Σ ECONOMIC *i* INSIGHTS Pty Ltd

Economic Benchmarking Results for the Australian Energy Regulator's 2018 TNSP Annual Benchmarking Report

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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

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 2017 TNSP Benchmarking Report (AER 2017). 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 2016–17 financial and March years (as relevant) reported by the TNSPs in their latest Economic Benchmarking Regulatory Information Notice (EBRIN) returns.

1.1 Specification used for productivity measurement

In 2017 the AER undertook a review of output and input specification used for measuring TNSP productivity. Following assessment of the issues, Economic Insights (2017a) recommended making the following three changes to the TNSP economic benchmarking model that had been used prior to that:

1) substitution of jurisdictional end–user numbers for the original voltage–weighted connections output
2) adoption of revised output cost share weights derived from a Leontief cost function model applied to data for the 2006 to 2015 period, and
3) application of a cap of 5.5 per cent of gross revenue on the output share of energy not served with the cap being achieved by changes in the price of energy not served rather than its quantity.

Results presented in AER (2017) and Economic Insights (2017b) used the revised specification and that specification is again used in this report. The TNSP MTFP and TFP measures thus include five outputs:

- Energy throughput (with 23.1 per cent share of gross revenue)
- Ratcheted maximum demand (with 19.4 per cent share of gross revenue)
- End–user numbers (with 19.9 per cent share of gross revenue)
- Circuit length (with 37.6 per cent share of gross revenue), and
- (minus) Minutes off–supply (with the weight based on current AEMO VCRs capped at a maximum absolute value of 5.5 per cent of gross revenue).

The TNSP MTFP and TFP measures include four inputs:

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

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

The 2016 and 2017 years have seen increased volatility in TNSP reliability relative to earlier periods. Although this volatility is around already high levels of reliability (and, hence, low levels of energy not supplied), it can have a material impact on measured productivity growth rates. As a result, in this report we present separate output and TFP indexes that include and exclude the reliability output for information. The multilateral productivity and the contributions to TFP growth analyses all include 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, 2006–2017**

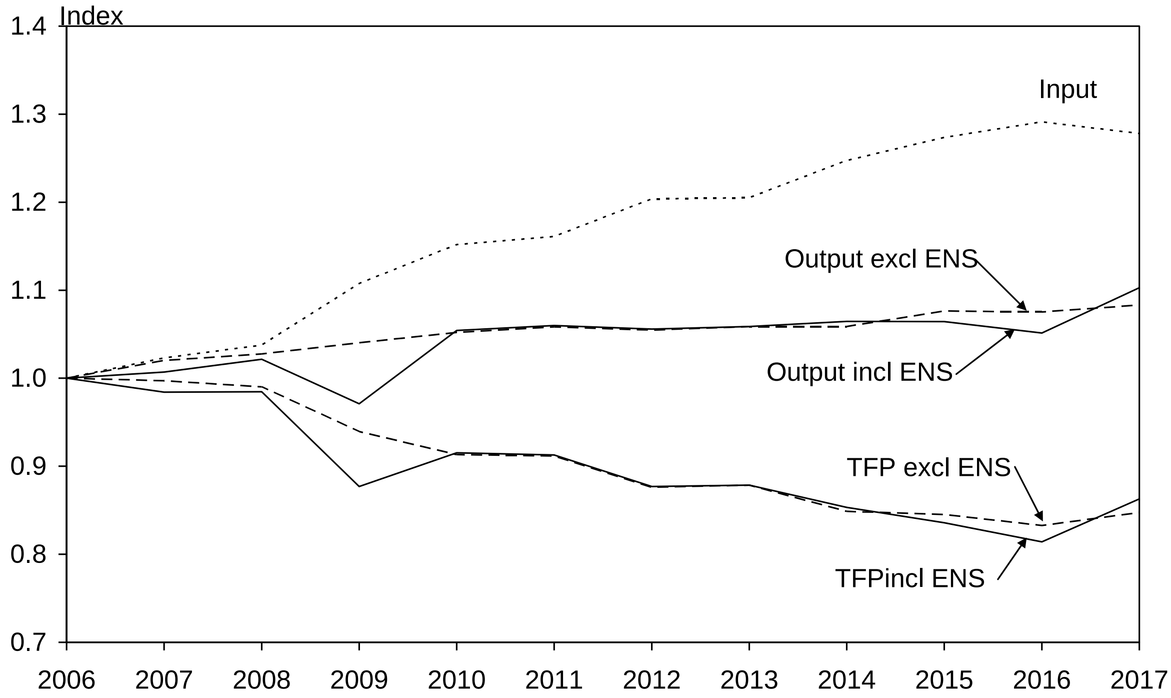


Table 2.1 **Industry–level transmission output, input and total factor productivity and partial productivity indexes, 2006–2017**

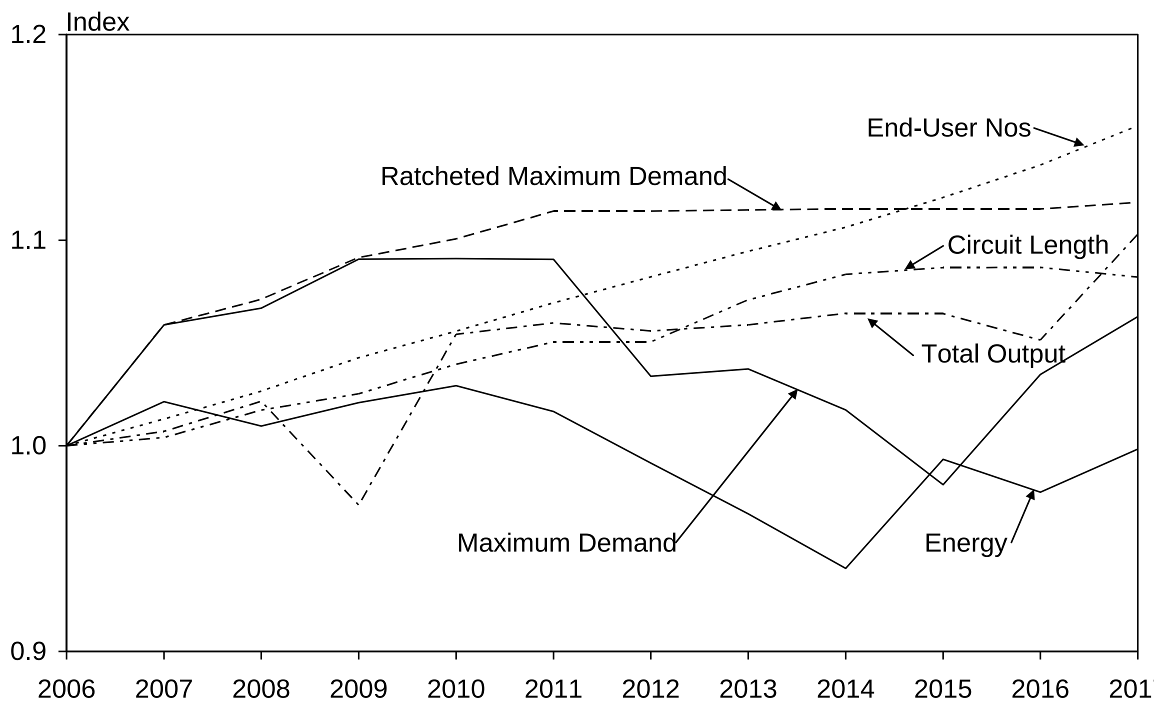
Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index Opex*	*PFP Index Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.007	1.023	0.984	1.005	0.976
2008	1.022	1.038	0.985	1.025	0.968
2009	0.971	1.107	0.877	0.951	0.848
2010	1.054	1.152	0.915	0.985	0.887
2011	1.060	1.161	0.913	1.041	0.868
2012	1.056	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	1.051	1.291	0.814	0.939	0.773
2017	1.103	1.278	0.863	0.993	0.820
Growth Rate 2006–17	0.89%	2.23%	–1.34%	–0.06%	–1.81%
Growth Rate 2006–12	0.91%	3.09%	–2.19%	0.13%	–3.07%
Growth Rate 2012–17	0.87%	1.20%	–0.32%	–0.28%	–0.29%

Over the 12–year period 2006 to 2017, industry level TFP declined with an average annual rate of change of –1.3 per cent. Although total output increased by an average annual rate of 0.9 per cent, total input use increased faster, at a rate of 2.2 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 four years – 2008, 2010, 2013 and 2017. 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 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.

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 six 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.

Figure 2.2 **Industry–level transmission output quantity indexes, 2006–2017**



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 2017 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 more 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 2017 has still been higher than the growth in distribution network length over the period which was only 4 per cent, likely reflecting the requirement for transmission to connect new generation sources.

The output that increased the most over the period is end–user numbers with an increase of 16 per cent between 2006 and 2017. 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 and has only partially recovered since then. In 2017 transmission energy throughput was marginally less than it was in 2006.

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 again in 2014 and 2015. This fall in maximum demand and energy throughout since around 2009 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.

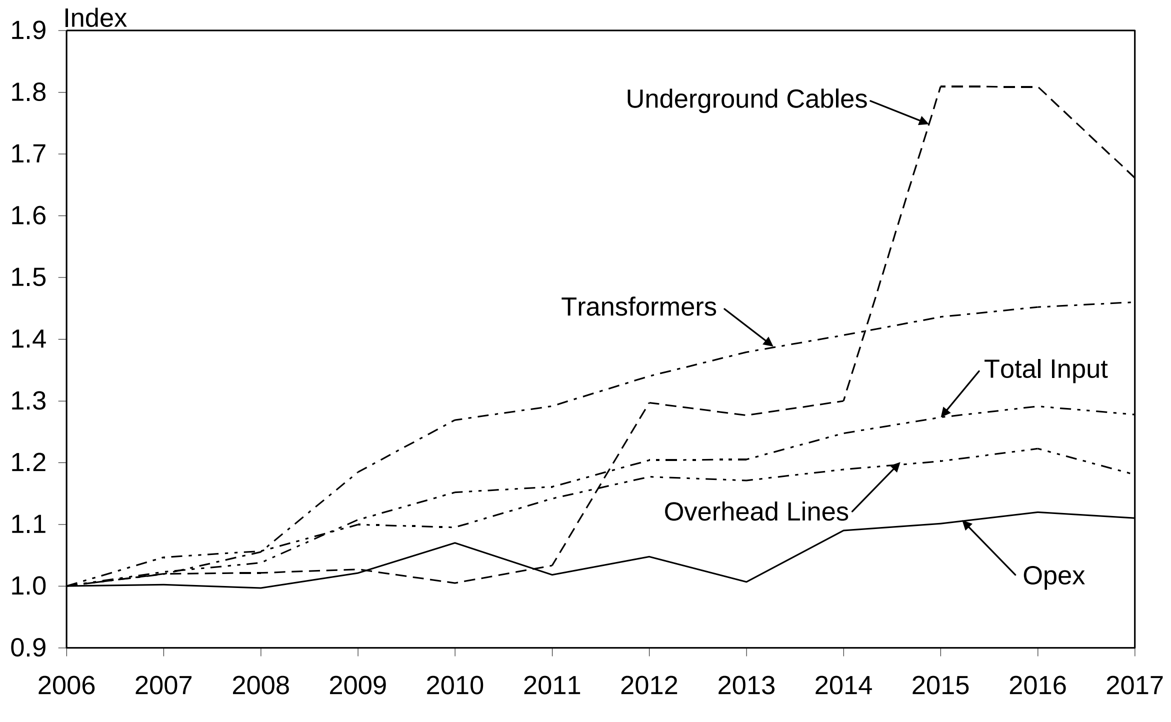
Ratcheted maximum demand increased at a similar rate to maximum demand up to 2009, increased at a slower rate in 2010 and has been relatively flat since 2011. We do observe some small increases in this output since 2009 as it is the sum of ratcheted maximum demands across the five TNSPs and maximum demand for some TNSPs increased above earlier peaks in some years even though aggregate maximum demand is still below its 2009 peak. In 2017 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 it spiked upwards in 2009 associated with a transformer failure at ANT’s South Morang Terminal Station. 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. However, ENS again increased in 2015 and 2016 before falling sharply in 2017. In 2017 ENS was only 31 per cent of the level it had been in 2006. However, the previous year it had been 180 per cent higher than it was 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, end–user numbers and energy throughput outputs receive a combined weight of around 80 per cent of gross 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 end–user numbers 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 2 per cent of gross revenue on average), particularly in 2009 and again in 2016 and 2017. However, the impact of these ENS events on total output is smaller than under the original specification given the capping of this output's weight in the current specification.

Figure 2.3 **Industry–level transmission input quantity indexes, 2006–2017**



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 12–year period, being 11 per cent higher in 2017. 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 marginally in 2017. 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

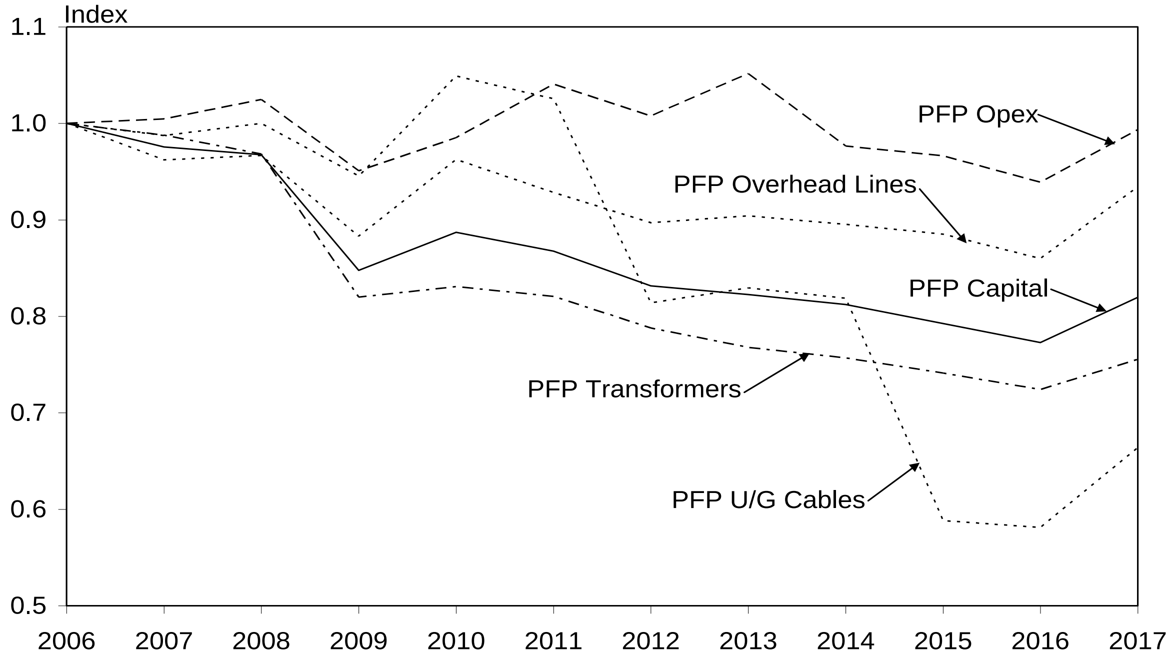
2017 was 46 per cent above its 2006 level. Given its large share of total costs, transformer inputs is an important driver of the total input quantity index.

