Memorandum

From: Denis Lawrence and Tim Coelli **Date:** 4 February 2019

To: AER Opex Team

Subject: Forecast Opex Productivity Growth

We have been asked to respond to 12 questions on issues relating to the appropriate forecast opex productivity trend to include in the 'base/step/trend' method following the receipt of submissions on the AER (2018) draft report. Answers to the 12 questions are presented in this memo. Issues relating to the treatment of the share of underground variable in the opex cost function models are addressed in a separate memo.

Background

The rate of change method for calculating the efficient future opex allowance for regulated DNSPs takes efficient opex for a base year (usually the second last year of the preceding regulatory period) and rolls it forward each year by the forecast rate of change in opex input prices plus the forecast rate of change in output minus the forecast rate of change in opex partial factor productivity (PFP). The idea is that over time more opex allowance will be required if opex input prices increase relatively rapidly and if output increases (as more inputs are required to supply more output). But increases in opex partial productivity over time will normally reduce the quantity of opex required per unit of output, all else equal, and so this also has to be allowed for. This requires a forecast of opex productivity growth for the next regulatory period to be made. The forecast will usually draw on observed or historic opex productivity growth but should reflect the productivity growth achievable by efficient DNSPs, ie it should ideally reflect movement of the efficient frontier and exclude catch–up effects.

The base/step/trend method is similar to the rate of change method except that step changes may be added to the efficient base year opex to reflect changes in NSPs' recognised responsibilities over time. The presence of step changes has important implications for measuring and interpreting historic opex productivity growth and how it is used to forecast future productivity growth.

1. When using historical productivity growth for the purposes of forecasting productivity going forward, is there a minimum or preferred period of time over which to measure historically achieved productivity growth?

As a general rule, the more data one has available to undertake productivity analysis, the better. This applies as much to estimating productivity growth trends as it does to estimating efficiency levels. However, the data available has to be consistent and reflect business as usual circumstances. If part of the available time period reflects unusual circumstances then estimating a trend that incorporates that period may produce a distorted estimate of future productivity growth possibilities. This may necessitate use of a shorter time period to base the trend estimate on where this time period is more likely to reflect business as usual conditions.

If such a time period is relatively short, then an appropriate degree of caution would need to be exercised regarding the exact magnitude of the resulting trend estimate.

Alternatively, drawing on a longer time–series of productivity results may allow for the effects of the unusual circumstances to be 'washed out' or at least reduce their impact on the resulting trend estimate. If such a longer time period of results is not available domestically, another option may be to use a longer time period of data from the same industry in other countries. Similarly, another option is to draw on the productivity growth of broadly similar industries – both domestically and overseas – that have been less affected by the unusual circumstances.

A further and in many ways preferred option is to form an estimate informed by a combination of sources. These could include available data for the DNSPs in question that covers business as usual conditions – even if this is for a relatively short period, longer term trends using overseas data for the same industry and trends estimated for broadly similar industries but which have not experienced the unusual conditions in question.

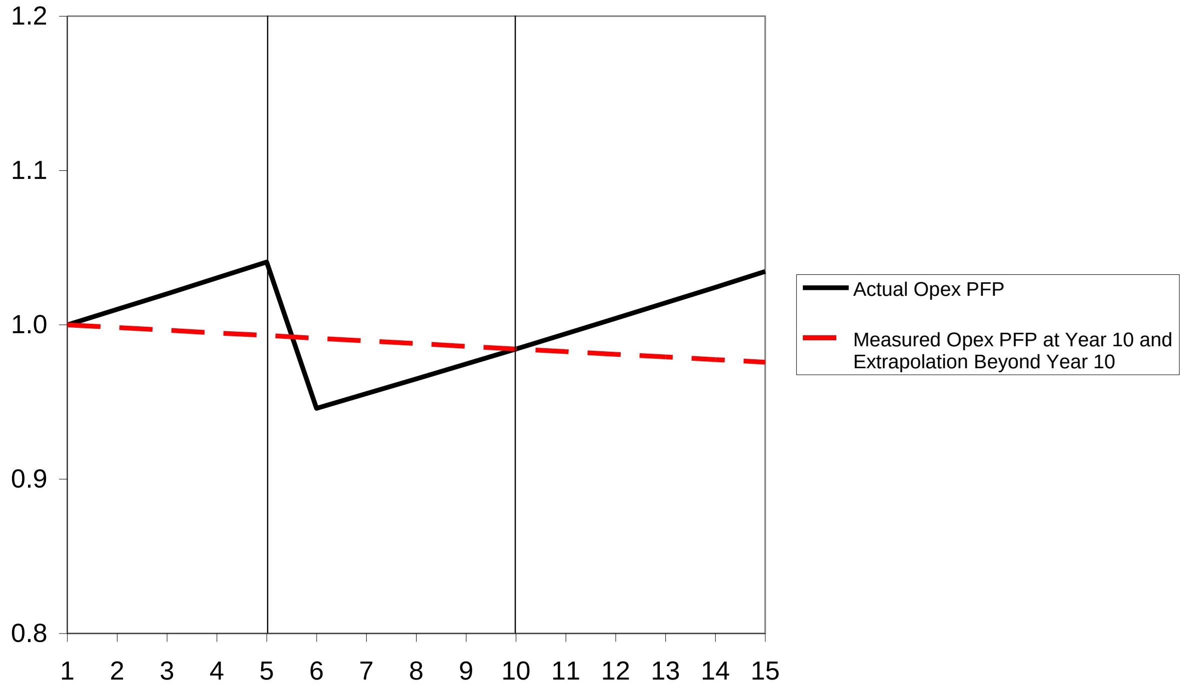
The main departure from business as usual conditions for Australian DNSPs since 2006 has been the granting of extensive step changes up to 2012. For example, in the Victorian DNSP resets conducted by the AER for the 2011 to 2015 regulatory period, the five Victorian DNSPs were allowed average step change increases in opex of just under 10 per cent, mainly in recognition of increased vegetation management requirements following the February 2009 Victorian bushfires. The step changes ranged up to 13 per cent for Powercor. And in NSW, Ausgrid was granted an opex step change of over 6 per cent for its 2010 to 2014 regulatory period, mainly associated with meeting higher mandated reliability standards. Step changes affecting this period were also granted to other DNSPs but were not always clearly or consistently quantified by previous jurisdictional regulators and in early AER determinations.

Step changes are likely to have significant implications for measured productivity growth as, without specific allowance for the step changes, they will make measured opex PFP look worse than what it would be for more like–with–like comparisons over time which removed the step change from reported historic opex. Without allowance for past step changes, there is a risk that NSPs could potentially get a double benefit – once from the step change itself plus a lower opex PFP growth rate in the roll forward for subsequent regulatory periods as well.

To illustrate this consider the case of DNSPs over three five–year regulatory periods where a 10 per cent step change is granted at the start of the second regulatory period to cover increased mandated obligations. There is no step change at the start of the third regulatory period. The annual opex productivity growth rate is constant at 1 per cent within each of the three regulatory periods. Now consider the regulator's decision regarding the forecast opex productivity growth rate to incorporate in the rate of change for the third regulatory period. If the regulator does not allow for the 10 per cent step change at the start of the second regulatory period and instead uses a simple extrapolation of observed historic opex productivity growth rate over the first and second regulatory periods, the longest period of data available at the time, the forecast opex productivity growth rate for the third period will be significantly underestimated. This is illustrated in figure A below.

If the step change at the start of the second regulatory period is not allowed for when calculating the opex partial productivity growth rate at the reset at the end of the second period then the measured opex PFP growth rate for the third period would be –0.2 per cent per annum instead of the actual (common within–period) growth rate of 1 per cent. As a result the DNSP's efficient opex for the third period would be overestimated and the DNSP would be overcompensated and earn excess returns.

