Memorandum

From: Denis Lawrence, Tim Coelli and John Kain **Date:** 20 November 2020

To: AER Economic Benchmarking Team

Subject: Advice on selected issues raised in DNSP ABR submissions

The AER has asked Economic Insights to provide advice on selected issues raised in DNSP submissions on the AER's 2020 draft Annual Benchmarking Report. The AER also circulated the Economic Insights (2020) report to DNSPs at the same time as its Annual Benchmarking Report. The issues advice has been sought on relate to the corrections to output weights used in the multilateral total and partial factor productivity (MTFP/MPFP) index number analyses. We list the selected issues and our responses ordered by DNSP in this memo.

Ausgrid (AGD)

Issue: AGD argue the Leontief regressions are not statistically significant.

Response

It is important to review the context in which the Leontief regressions are used. The MTFP/MPFP analysis includes functional outputs which reflect the key services DNSPs provide which are valued by customers and which reflect the basis on which the regulator forms its estimates of the efficient cost requirement DNSPs should be allowed to recover. Because these functional outputs differ from the basis on which DNSPs charge customers, we require estimates of the cost shares attributable to each functional output. Because we are using an MTFP/MPFP framework, we require relevant shares in total cost (ie operating plus capital costs). Econometric estimation of these shares is the only practical tool available. However, the absence of consistent overseas data on capital quantities and values means we only have the Australian database available for this exercise.

We showed in Economic Insights (2014, pp.28–29) that there is insufficient cross–sectional variation in the Australian data to support reliable estimation of the more complex and now traditional cost functions (such as the Cobb Douglas and translog) using only the Australian data sample. Instead, we have to use more simplistic functional forms that minimise the number of parameters to be estimated. The Leontief function is the simplest available and involves DNSP–by–DNSP estimation of a basic fixed proportions model. This is equivalent, in a two–dimensional context, to fitting a right–angle to a scatter of data points. As such, we cannot expect the simplistic model to perform well on standard statistical indicators that are more appropriately used to assess the performance of fitting a smooth curve to the scatter of data points. Furthermore, the fixed proportions model will sometimes produce corner solutions for a particular DNSP (ie it will set some shares to zero). To reduce the impact of this we take a weighted average of shares over the full sample.

While we would prefer to use a more complex cost function model to form these output weights, no such models have yet proven sufficiently tractable using the Australian sample only. And, using the opex cost function results from the entire three–country sample is not appropriate because they relate only to opex and not total cost. The only tractable solution has been to use the simplistic Leontief model instead. While it is unlikely to ever produce impressive–looking statistical results using standard statistical indicators given its fixed proportions form and lack of flexibility to fit a scatter of data points, we note that its coefficient significance performance is at least as good as we, as practitioners, would expect based on past experience (Economic Insights 2020, pp.10–11). The statistical performance of a simple fixed proportions model cannot be judged by the same standards we would use for fitting smooth functions such as the Cobb–Douglas or translog. Taking a stylised example from two dimensional space, the fit of a smooth curve to a scatter of data will generally be better than is possible using a right angle (which is what a fixed proportions model is in this case). That said, the correction of the time trend error has substantially improved the statistical performance of the Leontief input demand regressions. And, returning to the stylised example, if it is not tractable to fit a smooth curve, the right–angle model can still provide useful information.

Issue: AGD argue there is a risk that the regression analysis could mistake correlation with causation.

Response

AGD (2020, p.8) suggests that the Leontief regression analysis could mistake correlation with causation. It suggests the resulting weights should accordingly be scrutinised 'on economic and engineering grounds'. This was done at some length in Economic Insights (2020, pp.5–10) where we demonstrated that total cost output weights can be expected to be oriented towards those outputs that are the best proxies for fixed costs given the production characteristics of DNSPs which involve high degrees of capital intensity of long–lived, immobile structure–type assets (ie lines, cables and transformers). This is consistent with the circuit length output having the highest weight followed by the ratcheted maximum demand (RMD) output (in its role of representing previous expansions of capacity to meet demand levels that have since declined) followed by customer numbers (representing the costs of connecting and maintaining assets located close to the end–users) and lastly by energy throughput (representing a smaller association with line, cable and transformer inputs).