The next key component of TNSP input is the quantity of overhead lines. This input quantity increased the second least over the period, being 18 per cent higher in 2017 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 30 per cent of total TNSP costs on average.

The fastest growing input quantity is that of underground cables whose quantity was 66 per cent higher in 2017 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 so the starting point 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.

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 70 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.

Figure 2.4 **Industry–level transmission partial productivity indexes, 2006–2017**



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 34 per cent lower in 2017 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 24 per cent lower in 2017 than in 2006. Opex partial productivity declined the least. In 2013 opex partial productivity was 5 per cent above its 2006 level but by 2016 it had fallen to be 6 per cent below its 2006 level before recovering in 2017 to be at around the same level 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[1].

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 –1.3 per cent over the 12–year period 2006 to 2017. In figure 2.6 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 12–year period. Circuit length increased at an average annual rate of 0.7 per cent – less than the rates for end–user numbers and RMD – but it receives a weight of around 38 per cent in total output so it makes the highest contribution to TFP change at 0.3 percentage points.

The second highest contribution to TFP change comes from end–user numbers which have grown steadily by 1.3 per cent annually over the whole period as end–user numbers generally

[1] The contribution analysis presented in this report is based on time–series Törnqvist TFP indexes, not MTFP.

increase in line with population growth. As end–user numbers receive a weight of 20 per cent but have the highest growth rate of the output components, they contribute just under 0.3 percentage points to TFP change over the period.

Figure 2.5 **Transmission industry output and input percentage point contributions to average annual TFP change, 2006–2017**

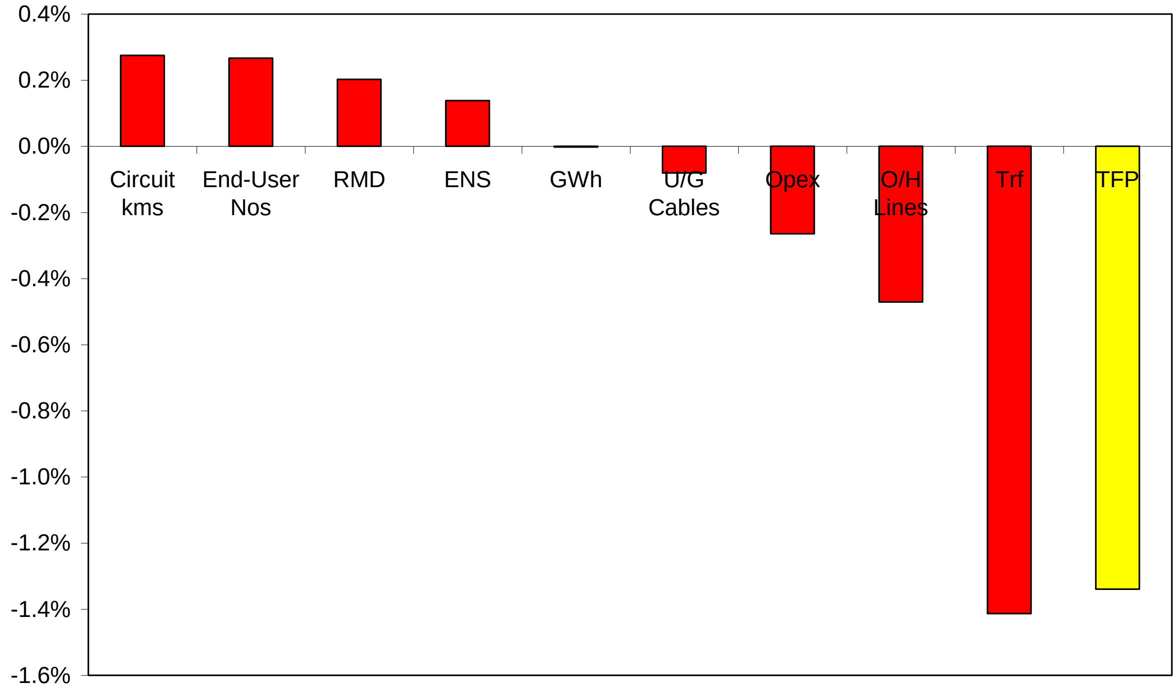


Table 2.2 **Transmission industry output and input percentage point contributions to average annual TFP change: 2006–2017, 2006–2012 and 2012–2017**

Year	*2006 to 2017*	*2006 to 2012*	*2012 to 2017*
Energy (GWh)	0.00%	–0.03%	0.03%
Ratcheted Max Demand	0.20%	0.36%	0.02%
Customer Numbers	0.27%	0.27%	0.27%
Circuit Length	0.28%	0.32%	0.23%
ENS	0.15%	–0.01%	0.33%
Opex	–0.26%	–0.20%	–0.34%
O/H Lines	–0.47%	–0.84%	–0.03%
U/G Cables	–0.08%	–0.07%	–0.09%
Transformers	–1.41%	–1.97%	–0.74%
TFP Change	–1.34%	–2.19%	–0.32%

Ratcheted maximum demand, despite flattening out after 2011, had the second highest average annual output growth rate over the period of 1.0 per cent. Combined with its weight of around 20 per cent, this led to RMD contributing 0.2 percentage points to TFP change over the period.

Since energy throughput ended the 12–year period at around the same level it started the period, it made no contribution to TFP change.

The ENS output receives a weight of only around minus 2 per cent in the total output index but, combined with an average annual change of –10.7 per cent, contributed 0.1 percentage points to average annual TFP change (ie the decrease in ENS increases output).

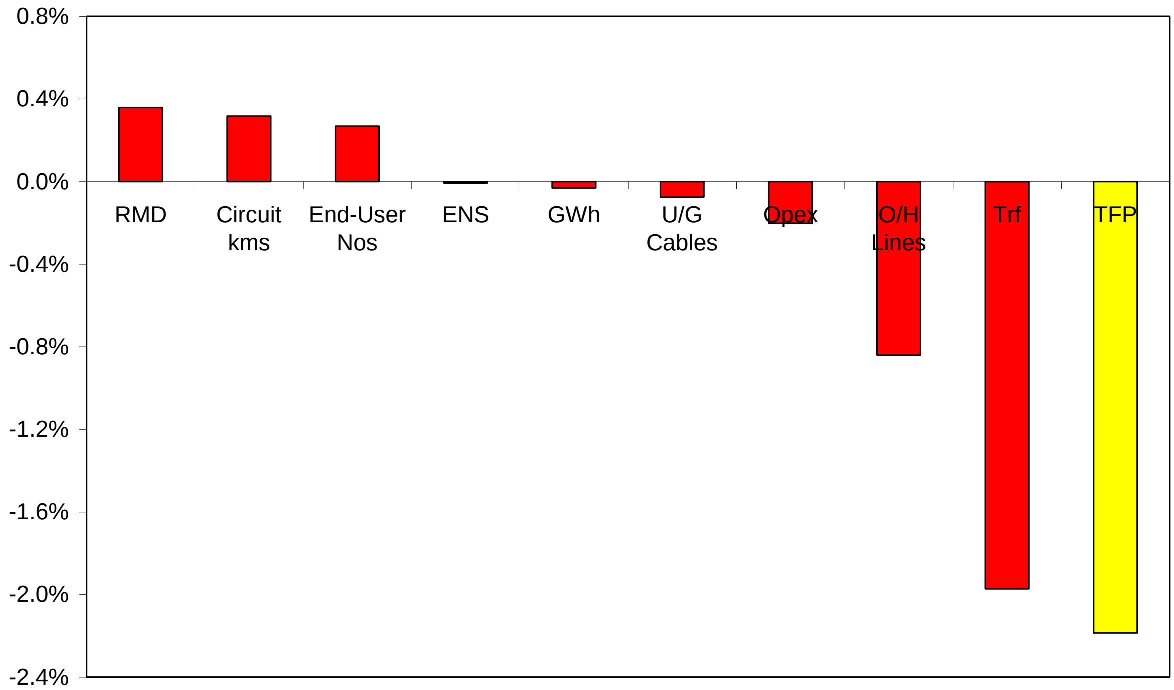
All four inputs made negative contributions to average annual TFP change. That is, the use of all four inputs increased over the 12–year period. The two inputs with the largest shares in the total input index are overhead lines and transformers with shares of 42 per cent and 30 per cent, respectively. Since transformers have the second highest input average annual growth rate at 3.4 per cent, they make the largest negative contribution to TFP change at –1.4 percentage points.

Overhead lines has a lower average annual growth rate at 1.5 per cent and, when combined with its 30 per cent share of total inputs, it makes the second most negative contribution to TFP change at –0.5 percentage points.

Opex has the lowest average annual input growth rates of 1.0 per cent. But combined with its weight in total input of 27 per cent, it has the third most negative contribution to TFP change at –0.3 percentage points.

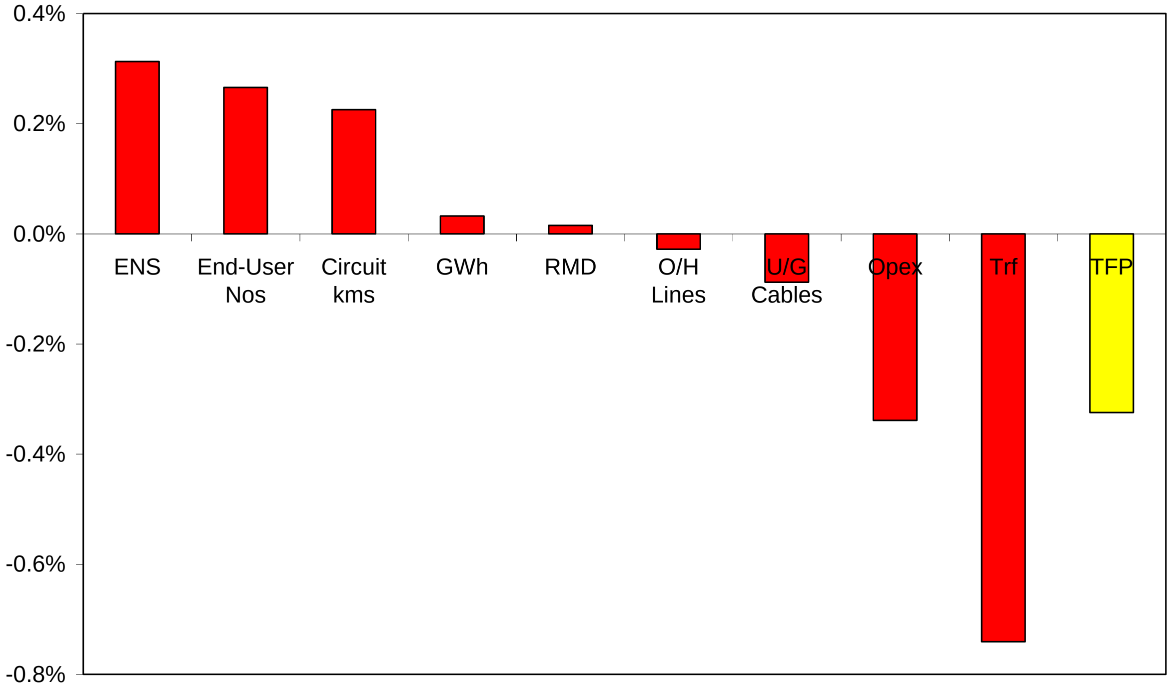
Despite having the highest input average annual growth rate of 4.6 per cent, underground subtransmission cables only have a weight of 2 per cent in total inputs and so make the least negative contribution to TFP change of the four inputs at –0.1 percentage points.

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 slightly more negative at –2.2 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 one minor exception. The contributions from the transformers and overhead lines were both somewhat more negative in the period up to 2012 at –2.0 percentage points and –0.8 percentage points, respectively.

Figure 2.7 Transmission industry output and input percentage point contributions to average annual TFP change, 2012–2017



Contributions to average annual TFP change for the period from 2012 to 2017 are presented in figure 2.7 and table 2.2. Average annual TFP change improves for this period with a growth rate of –0.3 per cent. The most significant change relative to the earlier period is the contribution of ENS to TFP change which has changed from being a marginally negative contributor up to 2012 to being the most positive contributor after 2012. For the period since 2012 it has contributed 0.3 percentage points to TFP change. As noted above, ENS increased significantly in 2015 and 2016 but then fell sharply in 2017.

At the same time, the contribution of the RMD output falls from 0.4 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 transformer 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 –0.1. 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 2017.

Table 2.3 Transmission industry output and input annual changes, 2006–2017

Year	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
GWh	2.1%	–1.2%	1.1%	0.8%	–1.2%	–2.5%	–2.5%	–2.8%	5.5%	–1.6%	2.1%
RMD	5.7%	1.2%	1.9%	0.8%	1.2%	0.0%	0.1%	0.0%	0.0%	0.0%	0.3%
EndUs	1.3%	1.3%	1.6%	1.2%	1.3%	1.2%	1.1%	1.1%	1.3%	1.4%	1.7%
Kms	0.4%	1.3%	0.8%	1.4%	1.0%	0.0%	1.9%	1.2%	0.3%	0.0%	–0.4%
ENS	55%	–29%	162%	-202%	5%	2%	7%	–44%	102%	45%	-222%
Opex	0.2%	–0.5%	2.4%	4.7%	–5.0%	2.8%	–4.0%	7.9%	1.0%	1.7%	–0.9%
O/H	4.6%	1.0%	4.0%	–0.4%	4.2%	3.0%	–0.5%	1.5%	1.1%	1.7%	–3.5%
U/G	2.0%	0.2%	0.6%	–2.2%	2.8%	22.7%	–1.6%	1.8%	33.0%	0.0%	–8.5%
Trform	1.9%	3.4%	11.6%	6.9%	1.8%	3.7%	2.9%	2.0%	2.1%	1.1%	0.6%

Table 2.4 Transmission industry output and input percentage point contributions to annual TFP change, 2006–2017

