TransGrid

TransGrid Revenue Proposal
2018/19 – 2022/23

Appendix F

Frontier Economics:

Review of the AER's 2016 Benchmarking Results

Review of the MTFP and MPFP analysis in the AER's 2016 Annual Benchmarking Report

A REPORT PREPARED FOR TRANSGRID

January 2017

Review of the MTFP and MPFP analysis in the AER's 2016 Annual Benchmarking Report

Review of the MTFP and MPFP analysis in the AER's 2016 Annual Benchmarking Report

Figures

Tables

1 Introduction

On 30th November 2016, the AER published its Annual Benchmarking Report[1] for the Australian electricity transmission network service providers (TNSPs). TransGrid has engaged Frontier Economics to review and comment on the AER's calculation and use of multilateral total factor productivity (MTFP) and multilateral partial factor productivity (MPFP) measures in its 2016 annual benchmarking report.

1.1 Instructions

TransGrid has engaged Frontier Economics to review and comment on technical aspects of the AER's MTFP, Opex MPFP and Capital MPFP analysis in the benchmarking report, having regard to:

- the impact of using the latest available RIN data from 2016;
- the selection of inputs and outputs;
- the assessment of input prices through the PRTC index;
- potential inconsistencies with the AER's own approach to benchmarking in the distribution sector in Australia; and
- any other matter that Frontier Economics considers relevant.

Our instructions are reproduced in Annexe 2 to this report.

1.2 Authors of this report

The authors of this report are Mike Huggins and Professor Bob Bartels.

Mike Huggins

Mr. Huggins has over 20 years of experience advising on competition and regulation matters in the energy sector. He is an expert on regulatory design and has advised numerous energy regulators, companies and investors on regulatory matters, including efficiency analysis. Mr. Huggins has experience in applying a wide range of benchmarking techniques to measure relative efficiency, including regression techniques such as Corrected Ordinary Least Squares (COLS) and Stochastic Frontier Analysis (SFA) to cross section and panel data, as well as linear

1 AER (Nov 2016), *Annual Benchmarking Report: Electricity Transmission Network Service Providers*. See: https://www.aer.gov.au/system/files/Final%20TNSP%20annual%20benchmarking%20report%202016%20-%20for%20release_0.pdf

programming techniques such as Data Envelopment Analysis (DEA). Mr. Huggins also has extensive experience of advising on regulatory appeal cases, including acting as an expert witness.

Mr. Huggins advised Networks NSW on the AER's first application of benchmarking in Australia in 2014-15. These networks subsequently appealed the AER's decisions to the Australian Competition Tribunal. Mr. Huggins was engaged by Counsel for the networks appealing, to assist the legal team throughout legal proceedings on technical benchmarking issues. The Tribunal overturned the AER's benchmarking analysis in its entirety and quoted extensively from Frontier Economics' work in its judgment.

Mr. Huggins advised Northern Powergrid, an operator of two electricity distribution grid licences in Great Britain, in respect of its recent appeal against Ofgem's RIIO-ED1 regulatory determination. He advised in respect of each of the three grounds of appeal, covering the assessment of future smart grid benefits, real price effects and regional labour cost adjustments. Mr. Huggins provided an expert report as part of the Notice of Appeal, and appeared at an oral hearing to assist the client in the presentation of his analysis.

Mr. Huggins also advised Northern Ireland Electricity (NIE) during Regulatory Period 5 on how it could be benchmarked against the distribution network operators in Great Britain in the light of significant differences in cost reporting structures, providing a series of expert reports for submission to the Utility Regulator and, ultimately, to the Competition Commission (now known as the Competition and Markets Authority) when NIE chose to appeal against the regulator's determination. Mr. Huggins acted as an expert on behalf of NIE, on benchmarking issues, through its appeal before the Competition Commission, including appearing on behalf of NIE at an oral hearing.

Mr. Huggins has also applied benchmarking techniques on numerous other cases. He was involved at every stage of the first price control conducted by the Dutch regulator, in which DEA played a central role. He subsequently provided further advice on the ways in which regional differences between gas and electricity distributors service regions might be recognised in benchmarking and in regulatory settlements.

More recently Mr. Huggins was the lead author of a report for Ofgem on the future role of benchmarking, a report commissioned as part of Ofgem's RPI-X@20 review. The report provided recommendations for both electricity and gas at the transmission and distribution levels, and its recommendations included a more prominent role for total cost benchmarking. Mr. Huggins subsequently led a large scale econometric study commissioned by the electricity distribution industry and Ofgem to develop a total cost benchmarking model. This work has informed Ofgem's efficiency analysis at the ongoing RIIO-ED1 review. Mr. Huggins has previously worked as an Economist at the Energy Policy and Analysis Unit within the UK Civil Service. He holds a B.Sc. (Hons) in Mathematics from the University of Sheffield, and M.Sc. in Economics (Distinction) from Birkbeck College, London.

Professor Bob Bartels

Professor Bartels leads Frontier Economics' econometrics team in Australia. He has over 25 years of experience in applying econometric and statistical methods across a diverse range of applications in business and government, with particular strength in performance measurement.

Professor Bartels has led all of the econometric efficiency modelling (Stochastic Frontier Analysis, Least Squares Econometrics) undertaken by the Frontier Economics team that has advised Ergon Energy and the NSW electricity distributors during the most recent AER resets. Professor Bartels has also advised Networks NSW on benchmarking issues in its appeal to the Australian Competition Tribunal.

Recently, Professor Bartels led a major project to develop an econometric opex output growth forecasting model for CitiPower and Powercor Australia using Regulatory Information Notice data published by the AER. As such, he is intimately familiar with the data that the AER has used for its benchmarking and efficiency analysis. Professor Bartels also led a major study for the New Zealand ENA that investigated the use of econometric models for forecasting opex, capex and output growth for regulated electricity networks.

Professor Bartels was a senior consultant on the first major performance studies for the Australian electricity supply industry.[2] He has also published in the leading international academic journal, *Journal of Productivity Analysis*, on the efficiency of electricity distribution, and on the efficiency of telecommunications in developing countries.[3], [4]

Professor Bartels is an Emeritus Professor in Business Analytics at the University of Sydney, and is an elected member of the International Statistical Institute. Prior to joining Frontier Economics, he held various full-time academic positions at the University of Sydney, including Head of the School of Business and Professor in Econometrics and Business Statistics. He has published over 50 refereed academic papers and has served on the editorial boards of the international journals *Energy*

---

2 The work by London Economics led to two landmark reports: ESAA (1993), Measuring the Efficiency of the Australian Electricity Supply Industry, and ESAA (1994), International Performance Measurement for the Australian Electricity Supply Industry 1990-1991.

3 Zhang, Y. and Bartels, R. (1998), "The effect of sample size on the mean efficiency in DEA with an application to electricity distribution in Australia, Sweden and New Zealand", Journal of Productivity Analysis, 9, 187-204.

4 Bartels, R. and Islam, T. (2002), "Supply restricted telecommunications markets: The effect of technical efficiency on waiting times", Journal of Productivity Analysis, 18(2), 161-169.

Economics, *Statistical Papers* and *Utilities Policy*. The authors' CVs are provided in Annexe 3 to this report.

The authors have been assisted in the preparation of this report by Sucheta Shanbhag and Fulvio Bondiolotti who are both core members of the Frontier Economics team that advised Networks NSW and Ergon Energy in 2014-15 on AER's first application of benchmarking in Australia. They have both worked under Mr. Huggins' and Professor Bartels' supervision in the past.

Sucheta holds a Master of Economics degree from the University of Warwick in the UK. She has recently joined Frontier Economics' Melbourne office, having previously worked in our sister company's Energy Practice in London. Sucheta specialises in electricity network regulation, and has advised a number of network operators across Europe and Australia on the estimation of comparative efficiency and ongoing productivity in regulatory price controls.

Fulvio Bondiolotti holds a Master's Degree in Economic and Social Sciences from Bocconi University in Milan. He is a skilled econometrician, having graduated *cum laude* in both his Economics and Mathematics degrees.

The authors confirm that all the opinions expressed in this report are their own, based on their relevant specialised knowledge, training and experience. Except where they have indicated otherwise in this report, the authors of this report maintain the views set out in their prior reports on the issue of economic benchmarking of regulated electricity transmission networks.

The authors have read, understood and complied with the Federal Court of Australia's Expert Evidence Practice Note (GPN-EXPT) dated 25 October 2016 concerning expert witnesses.

1.3 Structure of remainder of report

In Section 2 we summarise the steps used by the AER to estimate its MTFP, Opex MPFP and Capital MPFP indices. The AER benchmarking work relies heavily on analysis and econometric modelling undertaken by Economic Insights (EI) on behalf of the AER. Having reviewed the analysis undertaken by EI, we consider that this analysis contains a number of serious shortcomings. The remainder of our report is structured around the implications of these flaws for the AER's analysis. We summarise these shortcomings below.

- The AER's preferred model becomes inoperable when the latest data is used. Furthermore, it is clear that EI had access to the latest data since it was used in other parts of its analysis. This is discussed in Section 3.
- EI's model for benchmarking TNSPs violates two of the criteria that EI strongly emphasised when benchmarking the DNSPs. This is discussed in Section 4.

  - EI has argued previously that the small sample of 108 DNSP observations "makes any econometric model estimated using only the RIN data insufficiently robust to support regulatory decisions."[5] But econometric modelling has been undertaken and relied upon for the TNSPs, despite the available sample size for TNSPs being much smaller. We elaborate on this in Section 4.1.
  - EI has also argued previously that an econometric model that violates the so-called monotonicity conditions (the requirement that an increase in any output involves an increase in cost) is "unsuitable for efficiency measurement".[6] Analysis of EI's econometric model for the TNSPs reveals more material breaches of monotonicity than those criticised by EI in the DNSP work. Despite this, the AER has relied upon EI's econometric modelling to undertake its benchmarking of TNSPs. This is discussed in Section 4.2.
- The AER's preferred model fails to control for important cost drivers. Our concerns in this regard are discussed in Section 5.
  - As outlined in Section 5.2, the AER's model fails to control adequately for scale effects.
    - The AER's multiplicative treatment of circuit length and capacity in its input specification is likely to create a bias against the large networks in the sample, as shown in Section 5.2.1.
    - This bias is illustrated by the strong negative correlation between a range of different measures of TNSP scale and the AER's assessment of total and capital efficiencies, as shown in Section 5.2.2.
    - The AER's failure to control adequately for scale effects is also illustrated by the implausibly large diseconomies of scale implied by its preferred model specification, as shown in Section 5.2.3.
  - As outlined in Section 5.3, the AER's model fails to control adequately for operating environment.
  - The AER's construction of input prices (through the PRTC index) lacks any theoretical justification and produces implausible results. This is discussed in Section 5.4.
  - The AER's model produces efficiency scores that imply such enormous differences in managerial performance as to be not credible. This is discussed in Section 5.5.

---

5 Economic Insights (Apr 2015), *Response to Consultants' Reports on Economic Benchmarking of Electricity DNSPs*, p. 25.

6 Economic Insights (Apr 2015), *op. cit.*, p. 32.

Owing to these errors in approach, we believe that the results contained in the AER's 2016 annual benchmarking report are entirely unsuitable to be used to support regulatory decisions on the relative efficiencies of the TSNPs.

2 Outline of the AER/EI approach

To provide context to the discussion in the remainder of this report, in this section we begin by outlining the steps used by the AER to estimate its MTFP, Opex MPFP and Capital MPFP indices. In the remainder of this report, we cross-reference our findings to our summary of the AER's approach in this section to make clear exactly which aspects of the AER's methodology we are commenting upon.