It should be noted the output weights relevant to variable costs (ie opex) are expected to be different to those of total cost with a higher share attributed to customer numbers being expected (reflecting opex associated with meeting and anticipating customer service requests and improving reliability) although maintenance of the key fixed assets will also be important (as reflected by the circuit length and RMD outputs).

The results associated with both the total cost output weights for MTFP/MPFP analysis derived from the Leontief regressions and the opex output weights derived from the opex cost function estimation are thus consistent with economic and engineering–based expectations.

AGD (2020, p.8) states 'Customer numbers, for example, cannot simultaneously drive 18.52% of operating costs (productivity index model) and 53.35% of costs (econometric models)'. Apart from being the wrong way around – the index number model uses the share of total costs and the econometric models produce shares of opex – this statement is also conceptually incorrect as we demonstrate above the prevalence of fixed costs in total costs can be expected to produce quite different output weights to those relevant to opex.

We also note that the AGD (2020, p.6) criticism of the inclusion of the RMD output fails to recognise its intended role of recognising the capacity that DNSPs have installed to meet previously higher levels of demand that have not subsequently been reattained. Without such an output, DNSPs' measured productivity performance over time would be considerably worse and this would not be a fair representation of DNSP performance in light of unforseen developments subsequently rendering some long–lived assets either stranded or underutilised.

Issue: AGD argue there are inconsistent results for ratcheted maximum demand for Ausgrid (7.928) and SA PowerNetworks (–6.193).

Response

AGD (2020, p.9) suggests that the Leontief RMD output coefficients for AGD of 7.928 and for SA PowerNetworks (SAPN) of –6.193 are 'inconsistent'. However, AGD does not recognise that the coefficients enter the Leontief input demand functions in squared form and will hence have the same effect in the model regardless of whether they are allocated a positive or negative sign. Thus, rather than being different or 'inconsistent' as suggested by AGD, these estimated coefficients are instead very similar in their impact in the estimated Leontief models.

Issue: AGD suggest there is disproportionate focus in the benchmarking report on productivity index number (PIN) rankings given that econometric models are used to make efficiency adjustments in resets.

Response

The econometric models only examine opex efficiency. Opex accounts for only just over one third of total DNSP costs. To gain a thorough understanding of DNSP productivity and efficiency performance we thus need to look at capital costs as well as opex because capital costs account for nearly two thirds of total costs. Given the absence of consistent capital quantity and value data for the overseas jurisdictions, it is not tractable to extend the econometric models to include capital, leaving the PIN models as currently the only way to examine the Australian DNSPs' overall efficiency. Examining overall efficiency performance is important in setting the context for many regulatory decisions, including those on opex. Since a wider and more detailed range of information on efficiency performance is currently available from PIN models, the focus of the annual benchmarking reports is, by necessity, on PIN results. An example of this is the inclusion of detailed sections in Economic Insights (2020) and earlier reports looking at the contributions of individual outputs and inputs to productivity change. It is currently only possible to do this using PIN models.

While economic benchmarking has not, as yet, been extended for use in the AER's regulatory decisions on capital inputs, it is possible to draw on information from both PIN and econometric models in regulatory decisions concerning opex. Thus, the annual benchmarking report has an important role in providing information on all aspects of productivity and efficiency performance while the concentration in individual DNSP resets is on opex efficiency performance as it is a direct input to the regulatory decision–making. This means the focus of the annual benchmarking reports tends to be more oriented to PIN models while the focus of reset reports tends to be more towards econometric models (including appropriate operating environment factor adjustments). We believe this difference in focus is entirely appropriate.

Issue: AGD claim there are now large differences in the efficiency scores calculated by the PIN and econometric models.

