Review of Economic Benchmarking of Transmission Network Service Providers – Issues Paper

Report prepared for
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TNSP NAME ABBREVIATIONS

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

Abbreviation	*TNSP name*	*State*
ANT	AusNet Transmission	Victoria
ENT	ElectraNet	South Australia
PLK	Powerlink	Queensland
TNT	TasNetworks Transmission	Tasmania
TRG	TransGrid	New South Wales

EXECUTIVE SUMMARY

The AER has presented economic benchmarking results for Australia's five transmission network service providers in its first three annual transmission benchmarking reports. The main measures presented are multilateral total factor productivity and multilateral partial factor productivity measures developed in Economic Insights (2014b). These measure the relative productivity of transmission networks and track productivity changes over time. Productivity is measured as the ratio of the quantity of total outputs produced to the quantity of inputs used.

The main area where there is not yet a consensus position on the economic benchmarking of electricity networks is the appropriate measurement of outputs for transmission networks. As a result, while the AER currently uses economic benchmarking in its TNSP regulatory determinations to derive its forecast of future productivity changes used in assessing TNSP opex forecasts, it does not currently use benchmarking to make efficiency adjustments.

The current TNSP productivity measures have five outputs: energy throughput, ratcheted maximum demand, voltage–weighted entry and exit connections, circuit length and (minus) energy not supplied.

The AER is undertaking a review of TNSP economic benchmarking and has asked Economic Insights to prepare this issues paper to focus discussion to facilitate further refinement.

TNSPs have raised a number of issues with the output specification used in economic benchmarking. The key issues raised have been:

- the appropriateness of the voltage–weighted entry and exit connections output variable
- the way entry and exit connection points and voltages are measured
- the appropriateness of the VCR–based weight applied to the reliability variable
- the econometrically–derived weights applied to the other four outputs, and
- 'additive' versus multiplicative incorporation of capacity–related outputs.

This issues paper considers each of these issues in turn and lists questions for discussion. For convenience, the issues for discussion are compiled below.

Connection points output variable versus end–user numbers

1. *Would the use of downstream customer numbers be a better output measure than the current voltage weighted connections output variable?*
2. *Would the use of end–user customer numbers for the state the TNSP operates in be appropriate or would allowance need to be made for interconnectors and special situations such as the Snowy Mountains Scheme on end–user numbers?*
3. *Would there also be a need to include a measure of entry points or would the end–user customer numbers measure be adequate?*
4. *Would the simple addition of the number of entry and exit points be a viable output measure?*

Construction of the connection points output variable

5. *If we retain the voltage weighted connections variable, is there a better approximation to the 'size' of connections than the current multiplicative variable?*
6. *Should the voltage weighted connections output variable use the voltage at the customer side or the TNSP side or entry and exit point transformers? Which measure would better reflect the service provided by TNSPs to customers?*
7. *Is there a case for the treatment being consistent with AEMO's Marginal Loss Factor reports, which uses downstream voltage?*
8. *In accounting for terminal stations that connection to multiple DNSPS:*
   (a) *Should connections to multiple DNSPs at the one terminal station be counted separately or as one connection?*
   (b) *How would counting the connections separately or as one connection advantage or disadvantage particular TNSPs?*

Reliability output weighting

9. *Should the weight placed on the TNSP reliability output be reduced to avoid volatile movements in MTFP?*
10. *If so, should a cap be placed on the weight itself or on the volume of unserved energy incorporated in the model?*
11. *The value of the reliability output relative to total TNSP revenue exceeded 5% in only 7 of our current 50 observations. Of these all were less than 8.5% except AusNet in 2009 which equalled 29%. If we were to cap this weight, what should the size of the cap be?*
12. *Should a cap be made to be consistent with the current TNSP STPIS, which applies a cap on the impact of unplanned outages? If so, how would this be applied to the reliability output measures for benchmarking purposes?*
13. *Would using a rolling average of unserved energy be an alternative way of handling annual volatility in reliability?*

Econometrically–derived weights for outputs other than reliability

14. *Do the current output cost share weights of 21.4 per cent for energy, 22.1 per cent for ratcheted maximum demand, 27.8 per cent for weighted entry and exit connections and 28.7 per cent for circuit length seem reasonable?*
15. *Should the output cost shares be updated to take account of the latest information?*

