015b) are claimed to allow for inherent differences in operating environments. They do this by attributing systematic differences in performance to latent (or unidentified) differences in operating environments. These methods, hence, all tend to overestimate efficiency scores because they do not allow for ongoing differences in efficiency levels over the sample period.

Huegin (2015b) claims to have found 4 'latent classes' but does not include country dummy variables. One would expect the three countries to show as separate classes when no adjustment is made for cross–country differences – our econometric models, on the other hand, do include such an adjustment. And Huegin's 'k–means clustering' simply identifies clusters of DNSPs that are similar to each other in terms of closeness of their means. It does not provide evidence that the DNSPs in these clusters are significantly different from each other nor that they belong to separate cost functions.

We believe our approach of estimating models which take account of the key density and undergrounding variables for all DNSPs in the sample and then making additional adjustments for identified additional material operating environment factors for the Australian DNSPs is a superior approach. Failure to allow for these additional operating environment factors would tend to underestimate some DNSPs' efficiency scores (and overestimate base year opex adjustments) while adopting the latent heterogeneity approach tends to overestimate their efficiency scores (and underestimate base year opex adjustments). Our use of the two stage process for calculating the overall adjustment for operating environment differences provides a means of reaching the most appropriate point within the range of possible base year adjustments.

3.10.4 Inadequate observations lead to 'efficiency by default'

As discussed in section 3.7, the DEA models reported in FE (2015a), Huegin (2015a) and Synergies (2015b) suffer, to varying degrees, from the 'efficiency by default' problem encountered in applying DEA to relatively small and diverse datasets. This leads to some firms being identified as efficient solely because DEA is not able to compare them with other sampled firms. This also leads to the inclusion of more outputs and inputs for a given sample size in DEA producing higher efficiency scores simply because the method has difficulty finding similar combinations of outputs and inputs so more firms become efficient by default, regardless of whether they are truly efficient or not.

3.10.5 Inadequate or incomplete model specification

A number of the DNSPs' consultants' models have inadequate specifications or specifications that are not relevant to assessing the DNSPs' opex forecasts. For example, as noted in section 2.1, CEPA (2015a,b) include only one primary output and varying numbers of claimed operating environment factor variables. To adequately model the cost characteristics of DNSPs, we believe several output variables are required to adequately represent the functional output dimensions of a DNSP. Key candidates include energy delivered, customers served, line length, transformer capacity or actual demand and reliability.

FE (2015b) include an ad hoc additional second order term to model a potential non–linearity in customer density when this is done in a more comprehensive way in Economic Insights (2014) using the translog functional form and found not to be material.

Huegin (2015a) include several sets of opex MPFP results using output specifications that were discussed during the workshop process in 2013 used to develop and refine our preferred output specification. These specifications were subsequently superseded.

And Synergies (2015b) presents a DEA model that covers three inputs (opex and two capital input measures) and is thus not relevant to the issue at hand of assessing opex efficiency. It furthermore appears to mistakenly use a measure of the cost of a capital input as its corresponding capital quantity measure.

3.10.6 Other overseas data limits model specification

PEGR (2014) presents the results of a model combining EBRIN and US data. However, this exercise highlights the significant limitations of current US data collection and reporting and the limitations it places on model specification. While a large amount of data is reported in the US, this mainly concentrates on financial variables and many quantity measures that are fundamental to productivity measurement are either not reported at all or are not reported consistently. For example, there is very little line length data available for the US and what there is available is typically not consistently reported and is for route length rather than circuit length. There are also no data available for distribution transformer capacity and no consistently reported data for key output variables including maximum demand and reliability.

PEGR (2014) was only able to assemble an unbalanced data panel for 15 US DNSPs that had the minimal data required for two or more years. While there are 170 US DNSP observations in the PEGR (2014) database, data for four of the 15 US DNSPs covers 18 or more years and for another 6 DNSPs covers 12 to 15 years. Four of the US DNSPs, on the other hand, have only three years or less data. The remaining DNSP has only 5 years of data. The effects of this very unbalanced panel on the currency, representativeness and accuracy of resulting parameter estimates are not clear.

Furthermore, the US data are not generally comparable in terms of coverage and definition with the New Zealand and Ontario data and did not support our preferred specification using Australian data. A further complication with the US data is that many network businesses are vertically integrated with generation and other activities and thus cost allocation issues can be significant.

In our view, the use of US DNSP data in the PEGR (2014) model unnecessarily limits the use of appropriate output and input specifications and involves the use of data that is likely to be less consistent and robust than the New Zealand and Ontario databases used in Economic Insights (2014). It also provides access to many fewer additional observations and is thus likely to provide less precise parameter estimates.

3.10.7 Other issues and summary

In Economic Insights (2014) we made adjustments to the opex data before estimation to make them as consistent as possible across the Australian DNSPs. These adjustments included removing feed–in tariffs, costs associated with metering services, public lighting services, etc. CEPA (2015a, Annex A) lists substantial additional adjustments it has made to the EBRIN data ‘for differences in overhead capitalisation rates across DNSPs’. However, providing adjustments for differences in capitalisation practices in only certain categories is likely to bias opex forecasts. This is because a DNSP is likely to only identify differences in practice that provide it with a cost disadvantage, therefore increasing its operating environment factor adjustment. A better method, in our view, is to examine the opex to totex ratio at the overall level. This accounts for differences in opex/capex trade–offs and differences in accounting policies. The latter approach is used in AER (2014a,b,c,d and 2015a,b,c,d,e) and the results are incorporated in our ex post adjustments for additional operating environment factors.

Another issue identified in our review of the consultants’ modelling files we have had access to is that PEGR (2014) appears to have made a Stata coding error in its formation of its Victorian bushfire operating environment variable. PEGR (2014) forms this variable by multiplying a bushfire risk metric by a dummy variable that equals one for the Victorian DNSPs (other than CIT) for the years 2009 to 2013 and zero otherwise. However, PEGR (2014) mean–scales the bushfire metric before multiplication with the dummy variable which leads to the operating environment variable having positive values for PCR and AND but *negative* values for JEN and UED. Since JEN and UED also incurred additional costs as a result of changes introduced following the bushfires, the PEGR coding error will bias its results. It also ignores the fact that CIT's costs have increased following the VBRC as well.