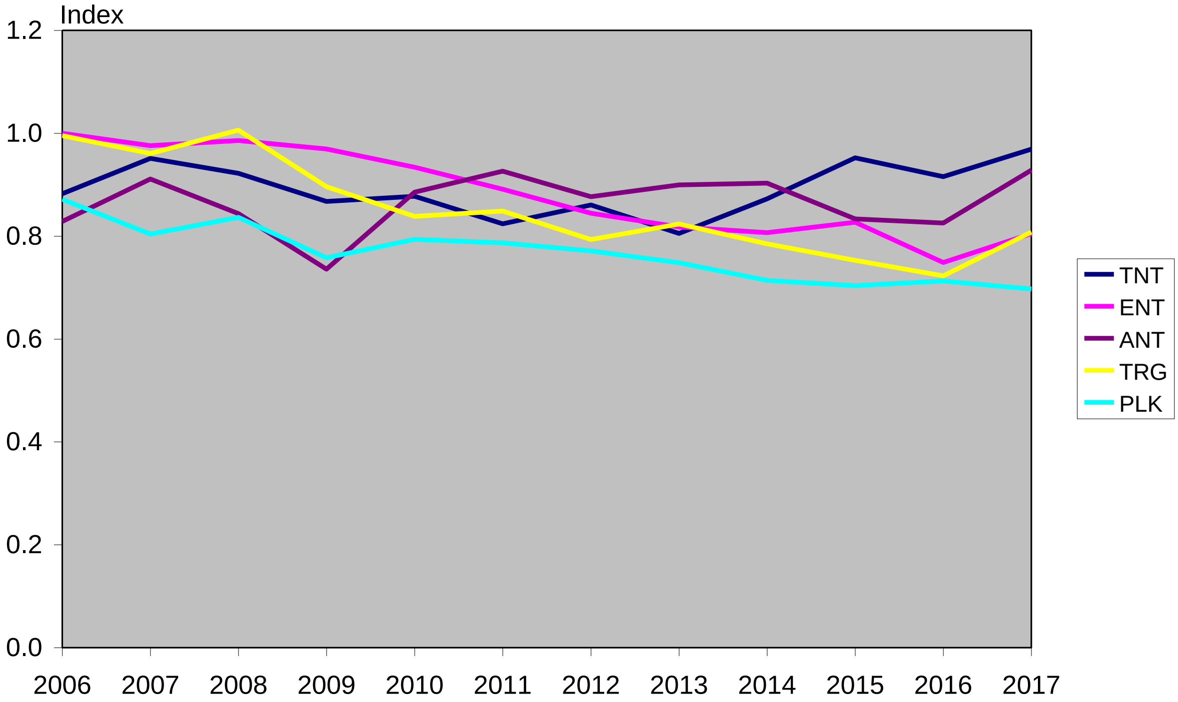
Year	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
GWh	0.5%	–0.3%	0.3%	0.2%	–0.3%	–0.6%	–0.6%	–0.7%	1.3%	–0.4%	0.5%
RMD	1.1%	0.2%	0.4%	0.2%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
EndUs	0.3%	0.3%	0.3%	0.3%	0.3%	0.2%	0.2%	0.2%	0.3%	0.3%	0.3%
Kms	0.2%	0.5%	0.3%	0.5%	0.4%	0.0%	0.7%	0.4%	0.1%	0.0%	–0.2%
ENS	–1.4%	0.7%	–5.3%	5.9%	–0.1%	0.0%	–0.1%	0.5%	–1.8%	–1.1%	3.3%
Opex	–0.1%	0.2%	–0.7%	–1.2%	1.3%	–0.7%	0.9%	–2.2%	–0.3%	–0.4%	0.2%
O/H	–1.5%	–0.3%	–1.2%	0.1%	–1.3%	–0.9%	0.2%	–0.4%	–0.3%	–0.5%	0.9%
U/G	0.0%	0.0%	0.0%	0.0%	0.0%	–0.4%	0.0%	0.0%	–0.6%	0.0%	0.1%
Trform	–0.7%	–1.3%	–4.6%	–2.9%	–0.7%	–1.6%	–1.2%	–0.8%	–0.9%	–0.5%	–0.3%
TFP	–1.6%	0.0%	–12%	4.3%	–0.3%	–4.0%	0.2%	–2.9%	–2.1%	–2.6%	5.8%

Taking 2017 as an example, the contribution of the ENS output is a relatively high 3.3 percentage points as ENS swings from well above average levels in 2016 to well below average levels in 2017. There is also a strong contribution of 0.9 percentage points from a reported reduction in overhead line inputs in 2017. Transformers are the only input making a negative contribution in 2017. Combining the output and contributions leads to TFP change in 2017 of 5.8 per cent.

3 TNSP MULTILATERAL PRODUCTIVITY RESULTS

In this section we present updated TNSP MTFP and MPFP results. TNSP MTFP indexes are presented in figure 3.1 and table 3.1.

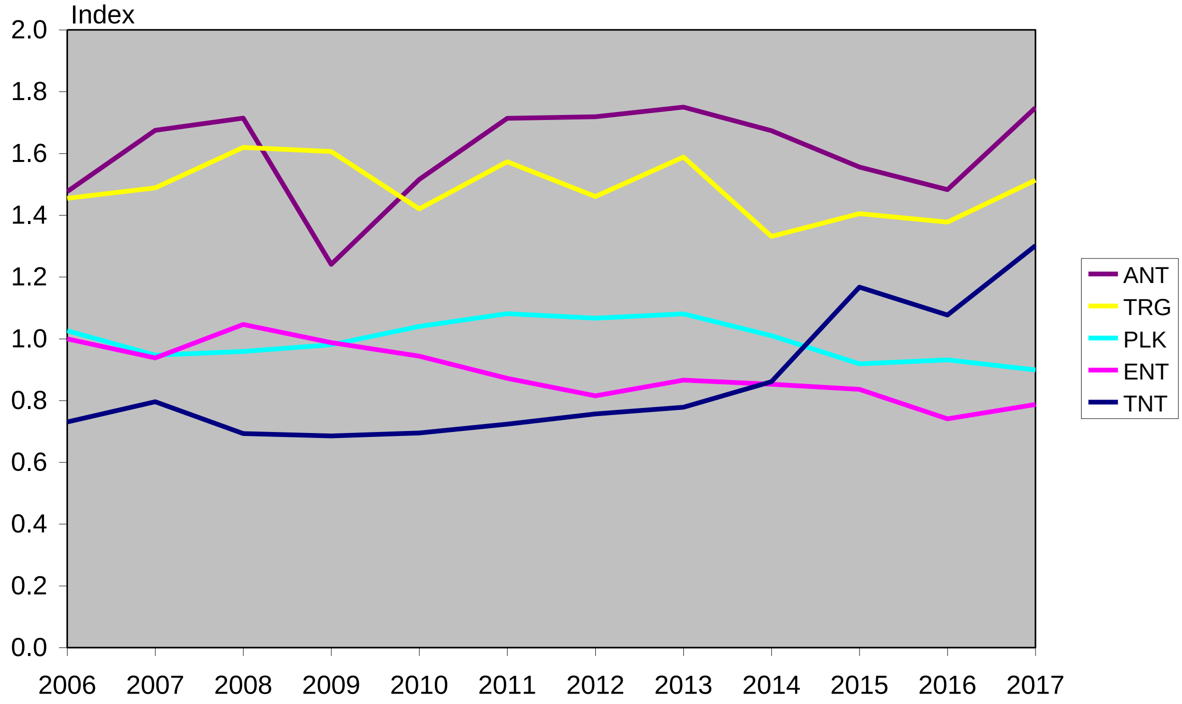
Figure 3.1 **TNSP multilateral total factor productivity indexes, 2006–2017**



From figure 3.1 we see that MTFP levels form a relatively tight band. The MTFP levels of three TNSPs – ENT, TRG and PLK – have declined over the 12–year period while those of ANT and TNT have increased over the period. The MTFP levels of all TNSPs except PLK improved noticeably in 2017 due mainly to improvements in reliability performance. ENT and TRG started the period having the highest MTFP levels but with average annual rates of MTFP change of –2.0 and –1.9 per cent, respectively, finished the period with towards the lowest MTFP levels. PLK's MTFP has had less than the industry average annual TFP rate of change at –2.0 per cent and has been the lowest MTFP level in most years. 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 markedly and it had the highest MTFP level from 2011 to 2014 and the second highest MTFP level in 2015, 2016 and 2017. TNT's MTFP level was in the middle of the range up until 2013 but increased noticeably in 2014 and 2015 with the introduction of restructuring and reform initiatives.

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

Figure 3.2 **TNSP multilateral opex partial productivity indexes, 2006–2017**



From figure 3.2 we see that the two largest TNSPs – ANT and TRG – have had the highest opex MPFP levels over the 12–year period, likely reflecting economies of scale. TNT, on the other hand, had the lowest opex MPFP levels from 2006 to 2013 but marked increases in opex MPFP in 2015 and again in 2017 took it to the middle of the range and gave it an average annual opex MPFP growth rate for the period of 5.3 per cent. ANT's and TRG's opex MPFP average annual changes over the period were also positive at 1.5 and 0.4 per cent, respectively. Opex MPFP average annual changes for ENT and PLK were negative at –2.2 and –1.2 per cent, respectively.

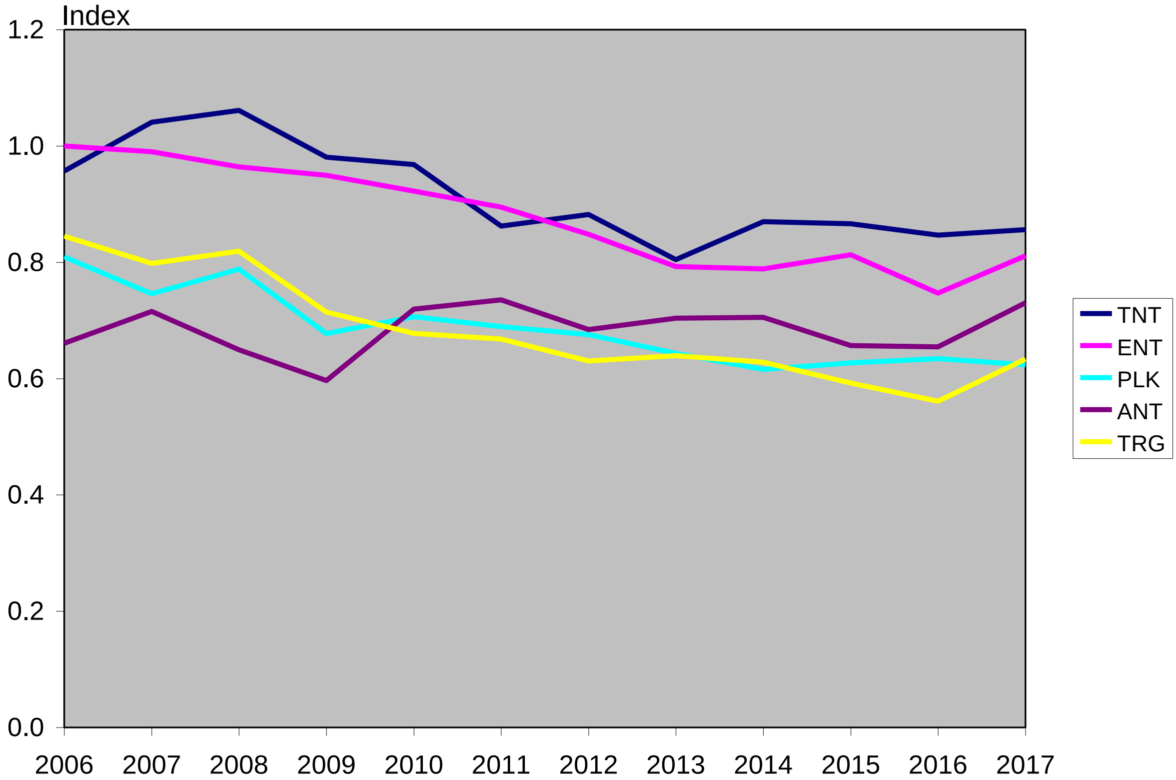
Table 3.1 **TNSP multilateral total factor productivity indexes, 2006–2017**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
ANT	0.83	0.91	0.84	0.74	0.89	0.93	0.88	0.90	0.90	0.83	0.83	0.93
ENT	1.00	0.98	0.99	0.97	0.93	0.89	0.84	0.82	0.81	0.83	0.75	0.80
PLK	0.87	0.80	0.84	0.76	0.79	0.79	0.77	0.75	0.71	0.70	0.71	0.70
TNT	0.88	0.95	0.92	0.87	0.88	0.82	0.86	0.81	0.87	0.95	0.92	0.97
TRG	1.00	0.96	1.01	0.90	0.84	0.85	0.79	0.82	0.78	0.75	0.72	0.81

Table 3.2 **TNSP multilateral opex partial productivity indexes, 2006–2017**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
ANT	1.48	1.67	1.71	1.24	1.52	1.71	1.72	1.75	1.67	1.56	1.48	1.75
ENT	1.00	0.94	1.05	0.99	0.94	0.87	0.82	0.87	0.85	0.84	0.74	0.79
PLK	1.03	0.95	0.96	0.98	1.04	1.08	1.07	1.08	1.01	0.92	0.93	0.90
TNT	0.73	0.80	0.69	0.69	0.69	0.72	0.76	0.78	0.86	1.17	1.08	1.30
TRG	1.45	1.49	1.62	1.61	1.42	1.57	1.46	1.59	1.33	1.41	1.38	1.51

Figure 3.3 **TNSP multilateral capital partial productivity indexes, 2006–2017**



From figure 3.3 we can see that capital MPFP levels have generally declined over the 12–year period. The one exception is ANT whose capital MPFP has been virtually constant especially over the later period since 2010. In 2017, capital MPFP change was positive for four of the TNSPs ranging from 1.1 per cent for TNT to 12 per cent for TRG. Large swings from worse than average to better than average reliability performance in 2017 were a major factor in some of these high growth rates. PLK's capital MPFP level reduced by 1.7 per cent in 2017.

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

4 TNSP OUTPUTS, INPUTS AND PRODUCTIVITY CHANGE

In this section we review the outputs, inputs and productivity change results for the five NEM TNSPs.

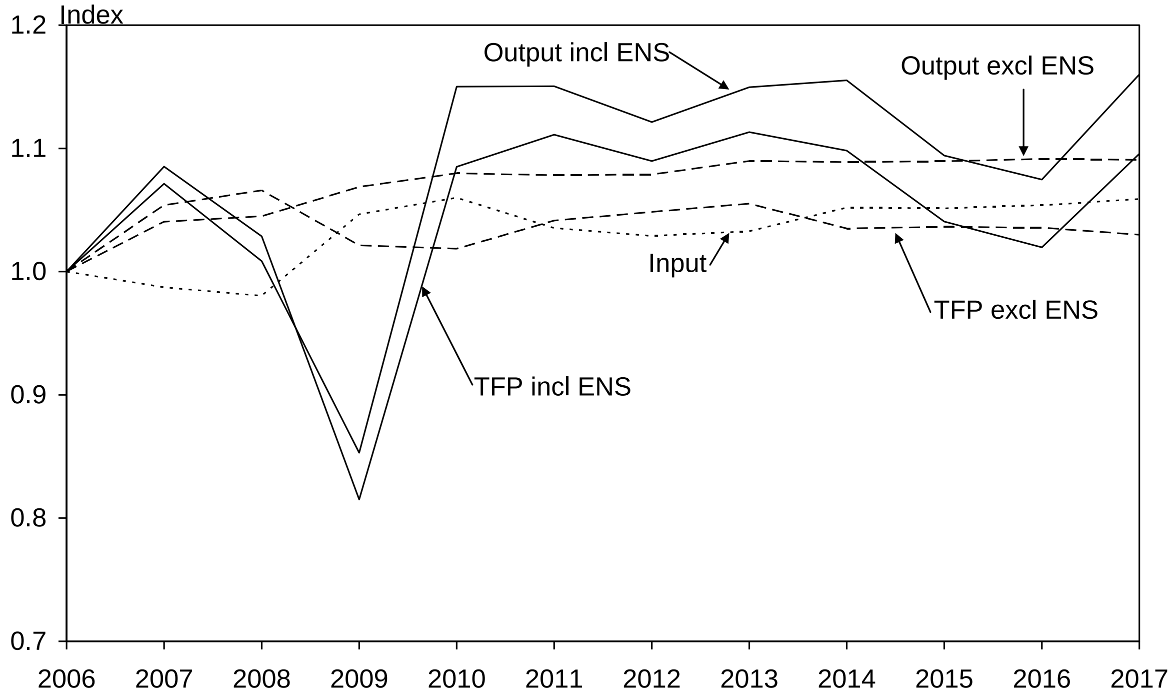
4.1 AusNet Services Transmission

In 2017 AusNet Services Transmission (ANT) transported 46,829 GWh of electricity over 6,560 circuit kilometres of lines and cables. It forms a critical part of Victoria's energy supply chain serving 2.9 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, 2006–2017**



Over the 12–year period 2006 to 2017, ANT's TFP increased at an average annual rate of 0.8 per cent. Its total output increased by an average annual rate of 1.4 per cent, faster than its rate of increase in total input use of 0.5 per cent. This differs from the situation for the transmission industry as a whole where input use increased considerably more than 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. Since 2010, input use has remained relatively flat leading to TFP change following output change closely since 2010. After quite strong growth in output up to 2012 at an average annual rate of 0.9 per cent, output has increased in the period since but at a reduced rate of 0.7 per cent. This has produced positive average annual TFP change since 2012 but only at the rate of 0.1 per cent.