'Additive' versus multiplicative capacity measures

16. *Does the current separate inclusion of output capacity variables and the MVAkms based input specification introduce any biases?*

17. *Is there an objective basis on which to divide a category of very high voltage lines from other lower voltage transmission lines (noting that productivity indexes require non–zero quantities and values for all input categories for all TNSPs)?*
18. *Can TNSP asset values be reliably and accurately split and provided on a similar basis?*

1 BACKGROUND

The Australian Energy Regulator (AER 2014) produced initial benchmarking results for Australia's five transmission network service providers (TNSPs) operating in the National Electricity Market (NEM). As well as presenting a range of partial performance indicators, AER (2014) also presented economic benchmarking results for multilateral total factor productivity (MTFP) and multilateral partial factor productivity (MPFP) measures developed in Economic Insights (2014b). These measure the relative productivity of transmission networks and track productivity changes over time. Productivity is measured as the ratio of the quantity of total outputs produced to the quantity of inputs used. These results were subsequently refined and updated in Economic Insights (2015, 2016) and AER (2015, 2016a).

The main area where there is not yet a consensus position on the economic benchmarking of electricity networks is the appropriate measurement of outputs for transmission networks. The whole of business benchmarking of transmission networks is relatively new (although transmission networks have benchmarked their own costs at a more specific level for some time). Economic Insights (2014b, p.2) noted:

> 'While economic benchmarking of distribution network service providers (DNSPs) is relatively mature and has a long history, there have been very few economic benchmarking studies undertaken of TNSPs. Economic benchmarking of transmission activities is in its relative infancy compared to distribution. As a result, in this report we do not apply the above techniques to assess the base year efficiency of TNSPs. We present an illustrative set of MTFP results using an output specification analogous to our preferred specification for DNSPs but caution against drawing strong inferences about TNSP efficiency levels from these results. However, output growth rates and opex input quantity growth rates can be calculated with a higher degree of confidence and used to forecast opex partial productivity growth for the next regulatory period which is a key component of the rate of change formula.'

Submissions from TNSPs on AER (2016a) raised a number of issues and potential refinements to TNSP economic benchmarking, mainly regarding the specification of outputs. The AER has decided to undertake a review of TNSP economic benchmarking based on these and related submissions. The AER has asked Economic Insights to prepare this issues paper to focus discussion at a stakeholder workshop to gather input to the review.

1.1 The current TNSP economic benchmarking model specification

The current TNSP MTFP measure has five outputs included as follows:

- Energy throughput (with 21.4 per cent share of gross revenue)
- Ratcheted maximum demand (with 22.1 per cent share of gross revenue)
- Voltage–weighted entry and exit connections (with 27.8 per cent share of gross revenue)
- Circuit length (with 28.7 per cent share of gross revenue), and

- (minus) Energy not supplied (with the weight based on current AEMO VCRs).

The current TNSP MTFP measure includes four inputs:

- Opex (total opex deflated by a composite labour, materials and services price index)
- Overhead lines (quantity proxied by overhead MVAkms)
- Underground cables (quantity proxied by underground MVAkms), and
- Transformers and other capital (quantity proxied by transformer MVA).

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

During the AER's economic benchmarking development process, Economic Insights (2014a) considered four different options for the output specification. Each option included measures of reliability, voltage–weighted connection points and energy throughput, with differences being the addition of system capacity, ratcheted maximum demand and/or circuit length. We conducted analysis of each option and recommended the currently adopted option because it did not appear to favour any particular type of TNSP, represented a useful way of capturing the key elements of a TNSP output and was also broadly comparable with the output specification used for DNSPs which has been the subject of extensive development work over many years.

The AER currently uses economic benchmarking in its TNSP regulatory determinations to derive its forecast of future productivity changes used in assessing TNSP opex forecasts, but it does not currently use benchmarking to make efficiency adjustments. AER (2016b, pp.15–16) noted it does not use benchmarking to make efficiency adjustments because:

- there is only a very small sample of transmission businesses which limits the range of benchmarking techniques that can be applied (specifically, only index number methods can be used because more sophisticated econometric models are not tractable)
- economic benchmarking output measures require further refinement, and
- a better understanding of the impact of operating environment factors (OEFs) affecting TNSPs is needed.