Response

AGD (2020, p.9) presents a table which it claims show 'large' proportional differences in opex efficiency scores for 7 of the 13 included DNSPs between the PIN models and the econometric models. AGD fails to acknowledge that there are several fundamental differences between the efficiency scores presented. These are summarised in Economic Insights (2020, p.15) as follows:

'There are several important differences across the various models. The opex cost function models include allowance for the key network density differences and the degree of undergrounding. The opex MPFP model includes allowance for the key network density differences but not the degree of undergrounding. The opex cost function models include three outputs whereas the opex MPFP model includes five outputs (the same three as the opex cost function models plus energy delivered and reliability). The opex cost function models use parametric methods whereas the opex MPFP model uses a non–parametric method. [Within the econometric models] (t)he LSE opex cost function models use least squares (line of best fit) estimation whereas the SFA models use frontier estimation methods. The LSE opex cost function models include allowance for heteroskedasticity and autocorrelation whereas the SFA models do not. Despite all these differences in model features, the opex efficiency scores produced by the five models are broadly consistent with each other.'

To this list we need to add that the PIN models use total cost weights in forming the output weights while the econometric models rely solely on opex. And, the PIN models draw only on the Australian sample data whereas the econometric models use data from the Australian, New Zealand and Ontario databases.

Given this list of differences between the models, we do not consider the differences in opex efficiency scores to be 'large'. Rather, we consider them to be relatively close given the fundamental differences between the models. Furthermore, inclusion of this wide range of different bases for calculating opex efficiency is consistent with the Australian Competition Tribunal (2016) finding that a wide range of benchmarking models should be considered in regulatory decision–making rather than just one model. We note though that the AER has to date only used the results from the econometric opex cost function models to inform the extent of base year opex adjustment under resets. Consequently, the PIN model opex efficiency scores currently provide additional context for base year adjustment decisions based on econometric opex cost function model results.

CitiPower, Powercor and United Energy with commissioned report from NERA (CPUN)

Issue: CPUN note that no constant is included in the Leontief models and claim this upwardly biases the number of statistically significant coefficients.

Response

As noted above, econometric estimation of output cost weights using more sophisticated functional forms has, to date, not proven tractable using the Australian DNSP sample due to lack of cross–sectional variation in the data and high levels of multicollinearity. To form output cost weights for use in MTFP/MPFP analysis, estimates of total cost–based weights are required. Weights derived from the three–country econometric opex cost function models are not appropriate for use in MTFP/MPFP PIN analysis because they relate only to opex and not total costs.

To provide a tractable solution to this we have used the simplistic Leontief cost function model (via its input demand functions) estimated separately for each DNSP. As this simple fixed proportions functional form will in many cases produce corner solutions (ie set some output weights to zero), we take a weighted average of resulting output weights across all the included DNSPs to produce the best estimate available. To implement this approach a number of choices have to be made which involve trade–offs. We have consistently adopted the strategy of minimising the number of parameters to be estimated per equation given there are very few degrees of freedom available.

NERA (2020, pp.18–20) criticise our decision not to include a constant in the model. The fixed proportions Leontief model can be implemented in its simplest form without a constant. Returning to the stylised two–dimensional depiction, this is equivalent to fitting a right angle to a scatter of data points. While we note there may be some statistical arguments for including a constant term, the loss of degrees of freedom comes at a cost as illustrated by the lack of full convergence in NERA's regressions. Consequently, we have opted for a specification that maximises the limited degrees of freedom as we consider this to be the more important consideration, combined with checking that the resulting estimates make economic and engineering sense (see Economic Insights 2020, pp.5–10). As noted below, a similar consideration has influenced the way we include the time trend in the model.

Issue: CPUN claim that the treatment of the time trend in the Leontief models is non–standard as it is multiplicative rather than additive.