The AER's benchmarking methodology comprises four broad steps:

- **Step 1: Selection of input and output variables for inclusion in the indices.** The AER's MTFP and MPFP indices are ratios of TNSP outputs to inputs over time. The AER's first step is therefore to select the inputs and outputs that comprise the input and output indices, respectively.
  - **A) Selection of output variables.** The AER's preferred output specification includes 5 output variables: Energy, Ratcheted Maximum Demand, Weighted Entry and Exit Connections, Circuit Length, and Reliability. The same output variables are used to calculate the MTFP, Opex MPFP and Capital MPFP indices.
  - **B) Selection of input variables.** The AER's preferred input specification includes 4 input variables: Opex, Overhead MVA*kms, Underground MVA*kms, and Transformers & Other MVA. The MTFP input index includes all four inputs. Whereas the Opex MPFP index and Capital MPFP index include only the Opex and Capital inputs, respectively.
- **Step 2: Estimation of output and input weights.** In order to operationalise any productivity index methodology, it is necessary to determine output weights for the output index, and input weights for the input index.
  - **A) Estimation of the output weights.** The AER's weights for the output variables[7] in step 1A are estimated through a Translog econometric regression of 'real total costs' on each of the outputs. The rationale behind this approach is to determine the relative cost share of each of the output variables. 'Real total costs' are estimated as follows.
    - i) 'Total costs' (nominal) = opex + AUC[8] overhead lines + AUC underground cables + AUC transformers and other; and

---

7 This does not include 'reliability', the weight for which is determined separately using the AER's current estimates for VCR.

8 Where the annual user cost of capital (AUC) = return on capital (opening RAB * benchmark WACC) + regulatory depreciation + benchmark tax liability.

  - ii) 'Real total costs' = 'Total costs' (nominal)/EI's utility-specific price index (which it calls 'PRTC').

  We note that the same output weights are used to calculate the MTFP, Opex MPFP and Capital MPFP indices. Separate output weights have not been determined for opex, capital and total costs.

- **B) Estimation of the input weights.** The AER's weights for the MTFP input index are determined as follows:
  - i) Opex share = opex/ 'Total cost (nominal)' from step 2Ai) above
  - ii) Overhead MVA*kms share = AUC overhead lines/'Total cost (nominal)' from step 2Ai) above
  - iii) Underground MVA*kms share = AUC underground lines/'Total cost (nominal)' from step 2Ai) above
  - iv) Transformers&other MVA share = AUC transformers&other /'Total cost (nominal)' from step 2Ai) above.

  We note that the Opex MPFP input index includes only opex, and therefore does not require any weights. The Capital MPFP weights are calculated as above, excluding opex from 'Total cost (nominal)' to determine capital only weights, excluding opex.

- **3) Deriving the input and output indices.**
  - **A) Calculating the output index.** The output index combines the output variables from step 1A, using output weights derived in step 2A. The same set of output variables and output weights are used to calculate the MTFP, Opex MPFP and Capital MPFP output indices. In other words, the same output index is used in the MTFP and MPFP calculations.
  - **B) Calculating the input index.** The input index combines the input variables from step 1B, using input weights derived in step 2B. The MTFP index includes all four inputs. Whereas the Opex MPFP and Capital MPFP include only the Opex and Capital inputs, respectively.
- **4) Calculating the MTFP index.** The MTFP and MPFP indices are simply the ratio of the output index from step 3A and the respective input index from step 3B.

As the AER's benchmarking analysis is based on work undertaken by Economic Insights (EI), we refer to the AER's analysis and EI's analysis interchangeably in the remainder of this report.

3 The AER's preferred model becomes inoperable when latest data is used

In certain aspects of its work, the AER has not used the most up to date data available. This is unusual in the context of regulatory work, where typically the most up to date information will be used in any analysis, unless there are concerns over the quality/veracity of such information. Since no such concerns have been expressed by the AER, we have investigated in considerable detail how the AER's results change if the latest data had been used. We have found that:

- when the latest data is used, the AER model becomes inoperable; and
- there is an inconsistency in the basis of information used in different aspects of the AER's analysis.

We discuss each of these issues in turn.

3.1 When the latest data is used, the AER model becomes inoperable

In attempting to replicate the results in the AER's 2016 annual benchmarking report, we have discovered that the AER's underlying econometric output weightings (Step 2A of the AER's methodology summarised in Section 2) have been calculated using outdated RIN data published in 2014, which does not include the data revisions made by the TNSPs in 2015 and 2016, and does not incorporate the two additional years of data that were available to the AER at the time of writing the 2016 annual benchmarking report[9].

These data revisions were acknowledged by EI in its November 2016 MTFP memo:

> "There have been a small number of data revisions included in the updated TNSP analysis. Most of these relate to calculation of the voltage–weighted entry and exit points output variable and the MVA rating of lines. TransGrid has revised its numbers of entry and exit points for the whole period. AusNet, ElectraNet and TransGrid have made minor refinements to the MVA rating of particular line categories in some years. And ElectraNet has corrected an error in its reported maximum demand data for 2014. In addition, the latest WACC data are used and a change has been made to the method used to index the value of consumer reliability (VCR)." [10]

---

[9] In order to replicate the AER's results, and to produce the sensitivities that we have presented in the remainder of this report, we have relied on a model supplied to us by TransGrid (Excel file: "*AER benchmark - reverse engineered - for expert*"), which we assume to accurately reflect the AER's methodology.

[10] Economic Insights (Nov 2016), *Memo on TNSP multilateral total factor productivity results – 8 November 2016*, p. 1 - 2.

Similarly, data revisions from 2014 to 2015 were acknowledged by EI in its November 2015 MTFP memo:

> "There have been a small number of data revisions included in the updated TNSP analysis. Most of these relate to calculation of the voltage–weighted entry and exit points output variable. ElectraNet has revised its numbers of entry and exit points for the whole period. And an exit point supplying more than one DNSP is now counted as one exit point rather than separately for each DNSP as previously – this mainly affects AusNet Transmission and Transgrid." [11]

We have attempted to reproduce the AER's econometric output weightings using the latest available information. To isolate the impact of the latest two years of data, from the impact of the change in variable definitions, we have re-estimated the AER's preferred econometric regression specification (Step 2A in the AER's methodology summarised in Section 2) on the following five samples of data:

- The AER's sample which was based on data covering the period 2006 – 2013 (using old variable definitions underlying the RIN data published in 2014)
- Sensitivity 1: Using the same sample period that the AER used (2006 – 2013), but with the revised data definitions underlying the RIN data published in 2015. The aim of this exercise is to isolate the impact of data revisions made in 2015.
- Sensitivity 2: Using the same sample period that the AER used (2006 – 2013), but with the revised data definitions underlying the RIN data published in 2016. The aim of this exercise is to isolate the impact of data revisions made in 2016.
- Sensitivity 3: The sample period 2006 – 2014, using RIN data published in 2016. The aim of this exercise is to test the impact of adding one additional year of RIN data to the analysis, using the most recently published RIN data.
- Sensitivity 4: The sample period 2006 – 2015, using RIN data published in 2016. The aim of this exercise is to test the impact of adding two additional years of RIN data to the analysis, using the most recently published RIN data.

The results are presented in Table 1 below.

11 Economic Insights (Nov 2015), *Memo on TNSP MTFP results*, p. 1.

Table 1: Sensitivity of estimated cost shares to using revised and updated data

	Impact of data revisions			Impact of changes to the sample period	
Regression variable	**2006-2013 (Results from AER's analysis)**	**2006-2013 revised in 2015 (To isolate impact of data revisions in 2015)**	**2006-2013 revised in 2016 (To isolate impact of data revisions in 2016)**	**2006-2014 (To test the impact of adding one additional year of RIN data)**	**2006-2015 (Adding two additional years of RIN data)**
Log of energy	0.279**	0.378***	0.452***	0.446***	0.290***
Log of connections	0.362*	-0.288*	-0.176	-0.236*	0.041
Log of ratcheted maximum demand	0.288*	0.586***	0.392***	0.418***	0.516***
Log of circuit length	0.374*	0.108	0.143	0.171*	0.082
Time trend	0.022***	0.025***	0.023***	0.025***	0.015***
Constant	12.665***	12.374***	12.408***	12.398***	12.492***

Source: Frontier Economics analysis

*Notes: The table presents the first-order coefficients in EI's preferred Translog regression specification for costs as a function of outputs. *** p-value <0.01, ** p-value <0.05, * p-value<0.1*

This analysis shows that the econometric model coefficients are markedly different when the preferred model is re-estimated using revised or updated data. Importantly, when re-estimated using the revised or updated data, the coefficient for the output cost share for customer connections in EI's preferred econometric Translog specification is negative in three out of four cases (shown in light red in the table), and statistically significant at the 10% level of significance in two out of those three cases. The interpretation of the negative coefficients is that, all other things remaining equal, an increase in customer connections would result in a decrease in a TNSP's total costs. This result is economically not plausible, which indicates that the model has been mis-specified or represents a spurious relationship between total costs and the cost drivers included in the model. Hence, with the revised or updated data, the AER's econometric model no longer produces usable cost shares.

Furthermore, when re-estimated using the latest 2016 RIN data, for the 2006 – 2015 sample period, the econometric model coefficients for the output cost shares for customer connections and circuit length in EI's preferred econometric Translog specification are statistically insignificantly different from zero (shown in grey in the table).

In addition to obtaining negative and statistically insignificant coefficients, we find that the coefficients on other output variables also change markedly when the revised or updated data is used to estimate the model. This further highlights the profound instability of the results found in EI's work, to what are relatively modest changes in the dataset.

We note that the instability that we find in the results when using different sample periods, while partly due to the data revisions and additional years of data in the new sample, is also due to the small available sample size and multicollinearity between the drivers. If there is high multicollinearity between cost drivers (in other words, if the cost drivers included in the regression are highly correlated with one another), it is difficult to obtain robust estimates of the individual cost shares, even if they are all statistically significant. Table 2 below shows the correlations between different output variables.

Table 2: Correlation between variables (in logs)

	Energy	Connection number	Ratcheted maximum demand	Circuit length
Energy	1.000			
Connection number	0.885	1.000		
Ratcheted maximum demand	0.978	0.919	1.000	
Circuit length	0.872	0.960	0.924	1.000

Source: Frontier Economics analysis; Note: These correlations are based on the latest RIN data published in 2016

It can be seen that all the correlation are above 0.85 with four correlations exceeding 0.90. Models in which the explanatory variables are highly correlated are known to be quite sensitive to even small changes in the data used to estimate the model, particularly when the sample size is small. Hence estimates of elasticities and cost shares based on these models will be fragile and will likely change considerably when revised or updated data is used when estimating the model.

This leads to the conclusion that the AER's model lacks credibility for use in the AER's economic benchmarking analysis.

3.2 There is an inconsistency in the information used in different aspects of the AER's analysis

Our review of the AER's model has also revealed that there is an inconsistency in the information used in different aspects of its analysis.

- The AER has not used the latest RIN information to produce its econometrically estimated output weights (Step 2A of the AER's methodology summarised in Section 2).
- The AER has used the latest RIN information, including the data revisions and latest year of data, to generate its MTFP and MPFP output indices (Step 3A in the AER's methodology summarised in Section 2).

Therefore, there is an inconsistency in the definition of outputs and sample period in the data used to derive:

- the output cost shares, on the one hand; and
- the output index, on the other hand.

