Economic Benchmarking Results for the Australian Energy Regulator's 2020 TNSP Annual Benchmarking Report

Report prepared for
Australian Energy Regulator

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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 Services Transmission	Victoria
ENT	ElectraNet	South Australia
PLK	Powerlink	Queensland
TNT	TasNetworks Transmission	Tasmania
TRG	TransGrid	New South Wales

OTHER ABBREVIATIONS

Abbreviation	*Description*
AEMO	Australian Energy Market Operator
AUC	Annual user cost of capital
CAM	Cost allocation methodology
EBRIN	Economic Benchmarking Regulatory Information Notice
ENS	Energy Not Supplied
MPFP	Multilateral partial factor productivity
MTFP	Multilateral total factor productivity
MVA	Megavolt ampere
MVAkms	Megavolt ampere kilometres
NEM	National Electricity Market
PFP	Partial factor productivity
RMD	Ratcheted maximum demand
TFP	Total factor productivity
TNSP	Transmission network service provider
VCR	Value of customer reliability

1 INTRODUCTION

Economic Insights has been asked to update the electricity transmission network service provider (TNSP) multilateral total factor productivity (MTFP) and multilateral partial factor productivity (MPFP) results presented in the Australian Energy Regulator's 2019 TNSP Annual Benchmarking Report (AER 2019a). We also update the analyses examining the contributions of each individual output and input to total factor productivity (TFP) change. The update involves including data for the 2018–19 financial and March years (as relevant) reported by the TNSPs in their latest Economic Benchmarking Regulatory Information Notice (EBRIN) returns. It also includes four updates to the methodology which are discussed in the following section.

1.1 Updates to productivity measurement methodology

In this report updates are made to four elements of the productivity measurement methodology:

- the weights used to combine non–reliability outputs
- the value of consumer reliability used in weighting the reliability output
- the cap applied to reliability output weights, and
- the index number method used.

Updated weights for non–reliability outputs

A report submitted to one of the AER's distribution determinations has identified a coding error in the formation of the time trend variables included in the regressions from which the four non–reliability output weights are derived (Frontier Economics 2019, p.11). This error was also carried across to the TNSP analysis. The time trends should have a common base or starting point for each TNSP and, by implication, for each of the 20 separate regressions. In earlier applications of this method the time trend variable was formed outside the Shazam econometrics program code and was instead read in as part of the data file (eg Lawrence 2003). We have generally adopted the common practice observed in cost function studies of starting the time trend from a common integer value in the first year of the period and incrementing its value by one each subsequent year. However, in Economic Insights (2014) (which used data covering the 8 years 2006 to 2013) and in Economic Insights (2017a) (which used data covering the 10 years 2006 to 2015) the time trend was formed by Shazam code. Instead of resetting the time trend to a common base for the observations applying to each TNSP, the time trend was mistakenly formed over the entire sample. Thus, in Economic Insights (2017a), for example, instead of the time trend running from 1 to 10 for the annual observations for all TNSPs, the time trend ran from 1 to 10 for the first TNSP in the database, from 11 to 20 for the second TNSP and so on. Because the models are non–linear, this could have a distorting effect on the results obtained.

TNSP output cost weights were updated at the review of the output specification in 2017. This was necessitated by a change to the outputs included in the model and the plan was to leave these weights unchanged for a period of around 5 years. Since an extra three years of published economic benchmarking data are now available, we undertake the correction to the models using data covering the period 2006 to 2018.

The effect of correcting the time trend error on the output cost weights is shown in table 1.1. Weight is transferred from end–user customer numbers and energy throughput to circuit length and ratcheted maximum demand (RMD). The uncorrected weight on energy throughput was 23 per cent but this falls to 15 per cent with the correction. The uncorrected weight on end–user customer numbers was 20 per cent but this falls to 8 per cent with the correction. The uncorrected weight on circuit length was 38 per cent but this increases to just over 50 per cent with the correction. And, the uncorrected weight on RMD was 19 per cent but this increases to 25 per cent with the correction.

The corrected output weights are consistent with what we would expect conceptually. The main function of the transmission network is the transport of bulk electricity from generation points to load centres. As such, we would expect circuit length to be the most important output. The end–user customer numbers output was included in Economic Insights (2017a) as an additional measure of network size and complexity. While it provides information on the additional functions the TNSP has to perform as load centres become larger and more complex, it can be expected to be of secondary importance compared to the primary transport function. Similarly, the capacity of the lines the TNSP has to provide can be expected to be primarily influenced by maximum demand with energy throughput playing an important but secondary role. The corrected output weight relativities observed in table 1.1 are in line with these expectations with circuit length and RMD having the bulk of importance followed further back by throughput and, lastly, end–user customer numbers. This will be discussed further in the following section.

Table 1.1 **TNSP Leontief cost function output cost weights**

Output	*Uncorrected 2006-2015*	*Corrected 2006-2018*
Energy throughput	23.11%	14.91%
Ratcheted max. demand	19.44%	24.71%
End–user customer numbers	19.90%	7.59%
Circuit length	37.55%	52.79%

More details on the estimation process are provided in appendix B.

Updated VCR estimates used to proxy the cost of reliability

The second element updated in this study is the value of consumer reliability used to assign a value to the reliability output. Up until now the AER’s economic benchmarking has relied on VCR estimates compiled by the Australian Energy Market Operator (AEMO 2014). A VCR time–series is formed by indexing these point estimates backwards and forwards using an appropriate price index. AER (2019b) has recently compiled updated VCR estimates and these are used in this report.

Changed cap applied to reliability output

The third element updated in this study is the cap placed on the value of the reliability output. Since direct data are not readily available on the cost of improving TNSP reliability, economic benchmarking has to date relied on the VCR, a measure of how consumers value energy not supplied. In theory this measure could be expected to provide a proxy for TNSP costs of improving reliability since in equilibrium reliability would be improved to the point where the marginal cost of further improvement equals the marginal benefit of further improvement. However, unconstrained reliance on the VCR can produce some very large weights for the reliability output where unusual one–off outages occur, such as that resulting from the transformer failure at AusNet's South Morang terminal station in 2009. As a result, the 2017 review introduced a cap of 5.5 per cent of gross revenue (total revenue plus the value of the reliability output) on the reliability output weight. This cap was derived from statistical analysis of the energy not served (ENS) series.

A weakness of this approach to calculating the cap is that it is not directly related to the regulatory regime TNSPs face. To address this weakness, we have linked the cap to the relevant Service Target Performance Incentive Scheme (STPIS) parameters TNSPs face. The relevant revenue–at–risk is for the service component, capped at ±1.25 per cent of annual maximum allowed revenue (MAR) for TNSPs. This gives rise to revenue decrement/increment ranging from –1.25 per cent to 1.25 per cent of annual revenue. Therefore, the total range of revenue at risk for TNSPs is 2.5 per cent of MAR. We thus implement a cap on the reliability output weight of 2.5 per cent of total revenue in this study instead of the cap of 5.5 per cent of gross revenue previously used.

Change to the indexing method

The fourth element of the methodology updated this year concerns the indexing method used. Up until now the examination of each TNSP's and the industry's TFP growth and the contributions of each output and input to that growth has been based on standard time–series index number methods. These indexes satisfy a number of desirable properties for index numbers to be used in time–series analyses but they do not satisfy the property of transitivity – the property that the results of comparison of two observations should be the same regardless of whether the comparison is done directly or indirectly through other observations. This is not normally an issue in time–series analysis where output and input quantities change in a non–erratic manner over time. However, the TNSP energy not supplied output has continued to exhibit very large annual percentage changes as first seen in 2009 and 2010 for ANT with its large one–off outage, but now also includes some TNSPs achieving close to or actually achieving perfect reliability in some years (eg PLK achieving zero ENS in 2019). The fact that TNSPs generally operate at very high levels of reliability means that relatively small changes in ENS (relative to total energy supplied) translate to very large percentage changes in ENS.

The standard time–series indexes are less able to accurately capture the impact of these large percentage changes, particularly when values are capped, because they do not satisfy the transitivity property. This can lead to the standard time–series indexes being subject to some degree of 'drifting' higher or lower after a spike in the ENS variable[1]. All else equal, we would expect the output index including reliability to lie above (below) the output index excluding reliability in years where reliability is significantly better (worse) than in the base

[1] This is analogous to the problem of chained index drifting in highly seasonal data discussed in Australian Bureau of Statistics (ABS 1996).

year. For an output index subject to drift, this property may not hold following a spike (in either direction) in the reliability variable.

To provide improved accuracy in the face of these large ENS percentage changes (albeit generally from small bases) we change to using the multilateral Törnqvist index method used in our panel data comparisons for our TNSP productivity growth and contributions to growth analyses as well[2]. This index does satisfy the transitivity property and is not subject to drifting following reliability variable spikes. This change means we now use the one index method throughout the report. For the productivity growth and contributions analyses the multilateral Törnqvist index is applied to the 14 annual time–series observations sample for the relevant TNSP or the industry as a whole whereas for the panel data comparisons the index is applied across the full sample of 70 observations.

Because the multilateral Törnqvist indexes focus on preserving comparability over time by doing all comparisons through the sample mean, there may sometimes be minor changes in historical results as the sample is updated and, hence, the sample mean changes over time (as the annual updates are undertaken). This is a necessary trade–off for the multilateral indexes to satisfy the technical property of transitivity which allow more accurate comparisons over time when we have erratically moving outputs. We intend to monitor the extent of these changes as the economic benchmarking database is updated each year.

Information on the impact of these four methodology changes is provided in appendix D where we present industry level productivity index and panel data multilateral MTFP and opex MPFP results for 2006 to 2019 using:

- the methodology used in Economic Insights (2019)
- the Economic Insights (2019) methodology with the revised output weights
- the Economic Insights (2019) methodology with the revised treatment of the reliability output (the updated VCR estimates and the change to the cap applied to the reliability output), and
- for the industry level productivity indexes, the Economic Insights (2019) methodology with the revised index number method.

1.2 TNSP comments on draft report

In line with previous practice, the AER made the draft version of this report available to the five included TNSPs for comment. Feedback was received from three TNSPs.

ANT noted that the correction to the output weights had a material impact on benchmarking results demonstrating a sensitivity to model specification. As a result, ANT noted that ‘benchmarking is effective at providing insights into the productivity of individual TNSPs and the industry as a whole over time, but is not suitable to compare the productivity of TNSPs relative to their peers’.

We have always been cautious about using the TNSP economic benchmarking results to compare productivity levels across TNSPs given the difficulty of specifying the outputs of

[2] In earlier reports the alternative terminology of multilateral translog index has been used. Our previous TNSP reports have used the Fisher index method for time–series analysis.

TNSPs in a productivity measurement context and the lack of precedent to go on. For example, Economic Insights (2014, p2) 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, … we … 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.'

At the same time, it is important to progress TNSP productivity and efficiency measurement and the workstream initiated by the AER in 2013 has led to ongoing development and refinement of TNSP economic benchmarking. The changes introduced in this report represent more steps along this path.

ANT also requested more information on why it was thought the circuit length output should be viewed as the primary TNSP output as it expected 'customers to value other factors highly (such as reliability, energy throughput and the ability to meet peak demand), and be less focussed on the length of the circuit required to deliver energy'.

In considering this issue, it is important to recognise that output weights in the MTFP/MPFP framework are based on shares of total cost. To assess the likely distribution of total costs across outputs, it is useful to examine the shares of the main input components in total cost. For the industry as a whole, on average over the 14 years opex made up around 30 per cent of total costs, lines and cables inputs made up around 30 per cent and transformer and other capital inputs made up around 40 per cent. We would expect the lines and cables input costs to mainly be associated with the circuit length output although some would also be associated with RMD. It is important to note that RMD is included as an output to capture system capacity that was installed to meet previous peak demands even though it may now be underutilised given the tendency for RMD to have fallen, or at least to have not reattained its previous peaks over time. This ensures the TNSP still gets credit for that output despite the assets now being underutilised.

We would expect the transformer and other capital input costs to be spread across the circuit length, RMD and end–user numbers outputs. More transformers will generally be required with more line length and capacity and higher RMD will require greater transformer capacity. Similarly, we would expect some transformer costs to be from now underutilised capacity given falls in peak demand over time and so would also be associated with the RMD output. Some transformer costs would also be associated with having more end–users as this output is primarily included as a proxy for the complexity required in the transmission system. And, of course, a portion of both transformer and line and cable input costs would be associated with TNSP throughput.

In the case of TNSPs, opex can be expected to be mainly associated with the circuit length, RMD and throughput outputs and, to a lesser extent, with the end–user numbers output. Preventative line and cable maintenance tasks will be associated with circuit length, RMD and throughput outputs and transformer maintenance will be associated with line length and RMD and end–user numbers (where the latter is a proxy for system complexity).

Based on these expectations of how the key input costs can be expected to be attributed to the main functional output components, we would expect total costs to be more closely associated with circuit length, RMD and throughput given the importance of long–lived fixed assets in the transmission industry. End–user numbers will play a lesser role as a proxy for system complexity. The total cost output weights produced by the corrected Leontief input demand function models thus appear reasonable as they recognise the importance of fixed costs in transmission industry total costs.

In its comments, PLK noted that the reduction in the cap on the reliability output's weight to 2.5 per cent of total revenue is designed to align more closely with TNSP STPIS–related revenue at risk. However, PLK noted that 'only the Loss of Supply and Average Outage Duration parameters in the Service Component relate to ENS' and that the 'other parameters relate to element outage rates, which at the transmission level rarely result in loss of supply to customers'. It was of the view that if the intent is to align the reliability output weight to the relevant STPIS parameters, then only the Loss of Supply and Average Outage Duration parameters should be included which would lead to the cap being 1 per cent of total revenue rather than the 2.5 per cent currently used.

We note the distinction between STPIS parameters made by PLK but think that it is appropriate to retain the 2.5 per cent cap as this ensures that we are taking into account all of the different aspects of reliability incorporated into the STPIS. While some of the caps may not be triggered that often, we believe it is best to start with an alignment with the STPIS that takes a broad a view of reliability and performance of the network. However, we will review this and, if necessary, refine as relevant in future reports.

In its comments, TNT welcomed 'the greater weighting given to circuit length and ratcheted maximum demand as TNSP output measures, as well as the reduced weighting placed on energy throughput and end–user customer numbers'. TNT agreed with the assessment that 'end–user customer numbers and energy throughput are only of secondary importance in comparison with other factors as drivers of cost for TNSPs, ratcheted maximum demand in particular'.

TNT also supported 'the use of the AER's recently compiled Value of Customer Reliability and the linking of the cap on the weighting given to the reliability output to the relevant Service Target Performance Incentive Scheme parameters'. TNT also welcomed 'the generally smoother results presented by the 2020 benchmarking calculations, which Economic Insights attribute to the changes in benchmarking methodology introduced this year' and thought these 'represent a step forward in this regard'.

1.3 Specification used for productivity measurement

The TNSP MTFP and TFP measures reported here generally include five outputs:

- Energy throughput (with 14.9 per cent share of gross revenue)
- Ratcheted maximum demand (with 24.7 per cent share of gross revenue)

- End–user numbers (with 7.6 per cent share of gross revenue)
- Circuit length (with 52.8 per cent share of gross revenue), and
- (minus) Energy not supplied (with the weight based on current AER VCRs capped at a maximum absolute value of 2.5 per cent of total revenue).

The TNSP MTFP and TFP measures include four inputs:

- Opex (total opex deflated by a composite labour, materials and services price index), making up 27 per cent of total costs on average
- Overhead lines (quantity proxied by overhead MVAkms), making up 29 per cent of total costs on average
- Underground cables (quantity proxied by underground MVAkms), making up just 2 per cent of total costs on average, and
- Transformers and other capital (quantity proxied by transformer MVA), making up 42 per cent of total costs on average.

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.

The 2016 and 2017 years showed increased volatility in TNSP reliability relative to earlier periods. Although this volatility was around already high levels of reliability (and, hence, low levels of energy not supplied), it had a material impact on measured productivity growth rates in some instances. As a result, in Economic Insights (2018) we presented separate output and TFP indexes that included and excluded the reliability output for information. The multilateral productivity and the contributions to TFP growth analyses all included the reliability output. We again present output and TFP indexes both including and excluding the reliability output for information.[3]

Growth rates in productivity indexes can be reported using either logarithmic or trend measures. Logarithmic measures track the series from endpoint to endpoint exactly. Trend measures are based on a linear regression line of best fit that may not coincide with the endpoints, particularly if they are outliers. In keeping with previous practice, all growth rates reported in the body of this report are logarithmic measures. However, we also now include tables of trend growth rates in appendix C.

[3] If it is not explicitly stated that the output measure excludes reliability, the measure reported includes the reliability output.

2 INDUSTRY–LEVEL TRANSMISSION PRODUCTIVITY RESULTS

Transmission industry–level total output, total input and TFP indexes are presented in figure 2.1 and table 2.1. Opex and capital partial productivity indexes are also presented in table 2.1.

Figure 2.1 **Industry–level transmission output, input and total factor productivity indexes, 2006–2019**

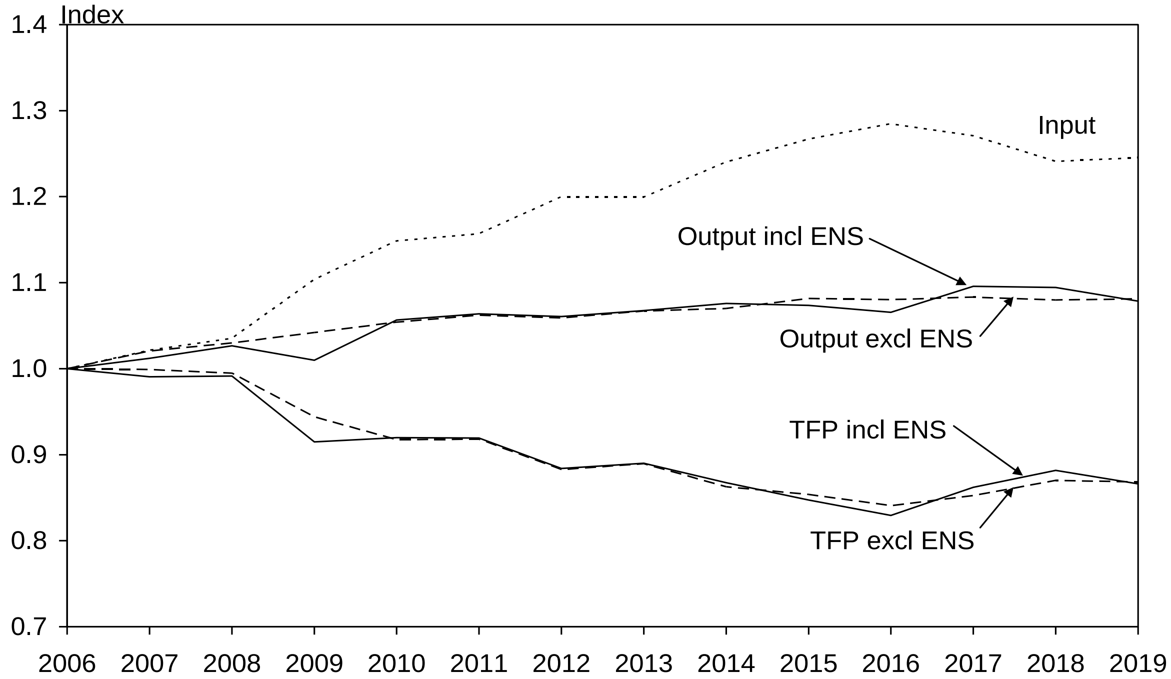


Table 2.1 **Industry–level transmission output, input and total factor productivity and partial productivity indexes, 2006–2019**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index Opex*	*PFP Index Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.012	1.022	0.991	1.010	0.983
2008	1.027	1.035	0.991	1.030	0.977
2009	1.010	1.104	0.915	0.989	0.885
2010	1.057	1.149	0.920	0.987	0.893
2011	1.064	1.157	0.919	1.045	0.874
2012	1.061	1.200	0.884	1.012	0.839
2013	1.068	1.199	0.890	1.060	0.832
2014	1.076	1.240	0.867	0.987	0.824
2015	1.074	1.267	0.847	0.975	0.802
2016	1.065	1.285	0.829	0.952	0.786
2017	1.096	1.271	0.862	0.987	0.817
2018	1.094	1.241	0.882	1.119	0.805
2019	1.079	1.245	0.866	1.091	0.793
Growth Rate 2006–19	0.58%	1.69%	–1.11%	0.67%	–1.78%
Growth Rate 2006–12	0.98%	3.04%	–2.06%	0.20%	–2.93%
Growth Rate 2012–19	0.24%	0.53%	–0.29%	1.07%	–0.79%

Over the 14–year period 2006 to 2019, industry level TFP declined with an average annual rate of change of –1.1 per cent. Although total output increased by an average annual rate of 0.6 per cent, total input use increased faster, at a rate of 1.7 per cent. Since the average rate of change in TFP is the average rate of change in total output less the average rate of change in total inputs, this produced a negative average rate of productivity change. TFP change was, however, positive in five years – 2008, 2010, 2013, 2017 and 2018. In the first and third of these years, the rate of input use increase moderated to be at a lower rate than output increase, while in 2010 output increased following a downturn in 2009 due to poor reliability performance that year. Similarly, output increased markedly in 2017 following relatively poor reliability performance in 2016. In 2018 a large reduction in input use more than offset a reduction in output resulting from reduced throughput. In figure 2.1 we present output and TFP indexes both including and excluding the reliability output. It can be seen that worse than average reliability depressed both output and TFP in 2016 while a return to better than average reliability in 2017 boosted both output and TFP. Reliability further improved in 2018 but worsened somewhat in 2019.

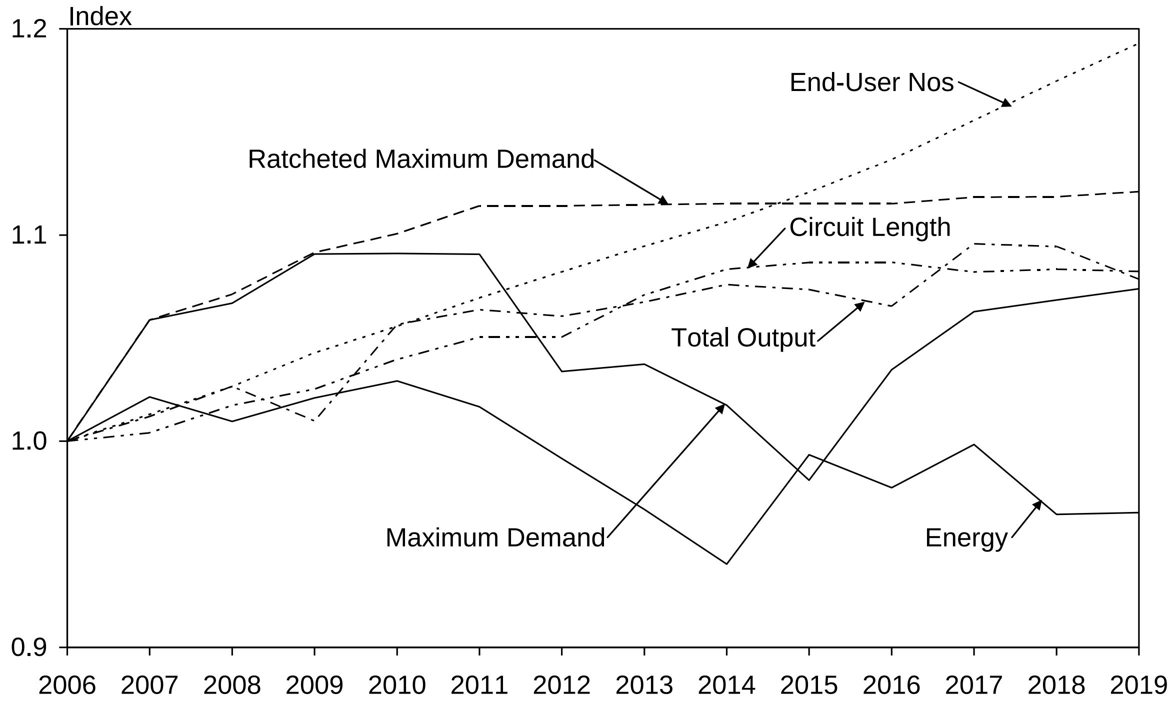
2.1 Transmission industry output and input quantity changes

To gain a more detailed understanding of what is driving these TFP changes, we need to look at the pattern of quantity change in our five transmission output components and our four transmission input components. We also need to consider the weight placed on each of these components in forming the total output and total input indexes. Later we will present results that show the contributions of each output and each input to TFP change taking account of the change in each component's quantity over time and its weight in forming the TFP index. First, however, we will look at the quantity indexes for individual outputs in figure 2.2 and for individual inputs in figure 2.3. In each case the quantities are converted to index format with a value of one in 2006 for ease of comparison.

From figure 2.2 we see that the output component that receives the largest weight in forming the TFP index, circuit length, increased steadily up to 2014 before levelling off. It was 8 per cent higher in 2019 than it was in 2006. The relatively modest growth in the circuit length output reflects the fact that most of the increase in end–use customer numbers over the period has been able to be accommodated by 'in fill' off the existing DNSP networks that does not require large extensions of the transmission network length. That is, the bulk of population growth is occurring on the fringes of cities and towns and as cities move from being low density to medium to high density and so the required increases in transmission network length between existing generation and load centres are modest compared to the increase in customer numbers being serviced. However, the growth in transmission network length between 2006 and 2019 has still been higher than the growth in distribution network length over the period which was only 4 per cent.

The output that increased the most over the period is end–user numbers with an increase of 19 per cent between 2006 and 2019. This steady increase is to be expected as the number of electricity end–use customers will increase roughly in line with growth in the population. However, we see that energy throughput for transmission peaked in 2010 and fell steadily through to 2014 before a partial recovery and then another marked fall in 2018. In 2019 transmission energy throughput was 3 per cent less than it was in 2006.