This review focuses on the second of these limitations, namely the specification of TNSP outputs for economic benchmarking which has been the main focus of TNSP submissions. While some TNSPs have also submitted that more focus on material OEFs and the impact of differences in capitalisation policies is required[1], the AER will consider these issues separately to this process.

[1] For example, Transgrid (2016, p.1) and Powerlink (2016, pp.1–2)

2 ISSUES RAISED BY TNSPS

Since the inception of the AER's transmission benchmarking analysis, the TNSPs have each raised a number of issues with the output specification used. The key issues raised have been:

- the appropriateness of the voltage–weighted entry and exit connections output variable
- the way entry and exit connection points and voltages are measured
- the appropriateness of the VCR–based weight applied to the reliability variable
- the econometrically–derived weights applied to the other four outputs, and
- 'additive' versus multiplicative incorporation of capacity–related outputs.

This section considers each of these issues in turn and lists questions for discussion.

2.1 Connection points output variable versus end–user numbers

The selection of output measures is an economic and engineering choice that is intended to reflect relevant services provided by the network. Network entry and exit connection point numbers provide a proxy for the services the TNSP has to provide at connection points. As explained in Economic Insights (2013, pp.35–36):

> 'Some TNSPs impose fixed charges for users at both entry and exit points from the transmission network. These charges are related to activities the TNSP has to undertake regardless of the level of energy throughput which include the establishment of the connection point itself as well as, for example, metering services and connection related capacity. They can be imposed on generators (upstream users) and downstream users including distribution networks, other connected transmission networks and directly connected end–users. Going back to the road analogy, the TNSP will need to provide and maintain entry and exit ramps to the freeway, regardless of the amount of traffic on the freeway. In economic benchmarking studies, the quantity of these functions could be proxied by the number of TNSP entry and exit points.'

This is similar to the customer connections output used in distribution benchmarking. However, instead of using the number of connection points (as we would for counting distribution customer connections), we take the sum of the number of connection points multiplied by each connection point's transformer voltage level. As noted in AER (2016a, p.28), this reflects an assumption that higher voltage connections will typically require more assets as they will have a higher capacity. But there are a number of limitations with this measure including identifying the number of connection points on a consistent basis and the adequacy of the simple multiplication of connection point numbers by their respective voltage levels in approximating a more complex engineering relationship. AER (2014, pp.12–13) stated:

> 'The transmission node identifiers (TNIs) will not perfectly capture the transmission assets at each entry and exit point. This was raised with us in submissions. However the number of TNIs is the most consistent data that is currently available to us. Further we consider that the summation of TNI voltages

> is a workable reflection of the number and significance of transmission network connections.'

A number of TNSPs have questioned the adequacy of the current connection point output measure in reflecting the service provided by each transmission network. For example, AusNet (2016) submitted that a higher measure of voltage weighted connection points does not necessarily reflect a greater number or amount of services provided (eg demand being serviced and energy throughput – both of which we note are included elsewhere in the output specification). Instead it considers that significant differences simply reflect historical decisions about the relative voltage levels of the transmission and distribution networks in each state. As an example, AusNet (2016, p.7) stated:

> 'Powerlink's large number of 132kV exit connection points reflects the relatively high exit voltage of its network relative to AusNet Services, which primarily has distribution connecting at 66kV. These differences drive the substantive difference between the voltage weighted connection point outputs of each TNSP – approximately 9,000 (AusNet Services) compared with 17,000 (Powerlink) in 2015 – and hence to the productivity scores of each network.
>
> 'The relativity of this output result is in contrast to other measures of output, such as energy throughput and maximum demand, which do not differ to nearly the same extent between AusNet Services and Powerlink. Further, the numbers of electricity customers served in Victoria and Queensland, which are ultimately the reason both transmission networks exist, are in stark contrast to the voltage weighted connection outputs presented above. In 2015 AusNet Services served 32% more end use customers through its network than were served in Queensland, with Queensland having 2.1million customers compared to Victoria's 2.8million.'