The McKell Institute (2014) study used the EBRIN data to benchmark the Australian DNSPs using a simple partial indicator measure of opex per customer. It then attempts to separate opex into 'upkeep costs' (poles and wires expenditure) and 'state–specific costs' (taxes and levies, insurance and corporate financing costs). It regresses upkeep costs per customer against line length and finds a positive relationship. It goes on to claim, somewhat surprisingly, that upkeep costs should be excluded from future assessments of relative DNSP efficiency 'because of the substantial differences in the physical span of networks, as well as other environmental factors such as energy intensity and the share of the network in underground assets'. However, restricting this major component of network opex from scrutiny would involve customers paying ongoing costs for DNSP inefficiency without check.

The McKell study can best be described as very simplistic. It has a minimalist coverage of DNSP outputs and does not attempt to estimate a cost function within a consistent framework. Similarly, its treatment of operating environment differences is limited to one rudimentary regression. We note that our economic benchmarking contains outputs which account for differences in customer density, energy density and network scale. And the other operating environment factors McKell Institute expresses concern about are addressed either directly in our econometric modelling or via our ex post adjustments. The Energy Supply Association of Australia (2014) provides a useful review of the McKell Institute's analysis.

Table 3.4 **Problems identified with DNSPs' consultants' models**

Problem identified	*Consultant models affected*
1. The Australian data has inadequate variation to support robust model estimation where it is the only data source used and where tests for parameter differences across countries are made	CEPA (2015a,b) FE (2015a,b) Huegin (2015a,b,c) Synergies (2015b) PEGR (2014)
2. Use of a 132kV line variable inadvertently picks up other effects and leads to efficiency gaps being understated	CEPA (2015a,b) FE (2015b) PEGR (2014)
3. Latent heterogeneity models incorrectly allocate persistent inefficiency effects to operating environment differences	FE (2015a) Huegin (2015b)
4. Inadequate observation numbers lead to some models misleadingly finding DNSPs to be 'efficient by default'	FE (2015a) Huegin (2015a) Synergies (2015b)
5. Some output and input specifications are inadequate and/or not relevant	CEPA (2015a,b) FE (2015b) Huegin (2015a,b) Synergies (2015b)
6. Other overseas data sources unduly limit the range of variables and number of comparators that can be included	PEGR (2014)

In summary, after a detailed review we have found that all the alternative models submitted by the DNSPs' consultants have serious flaws and should not be relied upon to assess DNSP efficiency levels nor be used to base regulatory decisions on. We have identified six key problem areas and all the DNSPs' consultants' models are subject to at least three of these key problems. A summary of the key problem areas and which consultants' reports are affected by each is presented in table 3.4.

Based on our detailed review of the DNSPs' consultants' reports we find no reason to modify the basic approach we adopted to economic benchmarking of the NSW and ACT DNSPs in Economic Insights (2014) and so that approach is updated in this report and extended to cover the Queensland DNSPs.

4 THE APPROPRIATE BENCHMARK FRONTIER

In this section we respond to the following issues raised in the DNSPs' consultants' reports:

- calculating average versus 2013 efficiency scores
- moving from average to 2013 efficiency measures
- apparent narrowing of the performance gap, and
- views presented on targets and operating environment factors.

After considering the submissions we then present our recommendations for appropriate base year opex adjustments in section 5.

4.1 Calculating average versus 2013 efficiency scores

The DNSPs' consultants' reports present mixed and often internally conflicting views on whether DNSP opex efficiency should be calculated on the basis of average performance over a number of years or on the basis of the most recent year available. For example, FE (2015a, p.xix) recommends that the AER 'rely on most recent evidence from 2013'. However, FE (2015a, p.67) also notes, in the context of cross sectional analysis, that 'it is similarly not clear which year of data may be representative of the forthcoming regulatory period across the industry, and hence which year should be preferred'. But, at the same time, FE (2015a, p.67) criticises the use of average efficiency scores because they 'may well be heavily influenced by either past inefficiency that has already been addressed, or by past costs incurred to deliver activities that are now no longer undertaken at all or undertaken in the same volume'.

Similarly, PEGR (2015, p.64) notes:

> 'The limitations of focusing on average efficiency over the full sample period should also be noted. It is important for the regulatory community to have information about recent performance rankings.'

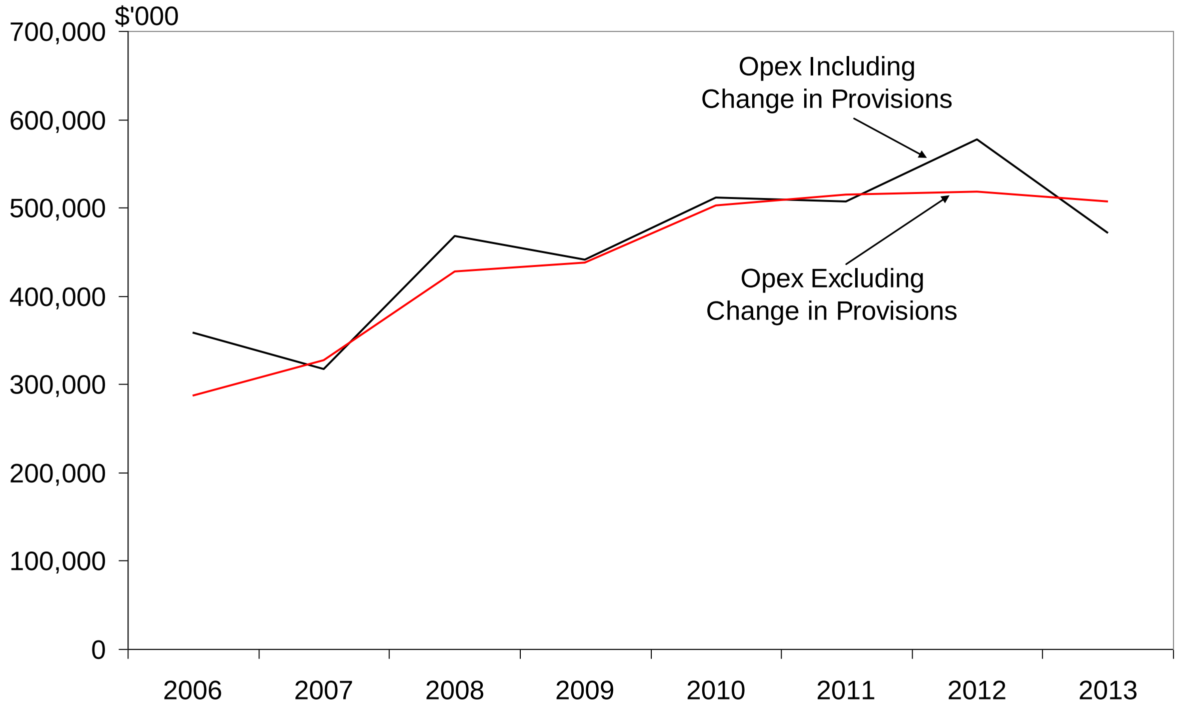
PEGR (2015, p.60) also notes that DNSPs should be evaluated over 'the most recent years … which is arguably much more relevant than their activities many years ago'. However, PEGR (2015, p.17), after noting the potential volatility of year–by–year results, states 'more stable results can be achieved by taking an average of performance comparisons over several years'.