Response

NERA (2020, pp.20–21) criticise our inclusion of the time trend in the Leontief input demand equations as a multiplicative term with the output coefficients rather than as a separate additive variable. While including the time trend as a separate additive term is a more standard approach when analysing how input demand changes over time, in this case the primary purpose of the exercise is to derive output cost weights and so it is important to allow for changes in the relationship between outputs and inputs over time. Our initial intention was to include a separate time trend for each output but this was precluded by the very small number of degrees of freedom available leading to us adopting the current specification which imposes a common time effect across all four of the included outputs for each DNSP. Consequently, the multiplicative incorporation of the time trend is better suited to the purpose at hand.

Issue: CPUN claim the output weights derived from the Leontief models are no more meaningful than a random variable.

Response

NERA (2020, pp.30–33) criticises the specification of the Leontief models for not allowing for negative relationships between outputs and inputs. The output coefficients in the input demand equations enter in squared form which forces the relationship between the output and input to be positive or zero. NERA claim this is an unnecessary restriction that can lead to bias. We reject this line of criticism.

Imposition of a non–negativity constraint in this instance is equivalent to the requirement for the econometric opex cost function models to satisfy the monotonicity property. That is, there can be no 'free lunches' by output being able to be increased by reducing input use. This is a standard requirement in economic production theory. This constraint can be applied via the squared term in the Leontief function modelling, and thus we can estimate a well–behaved function that meets the monotonicity requirement. This constraint may not be easily applied to flexible functional forms such as the translog function and, as a result, we have to examine monotonicity violations for those functions.

Issue: CPUN claim there is very little evidence the true values of any or all coefficients in the Leontief models are not zero.

Response

In Economic Insights (2020, p.11) we noted that across the 52 equations, on average one third of the estimated 5 coefficients are significant at the (unadjusted) 5 per cent level. NERA (2020, pp.21–23) argue that studies that involve a large number of estimated coefficients should use the Bonferroni adjustment to significance levels which allow for the possibility that a percentage of coefficients may be found to be significant 'by chance' when many coefficients are estimated. NERA propose an adjustment based on there being 260 estimated coefficients in the overall Leontief regressions. However, this would only be appropriate if we were estimating one large regression with 260 variables. In practice, we only have 5 variables per regression and so any adjustment, were it to be made, would be very small rather than the large adjustment proposed by NERA.

Furthermore, we note that a very low percentage of published empirical studies appear to apply the Bonferroni correction and we have been unable to identify any NERA studies that have actually used this correction. Even in the field of medical research where regressions with large numbers of variables are more common, the Bonferroni correction is controversial. For example, Perneger (1998) finds:

> 'In summary, Bonferroni adjustments have, at best, limited applications in biomedical research, and should not be used when assessing evidence about specific hypotheses.'

As noted above in response to the claim of lack of significance made by AGD, while we would prefer to use a more complex cost function model to form these output weights, no such models have yet proven sufficiently tractable using the Australian sample only. And, using the opex cost function results from the entire three–country sample is not appropriate because they relate only to opex and not total cost. They cannot be extended to total cost because of the lack of consistent capital quantity and value data in the overseas jurisdictions. The only tractable solution has been to use the simplistic Leontief model instead. While it is unlikely to ever produce impressive–looking statistical results using standard statistical indicators given its fixed proportions form and lack of flexibility to fit a scatter of data points, we note that its coefficient significance performance is at least as good as we, as practitioners, would expect based on past experience (Economic Insights 2020, pp.10–11). The statistical performance of a simple fixed proportions model cannot be judged by the same standards we would use for fitting smooth functions such as the Cobb–Douglas or translog.

We note that NERA (2020) provides no alternative methods for obtaining total output cost shares using the Australian DNSP data. Useful suggestions are made regarding extending the opex cost function methodology but, as will be discussed further below, these are confined to analysing opex and are consequently not useful for examining overall productivity performance.