Figure A: **Impact of step change on measured opex productivity growth**



In this example, using the longest period of available data to estimate the opex productivity trend does not produce the best forecast. Basing the opex PFP growth rate for the third regulatory period on the within–period opex PFP growth rate for the second regulatory period (and possibly the first regulatory period if the size of the step change is known) would, all else equal, provide a more accurate forecast given that there was a sizeable step change in the historic time period. Thus, in this case longer is not better given the existence of unusual circumstances.

NERA (2018, p.34) quote the AEMC (2011, p.23) as supporting the proposition that 'at least 8 years of robust and consistent data will be required to establish a TFP growth rate that could be used in a TFP methodology for price and revenue determinations'. The operative word here is *consistent*. As illustrated above, if the data are not consistent due to the existence of unusual circumstances, then 8 or 10 years of data may produce a less accurate forecast than 5 or 6 years of data does. Furthermore, the AEMC (2011) review was of the use of productivity indexes in productivity–based regulation rather than in building blocks regulation. *All* of the DNSP's revenue is at risk based on the productivity index measures under productivity–based regulation. This differs from building blocks regulation where a major part of the DNSP's revenue is guaranteed by the return on and return of capital building blocks components for sunk capital. Where all of the DNSP's revenue is at risk – as is the case under productivity–based regulation – a more conservative approach to estimating the productivity trend is likely to be required. But, as noted, in this case the prime requirement is again for consistent data.

2. How important are the selection of the start and end year and the selection of the sample when measuring historical productivity growth?

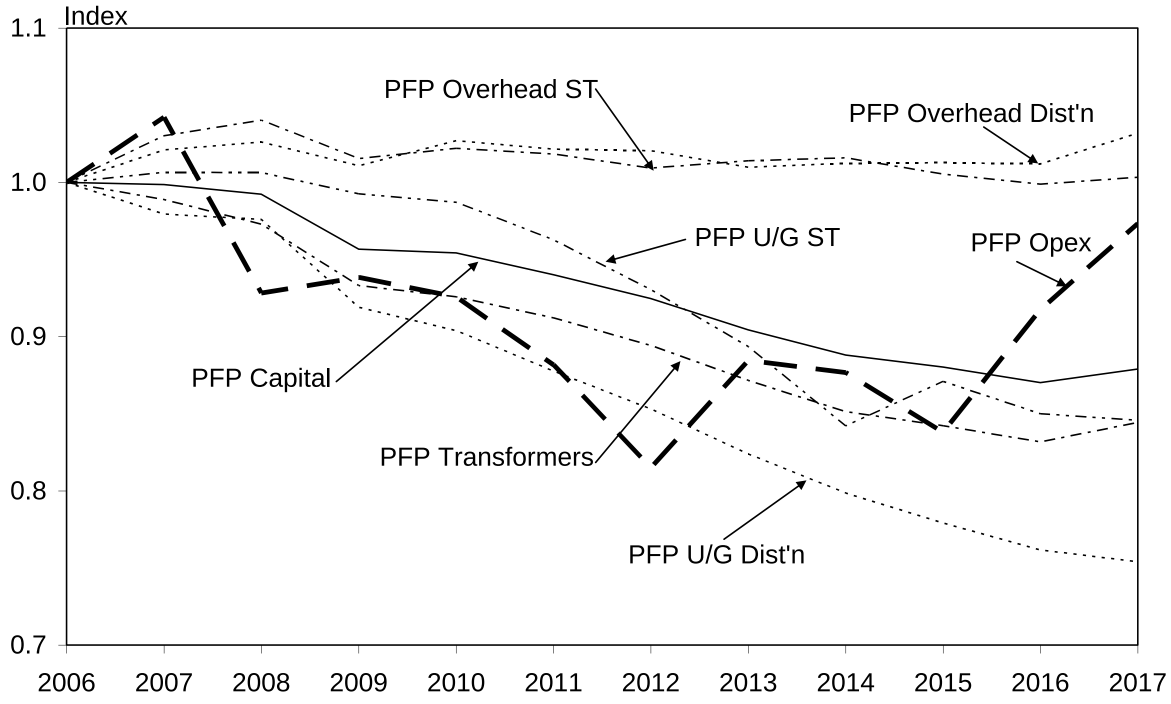
AER (2018) has been criticised in submissions (eg NERA 2018, pp. 36–41) for:

- taking an unweighted rather than a weighted average of DNSP opex productivity growth rates
- only presenting average annual growth rates of opex productivity for before and after 2012
- using a sample of DNSPs the AER 'did not find materially inefficient', and
- using an endpoint–to–endpoint growth rate rather than a regression–based growth rate.

We agree with NERA (2018, pp.36–7) and CCP (2018, p.23) that it is preferable to take a weighted average of individual DNSP opex productivity growth rates when forming a representative measure rather than an unweighted average. This avoids undue weight being given to small DNSPs and inadequate weight being given to large DNSPs in forming the representative measure. All aggregate growth rates presented in Economic Insights (2018) and our earlier benchmarking reports are weighted rather than unweighted.

By definition, productivity growth rates can be sensitive to the time period used and the sample of DNSPs selected. In this case, however, we think there is reasonable prima facie evidence to indicate that the decline in industry opex productivity after 2007 started to reverse around 2012. This can be seen in the following graph where opex productivity increases markedly in 2013 before levelling off in 2014, falling somewhat in 2015 and then growing strongly in 2016 and 2017.

Figure B: **Industry–level distribution opex productivity indexes, 2006–2017**



Source: Economic Insights (2018, p.8)

The average annual opex productivity growth rate for the industry from 2006 to 2012 is –3.4 per cent while the average annual growth rate for 2012 to 2017 is 3.6 per cent.

Sample selection is an important issue for the forecast opex productivity growth rate to include in the base/step/trend methodology because the objective of including forecast productivity is to reflect growth in the efficient frontier over time rather than industry average productivity growth which will also include an element of catch–up by initially inefficient DNSPs. Since catch–up gains are usually larger than frontier shifts, including DNSPs going through catch–up may overstate the forecast rate.

For index analysis, we believe a wider range of DNSP groupings should be examined than just the industry as a whole or DNSPs found by the AER 'not to be materially inefficient'. This is because we expect both of these groups to include a significant degree of catch–up productivity growth. A wider range of groupings is likely to be needed to identify the best proxy for frontier productivity growth. Similarly, we believe there is merit in undertaking sensitivity analysis around the time period chosen. We present the results of this analysis below for opex MPFP. We use the same method used to aggregate to the group level as used to aggregate to industry productivity growth in Economic Insights (2018). We will examine the sensitivity of our opex cost function time trend for Australia to the time period chosen for estimation in the response to question 4 below.

Before looking at sensitivity analysis, however, we address the issue of endpoint–to–endpoint growth rates (or compound average growth rates) versus regression–based growth rates. Both methods have been used extensively in previous regulatory analyses, including those done by ourselves. Both methods have some advantages and some potential disadvantages. The endpoint–to–endpoint method is easy to calculate and tracks the data accurately from the start to the end of the period. But it needs to be interpreted with caution if the endpoint observations are outliers. The regression–based method is less convenient to calculate but does provide more smoothing. However, it may not reflect where the data starts and ends very well.

We disagree with the NERA (2018, p.37–8) statements that the endpoint–to–endpoint method 'relies only on the start and end years of the averaging period' and 'ignores any information that might be provided by interim years in the sample'. This is clearly not the case because the progression of the time–series over the interim years is instrumental in determining the values of the endpoints. And, the regression–based method is not without its own risk of producing unrepresentative results. Consider the example of a time–series where all observations are close to the underlying trend except the second last observation which is subject to either very unusual circumstances or significant measurement error but the last observation returns to the underlying trend. The endpoint–to–endpoint method will accurately measure the underlying trend in this case while the regression–based method will be distorted by the influence of the second last observation.