We agree with PEGR (2015, p.17) that average efficiency scores are preferable because they reduce the impact of year–specific fluctuations not under the control of the DNSP (such as weather conditions) while also reducing the scope for the DNSP to engage in gaming by strategically reducing its reported opex in a single, nominated benchmark year. This is the first step of the two stage approach we adopted in Economic Insights (2014). Since the RIN database covers a period of 8 years from 2006 to 2013, it will be sufficiently recent to reflect the current situation. We similarly supplemented the RIN data with only the most recent 8 years of data available for New Zealand and Ontario DNSPs to maintain a balanced panel.

This contrasts with the unbalanced US database used to supplement the RIN data in PEGR (2014) which contains observations for four of the 15 US DNSPs covering 18 or more years and for another 6 DNSPs covering 12 to 15 years. In this context one can appreciate the concern expressed in PEGR (2015, p.60) regarding the relevance of activities from 'many years ago'. Dated observations may influence parameter estimates and produce incorrect efficiency results. This issue is not relevant for the approach adopted in Economic Insights (2014) of only taking the most recent 8 years of data and using average efficiency scores for this period as the starting point. Similarly, our approach has the advantages of not being dependent on any one year and its special circumstances or DNSP gaming in that year, while being sufficiently recent to avoid the potential loss of current relevance noted in FE (2015a, p.67). And the method outlined in the following section is used to update the scores to 2013.

It is particularly relevant to examine the changes in year–to–year opex reported by some of the NSW/ACT DNSPs as it highlights the potential problems of relying on one particular year for efficiency assessments as FE (2015a, p.xix) advocates – we note there are insufficient observations to reliably do this in any case. Reported opex for network services will be influenced by the timing of changes in provisions recorded by the DNSP. If one is working with opex inclusive of changes in provisions – as is the standard basis for reporting – then there is some scope for the DNSP to choose the timing of reported changes in provisions. Over time one would expect the opex series inclusive and exclusive of changes in provisions to be approximately equal on average. But in any one year there can be significant variations.

Figure 4.1 **Ausgrid opex including and excluding change in provisions, 2006–2013**



In figure 4.1, for example, we present Ausgrid's nominal opex series including and excluding change in provisions. The series inclusive of the change in provisions is considerably higher than the series excluding the change in provisions in 2012 but lower than it in 2013. An assessment of efficiency scores for 2013 only based on the series including the change in provisions would put Ausgrid in a more favourable light than if the series excluding the change in provisions was used. Similarly, using the series including the change in provisions will lead to an apparent marked upturn in performance in 2013 compared to using the series excluding the change in provisions which would reflect more steady performance. If one takes the average efficiency performance over the 8 year period, however, there will be little difference between the results obtained from using either series. Broadly similar patterns are also observed for Endeavour Energy and Essential Energy which both exhibit apparent marked upturns in opex performance in 2013 due to the timing of (negative) changes in provisions.

4.2 Moving from average to 2013 efficiency measures

In Economic Insights (2014) we rolled the average opex efficiency score for each DNSP forward to 2013 by calculating the DNSP's average constant price efficient opex level and then rolling this forward to 2013 using a rate of change formula. This formula rolls the constant price opex forward by the change in output (derived using weights calculated in the opex cost function) less the rate of (DNSP–specific) opex PFP growth derived from the opex cost function. If a DNSP has increased its constant price opex by less between the average of the period and 2013 than the rate of change formula allows then it would receive a smaller base year opex reduction compared to that implied by its efficiency assessment at the sample average. Conversely, if the DNSP has increased its constant price opex by more than the rate of change formula allows then it would receive a larger base year opex reduction compared to that implied by its efficiency assessment at the sample average.

Huegin (2015a) and Synergies (2015b) were the only DNSP consultant reports to comment on this process. Huegin (2015a, p.22) states:

> 'The use of averages over time also erode the accuracy of the measures as they relate to current efficient expenditure, as businesses that have increased expenditure will reap the benefit of the historical average against businesses that have not. Taking historical averages also assumes that past conditions are representative of current and future conditions, which is unlikely given the amount of change and reform in the industry over the past four years.'

Synergies (2015b, p.34) states:

> 'It is possible that Australian DNSPs with low average efficiency scores from these measures have, in fact, exhibited substantial efficiency gains in later years. If this be so, then reducing 2013 operating costs by an amount equal to the average level of inefficiency over the study period would have the effect of reducing operating costs below the efficient level for that DNSP.'

Both these statements are incorrect as they fail to recognise the roll–forward rate of change mechanism we have used which allows for differences in DNSPs' relative opex growth rates between the average and 2013. As noted above, if a DNSP has increased its constant price opex by less between the average of the period and 2013 than the rate of change formula allows then it would receive a smaller base year opex reduction compared to that implied by its efficiency assessment at the sample average. Furthermore, changes in the industry over the last four years have largely been influenced by the reduction in energy throughput and peak demands and these are allowed for in our rate of change mechanism.

Huegin (2015a, p.26) goes on to state:

> 'We also consider that an almost complete focus on historical data, rather than the forecast provided by the businesses, undermines the fitness for purpose of the measures as determinants of efficient levels of expenditure in the forthcoming regulatory period.'

We find this statement difficult to understand as the purpose of the AER's economic benchmarking approach is to provide an independent check on the reasonableness of the DNSP's forecast opex. It does this by forming an alternative forecast of the DNSP's efficient opex requirements using the base/step/trend approach. Economic benchmarking contributes to the base and trend elements of this alternative forecast. If the DNSP's opex forecast is markedly higher than the AER's alternative forecast then the AER has the option of disallowing the DNSP's forecast and substituting the alternative forecast for it. To rely solely on the 'forecast provided by the businesses' would run the risk of the regulator being gamed and consumers paying for inefficiently high levels of expenditure.

Based on the consultants' reports submitted there is no reason to change from using the rate of change mechanism to roll the DNSP opex adjustments from the average of the 8 year sample forward to 2013. And, as noted in the preceding section, our approach has the advantage of our efficiency estimate not being dependent on any one year and its special circumstances or DNSP gaming in that year while allowing that estimate to then be rolled forward to 2013 using an objective and consistent methodology.