As noted above, the current specification takes the voltage of each connection point into account based on an assumption that higher voltage connections require more or higher capacity assets. However, TasNetworks (2015, p.1) has questioned this assumption as follows:

> 'TasNetworks does not agree that there is a link between voltages and the quantity of assets required to serve a particular connection point. Higher voltage connections do not necessarily require the use of more assets – just higher voltage assets. TasNetworks operates a comparatively low voltage transmission network that delivers a relatively small amount of energy, but has a high number of connection points (and therefore connection assets) because it connects around 30 generation sites, as well as a significant number of directly connected load customers.
>
> 'Focussing on the sum of connection point voltages as a network output also ignores the complexity of those connections, which is a significant driver of cost for TNSPs.'

AusNet (2016, p.7) similarly argued that connection capacity is not a significant output in that TNSP costs are not dominated by the provision of connection capacity. AusNet went on to argue that the voltage weighted connection points output did not perform well against the three selection criteria for outputs set out in Economic Insights (2013, 2014b):

> ‘In particular, transmission networks ultimately exist to provide electricity services to end-users, which is reflected in the NER expenditure objective of “meet or manage the expected demand for prescribed transmission services.” While end–users do not directly receive prescribed transmission services, they are the ultimate beneficiary and driver of these services.

AusNet proposed an alternative to the voltage weight connection point variable as follows:

> ‘Accordingly, AusNet Services considers that the AER should give due consideration to the removal of connection from the transmission MTFP model. Connection could be replaced by the number of end–user customers in each TNSP’s service area, which, despite not being a direct output of transmission networks, is a more appropriate measure of a product provided by transmission networks.’

We consider this suggestion has merit. It directly reflects the services provided to end–users and focuses on a significant output while also linking closely to the NEL/NER. It can be based on relatively uniform and unambiguous data and avoids many of the issues with construction of the current variable discussed in the following section. Disadvantages though are that it only focuses on downstream users and does not capture the entry side of the transmission network and does not differentiate the size of end–users (eg a smelter versus a household).

Issues for discussion

1. *Would the use of downstream customer numbers be a better output measure than the current voltage weighted connections output variable?*
2. *Would the use of end–user customer numbers for the state the TNSP operates in be appropriate or would allowance need to be made for interconnectors and special situations such as the Snowy Mountains Scheme on end–user numbers?*
3. *Would there also be a need to include a measure of entry points or would the end–user customer numbers measure be adequate?*
4. *Would the simple addition of the number of entry and exit points be a viable output measure?*

2.2 Issues with the construction of the connection points output variable

If we retain the voltage weighted connections output, there is still some debate about the way this variable should be constructed and measured.

First, the connection point voltages are measured at the customer side of the transformers at each connection point (ie distribution and generation customers). For distribution customers this means the lower voltage level of the distribution network. The current measure is consistent with AEMO’s Marginal Loss Factor (MLF) reports which use the downstream voltage. For generation customers the customer side of the transformers at each entry point means the lower voltage level at the generator before it is stepped up to the transmission network voltage. This approach has been applied consistently since 2015.

ElectraNet (2016, p.2) raised concerns with this approach as follows:

> 'the low side/ distribution voltage is an inappropriate measure for transmission scale services. The overwhelming majority of the equipment owned and maintained by ElectraNet (and other TNSPs) within each connection point will be at the high side/ transmission voltage. Therefore, ElectraNet is of the opinion that reporting the high side/ transmission voltage more reasonably reflects the voltage of the connection point owned and maintained by ElectraNet.'

Second, AusNet (2016, pp.8–9) raised a further issue with the current specification of the connections output relating to the way connections to multiple DNSPs at the one terminal station are treated. AusNet and TransGrid serve multiple DNSP customers at some of their connection points. Currently, only one DNSP connection is counted where multiple DNSPs are connected to the station. This approach was adopted in 2015 in an attempt to provide consistency with jurisdictions that have fewer DNSPs. However, AusNet claimed that it had to provide extra infrastructure and administration to accommodate its multiple DNSPs so it used extra inputs compared to states with few DNSPs but it received no credit for this on the output side.