Output increased markedly in 2017 following the worst reliability performance of the period in 2016 and a turnaround to near perfect reliability in 2017. 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 change return to near perfect reliability in 2017 boosted both output and TFP strongly that year. If reliability is excluded, ANT's TFP would have grown at an average annual rate of 0.3 per cent over the 12 years, instead of 1.4 per cent.

Table 4.1 **ANT's output, input and total factor productivity and partial productivity indexes, 2006–2017**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.071	0.987	1.085	1.126	1.072
2008	1.008	0.980	1.029	1.170	0.987
2009	0.853	1.047	0.815	0.775	0.827
2010	1.150	1.060	1.085	1.040	1.098
2011	1.150	1.035	1.111	1.152	1.099
2012	1.121	1.029	1.090	1.199	1.061
2013	1.150	1.033	1.113	1.215	1.086
2014	1.155	1.052	1.098	1.158	1.083
2015	1.094	1.051	1.041	1.099	1.026
2016	1.075	1.054	1.020	1.042	1.016
2017	1.160	1.059	1.096	1.170	1.076
Growth Rate 2006–17	1.35%	0.52%	0.83%	1.43%	0.67%
Growth Rate 2006–12	1.91%	0.48%	1.43%	3.03%	0.98%
Growth Rate 2012–17	0.68%	0.57%	0.11%	–0.50%	0.29%

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

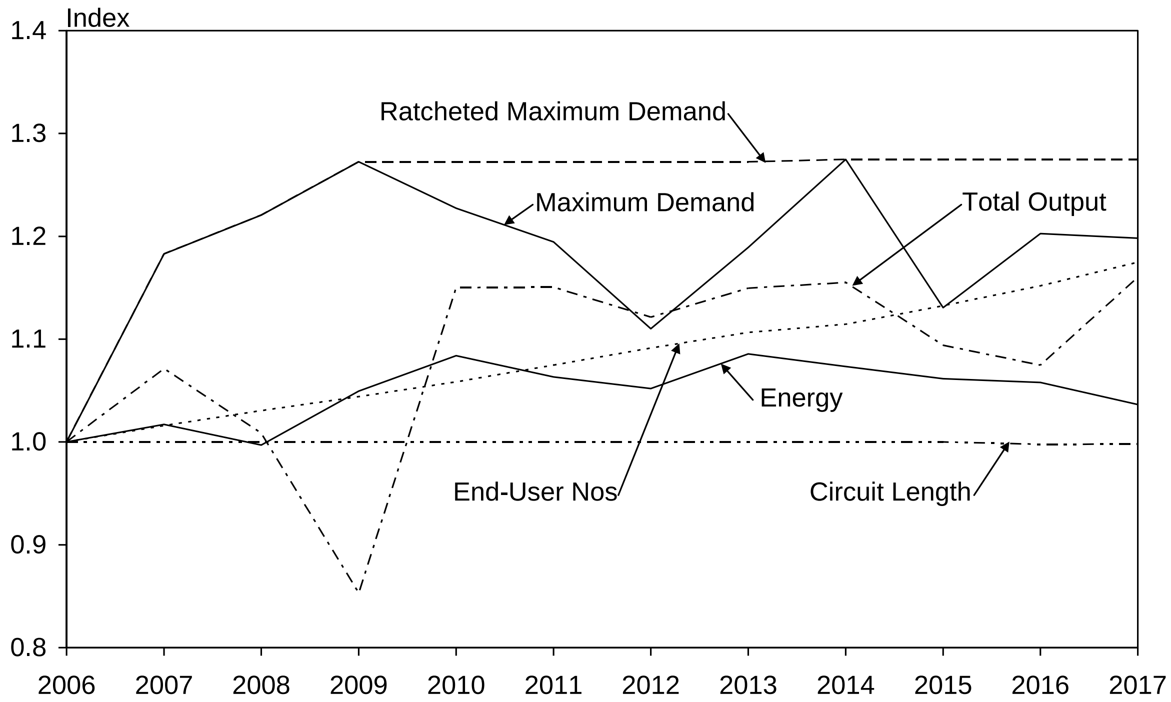
ANT's output and input quantity changes

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 12–year period.

This contrasts with the transmission industry as whole where circuit length was 8 per cent higher in 2016 than it was in 2006.

Figure 4.2 **ANT's output quantity indexes, 2006–2017**



ANT's maximum demand and energy throughput outputs have, however, grown considerably more 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 in 2017 was 20 per cent above its 2006 level. Again, this contrasts with the industry's 2017 maximum demand being only 4 per cent above its 2006 level. In 2017 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 shown a steadier pattern for ANT than for the industry as a whole. ANT's throughput increased through to 2010 and has declined gradually since then whereas throughput for the industry fell steadily from 2010 to 2014 and has only partially recovered since then. In 2017 ANT's transmission energy throughput was 4 per cent above its 2006 level whereas for the industry it was around the same level it was in 2006.

The output that increased the second most over the period for ANT is end–user numbers with an increase of 18 per cent between 2006 and 2017, slightly higher than the increase of 16 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.

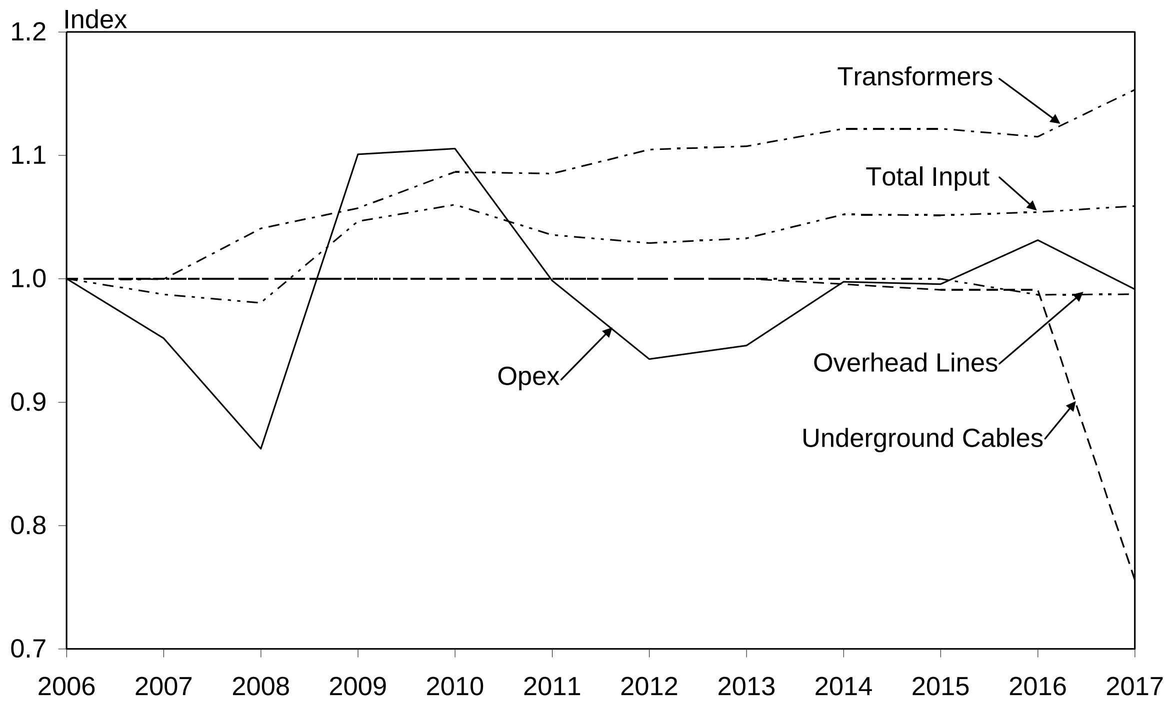
The output that is not shown in figure 4.2 is total energy not supplied (ENS). ANT's ENS spiked upwards in 2009 to 13 times its 2006 level associated with the transformer failure at the South Morang Terminal Station. With the exception of 2009, ANT's ENS generally trended downwards to 2014 and, hence, contributed more to total output than was the case in

2006. However, ENS again increased in 2015 and 2016 before falling to near zero in 2017. This was ANT's ENS being triple its 2006 level in 2016. The industry's ENS has followed a broadly similar pattern to that of ANT.

Since the circuit length, end–user numbers and energy throughput outputs receive a combined weight of around 80 per cent of gross 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 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 2009 and again in 2016 and 2017 (noting that an increase in ENS has a negative impact on total output and is given an average weight of around 3 per cent of gross revenue on average for ANT).

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 falls away in 2017.

Figure 4.3 **ANT's input quantity indexes, 2006–2017**



The quantity of opex increased the next least of ANT's four inputs over the 12–year period, being slightly lower in 2017 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 and falling in 2017. ANT's near zero overall opex change between 2006 and 2017 compares to an 11 per cent increase 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 44 per cent, is transformers. ANT's quantity of transformers increased steadily to 2014 before levelling off to 2016 and then increasing again in 2017. In 2017 ANT's transformers input was 15 per cent above its 2006 level – a considerably smaller increase than the industry's 46 per cent. Given its large share of total costs, transformer inputs is 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 driven by variations in opex use.

ANT's output and input contributions to TFP change

In table 4.2 we present the percentage point contributions of each output and each input to ANT's average annual rate of TFP change of 0.8 per cent over the 12–year period 2006 to 2017.

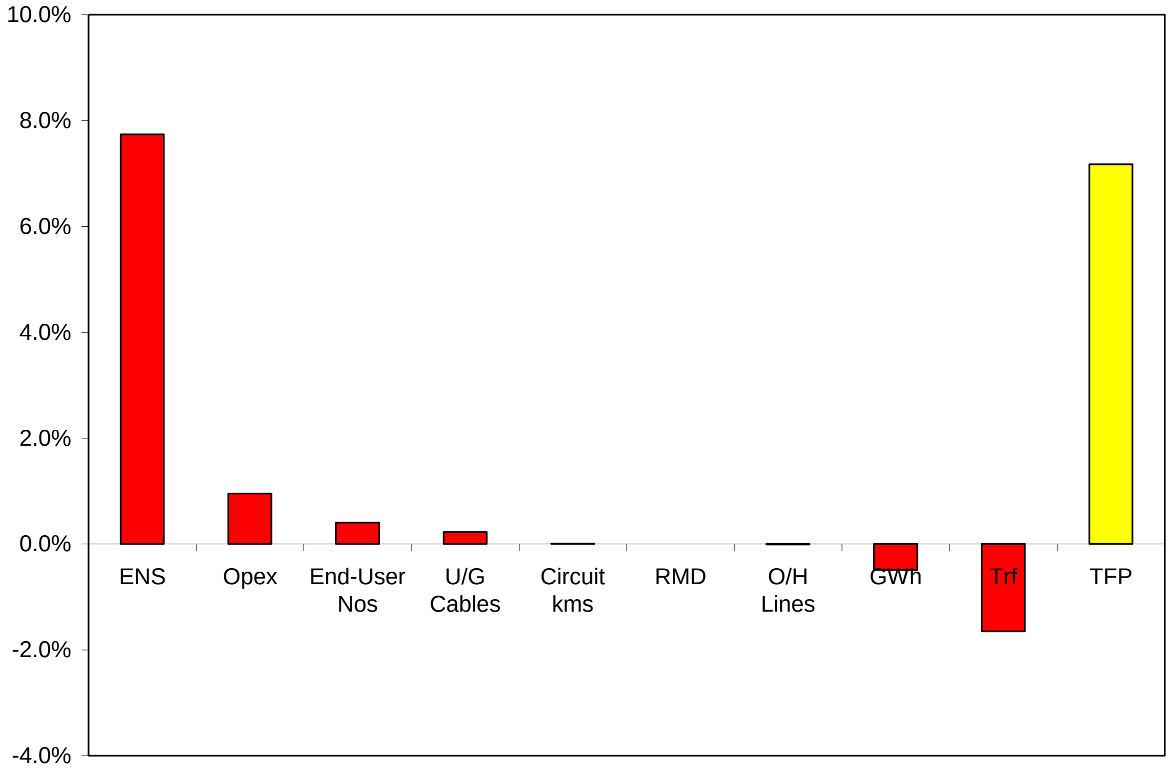
Table 4.2 **ANT's output and input percentage point contributions to average annual TFP change: 2006–2017, 2006–2012 and 2012–2017**

Year	*2006 to 2017*	*2006 to 2012*	*2012 to 2017*
Energy (GWh)	0.08%	0.21%	-0.07%
Ratcheted Max Demand	0.44%	0.80%	0.01%
Customer Numbers	0.30%	0.30%	0.30%
Circuit Length	-0.01%	0.00%	-0.02%
ENS	0.53%	0.60%	0.46%
Opex	0.00%	0.23%	-0.28%
O/H Lines	0.03%	0.00%	0.07%
U/G Cables	0.02%	0.00%	0.05%
Transformers	-0.57%	-0.71%	-0.41%
TFP Change	0.82%	1.43%	0.11%

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 virtually no contribution to ANT's TFP growth whereas it is the largest contributor for the industry. RMD and energy contribute 0.4 and 0.1 percentage points, respectively, to ANT's TFP growth compared to 0.2 and zero percentage points, respectively, for the industry, reflecting stronger growth in demand in Victoria compared to the market overall. ENS contributes 0.5 percentage points for ANT compared to 0.2 percentage points for the industry, making ENS the largest positive contributor for ANT versus the fourth most positive contributor for the industry. Transformer input growth contributes –0.6 percentage points to ANT's TFP change compared to –1.4 percentage points for the industry, reflecting the much smaller growth in ANT's transformer input quantity. And opex use also makes no contribution to ANT's TFP change compared to –0.3 percentage points for the industry, again reflecting the industry's higher increase in opex usage over the period.

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 0.8 percentage points before 2012 to near zero after 2012 as maximum demand flattens out and the smaller positive contribution of ENS after 2012 of 0.5 percentage points versus 0.6 percentage points before 2012 as ENS fluctuated in the last two years of the period. 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. On the input side, the contribution of opex becomes negative after 2012 at –0.3 percentage points compared to 0.2 percentage points before 2012 as opex change goes from being negative (ie opex decreasing) before 2012 to being positive (ie opex increasing) after 2012. This is partly offset by a reduction in the negative contribution of transformers input before 2012 of –0.7 percentage points to –0.4 percentage points after 2012 as transformer inputs level off from 2014 onwards before increasing in 2018.