Since (a) the AER's output cost index (Step 3A) cannot be made operational without output weights (Step 2A), and (b) the AER's chosen econometric model specification doesn't produce usable output weights, it is clear that the AER's entire benchmarking approach simply cannot be applied when the latest RIN data is considered. This conclusion also extends to the AER's assessment of opex escalation and productivity change, as they are also driven by the same erroneous econometric output weights (Step 2A).

3.3 The AER does not estimate separate output weights for opex, capital and total costs

A further issue with the AER's output weights (Step 2A in Section 2) is that they have not been derived separately for opex, capital and total costs. Instead, they are estimated through a Translog econometric regression of 'Total costs' on each of the outputs, where 'Total costs' include both opex and capital (estimated as the sum of AUC[12] overhead lines, AUC underground cables and AUC transformers and other).

The same econometrically estimated output weights are used to determine the output cost shares for each of the MTFP, Opex MPFP and Capital MPFP indices. The AER should, in principle, generate separate output cost shares for total costs, opex and capital, unless there is evidence to suggest that cost shares would be the

12 Where the annual user cost of capital (AUC) = return on capital (opening RAB * benchmark WACC) + regulatory depreciation + benchmark tax liability.

same for all three cost categories. We note that no such evidence has been presented by EI, and we can see no valid reason why this should simply be presumed. Furthermore, AER's econometric output weights are also central to the AER's opex output growth forecasting for the next regulatory period. Again, it is unclear why cost shares for this exercise should be determined using a regression that incorporates capital in the cost function.

We have attempted to estimate separate cost shares for opex and capital using EI's preferred set of output variables, as shown in Table 3 below. We find that coefficients are markedly different for opex and capex and that this is the case irrespective of the data set used and/or the functional specification applied. This provides evidence to suggest that it may not be reasonable to use the same output weights across all different inputs. Moreover, as can be seen from Table 3 below, these models produce negative first-order coefficients and therefore lack any meaningful economic interpretation. Owing to this, they cannot be used reasonably to determine output weights.

Table 3: Separate regressions for opex and capital cost shares

	2006-2013	2006-2013 revised in 2014	2006-2013 revised in 2015	2006-2014	2006-2015
Opex cost shares					
Log of energy	0.044	0.181	-0.067	-0.253	-0.016
Log of connections	0.964**	-0.356	-0.258	-0.329	0.124
Log of ratcheted maximum demand	0.353	-0.128	0.165	0.364	0.054
Log of circuit length	-0.262	1.090***	0.935***	1.016***	0.722**
Time trend	-0.027**	-0.005	-0.001	-0.005	-0.013
Constant	11.591***	11.333***	11.406***	11.400***	11.327***
Capital cost shares					
Log of energy	0.154	0.908**	0.793**	0.710*	0.475
Log of connections	1.642***	-1.250***	-1.265***	-1.819***	-1.084
Log of ratcheted maximum demand	0.133	0.420	0.160	0.982	0.669
Log of circuit length	-0.561	-0.122	0.326	-0.514	-0.066
Time trend	0.064***	0.090***	0.091***	0.075***	0.059***
Constant	12.819***	11.390***	11.382***	12.006***	12.032***

Source: Frontier Economics analysis

*Note: The stars indicate the statistical significance of each estimated coefficient: *** p<0.01, ** p<0.05, * p<0.1.*

4 Economic Insights' model for benchmarking TNSPs violates two criteria that it strongly emphasised when benchmarking the DNSPs

When benchmarking the Australian DNSPs, Economic Insights strongly emphasised two requirements of a robust econometric benchmarking model:

- EI argued that the small sample of 108 DNSP observations "makes any econometric model estimated using only the RIN data insufficiently robust to support regulatory decisions." [13]
- EI also argued that an econometric model that violates the so-called monotonicity conditions is "unsuitable for efficiency measurement." [14]

EI ignored these two criteria when implementing its methodology for benchmarking the TNSPs (Step 2B of its benchmarking methodology for the TNSPs, summarised in Section 2). We discuss each of these criteria in turn.

4.1 EI argued that the small sample of 108 DNSP observations "makes any econometric model estimated using only the RIN data insufficiently robust to support regulatory decisions."

When benchmarking the Australian DNSPs, Economic Insights strongly emphasised that the sample of 108 observations available in the RIN templates for the 13 DNSPs **"makes any econometric model estimated using only the RIN data insufficiently robust to support regulatory decisions"**.[15] As the number of observations available for the econometric modelling of the TNSPs is far less than was the case for the DNSPs (approximately half the size of the sample), it is not clear why EI has decided to rely on econometric analysis to support its benchmarking exercise for TNSPs without providing any caveat at all. It is useful to present two particularly relevant quotes from previous EI work.

13 Economic Insights (Apr 2015), *Response to Consultants' Reports on Economic Benchmarking of Electricity DNSPs*, p. 25.

14 Economic Insights (Apr 2015), *op. cit.*, p. 32.

15 Economic Insights (Apr 2015), *op. cit.*, p. 25.

> "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." [16]

We agree that this is a highly relevant concern for an econometric study. Our findings on the instability of results to minor changes in specification, which will become evident on a wider review of our report, reveals that this weakness pervades EI's analysis.

> "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." [17]

EI clearly has serious concerns around sample size and statistical robustness, and should have been aware of these concerns in respect of its analysis for TNSPs. In our view, EI has erred in judging that the sample size in the case of the TNSP analysis is sufficiently large to allow reliance on the results of its analysis for regulatory purposes.

4.2 EI also argued that an econometric model that violates the so-called monotonicity conditions is "unsuitable for efficiency measurement"

When benchmarking the Australian DNSPs, Economic Insights strongly emphasised that an econometric model that violates the so-called monotonicity conditions (the requirement that an increase in any output involves an increase in cost) is **"unsuitable for efficiency measurement"**. [18] Indeed EI regarded this criterion as sufficiently binding that it relied on this criterion to justify rejecting the use of

16 Economic Insights (Apr 2015), *Response to Consultants' Reports on Economic Benchmarking of Electricity DNSPs*, p. 24 – 25.

17 Economic Insights (Apr 2015), *op. cit.,* p. 25.

18 Economic Insights (Apr 2015), *op. cit.*, p. 32.

the Translog functional form when benchmarking DNSPs,[19] despite otherwise presenting compelling reasons for why it should be preferred.[20]

Economic Insights chose to adopt a Cobb-Douglas functional form over the Translog functional form for its econometric model of the cost function of the DNSPs, because it found that the DNSP Translog models violated monotonicity conditions.

Our analysis of the violations of monotonicity in EI's Translog model for the DNSPs revealed that:

- the monotonicity violations were small (the most negative elasticity that EI found in the distribution sector was -0.08); and
- the monotonicity violations were statistically highly insignificant (smallest p-value was 0.25 in EI's DSNP Translog model). In other words, they were statistically not significantly different from 0, and convincingly so.

Despite the fact that, in the case of DNSPs, the violations of the monotonicity condition were very mild, EI insisted these mild violations made the Translog model unsuitable for efficiency measurement.

> "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

---

19 See comment in Economic Insights (Nov 2014), *Economic Benchmarking of NSW and ACT DNSP Opex*, p. 32- 33. "We next investigated the monotonicity properties of the translog models (this requirement states that an increase in output can only be achieved with an increase in cost – since the translog model includes second order terms we need to check the sign of the output cost elasticities to ensure they are positive so that an increase in output leads to an increase in opex cost, all else equal). For the large dataset, all bar one of the Australian DNSPs satisfied monotonicity for the LSE model (and that violation was quite small) but 11 of the Australian DNSPs had monotonicity violations for the SFA model (some of which were quite large). For the medium dataset, all the Australian DNSPs satisfied monotonicity for the LSE model but 7 of the Australian DNSPs had monotonicity violations for the SFA model. For the small dataset, monotonicity violations were larger and more widespread for the Australian DNSPs in both the LSE model and the SFA model. We therefore conclude that the medium dataset produces the most robust and reliable results (although the large dataset comes close to it). We also conclude that the translog SFA model does not produce robust and reliable results in any of the datasets and it is therefore not further considered. Given this result and our discussion of the relative merits of the various methods, we select the SFA Cobb–Douglas model as our preferred model."

20 See comment in Economic Insights (Nov 2014), *Economic Benchmarking of NSW and ACT DNSP Opex*, p. 35. "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."; See also comment on page 44: "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."

output involves an increase in cost) for 7 of the 13 Australian DNSPs using the medium data set, **making it unsuitable for efficiency measurement**." [21]

When we investigated EI's TSNP Translog model for monotonicity violations, we found that there were a considerable number of cases where the magnitude of the monotonicity violations are large, and statistically significant. This is summarised in Table 4 below. The most negative elasticity we find in EI's analysis in the transmission sector is -1.77, which implies an implausibly large negative relationship between costs and cost drivers.

In particular, we found that:

- 6 observations for Electranet violate the assumption of monotonicity in the number of connections at the 5% level of significance;
- all observations for Powerlink violate the assumption of monotonicity in circuit length at the 1% level of significance.

Table 4: Monotonicity violations in EI's preferred Translog model

	Cases for which the first derivative is negative	Cases for which the first derivative is significantly negative at the 10%	Cases for which the first derivative is significantly negative at the 5%	Cases for which the first derivative is significantly negative at the 1%
Energy	8	0	0	0
Ratcheted maximum demand	21	4	0	0
Connections	21	9	8	0
Circuit length	13	8	8	8

Source: Frontier Economics analysis of EI's Translog model

Note: Number of cases out of 40 observations

These violations of the monotonicity condition are much more severe than in the case of the Translog model for DNSPs. Given the clarity and vigour with which EI has hitherto asserted that monotonicity must not be violated, it is therefore entirely unclear why EI has chosen to rely on this econometric model as part of its appraisal of TNSPs.

21 Economic Insights (Apr 2015), *Response to Consultants' Reports on Economic Benchmarking of Electricity DNSPs*, p. 32.

5 The AER's preferred model fails to control for important cost drivers

We have reviewed in detail the preferred model developed by the AER/EI and the results that it produces. This analysis has led us to conclude that the AER/EI model is inadequate, as it fails to control appropriately for important cost drivers. It also produces efficiency scores that imply such enormous differences in managerial performance as to be not credible.

To outline our assessment in this regard, we provide a summary of the types of factors that are likely to affect a TSNP's costs in Section 5.1. We then outline our assessment that the AER has failed to control adequately for a number of these factors.

- The AER's model fails to control adequately for scale effects, as shown in Section 5.2.
- When the AER's output variables are assessed against the discussion in Section 5.1, it is clear that the AER's model fails to control adequately for operating environment. We address this issue in Section 5.3.
- The AER's assessment of input prices (through the PRTC index) lacks any theoretical justification and produces implausible results, as shown in Section 5.4.
- AER's model produces efficiency scores that imply such enormous differences in managerial performance as to be not credible, as shown in Section 5.5.

5.1 Summary of the types of factors that are likely to affect a TSNP's costs

The selection of outputs or cost drivers is central to any benchmarking exercise. It is necessary for cost driver selection to be guided by a clear underpinning economic rationale and that the selected cost drivers have well-focused and appropriate incentive properties. To motivate our discussion of factors missing from the AER's assessment, below we outline the range of cost drivers that will affect a TSNP's costs.

- **Core-outputs/demand-side outputs:** This set contains a TSNP's main outputs, such as customer connections and maximum demand served in each year. We refer to these as 'core outputs' or 'demand-side' because they are directly observed, valued by customers, largely outside managerial control, and capture well the scale of the networks. These are the primary drivers of a TNSP's costs.