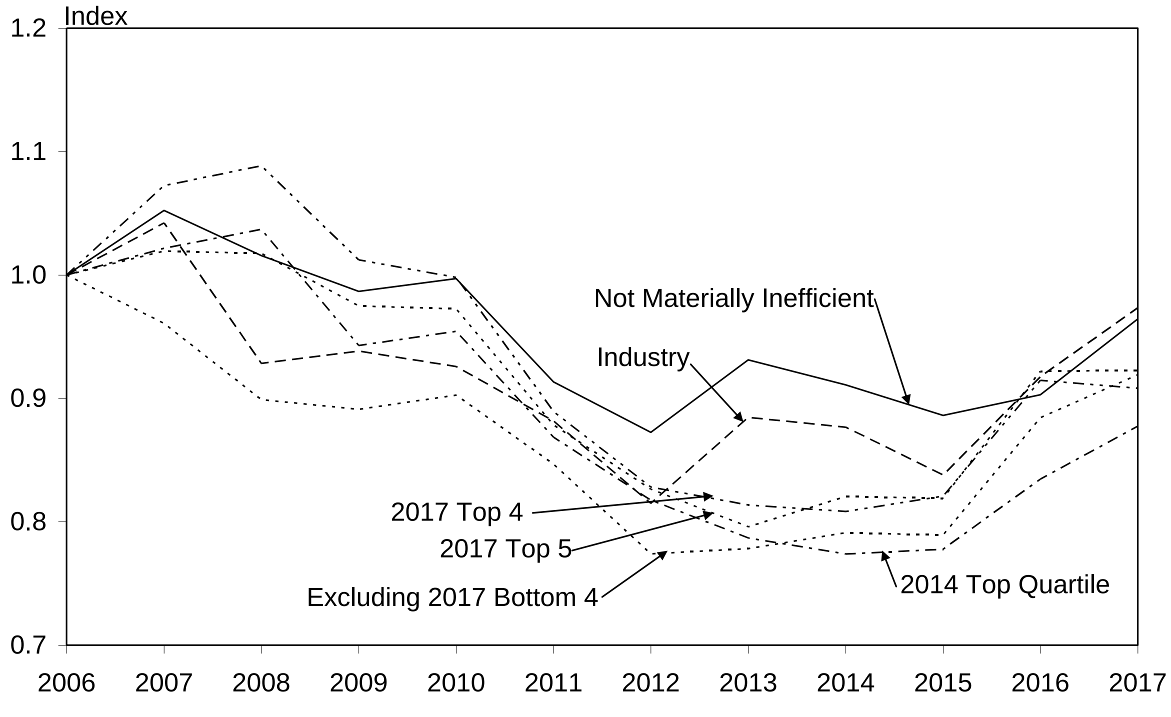
We note that the NERA (2018, p.37) formula for the endpoint–to–endpoint growth rate is incorrect. The numerator should be the natural logarithm of the ratio of the endpoints rather than their difference.

Turning to the sensitivity analysis of DNSP grouping and time periods, we have constructed aggregate opex productivity indexes for five groups that would inform assessments of movements in the efficient frontier over time. These groupings are:

- Not Materially Inefficient (NMI): this excludes the four DNSPs (ACT, AGD, ESS and ENX) the AER found to be inefficient in their use of opex in its 2014 and 2015 determinations
- 2014 Top Quartile (TQ): this includes the five DNSPs (CIT, PCR, SAP, AND and UED) found to have opex efficiency scores in excess of 0.75 in Economic Insights (2014)
- 2017 Top 5 (T5): this includes the five DNSPs with the highest 2017 opex MPFP levels in Economic Insights (2018) and comprises CIT, ENX, PCR, SAP and UED
- 2017 Top 4 (T4): this includes the four DNSPs with the highest 2017 opex MPFP levels in Economic Insights (2018) and comprises CIT, PCR, SAP and UED, and
- 2017 Top 9 (T9): this excludes the four DNSPs with the lowest 2017 opex MPFP levels in Economic Insights (2018) – the excluded DNSPs are AGD, ERG, JEN and TND.

Opex productivity indexes for the five groups and the DNSP industry are presented in figure C below.

Figure C: **DNSP opex productivity indexes by group, 2006–2017**



All five groups follow a similar pattern to the industry opex productivity index with a period of decline from 2006 to 2012 before a period of levelling off and subsequent increase after 2012. The main difference is a marked increase in opex productivity in 2013 for the industry and NMI indexes compared to levelling out of the over four indexes in 2013. This is explained by marked increases in opex productivity in 2013 by ERG and TND which are only included in the NMI (and industry) indexes.

With regard to time periods, we examine different time periods commencing between 2011 and 2015 and ending in 2017 or 2016. We do not include periods shorter than three years (ie two annual changes). We agree with CCP (2018, p.26) that 2011 is likely to be heavily affected by the impact of step change effects but include it for completeness and to cover the argument made by Endeavour Energy (2018, p.15) that 2012 is unduly affected by changes in provisions.

Table A: **DNSP opex productivity indexes and endpoint–to–endpoint growth rates by group, 2006–2017**

Year	*Industry*	*NMI*	*TQ*	*T5*	*T4*	*T9*
2006	1.000	1.000	1.000	1.000	1.000	1.000
2007	1.042	1.052	1.022	1.019	1.072	0.961
2008	0.928	1.016	1.037	1.018	1.088	0.899
2009	0.938	0.987	0.943	0.975	1.012	0.891
2010	0.926	0.997	0.954	0.972	0.998	0.903
2011	0.882	0.913	0.868	0.878	0.889	0.847
2012	0.815	0.872	0.817	0.826	0.828	0.774
2013	0.885	0.931	0.787	0.796	0.814	0.778
2014	0.877	0.911	0.774	0.820	0.808	0.791
2015	0.838	0.886	0.778	0.819	0.821	0.789
2016	0.918	0.903	0.835	0.922	0.915	0.884
2017	0.973	0.964	0.877	0.923	0.908	0.919
Annual Growth 2006–2017	–0.25%	–0.33%	–1.19%	–0.73%	–0.87%	–0.77%
Annual Growth 2006–2012	–3.41%	–2.28%	–3.36%	–3.18%	–3.14%	–4.27%
Annual Growth 2012–2017	3.55%	2.01%	1.42%	2.21%	1.85%	3.44%
Annual Growth 2011–2017	1.65%	0.91%	0.17%	0.82%	0.35%	1.37%
Annual Growth 2013–2017	2.39%	0.88%	2.73%	3.70%	2.75%	4.16%
Annual Growth 2014–2017	3.48%	1.90%	4.19%	3.92%	3.89%	5.00%
Annual Growth 2015–2017	7.49%	4.23%	6.03%	5.97%	5.06%	7.61%
Annual Growth 2011–2016	0.80%	–0.23%	–0.80%	0.97%	0.56%	0.87%
Annual Growth 2012–2016	2.96%	0.86%	0.52%	2.73%	2.48%	3.33%
Annual Growth 2013–2016	1.22%	–1.03%	1.96%	4.90%	3.90%	4.26%
Average 2011 onwards	2.94%	1.19%	2.03%	3.15%	2.61%	3.76%
Average 2011 onwards with at least 4 annual changes	2.27%	0.88%	0.81%	2.09%	1.60%	2.63%
Average 2011 onwards with at least 5 annual changes	2.00%	0.90%	0.26%	1.33%	0.92%	1.89%

The average annual growth rates of opex productivity are strongly negative for all groups for the period 2006 to 2012 and then positive for all groups for the period from 2012 to 2017 with growth rates ranging from 1.4 per cent for TQ to 3.4 per cent for T9. Starting the period a year earlier in 2011 reduces the average annual growth rates somewhat with a range of 0.2 per cent for TQ to 1.4 per cent for T9. Starting the period a year later in 2013 generally increases average annual growth rates with a range of 0.9 per cent for NMI to 4.2 per cent for T9. Starting the period one or two years later in 2014 or 2015 substantially increases the average annual growth rates again with a range of 1.9 per cent for NMI starting in 2014 to 7.6 per cent for T9 starting in 2015.