Figure 4.4 **ANT's output and input percentage point contributions to annual TFP change, 2016–17**



In figure 4.4 we present the contributions of outputs and inputs to ANT's TFP change in the 2017 year. The huge turnaround in ENS from period highs in 2016 to near zero in 2017 leads to it making the largest positive contribution to TFP change at 7.7 percentage points. Falls in energy throughput in 2017 lead to it making a negative contribution of –0.5 percentage points. Given its large weight in total costs, an increase in transformer input quantities in 2017 make a contribution to TFP change of around –1.7 percentage points. But the decrease in opex usage in 2017 led to opex making the second highest positive contribution in the latest year of 1.0 percentage points. ANT's TFP change in 2017, 7.2 per cent, was better than TFP change in 2017 for the industry as a whole which was a quite high 5.8 per cent.

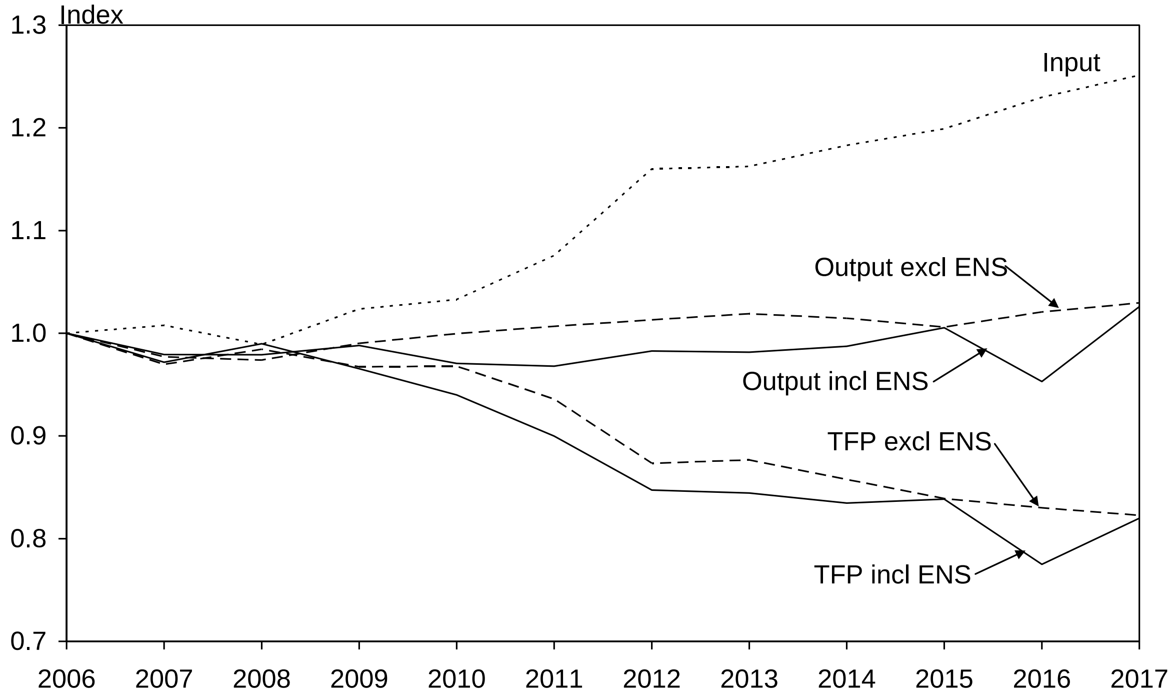
4.2 ElectraNet

In 2017 ElectraNet (ENT) transported 14,525 GWh of electricity over 5,520 circuit kilometres of lines and cables. It forms a critical part of South Australia's energy supply chain serving 878,300 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, 2006–2017**



Over the 12–year period 2006 to 2017, ANT's TFP decreased at an average annual rate of change of –1.8 per cent. Its total output grew over the period with an average annual rate of change of 0.2 per cent. This compares to an industry growth in output of 0.9 per cent per annum on average. ENT's average annual rate of increase in input use of 2.0 per cent was less than the rate of increase in total input use for the industry of 2.2 per cent. When combined with its small increase in output, this gives ENT an average annual change in TFP of –1.8 per cent compared to the industry's average annual change of –1.3 per cent. ENT's TFP change was positive in 2008, 2015 and 2017. Input use declined in 2008 to produce positive TFP change that year despite a marginal reduction in output. 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 led to TFP change of –7.8 per cent that year followed by TFP growth of 5.6 per cent in 2017 as ENS returned to a more average level. If ENS is excluded as an output, TFP change in 2017 would have been –0.9 per cent (see figure 4.5). For the period after 2012, the rate of average annual growth in input usage moderated somewhat and the average annual reduction in output (including ENS) reversed leading to an improvement in TFP change from –2.8 per cent before 2012 to –0.7 per cent after 2012.

Table 4.3 **ENT's output, input and total factor productivity and partial productivity indexes, 2006–2017**

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	0.979	1.008	0.972	0.937	0.989
2008	0.979	0.989	0.990	1.044	0.963
2009	0.988	1.024	0.965	0.989	0.952
2010	0.971	1.033	0.940	0.952	0.931
2011	0.968	1.076	0.900	0.882	0.905
2012	0.983	1.160	0.847	0.820	0.856
2013	0.982	1.162	0.844	0.873	0.830
2014	0.987	1.183	0.835	0.859	0.822
2015	1.005	1.199	0.839	0.834	0.838
2016	0.953	1.230	0.775	0.754	0.782
2017	1.026	1.251	0.820	0.786	0.833
Growth Rate 2006–17	0.23%	2.04%	–1.80%	–2.19%	–1.66%
Growth Rate 2006–12	–0.29%	2.47%	–2.76%	–3.30%	–2.59%
Growth Rate 2012–17	0.86%	1.52%	–0.66%	–0.86%	–0.53%

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

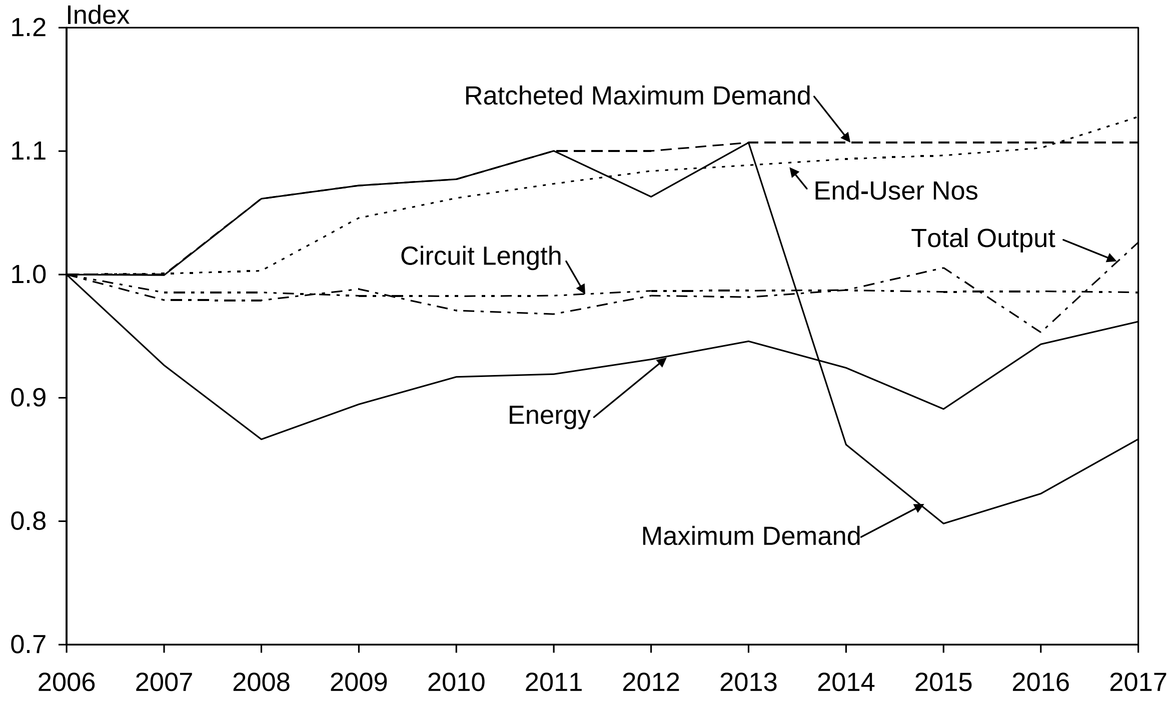
Quantity indexes for ENT's individual outputs are presented in figure 4.6 and for individual inputs in figure 4.7. In each case the quantities are converted to index format with a value of one in 2006 for ease of comparison.

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 12–year period. This contrasts with the transmission industry as whole where circuit length was 8 per cent higher in 2017 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, ENT's maximum demand was 13 per cent below its 2006 level in 2017. This contrasts with the industry's 2017 maximum demand being 6 per cent above its 2006 level. In 2017 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 has trended up somewhat since 2008 and in 2017 was 4 per cent below its 2006 level compared to the industry's throughput then being around the same as it was in 2006.

Figure 4.6 **ENT's output quantity indexes, 2006–2017**

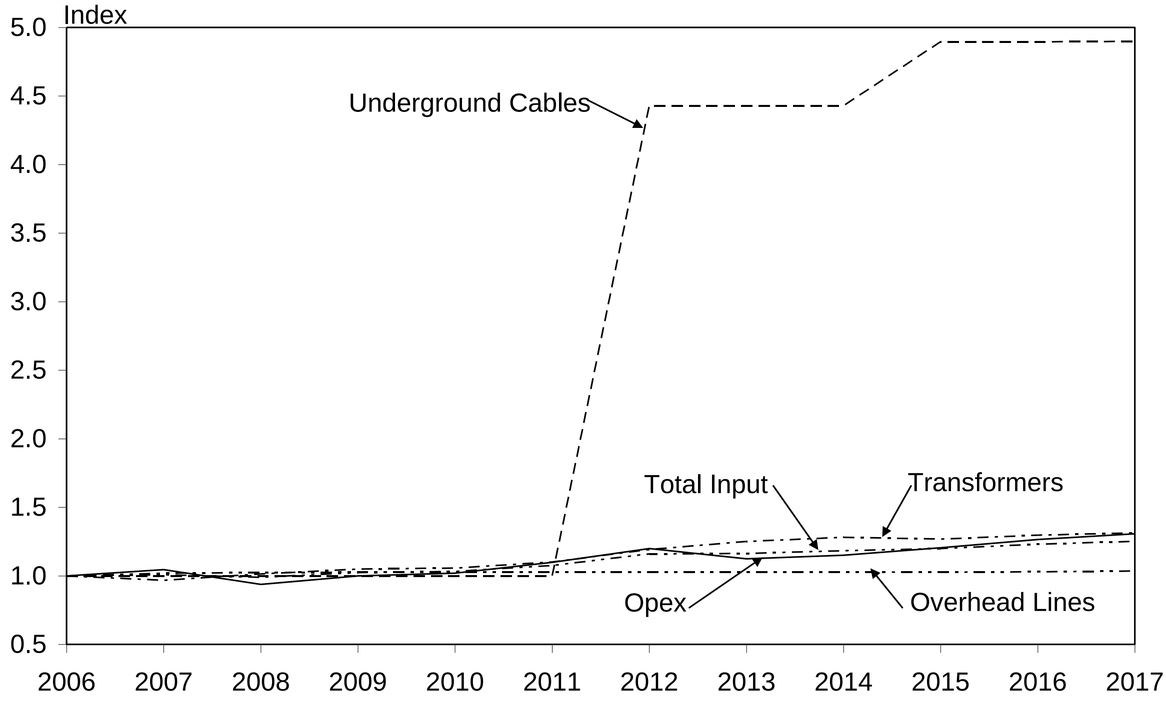


The output that increased the most over the period for ENT is end–user numbers with an increase of 13 per cent between 2006 and 2017, less than the increase of 16 per cent for the industry. ENT's end–user numbers remained largely unchanged between 2006 and 2008 before a more rapid increase in 2009 followed by reducing increases in subsequent years until 2017 when growth increased. This is a less steady pattern that 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. 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 83 per cent of ENT's gross 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 3 per cent of gross revenue on average for ENT).

Figure 4.7 **ENT's input quantity indexes, 2006–2017**



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 12–year period, being 31 per cent higher in 2017 than it was in 2006. Opex usage increased by 20 per cent between 2010 and 2012. ENT's overall opex increase between 2006 and 2017 was well over twice the increase for the industry. Opex has the second largest average share in ENT's total costs at 31 per cent.

The input component with the largest average share of ENT's total cost, at 43 per cent, is transformers. ENT's quantity of transformers increased steadily from 2007 to 2014 before levelling off and by 2017 was 31 per cent above its 2006 level – a smaller increase than the industry's 46 per cent. Given its large share of total costs, transformer inputs is 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 74 per cent of total costs).

ENT's output and input contributions to TFP change

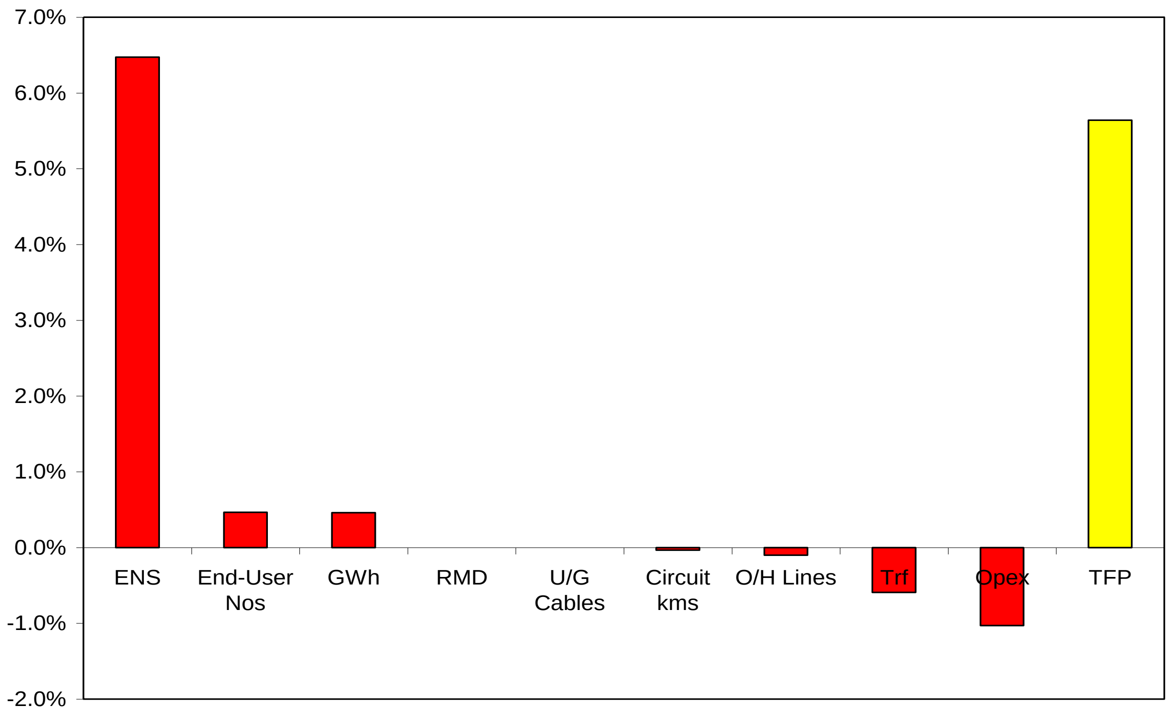
In table 4.4 we present the percentage point contributions of each output and each input to ENT's average annual rate of TFP change of –1.8 per cent over the 12–year period 2006 to 2017.