4.3 Apparent narrowing of the performance gap

Two consultants' reports have commented on an apparent narrowing of the gap between the best and worst opex efficiency performers over the second half of the period. These comments are largely based on annual opex MPFP scores reported in Economic Insights (2014), since our econometric results apply to the sample average and are then rolled forward to 2013 for the NSW/ACT DNSPs as discussed above. For example, PEGR (2015, p.64) notes:

> 'Among the Australian DNSPs, some state–owned distributors (e.g., Ausgrid and Ergon) improved their relative performance in later years of the sample period while certain privately–held distributors (e.g., SA Power Networks) regressed.'

Huegin (2015a, p.55) states:

> 'Whilst the AER have allowed for the change in productivity of the businesses (which has a benefit for Endeavour Energy and Ausgrid, but a penalty for ActewAGL and Essential Energy) since the midpoint of their data, they have not recognised the current position of the frontier – 9% lower productivity than the midpoint. The efficiency gap assumed for all four businesses is therefore 9% more than it should be assumed to be.'

Huegin (2015a, p.53) also states:

> 'It is worth noting that the primary driver of the convergence of productivity scores of the frontier relative to the NSW and ACT businesses is largely driven by

increases in vegetation management expenditure by the frontier businesses (which in turn were precipitated by the Victorian bushfires).'

A number of points need to be made in response to these statements. Firstly, as identified above in figure 4.1, extreme caution needs to be exercised regarding statements about changes in the NSW DNSPs' opex performance in 2013 due to the influence of change in provisions timing. The DNSPs' decisions to include a large negative change in provisions in 2013 have the effect of making the DNSPs' performance appear considerably better in 2013 than is the case using the series that excludes the change in provisions. Consequently, the figures in 'exhibit 4.13' and 'exhibit 4.14' in Huegin (2015a, pp.54–5) are likely to give an artificial impression of a significantly closing gap at the end of the period. This is particularly the case for 'exhibit 4.14' which only includes data points for 2006, 2009 and 2013.

We do, however, note that the Victorian DNSPs' opex MPFP has tended to reduce in the second half of the period. This largely reflects the granting of an overall average step increase in opex of around 10.4 per cent for the regulatory period commencing in 2011. Much of this step change was the result of increased opex requirements following the implementation of Victorian Bushfires Royal Commission (VBRC) recommendations. And SA Power Networks' opex MPFP also reduced in 2011 due in part to a step change allowance for increased vegetation management. SA Power Networks attributed this step change to the need to move from a three year cycle to an annual cycle in bushfire risk areas due to legislation restricting it from clearing vegetation to a greater distance from power lines. These step changes are important contributors to the estimated negative rate of technical change which leads to a negative rate of opex partial productivity growth being used in the rate of change formula used to roll average efficiency results forward to 2013.

It is also important to recognise that the SFA and LSE models calculate average efficiency levels over the period and these averages incorporate the influence of the situation at the end of the period. Or, to put it another way, they calculate average efficiency for the period rather than midpoint efficiency. The Huegin (2015a) argument is based on it being a midpoint estimate and hence not making any allowance for changed conditions at the end of the period. But, because the efficiency score is an average, it already partially allows for the changed conditions at the end of the period (assuming they have in fact changed).

This was allowed for in the input adjustment applied to the top quartile firms in Economic Insights (2014). Assuming that the requirements introduced in Victoria following the VBRC are more onerous than those applying in NSW/ACT, the Victorian DNSPs now have to use more opex than their NSW/ACT peers, all else equal, due to the more stringent bushfire–related opex requirements they face. The extent of this additional opex requirement was estimated by AER (2014a,b,c) and the opex disadvantage facing the Victorian DNSPs was offset against the operating environment advantages the top quartile DNSPs enjoy relative to the NSW/ACT DNSPs in arriving at the net 10 per cent input margin applied to the top quartile DNSPs in Economic Insights (2014).

The adjustment applied for VBRC recommendation effects was predicated on the current Victorian bushfire standards being higher than those which apply in NSW/ACT and the pre–VBRC standards generally being similar across the south–eastern states. It is not straightforward to compare bushfire–related opex standards across Victoria and NSW. The

NSW regime has been at DNSP discretion but subject to safety regulator approval throughout the period 2006 to 2013 and there has been no change in underlying requirements. The Victorian regime pre–VBRC, on the other hand, was more prescriptive than that in NSW although exemptions were regularly granted by the Victorian safety regulator. Following the VBRC, the Victorian requirements have been made more stringent and previous exemptions have not been renewed.

Subsequent analysis in AER (2015a,b,c) indicates that Victoria has higher inherent bushfire risk than NSW so that, all else equal, a prudent Victorian DNSP would be expected to spend more on bushfire risk mitigation than a prudent NSW DNSP. However, this may be partly offset by a higher degree of forestation for some NSW DNSPs. And duty of care requirements can be expected to lead to the NSW DNSPs progressively adhering to some of the higher Victorian requirements even though this is not a formal requirement they face.

We therefore conclude that pre–VBRC Victorian DNSP bushfire–related opex would have been at least as high as in NSW when differences in the nature of the regimes are taken into account. And post–VBRC Victorian DNSP bushfire–related opex increased due to the more stringent and onerous explicit requirements now imposed on the Victorian DNSPs in key areas. Over time we would expect the NSW DNSPs to move to match, at least in part, the higher Victorian standards due to duty of care considerations. We note that the more detailed analysis in AER (2015a,b,c) indicates that the opex cost disadvantage facing the Victorian DNSPs is now around 0.5 per cent rather than the earlier estimate of 2.4 per cent once the higher degree of forestation facing some NSW DNSPs and the implications of duty of care considerations are allowed for.

We therefore believe the broad treatment of bushfire–related opex requirements in Economic Insights (2014) was appropriate since available information is consistent with Victorian and NSW DNSP bushfire–related opex practices being at least broadly equivalent pre–VBRC and the new Victorian explicit standards being more onerous than previous practice commonly adopted in NSW. Consequently, no further changes are required to the general approach used to form base year opex recommendations in Economic Insights (2014) despite an apparent narrowing of the opex performance gap from 2011 onwards. Updated estimates of the impact of bushfire–related regulations and practices (and of other operating environment factors) based on the more detailed analysis in AER (2015a,b,c,d,e) are incorporated in our updated findings in section 5.