Ending the period one year earlier in 2016 and starting in 2011 leads to somewhat lower average annual growth rates for the NMI, TQ and T9 groups but to somewhat higher average annual growth rates for the T5 and T4 groups compared to the 2011 to 2017 period. Similar patterns are observed for the period 2012 to 2016 relative to the period 2012 to 2017, and for the period 2013 to 2016 relative to the period 2013 to 2017.

Since the objective is to obtain information on likely growth of the efficient frontier, we believe the five groups examined in table A can be further narrowed. The T9 and NMI groups are likely to both contain DNSPs exhibiting significant catch–up gains. Both these groups contain 9 DNSPs. It is unlikely they would all be frontier firms. This leaves the TQ, T5 and T4 groups that contain either five or four of the top ranked DNSPs at either the period 2006 to 2013 or at 2017.

The difference in composition between the TQ and T5 groups is that both contain CIT, PCR, SAP and UED and TQ then includes AND as the fifth DNSP whereas T5 includes ENX as the fifth DNSP. The TQ group contains the five DNSPs found to have the highest average opex cost function efficiency scores over the period 2006 to 2013 in Economic Insights (2014). While the first four of these DNSPs have maintained high opex MPFP rankings, AND's opex MPFP level and ranking both declined from 2012 to 2016 before a partial recovery in 2017. AND was significantly affected by the 2009 Victorian bushfires and has undertaken several years of additional spending in its wake. As a result, the Victorian step changes following the Victorian Bushfires Royal Commission can be considered to have had a prolonged impact on AND. The impact of this on group opex productivity growth rates can be seen by comparing the growth rates of the TQ and T4 groups, the composition of which is the same except for TQ including AND whereas T4 excludes it. The growth rates for TQ are generally lower than for T4 due to AND's downward opex productivity movement over most of the period from 2011 onwards. Because AND is unlikely to reflect frontier efficiency over this later period, we believe TQ does not present a good basis for assessing frontier productivity growth.

This leaves the T5 and T4 groups which contain DNSPs with the highest opex MPFP levels in 2017. The difference between the two groups is the inclusion of the DNSP with the fifth highest opex MPFP level in 2017, ENX, in T5. Since ENX was assessed as not being materially efficient (albeit by a small margin) in the AER's 2015 determination, it is likely that ENX has exhibited catch–up over the ensuing period. This can be seen by comparing the growth rates for T5 and T4 with the T5 rates being higher in all cases. We thus favour T4 over T5 although the four DNSPs that make up T4 (CIT, PCR, SAP and UED) now share largely common management and ownership.

We next have to consider the best time period over which to estimate productivity growth for these groups. One option is to take an average of the growth rates observed for different periods. This reduces the risk that the period chosen is atypical or that the start and end points reflect unusual circumstances. As can be seen from table A, the average growth rate for T4 for the periods reported is 2.6 per cent. However, this includes some relatively short periods that exhibit very high growth rates. To further reduce the risk of choosing an unrepresentative growth rate, we also report in table A the averages for the growth rates from the five periods that have at least five years of data (ie four annual changes) and for the three periods that have at least six years of data (ie five annual changes). Generally we are of the view that at least six years of data (ie five annual changes) are required to base a trend estimate on. The average growth rate for the five year periods for T4 is 1.6 per cent while the average for the six year periods for T4 is 0.9 per cent. Consequently, an appropriately conservative interpretation of the results in table A points to a current frontier growth rate of around 1 per cent per annum.

For completeness, regression–based opex productivity growth rates are presented in table B.

Table B: **DNSP opex productivity regression–based growth rates by group, 2006–2017**

Period	*Industry*	*NMI*	*TQ*	*T5*	*T4*	*T9*
Annual Growth 2006–2017	–0.95%	–1.18%	–2.41%	–1.69%	–2.19%	–1.30%
Annual Growth 2012–2017	2.72%	1.09%	1.53%	2.83%	2.37%	3.54%
Annual Growth 2011–2017	1.71%	0.65%	0.22%	1.41%	0.97%	1.88%
Annual Growth 2011–2016	0.78%	–0.09%	–1.04%	0.70%	0.31%	0.84%

The relativities of the regression–based growth rates in table B are broadly similar to that of the corresponding endpoint–to–endpoint growth rates reported in table A. For the T4 group the regression–based rates for 2012 to 2017 and for 2011 to 2017 are somewhat higher than the corresponding endpoint–to–endpoint rates while the regression–based rate for 2011 to 2016 is slightly lower. The average of these three growth rates using the regression method is 1.2 per cent compared to an average of 0.9 per cent using the endpoint–to–endpoint method.

3. In the context of the electricity distribution industry productivity performance since 2006, what are the pros and cons of measuring productivity over the 2006–17 period relative to a more recent period, such as 2012–17?

As noted above, the main departure from business as usual conditions for Australian DNSPs since 2006 has been the granting of extensive step changes up to 2012. For example, in the Victorian DNSP resets conducted by the AER for the 2011 to 2015 regulatory period, the five Victorian DNSPs were allowed average step change increases in opex of just under 10 per cent, mainly in recognition of increased vegetation management requirements following the February 2009 Victorian bushfires. The step changes ranged up to 13 per cent for Powercor. And in NSW, Ausgrid was granted an opex step change of over 6 per cent for its 2010 to 2014 regulatory period, mainly associated with meeting higher mandated reliability standards. Step changes affecting this period were also granted to other DNSPs but were not always clearly or consistently quantified by previous jurisdictional regulators and in early AER determinations.

A review of the magnitude and timing of the impact of step changes is provided in CCP (2018, pp.19–22). With regard to the increased reliability standards in NSW, it is noted that in the period up to 2009 IPART was able to approve increased costs to meet the increased standards on a pass–through basis. In the case of Country Energy (now Essential Energy) a $45 million allowance was approved for the three years to 2009 (relative to 2009 allowed opex of $396 – all in 2009 prices). The AER then included a further $135 million in base opex for the 2010 to 2014 regulatory period it recognised was necessary to comply with the new standards. Similarly, the AER included $116 million in analogous step changes in Ausgrid's opex allowance for the same regulatory period. Ausgrid (2018, p.118) recently noted the impact of the increased standards as follows:

> 'Mandated licence conditions, which increased reliability standards and rising peak demand led to an increase in our operating costs base to support the required rapid increase in capex from 2007 to 2012.'

While the deadline for implementation of the new reliability standards in NSW was 2014, the NSW DNSPs appear to have complied with the standards well in advance of this. AEMC (2012, p.4) found the following:

> 'Recent performance against the reliability standards indicates that the NSW DNSPs have been out–performing against the standards, which may suggest that compliance with the standards could have been achieved with a lower expenditure.'

Early compliance with the increased standards was further evidenced by the AEMC (2012, p.12) finding that only small proportions of the NSW DNSPs' feeders were non–compliant with the new standards as at July 2011.

CCP (2018, pp.21–2) notes that the Victorian DNSPs' substantial step changes following the 2009 Victorian bushfires were heavily front–end loaded to the 2011 year of the 2011 to 2015 regulatory period.

The presence of extensive opex step changes in the 2006 to 2012 data make inclusion of this period in the calculation of forecast future productivity trends problematic. Data for the period 2012 to 2017 is likely to provide a more accurate basis for forming these forecasts as the impact of step changes appears to have been largely worked through by 2012. As noted above, AND appears to be a possible exception to this as its opex continued at higher levels through to 2016 before significant reductions were implemented in 2017. As illustrated in figure A above, failure to allow for the impact of the sizable step changes up to 2012 could lead to a significant underestimation of the future rate of opex productivity growth which could lead to DNSPs earning excess returns.