Table 4.4 **ENT's output and input percentage point contributions to average annual TFP change: 2006–2017, 2006–2012 and 2012–2017**

Year	*2006 to 2017*	*2006 to 2012*	*2012 to 2017*
Energy (GWh)	–0.08%	–0.27%	0.16%
Ratcheted Max Demand	0.18%	0.31%	0.02%
Customer Numbers	0.22%	0.27%	0.16%
Circuit Length	–0.05%	–0.08%	–0.01%
ENS	–0.08%	–0.58%	0.52%
Opex	–0.73%	–0.89%	–0.55%
O/H Lines	–0.08%	–0.13%	–0.02%
U/G Cables	–0.13%	–0.18%	–0.07%
Transformers	–1.06%	–1.21%	–0.87%
TFP Change	–1.80%	–2.76%	–0.66%

There are some 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. ENS contributes –0.1 percentage points for ENT compared to 0.2 percentage points for the industry. Transformer input growth contributes –1.1 percentage points to ENT's TFP change compared to –1.4 percentage points for the industry, reflecting the smaller growth in ENT's transformer input quantity. And, opex use also makes a more negative contribution to ENT's TFP change at –0.7 percentage points compared to –0.3 for the industry, again reflecting the industry's lower increase in opex usage over the period.

Figure 4.8 **ENT's output and input percentage point contributions to annual TFP change, 2016–17**



Comparing the periods before 2012 and after 2012 in table 4.4, the main differences for ENT are that most outputs contribute less to TFP growth after 2012 but the contribution from ENS reverses from –0.6 percentage points before 2012 to 0.5 percentage points after 2012. However, all inputs also make less negative contributions after 2012 with the contribution of opex going from –0.9 percentage points before 2012 to –0.6 percentage points after 2012. Overall, TFP average annual change improves from –2.8 per cent before 2012 to –0.7 per cent after 2012.

In figure 4.8 we present the contributions of outputs and inputs to ENT's TFP change of 5.6 per cent in the 2017 year. The very large reduction in ENS in 2017 leads to it making by far the largest positive contribution to TFP change at 6.5 percentage points. Stronger growth in end–user numbers in 2017 leads to it making the second largest positive contribution at 0.5 percentage points. However, the increase in opex usage in 2017 led to opex making the most negative contribution in the latest year of –1.0 percentage points. ENT's large positive TFP change in 2017, driven largely by ENS, was similar to TFP change in 2017 for the industry as a whole which was 5.8 per cent.

4.3 Powerlink

In 2017 Powerlink (PLK) transported 54,253 GWh of electricity over 14,533 circuit kilometres of lines and cables. It forms a critical part of Queensland's energy supply chain serving around 2.2 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.

Over the 12–year period 2006 to 2017, PLK's TFP decreased at an average annual rate of change of –2.2 per cent. Its total output increased over the period with an average annual rate of change of 1.4 per cent. This was considerably higher than the industry average annual growth in output of 0.9 per cent. However, PLK's average annual rate of increase in input use of 3.7 per cent was well above the rate of increase in total input use for the industry of 2.2 per cent, giving PLK an average annual change in TFP of –2.2 per cent compared to the industry's average annual change of –1.3 per cent. PLK's

TFP change was positive in 2008 and 2010. In both these years PLK's output growth was very strong leading to positive TFP growth despite input growth also being strong in those years. Output growth in these years was mainly due to recovery from upwards spikes in ENS occurring the year before (see figure 4.9). PLK had negative TFP change for the other 10 years. If ENS is excluded from the output measure then TFP change was also negative for 2008 and 2010. In 2017 TFP change was negative at –0.4 per cent, mainly as the result of moderation in the rates of growth of both outputs and inputs. For the period after 2012, the rate of average annual growth in input usage moderated but so did the average annual increase in output leading to only a small alteration in average annual TFP change compared to the period before 2012.

Figure 4.9 **PLK's output, input and total factor productivity indexes, 2006–2017**

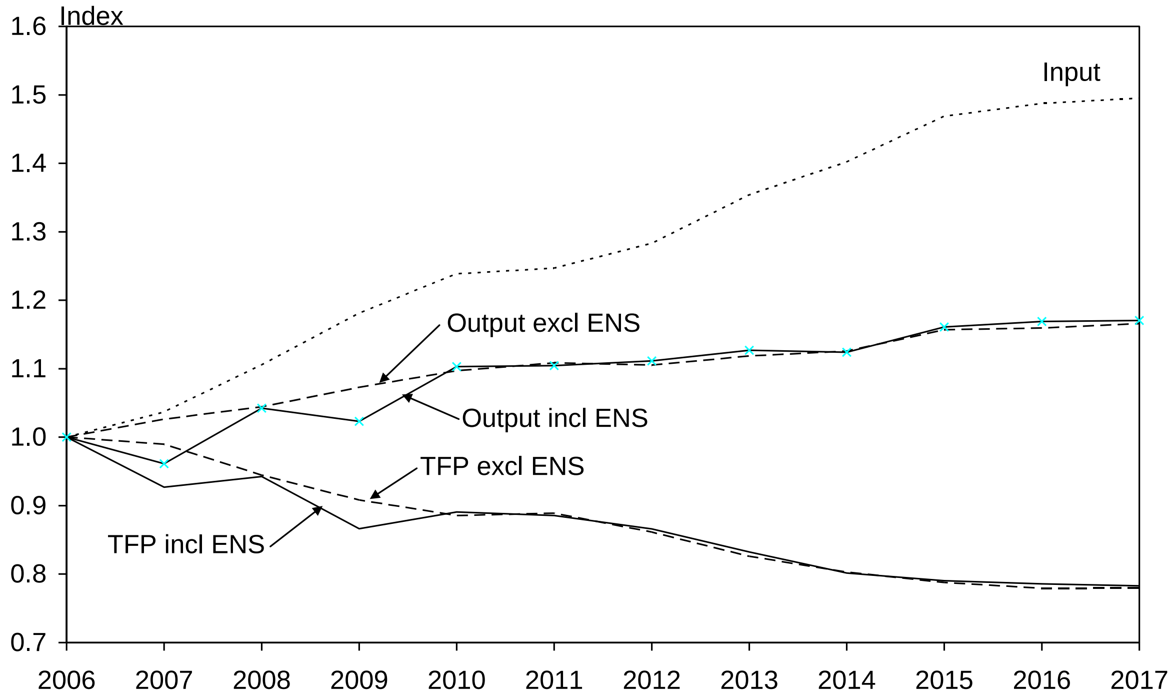


Table 4.5 **PLK's output, input and total factor productivity and partial productivity indexes, 2006–2017**

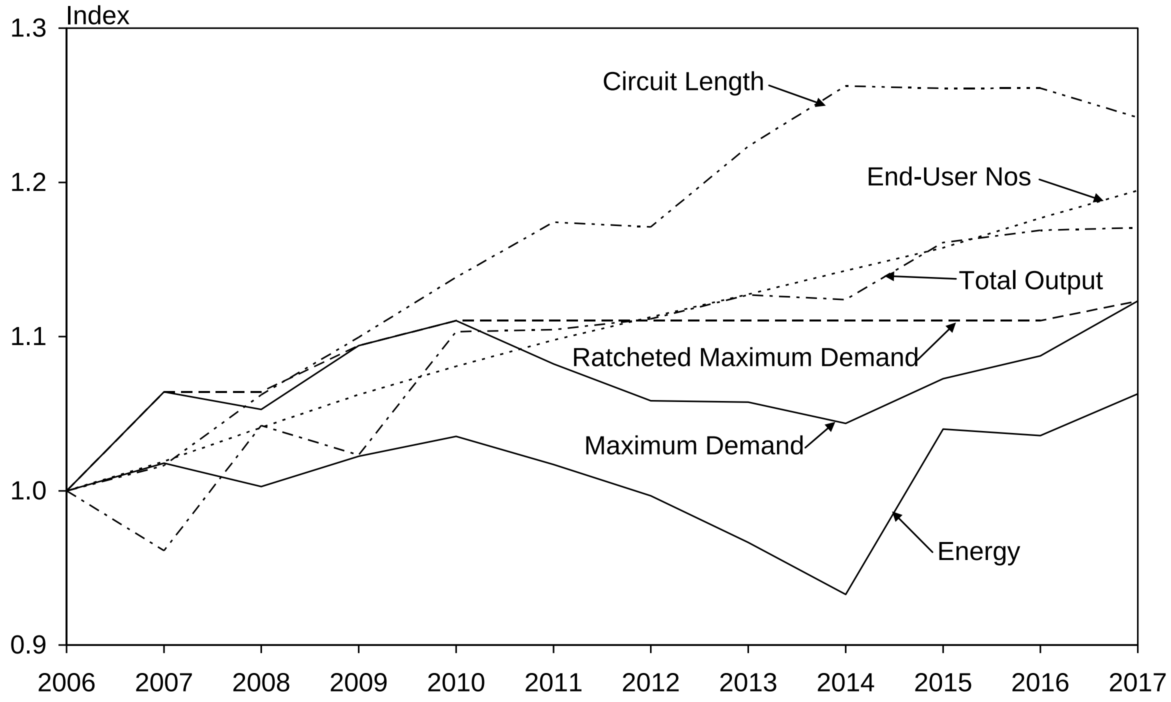
Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index Opex*	*PFP Index Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	0.961	1.037	0.927	0.931	0.925
2008	1.042	1.106	0.943	0.935	0.946
2009	1.023	1.181	0.866	0.965	0.830
2010	1.103	1.239	0.891	1.006	0.849
2011	1.104	1.247	0.886	1.052	0.831
2012	1.112	1.283	0.866	1.030	0.812
2013	1.127	1.354	0.832	1.035	0.771
2014	1.124	1.402	0.802	0.982	0.746
2015	1.161	1.469	0.790	0.890	0.759
2016	1.169	1.488	0.786	0.886	0.754
2017	1.171	1.495	0.783	0.871	0.755
Growth Rate 2006–17	1.43%	3.66%	–2.23%	–1.26%	–2.55%
Growth Rate 2006–12	1.76%	4.16%	–2.40%	0.49%	–3.46%
Growth Rate 2012–17	1.03%	3.06%	–2.02%	–3.35%	–1.46%

The partial productivity indexes in table 4.5 show that the reduced negative rate of change in capital PFP after 2012 was largely offset by the average annual opex PFP rate of change turning from positive before 2012 to negative after 2012.

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.

Figure 4.10 **PLK's output quantity indexes, 2006–2017**



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 2017, 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 2016 than it was in 2006.

PLK's maximum demand and energy throughput outputs have shown a broadly similar pattern compared to the industry as a whole. PLK's maximum demand peaked in 2010 and then declined through to 2014 before recovering in the last three years. PLK's maximum demand was 12 per cent above its 2006 level in 2017. The industry's 2017 maximum demand was also 12 per cent above its 2006 level. In 2017 PLK's ratcheted maximum demand was 12 per cent above its 2006 level, the same as for the industry.

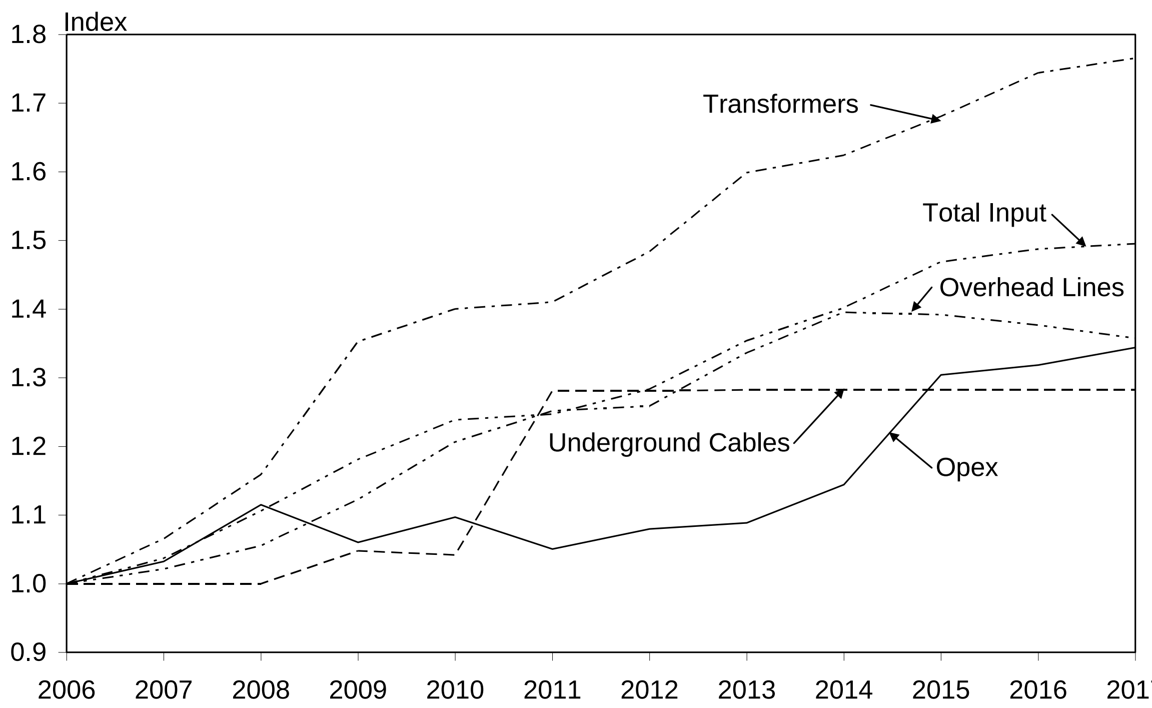
Similarly, we see that energy throughput for PLK initially peaked in 2010 before falling though to 2014 and recovering strongly in 2015 and 2017. PLK's throughput in 2017 was 6 per cent above its 2006 level compared to the industry's throughput then being around the same as it was in 2006.

The output that increased the second most over the period for PLK is end–user numbers with an increase of 20 per cent between 2006 and 2017, somewhat higher than the increase of 16 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. In 2017 PLK's ENS was around half of what it was in 2006. Overall, PLK's ENS will have had an increasingly 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 82 per cent of PLK's gross 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 and 2009 (noting that an increase in ENS has a negative impact on total output and is given an average weight of around 2 per cent of gross revenue on average for PLK).

Figure 4.11 **PLK's input quantity indexes, 2006–2017**



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 for the industry but its underground cables input quantity increased less than for the industry. PLK's overhead lines input increased by 36 per cent and its underground cables input quantity increased by 28 per cent between 2006 and 2017. This compares to corresponding respective increases for the industry of 18 per and 66 per cent.

PLK's quantity of opex increased the third most of its four inputs over the 12–year period, being 34 per cent higher in 2017 than it was in 2006. Opex usage increased only modestly through to 2013 but increased rapidly in 2014 and 2015. PLK's overall opex increase between

2006 and 2017 was much higher than the 12 per cent increase 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 2017 was 77 per cent above its 2006 level – a much larger increase that the industry's 46 per cent. Given its large share of total costs, transformer inputs is 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 present the percentage point contributions of each output and each input to PLK's average annual rate of TFP change of –2.2 per cent over the 12–year period 2006 to 2017.