4.4 Views presented on targets and operating environment factors

4.4.1 Targets

Economic Insights (2014) set a target for opex efficiency performance equal to the customer weighted average opex efficiency score of the five Australian DNSPs achieving opex efficiency scores in the top quartile of possible scores (ie those achieving opex efficiency scores in excess of 0.75) in our opex cost function modelling. The resulting opex efficiency target was 0.86, in contrast to the highest opex efficiency score achieved by an Australian DNSP of 0.95. We then allowed for additional operating environment factors not included in the econometric modelling which further reduced this target to 0.78 for the NSW DNSPs and 0.66 for ActewAGL. The reasons for this conservative approach were described as follows:

> 'we are of the view that it is prudent to adopt a conservative approach to choosing an appropriate benchmark for efficiency comparisons. Adopting a conservative approach allows for general limitations of the models with respect to the specification of outputs and inputs, data imperfections and other uncertainties. This is because all models are by definition a simplification of reality and may not capture all relevant effects. That said, however, it should be noted that the country–specific dummies we have included in the opex cost functions do allow for any systematic differences between countries.' (Economic Insights 2014, p.47)

FE (2015a, p.xix) supports this conservative approach as it recommends the AER:

> 'Recognise explicitly that no benchmarking model is perfect, and that any modelling of this kind is subject to uncertainty (deriving from data limitations, heterogeneity in firm characteristics that is difficult to account for, model limitations and statistical noise)'.

Other regulators adopt a broadly similar cautious approach in setting efficiency targets to the one we have. For example, Ofgem in the UK sets a target of the upper quartile DNSP's performance in electricity distribution and of closing 75 per cent of the gap to the upper quartile firm's performance in gas distribution (FE 2015a, p.97). The Economic Insights (2014) approach of adopting a weighted average of the scores of DNSPs in the upper quartile of possible scores resulted in a slightly higher target than had we to adopted Ofgem's electricity distribution approach of taking the performance of the upper quartile DNSP as the target (which in this case would result in a target efficiency score of around 0.84 compared to our weighted average target of 0.86). However, we further significantly reduced our target by allowing for additional operating environment factors not included in the econometric modelling.

PEGR (2015, p.64) supports a broadly similar approach:

> 'We recommend that a competitive market standard, like that employed by Ofgem, be used to assess the need for potential opex revenue adjustments. Utilities should be considered for disallowances only to the extent that their measured efficiency fails to reach the lower bound of the top quartile of the sample distribution. All performers above this level should be eligible for superior rates of return.'

CEPA (2015a, p.35) appeared to advocate a more cautious approach:

> 'Given the lack of explanatory variables in the modelling and the wide range of efficiency scores I would have expected the AER to have adopted a much more cautious approach to setting the efficiency target in line with international precedent.'

However, as noted above, our approach resulted in an efficiency target only slightly higher than had we used the approach adopted by Ofgem before allowance for additional operating environment factors not included in the econometric modelling, although Ofgem does also average results from different models. After allowing for additional operating environment factors not included in the econometric modelling, our target was reduced by at least a further 8 percentage points.

Synergies (2015b, p.13) also appears to advocate a more cautious approach which takes account of the confidence interval around the efficiency target, although it goes on to note that caution is required in interpreting SFA confidence intervals.

In a similar vein, FE (2015a, p.xviii) puts forward a range of options for 'moderating' application of our results as follows:

- 'using glide paths;
- combining their modelling results with company forecasts;
- locating the efficient frontier derived from benchmarking in a less onerous manner; or
- using benchmarking analysis to determine relative efficiency rankings then using those rankings to set pre–determined moderated efficiency adjustment factors for cohorts of networks'.

However, with the possible exception of the third and, possibly, the fourth options, these options do not reflect a close familiarity with the application of the building blocks regime in Australia as required by the National Electricity Rules (NER). The NER require the AER to accept forecast opex that reflects efficient costs that would be incurred by a prudent operator. This makes the first option questionable as allowed costs for part of the period would not be efficient. A similar problem arises with the second option if the company forecasts are not efficient and there is also widespread scope for DNSP gaming under this option. Our current approach is consistent with the third option and the fourth option is simply a variant of it.

Importantly, the approach used by the Ontario Energy Board discussed by FE (2015a, p.xviii) of setting 'stretch factors' for cohorts of DNSPs based on efficiency rankings is a form of productivity–based regulation where rankings and stretch factors are set based on total cost (or TFP) performance rather than on components of costs as under the Australian building blocks regime. Under the building blocks regime the X factor is specifically set to equate the net present value of forecast revenue with that of revenue requirements (which is built up from the separate opex, capital building and taxation components). But under a productivity–based regulatory regime the X factor is set based on the industry TFP growth rate plus any stretch factors. The differences between building blocks regulation and productivity–based regulation are illustrated in the Economic Insights (2010) quantitative model available on the Australian Energy Market Commission website.

This distinction between productivity–based regulation and building blocks regulation also lies at the heart of the approach developed for the New Zealand Commerce Commission in Lawrence (2003) and quoted in CEPA (2015a, p.40; 2015b, p.14). The then New Zealand 'thresholds' regime was a relatively pure example of productivity–based regulation where a maximum price path (ie total cost trajectory) was set based on industry productivity growth and three broad groupings of MTFP rankings. Since a productivity–based regime has to take account of total input efficiency and of adjustment times – and given the capital intensity of electricity networks and the long–lived nature of that capital – an adjustment period of 10 years to achieve convergence of productivity levels was thought reasonable. This was also at a time of considerable change in the New Zealand industry with many amalgamations having recently occurred and no price regulation having previously been in place.

Under building blocks regulation, a lengthy adjustment period for total costs is inbuilt because the bulk of DNSPs' prices are determined by the return on and return of existing capital with only a minority directly affected by current opex and capex. The focus in building blocks is then mainly about achieving efficient levels of opex and capex which can be adjusted relatively quickly without endangering the DNSP's financial viability. However, under productivity–based regulation the return on and return of existing capital is not necessarily guaranteed as it is under building blocks regulation and so lengthy adjustment periods have to be factored into the setting of X factors. Furthermore, the Australian industry, unlike the New Zealand industry in 2003, is relatively settled and has been subject to price regulation for an extended period. The quotes in CEPA (2015a,b) from Lawrence (2003) are therefore not relevant to the building blocks review of the NSW, ACT and Queensland DNSPs. And it should be noted that the New Zealand DNSP regulatory regime has since changed to a high level building blocks regime sharing many similarities with that found in Australia.