If the period prior to 2012 was included in estimation of the trend with no allowance for step changes, maintenance of the NPV=0 condition would likely require the inclusion of offsetting negative step changes at future resets. This is because the objective is to set the opex allowance based on an unbiased estimate of efficient opex over the next regulatory period. If this is fed into the building blocks process along with estimates of the efficient return on and return of capital then the present value of DNSPs' allowed revenue streams will equal the present value of their efficient costs. If the regulator underestimates the rate of opex productivity growth in estimating future efficient opex (because it has not allowed for the step change effect) then it is overestimating future efficient costs in building blocks and, all else equal, the present value of DNSPs' revenue will exceed the present value of their actual costs. This can be corrected either by making sure the opex productivity growth rate is not underestimated (ie by excluding the effect of step changes) or, alternatively, by using the reported data (which includes step changes) and making an offsetting negative step change at the start of the next period (effectively to offset the triangle at the right of figure A between the solid black line and the dashed red line).

While data from 2012 onwards is likely to provide a more accurate basis for forecasting future opex productivity trends, it has the disadvantage of being of shorter duration than is ideal. This points to the need to use a range of sources of information which are not impacted by the step changes to form the productivity trend forecast. In addition to the more recent DNSP data, it would be useful to draw on longer term trend information for electricity distribution networks in other countries and on Australian data for similar industries not impacted by step changes. AER (2018) has drawn on gas distribution studies to obtain information on a similar industry.

With regard to longer term estimates for electricity networks, CCP (2018, pp.17–8) note that the Productivity Commission (2012, p.20) found a longer term trend multi–factor productivity annual growth rate for the whole electricity supply sector was around 1.3 per cent over the 34–year period from 1974 to 2009. This series has not subsequently been updated. It drew on Australian Bureau of Statistics National Accounts data. We note that ABS data is not currently available at the networks level and broader ABS data will also incorporate the effects of step changes.

Overseas electricity distribution studies are likely to provide more useful information on longer term productivity trends. The most current information is a study of productivity in UK electricity networks since 1990 recently released by Ofgem and conducted by the University of Cambridge's Energy Policy Research Group (EPRG 2018). Ofgem provided data to EPRG covering the UK's 14 DNSPs for the period 1991 to 2017. EPRG examined five different TFP models. The first model included customer numbers, energy deliveries and network length as outputs and produced an average annual productivity growth estimate of 1.1 per cent for the 27–year period to 2017. EPRG's second model adds customer minutes not supplied and the number of interruptions and produces an average annual productivity growth rate of 2.0 per cent. Further adding energy losses produced an average annual productivity growth rate of 1.9 per cent.

EPRG's model that comes closest to our own includes customer numbers, energy deliveries, network length and peak demand as outputs and also includes customer minutes not supplied and the number of interruptions. Data for this model is only available for the period 2014 to 2017 and it produces an average annual productivity growth rate of 0.9 per cent.

While the EPRG models cover both opex and capital, they provide a conservative guide to likely longer term opex productivity growth rates. This is because capex in constant prices (which is the measure of capital input used) trends upwards somewhat over the period whereas opex trends downwards over the period as a whole (EPRG 2018, p.34). Given EPRG's total productivity growth (which uses opex and capital) is positive, then using just opex would produce a higher partial productivity growth rate. This is because the total productivity is a weighted average of the opex and capital partial productivities. The capital input quantity's upward trend will be dragging the weighted average (or total) productivity down so it must be being offset by partial opex productivity growth that is higher than that for total productivity.

The average annual productivity growth rates EPRG finds both over the longer term 27–year period and the more recent 5–year period are consistent with the average annual growth rate of Australian DNSP opex productivity reported above for the five and six–year periods from 2011 onwards of around 1 per cent.

There has also been a number of productivity studies conducted of US electricity distribution businesses. These productivity studies have nearly always focused on total productivity measures. They have often used throughput–based output measures and generally use a 'monetary' approach to measuring the stock of capital inputs. Longer term US electric and gas utility productivity studies have recently been reviewed by Pacific Economics Group (PEG 2018). PEG report that for a wide range of US regulator–approved rate decisions, the average annual 'acknowledged productivity trend' for electricity distribution businesses is 0.60 per cent and for gas distribution businesses is 0.63 per cent. PEG (2018, p.41) also noted its own most recent research on US electricity distribution productivity trends produced average annual growth estimates of 0.45 per cent for the period 1980 to 2014 and of 0.43 per cent for the more recent period 1996 to 2016.

4. What is the impact on the econometric time trend (or technical change variable) when we allow for country–specific time trends rather than a common time trend?

The opex cost function models reported in Economic Insights (2018) contain a common time trend variable across all DNSPs. A number of submissions (eg Endeavour Energy 2018, p.23) note that the time trend coefficient remains positive when the estimation period is changed from 2006 to 2017 to 2012 to 2017 even though the index number analysis shows positive productivity growth for the Australian DNSPs over this later period. This could be explained by ongoing declines in productivity growth in the New Zealand and Ontario DNSPs outweighing the impact of positive opex productivity growth among the Australian DNSPs in estimating the coefficient of the common time trend. It was suggested by some participants at the AER's workshop in November 2018 that country–specific time trends should be used in the models rather than a common time trend.

In this section we report the results of re–estimating the models with country–specific time trends. We do this for the 2006 to 2017 and the 2012 to 2017 time periods. And we undertake similar sensitivity analysis to the index number analysis reported above with the models also estimated over the periods 2011 to 2017 and 2011 to 2016. We do not report results for less than five years of time–series data as this would likely be inadequate to estimate a reliable time trend. The results are reported in table C. For simplicity only the time trend coefficients are reported in table C[1].

The results indicate that for the whole 12–year period, 2006 to 2017, the average time trend coefficient using a common trend across the four models implies an annual growth rate in opex of 1.9 per cent, all else equal (ie a decline in opex productivity). When we move to country–specific trends, the average growth in opex across the four models is lower for Australia at 1.3 per cent. It is also slightly lower for Ontario at 1.8 per cent but higher for New Zealand at 2.5 per cent.

[1] All time trend coefficients are strongly significant in all the SFA models. For the LSE models all are significant except for the Australia–specific coefficient which is marginally significant for 2011–2017 and not significant for 2011–2016. But it is quite significant for 2012–2017.

Table C: **Opex cost function time trend coefficients for various periods**

Time Period: 2006 to 2017

	Common Trend	Country–specific Trends		
Model		*Australia*	*NZ*	*Ontario*
LSECD	0.019	0.013	0.026	0.018
LSETLG	0.020	0.012	0.028	0.019
SFACD	0.018	0.015	0.023	0.017
SFATLG	0.017	0.012	0.023	0.016

Time Period: 2012 to 2017

	Common Trend	Country–specific Trends		
Model		*Australia*	*NZ*	*Ontario*
LSECD	0.017	–0.029	0.026	0.029
LSETLG	0.018	–0.027	0.027	0.030
SFACD	0.015	–0.031	0.027	0.024
SFATLG	0.015	–0.034	0.027	0.024

Time Period: 2011 to 2017

	Common Trend	Country–specific Trends		
Model		*Australia*	*NZ*	*Ontario*
LSECD	0.021	–0.012	0.023	0.032
LSETLG	0.022	–0.012	0.024	0.034
SFACD	0.019	–0.019	0.023	0.029
SFATLG	0.018	–0.022	0.023	0.029

Time Period: 2011 to 2016

	Common Trend	Country–specific Trends		
Model		*Australia*	*NZ*	*Ontario*
LSECD	0.019	–0.010	0.020	0.029
LSETLG	0.021	–0.009	0.021	0.031
SFACD	0.019	–0.013	0.019	0.030
SFATLG	0.019	–0.015	0.019	0.030

Looking at the period 2012 to 2017, the common time trend models still have positive coefficients with an average value of 1.6 per cent. However, when we move to country–specific time trend models, Australia now has negative coefficients for all four models with an average value of –3.0 per cent. That is, the country–specific time trend models show substantial productivity *improvement* for Australia. The coefficients for New Zealand and Ontario do, however, remain positive for this period which explains the positive value of the common time trend for the period.