AusNet quoted the example of Templestowe Terminal Station (TSTS) that currently has complex connections to four DNSPs but these are currently only counted as one connection in measuring the connections output. AusNet submitted that this approach does not consistently measure inputs and outputs across jurisdictions and penalises AusNet Services for the historic decision to privatise Victorian distribution into five networks. The connection assets at TSTS include a complex configuration with multiple transformers and circuit breakers which are required to provide adequate security and service the load of the four DNSPs connected at TSTS. Accordingly, while the capacity of the transformers and capital cost of these assets is counted as an input in the AER's MTFP model, the associated outputs – service to four connections – have not been counted as outputs. Furthermore, the existence of multiple connection points drives additional inputs for AusNet, including the operating costs associated with administering separate connection agreements with each DNSP. AusNet requested that all its DNSP connections be counted to ensure parity of treatment.

Issues for discussion

5. *If we retain the voltage weighted connections variable, is there a better approximation to the 'size' of connections than the current multiplicative variable?*
6. *Should the voltage weighted connections output variable use the voltage at the customer side or the TNSP side or entry and exit point transformers? Which measure would better reflect the service provided by TNSPs to customers?*
7. *Is there a case for the treatment being consistent with AEMO's Marginal Loss Factor reports, which uses downstream voltage?*
8. *In accounting for terminal stations that connection to multiple DNSPS:*

(a) Should connections to multiple DNSPs at the one terminal station be counted separately or as one connection?

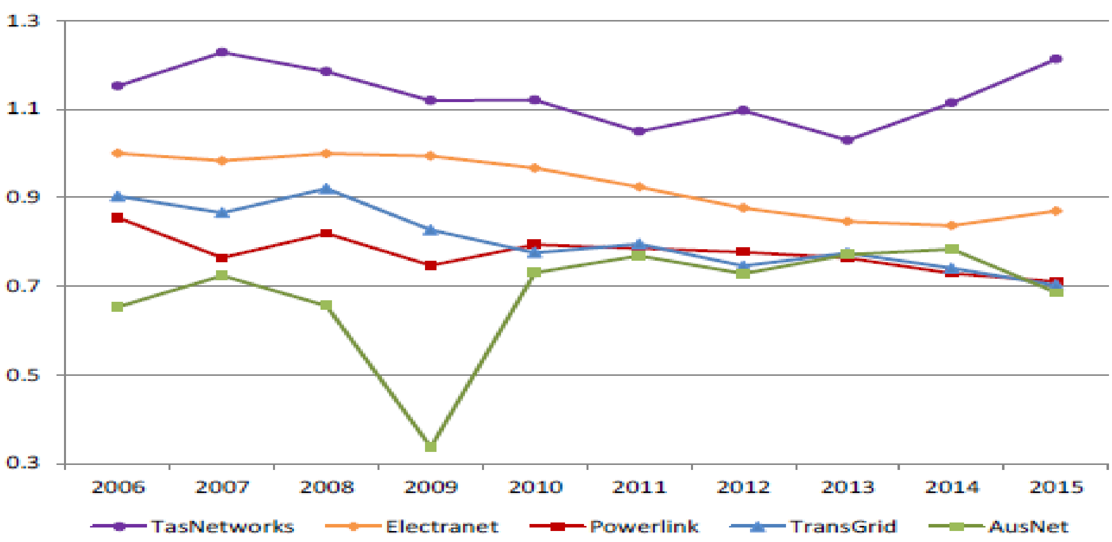
(b) How would counting the connections separately or as one connection advantage or disadvantage particular TNSPs?

2.3 Reliability output weighting

The reliability output measure is a negative output variable that captures energy not supplied as a result of network outages (unsupplied energy). Unsupplied energy is typically a very small proportion of total energy, but the economic and social costs of transmission outages can be very large. The weight applied to unsupplied energy is currently based on the Australian Energy Market Operator's jurisdictional values of customer reliability (VCR) (AEMO 2014).