Figure 2.2 **Industry–level transmission output quantity indexes, 2006–2019**



Maximum demand has followed a broadly analogous pattern to energy throughput although it increased more rapidly between 2006 and 2009 before levelling off and then falling markedly in 2012 and again in 2014 and 2015. This fall in maximum demand and energy throughput since around 2010 partly reflects economic conditions being more subdued since the 'global financial crisis' but, more importantly, the increasing impact of energy conservation initiatives, more energy efficient buildings and appliances and greater penetration of local distributed generation. Transmission networks, thus, have to service a steadily increasing number of end–use customers at a time of falling throughput and lower demand. In recognition of this, we include ratcheted maximum demand as our output measure rather than maximum demand so that TNSPs get credit for having had to provide capacity to service the earlier higher maximum demands than are now observed.

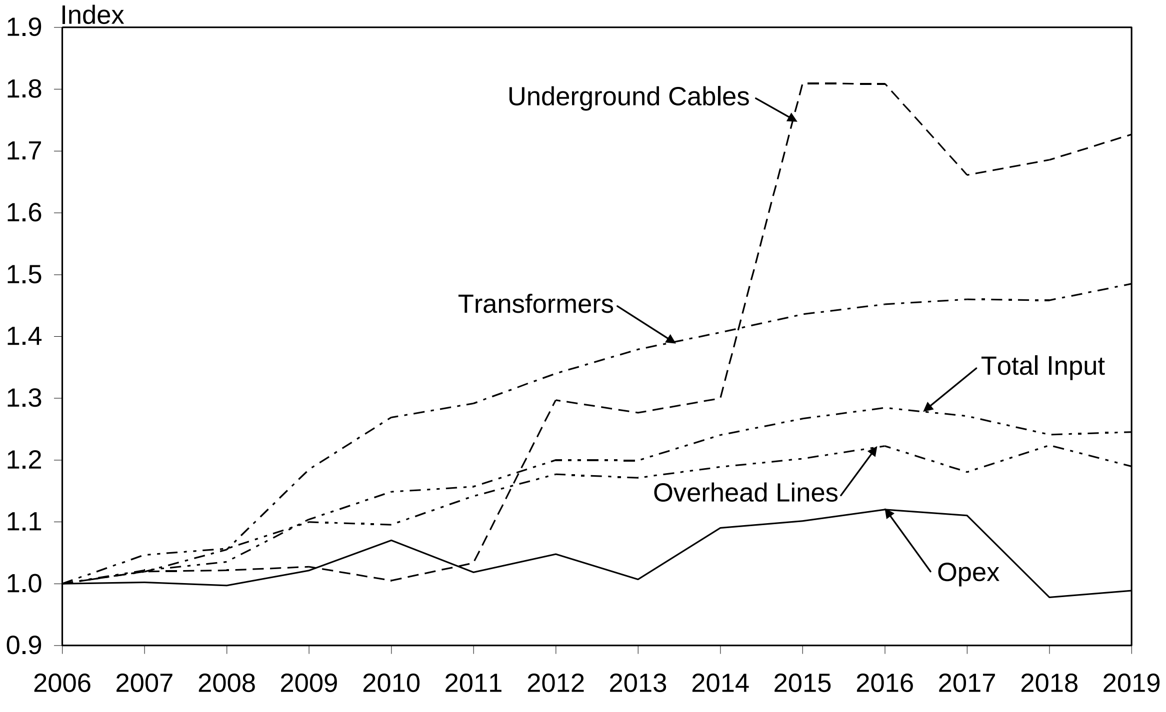
Ratcheted maximum demand increased at a similar rate to maximum demand up to 2009, increased at a slower rate in 2010 and has been relatively flat since 2011. We do observe some small increases in this output since 2009 as it is the sum of ratcheted maximum demands across the five TNSPs and maximum demand for some TNSPs increased above earlier peaks in some years even though aggregate maximum demand is still below its 2010 peak. In 2019 overall ratcheted maximum demand was 12 per cent above its 2006 level.

The last output is total energy not supplied (ENS) because of TNSP limitations. This enters the total output index as a negative output since a reduction in ENS represents an improvement and a higher level of service for end–use customers. Conversely, an increase in ENS reduces total output as end–use customers are inconvenienced more by not having supply over a wider area and/or for a longer period. ENS is not shown in figure 2.2 as the upwards spike in 2009 associated with a transformer failure at ANT's South Morang

Terminal Station cannot be included using a scale which adequately shows movements in the other outputs. With the exception of this event, ENS generally trended downwards to 2014 and, hence, contributed more to total output than was the case in 2006, holding all else constant. However, ENS again increased in 2015 and 2016 to be 180 per cent higher than it was in 2006. It fell sharply in 2017 and fell some more in 2018 before increasing in 2019. In 2019 ENS was 32 per cent above the level it had been in 2006. This needs to be viewed from the perspective that transmission outage rates are usually very low so they can appear to be very volatile in years where unusual events happen.

Since the circuit length, RMD and energy throughput outputs receive a combined weight of around 94 per cent of total revenue in forming the total output index, in figure 2.2 we see that the total output index tends to lie close to the circuit length output index and be bounded by the RMD and energy throughput indexes. Total output movements are also influenced by the pattern of movement in the ENS output (noting that an increase in ENS has a negative impact on total output and is given a weight of around 1.3 per cent of total revenue on average), particularly in 2009 and again in 2015, 2016 and 2019. However, the impact of these ENS events on total output is limited by capping of this output's weight (in absolute terms) at 2.5 per cent of total revenue.

Figure 2.3 **Industry–level transmission input quantity indexes, 2006–2019**



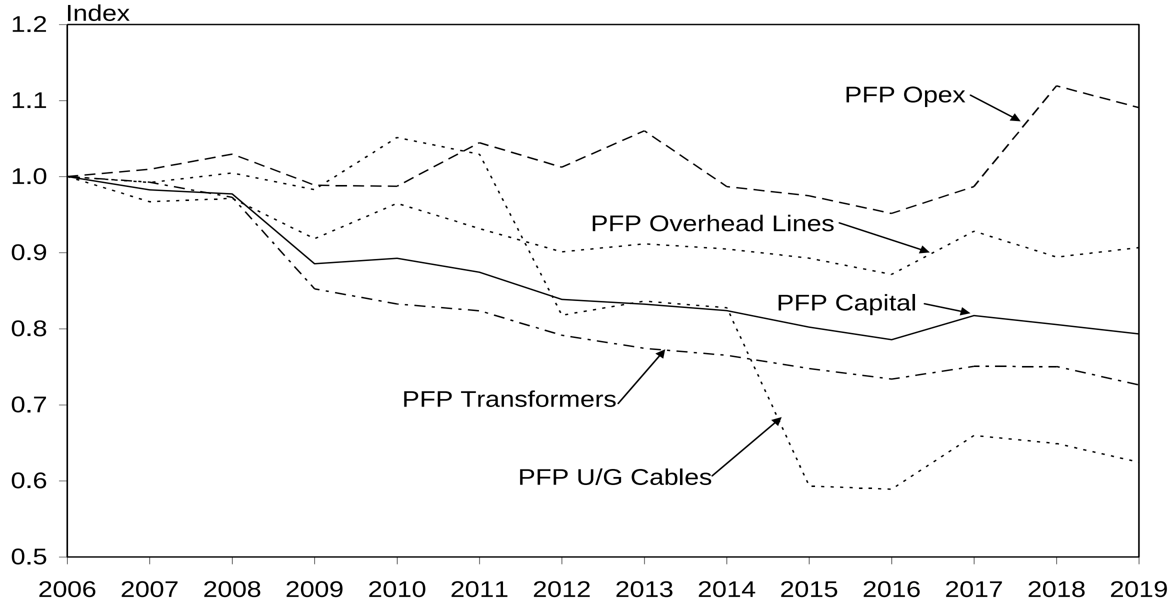
Turning to the input side, we present quantity indexes for the four input components and total input in figure 2.3. The quantity of opex (ie opex in constant 2006 prices) increased the least of the four inputs over the 14–year period and, after falling markedly in 2018, was 1 per cent lower in 2019 than in 2006. Opex usage increased by 7 per cent between 2006 and 2010 before falling back to close to its 2006 level in 2013 and then increasing again through to 2016 and falling by 12 per cent in 2018. Opex has the third largest average share in total costs at 27 per cent.

The input component with the largest average share of total cost, at 42 per cent, is transformers. The quantity of transformer input has increased steadily over the period and by 2019 was 49 per cent above its 2006 level. Given its large share of total costs, transformer inputs is an important driver of the total input quantity index.

The next key component of TNSP input is the quantity of overhead lines. This input quantity increased the second least over the period, being 19 per cent higher in 2019 than it was in 2006. It should be noted that overhead line input quantities take account of both the length of lines and the overall 'carrying capacity' of the lines. The fact that the overhead lines input quantity has increased substantially more than network length reflects the fact that the average capacity of overhead lines has increased over the period as new lines and replacement of old lines are both of higher carrying capacity than older lines. Overhead lines account for around 29 per cent of total TNSP costs on average.

The fastest growing input quantity is that of underground cables whose quantity was 73 per cent higher in 2019 than it was in 2006. However, this growth starts from a quite small base and so a higher growth rate is to be expected. Most of the increase in transmission underground cables input quantity has occurred since 2011. The scope to put significant parts of the transmission network underground is considerably less than it is for distribution and the cost relativity greater. As a result, the starting underground cable length for transmission is very small which leads to a higher growth rate relative to distribution. The lesser role played by underground cables in transmission is reflected in them having an average share of total costs of only 2 per cent, compared to a share in total costs of 14 per cent for distribution.

Figure 2.4 **Industry–level transmission partial productivity indexes, 2006–2019**



From figure 2.3 we see that the total input quantity index lies between the quantity indexes for transformers and overhead lines (which have a combined weight of 71 per cent of total costs). The faster growing underground transmission cables quantity index lies above this group of quantity indexes in later years which in turn lie above the slower growing opex quantity index.

From figure 2.4 we see that movements in transmission industry–level partial productivity indexes follow an essentially inverse pattern to input quantities (since a partial productivity index is total output quantity divided by the relevant input quantity index). The opex partial productivity index is consequently the highest over the period, although the level of underground cables partial productivity was temporarily higher in 2010, before declining sharply from 2011 as the increase in underground cables gathered pace. Underground transmission cables partial productivity declines the most over the period, being 38 per cent lower in 2019 than in 2006. As noted above, this is because underground transmission cables have increased rapidly from a small base. The partial productivity indexes of the other two inputs – transformers and overhead lines – decline over the period which means the quantities of those inputs have increased faster than total output. Transformer partial productivity has declined by the next largest amount, being 27 per cent lower in 2019 than in 2006. Opex partial productivity declined the least. In 2013 opex partial productivity was 6 per cent above its 2006 level but by 2016 it had fallen to be 5 per cent below its 2006 level before recovering to be 9 per cent higher in 2019 than it was in 2006.

2.2 Transmission industry output and input contributions to TFP change

Having reviewed movements in individual output and input components in the preceding section, we now examine the contribution of each output and each input component to annual TFP change. Or, to put it another way, we want to decompose TFP change into its constituent parts. Since TFP change is the change in total output quantity less the change in total input quantity, the contribution of an individual output (input) will depend on the change in the output's (input's) quantity and the weight it receives in forming the total output (total input) quantity index. However, this calculation has to be done in a way that is consistent with the index methodology to provide a decomposition that is consistent and robust. In appendix A we present the methodology that allows us to decompose productivity change into the contributions of changes in each output and each input.

In figure 2.5 and table 2.2 we present the percentage point contributions of each output and each input to the average annual rate of TFP change of –1.1 per cent over the 14–year period 2006 to 2019. In figure 2.5 the red bars represent the percentage point contribution of each of the outputs and inputs to average annual TFP change which is given in the yellow bar at the far right of the graph. The contributions appear from most positive on the left to most negative on the right. If all the positive and negative contributions (red bars) in figure 2.5 are added together, the sum will equal the yellow bar of TFP change at the far right.

In figure 2.5 we see that growth in circuit length provided the highest positive contribution to TFP change over the 14–year period. Circuit length increased at an average annual rate of 0.6 per cent – less than the rates for end–user numbers and RMD – but it receives a weight of around 54 per cent in total output so it makes a contribution to TFP change of just over 0.3 percentage points.

The second highest contribution to TFP change comes from growth in ratcheted maximum demand. Despite flattening out after 2011, RMD had the second highest average annual output growth rate over the period of 0.9 per cent. Combined with its weight of around 25 per cent, this led to RMD contributing 0.2 percentage points to TFP change over the period.

Figure 2.5 **Transmission industry output and input percentage point contributions to average annual TFP change, 2006–2019**

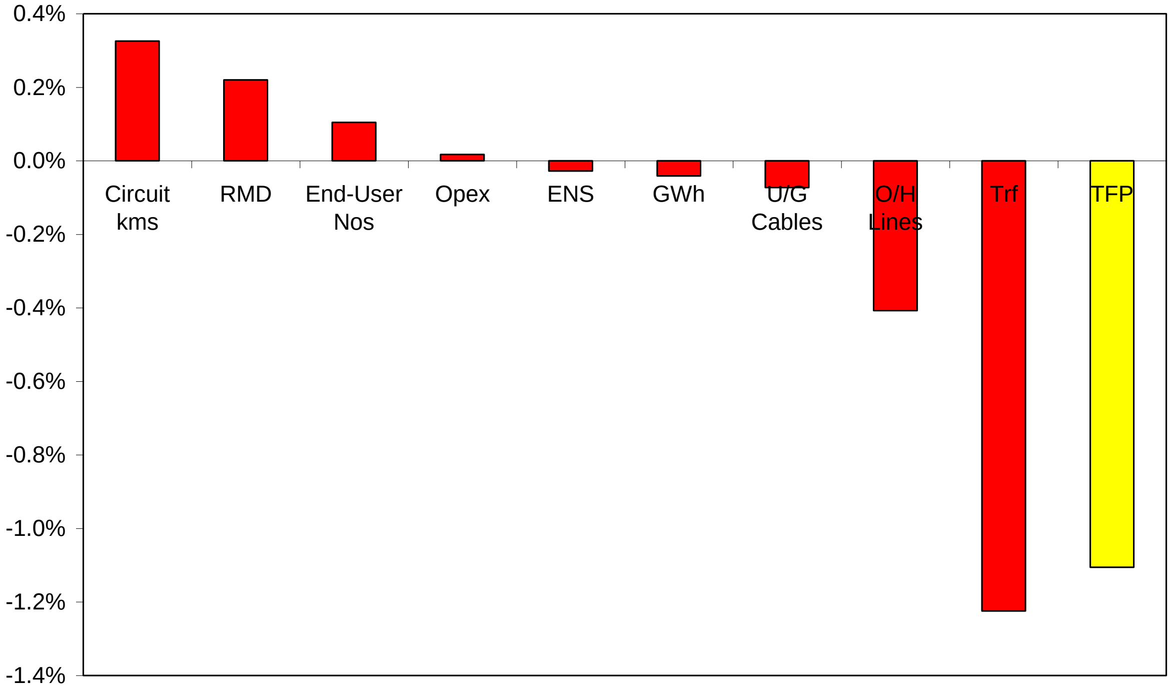


Table 2.2 **Transmission industry output and input percentage point contributions to average annual TFP change: 2006–2019, 2006–2012, 2012–2019 and 2018–19**

Year	*2006 to 2019*	*2006 to 2012*	*2012 to 2019*	*2018–19*
Energy (GWh)	–0.04%	–0.02%	–0.06%	0.01%
Ratcheted Max Demand	0.22%	0.45%	0.02%	0.06%
Customer Numbers	0.10%	0.10%	0.11%	0.12%
Circuit Length	0.33%	0.44%	0.23%	–0.05%
ENS	–0.03%	0.01%	–0.06%	–1.60%
Opex	0.02%	–0.22%	0.22%	–0.29%
O/H Lines	–0.41%	–0.85%	–0.03%	0.79%
U/G Cables	–0.07%	–0.08%	–0.07%	–0.03%
Transformers	–1.22%	–1.89%	–0.65%	–0.80%
TFP Change	–1.11%	–2.06%	–0.29%	–1.79%

End–user numbers have grown steadily by 1.4 per cent annually over the whole period as end–user numbers generally increase in line with population growth. But as end–user numbers receive a weight of only 8 per cent despite having the highest growth rate of the output components, they contribute just 0.1 percentage points to TFP change over the period.

Since energy throughput ended the 14–year period at a somewhat lower level than it started the period, it made a marginally negative contribution to average TFP change.

The ENS output receives an average weight of only minus 1.3 per cent in the total output index but, combined with an average annual change of 2.2 per cent, also made a marginal negative contribution to average annual TFP change (ie the decrease in ENS increases output).

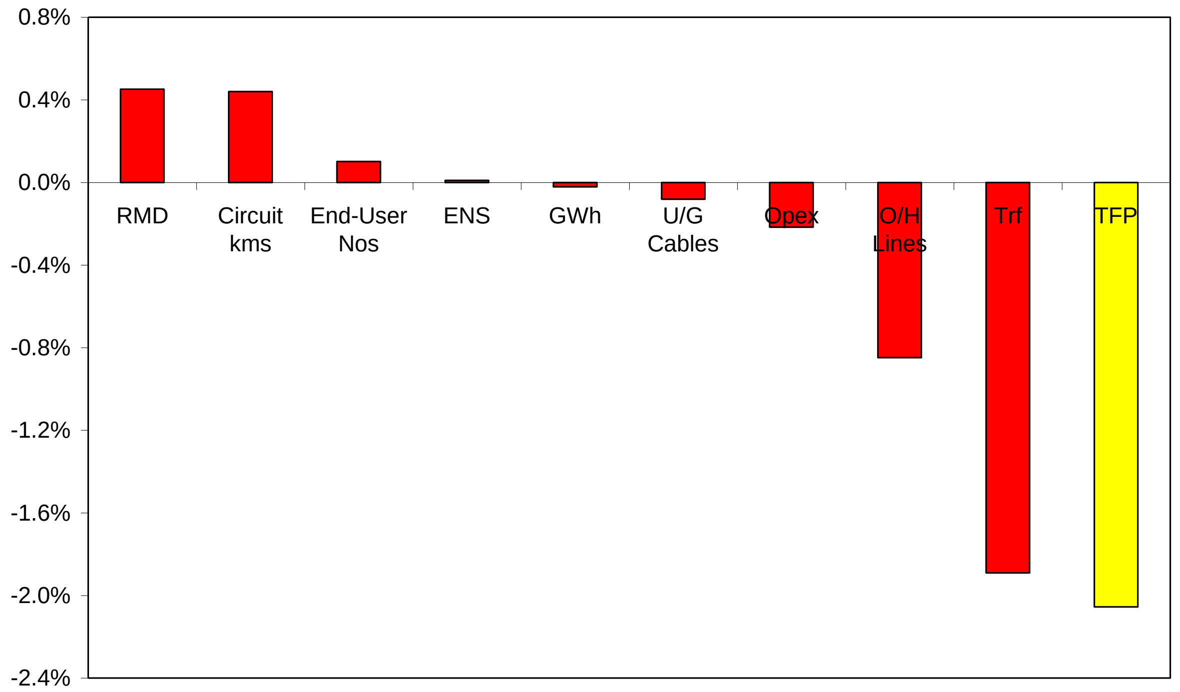
Three of the four inputs made negative contributions to average annual TFP change. That is, the use of these three inputs increased over the 14–year period. The two inputs with the largest shares in the total input index are transformers and overhead lines with shares of 42 per cent and 29 per cent, respectively. Since transformers have the second highest input average annual growth rate at 3 per cent, they make the largest negative contribution to TFP change at –1.2 percentage points.

Overhead lines has a lower average annual growth rate at 1.3 per cent and, when combined with its 29 per cent share of total inputs, it makes the second most negative contribution to TFP change at –0.4 percentage points.

Despite having the highest input average annual growth rate of 4.4 per cent, underground subtransmission cables only have a weight of 2 per cent in total inputs and so make a small negative contribution to TFP change at –0.1 percentage points.

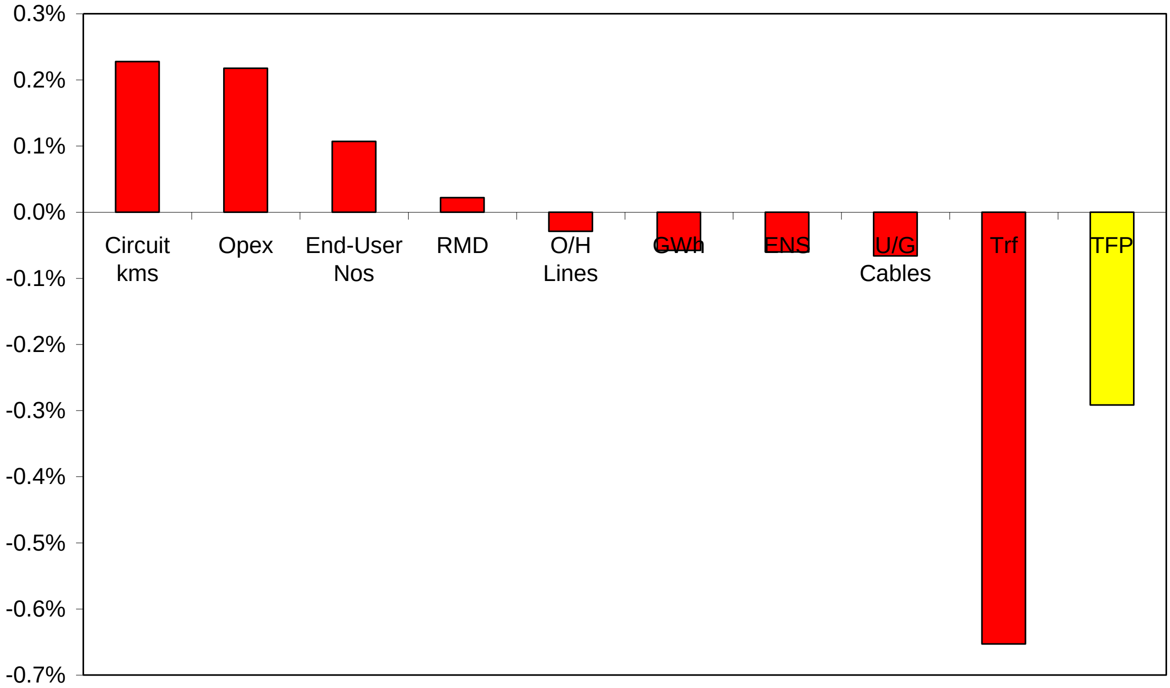
Opex was the only input to reduce over the period and so has the lowest average annual input growth rate of –0.1 per cent. Combined with its weight in total input of 27 per cent, it made a marginally positive contribution to TFP change over the 14–year period.

Figure 2.6 **Transmission industry output and input percentage point contributions to average annual TFP change, 2006–2012**



We next look at contributions to average annual TFP change for the period up to 2012 and then for the period after 2012. The results for the period from 2006 to 2012 are presented in figure 2.6 and table 2.2. Average annual TFP change for this period was somewhat more negative at –2.1 per cent. From figure 2.6 we can see a similar pattern of contributions to TFP change for most outputs and inputs for the period up to 2012 as for the whole period with two minor exceptions. The contributions from the transformers and overhead lines were both somewhat more negative in the period up to 2012 at –1.9 percentage points and –0.9 percentage points, respectively. And, the contribution of opex was negative for the first half of the period compared to marginally positive for the whole period.

Figure 2.7 **Transmission industry output and input percentage point contributions to average annual TFP change, 2012–2019**



Contributions to average annual TFP change for the period from 2012 to 2019 are presented in figure 2.7 and table 2.2. Average annual TFP change improves for this period but is still negative at –0.3 per cent. The most significant changes relative to the earlier period are the contribution of opex to TFP change which has changed from being negative up to 2012 to being positive contributors after 2012 and the reduction in the negative contributions of transformers and overhead lines. Opex has changed from making a contribution of –0.2 percentage points before 2012 to making a contribution of 0.2 percentage points after 2012, driven largely by the sizable fall in opex in 2018.

For the period since 2012, ENS has contributed –0.1 percentage points to TFP change compared to a marginal positive one before 2012. As noted above, ENS increased significantly in 2015 and 2016 but then fell sharply in 2017 and fell again in 2018 before increasing again in 2019. At the same time, the contribution of the RMD output falls from 0.5 percentage points to near zero as maximum demand mainly stays below its peak levels prior to 2012. This leads to RMD being virtually unchanged from 2012 onwards.

Offsetting the less positive contribution from RMD are less negative contributions from transformers and overhead lines inputs. The contribution of transformer inputs improves by 1.2 percentage points to –0.7 while the contribution of overhead lines improves by 0.8 percentage points to be only marginally negative. The rate of increase in these two inputs reduces after 2012 compared to the period before 2012.

In tables 2.3 and 2.4, respectively, we present the annual changes in each output and each input component and their percentage point contributions to annual TFP change for each of the years 2007 to 2019.