- **Non-core outputs/demand side outputs:** There are other network-related outputs which also affect a TNSP's costs, such as circuit length, and system capacity, which we refer to as 'core outputs' or 'supply-side' outputs as they are not directly observed and valued by customers. Over the intermediate to long term, the levels of these supply-side variables are, to some extent, determined by managerial decisions. Including such asset-related variables in total cost modelling could potentially create perverse incentives for over-investment in assets. Nevertheless, including some of these variables, such as circuit length, in the modelling alongside the core outputs may serve as an (albeit imperfect) proxy for density effects, which can be a material driver of costs.
- **Environmental variables:** these are the variables that describe the operating environment of the firm; these variables are outside the firm's control (e.g. weather and terrain) but may affect its observed costs. To ensure that measured differences in managerial efficiency are not driven by differences in the operating environment of TNSPs, it is necessary that these are included in the AER's assessment.
- **Input prices:** this group contains the prices of the inputs used by the firm, such as labour and capital, in order to capture changes in costs that arise as a result of changes in the prices of inputs. To ensure that perceived differences in managerial efficiency are not driven by differences in the input prices of the TNSPs, it is necessary that these are accounted for in the AER's assessment.
- **Reliability:** Delivering electricity with fewer and shorter interruptions is costly for TNSPs, and they consequently face a trade-off between quality and cost. This means that it is necessary to take account of quality.

In order to ensure that its comparisons across TNSPs are done on a like-for-like basis, it is necessary for the AER to control for at least the most material factors above. As discussed in the remainder of this section, the AER has failed to account adequately for scale effects (as shown in Section 5.2), operating environment (as discussed in Section 5.3), and input prices (as shown in Section 5.4). Finally, as discussed in Section 5.5, AER's model produces efficiency scores that imply such enormous differences in managerial performance as to be not credible.

5.2 AER's model fails to control adequately for scale effects

Our assessment of the AER's preferred model specification suggests that it is likely to be biased against the larger networks in the sample due to the following three reasons.

- The AER's multiplicative treatment of MVA and capacity in its input specification, which is not mirrored in its output specification, is likely to create a bias against large networks. This is discussed in Section 5.2.1.

- This likely bias in favour of small networks over large networks is also illustrated by the strong negative correlation between the different measures of TNSP scale and the AER's assessment of total and capital efficiencies, as shown in Section 5.2.2.
- Finally, the AER's failure to control adequately for scale effects is also illustrated by the implausibly large diseconomies of scale implied by its preferred model specification, as shown in Section 5.2.3.

5.2.1 The AER's multiplicative treatment of circuit length and capacity in its input specification is likely to create a bias against the large networks in the sample

In developing its preferred model specification in 2014, which the AER continues to adopt in 2016, it considered four alternative output specifications, and three alternative input specifications.

Output specifications considered by EI (for Step 1A of the AER's benchmarking methodology, summarised in Section 2)

- Output Specification #1: Energy, MVA*kms, Weighted Entry and Exit Connections, Reliability
- Output Specification #2: Energy, Ratcheted Maximum Demand, Weighted Entry and Exit Connections, Reliability
- Output Specification #3: Energy, Ratcheted Maximum Demand, Weighted Entry and Exit Connections, Circuit Length, Reliability
- Output Specification #4: Ratcheted Maximum Demand, Weighted Entry and Exit Connections, Reliability

Input specifications considered by EI (for Step 1B of the AER's benchmarking methodology, summarised in Section 2)

- Input Specification #1: OPEX, O/H MVA*kms, U/G MVA*kms, Transformers & Other MVA
- Input Specification #2: OPEX and Constant Price Depreciation
- Input Specification #3: OPEX and Constant Price Depreciated Asset Value

The AER's current preferred model specification is a combination of Output Specification #3 and Input Specification #1 above. However, Output Specification #3 is not what the AER had intended to adopt in its Final Expenditure Forecast Assessment Guidelines. The AER had originally signalled its intention to include system capacity (MVA*kms) as an output variable. This variable was tested by Economic Insights (EI) in its Output Specification 1. As noted by EI, this output specification has its benefits:

> This specification concentrates on the supply side, giving TNSPs credit for the network capacity they have provided. It has the advantage of capturing both line and transformer dimensions of system capacity.[22]

However, EI was concerned that this output specification is likely to create a bias in favour of the larger networks in the sample.

> A potential disadvantage of the specification is the multiplicative nature of the system capacity variable which introduces a degree of non–linearity thereby potentially advantaging large NSPs.[23]

We understand that EI's concern is that both of the constituents of the multiplicative measure are likely to increase with scale.

- **Line length:** TNSPs with low customer density (as is typically the case for companies serving large areas) are likely to require more line length to service their customers; and
- **Capacity:** Those lines are likely to be designed to operate at higher voltages, and therefore have higher capacity, in order to transport electricity efficiently across long distances.

EI has therefore acknowledged that including this scale variable as an output in the model (the numerator to the TFP calculation) may result in a bias in favour of the large TNSPs.

However, it has failed to acknowledge that a similar bias also operates in respect of the input side of AER's model, since the multiplicative effect remains in the AER's preferred input specification (Input Specification #1 discussed above), which includes overhead MVA*km and underground MVA*km as input variables. This is likely to disadvantage large TNSPs at the expense of small TNSPs for the same reason that EI rejected Output Specification #1). AER does not appear to have assessed the potential effect of addressing only one of these potential biases.

Sensitivity analysis

In order to assess the effect of adopting a multiplicative input specification along with a multiplicative output specification, (which levels the playing field between large and small utilities), we test the use of a multiplicative output variable in the AER's preferred output specification. This sensitivity analysis specification includes the following output variables:

- Energy;
- Ratcheted maximum demand * Circuit length (kms);

22 Economic Insights (2014), *'Memo on TNSP MTFP results'*, July; p. 2.

23 Ibid; p. 3

- Weighted Entry and Exit Connections; and
- Reliability.

This is similar to EI's Output Specification #3, except that it includes ratcheted maximum demand and network length multiplicatively. By **mirroring the AER's multiplicative input specification**, this sensitivity check has the advantage of potentially netting out any bias associated with the multiplicative input specification discussed above. We therefore consider this output specification to be conceptually superior to the AER's output specification #3.

We have estimated this model using three different data sets (our overview of the data updates is provided in Section 3.1 above):

- The AER's sample which was based on data covering the period 2006 – 2013 (using old variable definitions)
- The sample period 2006 – 2014, using RIN data published in 2016. The aim of this exercise is to test the impact of adding one additional year of RIN data to the analysis, using the most recently published RIN data.
- The sample period 2006 – 2015, using RIN data published in 2016. The aim of this exercise is to test the impact of adding two additional years of RIN data to the analysis, using the most recently published RIN data.

We have also estimated the model using both the Translog and Cobb-Douglas functional forms (the rationale for testing these alternative functional forms is discussed in Section 4 above). Hence we have estimated 3 x 2 = 6 different variants of our model with the alternative specification of outputs. The estimated coefficients for these 6 different variants are shown in Table 5.

Table 5: Estimated coefficients for output specification sensitivity models (including multiplicative output variable)

	Translog			Cobb-Douglas		
	2006-2013	2006-2014	2006-2015	2006-2013	2006-2014	2006-2015
Log of energy	0.182***	0.301***	0.304***	0.370***	0.281***	0.262***
Log of connections	0.063	0.007	0.184	0.225**	-0.315**	-0.216
Log of (ratch max demand * circuit length)	0.469***	0.350***	0.295***	0.302***	0.518***	0.503***
Time trend	0.014***	0.016***	0.012***	0.013***	0.024***	0.019***
Constant	12.440***	12.435***	12.473***	12.382***	12.302***	12.350***

Source: Frontier Economics analysis

*Note: The stars indicate the statistical significance of each estimated coefficient: *** p<0.01, ** p<0.05, * p<0.1.*

Table 5 shows that this sensitivity analysis produces first-order coefficients (elasticities) which are negative and statistically insignificantly different from zero for the majority of alternative specifications. The only variant that produces positive and statistically significant coefficients is the Cobb-Douglas specification using the AER's 2006 – 2013 sample with the old RIN variable definitions. Table 6 shows the resulting output weights for this specification.

Table 6: Output weights from output specification sensitivity (including multiplicative output variable)

	Total cost output shares
Energy	41.3%
Connections	25.1%
Ratcheted maximum demand * circuit length	33.6%

Source: Frontier Economics analysis

Table 7 shows the impact on final MTFP and MPFP scores and rankings of this Cobb-Douglas specification with a multiplicative output variable relative to the AER's preferred model. These results are based on the alternative output weights from Table 6.

It can be seen from Table 7 that the Cobb-Douglas specification with a multiplicative output variable results in a significant improvement in efficiency scores for the larger networks in the sample. The magnitude of improvement in MTFP and MPFP for TransGrid, Powerlink and AusNet Services relative to the AER's results, is approximately 70%, 48% and 40%, respectively. Similarly, this sensitivity analysis results in a reduction in MTFP and MPFP scores and rankings for the smaller networks in the sample – TasNetworks and ElectraNet – relative to the AER's results.

We emphasise strongly that this sensitivity analysis does not mitigate the wider issues that we have identified with the AER's MTFP and MPFP analysis in the remainder of this report. For example, it is clear that this sensitivity analysis produces first-order coefficients (elasticities) which are negative and statistically insignificantly different from zero for the majority of alternative specifications. Furthermore, there is significant variability in the estimation results for the alternative specifications. Moreover, the majority of these specifications do not stand up to the latest data updates (as discussed in Section 3). Therefore, by presenting these alternative specifications, we do not claim to have identified the 'right models' or the true differences in managerial inefficiency between the Australian TNSPs.

Nevertheless, despite these shortcomings, it is clear that the inclusion of output variables in a multiplicative way (in order to mirror the AER's input specification), does appear to improve materially the efficiency scores for the larger networks in the sample (to the extent that TransGrid's 2015 MTFP ranking improves from the fourth under the AER's approach, to the first under the sensitivity where the output variables are included in a multiplicative way). This analysis clearly illustrates the potential bias in the AER's current input specification against the larger networks in the sample.

Table 7: Sensitivity of MTFP, Opex MPFP and Capital MPFP scores to including a multiplicative output variable

		AER's results				Efficiency score and rank from multiplicative output variable sensitivity (from model specification presented in Table 5 and Table 6 above)			
Model specification:		Translog				Cobb-Douglas			
		2006-2013				2006-2013			
		Multiplicative inputs only				Multiplicative inputs and outputs			
Model	TNSP	2015 efficiency score	2015 Rank	Average efficiency score	Average rank	2015 efficiency score	2015 Rank	Average efficiency score	Average Rank
MTFP	ElectraNet	0.87	2	0.93	2	0.85	5	0.92	5
	Powerlink	0.71	3	0.77	4	1.07	3	1.15	2
	AusNet Services	0.69	5	0.68	5	0.97	4	0.96	4
	TasNetworks	1.21	1	1.13	1	1.10	2	1.02	3
	TransGrid	0.70	4	0.80	3	1.19	1	1.37	1
Opex MPFP	ElectraNet	0.87	5	0.94	5	0.86	5	0.92	4
	Powerlink	0.92	4	1.00	4	1.38	3	1.49	3
	AusNet Services	1.32	2	1.32	2	1.87	2	1.86	2
	TasNetworks	1.47	1	1.01	3	1.34	4	0.91	5
	TransGrid	1.30	3	1.38	1	2.20	1	2.34	1
Capital MPFP	ElectraNet	0.86	2	0.92	2	0.84	4	0.92	4
	Powerlink	0.64	3	0.69	3	0.95	2	1.04	3
	AusNet Services	0.53	5	0.53	5	0.75	5	0.75	5
	TasNetworks	1.11	1	1.19	1	1.00	1	1.08	2
	TransGrid	0.55	4	0.65	4	0.94	3	1.12	1

Source: Frontier Economics analysis; Note: The average efficiency scores and rankings reported in this table are averages across years.