AusNet (2016, pp.4–6) submitted that the current MTFP model specification places too high a weight on reliability outcomes and these can 'swamp' the other outputs contained in the model. Unlike distribution, it states that transmission reliability incidents are of low probability and high consequence, and are often due to the failure of a major asset or external circumstance (eg a storm event). As such, it considers the current impact of major transmission outages on MTFP results are not reflective of underlying productivity achieved in a given year.

Figure 1 Multilateral total factor productivity index by TNSP, 2006 to 2015

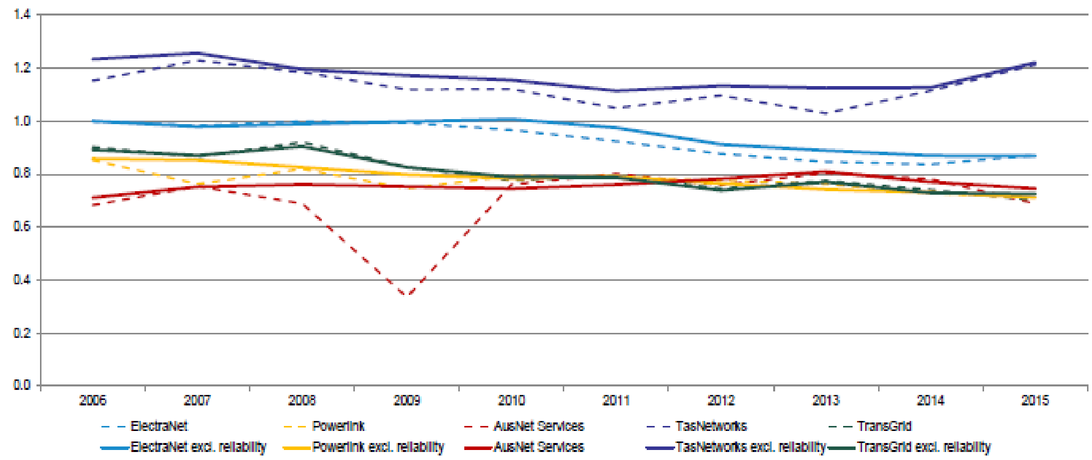


Source: AER (2016a)

To illustrate, Figure 1 shows that AusNet Services' MTFP results fell by 50 per cent in 2009 and total industry productivity also dropped by 13 per cent in that year. AusNet states this was the result of a transmission outage following the failure of AusNet's 500kV transformer at the South Morang Terminal Station. Similarly, AusNet states that its MTFP rank in 2015 declined from third to last largely a result of a loss of supply incident involving an outage on a transmission line connecting a major 500kV customer.

AusNet compared MTFP results from the current model with one that excluded the reliability output. AusNet's modelling showed that excluding reliability makes the results considerably less volatile without changing the trajectory of each TNSP's productivity. AusNet's results are presented in figure 2. AusNet concluded that moderating the effects of reliability would result in a MTFP model that is more reflective of the underlying productivity achieved in any given year and, therefore, better achieves the intended purpose of benchmarking.

Figure 2 MTFP results by TNSP excluding the reliability output, 2006 to 2015



Source: AusNet (2016, p.6)

AusNet suggested that one solution could be to include a cap on the weight given to reliability in any one year or, alternatively, a cap on the included amount of energy not supplied. AusNet (2016, p.6) noted:

> 'It would also align with the principle applied by the AER when it introduced a cap on unplanned outages in version 5 of the transmission STPIS, which was in part to ensure that transmission networks continue to have an incentive to manage reliability following the occurrence of a major unplanned outage.'

Economic Insights does not favour excluding the transmission reliability output as reliability is an important requirement for TNSPs. However, we acknowledge that the current approach does appear to place too much weight on reliability as evidenced by the very large impact of outages on the Victorian and industry productivity levels in 2009.