4.4.2 Operating environment factors

Operating environment factor differences across the included DNSPs was an issue raised in most of the DNSP consultants' reports. However, as discussed in section 2.3, Economic Insights (2014) adopted a detailed and thorough three stage process to allow for operating environment differences. Firstly, we made adjustments to the opex data before estimation to make them as consistent as possible across the Australian DNSPs. These included removing feed–in tariffs, costs associated with metering services, public lighting services, etc.

Next, we incorporated the main features of the key operating environment differences as reflected in network density effects (customer density, energy density and demand density) in our output specification. This is neatly illustrated in FE (2015b, p.39). This was combined with the extent of undergrounding in our econometric modelling. And our inclusion of country dummy variables for the New Zealand and Ontario DNSPs allowed for systematic differences in operating environments across countries (as well as for differences in reporting practices, etc across countries).

Finally, remaining operating environment effects which cannot be incorporated directly in the modelling, usually due to there being incomplete data on these factors across all the included DNSPs, were adjusted for ex post.

As discussed in section 3.5, FE (2015a,b) and Huegin (2015a,b) have attempted to identify residual sources of heterogeneity in DNSP operating environments by the use of 'latent heterogeneity' and 'latent class' models and calculations. However, upon review, none of these models and calculations is persuasive and they fail to invalidate the approach we have used in our economic benchmarking.

After reviewing the consultants' reports' material relating to operating environment factors we are of the view that our general approach to the treatment of operating environment factors in Economic Insights (2014) was appropriate and the does not require modification. In section 5 we update and extend our findings taking account of the subsequent more detailed analysis and incorporation of recent information (including from the DNSPs' revised proposals and submissions) in AER (2015a,b,c,d,e). This information is used to update our ex post adjustments for additional operating environment factors not included in our econometric models.

We have also reviewed the material in FE (2015b) relating to Ofgem's application of 'special factors' for DNSPs with unusual characteristics or for factors thought not to be adequately handled in their modelling. We note there would inevitably be a degree of arbitrariness in the application of such an approach. The potential candidates for special treatment identified in the consultants' reports are Essential Energy and Ergon Energy due to their relatively long line lengths and relatively low customer densities compared to other DNSPs. As noted in section 3.3, Huegin (2015a) claimed that Essential Energy has no peers in our frontier DNSP group. However, if our model was treating these DNSPs as outliers, we would expect considerably higher opex efficiency scores being allocated to them by the more flexible translog model than the less flexible Cobb–Douglas model. However, because the econometric models all find similar efficiency scores for these two DNSPs, there is no evidence to suggest that they are not being modelled adequately. This is supported by the EMCa (2015a) engineering review commissioned by the AER which indicates the relationship between maintenance opex and line length and between non–maintenance opex and customer numbers can be expected to be approximately linear for rural and remote DNSPs. Since the CD model implies approximately linear relationships over the variables' relevant ranges, no additional allowance for the characteristics of the remote DNSPs is required. Consequently, our combination of direct incorporation of the main operating environment factors in our econometric modelling and ex post adjustment for the effects of material operating environment factor differences among the Australian DNSPs means the need for consideration of applying additional 'special factor' allowances to a particular DNSP or DNSPs is redundant.

5 FINDINGS

In the preceding sections of this report we have reviewed the critiques by the NSW, ACT and Queensland DNSPs' consultants of the Economic Insights (2014) economic benchmarking of Australian electricity DNSPs. Based on our review of the arguments presented and of the alternative models presented by the consultants, we have found no reason to change the general approach adopted in our 2014 benchmarking analysis. We do, however, consider there is a case for revising the opex efficiency target. And updated and more detailed information on the impact of operating environment factors not explicitly included in the opex cost function model is now available. In this section we review each of these topics before presenting our findings on adjustments to the NSW, ACT and Queensland DNSPs' base year opex.

5.1 Opex efficiency target

As noted in section 4.4.1, Economic Insights (2014) set an initial target for opex efficiency performance equal to the customer weighted average opex efficiency score of the five Australian DNSPs achieving opex efficiency scores in the top quartile of possible scores (ie those achieving opex efficiency scores in excess of 0.75) based on our opex cost function modelling. Our approach resulted in a slightly higher target than were we to adopt Ofgem's electricity distribution approach of taking the performance of the upper quartile DNSP as the target (which in this case would result in a target efficiency score of around 0.84 compared to 0.86 using the weighted average score of the five DNSPs achieving opex efficiency scores in the top quartile of possible scores). Ofgem adopts a more conservative target in the case of gas distribution where it seeks to close 75 per cent of the gap to the upper quartile firm's performance, recognising that the quality of its gas data is not as high as that of its electricity data. And, Ofgem makes use of 'top–down econometric models, bottom–up unit cost analysis, bottom–up engineering assessments, assessments of historic costs and assessments of forecast costs, in order to provide the scope to cross check and sense check the efficiency estimates derived by any single approach' (FE 2015a, p.97). However, we then allowed for additional operating environment factors not included in the econometric modelling which further reduced our target to 0.78 for the NSW DNSPs and to 0.66 for ActewAGL.

We have previously noted that it is prudent to adopt a conservative approach to choosing an appropriate benchmark for efficiency comparisons. Adopting a conservative approach allows for general limitations of the models with respect to the specification of outputs and inputs, data imperfections and other uncertainties. While we have not found any of the criticisms made of our 2014 economic benchmarking study warrant changes to be made to our underlying approach, we are of the view there may be a case for setting a more conservative target than that used in Economic Insights (2014). This is particularly the case given that this is the first time economic benchmarking is being used as the primary basis for an Australian regulatory decision.

We are of the view that instead of using the customer weighted average of efficiency scores in the top quartile of possible scores, a more conservative approach of using the lowest of the efficiency scores in the top quartile of possible scores is appropriate. This would make the average efficiency score of 0.77 achieved by AusNet Distribution the appropriate opex efficiency target, before allowance for additional operating environment factors not included in the econometric modelling. Being a predominantly rural DNSP also makes choosing AusNet Distribution's score a relatively conservative choice for the efficiency target. This change represents a 9 percentage point reduction in the opex efficiency target (from 0.86 to 0.77) and so is a generous additional allowance for any remaining modelling limitations, data imperfections and other uncertainties. It also represents a lower target of around the bottom of the top third of DNSPs compared to Ofgem's target of the 75th percentile DNSP. Allowance for the additional operating environment factors not included in the econometric modelling then further reduces this target again (to between 0.62 and 0.69, depending on the DNSP).