Table 2.3 Transmission industry output and input annual changes, 2006–2019

Year	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*
Energy	2.13%	–1.17%	1.12%	0.80%	–1.22%	–2.49%	–2.52%
RMD	5.72%	1.17%	1.87%	0.83%	1.21%	0.00%	0.05%
CustomerNo	1.30%	1.32%	1.57%	1.24%	1.30%	1.17%	1.15%
Cct Length	0.40%	1.32%	0.78%	1.39%	1.03%	0.00%	1.93%
ENS	55.43%	–28.54%	162.04%	–202.04%	5.50%	1.84%	7.40%
Opex	0.23%	–0.52%	2.40%	4.67%	–4.95%	2.85%	–3.97%
O/H Lines	4.55%	0.96%	3.98%	–0.41%	4.16%	3.05%	–0.50%
U/G Cabl	1.96%	0.18%	0.56%	–2.21%	2.79%	22.73%	–1.60%
Transformer	1.93%	3.44%	11.56%	6.89%	1.75%	3.69%	2.86%

Year	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
Energy	–2.79%	5.49%	–1.62%	2.12%	–3.45%	0.08%
RMD	0.04%	0.00%	0.00%	0.29%	0.02%	0.22%
CustomerNo	1.06%	1.30%	1.40%	1.66%	1.63%	1.55%
Cct Length	1.16%	0.30%	0.01%	–0.43%	0.13%	–0.10%
ENS	–44.3%	102.37%	44.76%	–222.29%	–28.28%	174.05%
Opex	7.93%	1.02%	1.66%	–0.85%	–12.70%	1.13%
O/H Lines	1.51%	1.12%	1.68%	–3.50%	3.61%	–2.85%
U/G Cabl	1.83%	33.05%	–0.01%	–8.52%	1.46%	2.43%
Transformer	1.97%	2.08%	1.11%	0.56%	–0.12%	1.83%

Table 2.4 Transmission industry output and input percentage point contributions to annual TFP change, 2006–2019

Year	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*
Energy	0.32%	–0.18%	0.17%	0.12%	–0.19%	–0.38%	–0.38%
RMD	1.43%	0.30%	0.47%	0.21%	0.30%	0.00%	0.01%
CustomerNo	0.10%	0.10%	0.12%	0.10%	0.10%	0.09%	0.09%
Cct Length	0.21%	0.71%	0.41%	0.75%	0.55%	0.00%	1.03%
ENS	–0.87%	0.49%	–2.81%	3.36%	–0.10%	–0.01%	–0.11%
Opex	–0.07%	0.18%	–0.74%	–1.24%	1.30%	–0.72%	1.02%
O/H Lines	–1.48%	–0.46%	–1.10%	0.11%	–1.23%	–0.93%	0.17%
U/G Cabl	–0.02%	–0.04%	–0.01%	0.02%	–0.04%	–0.39%	0.03%
Transformer	–0.55%	–1.03%	–4.55%	–2.88%	–0.74%	–1.60%	–1.18%

Table 2.4 **Transmission industry output and input percentage point contributions to annual TFP change, 2006–2019 (cont'd)**

Year	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
Energy	–0.42%	0.83%	–0.24%	0.32%	–0.52%	0.01%
RMD	0.01%	0.00%	0.00%	0.07%	0.00%	0.06%
CustomerNo	0.08%	0.10%	0.11%	0.13%	0.12%	0.12%
Cct Length	0.62%	0.16%	0.00%	–0.24%	0.07%	–0.05%
ENS	0.50%	–1.32%	–0.62%	2.53%	0.20%	–1.60%
Opex	–2.17%	–0.14%	–0.51%	0.22%	3.39%	–0.29%
O/H Lines	–0.39%	–0.36%	–0.42%	1.01%	–1.00%	0.79%
U/G Cabl	–0.03%	–0.57%	0.03%	0.15%	–0.03%	–0.03%
Transformer	–0.78%	–1.04%	–0.48%	–0.30%	0.01%	–0.80%

Taking 2019 as an example, ENS output makes a large negative contribution –1.6 percentage points as ENS increased markedly in that year. Overhead line inputs are the only input making a positive contribution in 2019 which largely offset a negative contribution in 2018. The transformers input also made a sizable negative contribution at –0.8 percentage points as their capacity increased by 1.8 per cent in 2019. Combining the output and input contributions leads to TFP change in 2019 of –1.8 per cent.

3 TNSP MULTILATERAL PRODUCTIVITY RESULTS

In this section we present updated TNSP MTFP and MPFP results. As outlined in appendix A, MTFP and MPFP indexes allow comparisons of productivity levels as well as productivity growth to be made. For convenience, index results are presented relative to ENT in 2006 having a value of one. The results are invariant to which observation is used as the base.

Figure 3.1 **TNSP multilateral total factor productivity indexes, 2006–2019**

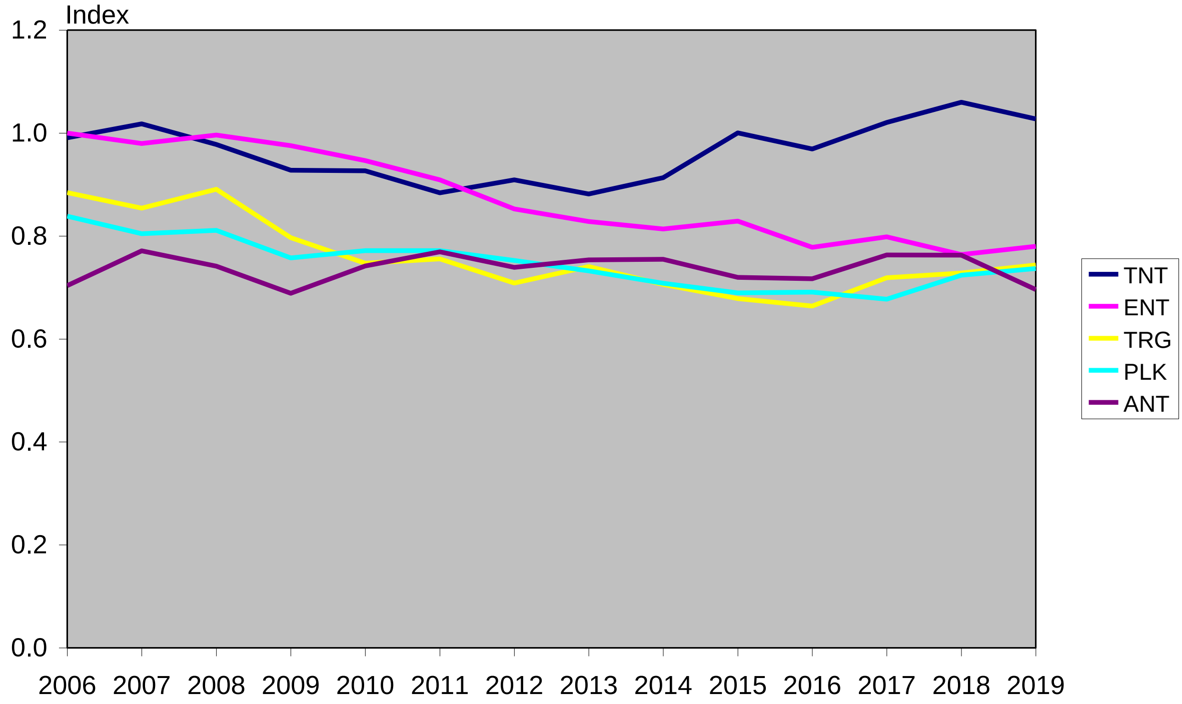


Table 3.1 **TNSP multilateral total factor productivity indexes, 2006–2019**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
ENT	1.000	0.980	0.996	0.976	0.946	0.909	0.853
PLK	0.839	0.805	0.811	0.758	0.772	0.772	0.753
ANT	0.704	0.771	0.741	0.689	0.742	0.769	0.739
TNT	0.991	1.018	0.978	0.928	0.927	0.884	0.909
TRG	0.884	0.854	0.891	0.797	0.747	0.756	0.709

Year	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
ENT	0.828	0.814	0.829	0.778	0.798	0.764	0.780
PLK	0.732	0.708	0.689	0.691	0.677	0.724	0.737
ANT	0.754	0.755	0.720	0.717	0.763	0.763	0.696
TNT	0.882	0.913	1.001	0.969	1.021	1.060	1.027
TRG	0.741	0.706	0.678	0.664	0.719	0.728	0.744

TNSP MTFP indexes are presented in figure 3.1 and table 3.1. In figure 3.1 TNSPs are ordered in the legend according to their 2019 MTFP scores and, with the exception of TNT, MTFP levels form a relatively tight band in the second half of the period. The MTFP levels of three TNSPs – ENT, TRG and PLK – trended down to around 2016 before levelling out or increasing somewhat while that of TNT generally trended down to around 2013 and has trended up since then. ANT's MTFP, on the other hand, has fluctuated over the 14–year period. The MTFP levels of three TNSPs – PLK, TRG and ENT – improved somewhat in 2019. PLK achieved a perfect reliability record in 2019, the first TNSP to do so in the sample period. ENT started the period having marginally the highest ranking in terms of MTFP levels and finished the period ranking second despite having an average rate of MTFP change of –1.9 per cent per annum. PLK's MTFP has had an average annual rate of change at –1.0 per cent, and it finished the period ranked a marginal fourth in terms of MTFP levels after its performance improved in 2018 and again in 2019. ANT, on the other hand, started the period with the lowest MTFP level, initially improved its performance before falling back in 2008 and 2009 due to increases in ENS and increases in input usage. Its MTFP subsequently improved and it had marginally the third highest ranking in 2018. However, its MTFP fell markedly in 2019 due to a sizable worsening in ENS although most of this was attributable to an outage affecting one large customer. It finished the period ranked last and had an average annual MTFP growth rate of –0.1 per cent. TNT's MTFP level generally ranked second up until 2011 but increased noticeably in 2014 and 2015 with the introduction of restructuring and reform initiatives. Despite a reduction in MTFP in 2019 due in part to an increase in opex, TNT ranked highest in MTFP levels again in 2019. After a trend decline up to 2016, TRG has increased its MTFP level each year since 2016 to rank third in 2019.

There are two main differences between the MTFP indexes presented above and those reported in Economic Insights (2017b, 2018, 2019) as a result of the revisions to the methodology introduced this year. The first difference to note is that the MTFP indexes reported here are generally smoother than those in the earlier reports and the second difference is that there have been some changes in relative TNSP MTFP levels.

Because we have revised the cap applied to the reliability output weight from 5.5 per cent of gross revenue to 2.5 per cent of total revenue, variations in the MTFP indexes from changes in reliability performance over time are now less pronounced. This can be seen, for example, in the MTFP indexes for ANT and ENT where the effects of the 2009 outage at the South Morang terminal station are now more muted for ANT and both indexes exhibit less pronounced fluctuations from 2016 onwards. The lower percentage value of the cap is now consistent with the range of rewards and penalties TNSPs face under the STPIS incentive regime. And the application of the cap to total revenue rather than gross revenue (which is total revenue plus the value of the reliability output) further reduces the impact of large outages on measured productivity since the cap is applied to a smaller base value in the year the outage occurs.

To understand the impact of the revised output cost weights on MTFP levels, it is useful to consider the relative output multilateral partial productivities. These are the quantity of a particular output divided by the total input quantity index. TNSPs that have a higher partial output productivity for a particular output will have a higher relative MTFP level if the revised weight for that output increases. Conversely, a TNSP's relative MTFP level will fall if the outputs where they have the highest partial output productivities now receive less weight than previously.

We present the average output multilateral partial productivities for the five TNSPs across the five outputs in table 3.2. These output partial productivities are again based so that ENT's 2006 output multilateral partial productivity is given a value of one. The relative results are indifferent to the observation chosen as the base value. The important thing to note in table 3.2 is that a higher value for a particular output means the TNSP is an 'intensive' producer of that output or produces relatively more of that output per unit of total input compared to other TNSPs. It will thus result in a higher relative MTFP if the weight on that output increases.

Table 3.2 **TNSP average output multilateral partial productivity indexes, 2006–2019**

Year	*Energy throughput*	*Ratcheted Max. Demand*	*End–user numbers*	*Circuit length*	*Energy Not Supplied*
ENT	0.808	0.954	0.948	0.872	2.524
PLK	0.948	0.837	0.722	0.668	1.294
ANT	1.299	1.060	1.470	0.495	5.336
TNT	1.286	1.036	0.541	0.969	3.604
TRG	1.189	1.116	1.067	0.531	0.888

From table 3.2 we can see that two of the large TNSPs, ANT and TRG, have among the highest output partial productivities for energy throughput, RMD and end–user numbers but the lowest output partial productivities for circuit length. The reallocation of weight between energy throughput and RMD will thus largely offset each other for these two TNSPs but the redistribution of weight from end–user numbers to circuit length will lead to them having lower MTFP levels, all else equal. Conversely, TNT has the second highest output partial productivity for energy throughput, the third highest for RMD and the lowest for end–user numbers, the latter by a wide margin. But, it has the highest output partial productivity for circuit length. So, it will be relatively unaffected by the redistribution of weight between energy throughput and RMD but the redistribution of weight from end–user numbers to circuit length will lead to it now having a relatively higher MTFP level, all else equal. ENT has among the lowest output partial productivities for energy throughput and RMD and mid–range output partial productivity for end–user numbers and circuit length. As a result, its MTFP level tends to be less affected by the revision to the output weights. Similarly, PLK has lower to mid–range output partial productivity levels for all the first four outputs in table 3.2 so its MTFP level also tends to be less affected by the revision to the output weights.

The role played by the ENS output now varies in several ways. Because the new AER VCRs are generally higher than the earlier AEMO VCRs, it will play more of a role when the cap on this output's weight is not binding. But, the cap is now considerably tighter than before and is binding on more observations. Noting that ENS enters MTFP as a negative output, those TNSPs with a lower output partial productivity in table 3.2 will have this output making a higher contribution to their MTFP level. Thus, on average, TRG and PLK have their MTFP levels increased by the inclusion of the ENS output while ANT and TNT have theirs lowered, all else equal.

Since the revised output weights affect only the construction of the total output index in the productivity calculations, the same explanations as outlined above will apply to changes in relative opex MPFP and capital MPFP levels between this report and the corresponding indexes reported in Economic Insights (2017b, 2018, 2019).

MTFP levels are an amalgam of opex MPFP and capital MPFP levels. Opex MPFP indexes are presented in figure 3.2 and table 3.3 while capital MPFP indexes are presented in figure 3.3 and table 3.4.

Figure 3.2 **TNSP multilateral opex partial productivity indexes, 2006–2019**

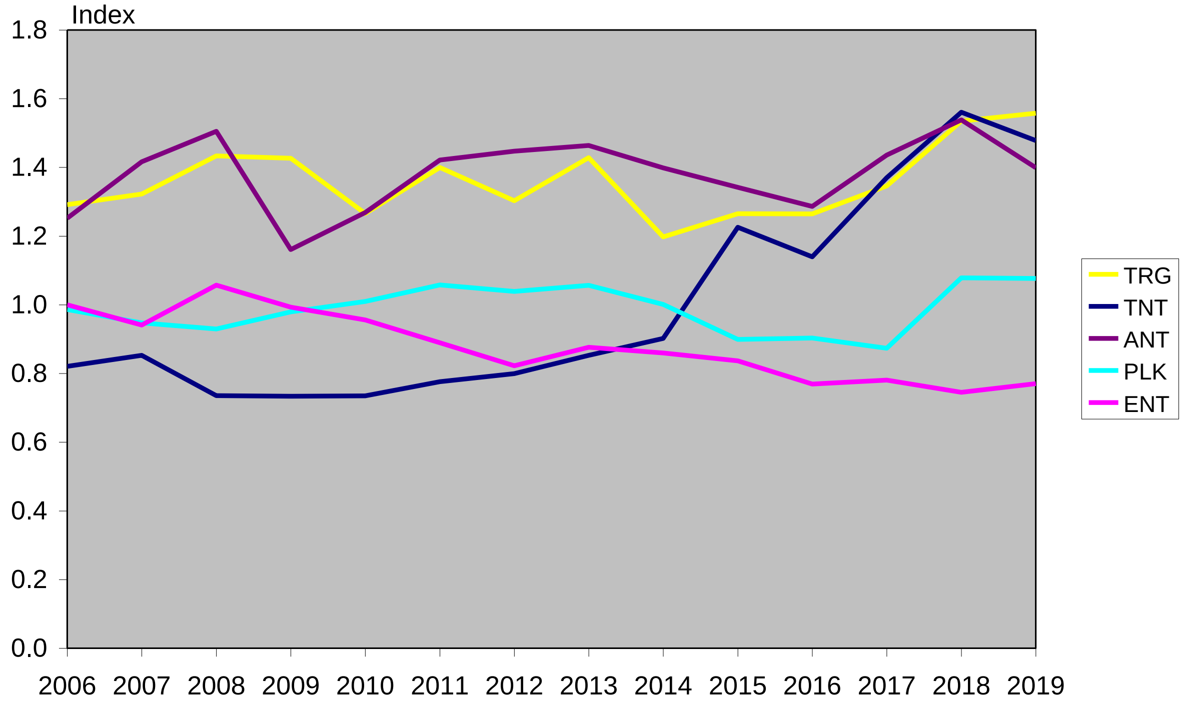


Table 3.3 **TNSP multilateral opex partial productivity indexes, 2006–2019**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
ENT	1.000	0.941	1.057	0.993	0.956	0.889	0.822
PLK	0.986	0.947	0.929	0.979	1.010	1.058	1.039
ANT	1.252	1.416	1.505	1.161	1.268	1.421	1.447
TNT	0.821	0.853	0.736	0.734	0.735	0.776	0.799
TRG	1.292	1.322	1.434	1.426	1.266	1.400	1.303

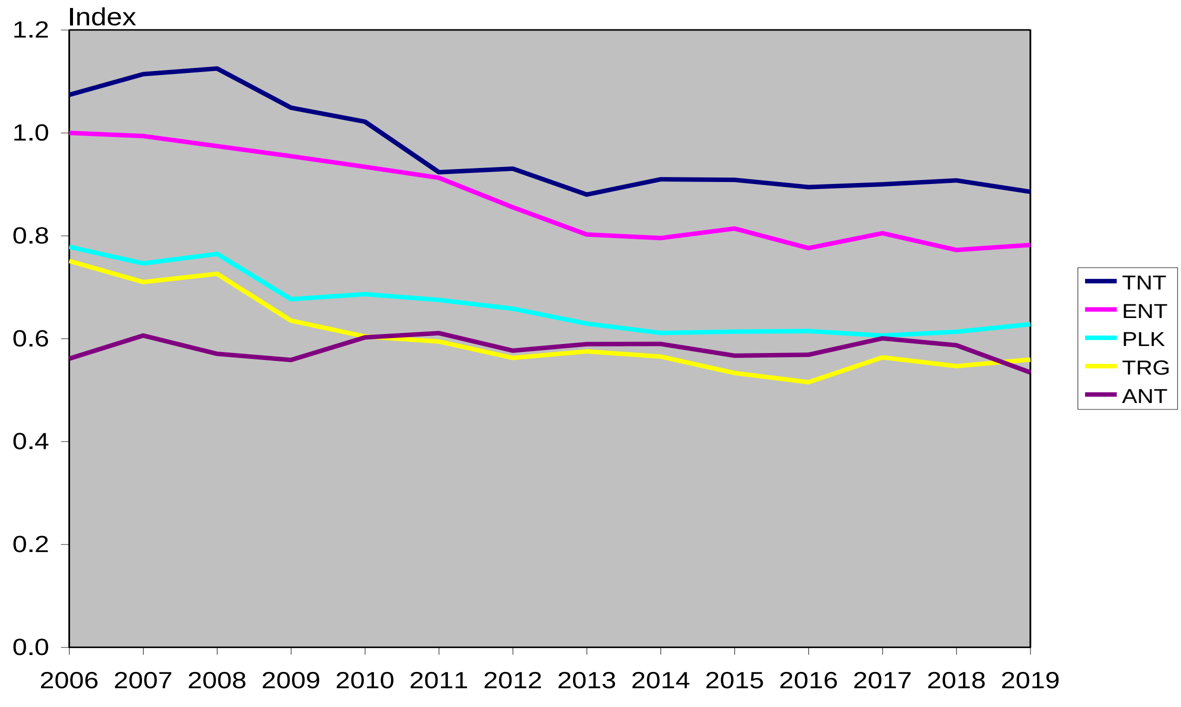
Year	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
ENT	0.876	0.860	0.837	0.769	0.781	0.745	0.770
PLK	1.057	1.001	0.899	0.903	0.873	1.079	1.077
ANT	1.464	1.398	1.342	1.286	1.436	1.538	1.399
TNT	0.853	0.902	1.226	1.139	1.370	1.561	1.478
TRG	1.428	1.197	1.265	1.264	1.346	1.535	1.558

From figure 3.2 we see that the two largest TNSPs – ANT and TRG – had the highest opex MPFP levels over the first half of the 14–year period but have been joined at the top by TNT since 2015. TNT had the lowest opex MPFP levels from 2006 to 2013 but marked increases in opex MPFP in 2015 and again in 2017 and 2018 took it to top ranking in 2018 before falling back to second ranking in 2019. It had an average annual opex MPFP growth rate for the period of 4.5 per cent. ANT's, TRG's and PLK's opex MPFP average annual changes over the period were also positive at 0.8, 1.4 and 0.7 per cent, respectively. Opex MPFP average annual change for ENT was negative at –2.0 per cent. TRG and ENT had opex MPFP increases in 2019 while PLK had a small decrease.

The main effect of the output weights correction on observed opex MPFP performance is to move the scores of the top three ranking TNSPs on this measure, TRG, TNT and ANT, closer together in recent years.

From figure 3.3 we can see that capital MPFP levels have generally declined over the 14–year period. The one exception is ANT whose capital MPFP has fluctuated over time but had a constant trend, although its capital MPFP level fell noticeably in 2019. In 2019, capital MPFP change was positive for PLK at 2.6 per cent, for ENT at 1.2 per cent and for TRG at 2.3 per cent. It was negative for ANT at –10 per cent and for TNT at –2.5 per cent. Average annual growth rates of capital MPFP for the whole 14–year period were negative for all five TNSPs.

Figure 3.3 **TNSP multilateral capital partial productivity indexes, 2006–2019**



Contributions of each of the three capital components making up overall capital productivity will be examined further in section 4.

Table 3.4 **TNSP multilateral capital partial productivity indexes, 2006–2019**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
ENT	1.000	0.994	0.974	0.955	0.934	0.913	0.855
PLK	0.778	0.746	0.765	0.677	0.686	0.675	0.658
ANT	0.561	0.606	0.571	0.559	0.602	0.611	0.577
TNT	1.074	1.114	1.125	1.049	1.022	0.923	0.930
TRG	0.751	0.710	0.726	0.635	0.604	0.595	0.563

Table 3.4 **TNSP multilateral capital partial productivity indexes, 2006–2019 (cont'd)**

Year	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
ENT	0.802	0.795	0.814	0.776	0.805	0.772	0.782
PLK	0.629	0.611	0.614	0.615	0.606	0.613	0.628
ANT	0.589	0.590	0.567	0.569	0.601	0.587	0.534
TNT	0.880	0.910	0.909	0.895	0.900	0.908	0.886
TRG	0.575	0.565	0.533	0.516	0.564	0.547	0.559

4 TNSP OUTPUTS, INPUTS AND PRODUCTIVITY CHANGE

In this section we review the outputs, inputs and productivity change results for the five NEM TNSPs. To provide context, individual TNSP results are generally compared with the corresponding transmission industry–level result presented earlier in section 2.

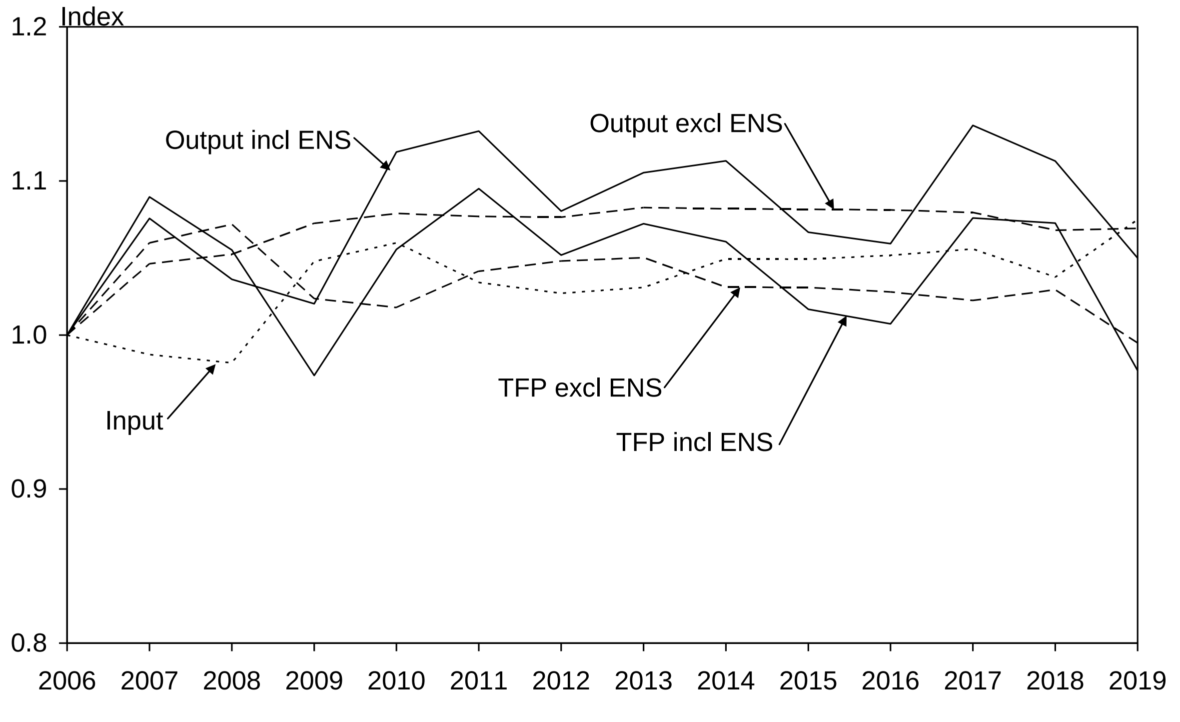
4.1 AusNet Services Transmission

In 2019 AusNet Services Transmission (ANT) transported 41,480 GWh of electricity over 6,628 circuit kilometres of lines and cables. It forms a critical part of Victoria's energy supply chain serving over 3 million end–users. ANT is the third largest TNSP in the NEM in terms of both energy throughput and circuit length but it serves the second largest number of end–users.

ANT's productivity performance

ANT's total output, total input and TFP indexes are presented in figure 4.1 and table 4.1. Opex and capital partial productivity indexes are also presented in table 4.1.

Figure 4.1 **ANT's output, input and total factor productivity indexes, 2006–2019**



Over the 14–year period 2006 to 2019, ANT's TFP changed at an average annual rate of –0.2 per cent[4]. Its total output increased by an average annual rate of 0.4 per cent, slightly less than its rate of increase in total input use of 0.6 per cent. This differs from the situation for the transmission industry as a whole where input use increased considerably more than output

[4] If it is not explicitly stated that productivity and output measures exclude reliability, the measure includes the reliability output.

growth over this period. ANT’s TFP change was quite negative in 2009 as output decreased due to the South Morang Terminal Station transformer failure and input use also increased markedly. From 2010 to 2018, input use remained relatively flat but it then increased by 3.5 per cent in 2019. After growth in output up to 2012 at an average annual rate of 1.3 per cent, output increased more modestly up to 2018 before falling by 5.8 per cent in 2019. Combined with the larger increase in inputs in 2019, ANT’s TFP change in the latest year was –9.3 per cent. This has produced negative TFP change for the period since 2012 with an average annual rate of change of –1.1 per cent.