Issues for discussion

9. *Should the weight placed on the TNSP reliability output be reduced to avoid volatile movements in MTFP?*

10. *If so, should a cap be placed on the weight itself or on the volume of unserved energy incorporated in the model?*

11. *The value of the reliability output relative to total TNSP revenue exceeded 5% in only 7 of our current 50 observations. Of these all were less than 8.5% except AusNet in 2009 which equalled 29%. If we were to cap this weight, what should the size of the cap be?*

12. *Should a cap be made to be consistent with the current TNSP STPIS, which applies a cap on the impact of unplanned outages? If so, how would this be applied to the reliability output measures for benchmarking purposes?*
13. *Would using a rolling average of unserved energy be an alternative way of handling annual volatility in reliability?*

2.4 Econometrically–derived weights for outputs other than reliability

There has been general agreement that a 'functional' outputs approach is more appropriate than a 'billed' outputs approach for economic benchmarking used in a building blocks context. This is because NSP pricing structures have often evolved on the basis of convenience rather than on any strong relationship to underlying relative costs. As a result, observed revenue shares are of limited usefulness (in a building blocks context) in forming weights for index number economic benchmarking techniques that need to aggregate output quantities into a measure of total output. Rather, it is necessary to form output weights based on the weights implicitly used in building blocks determinations. These are generally taken to be cost–reflective output weights.

In keeping with the approach commonly adopted in network industry productivity studies using index number methods, estimates of the relevant cost–reflective output shares are formed from the first–order coefficients of a simple econometric cost function. In this case a basic translog cost function was used (Economic Insights 2014b, p.9). However, the ability to form these estimates is significantly constrained by the small number of observations available.

TransGrid has recently submitted a report by Frontier Economics (FE 2017) which contains a number of criticisms of the econometrically–based output shares used in the AER's TNSP economic benchmarking. Specifically, FE raised the following issues:

- the estimates have not been updated to include data for 2014 and 2015
- the estimates have not been updated to include data revisions for earlier years
- output shares are estimated for total costs and not separately for opex and capital
- there is a high degree of correlation among the included outputs
- the estimated cost function violates the monotonicity requirement for some observations, and
- the price index used to deflate total costs.

Standard practice in functional output–based productivity index number studies has been to not update output shares annually. To do so would make it difficult to discern those changes due to genuine productivity growth and those due to weight changes. However, given data revisions and the very small number of observations available for TNSPs, there may now be a case for revisiting the estimation of output cost shares. In data constrained situations in the past we have used the more basic Leontief cost function rather than the more flexible but observation demanding translog functional form.

We disagree with FE's suggestion that a different output index should be used for partial productivity measures compared to that used for total factor productivity (TFP) measures and are not aware of any index–based economic benchmarking study that adopts this approach. Rather, adopting such an approach would break the internal consistency of the productivity index measures whereby the TFP index is effectively a weighted average of the relevant partial productivity indexes (where the weights are based on shares in total cost). FE appears to be confusing the approach adopted in productivity index measurement with that adopted in estimating an opex cost function where opex–specific output parameters are estimated and this is indeed what we do in our cost function analysis of DNSPs. However, the starting point for included outputs should be the same group of key functional outputs valued by customers.

We also disagree with the FE (2017, p.34) claim that the price index used to calculate output cost shares in Economic insights (2014b) 'lacks theoretical justification'. Rather, the input price index is simply total costs divided by a consistently aggregated measure of the quantity of total inputs as required by economic theory.

We note that FE (2017) provides no constructive suggestions for how it thinks quantitative estimates of TNSP output cost shares should be formed.

The choice of cost shares is, of course, dependent on the outputs included in the economic benchmarking exercise. Any significant changes to the output specification will therefore require re–estimation of output shares.

Issues for discussion

14. *Do the current output cost share weights of 21.4 per cent for energy, 22.1 per cent for ratcheted maximum demand, 27.8 per cent for weighted entry and exit connections and 28.7 per cent for circuit length seem reasonable?*
15. *Should the output cost shares be updated to take account of the latest information?*

2.5 'Additive' versus multiplicative capacity measures

The FE (2017, p.21) report submitted by TransGrid claims that the TNSP economic benchmarking model does not adequately control for TNSP scale effects. It argues that the separate inclusion of the key system capacity variables of ratcheted maximum demand and line length on the output side does not mirror the 'multiplicative' inclusion of line capacity on the input side. It claims that this will potentially disadvantage large TNSPs relative to small TNSPs.