5.2 Incorporating operating environment factors not explicitly included in the opex cost function model

Our opex cost function models include allowance for different network densities across DNSPs via the output specification used which includes customer numbers, line length, energy throughput and a maximum demand measure. We also explicitly include allowance for different degrees of undergrounding across DNSPs. And our inclusion of country dummy variables allows for systematic differences in operating environments across the three countries. Data availability across the entire three country sample precluded the explicit inclusion of additional operating environment factors. However, as discussed above, where relevant detailed data are available for the Australian DNSPs we allow for differences in other material operating environment factors by adjusting the input use of the target efficient DNSP to allow for operating environment differences between that DNSP and the DNSP in question. This then produces a modified efficient target for the DNSP in question taking account of the additional operating environment factors it faces.

Since Economic Insights (2014) was prepared, more detailed analysis has been undertaken of the impact of the additional operating environment factors on the NSW/ACT DNSPs and the DNSPs' revised regulatory proposals have been received and considered. Analysis has also been extended to examine relevant additional operating environment factors affecting the Queensland DNSPs. The results of the updated and extended analyses are presented in AER (2015a,b,c,d,e).

It should be noted that more detailed and improved estimates are now incorporated for factors with small impacts. A materiality threshold of 0.5 per cent of opex is adopted (to be consistent with the EBRIN process) and where a factor is not material but is exogenous to DNSP management and its effect is not included in other factors allowed for, the factor is assumed to have an impact of 0.5 per cent. If a precise estimate of the factor's impact is available, that estimate is used instead. The adjustment is positive for factors that disadvantage the DNSP being reviewed and negative for those that advantage it. This approach supports a more precise estimate of the effect of these factors for each DNSP.

The results of the updated and extended detailed analyses are summarised in the following sections.

5.2.1 NSW/ACT DNSPs

Economic Insights (2014) included adjustment for four additional operating environment factors for the three NSW DNSPs based on detailed analysis reported in AER (2014a,b,c). These factors included differences in subtransmission intensiveness, differences in OH&S regulations, differences in bushfire regulations and the accumulated effect of differences in other factors each having a small effect. The net effect of these factors was assessed to increase the opex requirements of the weighted average efficient target made up of Victorian and South Australian DNSPs by 10 per cent if it had to operate under the same conditions as each of the NSW DNSPs.

Similarly, Economic Insights (2014) included adjustment for five additional operating environment factors for ActewAGL based on detailed analysis reported in AER (2014d). These factors included differences in backyard reticulation, differences in capitalisation practices, differences in OH&S regulations, differences in standard control services connections and the accumulated effect of differences in other factors each having a small effect. The net effect of these factors was assessed to increase the opex requirements of the weighted average efficient target made up of Victorian and South Australian DNSPs by 30 per cent if it had to operate under the same conditions as ActewAGL.

Based on its updated and more detailed analysis of more than 60 operating environment factors covering those included in the initial analysis and additional factors raised in the DNSPs' revised proposals and submissions, AER (2015a,b,c,d) find there are five key additional operating environment factors that should be allowed for the NSW and ACT DNSPs. For the NSW DNSPs these comprise allowance for differences in subtransmission intensiveness, differences in OH&S regulations, differences in license conditions, differences in termite exposure and the accumulated effect of differences in other factors each having a small effect. For ActewAGL these comprise allowance for differences in backyard reticulation, differences in capitalisation practices, differences in OH&S regulations, differences in standard control services connections and the accumulated effect of differences in other factors each having a small effect.

Table 5.1 **Impact of additional operating environment factors for NSW and ACT DNSPs on target's input use**

Factor	*ActewAGL*	*Ausgrid*	*Endeavour*	*Essential*
Backyard reticulation	5.6%	0.0%	0.0%	0.0%
Capitalisation practices	8.5%	–0.5%	0.5%	–0.5%
Licence conditions	0.0%	1.2%	0.7%	1.2%
OH&S regulations	0.5%	0.5%	0.5%	0.5%
Service classification	4.0%	0.0%	0.0%	0.0%
Subtransmission	0.0%	5.2%	4.9%	3.1%
Termite exposure	0.0%	0.0%	0.2%	0.6%
Accumulated other factors	4.4%	5.3%	6.1%	5.8%
Total	23.0%	11.7%	12.9%	10.7%

Source: AER (2015a,b,c,d p.7–3)

The magnitudes of the impact of these additional operating environment factors on the input requirements of the efficient target DNSP are presented in table 5.1.

The most significant difference between the additional operating environment factor input requirements reported in table 5.1 and those used in Economic Insights (2014) relates to ActewAGL's capitalisation practices. This has been approximately halved relative to the 17.6 per cent figure used in Economic Insights (2014). The change is attributable to a reallocation of the change in ActewAGL's overhead allocation to capex and an increase in the adjustment for differences in IT and vehicle leasing. By adjusting the benchmarking results for the change in overhead allocation policy, the previous figure incorrectly included overheads that would be capitalised in the forecast period, in the forecast of opex.

The other significant change in table 5.1 relative to the factors used in Economic Insights (2014) relates to bushfire effects on opex between the NSW DNSPs and the target DNSPs. In the previous analysis bushfire regulations and requirements were considered to place the Victorian DNSPs at a larger opex disadvantage relative to the NSW DNSPs of 2.4 per cent. In the updated analysis this has been reduced to a smaller opex disadvantage of 0.5 per cent. Although the current Victorian bushfire regulations are more stringent than those applying in NSW and Victoria is subject to higher bushfire risk than NSW, some parts of NSW are subject to higher levels of forestation. Also, duty of care considerations make it likely some of the higher Victorian requirements will be progressively adopted by the NSW DNSPs. These countervailing effects are considered to reduce the size of the opex disadvantage previously thought to face the Victorian DNSPs.

5.2.2 Queensland DNSPs

The AER (2015e) has undertaken a detailed review of over 60 different operating environment factors identified by itself, service providers and other stakeholders that could affect the performance of the Queensland DNSPs. The AER has assessed that 10 of the operating environment factors not included in our econometric models would change the input use of the target Victorian DNSP if it operated under the same conditions as the Queensland DNSPs. As was the case for the NSW/ACT DNSPs, allowance is also made for a further 20 factors which individually may have a small or uncertain effect. The total impact of these operating environment factors would be to increase the input use of the target Victorian DNSP by 17 per cent and 24 per cent if it operated under the same operating environments as Energex and Ergon Energy, respectively. The magnitudes of the impact of these additional operating environment factors on the input requirements of the efficient target DNSP are presented in table 5.2.