Output increased markedly in 2017 following the worst reliability performance of the post–2012 period in 2016 and a turnaround to near perfect reliability in 2017. Output fell again in 2018 but this time due to a large reduction in energy throughput resulting from reduced exports to other states. Most of the large fall in output in 2019 was due to a large increase in ENS associated with a single outage event impacting supply to a single large customer. When ENS is excluded, output increased marginally in 2019. In figure 4.1 we present output and TFP indexes both including and excluding the reliability output. It can be seen that, following a period of good reliability performance from 2010 to 2014, the change to worse than average reliability depressed both output and TFP in 2015 and 2016, while the return to near perfect reliability in 2017 boosted both output and TFP strongly that year. Reliability changes had little impact on output and TFP change in 2018 but again reduced both output and TFP in 2019. If reliability is excluded, ANT’s TFP would have grown at an average rate of 0.0 per cent per annum over the 14 years, instead of –0.2 per cent.

Table 4.1 **ANT’s output, input and total factor productivity and partial productivity indexes, 2006–2019**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.076	0.987	1.090	1.130	1.077
2008	1.036	0.982	1.055	1.202	1.014
2009	1.020	1.048	0.974	0.927	0.990
2010	1.119	1.060	1.056	1.012	1.068
2011	1.132	1.034	1.095	1.134	1.082
2012	1.080	1.027	1.052	1.156	1.022
2013	1.105	1.031	1.072	1.169	1.044
2014	1.113	1.049	1.061	1.116	1.043
2015	1.067	1.049	1.017	1.071	1.000
2016	1.059	1.052	1.007	1.027	1.001
2017	1.136	1.056	1.076	1.146	1.055
2018	1.113	1.038	1.073	1.227	1.029
2019	1.050	1.075	0.977	1.117	0.937
Growth Rate 2006–19	0.38%	0.55%	–0.18%	0.85%	–0.50%
Growth Rate 2006–12	1.29%	0.45%	0.84%	2.41%	0.36%
Growth Rate 2012–19	–0.41%	0.65%	–1.06%	–0.48%	–1.25%

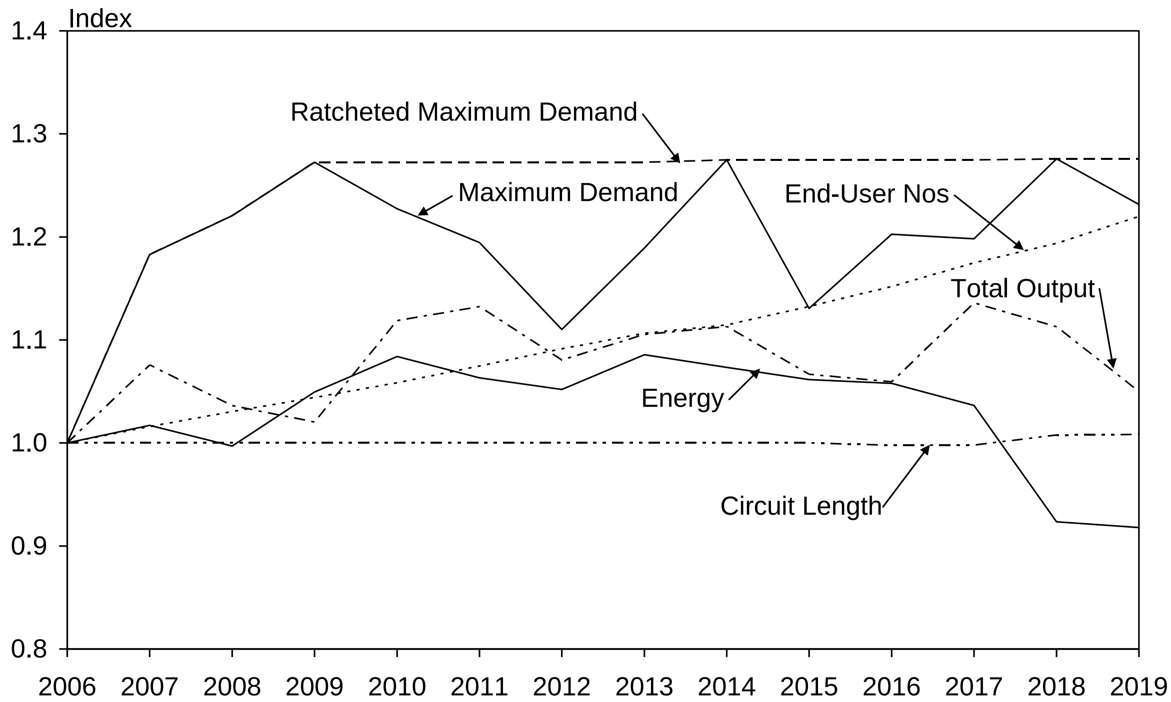
The partial productivity indexes in table 4.1 show that the reversal in average annual rates of change of TFP after 2012 were mirrored by reversed rates of change in both opex PFP and capital PFP.

ANT's output and input quantity changes

Quantity indexes for ANT's individual outputs are presented in figure 4.2 and for individual inputs in figure 4.3. In each case the quantities are converted to index format with a value of one in 2006 for ease of comparison.

From figure 4.2 we see that the output component that receives the largest weight in forming ANT's TFP index, circuit length, has remained virtually unchanged over the 14–year period. This contrasts with the transmission industry as whole where circuit length was 8 per cent higher in 2019 than it was in 2006.

Figure 4.2 **ANT's output quantity indexes, 2006–2019**



ANT's maximum demand output has, however, grown at a considerably higher rate than for the industry as a whole. ANT's maximum demand increased considerably more rapidly between 2006 and 2009 with an increase of 27 per cent compared to only 9 per cent for the industry. Although ANT's maximum demand has fluctuated since then, it briefly eclipsed its 2009 peak in 2014 and again in 2018 at which point it was 28 per cent above its 2006 level before again reducing by 3.5 per cent in 2019. Again, this contrasts with the industry's 2019 maximum demand being only 7 per cent above its 2006 level. In 2019 ANT's ratcheted maximum demand was 28 per cent above its 2006 level whereas the industry's RMD was only 12 per cent above its 2006 level.

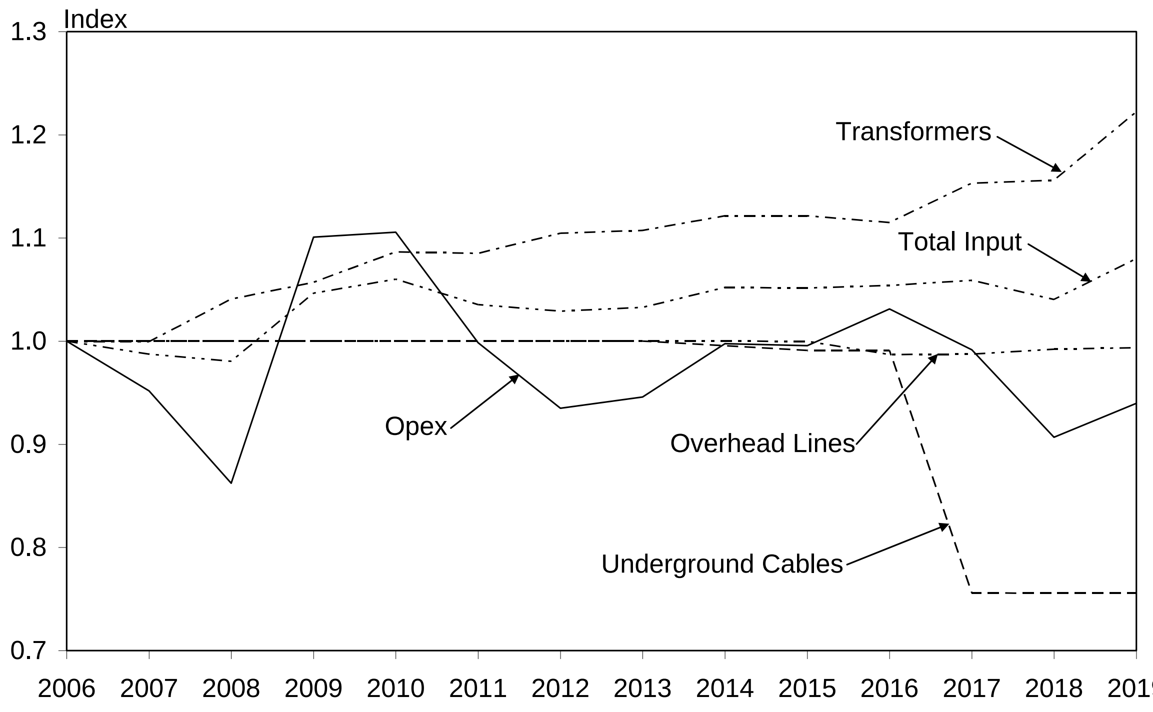
Similarly, we see that energy throughput has generally shown a steadier pattern for ANT than for the industry as a whole up to 2017 although ANT's energy throughput fell sharply in 2018 due to reduced energy exports. ANT's throughput increased through to 2010 and has generally declined gradually since then but with the sharp fall in 2018 whereas throughput for the industry fell steadily from 2010 to 2014 and has only partially recovered since then. In 2019 ANT's transmission energy throughput was 8 per cent below its 2006 level while for the industry it was around 4 per cent lower than it was in 2006.

The output that increased the second most over the period for ANT is end–user numbers with an increase of 22 per cent between 2006 and 2019, somewhat higher than the increase of 19 per cent for the industry. Again, this steady increase is to be expected as the number of electricity end–use customers will increase roughly in line with growth in the population.

The output that is not shown in figure 4.2 is total energy not supplied (ENS). ANT's ENS spiked upwards in 2009 to 13 times its 2006 level associated with the transformer failure at the South Morang Terminal Station. With the exception of 2009, ANT's ENS generally trended downwards to 2014 and, hence, contributed to an increase in total output relative to 2006, all else equal. However, ENS again increased in 2015 and 2016 before falling to near zero in 2017 and remaining low in 2018 before increasing significantly in 2019. The industry's ENS has followed a broadly similar pattern to that of ANT.

Since the circuit length, end–user numbers and RMD outputs receive a combined weight of around 86 per cent of total revenue in forming the total output index, in figure 4.2 we see that the total output index tends to lie close to the end–user numbers output index and lies above the circuit length index and below the RMD index. Total output movements are also influenced by the pattern of movement in the ENS output, particularly in 2009 and again in 2016, 2017 and 2019 (noting that an increase in ENS has a negative impact on total output and is given an average weight of around 1.5 per cent of total revenue on average for ANT). Despite its small weight, the size of the percentage changes in ENS means it still has a significant impact on total output and, hence, TFP growth.

Figure 4.3 **ANT's input quantity indexes, 2006–2019**



Turning to the input side, we present quantity indexes for ANT's four input components and total input in figure 4.3. We see that, in line with ANT's near constant circuit length output, ANT's input quantities for both overhead lines and underground cables have remained virtually constant over the whole period although the (relatively small) quantity of underground cables input reduces in 2017 as cable length falls from 11 to 9 kilometres.

After underground cables, opex decreased the next most of ANT's inputs over the 14–year period, being 6 per cent lower in 2019 than it was in 2006 but with significant variation over the intervening years. Opex usage increased by 11 per cent between 2006 and 2010 before falling back to be 6 per cent below its 2006 level in 2013 and then increasing again through to 2016, falling in 2017 and 2018 and then increasing by 3.6 per cent in 2019. ANT's –6 per cent overall opex change between 2006 and 2019 compares to –1 per cent change for the industry. Opex has the third largest average share in ANT's total costs at 24 per cent.

The input component with the largest average share of total cost, at 46 per cent, is transformers. ANT's quantity of transformers increased steadily to 2014 before levelling off to 2016 and then increasing again in 2017 and in 2019. In 2019 ANT's transformers input was 22 per cent above its 2006 level – a considerably smaller increase than the industry's 49 per cent. Given their large share of total costs, transformer inputs are an important driver of the total input quantity index.

From figure 4.3 we see that ANT's total input quantity index generally lies between the quantity indexes for transformers and overhead lines (which have a combined weight of 75 per cent of total costs). Fluctuations in the total inputs index are primarily driven by variations in opex use.

ANT's output and input contributions to TFP change

In table 4.2 we first present the percentage point contributions of each output and each input to ANT's average annual rate of TFP change of –0.2 per cent over the 14–year period 2006 to 2019.

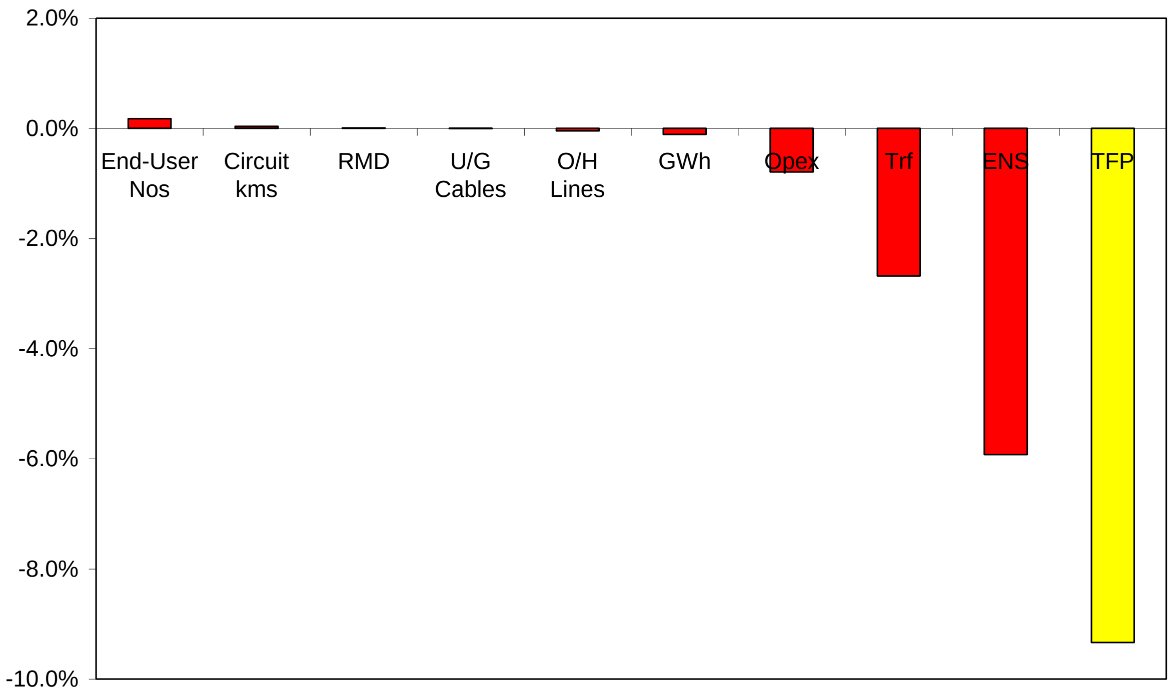
Table 4.2 **ANT's output and input percentage point contributions to average annual TFP change: 2006–2019, 2006–2012, 2012–2019, 2018–19**

Year	*2006 to 2019*	*2006 to 2012*	*2012 to 2019*	*2018–19*
Energy (GWh)	–0.10%	0.13%	–0.30%	–0.11%
Ratcheted Max Demand	0.47%	1.01%	0.01%	0.01%
Customer Numbers	0.12%	0.11%	0.12%	0.17%
Circuit Length	0.03%	0.00%	0.06%	0.04%
ENS	–0.15%	0.04%	–0.31%	–5.93%
Opex	0.11%	0.26%	–0.01%	–0.79%
O/H Lines	0.01%	0.00%	0.03%	–0.05%
U/G Cables	0.02%	0.00%	0.04%	0.00%
Transformers	–0.70%	–0.71%	–0.70%	–2.68%
TFP Change	–0.18%	0.84%	–1.06%	–9.34%

There are several key differences in factors contributing to ANT's TFP growth compared to the industry results presented earlier in table 2.2. Circuit length growth provides a marginal contribution to ANT's TFP growth whereas it is the largest contributor for the industry. RMD contributes 0.5 percentage points to ANT's TFP growth compared to 0.2 percentage points for the industry, reflecting stronger growth in demand in Victoria compared to the market overall. ENS contributes –0.2 percentage points for ANT compared to a marginal negative contribution for the industry. Transformer input growth contributes –0.7 percentage points to ANT's TFP change compared to –1.2 percentage points for the industry, in both cases the largest respective negative contributions. Opex use makes a 0.1 percentage point contribution to ANT's TFP change compared to near zero for the industry, again reflecting ANT's somewhat larger decrease in opex usage over the period. And, overhead lines inputs make a small positive contribution to ANT's TFP growth compared to –0.4 percentage points for the industry, reflecting the industry's higher rate of increase in this input.

Comparing the periods before 2012 and after 2012 in table 4.2, the main differences for ANT are the fall in the contribution of RMD of 1.0 percentage points before 2012 to near zero after 2012 as maximum demand flattens out and the reversal of the contribution of ENS after 2012 to –0.3 percentage points versus a marginal positive contribution before 2012 as ENS again increased in 2019. And the contribution of energy to ANT's TFP growth changes from positive for the period before 2012 to negative for the period after 2012 with a change from 0.1 to –0.3 percentage points contribution. On the input side, the contribution of opex becomes marginally negative after 2012 compared to 0.3 percentage points before 2012 as opex grew slightly on average after 2012. The negative contribution of transformers input before 2012 of –0.7 percentage points is maintained after 2012 as transformer inputs initially level off from 2014 onwards before increasing in 2017 and again in 2019.

Figure 4.4 **ANT's output and input percentage point contributions to annual TFP change, 2018–19**



In figure 4.4 and table 4.2 we present the contributions of outputs and inputs to ANT's TFP change in the 2019 year. Despite the small weight it receives, the large four–fold increase in ENS in 2019 leads to it making the largest negative contribution to TFP change at –5.9 percentage points. Growth in end–user numbers made a contribution of 0.2 percentage points, while growth in transformer and opex inputs made contributions of –2.7 and –0.8 percentage points, respectively. The fall in energy throughput of 0.6 per cent in 2019 leads to it making a negative contribution to TFP growth of –0.1 percentage points. ANT's TFP change in 2019 was –9.3 per cent and, thus, considerably below the TFP change in 2019 for the industry as a whole which was –1.8 per cent.

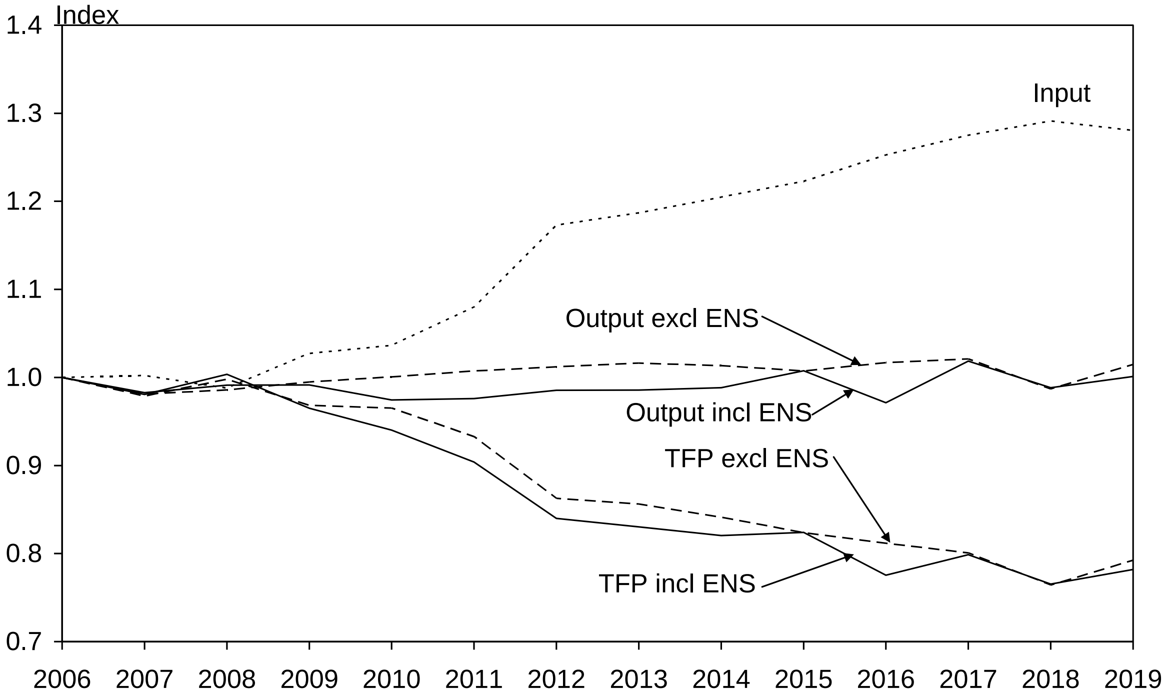
4.2 ElectraNet

In 2019 ElectraNet (ENT) transported 13,787 GWh of electricity over 5,513 circuit kilometres of lines and cables. It forms a critical part of South Australia's energy supply chain serving 906,198 end–users. ENT is the fourth largest of the five TNSPs in the NEM in terms of energy throughput, circuit length and the number of end–users.

ENT's productivity performance

ENT's total output, total input and TFP indexes are presented in figure 4.5 and table 4.3. Opex and capital partial productivity indexes are also presented in table 4.3.

Figure 4.5 **ENT's output, input and total factor productivity indexes, 2006–2019**



Over the 14–year period 2006 to 2019, ENT's TFP decreased at an average annual rate of change of –1.9 per cent. Its total output increased only marginally over the period with an average annual rate of change of 0.01 per cent. This compares to an industry growth in output of 0.6 per cent per annum on average. ENT's average annual rate of increase in input use of

1.9 per cent was slightly higher than the rate of increase in total input use for the industry. When combined with its marginal increase in output, this gives ENT an average annual change in TFP of –1.9 per cent compared to the industry's average annual change of –1.1 per cent. ENT's TFP change was positive in 2008, 2015, 2017 and 2019. Input use declined in 2008 and combined with positive output growth to produce positive TFP change that year. And in 2015 ENT's output growth was stronger leading to positive TFP growth. This was mainly due to a large reduction in ENS in 2015. However, an upwards spike in ENS in 2016 caused a TFP change of –6.1 per cent that year followed by TFP growth of 3.0 per cent in 2017 as ENS returned to a more average level. TFP increased by 2.1 per cent in 2019 due to stronger output growth and a reduction in input use. If ENS is excluded as an output, TFP change in 2019 would have been higher at 3.6 per cent (see figure 4.5).

For the period after 2012, the rate of average annual growth in input usage declines while output growth increases compared to the period before 2012. This leads to an improvement in TFP change from –2.9 per cent before 2012 to –1.0 per cent after 2012.

Table 4.3 **ENT's output, input and total factor productivity and partial productivity indexes, 2006–2019**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	0.983	1.002	0.981	0.941	1.000
2008	0.991	0.988	1.004	1.057	0.978
2009	0.991	1.027	0.965	0.993	0.954
2010	0.974	1.037	0.940	0.956	0.933
2011	0.976	1.080	0.904	0.889	0.911
2012	0.985	1.173	0.840	0.822	0.848
2013	0.986	1.187	0.830	0.876	0.811
2014	0.988	1.205	0.820	0.860	0.802
2015	1.008	1.223	0.824	0.836	0.819
2016	0.971	1.253	0.775	0.768	0.779
2017	1.018	1.275	0.799	0.780	0.808
2018	0.988	1.291	0.765	0.744	0.776
2019	1.001	1.280	0.782	0.771	0.787
Growth Rate 2006–19	0.01%	1.90%	–1.89%	–2.00%	–1.84%
Growth Rate 2006–12	–0.25%	2.66%	–2.91%	–3.26%	–2.75%
Growth Rate 2012–19	0.23%	1.25%	–1.02%	–0.92%	–1.06%

The partial productivity indexes in table 4.3 show that the moderation in negative average annual rates of change of TFP after 2012 were mirrored in reduced negative rates of change in both opex PFP and capital PFP.

ENT's output and input quantity changes

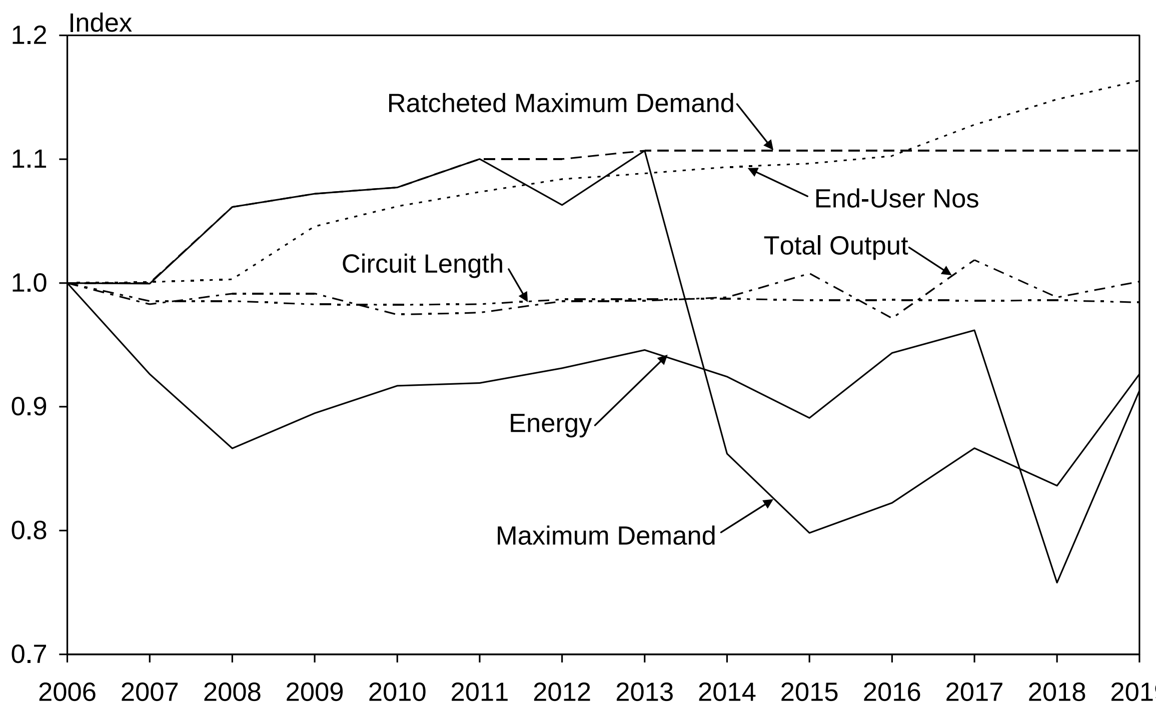
Quantity indexes for ENT's individual outputs are presented in figure 4.6 and for individual inputs in figure 4.7. In each case the quantities are converted to index format with a value of one in 2006 for ease of comparison.