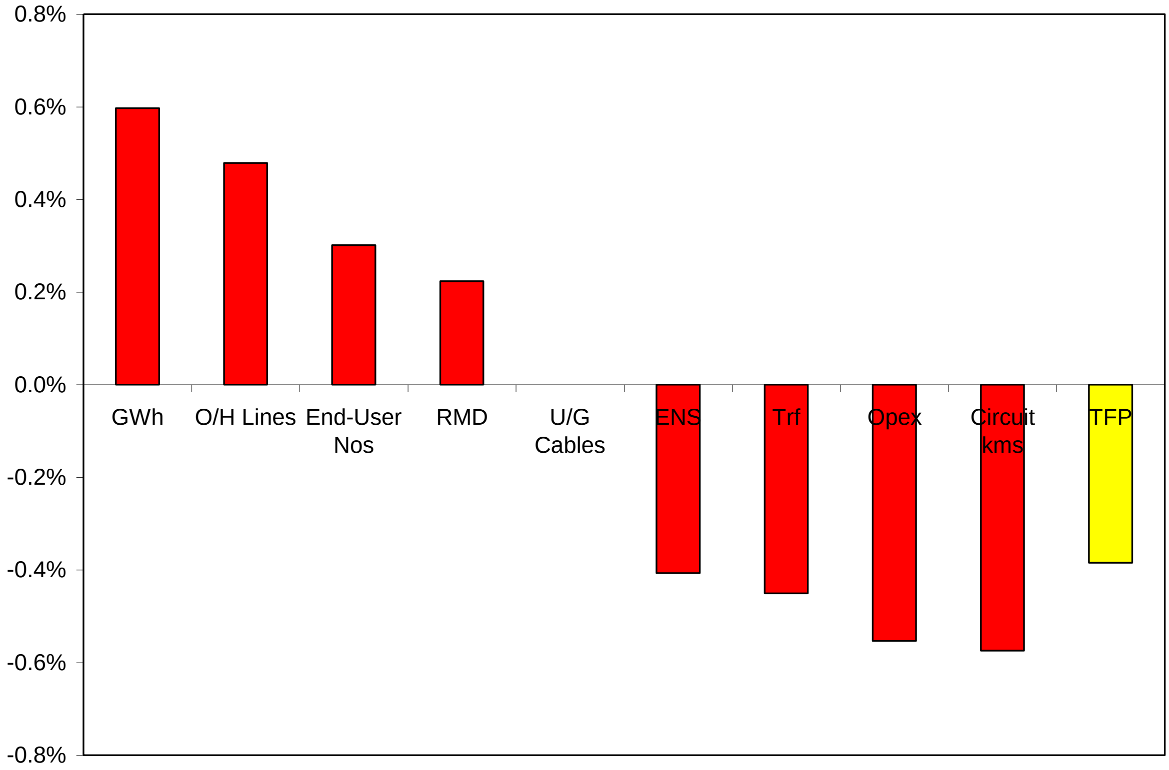
Table 4.6 **PLK's output and input percentage point contributions to average annual TFP change: 2006–2017, 2006–2012 and 2012–2017**

Year	*2006 to 2017*	*2006 to 2012*	*2012 to 2017*
Energy (GWh)	0.13%	–0.01%	0.30%
Ratcheted Max Demand	0.21%	0.35%	0.04%
Customer Numbers	0.33%	0.36%	0.28%
Circuit Length	0.76%	1.02%	0.44%
ENS	0.00%	0.03%	–0.04%
Opex	–0.75%	–0.39%	–1.17%
O/H Lines	–0.99%	–1.32%	–0.59%
U/G Cables	–0.01%	–0.03%	0.00%
Transformers	–1.91%	–2.41%	–1.30%
TFP Change	–2.23%	–2.40%	–2.02%

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 most positive contribution to PLK's TFP growth as it does for the industry but the contribution is 0.8 percentage points for PLK compared to 0.3 for the industry. ENS makes no contribution to TFP change for PLK whereas it contributes 0.2 percentage points for the industry. Transformer input growth contributes –21.9 percentage points to PLK's TFP change compared to –1.4 percentage points for the industry, reflecting the larger growth in PLK's transformer input quantity. And opex use also makes a more negative contribution to PLK's TFP change at –0.8 percentage points compared to –0.3 for the industry, again reflecting the industry's lower increase in opex usage over the period. Similarly, overhead lines input makes a more negative contribution to PLK's TFP change at –1.0 percentage points compared to –0.5 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, all outputs contribute less to PLK's TFP growth after 2012 except for energy throughput which changes from making a small negative contribution before 2012 to making a positive contribution after 2012. Opex usage makes a more negative contribution after 2012 with the contribution of opex going from –0.4 percentage points before 2012 to –1.2 percentage points after 2012. Offsetting this though are reductions in the negative contributions of overhead lines and transformer inputs. Overall, TFP average annual changes little before and after 2012.

Figure 4.12 **PLK's output and input percentage point contributions to annual TFP change, 2016–17**



In figure 4.12 we present the contributions of outputs and inputs to PLK's TFP change of –0.4 per cent in the 2017 year. The recovery in energy throughput in 2017 makes the largest positive contribution to TFP change at 0.6 percentage points. The reduction in circuit length and the increase in opex in 2017 both contribute around –0.6 percentage points to TFP change. PLK's negative TFP change in 2017 contrasts with TFP change for the industry as a whole of 5.8 per cent.

4.4 TasNetworks Transmission

In 2017 TasNetworks Transmission (TNT) transported 12,427 GWh of electricity over 3,564 circuit kilometres of lines and cables. It forms a critical part of Tasmania's energy supply chain serving over 287,000 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.

Figure 4.13 **TNT's output, input and total factor productivity indexes, 2006–2017**

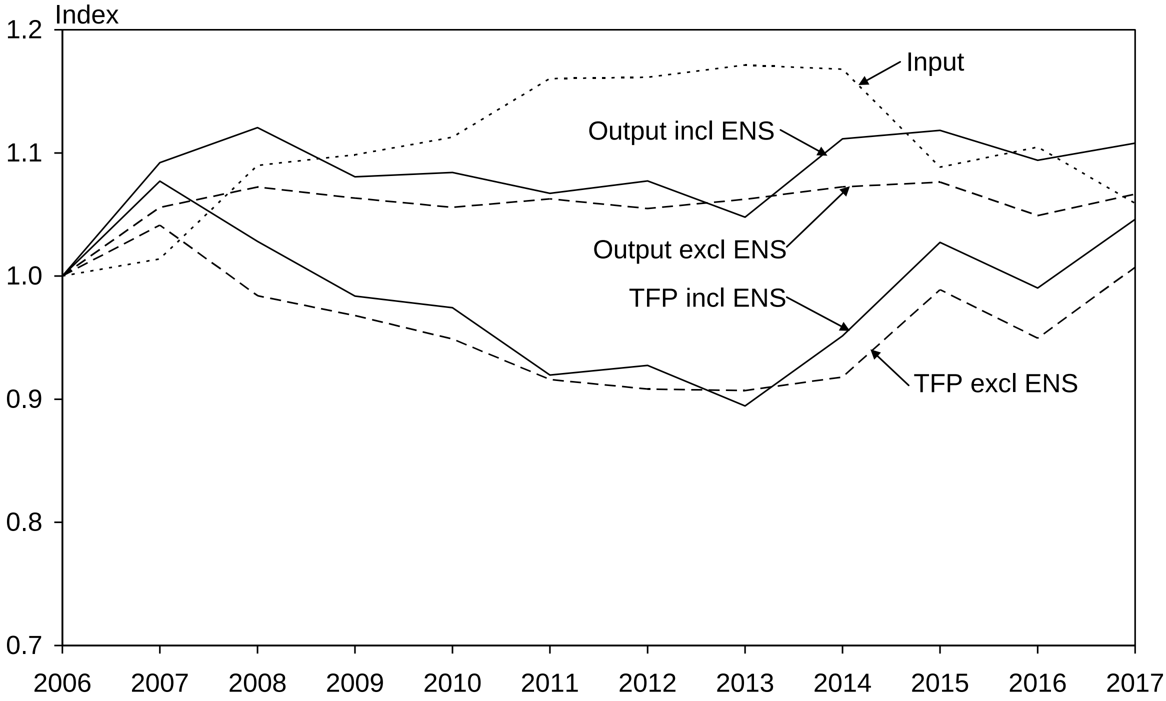


Table 4.7 **TNT's output, input and total factor productivity and partial productivity indexes, 2006–2017**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.092	1.014	1.077	1.075	1.078
2008	1.120	1.090	1.028	0.932	1.086
2009	1.081	1.099	0.984	0.931	1.014
2010	1.084	1.113	0.974	0.937	0.996
2011	1.067	1.160	0.920	0.983	0.895
2012	1.077	1.161	0.928	1.017	0.894
2013	1.048	1.171	0.894	1.068	0.836
2014	1.111	1.168	0.951	1.150	0.885
2015	1.118	1.088	1.027	1.557	0.884
2016	1.094	1.105	0.990	1.432	0.864
2017	1.108	1.059	1.046	1.736	0.877
Growth Rate 2006–17	0.93%	0.52%	0.41%	5.01%	–1.20%
Growth Rate 2006–12	1.24%	2.49%	–1.25%	0.29%	–1.86%
Growth Rate 2012–17	0.56%	–1.85%	2.41%	10.68%	–0.40%

Over the 12–year period 2006 to 2017, TNT's TFP increased at an average annual rate of 0.4 per cent. Its total output increased by an average annual rate of 0.9 per cent while its total input use increased slower at an average annual rate of 0.5 per cent. This differs from the situation for the transmission industry as a whole where input use increased considerably more 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 leading to strong TFP growths of 5.5 per cent. TNT's TFP level fell by 17 per cent between 2007 and 2013 before recovering subsequently to end up 4.6 per cent above its 2006 level.

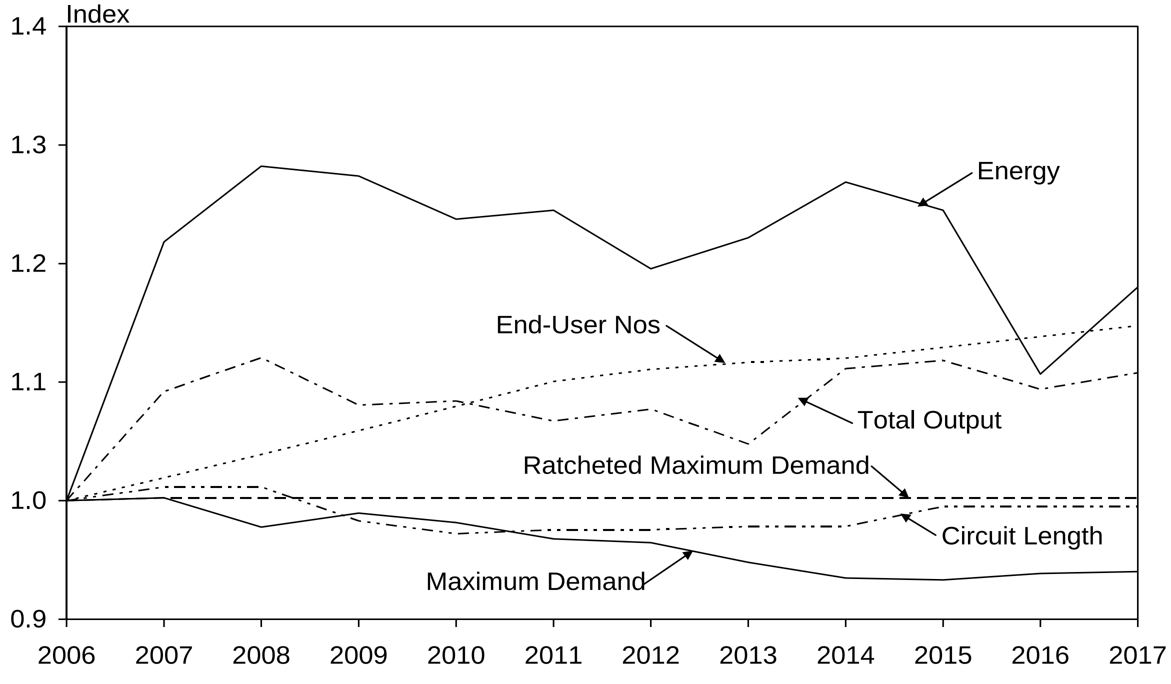
TNT's TFP performance was considerably better for the period after 2012 than for the period before 2012 going from an average annual rate of change of –1.3 per cent to 2.4 per cent after 2012. There was a substantial reduction in the average annual rate of output growth from 1.2 per cent before 2012 to 0.6 per cent after 2012. However, input use went from an average annual rate of change of 2.5 per cent before 2012 to –1.9 per cent after 2012.

The partial productivity indexes in table 4.7 show that a substantial improvement in opex PFP average annual change from 0.3 per cent before 2012 to 10.7 per cent after 2012 was the main reason for the improvement in TFP performance although there was also some improvement in capital PFP.

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, 2006–2017**



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 12–year period. This contrasts with the transmission industry as whole where circuit length was 8 per cent higher in 2017 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 6 per cent below its 2006 level in 2017. This contrasts with the industry's 2017 maximum demand being 6 per cent above its 2006 level. In 2017 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 in 2017 to finish up 18 per cent above its 2006 level. In 2017 energy throughput for the transmission industry was at around the same level as it was in 2006. TNT's energy throughput is affected by exports to the mainland and demand from large industrial users.

The output that had increased the second most for TNT by 2017 was end–user numbers with an increase of 15 per cent between 2006 and 2017, close to the same increase as 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.

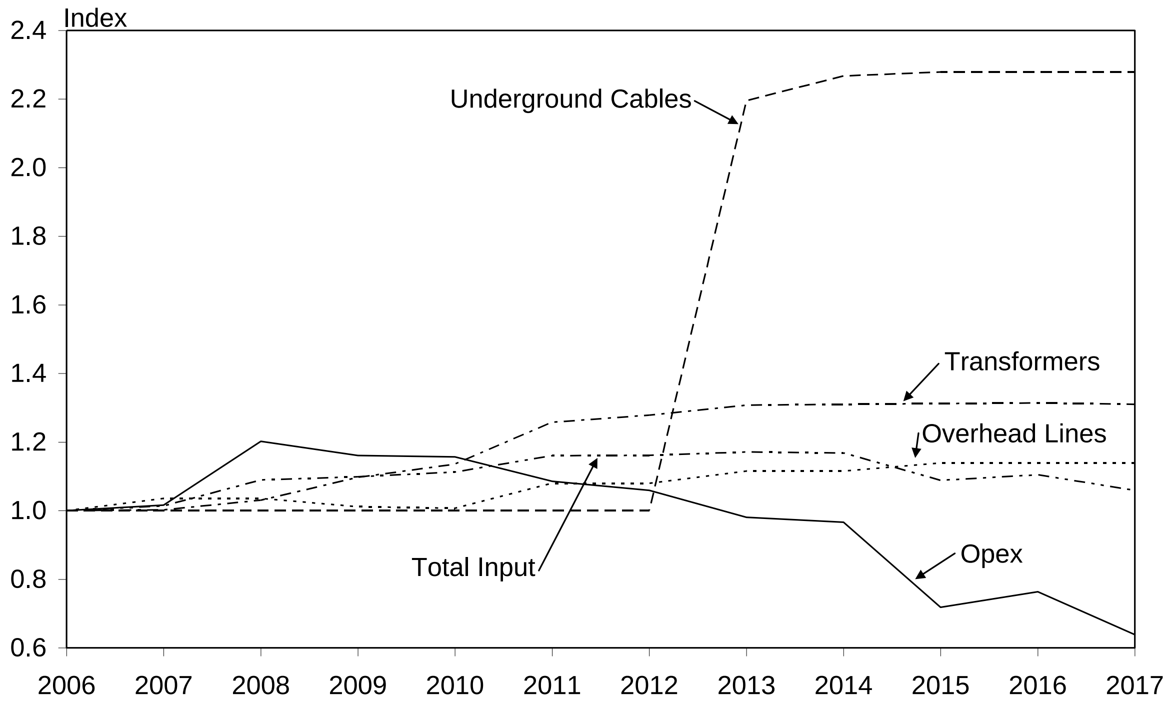
The output that is not shown in figure 4.14 is total energy not supplied (ENS). TNT's ENS has been relatively volatile but within a much smaller range than most other TNSPs. ENS fell from 2006 through to 2009 before trending up to be 60 per cent above its 2006 level in 2013. However, since then it has reduced each year to be at only 24 per cent of its 2006 level in 2017. 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, end–user numbers and energy throughput outputs receive a combined weight of around 64 per cent of gross revenue in forming the total output index, in figure 4.14 we see that the total output index tends to lie close to the end–user numbers 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, particularly in 2013 (noting that an increase in ENS has a negative impact on total output and is given an average weight of around 3 per cent of gross revenue on average for TNT). However, the impact of ENS events on total output is smaller for TNT given its narrower range of ENS than other TNSPs.