Looking at the period 2011 to 2017, the country–specific time trend models all have negative coefficients for Australia but of a lower average magnitude of –1.6 per cent. Similarly, the country–specific time trend models for the period of 2011 to 2016 all have negative coefficients for Australia with an average magnitude of –1.2 per cent.

The country–specific time trend models for the period from 2011 onwards are thus all consistent with the index number–based analysis reported above and point to annual opex productivity growth in excess of 1 per cent.

5. Several submissions have noted that a measured decline in productivity does not mean that productivity was not achieved. Rather, it may be because they delivered outputs not captured under our models. What is the magnitude of the risk/possibility that the time trend is capturing outputs that have not been specified? Can we still rely on our existing models, even if the models do not capture potentially material outputs delivered by distribution businesses?

Some submissions (eg NERA 2018, p.5) argue that negative measured productivity growth may simply reflect the fact that tops–down models cannot capture all the outputs being provided by a DNSP. As a result, if the DNSP is using inputs to increase an output not explicitly included in the model then its measured productivity will be negative, all else equal, because the models capture the increase in inputs but not the increase in the relevant output. This is, of course, possible as tops–down benchmarking measures are limited to only including a small number of high level and readily measurable outputs.

In the case of Australian DNSPs over the period 2006 to 2017, this issue is another manifestation of the step change issue discussed above. From 2006 to 2012 NSW and Victorian DNSPs were required to increase their input use to meet a range of higher standards relating to reliability and catastrophic bushfire prevention, respectively. In the case of NSW, the output the DNSPs are being required to supply more of is system security, through higher levels of asset redundancy. Higher levels of system security should eventually be reflected in improved reliability performance with reduced frequency, duration and severity of outages, particularly in key areas of economic activity such as the Sydney CBD. In the case of Victoria, the output the DNSPs are being required to supply more of is greater system safety through greater robustness to extreme summer weather conditions. These outputs were discussed in broad terms with stakeholders during the AER's consultation workshops in 2013 but were noted as being hard to adequately and objectively quantify for productivity measurement purposes.

The system security and safety outputs were also thought to be of a binary nature with required standards either being met or not being met. From a productivity measurement perspective, not including these outputs should not be a major issue provided the required standards remain constant over time. However, when required standards transition from one level to a higher level, not including the outputs explicitly will lead to an underestimate of productivity performance over the relevant time period. This was illustrated in figure A above where the increase in input use at the start of the second period leads to a downward bias in measured productivity performance across the first and second periods unless the increased input associated with meeting the change in standards (ie the step change) is removed or else the corresponding increase in the (currently unmeasured) output is included.

Using the currently available data and benchmarking models, there are several ways to address this issue including to develop and include additional outputs that reflect the required standards, to exclude the increase in inputs used to meet the increase in standards or else to base measurement on the shorter time period after the increase in input use to meet the standards has taken place. As noted above, the system security and safety outputs are hard to measure and would almost certainly require new data collection mechanisms being put in place going forward so the first option is unlikely to be feasible. Similarly, as noted above, jurisdictional regulator and early AER determinations did not always separately or consistently identify the increased input allowance associated with step changes so the second option is not feasible, at least not with any degree of accuracy and low transactions costs. This leaves the third option of focusing productivity measurement on the period following the period of step changes. We have done this in the index number and cost function analyses reported above. We also recommend supplementing these results with longer term productivity estimates for electricity DNSPs from overseas jurisdictions not subject to these step changes.

6. Please confirm that the econometric models better capture frontier shifts than opex MPFP, which may include catch–up and frontier shifts in any productivity measurement. Also, is there any theoretical and/or practical difference in the way that the SFA versus LSE models address this issue?

In principle there is unlikely to be any difference in what the opex MPFP indexes and the LSE opex cost functions measure over time. Both will include a combination of technical change and catch–up gains. Being parametric or statistical methods, the LSE cost functions involve more smoothing but typically only give a period average productivity growth result. Being non–parametric methods, the opex MPFP indexes do not do any smoothing but they provide annual rather than period average results.

NERA (2018, p.30) states '(a)n SFA model, by contrast, separately identifies the shift of the efficient frontier from firm–specific catch–up efficiency improvements'. We agree this is correct in theory. It can be illustrated as follows. Consider the hypothetical case where we know that over a 5–year period there has been no frontier shift but there has been inefficiency catch up. That is, there have been productivity improvements but only due to efficiency change. Now if we apply SFA and LSE models to this data we would expect there to be no technical change measured by the SFA model but the LSE model will measure some 'technical change'. This is because, on average, the data points have moved upwards over time and, because LSE fits a production surface in the middle of the moving data, it will identify a trend improvement over time. That is, where there is catch–up occurring, we would normally expect the magnitude of the time trend coefficient in LSE models to have a larger absolute value than the time trend coefficient in corresponding SFA models.

Another way of looking at this is that if we used deterministic non–parametric frontier methods such as data envelopment analysis (DEA), we would assume there is no noise and hence attribute all frontier deviations to efficiency. In this case if the no noise assumption is correct we will perfectly identify frontier shift and efficiency change. But if there is noise we could get some significant errors in both technical change and efficiency change estimates.

If we instead use LSE we can either assume that there is no efficiency change or, alternatively, assume that there is efficiency change and that the technical change measure is actually a mix of technical change and average efficiency change.

For the case of SFA we use the assumed two part error structure to attempt to disentangle noise and inefficiency. We know that it is not perfect and hence may not perfectly identify efficiency change and technical change. But it does help avoid making the stronger assumptions implicit in the alternative methodology options.

In practice, however, we often observe smaller differences in the magnitude of the time trend coefficients across LSE and SFA models applied to the same data than might be expected in the presence of significant catch–up efficiency gains. In the case of the DNSP data, this is illustrated in table C where the LSE and SFA models have relatively similar–sized time trend coefficients for most of the cases examined. This is because the ability of the SFA model to separate frontier shift from catch–up will depend on its assumed error structure and the amount of noise in the data. For the common time trend coefficients and the New Zealand and Ontario country–specific time trend coefficients we generally observe the expected relationship between the SFA and LSE estimates but generally only by a small margin. For the Australian country–specific results, we observe the SFA time trend coefficients generally being higher then the corresponding LSE estimates but generally only by a small margin. This result can be explained by reference to the graph of opex partial productivity indexes (as a proxy) in Economic Insights (2018, p.16) where two of the frontier DNSPs do exhibit relatively good productivity growth in recent years.

Given that the estimated time trend coefficients in both the LSE and SFA models are likely to include elements of both frontier shift and catch–up in practice, this again points to the need to draw on a wider range of sources in forecasting future frontier productivity growth rates. These will include index–based opex productivity growth rates for firms likely to be close to the frontier, longer term trend growth rates for similar overseas DNSPs and, for opex cost function models, averaging of results across different types of models. Averaging of models' results and drawing on a wider range of information sources are both consistent with the recommendations of the Australian Competition Tribunal (2016).

7. Does our measure of productivity growth need to be identical to the models we use to forecast output growth and base year opex?

In an ideal world where there was no shortage of information and data, and business as usual conditions always applied, a case can be made that it is desirable to have all four non–step change elements of the base/step/trend approach (ie base year efficiency adjustments and forecast output growth, opex price change and productivity growth rates) estimated from the same underlying model. This would maximise the degree of internal consistency across the various components. In the real world, however, the regulator faces asymmetric information, data sources are imperfect and incomplete and business as usual conditions do not always apply, as discussed above for the period 2006 to 2012. In this case the regulator will need to draw on a range of information sources to minimise the risk of making errors.

While it will be desirable to maintain as much consistency as possible across the various components of the base/step/trend approach, this has to be traded off against the amount and quality of information available and the consistency of the conditions applying through time. In this case the step changes applying to the transitions between required standards between 2006 and 2012 are likely to particularly impact the forecast productivity component more so than the other components. This points to the need to examine a wider range of model results for this component to obtain the best forecast possible and, as noted above, to draw on results for different time periods, the same industry in different jurisdictions and similar industries, all of which are less impacted by the unusual circumstances. Inevitably not all of these models will have exactly the same specification.