From figure 4.6 we see that the output component that receives the largest weight in forming ENT's TFP index, circuit length, declined marginally in 2007 and has then remained virtually unchanged for the remainder of the 14–year period. This contrasts with the transmission industry as whole where circuit length was 8 per cent higher in 2019 than it was in 2006.

ENT's maximum demand and energy throughput outputs have shown quite a different pattern compared to the industry as a whole. ENT's maximum demand increased though to 2011 and peaked in 2013 after a small reduction in 2012. However, ENT's maximum demand fell substantially between 2013 and 2015. Despite a small recovery in 2016 and 2017 and a larger increase in 2019, ENT's maximum demand was 7 per cent below its 2006 level in 2019. This contrasts with the industry's 2019 maximum demand being 7 per cent above its 2006 level. In 2019 ENT's ratcheted maximum demand was 11 per cent above its 2006 level while the industry's RMD was 12 per cent above its 2006 level. In ENT's case, this reflects growth in maximum demand up to 2013 before the substantial fall occurred.

Similarly, we see that energy throughput for ENT has had a different pattern compared to the industry as a whole. ENT's throughput decreased by 13 per cent between 2006 and 2008 whereas the industry's throughput increased by 1 per cent over the same period. ENT's throughput trended up somewhat between 2008 and 2017 before falling sharply by 24 per cent in 2018 and recovering by 19 per cent in 2019. It was 9 per cent below its 2006 level in 2019 compared to the industry's throughput then being 3.5 per cent less than it was in 2006.

Figure 4.6 **ENT's output quantity indexes, 2006–2019**



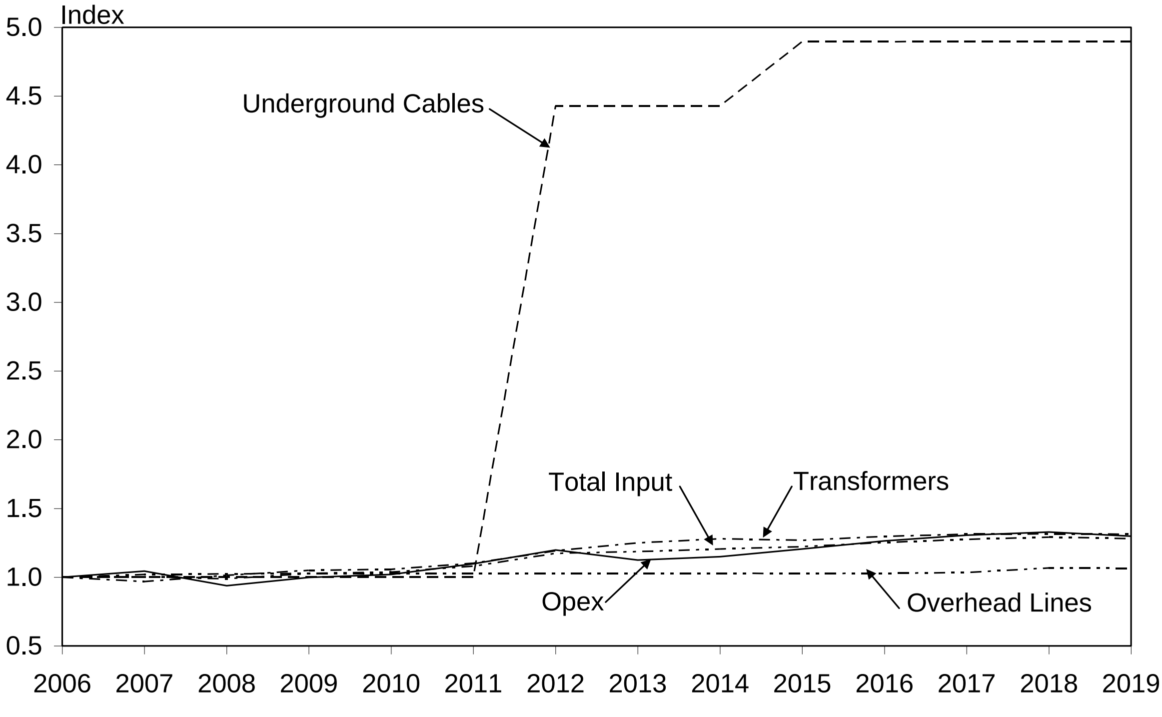
The output that increased the most over the period for ENT is end–user numbers with an increase of 16 per cent between 2006 and 2019, less than the increase of 19 per cent for the industry. ENT's end–user numbers remained largely unchanged between 2006 and 2008 before a more rapid increase in 2009 followed by reducing increases in subsequent years until

2017 when growth again increased. This is a less steady pattern than for the industry overall but reflects South Australia's lower rate of population growth overall.

The output that is not shown in figure 4.6 is total energy not supplied. ENT's ENS has been relatively volatile and spiked upwards in 2016 to 10 times its 2006 level after having been less than its 2006 level in 2015. However, ENT's ENS levels were considerably higher than its 2006 level in the period from 2010 to 2014. In 2019 ENT's ENS increased by 166 per cent to be 2.25 times its 2006 level. Overall, ENT's ENS will have had a negative impact on its total output over most of the period.

Since the circuit length, end–user numbers and energy throughput outputs receive a combined weight of around 77 per cent of ENT's total revenue in forming the total output index, in figure 4.6 we see that the total output index tends to lie close to the circuit length output index and be bounded by the end–user numbers and energy throughput indexes. Total output movements are also influenced by the pattern of movement in the ENS output, particularly in 2010 to 2012 and again in 2016 (noting that an increase in ENS has a negative impact on total output and is given an average weight of around 1.8 per cent of total revenue on average for ENT).

Figure 4.7 **ENT's input quantity indexes, 2006–2019**



Turning to the input side, we present quantity indexes for ENT's four input components and total input in figure 4.7. We see that, in line with ENT's near constant circuit length output, ENT's input quantity for overhead lines has increased only marginally over the whole period. Its underground cables input quantity increased by 350 per cent in 2012 but the length of underground cables increased from only 9 to 27 kilometres in that year reflecting this input's very small share of costs.

The quantity of opex increased the third most of ENT's four inputs over the 14–year period, being 30 per cent higher in 2019 than it was in 2006. Opex usage increased by 20 per cent between 2010 and 2012. ENT's overall opex increase between 2006 and 2019 was considerably higher than for the industry where opex quantity actually fell over the period. Opex has the second largest average share in ENT's total costs at 32 per cent. Opex usage fell by 2.3 per cent in 2019 after several years of increase.

The input component with the largest average share of ENT's total cost, at 44 per cent, is transformers. ENT's quantity of transformers increased steadily from 2007 to 2014 before levelling off and by 2019 was 31 per cent above its 2006 level – a smaller increase than the industry's 49 per cent. Given their large share of total costs, transformer inputs are an important driver of the total input quantity index.

From figure 4.7 we see that ENT's total input quantity index generally lies close to the quantity indexes for transformers and opex (which have a combined weight of 75 per cent of total costs).

ENT's output and input contributions to TFP change

In table 4.4 we present the percentage point contributions of each output and each input to ENT's average annual rate of TFP change of –1.9 per cent over the 14–year period 2006 to 2019.

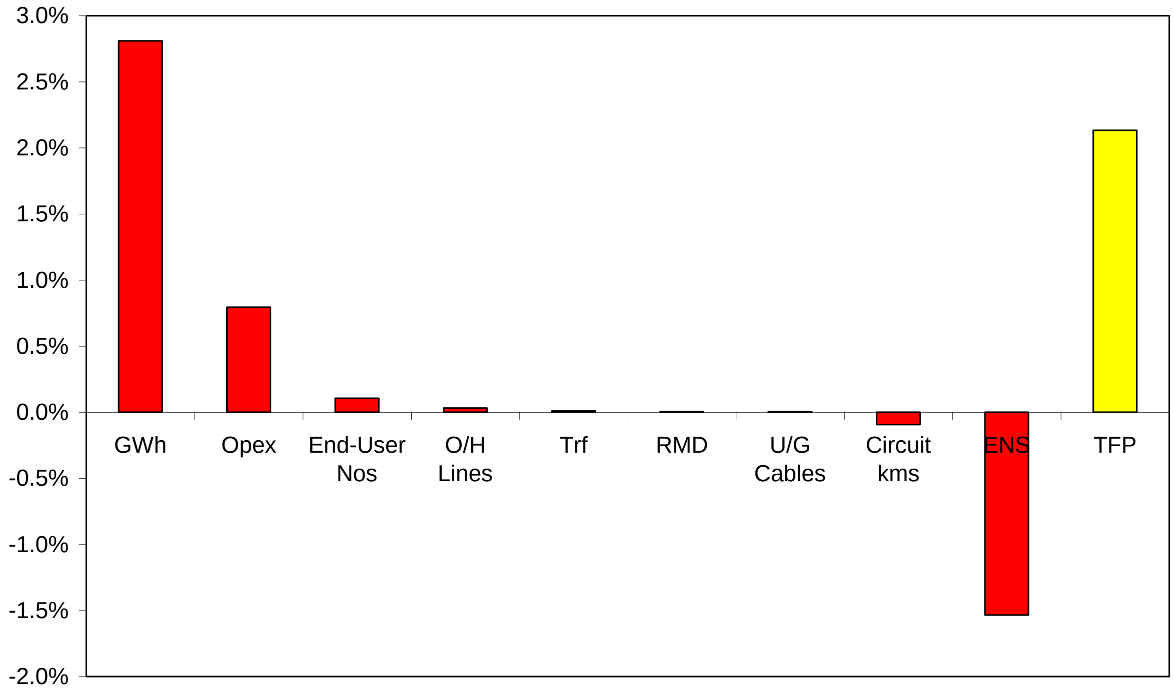
Table 4.4 **ENT's output and input percentage point contributions to average annual TFP change: 2006–2019, 2006–2012, 2012–2019, 2018–19**

Year	*2006 to 2019*	*2006 to 2012*	*2012 to 2019*	*2018–19*
Energy (GWh)	–0.11%	–0.18%	–0.04%	2.81%
Ratcheted Max Demand	0.20%	0.40%	0.02%	0.00%
Customer Numbers	0.09%	0.10%	0.08%	0.11%
Circuit Length	–0.07%	–0.12%	–0.02%	–0.09%
ENS	–0.11%	–0.45%	0.19%	–1.54%
Opex	–0.65%	–0.96%	–0.38%	0.79%
O/H Lines	–0.11%	–0.12%	–0.10%	0.03%
U/G Cables	–0.24%	–0.38%	–0.12%	0.00%
Transformers	–0.91%	–1.21%	–0.66%	0.01%
TFP Change	–1.89%	–2.91%	–1.02%	2.13%

There are some minor differences in factors contributing to ENT's TFP growth compared to the industry results presented earlier in table 2.2. Circuit length growth provides a marginally negative contribution to ENT's TFP growth whereas it is the largest positive contributor for the industry at 0.3 percentage points. ENS contributes –0.1 percentage points for ENT and close to that for the industry. Transformer input growth contributes –0.9 percentage points to ENT's TFP change compared to –1.2 percentage points for the industry, reflecting the smaller growth in ENT's transformer input quantity. And, opex use also makes a large negative contribution to ENT's TFP change at –0.7 percentage points compared to a marginally positive contribution for the industry, again reflecting the industry's small decrease in opex usage over the period compared to ENT's 30 per cent increase.

Comparing the periods before 2012 and after 2012 in table 4.4, the main differences for ENT are that some outputs contribute less to TFP growth after 2012 but the contribution from ENS reverses from –0.5 percentage points before 2012 to 0.2 percentage points after 2012. The contribution of energy goes from –0.2 percentage points before 2012 to –0.0 percentage points after 2012. However, all inputs make less negative contributions after 2012 with the contribution of opex going from –1.0 percentage points before 2012 to –0.4 percentage points after 2012 and transformers going from a –1.2 percentage point contribution before 2012 to a –0.7 percentage point contribution after 2012. Overall, TFP average annual change improves from –2.9 per cent before 2012 to –1.0 per cent after 2012.

Figure 4.8 **ENT's output and input percentage point contributions to annual TFP change, 2018–19**



In figure 4.8 we present the contributions of outputs and inputs to ENT's TFP change of 2.1 per cent in the 2019 year. The large increase in energy throughput in 2019 leads to it making by far the largest positive contribution to TFP change at 2.8 percentage points. The reduction in opex leads to it making the second largest contribution of 0.8 percentage points. Growth in end–user numbers in 2019 leads to it making the third largest positive contribution at 0.1 percentage points. However, the increase in ENS in 2019 led to it making a negative contribution in the latest year of –1.5 percentage points. ENT's large positive TFP change in 2019 of 2.1 per cent, driven largely by increased energy throughput, was much higher than TFP change in 2019 for the industry as a whole which was –1.8 per cent.

4.3 Powerlink

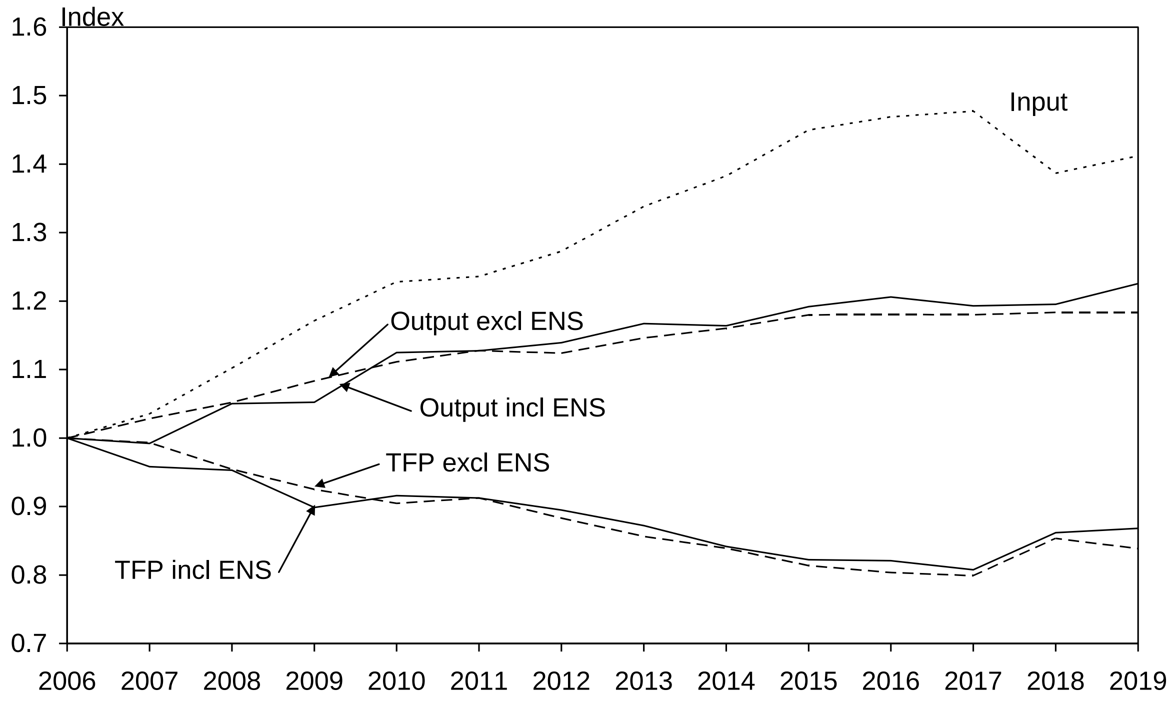
In 2019 Powerlink (PLK) transported 53,765 GWh of electricity over 14,526 circuit kilometres of lines and cables. It forms a critical part of Queensland's energy supply chain serving around 2.3 million end–users. PLK is the second largest of the five TNSPs in the NEM in terms of energy throughput but is the largest in terms of circuit length. It serves the third largest number of end–users.

PLK's productivity performance

PLK's total output, total input and TFP indexes are presented in figure 4.9 and table 4.5. Opex and capital partial productivity indexes are also presented in table 4.5.

PLK's TFP change was positive in 2010, 2018 and 2019. In the first of these years PLK's output growth was very strong leading to positive TFP growth despite input growth also being strong in that year. Output growth in 2010 was mainly due to recovery from an upwards spike in ENS occurring the year before (see figure 4.9). If ENS is excluded from the output measure then TFP change was negative for all years except for 2011 and 2018. In 2018 PLK had only marginally positive output growth but had a sizable reduction in input use, driven mainly by a large reduction in opex. In 2019 PLK's positive TFP growth was driven by output growth resulting from its achievement of zero ENS that year[5].

Figure 4.9 **PLK's output, input and total factor productivity indexes, 2006–2019**



For the period after 2012, the rate of average annual growth in input usage moderated substantially and more than offset a reduction in the average annual increase in output leading

[5] To permit index calculation for 2019 we include an ENS value of 1.0 MWh as a value of zero is not compatible with logarithmic calculations. A value of 1.0 does not unduly distort the result, which smaller values would do, while adequately capturing the effects of the perfect reliability performance that year.

to average annual TFP growth after 2012 of –0.4 per cent compared to –1.9 per cent for period before 2012.

Table 4.5 **PLK's output, input and total factor productivity and partial productivity indexes, 2006–2019**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	0.992	1.035	0.958	0.961	0.956
2008	1.050	1.102	0.953	0.942	0.962
2009	1.052	1.171	0.899	0.993	0.862
2010	1.125	1.228	0.916	1.026	0.874
2011	1.127	1.236	0.912	1.073	0.857
2012	1.139	1.273	0.895	1.055	0.841
2013	1.167	1.338	0.872	1.072	0.806
2014	1.164	1.383	0.842	1.017	0.781
2015	1.192	1.450	0.822	0.914	0.787
2016	1.206	1.469	0.821	0.915	0.785
2017	1.193	1.477	0.808	0.888	0.777
2018	1.195	1.387	0.862	1.095	0.785
2019	1.226	1.412	0.868	1.084	0.796
Growth Rate 2006–19	1.56%	2.65%	–1.09%	0.62%	–1.76%
Growth Rate 2006–12	2.17%	4.02%	–1.85%	0.90%	–2.89%
Growth Rate 2012–19	1.05%	1.48%	–0.44%	0.38%	–0.79%

The partial productivity indexes in table 4.5 show that the reduced negative rate of change in capital PFP after 2012 was in part offset by the positive average annual opex PFP rate of change reducing in size for the period after 2012.

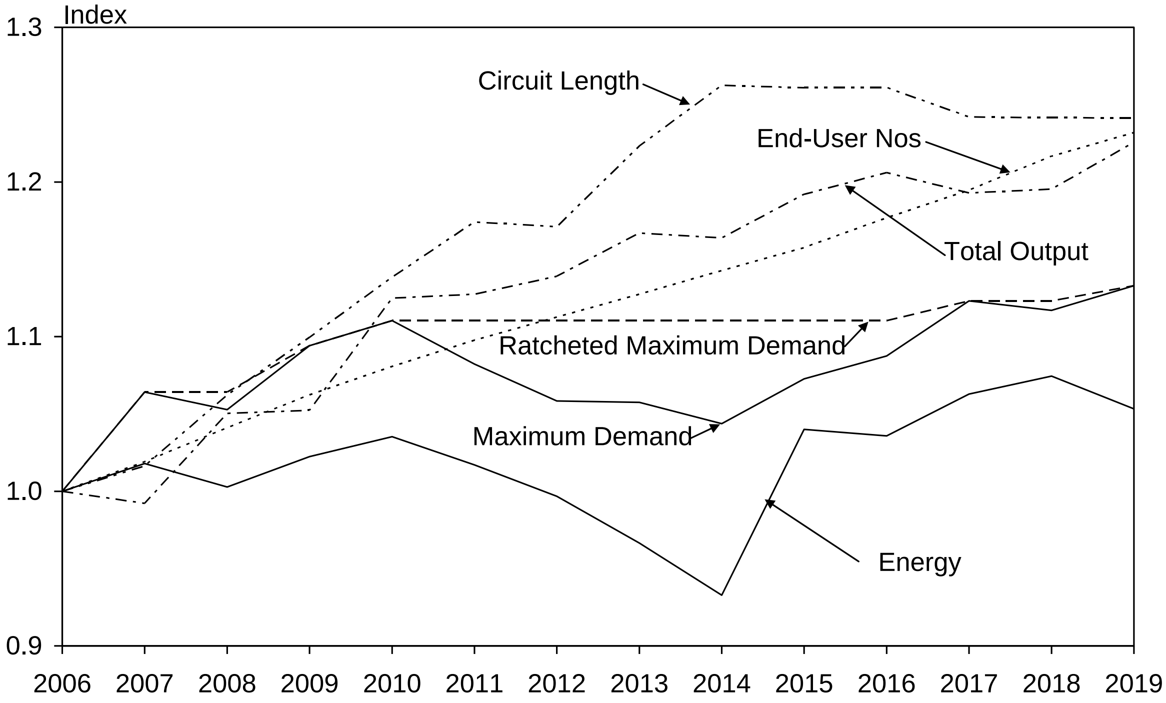
Over the 14–year period 2006 to 2019, PLK's TFP decreased at an average annual rate of change of –1.1 per cent. Its total output increased over the period with an average annual rate of change of 1.6 per cent. This was considerably higher than the industry average annual growth in output of 0.6 per cent. However, PLK's average annual rate of increase in input use of 2.7 per cent was above the rate of increase in total input use for the industry of 1.7 per cent by a similar amount, giving PLK the same annual change in TFP as that for to the industry.

PLK's output and input quantity changes

Quantity indexes for PLK's individual outputs are presented in figure 4.10 and for individual inputs in figure 4.11. In each case the quantities are converted to index format with a value of one in 2006 for ease of comparison.

From figure 4.10 we see that the output component that receives the largest weight in forming PLK's TFP index, circuit length, increased relatively steadily through to 2014 before levelling off. In 2019, PLK's circuit length was 24 per cent higher than it was in 2006. This is a much larger increase than for the transmission industry as whole where circuit length was 8 per cent higher in 2019 than it was in 2006.

Figure 4.10 **PLK's output quantity indexes, 2006–2019**



PLK's maximum demand and energy throughput outputs have shown a broadly similar pattern compared to the industry as a whole except that they have grown more in recent years. PLK's maximum demand peaked in 2010 and then declined through to 2014 before recovering in the following three years. PLK's maximum demand was 13 per cent above its 2006 level in 2019. The industry's 2019 maximum demand was 7 per cent above its 2006 level. In 2019 PLK's ratcheted maximum demand was 13 per cent above its 2006 level, compared to 12 per cent for the industry.

Similarly, we see that energy throughput for PLK initially peaked in 2010 before falling through to 2014 and recovering strongly subsequently and falling again in 2019. PLK's throughput in 2019 was 5 per cent above its 2006 level compared to the industry's throughput then being 3.5 per cent below its level in 2006.

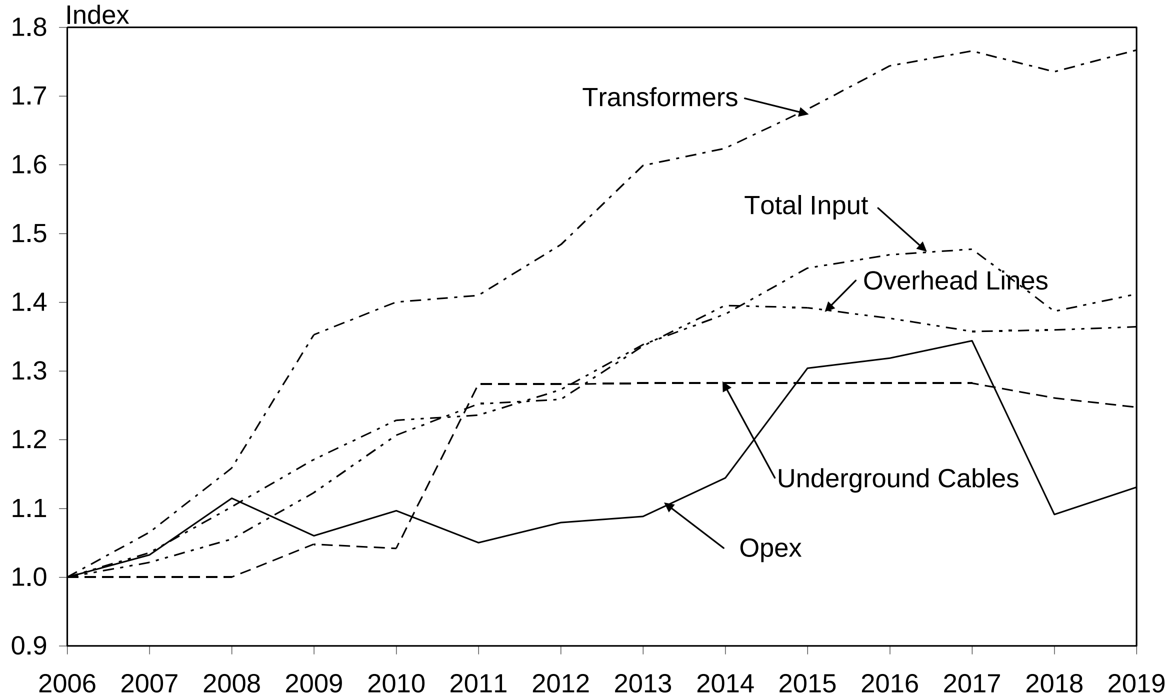
The output that increased the second most over the period for PLK is end–user numbers with an increase of 23 per cent between 2006 and 2019, somewhat higher than the increase of 19 per cent for the industry. PLK's end–user numbers have increased steadily over the period reflecting Queensland's strong rate of population growth.