As was the case with the NSW DNSPs, the largest single factor affecting the Queensland DNSPs but not the target DNSP is the subtransmission intensiveness of the Queensland networks. The Queensland DNSPs also have relatively 'upstream' boundaries with transmission and significant lengths of line above 66kV. We again allow for this by assuming that subtransmission lines are twice as costly to operate and maintain as distribution lines and making an allowance for the subsequent higher opex associated with the higher subtransmission intensiveness of these DNSPs relative to the target.

Queensland DNSPs are also subject to more extreme weather conditions than their southern peers. This can be divided into the effects of tropical storms and floods, and cyclones. Extreme weather conditions were assumed to affect both the Energex and Ergon Energy service areas while cyclones were assumed to only affect the Ergon Energy service area. The impact of extreme weather was estimated based on the additional emergency response expenditure incurred by Energex in response to the three major storm and flood events during the sample period. Similarly, the impact of cyclones on opex was calculated based on Ergon Energy's switching and emergency response operations resulting from cyclones over the sample period.

Table 5.2 **Impact of additional operating environment factors for Queensland DNSPs on target's input use**

Factor	*Energex*	*Ergon Energy*
Bushfires	–0.5%	–2.6%
Cyclones	0.0%	4.6%
Extreme weather	2.7%	3.0%
Licence conditions	0.1%	0.5%
Network Access	–0.1%	1.1%
OH&S regulations	0.5%	0.5%
Taxes and levies	2.7%	1.7%
Termite exposure	0.2%	0.5%
Subtransmission	3.2%	4.6%
Vegetation management	3.4%	4.1%
Accumulated other factors	4.9%	6.4%
Total	17.1%	24.4%

Source: AER (2015e)

Adjustments are also made for differences in vegetation management responsibilities. In Queensland the DNSPs are responsible for all vegetation management whereas in Victoria DNSPs share responsibility with local councils. The adjustment is based on approximately 18 per cent of vegetation management being the responsibility of local councils in Victoria and the target DNSP's opex increasing by that proportion of its vegetation management costs if it were responsible for all vegetation management itself.

The Queensland DNSPs are also subject to some state–specific levies that do not apply in the other states. In particular, they have to pay the Energy Safety Office (ESO) levy and Queensland Competition Authority (QCA) Levies as Queensland specific taxes that do not exist in other jurisdictions. The adjustments for these levies were calculated based on the increase in efficient opex they would account for in the Queensland DNSPs' opex.

The other factor which would lead to an increase of more than one per cent in the target DNSP's opex if it operated under the same conditions as the Queensland DNSPs relates to network accessibility. Due to the extreme weather and wet conditions Ergon Energy faces in its service area, it has a lower proportion of lines accessible by standard vehicles than do the comparison firms and has to spend more on access track maintenance than other DNSPs. The adjustment was calculated based on the differential proportions of network accessible by standard vehicles and a unit rate per kilometre for track maintenance.

Finally, the other significant operating environment difference between Queensland and Victoria relates to bushfire risk and bushfire regulations. The AER's review of available evidence indicated that Victoria is subject to higher bushfire risk than Queensland and

Victoria's post–VBRC bushfire regulations are more stringent than those applying in Queensland. This will increase the comparison firm's opex relative to the Queensland DNSPs. Consequently, the comparison firm's opex would be reduced if it had to operate under the same conditions as Queensland DNSPs. The adjustment is calculated based on the step changes granted the Victorian DNSPs following the VBRC and weighted towards rural DNSPs.

5.3 Adjustments to base year opex

We undertake five steps in calculating the adjustments to base year opex required to reach the relevant efficiency target for each of the NSW, ACT and Queensland DNSPs. These are:

1) calculate the average efficient network services opex quantity for each DNSP taking account of the efficiency target adjusted for relevant operating environment factors (OEFs) not included in the econometric modelling
2) roll forward the average efficient network services opex quantity for each DNSP to 2013 using the rate of change method described in Economic Insights (2014)
3) convert the 2013 nominal total opex from the DNSP's Reset RIN to a basis consistent with network services opex
4) convert both the Reset RIN 2013 network services–equivalent opex and the 2013 efficient network services opex quantity to end of 2014 financial year prices for the NSW/ACT DNSPs and to end of 2015 financial year prices for the Queensland DNSPs, and
5) compare the resulting Reset RIN 2013 network services–equivalent opex and the 2013 efficient network services opex to calculate the adjustment required to the DNSP's base year opex.

The results of these calculations are presented in table 5.3.

Table 5.3 **NSW, ACT and Queensland DNSP opex efficiency scores, adjusted efficiency targets and 2013 network services opex and base year opex adjustments to reach the target**

DNSP	*Efficiency score*	*Target allowing for additional OEFs*	*Reduction to base year opex*
Ausgrid	44.7%	68.7%	24.0%
Endeavour	59.3%	68.0%	0.0%
Essential Energy	54.9%	69.4%	26.4%
ActewAGL	39.9%	62.4%	32.8%
Energex	61.8%	65.6%	15.5%
Ergon Energy	48.2%	61.7%	10.7%

As expected, the adoption of a more conservative initial efficiency target moderates the size of base year opex reductions required by the NSW and ACT DNSPs to reach their efficiency targets taking account of additional operating environment factors, although in three out of the four cases the adjustments required are still quite significant. Although the calculations for Endeavour Energy actually indicate an increase in base year opex being required to achieve its efficiency target, this simply indicates that Endeavour is already exceeding its (conservatively set) target and so no adjustment to its base year opex is required.

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

In Economic Insights (2014) we expressed the view that a forecast opex productivity growth rate of zero should be used in the rate of change formula. This was because there is a reasonable prospect of opex productivity growth moving from negative productivity growth towards zero change in productivity in the next few years as energy use and maximum demand stabilise, given the excess capacity that will exist in the short to medium term and as the impact of abnormal one–off step changes recedes. We also expressed concerns with the incentive effects of including negative opex partial productivity growth rates in the rate of change formula – to some extent this would be akin to rewarding the DNSPs for having previously overestimated future output growth and now entrenching productivity decline as the new norm. We also noted that if the effects of step changes can be clearly identified, the forecast opex growth rates should be adjusted to net these effects out.

None of the DNSP consultant reports challenged our view that a zero opex partial productivity growth rate should be used in the rate of change formula used to form the forecast of future opex requirements. The case for adopting a zero forecast opex partial productivity growth rate is, in fact, further strengthened by the adoption of a more conservative opex efficiency target in calculating the adjustment required to base year opex. We, therefore, remain of the view that a zero forecast opex partial productivity growth rate is appropriate.

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