In all cases, we believe it is desirable to corroborate model results from as wide a range of sources of information as possible. It was for this reason that Economic Insights (2014) reported results from three different econometric models and from an index number model that had a different output specification. The Australian Competition Tribunal (2016) recommended drawing on a wider range of information sources again. To the extent that information from different models broadly coincides, the more confidence can be had in the results – provided the models are all reasonably specified and rigorously implemented.

8. When relying on measures of productivity that are not derived from the AER/Economic Insights economic benchmarking models, is it necessary that these other measures be specified using the same outputs as electricity distribution industry? How different from electricity distribution can these measures be before they are unusable?

The Economic Insights (2014, 2018) electricity DNSP economic benchmarking models use a functional output specification rather than a billed output specification. That is, because the charging practices of many network businesses have evolved on an ease–of–implementation basis, throughput charges often account for a much higher proportion of charges than they do of costs. Generally, the marginal costs for a network business of changes in throughput will be quite low. Consequently, measuring network business output by what they charge for may not provide an accurate reflection of the services they actually provide to customers and what customers truly value. Functional output measures attempt to capture the services the network provides that are valued by customers. Primary among these will be availability of the service. Consequently, functional output measures will usually include measures of customer numbers, network length and maximum demand. Throughput is usually also included but it can be expected to receive a low weight.

In practice, the choice and specification of functional outputs will be influenced by the availability and relative quality of data for the network in question. For example, reliable and consistent maximum demand data may not be available in all cases. And, for econometric models, the number of outputs (and inputs) that can be included will be influenced by the number of observations available and the degree of variability present in the data to support robust parameter estimation and whether there is multicollinearity between the variables.

When comparing the results of different studies, it is desirable that outputs be specified in broadly similar ways but the main requirement is that the output measures attempt to reflect functional outputs rather than simply billed outputs. Throughput measures are likely to be more volatile and will underestimate network outputs at a time of declining throughput. Thus, more weight could be placed on other studies using a functional output specification and less or minimal weight should be placed on studies using only billed outputs, particularly if only throughput measures are included.

We note that the recent EPRG (2018) study of UK electricity distribution businesses uses quite similar output specifications to Economic Insights (2014, 2018).

9. More specifically, how appropriate is the use of gas distribution productivity given that the chosen gas econometric models differ from the electricity distribution models? Is there merit to the arguments from submissions (specifically NERA and CEPA) that some of the gas modelling coefficients are not statistically significant, and that gas productivity time trend may include catch–up and frontier shift?

In principle gas distribution productivity is likely to be a very useful comparator for electricity distribution productivity. Both of these network industries are highly capital–intensive with very long–lived, sunk assets. Both supply key forms of energy to a mixture of domestic, commercial and industrial users. Both have faced some challenges in recent years on the demand side with electricity networks subject to rapidly increasing prices and increasing competition from rooftop solar and gas deliveries subject to rapidly increasing prices from export competition. However, gas distribution has not been subject to a period of major step changes resulting from transition between required reliability standards as electricity distribution has been.

Development of gas distribution economic benchmarking models actually preceded the current electricity distribution economic benchmarking models. There has been a long history of gas distribution economic benchmarking in Australia. The Economic Insights (2014) index number and econometric models for electricity distribution and their application in the base/step/trend approach were based in large part on the Economic Insights (2012) gas distribution index number and opex cost function models. These gas distribution models were then further developed in Economic Insights (2015, 2016). There is thus a high degree of commonality across the development of the two sets of models.

Starting with the index number models in Economic Insights (2012, 2015), the models are based on a detailed survey template which is broadly similar to the AER’s electricity distribution economic benchmarking RINs. The gas distribution outputs used in the index number studies are customer numbers, system capacity and throughput. The gas distribution system capacity measure is based on network length, pipeline diameters and pressures. It is thus more sophisticated than the electricity distribution measures of circuit length and ratcheted maximum demand to reflect the ability of the gas network to store gas to some extent as opposed to the electricity network’s need to accommodate instantaneous supply.

Turning to the opex cost function models, the need to include more gas distribution networks relative to those survey data were available for necessitated the reliance on public domain data sources across Australia and New Zealand for the gas distribution opex cost function studies. A smaller database is thus available for gas distribution and this has necessitated the use of models with typically fewer outputs and inputs than is the case for the electricity distribution models. However, the focus in these models remains on functional outputs. The models all include customer numbers as an output and Economic Insights (2016) also includes network length and throughput. It should be noted that the electricity distribution opex cost function models also contain fewer outputs than the corresponding index number models due to data and estimation constraints. The gas distribution models in Economic Insights (2016) also include a relatively detailed treatment of operating environment factors (OEFs) with four explicit OEFs allowed for compared to the electricity models’ one explicit OEF. Although the electricity and gas models are not the same in all respects, they are sufficiently similar for the gas distribution models to provide a useful source of information for appropriate forecast opex productivity trends for electricity distribution. As noted above, it is appropriate to draw on a range of sources of broadly relevant and comparable information. The gas distribution models provide one such source.

With regard to specific points, NERA (2018, pp.28–9) and CEPA (2018, pp.14–5) argue that time trend coefficients in the gas distribution models that are not statistically significant should be ignored. In economic modelling, there are two approaches to treating variables that do not produce statistically significant coefficients. One school of thought – and that apparently advocated by NERA and CEPA – is that statistically insignificant coefficients should be dropped from the model and/or ignored. We do not support this approach. The other school of thought is that the model specification should be based on underlying economic theory – and not statistical significance alone – and even statistically insignificant coefficients still provide useful information. That is, an insignificant estimate is better than a zero estimate – as long as the high standard error is noted.

It should also be noted that t–ratios are a coefficient estimate over a standard error and, as sample size increases, the variance decreases and hence the standard error decreases which will increase the t–ratio. Hence, the size of the t–ratio and hence significance is influenced by the sample size. If sample size is large enough it is easy to find that almost all regressors are 'significant'. The gas distribution models have relatively small databases compared to the electricity distribution models and so it is not surprising that some coefficients show as being not significant in the gas distribution models. The ACIL Allen (2016) models have smaller databases than the Economic Insights (2015, 2016) models so it is also not surprising that the ACIL Allen models again produce more insignificant estimates. But this does not mean that those estimates are of no value and should be ignored.

Another way of looking at this is that implicitly two options are being considered – either include all estimates to create an average trend estimate or drop the insignificant ones and use the remaining subset to create an average trend estimate. The latter can be viewed as a more extreme weighted average (with extreme weights of 0 or 1). There is no case for adopting this more extreme option.

NERA (2018, p.30) again argues that only SFA models should be used in deriving the productivity trend because the time trend coefficient in an SFA model should capture only frontier shift whereas LSE models' time trend coefficients will also include a degree of catch–up efficiency improvement. In this case NERA argues that 8 of the 14 gas distribution models examined in AER (2018) should be ignored because they are not SFA models. As noted above, in practice data noise and other effects will lead to the SFA models also including some degree of efficiency catch–up. Consequently, we consider a better strategy is to consider results from a range of models, including LSE models and index number–based non–parametric models. This is also consistent with the Australian Competition Tribunal (2016) recommendation to draw on a wider rather than narrower range of information sources.

We also note the following statement by CEPA (2018, p.15) in relation to the gas distribution opex cost function models:

> 'in almost all these models a material driver of opex costs appears to be the RAB, which is included as a proxy for capital inputs. In other words, as the gas networks increase their RABs their opex also increases. We note that the AER's

DNSP econometric modelling does not include a broad measure of the DNSPs' asset base as a proxy for capital services. Given this additional explanatory variable in the gas distribution modelling, the gas networks productivity estimates may be less applicable to the DNSPs and at a minimum the AER needs to consider these implications.'