The output that is not shown in figure 4.10 is total energy not supplied (ENS). PLK's ENS spiked upwards sharply in 2007 and 2009 to 6 times and 5 times, respectively, its 2006 level. However, since then PLK's ENS levels have tended to reduce and have shown less volatility in recent years than those of the other TNSPs. As noted above, in 2019 PLK's ENS was zero. Overall, PLK's ENS will have had a positive impact on its total output over the period.

Since the circuit length, end–user numbers and energy throughput outputs receive a combined weight of around 76 per cent of PLK's total revenue in forming the total output index, in figure 4.10 we see that the total output index tends to lie close to the end–user numbers output index and be bounded by the circuit length and energy throughput indexes. Total output movements are also influenced by the pattern of movement in the ENS output, particularly in 2007, 2010 and 2019 (noting that an increase in ENS has a negative impact on total output and is given an average weight of around 1 per cent of total revenue on average for PLK).

Turning to the input side, we present quantity indexes for PLK's four input components and total input in figure 4.11. We see that, in line with PLK's higher increase in circuit length output, its input quantity for overhead lines increased more than that for the industry but its underground cables input quantity increased less than that for the industry. PLK's overhead lines input increased by 36 per cent and its underground cables input quantity increased by 25 per cent between 2006 and 2019. This compares to corresponding respective increases for the industry of 19 per and 73 per cent.

Figure 4.11 **PLK's input quantity indexes, 2006–2019**



PLK's quantity of opex increased the least of its four inputs over the 14–year period, being 13 per cent higher in 2019 than it was in 2006. Opex usage increased only modestly through to 2013 but increased rapidly in 2014 and 2015 and then fell by 21 per cent in 2018 before increasing again by 3.6 per cent in 2019. PLK's overall opex increase between 2006 and 2019 was higher than the 1 per cent decrease for the industry. Opex has the third largest average share in PLK's total costs at 27 per cent.

The input component with the largest average share of PLK's total cost, at 37 per cent, is transformers. PLK's quantity of transformers increased steadily over the period and by 2019 was 77 per cent above its 2006 level – a much larger increase than the industry's 49 per cent. Given its large share of total costs, transformer inputs are an important driver of PLK's total input quantity index.

From figure 4.11 we see that PLK's total input quantity index generally lies close to the quantity indexes for transformers and overhead lines (which have a combined weight of 72 per cent of total costs).

PLK's output and input contributions to TFP change

In table 4.6 we first present the percentage point contributions of each output and each input to PLK's average annual rate of TFP change of –1.1 per cent over the 14–year period 2006 to 2019.

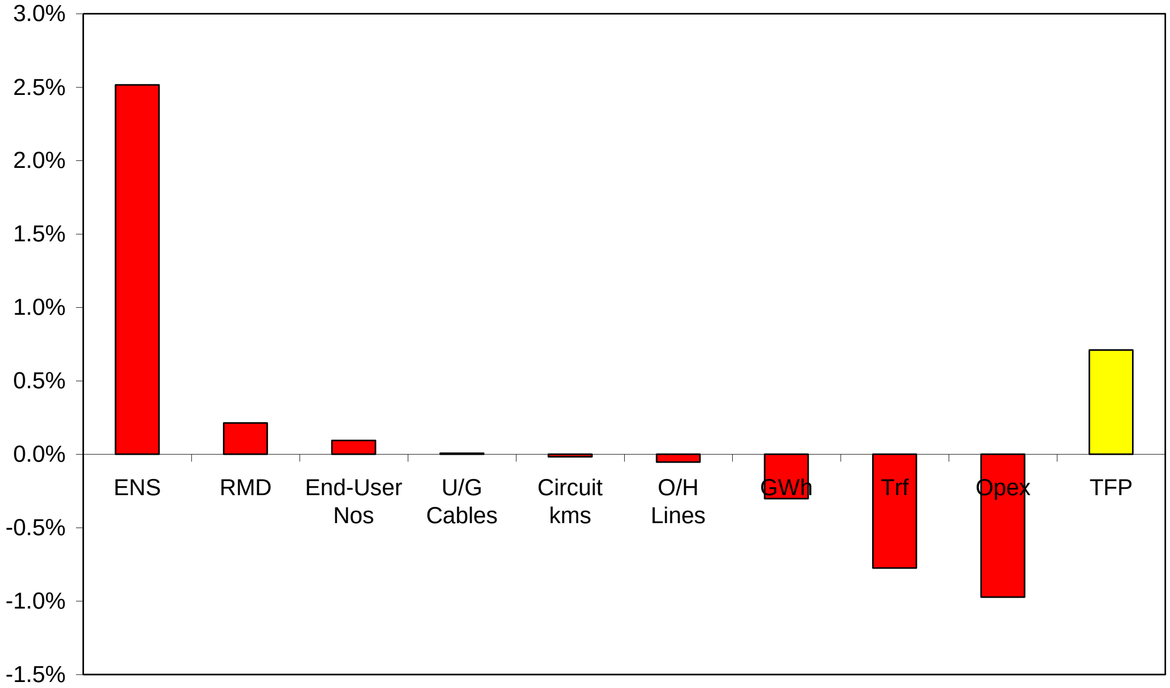
Table 4.6 **PLK's output and input percentage point contributions to average annual TFP change: 2006–2019, 2006–2012, 2012–2019, 2018–19**

Year	*2006 to 2019*	*2006 to 2012*	*2012 to 2019*	*2018–19*
Energy (GWh)	0.06%	–0.01%	0.12%	–0.30%
Ratcheted Max Demand	0.24%	0.44%	0.07%	0.21%
Customer Numbers	0.12%	0.14%	0.11%	0.09%
Circuit Length	0.89%	1.41%	0.44%	–0.02%
ENS	0.25%	0.20%	0.30%	2.52%
Opex	–0.27%	–0.41%	–0.16%	–0.97%
O/H Lines	–0.89%	–1.48%	–0.39%	–0.05%
U/G Cables	–0.01%	–0.03%	0.00%	0.01%
Transformers	–1.48%	–2.11%	–0.94%	–0.77%
TFP Change	–1.09%	–1.85%	–0.44%	0.71%

There are some differences in factors contributing to PLK's TFP growth compared to the industry results presented earlier in table 2.2. Circuit length growth provides the largest positive contribution to both PLK's and the industry's TFP growth but the contribution is 0.9 percentage points for PLK compared to 0.3 for the industry. ENS contributes 0.3 percentage points to TFP change for PLK whereas it makes a marginal negative contribution for the industry. Transformer input growth contributes –1.5 percentage points to PLK's TFP change compared to –1.2 percentage points for the industry, largely reflecting the larger growth in PLK's transformer input quantity. And opex use also makes a negative contribution to PLK's TFP change at –0.3 percentage points compared to marginally positive for the industry, again reflecting the industry's decrease in opex usage over the period. Similarly, overhead lines input makes a more negative contribution to PLK's TFP change at –0.9 percentage points compared to –0.4 for the industry, again reflecting the industry's lower increase in overhead lines input over the period.

Comparing the periods before 2012 and after 2012 in table 4.6, most outputs contribute less to PLK's TFP growth after 2012 except for energy throughput which changes from making a marginal negative contribution before 2012 to making a positive contribution after 2012 and for ENS which increases its contribution from 0.2 to 0.3 percentage points. Opex usage makes a contribution after 2012 of –0.2 percentage points compared to a contribution of –0.4 percentage points before 2012. There are also reductions in the negative contributions of overhead lines and transformer inputs. Average annual TFP growth improves from –1.9 per cent before 2012 to –0.4 per cent after 2012.

Figure 4.12 **PLK's output and input percentage point contributions to annual TFP change, 2018–19**



In figure 4.12 and table 4.6 we present the contributions of outputs and inputs to PLK's TFP change of 0.7 per cent in the 2019 year. The further improvement in ENS in 2019 makes the largest contribution of 2.5 percentage points to TFP growth. RMD and end–user numbers growth make contributions of 0.2 and 0.1 percentage points, respectively. The increase in opex makes the largest negative contribution at –1.0 percentage points, followed by the increase in transformer inputs at –0.8 percentage points and reduced throughput at –0.3 percentage points. The other outputs and inputs all make quite small contributions which largely cancel each other out. PLK's positive TFP change in 2019 of 0.7 per cent is better than that for the industry as a whole of –1.8 per cent.

4.4 TasNetworks Transmission

In 2019 TasNetworks Transmission (TNT) transported 12,885 GWh of electricity over 3,545 circuit kilometres of lines and cables. It forms a critical part of Tasmania's energy supply chain serving 290,446 end–users. TNT is the smallest TNSP in the NEM in terms of energy throughput, circuit length and the number of end–users.

TNT's productivity performance

TNT's total output, total input and TFP indexes are presented in figure 4.13 and table 4.7. Opex and capital partial productivity indexes are also presented in table 4.7.

Over the 14–year period 2006 to 2019, TNT's TFP increased at an average annual rate of 0.2 per cent. Its total output increased by an average annual rate of 0.5 per cent while its total input use increased somewhat slower at an average annual rate of 0.3 per cent. This differs from the situation for the transmission industry as a whole where input use increased faster

Figure 4.13 **TNT's output, input and total factor productivity indexes, 2006–2019**

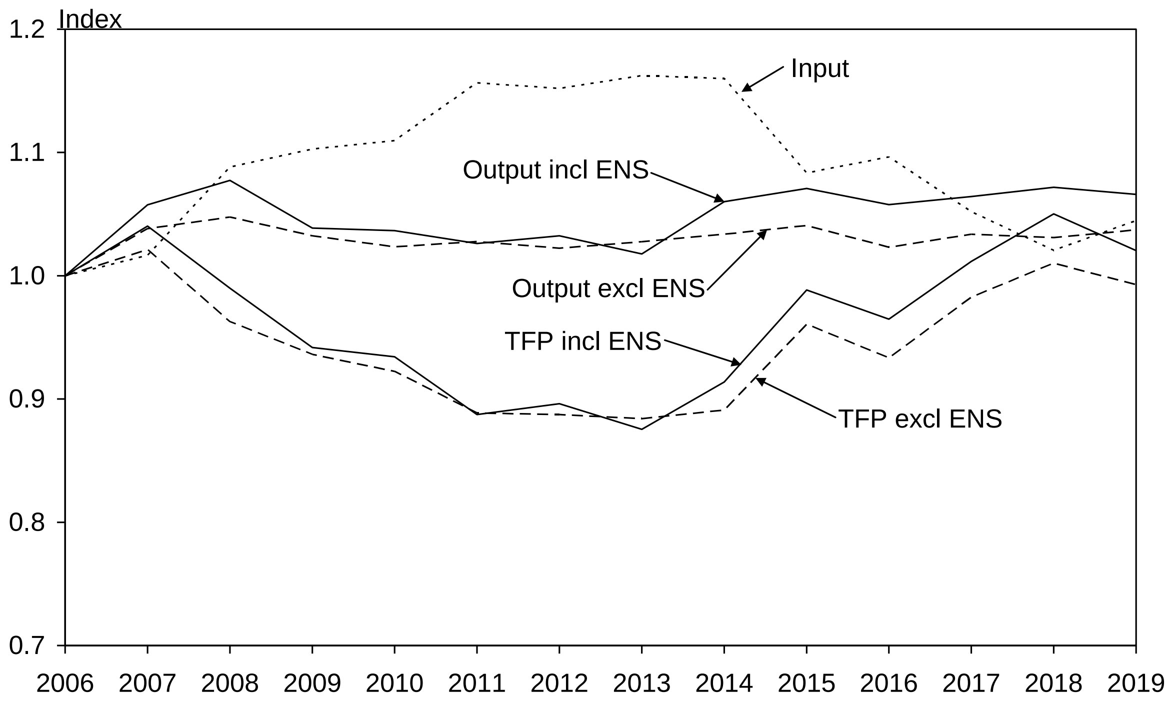


Table 4.7 **TNT's output, input and total factor productivity and partial productivity indexes, 2006–2019**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index Opex*	*PFP Index Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.058	1.017	1.040	1.041	1.047
2008	1.077	1.088	0.990	0.896	1.044
2009	1.039	1.103	0.942	0.895	0.974
2010	1.037	1.110	0.934	0.896	0.951
2011	1.026	1.156	0.887	0.945	0.860
2012	1.032	1.152	0.896	0.975	0.856
2013	1.018	1.162	0.875	1.038	0.811
2014	1.060	1.160	0.914	1.097	0.843
2015	1.071	1.083	0.988	1.491	0.844
2016	1.058	1.096	0.965	1.385	0.834
2017	1.064	1.052	1.012	1.667	0.841
2018	1.072	1.021	1.050	1.897	0.847
2019	1.066	1.045	1.020	1.801	0.827
Growth Rate 2006–19	0.49%	0.34%	0.16%	4.53%	–1.46%
Growth Rate 2006–12	0.53%	2.36%	–1.83%	–0.42%	–2.58%
Growth Rate 2012–19	0.46%	–1.40%	1.85%	8.77%	–0.50%

than output growth over this period. TNT's TFP change was strongly positive in 2007 as output increased markedly. It was also positive in 2012 as input use growth moderated and then strongly positive again in 2014 and 2015 as input use was reduced. TFP fell again in 2016, mainly due to a reduction in output and a return to input growth. However, input use was again reduced in 2017 and 2018 leading to strong TFP growths of 4.7 and 3.8 per cent, respectively. Output fell in 2019 while input use increased by 2.3 per cent leading to a decrease in TFP with a change of –2.9 per cent. TNT's TFP level fell by 17 per cent between 2007 and 2013 before recovering subsequently to end 2 per cent above its 2006 level in 2019.

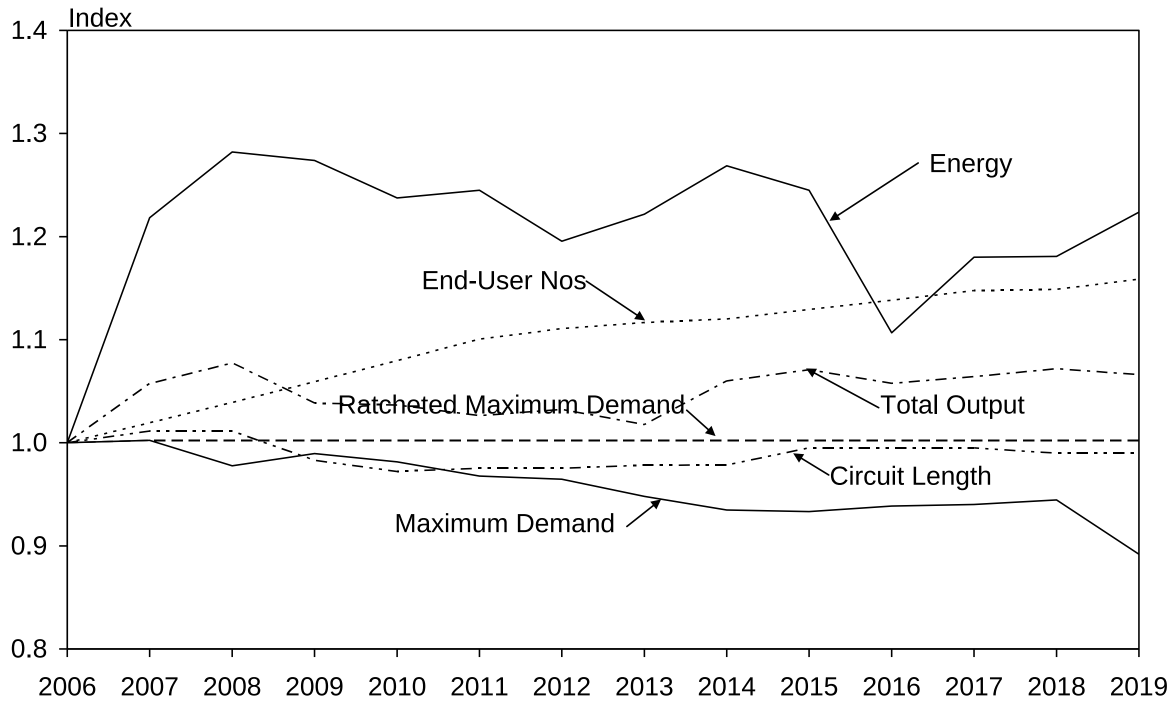
TNT's TFP performance was considerably better for the period after 2012 than for the period before 2012 going from an average annual rate of change of –1.8 per cent to 1.9 per cent after 2012. Although the average annual rate of output growth stayed much the same before and after 2012, input use went from an average annual rate of change of 2.4 per cent before 2012 to –1.4 per cent after 2012.

The partial productivity indexes in table 4.7 show that a substantial improvement in opex PFP from an average change of –0.4 per cent before 2012 to 8.8 per cent after 2012 was an important reason for the improvement in TFP performance although there was also a 2.1 percentage point improvement in capital PFP change.

TNT's output and input quantity changes

Quantity indexes for TNT's individual outputs are presented in figure 4.14 and for individual inputs in figure 4.15. In each case the quantities are converted to index format with a value of one in 2006 for ease of comparison.

Figure 4.14 **TNT's output quantity indexes, 2006–2019**



From figure 4.14 we see that the output component that receives the largest weight in forming TNT's TFP index, circuit length, has fluctuated somewhat but remained virtually unchanged over the 14–year period. This contrasts with the transmission industry as a whole where circuit length was 8 per cent higher in 2019 than it was in 2006.

TNT's maximum demand output has, however, grown considerably less than for the industry as a whole. TNT's maximum demand increased marginally in 2007 but has fallen subsequently to end up 11 per cent below its 2006 level in 2019. This contrasts with the industry's 2019 maximum demand being 7 per cent above its 2006 level. In 2019 TNT's ratcheted maximum demand was only marginally above its 2006 level whereas the industry's RMD was 12 per cent above its 2006 level.

However, we see that energy throughput for TNT has shown a very different pattern to that for the industry as a whole. TNT's throughput increased by 28 per cent between 2006 and 2008 before reducing somewhat through to 2012 and again increasing to close to its earlier peak in 2014. It then reduced substantially in the following two years before increasing again to finish up 22 per cent above its 2006 level in 2019. In 2019 energy throughput for the transmission industry was 3.5 per cent lower than it was in 2006. TNT's energy throughput is particularly affected by exports to the mainland and demand from large industrial users.

The output that had increased the second most for TNT by 2019 was end–user numbers with an increase of 16 per cent between 2006 and 2019, a little less than that for the industry. Again, this steady increase is to be expected as the number of electricity end–use customers will increase roughly in line with growth in the population.

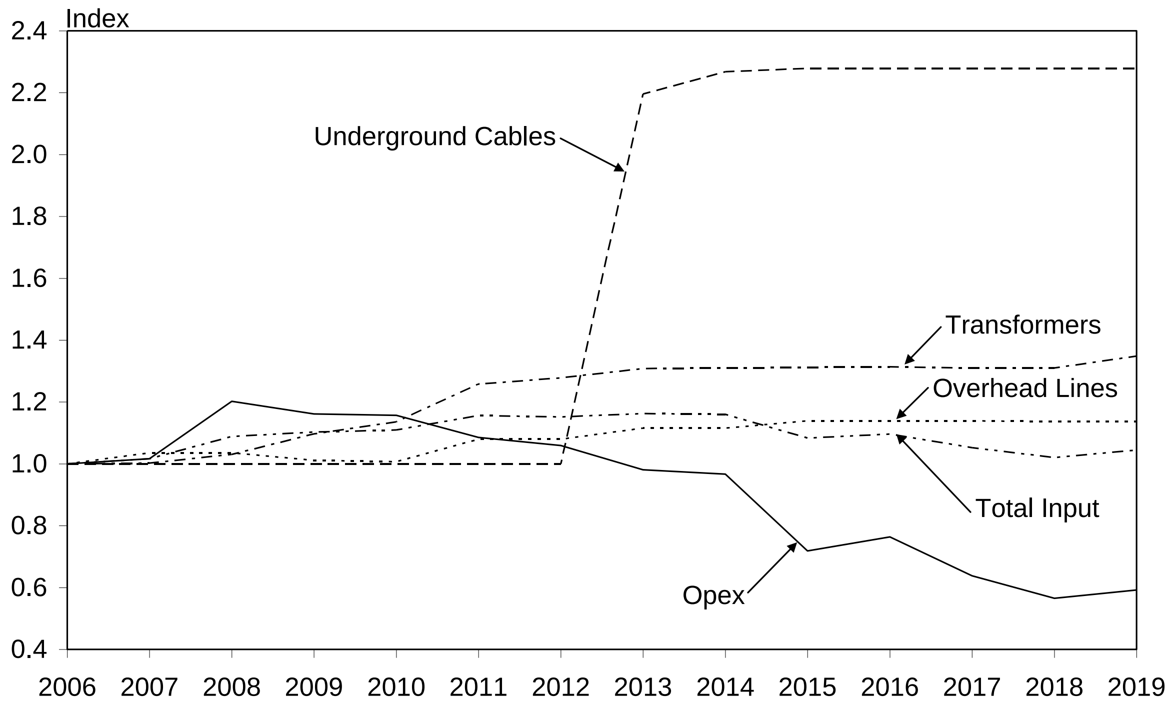
The output that is not shown in figure 4.14 is total energy not supplied (ENS). TNT's ENS has been relatively volatile but within a much smaller range than most other TNSPs. ENS fell from 2006 through to 2009 before trending up to be 60 per cent above its 2006 level in 2013. However, since then it has reduced most years to be at 28 per cent of its 2006 level in 2019, despite having increased by 116 per cent in 2019. The effect of ENS since 2013 being better than it was in 2006 can be seen in figure 4.13 where total output (and TFP) including ENS are consistently higher than they would be if ENS was excluded from the output measure.

Since the RMD, circuit length and energy throughput outputs receive a combined weight of around 94 per cent of total revenue in forming the total output index, in figure 4.14 we see that the total output index tends to lie below the energy throughput index and above the RMD and circuit length indexes. Total output movements are also influenced by the pattern of movement in the ENS output, particularly in 2013 and 2014 (noting that an increase in ENS has a negative impact on total output and is given an average weight of around 1.9 per cent of total revenue on average for TNT).

Turning to the input side, we present quantity indexes for TNT's four input components and total input in figure 4.15. TNT's input usage follows a similar pattern to that for the industry except that opex decreases for TNT over the period and transformer and overhead lines inputs grow less for TNT than for the industry. We see that, despite TNT's fluctuating but near constant circuit length output, TNT's input quantity for overhead lines has increased reflecting the use of higher capacity lines. Underground cables input more than doubles in 2013 but the length of underground cables goes from only 13 kilometres to 23 kilometres with the new cables being of considerably higher capacity.

The quantity of TNT's opex increased by nearly 20 per cent in 2008 but has fallen each year subsequently through to 2015, with the fall in 2015 being a very large 25 per cent. Opex use increased again in 2016 by 6 per cent but fell a further 16 per cent in 2017 and a further 11 per cent in 2018. Opex increased by 4.8 per cent in 2019 at which time it was then 41 per cent below its 2006 level. TNT's large fall in opex use between 2006 and 2019 contrasts with the industry's decrease in opex usage of only 1 per cent over the same period. Opex has the second largest average share in TNT's total costs at 28 per cent.

Figure 4.15 **TNT's input quantity indexes, 2006–2019**



The input component with the largest average share of total cost, at 48 per cent, is transformers. TNT's quantity of transformers increased steadily to 2013 before levelling off and by 2019 was 35 per cent above its 2006 level – a smaller increase than the industry's 49 per cent. Given its large share of total costs, transformer inputs are an important driver of the total input quantity index.

From figure 4.15 we see that TNT's total input quantity index generally lies close to the quantity indexes for transformers and overhead lines (which have a weight of 70 per cent of total costs). Fluctuations in the total inputs index are driven by variations in opex use.

TNT's output and input contributions to TFP change

In table 4.8 we first present the percentage point contributions of each output and each input to TNT's average annual rate of TFP change of 0.2 per cent over the 14–year period 2006 to 2019.

There are some key differences in factors contributing to TNT's TFP growth compared to the industry results presented earlier in table 2.2. Changes in opex, in energy and in ENS provide the largest positive contributions to TNT's TFP change whereas all three provide negligible contributions for the industry. RMD growth provides no contribution to TNT's TFP growth whereas it is a positive contributor for the industry. And, circuit length is a marginal negative contributor for TNT compared to the largest positive contributor for the industry at 0.3 percentage points. Transformer input growth contributes –1.1 percentage points to TNT's

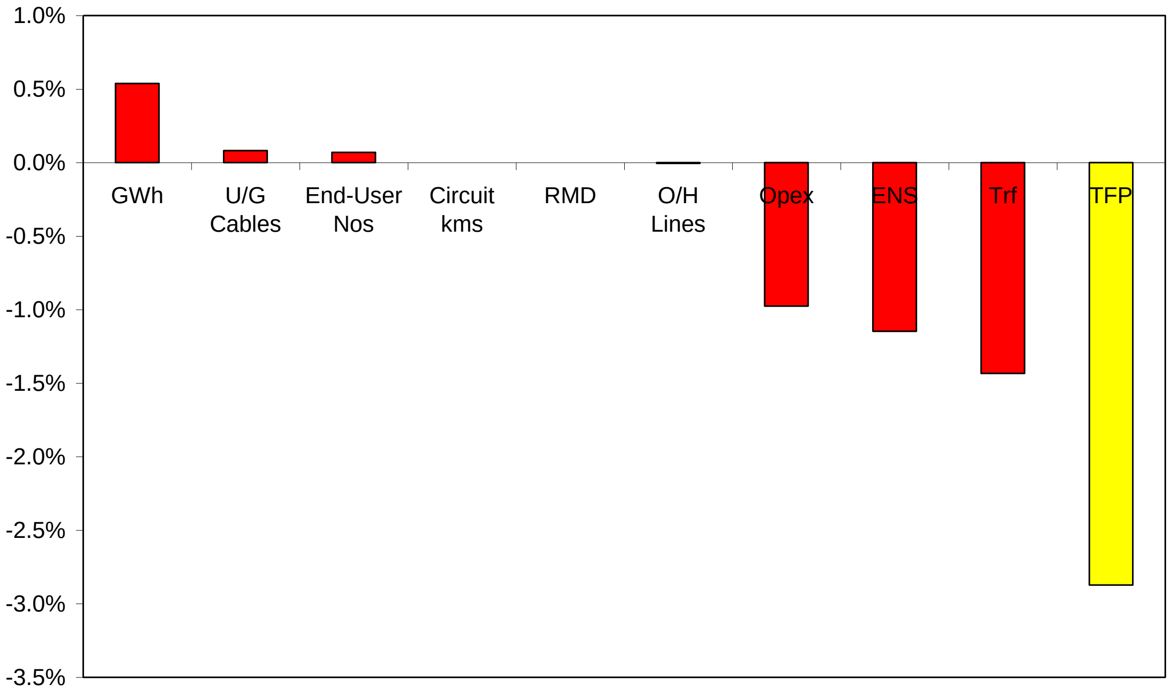
TFP change compared to –1.2 percentage points for the industry, reflecting the somewhat smaller growth in TNT's transformer input quantity.