It should be noted that Economic Insights (2014b, p.8) has previously examined including a multiplicative measure of system capacity based on installed distribution transformer and line length on the output side. We did not favour this approach because increases over time in both transformer capacity and line length led to unrealistic rates of output growth and divergences between measured output levels for large and small NSPs. The measure of line capacity on the input side, on the other hand, involves multiplying line lengths by a constant MVA conversion factor applicable to the line's voltage level and is thus a different situation.

The difference in the two cases can be seen considering a simple example. Consider a TNSP that has y MVA of transformer capacity, z MVA of ratcheted maximum demand and x circuit kilometres of line with a weighted average MVA rating of, say, 200. Under the multiplicative system capacity output approach the TNSP's capacity output is yx MVA*kms while under the separate inclusion approach it is *z* MVAs and *x* kilometres. Its input measure is *200x* MVAkms.

Now consider the situation of a TNSP of exactly twice the size. It has *2y* MVA of transformer capacity, *2z* MVA of ratcheted maximum demand and *2x* circuit kilometres of line with a weighted average MVA rating of 200. All else equal and assuming constant returns to scale, the doubling of all variables should lead to its productivity remaining the same. Under the multiplicative system capacity output approach the larger TNSP's capacity output is *2y2x=4xy* MVA*kms while under the additive approach it is *2z* MVAs plus *2x* kilometres. Its input measure is *200(2x)=400x=2(200x)* MVAkms. That is, under the multiplicative output approach the larger TNSP's output is four times larger than the smaller TNSP's output compared to its input which is twice as large. Under the separate inclusion approach, the larger TNSP's output is double that of the smaller TNSP as required. Given that input has also doubled, productivity is the same for both TNSPs under the separate inclusion output approach as required but it is twice as high for the larger TNSP under the multiplicative approach.

This example disproves FE's (2017, p.23) claim that the current output and input specifications do not adequately control for TNSP scale effects.

The above example assumes the same configuration of lines for the larger TNSP as for the smaller TNSP. If the larger TNSP was to configure its lines to use a higher proportion of very high MVA capacity lines then it would potentially have a higher share of its total MVAkms on the input side in these very high capacity lines. However, it remains necessary to convert circuit line lengths to a common unit so that the line input can be legitimately summed to an aggregate level for each TNSP. If this was not done, to use an aeroplane example, we would be counting a Cessna and a Jumbo jet equally in summing up the number of planes to form a proxy for total capital input quantity.

In our economic benchmarking of DNSPs, concern was expressed that some DNSPs have more subtransmission lines of higher voltage than their peers due to the different system histories across States. This led to those DNSPs that inherited more and higher voltage subtransmission having relatively more of their MVAkms of line input tied up in these assets which accounted for relatively small proportions of their asset base. To address this concern we disaggregated lines and cables into separate subtransmission and distribution inputs, given that we also had the DNSP regulatory assets bases disaggregated along these lines (Economic Insights 2014c, pp.12–13). In practice, making this refinement led to little change in the DNSP MTFP results. A similar disaggregation could, in principle, be adopted for TNSPs although the split between very high voltage lines and lower voltage transmission lines would be somewhat arbitrary and would require a similar disaggregation of asset values which we do not currently have.

Another approach to this issue has been adopted in our economic benchmarking of gas distribution businesses (for example Economic Insights 2012, 2015b) where pipeline lengths are separately included for services, low pressure, medium pressure and high pressure pipelines on the input side of productivity analysis. This requires data to be available or to be readily estimable for corresponding asset values. The greater diversity of TNSP line and cable capacities and the absence of disaggregated asset values make this approach less tractable for TNSPs.

It should be noted that this issue is only potentially of relevance to benchmarking total productivity levels across TNSPs. Currently, only TNSP opex MPFP growth rates are used in the AER's TNSP regulatory determinations. As illustrated in the example above, a move to include a multiplicative measure of capacity on the output side would distort measured productivity growth rates as well as productivity level comparisons.

Issues for discussion

16. *Does the current separate inclusion of output capacity variables and the MVAkms based input specification introduce any biases?*
17. *Is there an objective basis on which to divide a category of very high voltage lines from other lower voltage transmission lines (noting that productivity indexes require non–zero quantities and values for all input categories for all TNSPs)?*
18. *Can TNSP asset values be reliably and accurately split and provided on a similar basis?*

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