Issue: CPUN claim the Leontief function output weights vary substantially and counterintuitively across the 52 regressions

Response

As noted above, a characteristic of an empirically estimated Leontief model will be the presence of some corner solutions. Consequently, it would be unwise to rely on the estimates derived from one set of estimates or one sample only, particularly where the sample is relatively small. This can also be an issue even when the sample is larger as illustrated by the NERA (2020, pp.25–26) fixed effects panel model which has a corner solution which zeroes out the coefficient on circuit length. Consequently, the tractability of implementing the Leontief model has to be traded–off against its tendency to produce corner solutions. We manage the corner solutions issue by taking a weighted average of total cost output shares estimated from the estimated input demand equation across all DNSPs. Consequently, it is the weighted average result that is relevant rather than those for individual DNSPs. We further check that the resulting weighted average estimates are reasonable from economic and engineering perspectives (Economic Insights 2020, pp.5–10).

Issue: CPUN claim statistical significance of coefficients in the Leontief models is sensitive to underlying regression specifications

Response

As the presence of some corner solutions is a characteristic of the Leontief model, so too will the significance of particular coefficients vary as the model specification is varied. This reinforces our earlier point that this type of simplistic fixed proportions model will often not appear to perform well using statistical tests that are designed to assess the fit of a smooth curve to a scatter of data points rather than a right angle (in two–dimensional space and elsewhere). Again, it is the overall weighted average of relevant coefficients that are used in subsequent modelling rather than coefficients from individual regressions.

Issue: CPUN claim that variants on the Leontief model specification result in different output weights

Response

NERA (2020, pp.34–36) claim that output cost weights vary according to the regression specification used. They present output cost weights for the Economic Insights (2020)

Leontief models, three of their own Leontief specifications (constant included, additive time trend and panel fixed effects), two 'random variable' Leontief specifications, opex only Leontief results and the four econometric opex cost function models from Economic Insights (2020). We do not consider this to be a meaningful set of comparisons.

The econometric opex cost functions and the opex only Leontief results are relevant to opex and not total costs. Consequently, like is not being compared with like between these five sets of weights and the others. Economic Insights (2020, pp.5–10) shows how we expect from economic and engineering perspectives that total cost weights would be more oriented towards circuit length and RMD while opex output weights would be more oriented towards customer numbers. Next, we do not consider NERA's 'random variable' Leontief models to be either relevant or informative because they do not use the same database or variables. As noted above, the NERA panel fixed effects Leontief model produces a corner solution and so is not comparable. And the NERA constant added and additive time trend Leontief models both have convergence issues and, given the purpose at hand, the additive time trend model is less appropriate than the multiplicative time trend model. The Economic Insights (2020) Leontief output cost weights are consistent with economic and engineering expectations and the NERA (2020) comparisons do nothing to either disprove this or show that our output weights are inappropriate.

Issue: CPUN claim there is no precedent for the Leontief model specification used by Economic Insights

Response

The simple Leontief model used in Economic Insights (2020) and earlier reports for the AER was originally developed and applied by Professor Erwin Diewert and Denis Lawrence in 2003. The stream of work of which this development was part was initially published in Lawrence and Diewert (2006) and Lawrence (2003). Both these publications were subject to peer review processes. The situation we faced at the time was that we needed to obtain output cost weights for electricity DNSPs where a functional output specification better reflected the services provided by DNSPs and the basis on which they were regulated than a traditional billed outputs specification commonly used in competitive industry productivity studies. The DNSP sample had a small number of observations per DNSP and multicollinearity and lack of cross–sectional variation made whole of sample estimation methods less viable. The bespoke Leontief cost function approach provided a tractable solution, albeit at the cost of much greater simplicity. The approach has subsequently been applied widely to electricity and gas distribution and transmission network service provider productivity studies in Australia and New Zealand where similar issues arise (eg Lawrence 2005, Economic Insights 2009).

The method has not been used widely outside Australasian infrastructure applications because similar issues have not arisen. In non–infrastructure productivity applications the traditional billed outputs approach is generally adequate and does not require estimation of output cost weights. And in cost function applications outside of these industries there have generally been sufficient observations and data variability to support the standard Cobb Douglas and the translog and other flexible functional forms. Broadly analogous productivity studies have been undertaken in North America but have been able to draw on much larger cross sections containing many utilities and sufficient data variability to support whole of sample estimation of standard functional forms. In many cases those applications have also included fewer outputs and fewer inputs.