Table 4.8 **TNT's output and input percentage point contributions to average annual TFP change: 2006–2019, 2006–2012, 2012–2019, 2018–19**

Year	*2006 to 2019*	*2006 to 2012*	*2012 to 2019*	*2018–19*
Energy (GWh)	0.24%	0.45%	0.05%	0.54%
Ratcheted Max Demand	0.00%	0.01%	0.00%	0.00%
Customer Numbers	0.09%	0.14%	0.05%	0.07%
Circuit Length	–0.04%	–0.22%	0.11%	0.00%
ENS	0.21%	0.16%	0.25%	–1.15%
Opex	1.06%	–0.18%	2.12%	–0.98%
O/H Lines	–0.22%	–0.28%	–0.17%	–0.01%
U/G Cables	–0.08%	0.00%	–0.14%	0.08%
Transformers	–1.10%	–1.89%	–0.41%	–1.43%
TFP Change	0.16%	–1.83%	1.85%	–2.87%

Comparing the periods before 2012 and after 2012 in table 4.8, the main differences for TNT are the reversal in the contribution of opex from –0.2 percentage points before 2012 to 2.1 percentage points after 2012. And energy makes a small positive contribution to TNT's TFP after 2012 versus a 0.5 percentage point contribution before 2012. And, on the input side, there is also a reduction in the negative contribution of transformers input before 2012 of –1.9 percentage points to –0.4 percentage points after 2012 as transformer inputs level off from 2013 onwards.

Figure 4.16 **TNT's output and input percentage point contributions to annual TFP change, 2018–19**



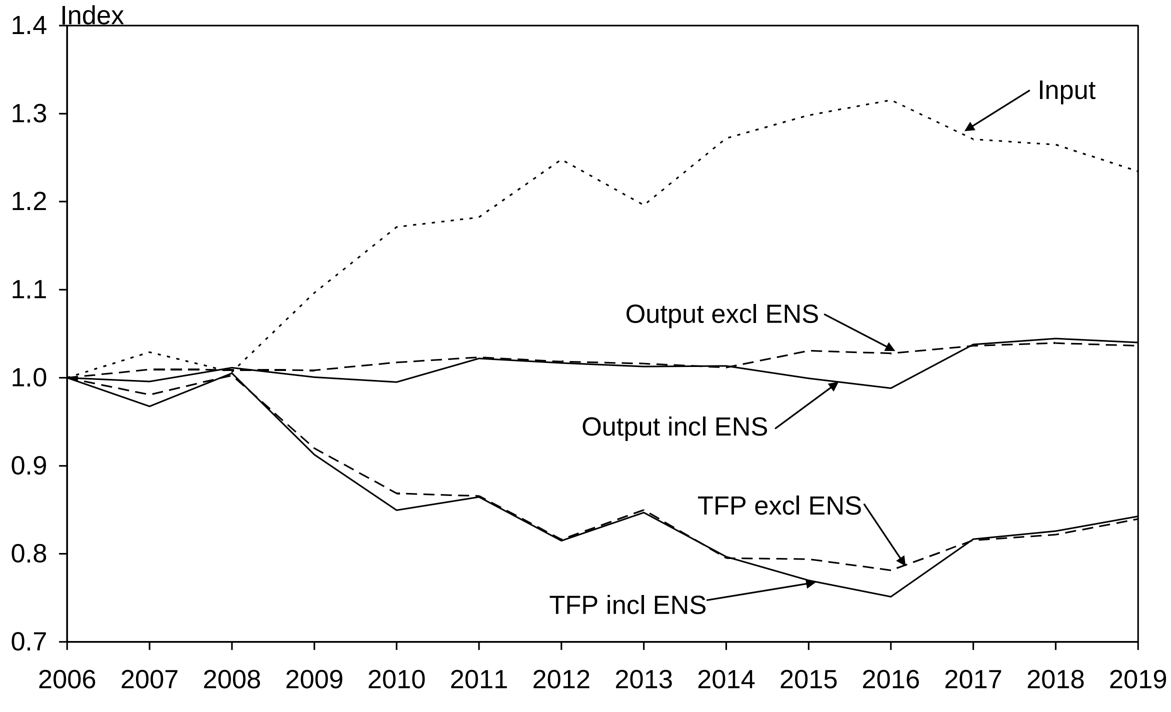
In figure 4.16 and table 4.8 we present contributions of outputs and inputs to TNT's TFP change of –2.9 per cent in the 2019 year. The largest positive contribution at 0.5 percentage points comes from the increase in throughput while the other positive contributors are underground cables input end–user numbers at 0.1 percentage points each. The largest downside contribution of –1.4 percentage points comes from the increase in transformer inputs. The increase in ENS contributes –1.1 percentage points while the increase in opex usage in 2019 leads to it making the third most negative contribution to TFP change at –1.0 percentage points. TNT's TFP change in 2019 of –2.9 per cent is more negative than the industry TFP change in 2019 of –1.8 per cent.

4.5 TransGrid

In 2019 TransGrid (TRG) transported 74,400 GWh of electricity over 13,052 circuit kilometres of lines and cables. It forms a critical part of New South Wales' energy supply chain serving around 3.9 million end–users. TRG is the largest of the five TNSPs in the NEM in terms of energy throughput and the number of end–users and the second largest in terms of circuit length.

TRG's productivity performance

Figure 4.17 **TRG's output, input and total factor productivity indexes, 2006–2019**



TRG's total output, total input and TFP indexes are presented in figure 4.17 and table 4.9. Opex and capital partial productivity indexes are also presented in table 4.9.

Over the 14–year period 2006 to 2019, TRG's TFP decreased at an average annual rate of change of –1.3 per cent. Its total output increased over the period with an average annual rate of change of 0.3 per cent. This compares to an industry growth in output of 0.6 per cent per annum on average. TRG's average annual rate of increase in input use of 1.6 per cent was close to that for the industry. When combined with its increase in output, this gives TRG an average annual change in TFP of –1.3 per cent compared to the industry's average annual change of –1.1 per cent. TRG's TFP change was positive in 2008, 2011, 2013, 2017, 2018 and 2019. Input use declined in 2008 to produce positive TFP change that year. Input use was also reduced in 2013 to produce positive TFP change in spite of a fall in output that year. TFP change in 2011, on the other hand, was positive due to strong output growth. Input use was reduced in each of 2017, 2018 and 2019 while 2017 also exhibited strong output growth.

Table 4.9 **TRG's output, input and total factor productivity and partial productivity indexes, 2006–2019**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index Opex*	*PFP Index Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	0.996	1.029	0.968	1.021	0.944
2008	1.011	1.006	1.005	1.110	0.966
2009	1.001	1.096	0.913	1.104	0.845
2010	0.995	1.171	0.849	0.978	0.800
2011	1.022	1.182	0.864	1.084	0.790
2012	1.017	1.248	0.815	1.009	0.748
2013	1.013	1.196	0.847	1.107	0.764
2014	1.013	1.272	0.797	0.928	0.749
2015	0.999	1.298	0.770	0.978	0.701
2016	0.988	1.315	0.751	0.978	0.678
2017	1.038	1.271	0.817	1.042	0.742
2018	1.045	1.265	0.826	1.189	0.720
2019	1.040	1.234	0.843	1.207	0.736
Growth Rate 2006–19	0.30%	1.62%	–1.32%	1.44%	–2.36%
Growth Rate 2006–12	0.28%	3.69%	–3.41%	0.16%	–4.84%
Growth Rate 2012–19	0.32%	–0.16%	0.48%	2.55%	–0.24%

In 2017 TRG had very strong TFP growth of 8.4 per cent, mainly as the result of an increase in output associated with reduced outages following unusually high levels of outages in 2015 and, in particular, 2016. Input use was also reduced in 2017 and 2018 and again in 2019. The effect of the upwards spike in ENS in 2015 and 2016 can be seen in figure 4.17 where output and TFP levels excluding ENS as an output are also plotted. When ENS is excluded from output, the total output and TFP indexes were markedly higher in 2015 and 2016. Correspondingly, TFP growth in 2017 is lower than when ENS is included but was still relatively high at 4.3 per cent due to the impact of reduced input use that year. In 2017 ENS returned to a level below where it was in 2006 and stayed below that level in 2018 and 2019 so the output and TFP indexes including and excluding ENS are again closer together.

For the period after 2012, the rate of average annual growth in output increased somewhat while the average annual change in input use reduced substantially. This led to an improvement in TFP change from –3.4 per cent before 2012 to 0.5 per cent after 2012.

The partial productivity indexes in table 4.9 show that the improvement in average annual rates of change of TFP after 2012 were mirrored in improvements in both opex PFP and capital PFP.

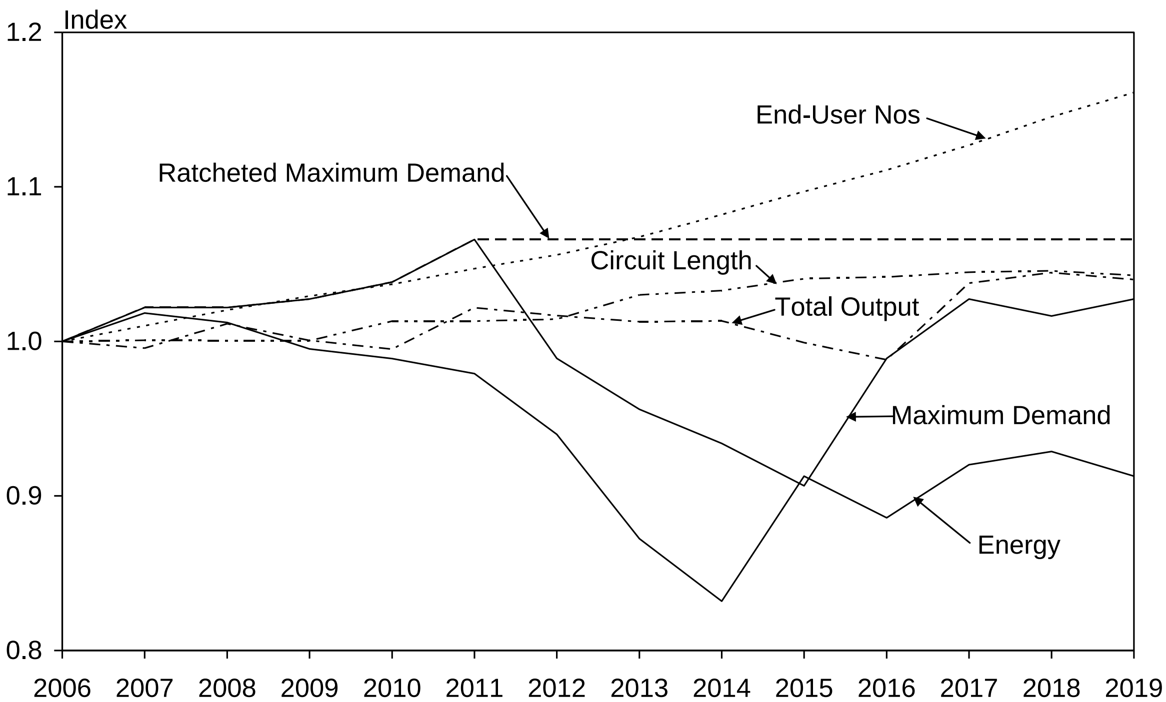
TRG's output and input quantity changes

Quantity indexes for TRG's individual outputs are presented in figure 4.18 and for individual inputs in figure 4.19. In each case the quantities are converted to index format with a value of one in 2006 for ease of comparison.

From figure 4.18 we see that the output component that receives the largest weight in forming TRG's TFP index, circuit length, has increased gradually over the 14–year period. By 2019 TRG's circuit length was only 4 per cent above its 2006 level compared to the transmission industry's corresponding increase in circuit length of 8 per cent.

TRG's maximum demand and energy throughput outputs show a broadly similar pattern to the industry as a whole. TRG's maximum demand increased through to 2011 but then fell substantially through to 2015 followed by a partial recovery in 2016 and 2017 before falling again in 2018 and recovering in 2019. TRG's maximum demand was 3 per cent above its 2006 level in 2019. The industry's maximum demand was 7 per cent above its 2006 level in 2019. In 2019 TRG's ratcheted maximum demand was 7 per cent above its 2006 level while the industry's RMD was 12 per cent above its 2006 level. In TRG's case, this reflects growth in maximum demand up to 2011 before the substantial fall occurred.

Figure 4.18 **TRG's output quantity indexes, 2006–2019**



Similarly, we see that TRG's energy throughput increased by 2 per cent in 2007 but then fell by around 18 per cent through to 2014. In 2019 it was 9 per cent below its 2006 level compared to the industry's throughput then being 4 per cent lower than it was in 2006.

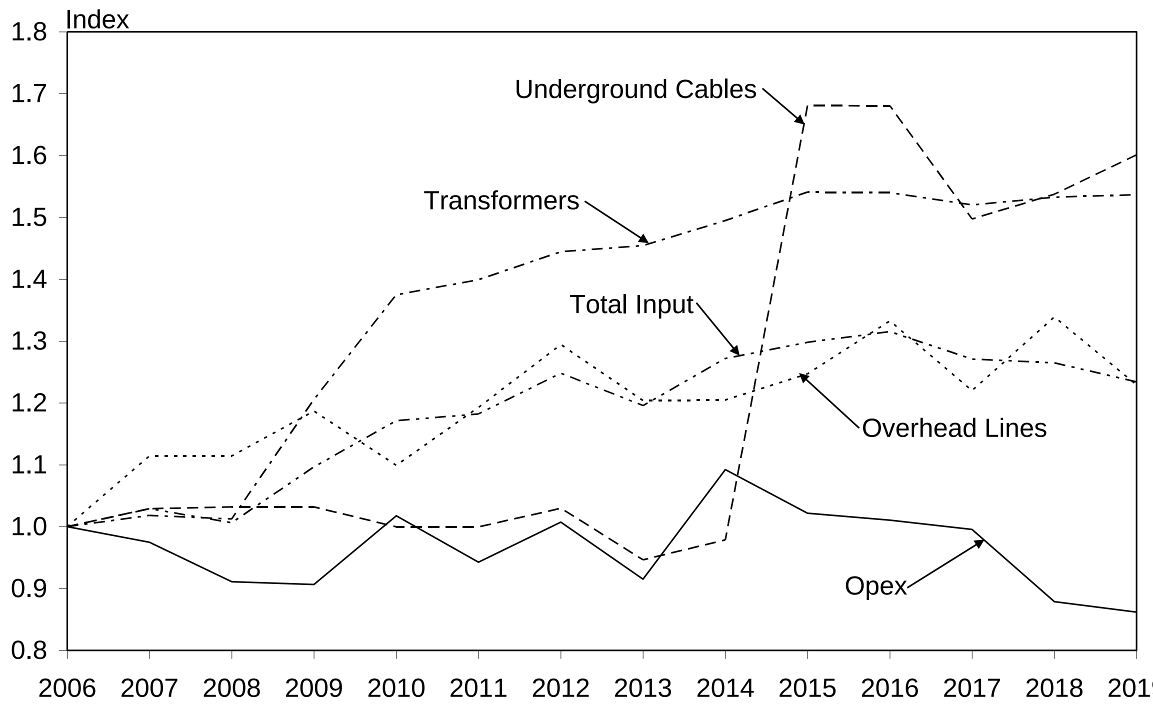
The output that increased the most over the period for TRG is end–user numbers with an increase of 16 per cent between 2006 and 2019, less than the increase of 19 per cent for the industry. TRG’s end–user numbers increase has been steady over the whole period, in line with NSW’s population growth.

The output that is not shown in figure 4.18 is total energy not supplied (ENS). TRG’s ENS fluctuated around its 2006 level through to 2014 before increasing sharply in both 2015 and 2016. In 2016 it was 10 times its 2006 level after having been less than its 2006 level in 2014. However, in 2017 ENS returned to 18 per cent below its 2006 level and in 2018 and 2019 to 52 and 41 per cent, respectively, below the 2006 level. TRG’s ENS levels also spiked higher in 2010 to be four times its 2006 level.

TRG’s total output index tends to lie close to the circuit length output index up to 2012 but falls below it after that as energy throughput drops lower but total output recovers in 2017 with the increase in energy and the large reduction in ENS that year. Total output has been relatively flat since 2017. Total output movements are also influenced by the pattern of movement in the ENS output in 2010 (noting that an increase in ENS has a negative impact on total output and is given an average weight of around 1.2 per cent of total revenue on average for TRG).

Turning to the input side, we present quantity indexes for TRG’s four input components and total input in figure 4.19. We see that TRG’s input quantity for overhead lines increased steadily up to 2012 before levelling off somewhat. It has tended to fluctuate somewhat depending on whether TRG has measured capacity at the time of summer, spring or winter peak, whichever is higher in the relevant year. Its underground cables input quantity increased by 68 per cent in 2015 although the length of underground cables increased from only 47 to 78 kilometres in that year. This input has a very small share of total costs.

Figure 4.19 **TRG’s input quantity indexes, 2006–2019**



The quantity of opex was the only one of TRG's four inputs to decrease over the 14–year period, being 14 per cent lower in 2019 than it was in 2006. Opex usage decreased by 9 per cent between 2006 and 2009 before then trending up through to 2014 and then falling in the last five years, including by a large 12.5 per cent in 2018. TRG's opex reduction between 2006 and 2019 of 14 per cent compares to a reduction for the industry of only 1 per cent. Opex has the second largest average share in TRG's total costs at 26 per cent.

The input component with the largest average share of TRG's total cost, at 44 per cent, is transformers. TRG's transformer input quantity increased more quickly from 2008 to 2010 before increasing more steadily through to 2015 and levelling off from 2016 onwards. By 2019 it was 54 per cent above its 2006 level – a somewhat larger increase than the industry's 49 per cent. Given its large share of total costs, transformer inputs are an important driver of the total input quantity index.

From figure 4.19 we see that TRG's total input quantity index generally lies close to the quantity index for overhead lines, above that for opex and below that for transformers.

TRG's output and input contributions to TFP change

In table 4.10 we first present the percentage point contributions of each output and each input to TRG's average annual rate of TFP change of –1.3 per cent over the 14–year period 2006 to 2019.

There are some minor differences in factors contributing to TRG's TFP growth compared to the industry results presented earlier in table 2.2. The main difference is that opex use makes a contribution of 0.3 percentage points to TRG's TFP whereas it has near zero impact for the industry. And, transformer input growth contributes –1.4 percentage points to TRG's TFP change compared to –1.2 percentage points for the industry, reflecting the faster growth in TRG's transformer input quantity.

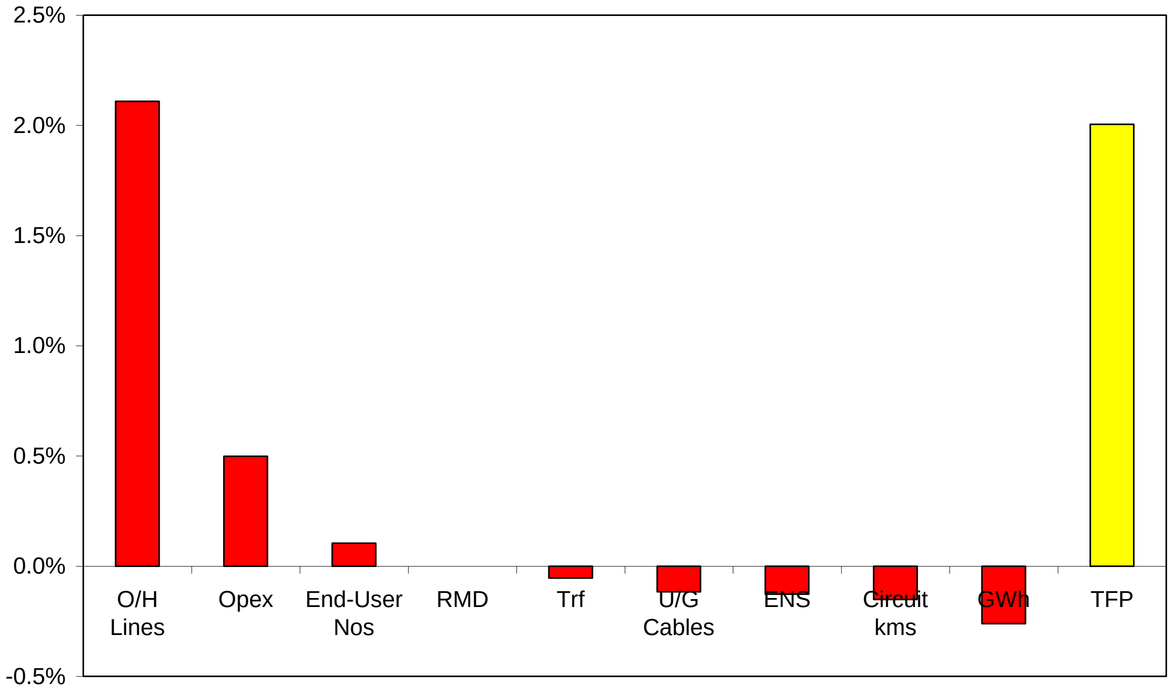
Table 4.10 **TRG's output and input percentage point contributions to average annual TFP change: 2006–2019, 2006–2012, 2012–2019, 2018–19**

Year	*2006 to 2019*	*2006 to 2012*	*2012 to 2019*	*2018–19*
Energy (GWh)	–0.11%	–0.16%	–0.06%	–0.26%
Ratcheted Max Demand	0.12%	0.27%	0.00%	0.00%
Customer Numbers	0.09%	0.07%	0.10%	0.10%
Circuit Length	0.17%	0.13%	0.21%	–0.15%
ENS	0.03%	–0.03%	0.07%	–0.13%
Opex	0.30%	0.00%	0.56%	0.50%
O/H Lines	–0.44%	–1.20%	0.20%	2.11%
U/G Cables	–0.12%	–0.02%	–0.19%	–0.12%
Transformers	–1.36%	–2.47%	–0.42%	–0.05%
TFP Change	–1.32%	–3.41%	0.48%	2.00%

Comparing the periods before 2012 and after 2012 in table 4.10, the main differences for TRG are that ENS goes from a marginal negative contribution before 2012 to a contribution of 0.1 percentage points after 2012. The contribution of transformers goes from –2.5 percentage points before 2012 to –0.4 after 2012 as growth in transformer inputs moderates.

And the contribution of overhead lines input changes from –1.2 percentage points before 2012 to 0.2 percentage points after 2012 as overhead lines input increased more rapidly in the earlier period before fluctuating in the more recent period depending on the season the peak has occurred in. And the contribution of ratcheted maximum demand goes from 0.3 percentage points before 2012 to zero after 2012. Overall, TFP average annual change improves from –3.4 per cent before 2012 to 0.5 per cent after 2012.

Figure 4.20 **TRG's output and input percentage point contributions to annual TFP change, 2018–19**



In figure 4.20 and table 2.10 we present the contributions of outputs and inputs to TRG's measured 2.0 per cent TFP change in the 2019 year. The reduction in reported overhead line capacity leads to it making the largest positive contribution to TFP change at 2.1 percentage points. The second largest positive contribution at 0.5 percentage points comes from the reduction in opex while the third largest positive contribution at 0.1 percentage points comes from end–users numbers growth. Negative contributions are made by the reduction in throughput at –0.3 percentage points and by increases in transformer inputs, underground cables and ENS, all at just more than –0.1 percentage points. TRG's TFP change of 2.0 per cent in 2019 was higher than TFP change for the industry as a whole which was –1.8 per cent. However, it should be noted that TRG's TFP growth in 2019 can be largely attributed to the shift in measuring the capacity of overhead lines input from a winter peak demand time in 2018 to a summer peak demand time in 2019. Without this change and assuming overhead lines input remained unchanged, TRG's TFP change in 2019 would have been –0.1 per cent[6]. While lower than the reported rate, this was still better performance than that for the industry as a whole. The issue of forming a more consistent basis for reporting line capacity over time will be further examined in next year's benchmarking report.

[6] We note that TRG reported a marginal change in overhead line length in 2019 of –0.3 per cent but a change in

APPENDIX A METHODOLOGY

A1 Time–series TFP

Productivity is a measure of the quantity of output produced from the use of a given quantity of inputs. Productivity is measured by constructing a ratio of output produced to inputs used. Productivity index number methods provide a ready way of aggregating output quantities into a measure of total output quantity and aggregating input quantities into a measure of total input quantity. For time–series analysis, the TFP index is the change in the ratio of total output quantity to total input quantity over time. The PFP index is the change in the ratio of total output quantity to the quantity of the relevant input over time.

To form the total output and total input measures we need a price and quantity for each output and each input, respectively. The quantities enter the calculation directly as it is changes in output and input quantities that we are aggregating. The relevant output and input prices are used to weight together changes in output quantities and input quantities into measures of total output quantity and total input quantity. Or, to put this another way, the TFP index is the ratio of the change in a weighted average of output quantities to the change in a weighted average of input quantities.