5.2.2 This bias against large networks is illustrated by the strong negative correlation between the different measures of TNSP scale and AER's assessment of total and capital efficiencies

- Our concerns about the likely bias against the large networks in the sample (Sections 5.2.1) appear to be justified, as can be seen through a simple assessment of the correlation between the AER's efficiency scores and different measures of TNSP scale.

Table 8 below shows that there is a highly negative correlation between:

- the AER's MTFP and Capital MPFP scores on the one hand; and
- different measures of scale (such as circuit length, energy delivered, maximum demand, voltage of connection points, and the RAB) on the other hand.

Table 8: Correlation between the AER's efficiency scores and different measures of TNSP scale

	Circuit line length (km) in 2015	Energy transported (GWh) in 2015	Maximum demand (MW) in 2015	Voltage of entry/exit points (KV) in 2015
Measures of TNSP scale				
ElectraNet	5,521	13,455	3,175	7,470
Powerlink	14,755	53,088	11,832	17,160
AusNet Services	6,573	47,655	9,098	9,320
TasNetworks	3,564	13,110	2,505	6,059
TransGrid	13,025	74,400	16,500	17,720
Correlation with MTFP scores				
2015	-70%	-77%	-76%	-69%
Avg 2006 - 2015	-59%	-73%	-69%	-58%
Correlation with Opex MPFP scores				
2015	-36%	7%	1%	-24%
Avg 2006 – 2015	28%	77%	71%	41%
Correlation with Capital MPFP scores				
2015	-68%	-86%	-83%	-70%
Avg 2006 – 2015	-61%	-80%	-76%	-62%

Source: Frontier Economics analysis

In other words, the AER's benchmarking efficiency scores for total cost and capital are highly negatively correlated with different measures of TNSP scale. This strong negative correlation between efficiency scores and TSNP scale suggests that the

AER's models tend to favour small networks over large networks. This supports our concern that AER's model is failing to account for the cost-increasing circumstances faced by those operating networks of very large scale.

5.2.3 The AER's failure to control adequately for scale effects is also illustrated by the implausibly large diseconomies of scale implied by its preferred model specification

We note that the sum of all the first-order scale variable coefficients from EI's Translog regression can be interpreted as the effect of economies of scale on total costs, when assessed at the geometric mean of the sample. As the sum of these coefficients in EI's model is 1.303 (0.279 + 0.288 + 0.362 + 0.374 = 1.303)[24], the interpretation is that a 1% increase in scale (at the geometric mean of the sample) would result in a 1.3% increase in costs, which is an implausibly large increase. Rather, one would expect a 1% increase in scale to result in an increase in costs of around 1%. The fact that EI's preferred Translog model implies implausibly large scale diseconomies raises further doubt about the extent to which the AER has adequately captured the impact of scale variables in its analysis.

5.3 AER's model fails to control adequately for operating environment

The AER's preferred model includes the following five cost drivers (Step 1A of the AER's benchmarking methodology, summarised in Section 2):

- Energy;
- Ratcheted Maximum Demand;
- Weighted Entry and Exit Connections;
- Circuit Length; and
- Reliability.

The list of the AER's output variables above, when assessed against the discussion in Section 5.1, reveals that what is clearly missing is an assessment of differences

24 Our assessment of EI's Translog output weights considers the following files provided to us by TransGrid, which we assume to accurately reflect the AER's methodology: i) various files from the directory: "*Economic Insights TNSP, from TransGrid's previous draft decision, Nov2014*"); and ii) the excel file: "*EI model for cost function - for expert*") that partially replicates the calculation steps taken by Economic Insights in order to weight their translog cost function. Further details are provided in Annexe 2.

in operating environment between the TNSPs, and how these influence costs. As acknowledged by EI in 2013:

> Operating environment conditions can have a significant impact on network costs and measured efficiency and in many cases are beyond the control of managers. Consequently, to ensure reasonably like–with–like comparisons it is desirable to adjust for at least the most important operating environment differences that are truly exogenous to the NSP.[25]

In 2013, EI proposed an initial operating environment factor short list summarised in Figure 1 below. EI summarised these factors under three headings, weather factors, terrain factors and network characteristics.

Figure 1: EI's own list of operating environment factors

Table 7: **TNSP operating environment factor short list**

Variable	Definition	Source
Weather factors		
Extreme heat days	Number of extreme cooling degree–days (above, say, 25° C)	BoM
Extreme cold days	Number of extreme heating degree–days (below, say, 12° C)	BoM
Extreme wind days	Number of days with peak wind gusts over, say, 90 km/hour	BoM
Average wind speed	Average recorded wind speeds for a representative sample of weather stations	BoM
Terrain factors		
Bushfire risk	Number of days over 50 per cent of service area subject to equivalent of NSW severe or higher bushfire danger rating	BoM & FAs
Rural proportion	Percentage of route line length classified as rural	TNSPs
Vegetation encroachment	Percentage of route line length requiring vegetation management by the TNSP on a cyclic pattern	TNSPs
Altitude	Percentage of circuit line length above 600 metres	TNSPs
Network characteristics		
Line length	Route length of lines	RIN
Variability of dispatch	Proportion of energy dispatch from non–thermal generators	TNSPs
Concentrated load distance	Greatest distance from node having at least, say, 30 per cent of generation capacity to node having at least, say, 30 per cent of load	TNSPs

Abbreviations: RIN – Regulatory Information Notice; BoM – Bureau of Meteorology; FA – Fire Authority

Source: Economic Insights (2013), 'Economic Benchmarking of Electricity Network Service Providers'.

[25] Economic Insights (2013), *'Economic Benchmarking of Electricity Network Service Providers'*, p. 72.

We agree that these are important factors that influence the input costs of TNSPs. Other factors that are also important, but not on this list, include changes in regulatory obligations which affect the way networks are managed, improvements in health and safety management, and increased compliance reporting obligations over time. These are all factors that lead to increased input costs but do not lead to additional outputs.

We note that no consideration has been given to these factors in the AER's 2016 annual benchmarking report, and the AER has not attempted to collect data on the majority of these variables. We appreciate that, owing to practical limitations, it is not possible to include all these variables in a single benchmarking model because:

- output variables tend to be highly correlated with each other, and cannot all be combined in the same model because of the statistical problem of multicollinearity; and
- even considering all nine years of data in the AER's RINs, the sample size is relatively small owing to the existence of only 5 TNSPs in the sample: this limits the number of explanatory variables that can be used.

However, to overcome these practical limitations, a wide range of approaches have been adopted by European regulators, including making a number of normalisations, exclusions and adjustments to their benchmarking models in an attempt to ensure that their comparisons are more like-for-like.

The AER's failure to include, within its benchmarking methodology, an explicit step to account for environmental factors suggests strongly that its application of benchmarking falls well short of best practice. In our view, owing to these omissions, the AER's benchmarking results will not provide a robust indication of managerial inefficiency, but are instead likely to conflate managerial inefficiency with a wide range of factors relating to the utilities' operating environment. We consider that the AER should learn from the experience of regulators in Europe and make adjustments for special factors an integral component of its benchmarking analysis.

5.4 The AER's assessment of input prices (through the PRTC index) lacks any theoretical justification and produces implausible results

In order to convert its proxy of 'total nominal costs' (Step 2Ai of the AER's benchmarking methodology, summarised in Section 2) to 'total real costs' (Step 2Aii), EI has developed its own utility-specific inflation series. EI's estimate of total nominal costs (in Step 2Ai) is estimated as follows:

$$\text{Total costs (nominal)} = \text{opex} + \text{AUC overhead lines} + \text{AUC underground cables} + \text{AUC transformers and other}$$

where the annual user cost of capital = return on capital (opening RAB * benchmark WACC) + regulatory depreciation + benchmark tax liability.

EI's price index variable, which it calls 'PRTC', is calculated by EI using the statistical software package SHAZAM. This can be seen, for example, in EI's SHAZAM input file entitled 'TranslogCostFn2In', one of the supporting files that was provided in the following folder: 'AER Draft decision TransGrid transmission determination - TransGrid 2014 - Economic Insights TNSP productivity files - November 2014'.[26]

The PRTC approach is summarised in Figure 2.

Figure 2: Illustration of EI's PRTC approach

PRTC is a Fisher price index constructed in SHAZAM. It is used to convert nominal total costs to real

	a Opex	b Overhead lines	c Underground cables	d Transformers & other
1 Total quantity	$ Real opex	Overhead lines (MVA-KM)	Underground cables (MVA-KM)	Transformers & other (MVA)
2 Total revenue	Estimated separately	Overhead lines AUC	Underground cables AUC	Transformers & other AUC
3 'Price' = revenue/quantity	Opex price index	AUC/MVA-KM Overhead lines	AUC/MVA-KM underground cables	AUC/MVA Transformers & other

PRTC is a Fisher price index of the prices in row (3) weighted by the quantities in row (1).

Source: Frontier Economics

As shown in Figure 2, EI's PRTC series is a Fisher price index constructed using the prices and quantities of the four underlying inputs used in its estimate of total costs (in Step 2Ai). This includes the following.

1) Overhead lines, where prices and quantities are calculated as follows:

- The '**quantity'** of overhead lines is measured as the MVA*km of overhead lines.
- The total '**revenue**' from overhead lines is estimated by the annual user cost of capital share of overhead lines. This is the return on and of capital of the RAB of overhead lines.

---

26 Our assessment of EI's PRTC index is based on the following files provided to us by TransGrid, which we assume to accurately reflect the AER's methodology i) various files from the directory: "*Economic Insights TNSP EB Update 13Nov2015*"; and ii) excel file: "*EI model for cost function - for expert*". Further details are provided in Annexe 2.

- The **'price'** of overhead lines is estimated to be the ratio of revenues and quantities above.

2) Underground cables, where prices and quantities are calculated as follows:

- The **'quantity'** of underground cables is measured as the MVA*km of underground cables.
- The total '**revenue**' from overhead lines is estimated by the annual user cost of capital share of underground cables. This is the return on and of capital of the RAB of underground cables.
- The **'price'** of underground cables is estimated to be the ratio of revenues and quantities above.

3) Transformers and other capital, where prices and quantities are calculated as follows:

- The **'quantity'** of transformers and other capital is measured as the total MVA of transformers and other capital.
- The total '**revenue**' from transformers and other capital is estimated by the annual user cost of capital share of transformers and other capital. This is the return on and of capital of the RAB of transformers and other capital.
- The **'price'** of transformers and other capital is estimated to be the ratio of revenues and quantities above.

4) Opex, where prices and quantities are calculated as follows:

- The 'quantity' of opex is measured as the $nominal opex spend, as reported in the RINs.
- The price of Opex is simply the opex price index that the AER has constructed from ABS data.