Issue: CPUN suggest reducing reliance on PIN techniques in the benchmarking reports and using econometric opex cost function models instead

Response

NERA (2020, pp.43–49) has proposed that the MTFP/MPFP year–by–year productivity results and decomposition analysis be replaced with alternative methods based on extensions of the econometric opex cost function modelling. We thank NERA for these constructive suggestions and will examine them in more detail to fully assess their merits. We may move in future to include these as supplementary analyses. However, it must be recognised that the proposed methods relate only to opex efficiency and its decomposition. They do not provide any information on the decomposition of total productivity into the contributions of individual outputs and inputs. As a result, they are not substitutes for the MTFP/MPFP analyses currently used.

The methods NERA propose avoid the need to derive total cost output weights but at the expense of limiting the coverage of the analysis to opex only. This is advocated in the context of price determinations where the use of economic benchmarking is currently confined to assessing opex requirement proposals. But broader coverage to include all inputs and outputs provides important context for DNSPs' opex performance in price determinations and is a key part of the AER's annual benchmarking reporting. We note that under the NER the AER has to prepare and publish a report describing the relative efficiency of DNSPs in providing direct control services over a 12–month period (clause 6.27). This requires inclusion of all inputs and examination of overall productivity, not just opex efficiency.

We note that NERA makes no proposals for improvements to the derivation of total output cost weights that form part of the current MTFP/MPFP analyses that address these broader issues. If consistent and comparable data on the quantity and value of capital inputs were available for the overseas jurisdictions included in the econometric database then there would be scope to extend the current Cobb Douglas and translog opex cost function models to total cost function models. This would provide a more sophisticated basis for deriving output cost weights for MTFP/MPFP analysis and/or extension of the decomposition methods proposed by NERA to cover all inputs. But this is not the case and reliance on more simplistic methods such as the Leontief cost function to derive output cost weights for MTFP/MPFP analysis remains, at this stage, the most tractable way forward for coverage of total productivity.

We also note that the MTFP/MPFP framework provides the best scope to include additional outputs such as reliability variables (currently) and DER variables (prospectively) where data coverage is incomplete or not consistent across national jurisdictions. And, inclusion of a wider range of economic benchmarking methods and specifications is consistent with the views expressed by the Australian Competition Tribunal (2016). The expected examination of the scope to include DER output variables in economic benchmarking will require further consideration of the total cost output weights issue and whether the Leontief cost function method remains the most tractable way of deriving this information.

Endeavour Energy (END)

Issue: END asks how the corrected output weights improve the accuracy of MTFP benchmarking and whether the appropriate trade–off is made between accuracy and consistency.

Response

As noted above, Economic Insights (2020, pp.5–10) reviews how we would expect total input costs to be allocated across the four non–reliability outputs from economic and engineering perspectives. The prevalence of fixed costs in DNSP total costs point to the circuit length output and the RMD output (the latter in its role as a proxy for past investments in system capacity) having the larger weights followed by the customer numbers output (as a proxy for end–user related assets and customer service requirements). The energy output would be expected to have a smaller weight as a secondary measure of system size. The corrected DNSP output weights are consistent with these expectations.

We acknowledge there is a trade–off between the frequency of specification changes and providing a consistent basis for comparisons over time. In normal circumstances we would support only making significant changes periodically. However, where errors are detected we believe it is important for those errors to be corrected as soon as possible.

Jemena Electricity Networks (JEN)

Issue: JEN questions the reliability of output weights derived using the Leontief cost function method.

Response

We have discussed the characteristics of the Leontief cost function–based output weights at some length above in response to issues raised by AGD and CPUN. While we would, of course, prefer to base total cost output weights on results from more complex functional forms, to date it has not proven to be sufficiently tractable to estimate these using only the Australian DNSP sample data. This leaves simple functional forms such as the Leontief as the most tractable option at this time. We will review this further as more data becomes available and, as noted above, in the context of possible extension of output coverage to include DER variables.

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