Different index number methods perform the aggregation and weighting in different ways. In previous TNSP benchmarking reports we have used the Fisher ideal index for time–series TFP analysis. This index is a member of a family of index number methods that have desirable properties such as providing second–order approximations to underlying technologies (see Economic Insights 2014). However, while these indexes satisfy a number of desirable properties for index numbers to be used in time–series analyses, they do not satisfy the property of transitivity – the property that the results of comparison of two observations should be the same regardless of whether the comparison is done directly or indirectly through other observations, as discussed further below. This is not normally an issue in time–series analysis where output and input quantities change in a non–erratic manner over time. However, the TNSP energy not supplied output has continued to exhibit very large annual percentage changes as first seen in 2009 and 2010 for ANT with its large one–off outage, but now also includes some TNSPs achieving close to or actually achieving perfect reliability in some years. The standard time–series indexes are less able to accurately capture the impact of these large percentage changes because they do not satisfy the transitivity property.

To provide improved accuracy in the face of these large ENS percentage changes (albeit generally from small bases) we change to using the multilateral Törnqvist index method used in our panel data comparisons for our TNSP productivity growth and contributions to growth analyses at both the industry and individual TNSP levels as well. This index does satisfy the transitivity property and is not subject to drifting following reliability variable spikes. This change means we now use the one index method throughout the report. For the productivity growth and contributions analyses the multilateral Törnqvist index is applied to the 14 annual

overhead line length capacity of –8.2 per cent.

time–series observations sample for the relevant TNSP or the industry as a whole whereas for the panel data comparisons the index is applied across the full sample of 70 observations.

A2 Multilateral TFP comparisons

Traditional measures of TFP, such as the Fisher ideal index and the Törnqvist index, have enabled comparisons to be made of *rates of change* of productivity between firms but have not enabled comparisons to be made of differences in the *absolute levels* of productivity in combined time series, cross section firm data. This is due to the failure of conventional TFP measures to satisfy the important technical property of transitivity. This property states that direct comparisons between observations *m* and *n* should be the same as indirect comparisons of *m* and *n* via any intermediate observation *k*.

Caves, Christensen and Diewert (1982) developed the multilateral Törnqvist TFP (MTFP) index measure to allow comparisons of the absolute levels as well as growth rates of productivity. It satisfies the technical properties of transitivity and characteristicity which are required to accurately compare TFP levels within panel data. 'Characteristicity' says that when comparing two observations, the index should use sufficient information relating to those two observations. The multilateral Törnqvist index satisfies these properties for the whole sample by making comparisons through the sample mean.

The Caves, Christensen and Diewert (CCD) multilateral Törnqvist index is given by:

$$\begin{aligned} \ln (TFP_m/TFP_n) = \; & \textstyle\sum_i (r_{im}+R_i^*) (\ln y_{im} - \ln Y_i^*)/2 - \\ & \textstyle\sum_i (r_{in}+R_i^*) (\ln y_{in} - \ln Y_i^*)/2 - \\ & \textstyle\sum_j (s_{jm}+S_j^*) (\ln x_{jm} - \ln X_j^*)/2 + \\ & \textstyle\sum_j (s_{jn}+S_j^*) (\ln x_{jn} - \ln X_j^*)/2 \end{aligned} \qquad (1)$$

where t and t–1 are adjoining time periods, there are N output quantities, y_i, r_i is the revenue weight given to output i, there are M input quantities, x_j, s_j is the share of input j in total cost, R_i^* (S_j^*) is the revenue (cost) share of the i–th output (j–th input) averaged over all utilities and time periods, ln is the natural logarithm operator and $\ln Y_i^*$ ($\ln X_j^*$) is the average of the natural logarithms of output i (input j). Transitivity is satisfied since comparisons between, say, two NSPs for 2009 will be the same regardless of whether they are compared directly or via, say, one of the NSPs in 2015. An alternative interpretation of this index is that it compares each observation to a hypothetical sample–average NSP with output vector Y_i^*, input vector X_j^*, revenue shares R_i^* and cost shares S_j^*.

Because the multilateral Törnqvist productivity indexes focus on preserving comparability of productivity levels across NSPs and over time by doing all comparisons through the sample mean, there may sometimes be minor changes in historical results as the sample is updated in each annual benchmarking report and, hence, the sample mean changes over time. This is a necessary trade–off for the MTFP index to satisfy the technical properties of transitivity and characteristicity which allow comparability of productivity levels across NSPs and over time.

A3 Output and input contributions to TFP change

The next task is to decompose TFP change into its constituent parts. Since TFP change is the change in total output quantity less the change in total input quantity, the contribution of an individual output (input) will depend on the change in the output's (input's) quantity and the weight it receives in forming the total output (total input) quantity index. However, this calculation has to be done in a way that is consistent with the index methodology to provide a decomposition that is consistent and robust. The multilateral Törnqvist index methodology allows us to readily decompose productivity change into the contributions of changes in each output and each input. The percentage point contribution of output i to productivity change between years *t* and *t–1* is given by the following equation:

(2) *Contribution of output i* $= (r_{i,t}+R_i^*)(\ln y_{i,t} - \ln Y_i^*)/2 - (r_{i,t-1}+R_i^*)(\ln y_{i,t-1} - \ln Y_i^*)/2$

And, the contribution of input *j* to productivity change between years t and t–1 is given by the following equation:

(3) *Contribution of input j* $= -(s_{j,t}+S_j^*)(\ln x_{j,t} - \ln X_j^*)/2 + (s_{j,t-1}+S_j^*)(\ln x_{j,t-1} - \ln X_j^*)/2$

where all variables in equations (2) and (3) have the same definition as those in equation (1).

Using these consistent equations ensures the sum of the percentage point contributions of all outputs and all inputs equals the rate of TFP change obtained in equation (1).

A4 Output weights

This study uses multi–output Leontief cost functions to estimate the output cost shares used in the index number methodology, using a similar procedure to that used in Lawrence (2003). This functional form essentially assumes that DNSPs use inputs in fixed proportions for each output and is given by:

$$(4) \qquad C(y^k, w^k, t) = \sum_{i=1}^{M} w_i^k \left[\sum_{j=1}^{N} (a_{ij})^2 y_j^k (1 + b_i t)\right]$$

where there are *M* inputs and *N* outputs, w_i is an input price, y_j is an output, *t* is a time trend representing technological change and there are *k* observations. The input/output coefficients a_{ij} are squared to ensure the non–negativity requirement is satisfied, ie increasing the quantity of any output cannot be achieved by reducing an input quantity. This requires the use of non–linear regression methods. To conserve degrees of freedom a common rate of technological change for each input across the four outputs was imposed but this can be either positive or negative.

The estimating equations were the *M* input demand equations:

(5) $$x_i^k = \sum_{j=1}^{N} (a_{ij})^2 y_j^k (1+b_i t)$$

where the *i*'s represent the *M* inputs, the *j*'s the *N* outputs and *t* is a time trend representing the 13 years, 2006 to 2018.

The input demand equations were estimated separately for each of the 5 TNSPs using the non–linear regression facility in Shazam (Northwest Econometrics 2007) and data for the years 2006 to 2018. Given the absence of cross equation restrictions, each input demand equation is estimated separately.

We then derive the estimated output cost shares, s_j^k, for each output *j* and each observation *k* from the 5 firm–specific cost functions as follows:

(6) $$s_j^k = \{\sum_{i=1}^{M} w_i^k [(a_{ij}^f)^2 y_j^k (1+b_i^f t)]\} / \{\sum_{i=1}^{M} w_i^k [\sum_{j=1}^{N} (a_{ij}^f)^2 y_j^k (1+b_i^f t)]\}$$

where *f*=1,..,5.

We then form a weighted average of the estimated output cost shares across all observations to form an overall estimated output cost share where the weight in the weighted average, g^k, for each observation, *k*, is given by that observation's estimated total cost divided by the overall sum of estimated total costs across all observations:

(7) $$g^k = C_f(b, y^k, w^k, t) / \sum_k C_f(b, y^k, w^k, t) .$$

APPENDIX B CORRECTED LEONTIEF REGRESSION RESULTS

TFP/MTFP models can be calculated on either a 'billed' output or a 'functional' output basis. The billed output basis only includes the outputs the firm directly charges customers for and the output weights used to form the total output quantity are then the revenue shares of the various billed outputs. This approach is appropriate for competitive industries where revenues can be expected to approximate the costs of providing the various outputs. However, many utilities provide a wider range of services and dimensions of output to customers than those they directly charge for. And, charges are usually implemented on the basis of convenience and historical precedence rather than being cost–reflective. For these industries, outputs in productivity analysis are specified on a functional basis which attempts to quantify the attributes valued by customers. This approach is also necessary where the firm's total revenue allowed by the regulator is designed to cover a wider range of activities than those the firm charges for, as is the case with building blocks regulation.

To form weights for the output quantities included, we can either do a detailed accounting exercise to allocate costs to each output quantity or else estimate the cost shares of each output econometrically. The accounting approach would be prohibitively resource intensive and would suffer from the usual cost allocation problems in any case. This leaves econometric estimation as the only tractable option.

TFP/MTFP indexes use total cost shares for aggregating output components into a measure of total output quantity. The partial productivity indexes measure movements in total output quantity relative to a particular input quantity such as opex and so generally use the same total cost shares applied to total output. This way the TFP index is effectively a weighted average of the various partial productivity indexes. To form the output cost shares we thus require data on the prices and quantities of all inputs, both operating and capital.

Economic Insights (2014, pp.28–29) illustrated how the Australian electricity NSP data at the time exhibited insufficient cross–sectional variation to support robust parameter estimation for the sample as a whole, including for more complex, second–order cost functions such as the translog. Instead, we have resorted to using much simpler cost function methods such as the Leontief which can be applied on an NSP by NSP basis.

The Leontief cost function methodology is relatively simplistic. It was outlined in section A4 and involves the estimation of 20 separate regressions – 4 input demand equations for each of the 5 TNSPs. The input demand equations cover opex, overhead lines, underground cables, and transformers. Each regression contains five parameters to be estimated – 4 input/output coefficients and a time trend coefficient. When the output shares were updated in Economic Insights (2017a), there were only 10 observations available per regression (ie 2006–2015). The Leontief model assumes there are fixed input proportions in each output. Stylistically, this can be thought of as fitting a right angle to the data rather than a smooth isoquant curve in two–dimensional space (ie in the case of two inputs and one output). As a result, the Leontief cost function will never produce impressive–looking statistical results. For a 4–output model we, as practitioners, would normally expect to get at least one significant output coefficient per regression equation, occasionally 2 significant and, on very rare occasions, 3 significant coefficients – see, for example, Lawrence (2003) where this methodology was first applied. The statistical performance of a simple fixed proportions model cannot be judged by the same standards we would use for fitting smooth functions such as the Cobb–Douglas or translog.

As noted in section 1.1, a report submitted to one of the AER's distribution determinations has identified a coding error in the formation of the time trend variables included in the regressions from which the four non–reliability output weights are derived (Frontier Economics 2019, p.11). This error was also carried across to the earlier TNSP analysis. The time trends should have a common base or starting point for each TNSP and, by implication, for each of the 20 separate regressions. In Economic Insights (2014) (which used data covering the 8 years 2006 to 2013) and in Economic Insights (2017a) (which used data covering the 10 years 2006 to 2015) instead of resetting the time trend to a common base for the observations applying to each TNSP, the time trend was mistakenly formed over the entire sample. Thus, in the case of Economic Insights (2017a), for example, instead of the time trend running from 1 to 10 for the annual observations for all TNSPs, the time trend ran from 1 to 10 for the first TNSP in the database, from 11 to 20 for the second TNSP and so on. Because the models are non–linear, this could have a distorting effect on the results obtained. This issue is corrected in the results presented here.

The Leontief cost function TNSP regressions are presented in tables B1 to B5. In terms of output coefficients, 11 of the 20 regressions have one significant output coefficient, 4 have two significant output coefficients and 2 have 3 significant output coefficients.[7] The energy throughput output is significant in 8 of the regressions, including 3 of the opex input demand equations.

All but two of the time trend coefficients lie well within a reasonable range, taken to be –10 per cent to 10 per cent per annum as suggested in FE (2019). If the underground cable input demand equations are excluded, the range is –3.94 per cent to 4.00 per cent. Since we observe very large percentage changes in underground cable capacities starting from (and remaining at) extremely small lengths, some larger time trend coefficients for underground cable capacities are to be expected. The time trend coefficients in the corrected model are considerably more reasonable than those in the uncorrected model of Economic Insights (2017a) where, by contrast, 10 lie outside the suggested range.

All the input demand equations converge readily, generally in well under 300 iterations from starting values of 0.001.

The input demand equation (equation (5) in appendix A4 above) estimation results are presented in tables B1 to B5 for each of the four inputs for each of the 5 TNSPs.

[7] t–statistic greater than 1.86 in absolute value with 8 degrees of freedom and 95 per cent confidence level.

Table B1: **ENT Leontief cost function regression results**

Variable	*OpEx*		*O/H Lines*		*U/G Cables*		*Transformers*	
	Coef	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*
Energy	0.658	1.42	0.000	0.00	0.244	1.42	0.375	4.60
RMD	0.000	0.00	2.934	0.41	0.227	0.47	–0.675	–1.36
Customer No	0.148	0.91	0.954	3.43	0.000	0.00	0.000	0.00
Circuit Length	2.027	1.07	13.668	7.61	0.000	0.00	–0.923	–3.27
Time	0.027	2.21	–0.002	–0.85	1.541	0.66	0.034	7.71

Table B2: **PLK Leontief cost function regression results**

Variable	*OpEx*		*O/H Lines*		*U/G Cables*		*Transformers*	
	Coef	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*
Energy	–1.112	–3.48	0.000	0.00	0.000	0.00	0.000	0.00
RMD	0.000	0.00	0.000	0.00	0.000	0.00	0.523	0.70
Customer No	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
Circuit Length	2.177	3.22	23.933	210.29	0.705	75.27	1.347	4.78
Time	0.007	1.04	0.009	6.73	0.005	1.41	0.032	4.55

Table B3: **ANT Leontief cost function regression results**

Variable	*OpEx*		*O/H Lines*		*U/G Cables*		*Transformers*	
	Coef	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*
Energy	–1.113	–5.81	–2.800	–8.65	0.338	82.15	0.231	2.86
RMD	0.000	0.00	2.316	7.76	0.000	0.00	0.528	4.19
Customer No	0.041	0.42	0.000	0.00	0.000	0.00	0.000	0.00
Circuit Length	0.000	0.00	29.523	123.27	0.000	0.00	–1.660	–21.85
Time	–0.003	–0.41	–0.001	–7.20	–0.015	–4.59	0.011	11.73

Table B4: **TNT Leontief cost function regression results**

Variable	*OpEx*		*O/H Lines*		*U/G Cables*		*Transformers*	
	Coef	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*
Energy	–1.646	–4.04	0.000	0.00	0.000	0.00	–0.057	–0.08
RMD	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
Customer No	0.188	1.07	1.058	4.01	0.000	0.00	0.152	11.61
Circuit Length	0.000	0.00	11.639	6.69	0.544	8.94	0.000	0.00
Time	–0.039	–8.60	0.009	3.35	0.208	2.76	0.015	4.10

Table B5: **TRG Leontief cost function regression results**

Variable	*OpEx*		*O/H Lines*		*U/G Cables*		*Transformers*	
	Coef	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*
Energy	0.000	0.00	3.588	1.02	0.580	2.60	0.000	0.00
RMD	0.808	0.17	19.369	6.58	0.000	0.00	–1.431	–53.68
Customer No	0.000	0.00	0.000	0.00	0.018	0.10	0.000	0.00
Circuit Length	2.901	1.46	0.000	0.00	0.000	0.00	0.000	0.00
Time	–0.003	–0.78	0.016	2.65	0.084	1.82	0.040	6.20

APPENDIX C REGRESSION–BASED TREND GROWTH RATES

Table C1 **Transmission output, input, total factor productivity and partial productivity index trend annual growth rates, 2006–2019**

TNSP	*Output*	*Input*	*TFP*	*PFP Index*	
Period	*Index*	*Index*	*Index*	*Opex*	*Capital*
Industry					
Growth Rate 2006–19	0.64%	1.89%	–1.25%	0.31%	–1.84%
Growth Rate 2006–12	1.09%	3.21%	–2.12%	0.22%	–3.05%
Growth Rate 2012–19	0.34%	0.62%	–0.27%	0.92%	–0.71%
ANT					
Growth Rate 2006–19	0.40%	0.47%	–0.07%	0.63%	–0.29%
Growth Rate 2006–12	1.47%	0.89%	0.58%	0.96%	0.45%
Growth Rate 2012–19	–0.13%	0.44%	–0.57%	0.05%	–0.77%
ENT					
Growth Rate 2006–19	0.08%	2.39%	–2.30%	–2.46%	–2.23%
Growth Rate 2006–12	–0.27%	2.42%	–2.68%	–2.86%	–2.60%
Growth Rate 2012–19	0.21%	1.46%	–1.25%	–1.96%	–0.91%
PLK					
Growth Rate 2006–19	1.58%	2.89%	–1.30%	0.14%	–1.88%
Growth Rate 2006–12	2.55%	4.23%	–1.68%	1.67%	–2.98%
Growth Rate 2012–19	0.85%	1.33%	–0.47%	–0.14%	–0.64%
TNT					
Growth Rate 2006–19	0.27%	0.04%	0.24%	5.70%	–1.88%
Growth Rate 2006–12	–0.01%	2.51%	–2.52%	–0.96%	–3.40%
Growth Rate 2012–19	0.58%	–1.92%	2.50%	10.11%	–0.06%
TRG					
Growth Rate 2006–19	0.26%	1.99%	–1.74%	0.51%	–2.57%
Growth Rate 2006–12	0.31%	3.91%	–3.60%	0.07%	–5.05%
Growth Rate 2012–19	0.44%	0.26%	0.19%	2.33%	–0.56%

APPENDIX D IMPACT OF METHODOLOGY UPDATES

In this appendix we present information on the impact of the methodology updates contained in this report. Industry level productivity index and panel data multilateral MTFP results for 2006 to 2019 are presented for a number of cases:

- tables D1.1 and D1.2 use the methodology in Economic Insights (2019)
- tables D2.1 and D2.2 use the Economic Insights (2019) methodology but with the revised output weights included
- tables D3.1 and D3.2 use the Economic Insights (2019) methodology but with the revised treatment of the reliability output included, and
- table D4 uses the Economic Insights (2019) methodology but with the revised index number method included.

Each of the methodology updates are added to the methodology used in Economic Insights (2019) separately, rather than added in sequentially, to maximise clarity and the scope for like–with–like comparisons.

Table D1.1 **Industry–level transmission output, input and total factor productivity and partial productivity indexes, 2006–2019, using the Economic Insights (2019) methodology**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.007	1.023	0.984	1.005	0.976
2008	1.022	1.038	0.985	1.025	0.968
2009	0.971	1.107	0.877	0.951	0.848
2010	1.054	1.152	0.915	0.985	0.887
2011	1.060	1.161	0.913	1.041	0.868
2012	1.056	1.204	0.877	1.008	0.832
2013	1.059	1.205	0.879	1.051	0.823
2014	1.064	1.247	0.853	0.976	0.812
2015	1.064	1.273	0.836	0.966	0.793
2016	1.049	1.291	0.812	0.937	0.771
2017	1.095	1.278	0.857	0.987	0.814
2018	1.092	1.247	0.876	1.117	0.802
2019	1.077	1.252	0.860	1.089	0.789
Growth Rate 2006–19	0.57%	1.73%	–1.16%	0.66%	–1.82%
Growth Rate 2006–12	0.91%	3.09%	–2.19%	0.13%	–3.07%
Growth Rate 2012–19	0.28%	0.56%	–0.28%	1.11%	–0.75%

Table D1.2 **TNSP multilateral total factor productivity indexes, 2006–2019, using the Economic Insights (2019) methodology**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
ENT	1.000	0.976	0.986	0.971	0.933	0.890	0.845
PLK	0.872	0.803	0.837	0.757	0.795	0.788	0.773
ANT	0.829	0.912	0.843	0.734	0.886	0.926	0.877
TNT	0.880	0.950	0.922	0.865	0.877	0.823	0.860
TRG	0.996	0.961	1.006	0.897	0.838	0.849	0.794

Year	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
ENT	0.818	0.806	0.828	0.748	0.805	0.758	0.785
PLK	0.748	0.714	0.705	0.712	0.697	0.748	0.773
ANT	0.901	0.904	0.832	0.824	0.927	0.914	0.798
TNT	0.803	0.872	0.953	0.916	0.970	1.011	0.981
TRG	0.824	0.785	0.753	0.721	0.808	0.822	0.840

Table D2.1 **Industry–level transmission output, input and total factor productivity and partial productivity indexes, 2006–2019, using the Economic Insights (2019) methodology with revised output weights included**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.007	1.023	0.985	1.005	0.976
2008	1.024	1.038	0.987	1.027	0.970
2009	0.973	1.107	0.878	0.952	0.849
2010	1.056	1.152	0.917	0.987	0.889
2011	1.064	1.161	0.916	1.044	0.871
2012	1.060	1.204	0.881	1.012	0.835
2013	1.067	1.205	0.886	1.060	0.829
2014	1.076	1.247	0.862	0.987	0.821
2015	1.070	1.273	0.840	0.971	0.796
2016	1.054	1.291	0.816	0.941	0.775
2017	1.095	1.278	0.857	0.987	0.814
2018	1.093	1.247	0.877	1.118	0.803
2019	1.076	1.252	0.859	1.088	0.788
Growth Rate 2006–19	0.56%	1.73%	–1.17%	0.65%	–1.83%
Growth Rate 2006–12	0.98%	3.09%	–2.11%	0.20%	–3.00%
Growth Rate 2012–19	0.21%	0.56%	–0.36%	1.04%	–0.82%

Table D2.2 **TNSP multilateral total factor productivity indexes, 2006–2019, using the Economic Insights (2019) methodology with revised output weights included**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
ENT	1.000	0.980	0.998	0.975	0.935	0.891	0.844
PLK	0.838	0.773	0.810	0.735	0.774	0.771	0.755
ANT	0.696	0.772	0.712	0.618	0.745	0.778	0.736
TNT	0.957	1.014	0.977	0.913	0.922	0.864	0.905
TRG	0.886	0.854	0.894	0.797	0.746	0.757	0.710

Year	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
ENT	0.816	0.806	0.829	0.745	0.798	0.765	0.779
PLK	0.737	0.708	0.691	0.697	0.679	0.725	0.750
ANT	0.753	0.756	0.693	0.685	0.773	0.768	0.667
TNT	0.845	0.912	0.999	0.969	1.019	1.062	1.026
TRG	0.742	0.708	0.673	0.645	0.721	0.731	0.747

Table D3.1 **Industry–level transmission output, input and total factor productivity and partial productivity indexes, 2006–2019, using the Economic Insights (2019) methodology with revised treatment of the reliability output included**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.010	1.023	0.988	1.008	0.979
2008	1.023	1.038	0.986	1.026	0.969
2009	0.996	1.107	0.899	0.975	0.869
2010	1.067	1.152	0.926	0.997	0.898
2011	1.073	1.161	0.924	1.054	0.878
2012	1.069	1.204	0.888	1.020	0.842
2013	1.072	1.205	0.890	1.065	0.833
2014	1.077	1.247	0.863	0.988	0.822
2015	1.080	1.273	0.848	0.981	0.804
2016	1.071	1.291	0.830	0.957	0.787
2017	1.112	1.278	0.870	1.002	0.827
2018	1.109	1.247	0.889	1.134	0.814
2019	1.095	1.252	0.875	1.108	0.803
Growth Rate 2006–19	0.70%	1.73%	–1.03%	0.79%	–1.69%
Growth Rate 2006–12	1.11%	3.09%	–1.98%	0.33%	–2.87%
Growth Rate 2012–19	0.35%	0.56%	–0.21%	1.18%	–0.68%

Table D3.2 **TNSP multilateral total factor productivity indexes, 2006–2019, using the Economic Insights (2019) methodology with revised treatment of the reliability output included**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
ENT	1.000	0.976	0.984	0.971	0.945	0.908	0.853
PLK	0.873	0.836	0.838	0.780	0.793	0.789	0.770
ANT	0.837	0.911	0.875	0.816	0.882	0.915	0.881
TNT	0.913	0.954	0.923	0.881	0.881	0.842	0.865
TRG	0.993	0.961	1.003	0.897	0.840	0.848	0.793

Year	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
ENT	0.830	0.814	0.828	0.781	0.805	0.757	0.786
PLK	0.744	0.715	0.704	0.706	0.696	0.747	0.759
ANT	0.902	0.902	0.862	0.861	0.916	0.907	0.831
TNT	0.840	0.874	0.954	0.916	0.971	1.010	0.982
TRG	0.823	0.782	0.758	0.741	0.806	0.818	0.836

Table D4 **Industry–level transmission output, input and total factor productivity and partial productivity indexes, 2006–2019, using the Economic Insights (2019) methodology with revised index number method included**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.008	1.022	0.987	1.006	0.979
2008	1.025	1.035	0.990	1.028	0.976
2009	0.984	1.104	0.891	0.963	0.862
2010	1.057	1.149	0.920	0.988	0.893
2011	1.064	1.157	0.920	1.045	0.875
2012	1.061	1.200	0.884	1.013	0.839
2013	1.068	1.199	0.890	1.060	0.833
2014	1.078	1.240	0.869	0.989	0.825
2015	1.069	1.267	0.844	0.971	0.799
2016	1.052	1.285	0.819	0.940	0.776
2017	1.100	1.271	0.865	0.990	0.820
2018	1.099	1.241	0.886	1.124	0.809
2019	1.077	1.245	0.865	1.089	0.792
Growth Rate 2006–19	0.57%	1.69%	–1.12%	0.66%	–1.79%
Growth Rate 2006–12	0.99%	3.04%	–2.05%	0.21%	–2.93%
Growth Rate 2012–19	0.22%	0.53%	–0.32%	1.04%	–0.82%

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