Our assessment of EI's PRTC index reveals that

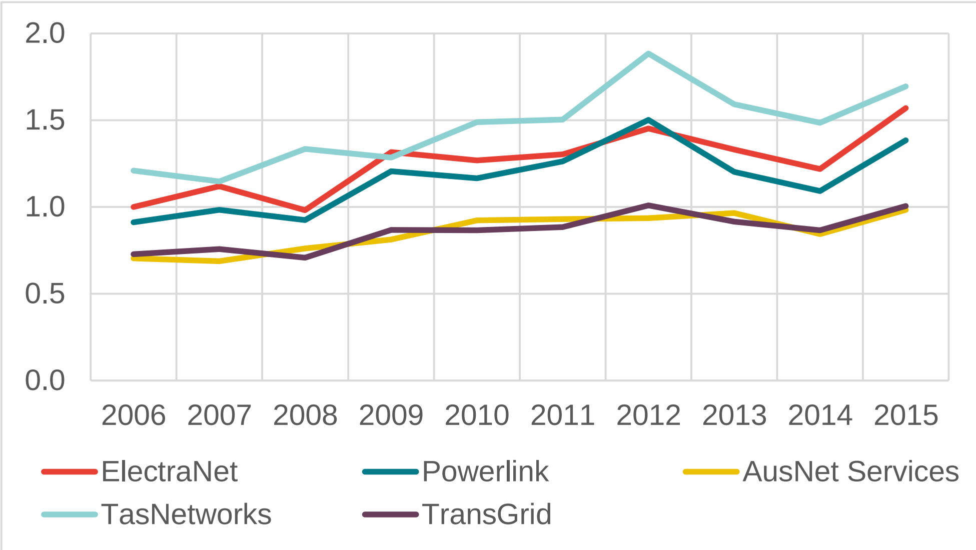
- The differences in the input prices of different TSNPs implied by the PRTC index are implausibly large; and
- EI's PRTC series lacks theoretical justification.

These two points are discussed in turn.

The PRTC index produces implausible results

EI's PRTC index for all the TNSPs are shown in Figure 3 below.

Figure 3: PRTC index



Source: Frontier Economics

Figure 3 shows that the implied differences in 'prices' between networks seems implausible. For example, the PRTC index suggests that TransGrid's 'price' is almost half of that of TasNetworks. While unit costs may fall as networks benefit from economies of scale, it seems unrealistic for some networks to procure inputs at half the cost of others. There is no reason to suppose that there are, in practice, such marked differences in the input prices for labour or for electrical network components between companies. It is therefore entirely possible that the PRTC method in fact incorporates a range of other factors in addition to input prices and may hence be materially distorting the analysis. **It is particularly counter-intuitive that the networks that are deemed to procure their inputs at the lowest unit costs according to the AER's assessment of prices, are also those that are deemed to be the least efficient in the sample**. The magnitude of the implied differences in the 'prices' of networks also raises questions about the reliability of the data that has been used to construct the PRTC index (data on physical capital quantities and annual user cost of capital estimates).

EI's PRTC series lacks theoretical justification

As it appears that the primary purpose of the PRTC index is to convert its proxy of 'nominal AUCs' (Step 2Ai of the AER's benchmarking methodology, summarised in Section 2) to 'real AUCs' (in Step 2Aii), it is unclear why the AER did not attempt to calculate real AUCs directly instead.

There are two approaches that regulators commonly adopt to calculate real returns:

A) Using an indexed RAB: Typical of the regulatory precedent from Ofgem and IPART. Inflation is compensated for through annual indexation which is applied to the assets on which a real return is allowed

B) Using a nominal WACC: The second approach is to wrap expectations of inflation into the nominal WACC calculation. Here, the regulatory asset base (RAB) is not adjusted to allow for inflation. The necessary compensation is provided by the WACC calculation itself.

The AER applies a nominal vanilla WACC to an indexed opening RAB (owing to what is specified in the NER), therefore counting inflation twice. To correct for this double-counting, the AER reduces the regulatory depreciation by the inflationary gain on the RAB. The calculation results in a nominal AUC, which EI has tried to convert to real using the PRTC construct.

The conceptually correct way to calculate real AUCs would be to apply an approach like IPART or Ofgem as in A) above, where a real WACC is applied to the indexed RAB, or the alternative described under B). We recommend that the AER adopt one of these two approaches to calculate real returns.

5.5 AER's model produces efficiency scores that imply such enormous differences in managerial performance as to be not credible

Table 9 below shows the spread in the AER's implied efficiency scores[27], as derived from the MTFP, Opex MPFP and Capital MPFP scores presented in its 2016 annual benchmarking report. It can be seen that the spread in the AER's implied efficiency scores for the latest year (2015) is around 50% for capital, around 40% for opex and for total costs. Spreads of this size are too wide to be credibly driven by differences solely in managerial efficiency. It is likely that a large part of the spread is driven by differences between the TNSPs that are not adequately captured in the AER's analysis (including those discussed in Sections 5.2, 5.3 and 5.4).

27 By "spread in the AER's implied efficiency scores", we are referring to the difference in efficiency scores of the implied most efficient and implied least efficient TNSP in the AER analysis.

Table 9: Spread of the AER's estimated "efficiency" scores

AER scores	2015 scores			Average scores 2006 – 2015		
	MTFP	Opex MPFP	Capital MPFP	MTFP	Opex MPFP	Capital MPFP
ElectraNet	0.87	0.87	0.86	0.93	0.94	0.92
Powerlink	0.71	0.92	0.64	0.77	1.00	0.69
AusNet Services	0.69	1.32	0.53	0.68	1.32	0.53
TasNetworks	1.21	1.47	1.11	1.13	1.01	1.19
TransGrid	0.70	1.30	0.55	0.80	1.38	0.65
AER's scores rebased to the score of the most efficient network						
ElectraNet	72%	59%	77%	82%	68%	77%
Powerlink	59%	62%	57%	68%	73%	58%
AusNet Services	57%	90%	48%	60%	96%	45%
TasNetworks	100%	100%	100%	100%	73%	100%
TransGrid	58%	88%	50%	71%	100%	54%
Spread in the AER's implied efficiency scores	43%	41%	52%	40%	32%	55%
Relative TNSP rankings						
ElectraNet	2	5	2	2	5	2
Powerlink	3	4	3	4	4	3
AusNet Services	5	2	5	5	2	5
TasNetworks	1	1	1	1	3	1
TransGrid	4	3	4	3	1	4

Source: Frontier Economics

Annexe 1: Declarations

We have read, understood and complied with the Federal Court of Australia’s Expert Evidence Practice Note (GPN-EXPT) dated 25 October 2016.

We have made all the inquiries that we believe are desirable and appropriate and that no matters of significance that we regard as relevant have, to our knowledge, been withheld from the Court.

Mike Huggins

Professor Bob Bartels

Annexe 2: Instructions

TransGrid

ABN 70 250 995 390
180 Thomas Street, Sydney
PO Box A1000 Sydney South
NSW 1235 Australia
T (02) 9284 3000
F (02) 9284 3456

Professor Bob Bartels
Frontier Economics
13/50 Margaret St,
Sydney, NSW 2000

Dear Professor Bartels

Re: Terms of Reference for Benchmarking

TransGrid would like to engage Frontier Economics to review and comment on technical aspects of the AER's MTFP, Opex MPFP and Capital MPFP analysis in its 2016 annual benchmarking report, having regard to:

> the impact of using the latest available RIN data from 2016;
> the selection of inputs and outputs;
> the assessment of input prices through the PRTC index;
> potential inconsistencies with the AER's own approach to benchmarking in the distribution sector in Australia; and
> any other matter that Frontier Economics considers relevant.

For the purpose of this investigation, TransGrid has supplied the following:

> A spreadsheet that reverse engineers the AER's benchmarking results in accordance with the methodology used to produce their 2015 benchmark report (Excel file: "AER benchmark - reverse engineered - for expert".
> Supporting data that was used by Economic Insights to produce the AER's 2015 benchmarking report (various files from the directory: "Economic Insights TNSP EB Update 13Nov2015").
> Data and scripts that were used by Economic Insights to weight their translog cost function (various files from the directory: "Economic Insights TNSP, from TransGrid's previous draft decision, Nov2014").
> A spreadsheet (Excel file: "EI model for cost function - for expert") that partially replicates the calculation steps taken by Economic Insights in order to weight their translog cost function.

TransGrid requests that your report complies with the Federal Court of Australia's Expert Evidence Practice Note (GPN-EXPT) dated 25 October 2016, and that you attach to the report a copy of this engagement letter and a copy of the CVs of the authors, containing their qualifications and relevant experience.

Yours faithfully

Shane Tennett
Regulatory Opex Manager

Annexe 3: CVs of Authors

Mike Huggins

5.5.1 Career

Jan 2013 to date	Director, Frontier Economics
April 2010 to Dec 2012	Associate Director, Frontier Economics
January 2003 to April 2010	Manager, Frontier Economics
September 1999-December 2002	Consultant, Frontier Economics
April 1998-August 1999	Consultant, London Economics
1994-98	Economist, Energy Policy and Analysis Unit, UK Civil Service

5.5.2 Education

1996-98	Birkbeck College, London, M.Sc. Economics, with distinction
1989-92	University of Sheffield, B.Sc. (Hons) Mathematics

5.5.3 Address

Frontier Economics,

Mid City Place,

71 High Holborn,

London WC1V6DA,

UK.

5.5.4 Selected experience in network regulation and benchmarking

- **CREG, Belgium:** advice on the design of an incentive to provide a sufficient level of quality of supply (2014).
- **ESB Networks, totex benchmarking:** For the upcoming regulatory review, Frontier is undertaking totex benchmarking for ESB Networks (2014).

- **Energy Networks Association:** - to carry out analysis of RPE allowances for RIIO-ED1, in particular estimating the size of the RPE allowances that the GB DNOs would receive under a range of different methodologies. (2014).

- **ESB Networks, price control support**: estimation of ESBN's cost of capital for its forthcoming price control (2014).

- **NIE networks, price control support:** led Frontier's advice to NIE on its fifth regulatory review across all aspects of its business, including the cost of capital efficiency analysis, incentive design, the regulatory treatment of pensions, real price effects, work force renewal and a miscellany of other elements of NIE's business. NIE's price control has now been referred to the Competition Commission and Mike continues to lead Frontier's advice. (2010-2014).

- **ESB Networks, price control support**: a review of recent relevant regulatory precedent to identify emerging trends and themes that may provide opportunities or threats for ESBN at its next review (2014).

- **Northern Powergrid, GB, RIIO-ED1:** advice on Ofgem's developing ideas in respect of efficiency analysis and the allowed rate of return, including preparing a response to Ofgem's recent consultation on the cost of equity (2012-ongoing).

- **ENA New Zealand:** advice on the methodologies that might be developed to forecast future costs for the electricity distribution companies.

- **Ofgem/DNO working group, RIIO-ED1:** conducted a large scale econometric analysis of the GB DNOs to develop an operational and robust totex efficiency model. This study, which was initiated by the DNOs, was eventually taken over by Ofgem and will be used as part of their efficiency "toolkit" to inform on so-called fast-track decisions and the appropriate level for regulatory allowances for ED1 more generally (2012-13).

- **Northern Powergrid, Great Britain, business plan development:** advised on the development of a well justified business plan for submission at the forthcoming RIIO-ED1 review (2011-12).

- **National Grid, price control support:** advised National Grid on the preparation of their initial and final TO business plan, as part of RIIO-T1. Advice focused on incentive design and risk modelling and the development of a network development policy, including associated modelling of the optimal approach to network reinforcement. (2011-2012).