This issue was covered in Economic Insights (2014, p.32) as follows:

> 'With regard to capital variables, due to the lack of comparable capital data available for Ontario, we were unable to include a capital measure in this instance. However, we do note that in the Australian data the aggregate capital quantity variable formed by aggregating physical measures of lines, cables and transformers and using annual user costs as weights has a very high correlation of 0.95 with the energy delivered (Energy) output and of 0.94 with the ratcheted maximum demand (RMDemand) output. Similarly the constant price capital stock variable had a correlation of 0.88 with both the customer number (CustNum) and RMDemand output variables. This suggests that the omission of a capital input variable is unlikely to have a significant bearing on the results as it is likely to be highly correlated with the included output variables.'

We therefore consider the CEPA concern is unlikely to be important.

10. One of our options in the draft decision forecast productivity based on the addition of gas distribution productivity forecasts (0.5%) and productivity growth from undergrounding electricity assets (0.5%). NERA (page 30) argue that this may involve some double–counting of productivity growth. Please consider this argument.

NERA (2018, pp.29–30) makes two separate arguments that the estimated undergrounding impact on future DNSP productivity and the proxy estimated gas distribution opex productivity trend cannot be simply added together as done in AER (2018) option three. The first argument NERA makes is that in the gas distribution studies there may be operating environment changes occurring that have an increasing impact over time and are hence captured in the gas distribution time trend coefficient. These may not be replicable in electricity distribution and so the gas distribution productivity trend would be an overestimate for electricity distribution in this scenario. As noted above, however, the Economic Insights (2015, 2016) gas distribution studies contain a quite detailed coverage of OEFs with either three or four separate OEFs included in all the reported models. These include customer density, network age, service area dispersion and load factors. We consider it unlikely there would be any other uniquely gas distribution–related OEF factors that would be having a consistently upward impact on the estimated gas distribution time trends.

The gas distribution network is already undergrounded so the opex benefits from ongoing increasing undergrounding available to electricity distribution are not available to gas distribution. We therefore consider it reasonable to add the undergrounding benefit to the gas distribution productivity trend when forming a proxy for forecast future electricity distribution opex productivity growth using this information source. As noted above, this is one of several sources of information that should be considered.

We note that other productivity growth estimates derived from electricity distribution studies using non–parametric methods such as index number analysis will already incorporate some degree of ongoing undergrounding and so it may not be appropriate to add an additional undergrounding benefit to those results when drawing on them to form the opex productivity forecast. For electricity distribution opex cost function studies that include the share of underground as an OEF variable, the time trend coefficient should, in principle, exclude the effects of undergrounding.

The second potential issue NERA (2018, p.29–30) raises regarding the sourcing of the undergrounding and technical change components from separate models in AER (2018) relates to variable correlation. NERA argues that since both the share of undergrounding and the time trend increase over time, the electricity distribution model may have difficulty separating the effects of technical change from undergrounding and vice–versa. While such an effect could be possible, we consider it unlikely to be an issue in the case of the electricity distribution models where the correlation between the year and share of underground variables is 0.015. It is also less likely to be an issue given AER (2018, pp.16–7) takes the undergrounding coefficient to be the average of those estimated in three separate models.

NERA go on to illustrate what they argue is the potential impact of combining estimates of undergrounding and technical change effects from different models. They do this by looking at changes in the electricity distribution model undergrounding coefficients when the time trend coefficients in those models are restricted to be the same value as the average gas distribution model time trend coefficient. NERA state they use the Economic Insights (2017) models. These models run over the period 2006 to 2016. We do not consider this to be an instructive exercise as it involves reversing the sign of the time trend coefficients. Furthermore, the models in Economic Insights (2017) all use a common time trend. If the sign of the common time trend coefficient is reversed as a restriction on the model then the other coefficients will, by definition, change to accommodate this restriction. A more useful exercise is that outlined above where country–specific time trend coefficients are included. Taking the period from 2012 onwards as an example, the Australian time trend changes sign to be the same as that of the gas models but the changes to the undergrounding coefficients are all quite small.

11. Should the time period of measuring productivity growth be consistent with the time period for measuring the undergrounding co–efficient?

In an ideal world all components of the base/step/trend method would be sourced from analysis based on a common database. However, as noted above, in practice it is likely to be necessary to draw on results from different data sources and different time periods, particularly if unusual circumstances and departures from business as usual affect parts of the primary database. These unusual circumstances may affect some parameters more than others. For example, the impact of step changes to accommodate transition in required reliability standards may impact the time trend coefficient significantly but have much less impact on other parameters such as the relationship between opex and output variables and between opex and OEF variables such as undergrounding which are less likely to vary over time. This was illustrated to be the case in the sensitivity analyses reported above and discussed in our response to question 10.

The ideal of sourcing all parameters from a common model and a common database therefore has to be tempered by the need to ensure estimates for sensitive parameters are based on data sources reflecting business as usual conditions. And, as noted above, it is desirable to corroborate results for each component by reference to a range of sources of information, provided those sources are based on consistent data and models that are all reasonably specified and rigorously implemented. Drawing on a wider range of sources of information is also consistent with the recommendations of the Australian Competition Tribunal (2016).

12. Energex and Ergon have argued that the inclusion of international data in the econometric modelling means that the results do not accurately reflect the scope of savings available to Australian distributors from undergrounding. Is there any merit to this argument?

In an ideal world there would be a sufficient number of Australian DNSPs and sufficient variability in the Australian data to support robust parameter estimation in opex cost function models. However, as shown in Economic Insights (2014, pp.28–9), this is not the case. It is therefore necessary to include data for overseas DNSPs to support robust parameter estimation. The New Zealand and Ontario electricity industries both have similar industry structures and institutional histories to the Australian industry and comparable data was also available for these jurisdictions. Differences in reported opex coverage and differences in operating environments across the three jurisdictions are allowed for by the inclusion of country dummy variables.

With regard to the undergrounding coefficient specifically, it is informative to look at the degrees of undergrounding and its spread across DNSPs from the three jurisdictions. We use data from 2017 for Australia and New Zealand and for 2016 for Ontario. The weighted average share of undergrounding for the 13 included Australian DNSPs is 14.9 per cent (where weighting is by circuit length). The range of shares of undergrounding for the Australian DNSPs is from a minimum of 4.5 per cent (for ESS) to a maximum of 55.7 per cent (for ACT). The distribution of the 13 DNSPs within this range is 6 with a share of less than 20 per cent and two with a share of more than 45 per cent.

The weighted average share of undergrounding for the 18 included New Zealand DNSPs is 28.7 per cent. The range of shares of undergrounding for the New Zealand DNSPs is from a minimum of 4.3 per cent to a maximum of 56.4 per cent. The distribution of the 18 DNSPs within this range is 8 with a share of less than 20 per cent and one with a share of more than 45 per cent.

The weighted average share of undergrounding for the 36 included Ontario DNSPs is 23.6 per cent. The range of shares of undergrounding for the Ontario DNSPs is from a minimum of 7.5 per cent to a maximum of 75.8 per cent. The distribution of the 36 DNSPs within this range is 4 with a share of less than 20 per cent and 15 with a share of more than 45 per cent.

The New Zealand DNSP sample thus has a similar spread and distribution of shares of undergrounding to the Australian DNSPs but has a higher weighted average share. The Ontario DNSP sample has a lower proportion of DNSPs with low undergrounding shares and a higher proportion with high shares but its weighted average is closer to that of the Australian DNSPs than is the case for the New Zealand DNSPs.

As is to be expected, neither the New Zealand nor the Ontario DNSP samples have exactly the same undergrounding characteristics as the Australian sample. However, the distribution of the New Zealand shares is similar to that for the Australian DNSPs and the weighted average for the Ontario DNSPs is relatively close to that of the Australian DNSPs. To obtain robust parameter estimates we need reasonable variation in the data but it is, of course, also desirable to have broadly comparable industry characteristics. The three country sample used in estimating the opex cost functions appears to provide a reasonable balance between these two often competing criteria.

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