- **Scotia Gas, efficiency analysis, RIIO-GD1:** provided an independent critique of Ofgem's approach to benchmarking at the recently completed gas distribution review (2012).

- **Ofgem, efficiency analysis under RIIO:** as part of its RPI-X@20 review Ofgem commissioned a study that looked at how its future use of benchmarking across all of the energy networks might better support its renewed focus on long term planning and the delivery of outputs under the then shaping RIIO framework. Frontier prepared a report that reviewed past conduct and present best practice, leading to a set of clear policy recommendations (2010).

- **Ofgem, outputs under RIIO:** Ofgem asked Frontier to provide it with a report that assessed how it might best define and use the outputs that it would in future ask companies to deliver under its then developing RIIO framework. Frontier, working with engineering consultants Consentec, developed a high level set of output areas and then considered the data that could be collected in each area. Based on this, Frontier developed a tiered system of output measurement and use, that focused on primary deliverables (which may be suitable for use directly in incentive mechanisms) and secondary deliverables (which should be monitored but were not apt for use in incentive mechanisms for a range of reasons). Frontier's recommendations were central to the outputs that are now established across the RIIO price controls (2010).

- **NMa, Netherlands, impact of DG on regulated networks:** led a study to investigate the differential effect of DG on the Dutch electricity distribution networks, in order to understand whether the existing treatment of DG in regulatory arrangements could be improved. Mike worked closely with an engineering advisor and discussed the issue widely with experts from the sector. (2011-2012).

- **NMa, Netherlands, transmission efficiency analysis:** prepared a feasibility study, in association with Consentec, reviewing the scope to successfully apply reference network modelling techniques in order to assess the efficiency of TenneT. (2011-2012).

- **ORES, regulatory policy, Belgium**: provided advice to ORES, an operator of both gas and electricity networks, on a range of regulatory issues. This included providing a critique of the regulator's proposed efficiency analysis (2011).

- **CE Electric:** advice on all aspects of DPCR5, including in particular advice on benchmarking, the cost of capital and the development of Ofgem's "Information Quality Incentive" mechanism. (2007-2010).

- **DTe, Netherlands, efficiency analysis:** a study to investigate the extent to which differences in cost arising from exogenous differences in connection density can be quantified and corrected for in regulatory decisions. (2007-2009)

- **DTe, Netherlands, regulatory policy:** provided DTe with an assessment of their overarching regulatory approach with a particular focus on the steps that they could take in order to make their regulatory decisions more robust. (2007)

- **Regulated gas network operator, Western Europe, regulatory advice**: assisting a gas network operator through its price control review (2004).

- **CREG, Belgium, regulatory design:** Managing Frontier's work to advise the CREG on its electricity distribution price control review, including advice on conducting efficiency analysis using DEA (2004).

- **CE Electric, UK, regulatory advice**: providing advice on a range of issues arising from a distribution price control review, in particular with regard to the incentives provided to the companies by some proposed changes to the regulatory regime (2004-05).

- **E-control, energy regulator in Austria:** Managing an exercise to produce preliminary estimates of relative efficiency to inform the gas and electricity distribution price control review (2003).

- **Ofgem, network regulation**: Provided advice on the development of Ofgem's regulation of the network monopolies, looking specifically at the inclusion of quality in efficiency analysis and the provision of clear, strong and balance incentives for efficient behaviour (2002-03).

- **A group of Northern European regulators, efficiency analysis:** Advised on the approaches that might be adopted to determine the relative efficiency of transmission system operators and how this analysis might inform regulatory policy (2001-02).

- **DTe (Dutch energy regulator), efficiency analysis:** Advised the client on the use of Data Envelopment Analysis, including data requirements (in particular the standardisation of capital costs), model selection and the policy implications of the results. The results from our DEA have underpinned the preliminary price determinations made by the regulator. In addition to advice on benchmarking techniques we have helped the client with the implementation of yardstick regulation and financial modelling. (1999-2001).

- **DTe, regulation of purchase costs:** Advised DTe on the incentive properties of a number of proposed schemes for the regulation of electricity purchase costs (2000).

Professor Bob Bartels

5.5.5 Career

2006 - present	Consultant, Frontier Economics
2006 - present	Emeritus Professor in Econometrics and Business Statistics, University of Sydney
2006	Head, School of Economics and Political Science, University of Sydney
2000 - 2002	Head, School of Business, University of Sydney
1996 - 1997	Director and Principal of Decision Vision, a market research company
1989 - 1998	Senior Associate, London Economics
1987 - 1988	Head, Department of Econometrics, University of Sydney
1983 - 2006	Academic consultant to the government and private sectors
1975 - 2006	Various positions, from Lecturer to Professor, in Econometrics and Business Statistics, University of Sydney
1972 - 1974	Lecturer in Statistics, Macquarie University

5.5.6 Education

1969 - 1972	PhD (Syd) in Economic Statistics (Thesis Topic: Stable Distributions in Economics)
1965 - 1968	BA (Hons 1) (Syd). University Medal in Mathematical Statistics. Majors in Mathematical Statistics and Pure Mathematics

5.5.7 Address

Frontier Economics,

Level 13,

50 Margaret Street

Sydney NSW 2000

5.5.8 Selected experience in network regulation and benchmarking

- **Litigation support - AER benchmarking of NSPs**. Assisted Counsel for Networks NSW prepare a merits review case, on opex issues, heard by the Australian Competition Tribunal. This involved undertaking a detailed assessment of the AER's benchmarking analysis (including advanced econometric and other modelling). (2015)

- **Advice on AER's benchmarking analysis**. Assisted Ergon Energy's legal counsel by reviewing the AER's application of benchmarking analysis to set cost allowances for regulated electricity distribution network service providers (DNSPs) in Australia. Demonstrated, using econometric modelling, that the AER had failed to account for large differences in operating circumstances between Ergon Energy and other DNSPs, such as sparsity of the network. (2015)

- **Network configuration in benchmarking analysis**. Engaged by two DNSPs to assess the impact of differences in electricity distribution network configuration on benchmarking analysis undertaken for the assessment of relative efficiency. (2015)

- **Peer review of consultant reports on AER's benchmarking.** Undertook a peer review for a DNSP of benchmarking analysis undertaken for the utility by two other economic consulting firms. This work involved reviewing both the conceptual arguments and the modelling undertaken by the consultants, and checking that it was to a standard that could be submitted to the Australian Energy Regulator. (2015)

- **ACCC's DTCS FAD Inquiry.** Was engaged by lawyers acting on behalf of Vodafone to provide expert econometric advice in connection with the ACCC review of benchmark prices for domestic transmission capacity services as part of its final access determination. As part of the engagement, undertook a detailed assessment of the dataset used by the ACCC for the benchmarking exercise and an extensive expert review of the econometric modelling undertaken by the ACCC's consultants using the dataset. (2014 – 2015)

- **High level review of models used for AER pricing determination.** Supervised a high level review of the forecasting models and procedures used by the three NSW DNSPs as part of the preparation for submissions to the AER for the next price determination. (2012 – 2013)

- **In-depth review of models used for AER pricing determination.** Supervised in-depth review for Endeavour Energy of their forecasting models and procedures as part of the preparation for submissions to the AER for the next price determination. The review has resulted in major changes to Endeavour's procedures. (2012 – 2014)

- **Validation of models for submission to APRA.** Undertook peer reviews for the Commonwealth Bank of several "Probability of Default" and "Loss Given Default" models as part of its validation and regulatory approval processes. The reviews examined conceptual, statistical, mathematical and computational issues arising in the development of the models, in the application of the models to predict future default rates and losses, and in the stress testing of the models that the Bank undertook using simulation methods. (2010 – 2012)
- **Review for ACCC of models used in Australia Post's 2010 pricing notification.** Advised the Australian Competition and Consumer Commission (ACCC) on the reasonableness of forecasts used by Australia Post in its 2010 Pricing Notification. This included:
  - reviewing the original and revised demand forecasting methodologies employed by Australia Post, which included advanced time-series forecasting techniques overlayed with specific management intelligence
  - analysis and commentary on whether cost forecasts were consistent with expectations that costs should fall in line with volumes. Frontier's analysis was a critical input into the ACCC's analysis of the Notification. (2010)
- **Review of NIEIR models used in AER regulatory review for Victoria.** Undertook an independent peer review of the National Institute for Economic and Industry Research (NIEIR) models, forecasting procedures and assumptions that underpin the forecasts contained in Powercor and CitiPower's submissions to the Australian Energy Regulator for the 2011-15 regulatory review. (2010)
- **Review of NIEIR models used in AER regulatory review for South Australia.** Provided support for ETSA's 2010-2015 regulatory proposal by reviewing its forecasting methodologies. (2010)
- **Review of electricity forecasting models for South Australia.** Undertook a review for a DNSP of the forecasting models for South Australia commissioned by the Australian Energy Regulator (AER) as part of the AER's assessment of the utility's regulatory proposal. (2009)
- **Telecommunications services price indices for ACCC.** Provided methodological advice as to how the Australian Competition and Consumer Commission (ACCC) should compile and update the mobile-telephone and internet components of the telecommunications services price indexes that it includes in its annual Div12 reports. The main issue is how to account for the rapid technological changes that characterise these services. In view of our methodological advice, the ACCC sought additional data from the relevant service providers. The second part of the project was to develop a spreadsheet system for the ACCC to use in compiling the revised indexes using the additional data provided by the carriers. (2009)

- **Review of forecasting in Western Australia.** Undertook a detailed review of the electricity demand forecasting procedures used in the South West Integrated System in Western Australia and advised the Independent Market Operator (IMO) on the appropriateness of these procedures for meeting its regulatory obligations. (2007-2008)

5.5.9 Publications

Refereed articles

1. Bartels, R., Fiebig, D.G. and van Soest, A. (2006), "Consumers and experts: An econometric analysis of the demand for water heaters", *Empirical Economics,* 31(2), 369-391.
2. Bartels, R., Fiebig, D.G. and McCabe, A. (2004), "The value of using stated preference methods: a case study in modelling water heater choices", *Mathematics and Computers in Simulation*, 64 (3&4), 487-495.
3. Bartels, R. and Islam, T. (2002), "Supply restricted telecommunications markets: The effect of technical efficiency on waiting times", *Journal of Productivity Analysis*, 18(2), 161-169.
4. Bartels, R. and Fiebig, D.G. (2000), "Residential end-use electricity demand: results from a designed experiment", *The Energy Journal*, 21(2), 51-81.
5. Zhang, Y. and Bartels, R. (1998), "The effect of sample size on the mean efficiency in DEA with an application to electricity distribution in Australia, Sweden and New Zealand", *Journal of Productivity Analysis,* 9, 187-204.
6. Sharma, D. and Bartels, R. (1997), "Distributed electricity generation in competitive energy markets: A case study in Australia", *The Energy Journal, (Special Issue), Distributed Resources: Toward a New Paradigm of the Electricity Business*, 17-40.
7. Bartels, R., Fiebig, D.G., and Plumb, M. (1996), "Gas or electricity, which is cheaper?: An econometric approach with application to Australian expenditure data", *The Energy Journal*, 17(4), 33-58.
8. Bartels, R., Fiebig, D.G., and Nahm, D. (1996), "Regional end-use gas demand in Australia", *Economic Record*, 72, 319-331.
9. Bartels, R. and Fiebig, D.G. (1996), "Metering and modelling residential end-use electricity load curves", *Journal of Forecasting*, 15, 415-426.
10. Fiebig, D.G., Bartels, R. and Krämer, W. (1996), "The Frisch-Waugh theorem and generalised least squares", *Econometric Reviews*, 15, 431-443.
11. Krämer, W., Bartels, R. and Fiebig, D.G. (1996), "Another twist on the equality of OLS and GLS", *Statistical Papers*, 37, 277-281.
12. Bartels, R. and Fiebig, D.G., (1995), "Optimal design in end-use metering experiments", *Mathematics and Computers in Simulation*, 39, 305-309.

13. Fiebig, D.G., McAleer, M. and Bartels, R. (1992), "Properties of OLS estimators in regression models with non-spherical disturbances", *Journal of Econometrics*, 54, 321-334.
14. Bartels, R., Fiebig, D.G., Garben, M. and Lumsdaine, R. (1992), "DELMOD: An end-use simulation model", *Utilities Policy*, 2(1), 71-82.
15. Bartels, R. (1992), "On the power function of the Durbin-Watson test", *Journal of Econometrics*, 51, 101-112.
16. Bartels, R. and Fiebig, D.G. (1991), "A simple characterization of seemingly unrelated regressions models in which OLS is BLUE", *American Statistician*, 45, 137-140.
17. Fiebig, D.G., Bartels, R. and Aigner, D.J. (1991), "A random coefficient approach to the estimation of residential end-use load profiles", *Journal of Econometrics*, 50, 297-328.
18. Bartels, R. Cohen, R. and Hoehn, T. (1991), "Das neue Elektrizitätssystem in Grossbritannien: Erste Erfahrungen und Perspektiven", *Zeitschrift für Energiewirtschaft*, 1/91, 27-36.
19. Bartels, R. and Fiebig, D.G. (1990), "Integrating direct metering and conditional demand analysis for estimating end-use loads", *The Energy Journal*, 11(4), 79-97.
20. Bartels, R., Murray, J., and Weiss, A.A. (1988), "The role of consumer and business sentiment in forecasting telecommunications traffic", *Journal of Economic Psychology*, 9, 215-232.
21. Andrews G., Hall W., Goldstein G., Lapsley H., Bartels R., and Silove D. (1985), "The economic costs of schizophrenia: Implications for public policy", *Archives of General Psychiatry*, 42, 537-543.
22. Hall W., Goldstein G., Andrews G., Lapsley H., Bartels R. and Silove D. (1985), "Estimating the economic costs of schizophrenia", *Schizophrenia Bulletin*, 11, 598-611.
23. Bartels, R. (1985), "Identification in econometrics", *American Statistician*, 39, 102-104.
24. Bartels, R. (1984), "The rank von Neumann test as a test for autocorrelation in regression models", *Communications in Statistics*, A13(20), 2495-2502.
25. Bartels, R. (1984), "Estimation in a bidirectional mixture of von Mises distributions", *Biometrics*, 40, 777-784.
26. Bartels, R., Bornholt, G. and Hanslow, K. (1982), "The polynomial trend model with auto-correlated residuals", *Communications in Statistics*, A11(12), 1393-1402.
27. Bartels, R. (1982), "The rank version of von Neumann's ratio test for randomness", *Journal of the American Statistical Association*, 77, 40-46.
28. Bartels, R. (1981), "Truncation bounds for infinite expansions for the stable distributions", *Journal of Statistical Computation and Simulation*, 12, 293-302.

29. Bartels, R. and Goodhew, J. (1981), "The robustness of the Durbin-Watson test", *The Review of Economics and Statistics*, 63, 136-139.

30. Bartels, R. (1979), "Fractiles for the non-symmetric stable distributions", *Journal of Statistical Computation and Simulation*, 9, 127-132.

31. Bartels, R. (1978), "Generating non-normal stable variables using limit theorem properties", *Journal of Statistical Computation and Simulation*, 9, 199-212.

32. Bartels, R. (1977), "Estimation in a first order autoregressive scheme with non-normal stable disturbances", *Journal of Statistical Computation and Simulation*, 6, 35-48.

33. Bartels, R. (1977), "On the use of limit theorem arguments in economic statistics", *American Statistician*, 31, 85-87.

Contributions to refereed books

34. Bartels, R. (2002), "Seemingly unrelated regressions", in A. El-Shaarawi and W. Piegorsch (eds), *Encyclopedia of Environmetrics*, 1959-1961.

35. Bartels, R. Cohen, R. and Hoehn, T. (1992), "Markets for Electricity: The British system", in E. Hope and S. Strom (eds), *Energy Markets and Environmental Issues*, Scandanavian University Press, 87-114.

36. Bartels, R. and Fiebig, D.G. (1992), "Efficiency of alternative estimators in generalized seemingly unrelated regression models", in R.Bewley and T.V.Hoa (eds), *Contributions to Consumer Demand and Econometrics: Essays in Honour of Henri Theil*, Macmillan, 125-139.

Monographs

37. Bartels, R. (1988), *Household Energy Consumption: Analysis of the 1984 Energy Survey*, Department of Energy of NSW and the Electricity Commission of NSW, DOE88/102.

38. Bartels, R., D.Fiebig, D.Aigner and T.leRoux (1988), *Domestic End-Use Study*, Electricity Commission of New South Wales, PD 88/5.

39. Bartels, R. (1986), *Energy Modelling in Australia: A Constructive Analysis*, Department of Resources and Energy, WS86/021.

40. Bartels, R., P. Lopert and S. Williamson (1986), *The Residential Demand for Electricity*, Energy Authority of New South Wales, EA85/9.

41. Bartels, R. (1985), *Appliance Penetration and Household Energy Consumption*, Energy Authority of New South Wales, EA85/50.

42. Bartels, R., G. Goldstein, R. Resnick and H. Lapsley (1984), *The Cost of Acute Myocardial Infarction in New South Wales: An Incidence Based Study*, Report to Department of Health, Australian Government Printing Service.

Published conference proceedings

43. Bartels, R., D.G.Fiebig, and A.McCabe (2001), "The Value of Using Stated Preference Methods: A Case Study in Modelling Water Heater Choices," in F. Ghassemi, M. McAleer, L.Oxley and M. Scoccimarro, *MODSIM 2001: Modelling and Simulation Society of Australia and New Zealand*, ANU, Canberra, 1421-1426.
44. Bartels, R. and D.G.Fiebig (1999), "Evidence of joint decision making", *Proceedings: International Congress on Modelling and Simulation*, Hamilton, NZ, 1999, 325-330.
45. Bartels, R. (1999), "International benchmarking of the economic performance of electricity utilities", *The Third International Symposium on Multinational Business Management*, Nanjing, China.
46. Bartels, R. (1999), "The contribution of electricity demand to the CO2 emissions by Australian industry", *22nd International Association of Energy Economists Annual International Conference*, Rome, 318-326.
47. Bartels, R., M. Smith and J. Louviere (1996),"The ordered beta model: Specification and estimation", *Econometric Society Australasian Meeting, Vol 2*, 663-676.
48. Bartels, R. and Y. Zhang (1996),"Are Australian electricity distributors more efficient?", *Econometric Society Australasian Meeting, Vol 4*,149-186.
49. Bartels, R., D.G. Fiebig, and M. Plumb (1996),"Gas or electricity, which is cheaper?: An analysis of household energy expenditures", *Econometric Society Australasian Meeting, Vol 4*,1996, 187-212.
50. Bartels, R. (1993),"The economic efficiency of electricity distribution in Australia", *Proceedings, DISTRIBUTION 2000, 2nd International Electricity Distribution Conference*, 7 pages.
51. Bartels, R., N. Crabb, P. Tang, G. Gangopadhyay, and D. Fiebig (1993), "Residential end-use study in NSW", *1993 ESAA Forecasting Forum*, 18 pages.
52. Bartels, R (1992),"The effect of a carbon tax on Australian industry", *Coping with the Energy Future: Markets and Regulations (Proceedings, 15th Annual Conference, International Association for Energy Economics)*, I1-I6.

Book reviews

53. Review of: Pesaran, M.H. and Schmidt, P., *Handbook of Applied Econometrics. Volume II: Microeconomics*, 1997, Blackwell, in *Statistical Papers*, 40, 1999, 239.
54. Review of: Lütkepohl, H., *Handbook of Matrices*, 1996, Wiley, in *The Statistician*, 47(1), 1998, 225.
55. Review of: Davidson, F., *Principles of Statistical Data Handling*, 1996, Sage, in *The Statistician*, 47(1), 1998, 220-221.

56. Review of: Pollitt, M.G., *Ownership and Performance in Electric Utilities*, 1995, Oxford UP, in *The Energy Journal*, 17, 1996,105-107.
57. Review of: Härdle, W. et al, *XploRe: An Interactive Statistical Computing Environment*, 1995, Springer-Verlag. in *The Statistician*, 45, 1996, 388-389.
58. Review of: Mumford, E. and Sackman, H., *Human Choice and Computers*, in *Australian Journal of Public Administration*, 37, 1978, 88-89.
59. Review of: Shubik, M., *The Uses and Methods of Gaming*, 1975, Elsevier, and Shubik, M., *Games for Society, Business and War: Towards a Theory of Gaming*, 1975, Elsevier, in *Australian Journal of Public Administration*, 36, 1977, 96-97.

Other articles and book contributions

60. *Statistical Basis for the Determination of Checktesting Validity Criteria*, 2004, prepared for the National Appliance and Equipment Energy Efficiency Committee, 1-27 (with Lloyd Harrington).
61. "Electric motors and industry energy efficiency", *Electricity Supply Magazine*, No17, Dec 1994, 4-5.
62. "Residential end-use electricity forecasting" in *Electricity Generation Planning in an Uncertain Environment*, G. McColl (ed.), Centre for Applied Economic Research, University of NSW, 1988, 113-122.
63. "Comments on two energy models" in *Energy Modelling in Australia*, Centre for Applied Economic Research, University of NSW, 1985, 128-132.
64. "The Donovan study of atomic test personnel: a critique", *Sana Update*, 19, 1984, p.16.

Unpublished conference papers

65. "Consumers and experts: An econometric analysis of the demand for water heaters", *2001 Econometric Society: Australasian Meetings*, Auckland NZ, 2001. (with D. Fiebig and A. van Soest).
66. "The residential demand for electricity in New South Wales", *Annual Conference of the Electricity Supply Engineers' Association of NSW, Sydney*, 1985. (with P. Lopert and S. Williamson).
67. "Interest rates, the money supply and inflation", *Third Conference of Economists, Adelaide*, 1973. (with D.J. Jüttner).

Discussion papers (not published elsewhere)

68. "Constrained estimation of the Hildreth-Houck random coefficient model", *Sydney University, Department of Econometrics*, Discussion Paper 90-02, January 1990 (with D. Fiebig).
69. "More on the grouped heteroskedasticity model", *Tilburg University, The Netherlands*, CentER Discussion Paper 9058, October 1990 (with D. Fiebig).

70. "Interest rates and price expectations", *Macquarie University, School of Economic and Financial Studies*, Research Paper No. 30, May 1973 (with D.J. Jüttner).
71. "Interest rates and the money supply", *Macquarie University, School of Economic and Financial Studies*, Research Paper No. 26, April 1973 (with D.J. Jüttner).

FRONTIER ECONOMICS
BRISBANE | MELBOURNE | SINGAPORE | SYDNEY
Frontier Economics Pty Ltd 395 Collins Street Melbourne Victoria 3000
Tel: +61 (0)3 9620 4488 Fax: +61 (0)3 9620 4499 www.frontier-economics.com.au
ACN: 087 553 124 ABN: 13 087 553 124