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.

Figure 4.15 **TNT's input quantity indexes, 2006–2017**



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 at which time it was then 36 per cent below its 2006 level. TNT's large fall in opex use between 2006 and 2017 contrasts with the industry's increase in opex usage of 11 per cent over the same period. Opex has the second largest average share in TNT's total costs at 30 per cent.

The input component with the largest average share of total cost, at 47 per cent, is transformers. TNT's quantity of transformers increased steadily to 2013 before levelling off and by 2017 was 31 per cent above its 2006 level – a smaller increase than the industry's 46 per cent. Given its large share of total costs, transformer inputs is an important driver of the total input quantity index.

From figure 4.15 we see that TNT's total input quantity index generally lies between the quantity indexes for transformers and overhead lines (which have a weight of 69 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

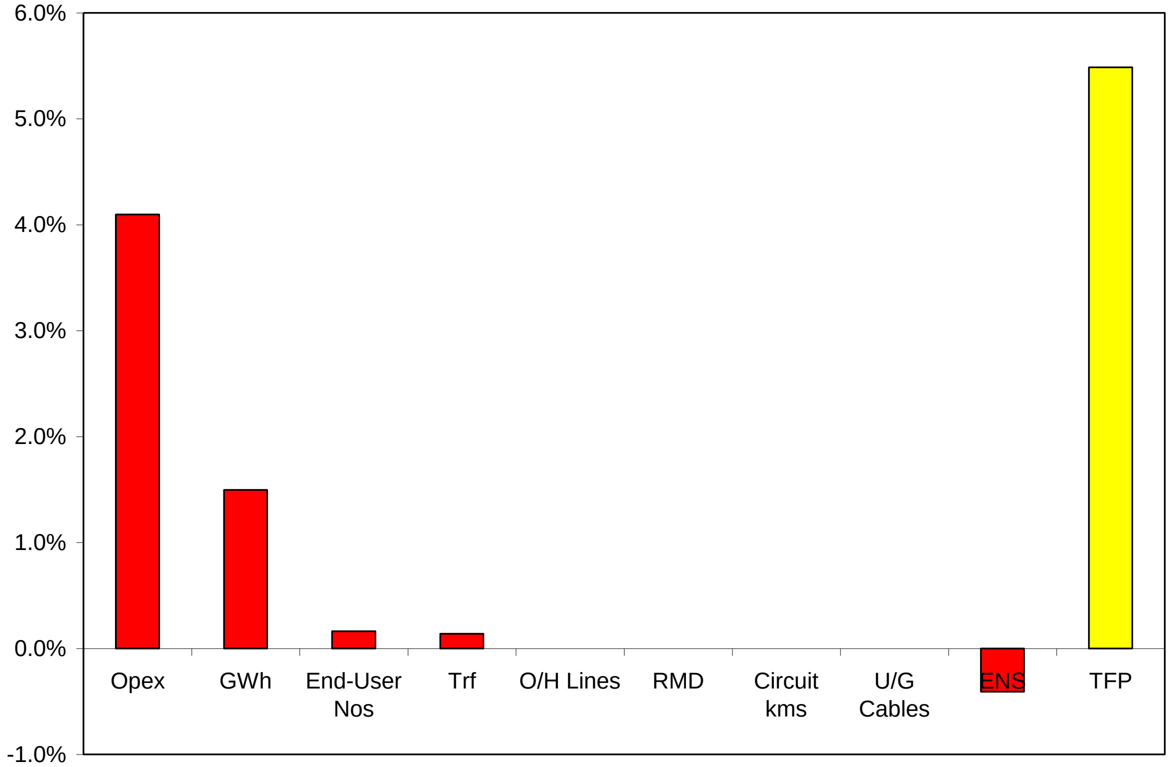
In table 4.8 we present the percentage point contributions of each output and each input to TNT's average annual rate of TFP change of 0.4 per cent over the 12–year period 2006 to 2017.

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 opex provides a negative contribution and energy provides no contribution for the industry. RMD growth provides no contribution to TNT's TFP growth whereas it is a positive contributor for the industry. And, transformer input growth contributes –1.1 percentage points to TNT's TFP change compared to –1.4 percentage points for the industry, reflecting the smaller growth in TNT's transformer input quantity.

Table 4.8 **TNT's output and input percentage point contributions to average annual TFP change: 2006–2017, 2006–2012 and 2012–2017**

Year	*2006 to 2017*	*2006 to 2012*	*2012 to 2017*
Energy (GWh)	0.37%	0.71%	–0.05%
Ratcheted Max Demand	0.00%	0.01%	0.00%
Customer Numbers	0.26%	0.36%	0.13%
Circuit Length	–0.02%	–0.16%	0.15%
ENS	0.32%	0.32%	0.32%
Opex	0.93%	–0.42%	2.56%
O/H Lines	–0.27%	–0.27%	–0.27%
U/G Cables	–0.10%	0.00%	–0.22%
Transformers	–1.09%	–1.81%	–0.23%
TFP Change	0.41%	–1.25%	2.41%

Figure 4.16 **TNT's output and input percentage point contributions to annual TFP change, 2016–17**



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 –0.4 percentage points before 2012 to 2.6 percentage points after 2012. And energy makes a small negative contribution to TNT's TFP after 2012 versus a 0.7 percentage point contribution. And, on the input side, there is also a reduction in the negative contribution of transformers input before 2012 of –1.8 percentage points to –0.2 percentage points after 2012 as transformer inputs level off from 2013 onwards.

In figure 4.16 we present the contributions of outputs and inputs to TNT's TFP change of 5.5 per cent in the 2017 year. The decrease in opex usage in 2017 leads to it making the largest positive contribution to TFP change at 4.1 percentage points. The increase in energy throughput in 2017 leads to it making the next largest positive contribution at 1.5 percentage points. The only negative contribution of note in the latest year is –0.4 percentage points from a small increase in ENS. TNT's TFP change in 2017 of 5.5 per cent is similar to the industry TFP change in 2017 of 5.8 per cent.

4.5 TransGrid

In 2017 TransGrid (TRG) transported 75,000 GWh of electricity over 13,078 circuit kilometres of lines and cables. It forms a critical part of New South Wales' energy supply chain serving around 3.8 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

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 12–year period 2006 to 2017, TRG's TFP decreased at an average annual rate of change of –1.8 per cent. Its total output increased over the period with an average annual rate of change of 0.4 per cent. This compares to an industry growth in output of 0.9 per cent per annum on average. TRG's average annual rate of increase in input use of 2.2 per cent was around the same as that for the industry. When combined with its increase in output, this gives TRG an average annual change in TFP of –1.8 per cent compared to the industry's average annual change of –1.3 per cent. TRG's TFP change was positive in 2008, 2011, 2013 and 2017. 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.

In 2017 TRG had very strong TFP of 10.8 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. 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 is still relatively high at 4.6 per cent due to the impact of reduced input use that year. In 2017 ENS returned to levels close to where it was in 2006 and so the output and TFP indexes including and excluding ENS again coincide.

Figure 4.17 **TRG's output, input and total factor productivity indexes, 2006–2017**

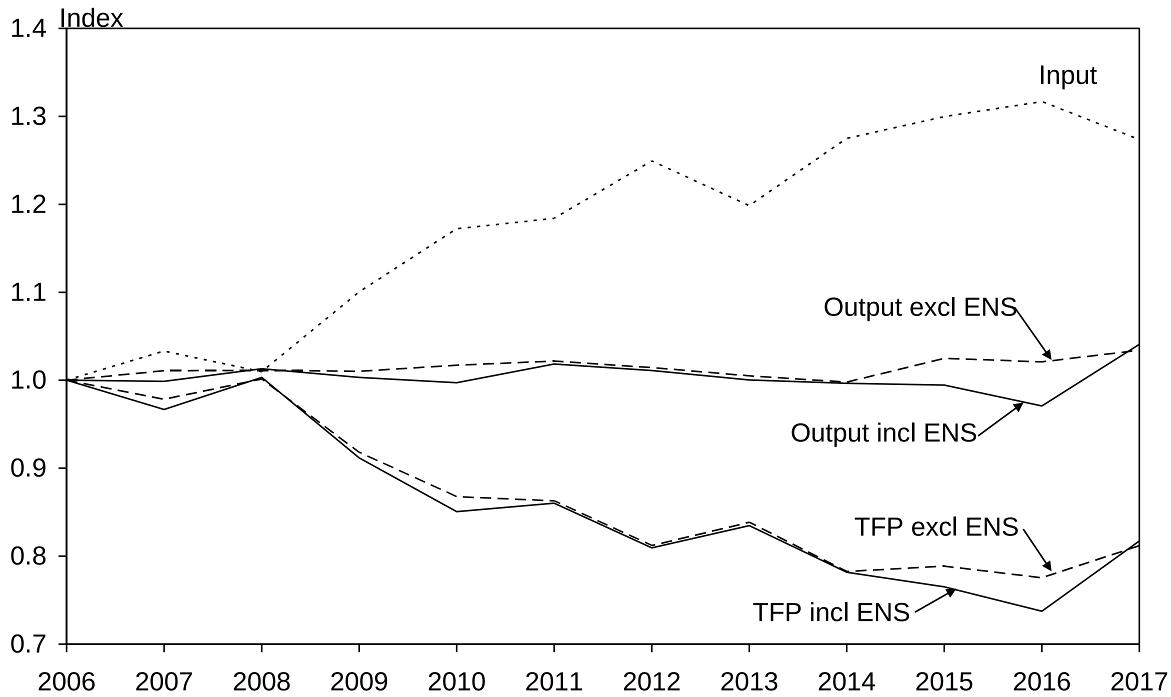


Table 4.9 **TRG's output, input and total factor productivity and partial productivity indexes, 2006–2017**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	0.999	1.033	0.967	1.025	0.942
2008	1.013	1.010	1.003	1.112	0.959
2009	1.003	1.100	0.912	1.106	0.841
2010	0.997	1.172	0.851	0.980	0.799
2011	1.019	1.184	0.860	1.081	0.784
2012	1.011	1.249	0.809	1.004	0.741
2013	1.000	1.198	0.835	1.093	0.751
2014	0.996	1.275	0.782	0.912	0.734
2015	0.995	1.300	0.765	0.973	0.696
2016	0.971	1.317	0.737	0.961	0.666
2017	1.041	1.274	0.817	1.045	0.742
Growth Rate 2006–17	0.36%	2.20%	–1.83%	0.40%	–2.71%
Growth Rate 2006–12	0.18%	3.71%	–3.53%	0.06%	–5.00%
Growth Rate 2012–17	0.58%	0.39%	0.20%	0.81%	0.05%

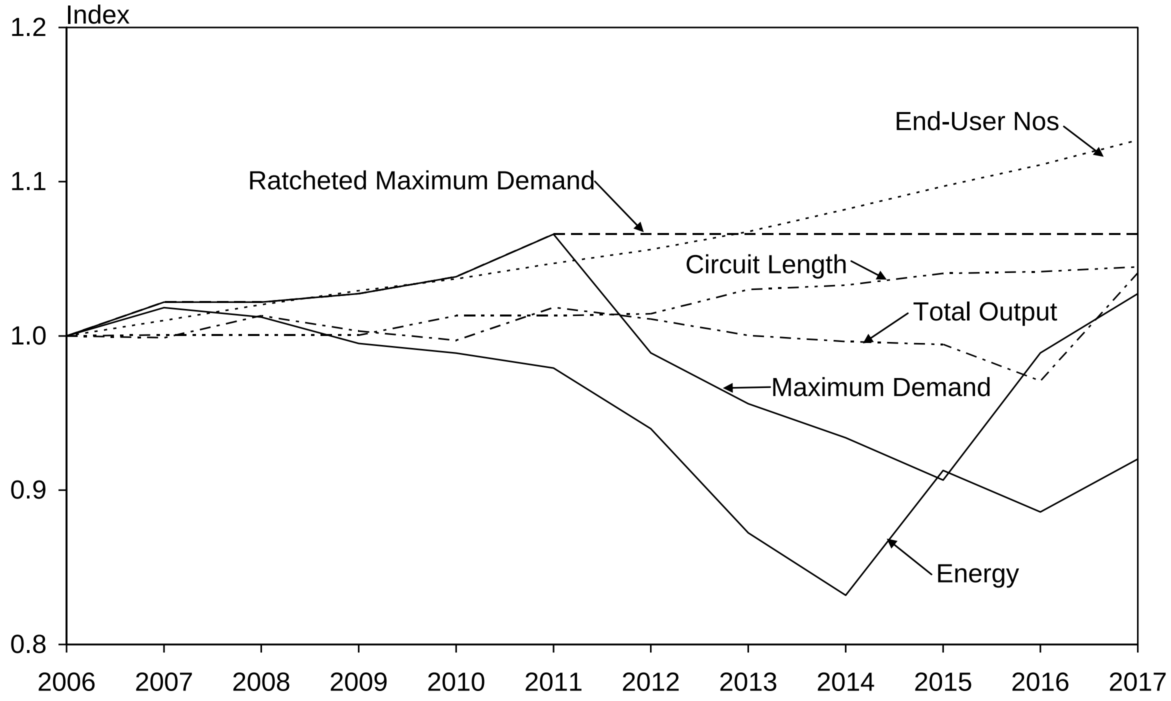
For the period after 2012, the rate of average annual growth in input usage increased substantially while the average annual change in input use reduced substantially. This led to an improvement in TFP change from –3.5 per cent before 2012 to 0.2 per cent after 2012.

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.

Figure 4.18 **TRG's output quantity indexes, 2006–2017**



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 steadily over the 12–year period. By 2017, however, TRG's circuit length was only 5 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 though to 2011 but then fell substantially through to 2015 followed by a partial recovery in 2016 and 2017. TRG's maximum demand was 3 per cent above its 2006 level in 2017. The industry's 2017 maximum demand was 6 per cent above its 2006 level in 2017. In 2017 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.

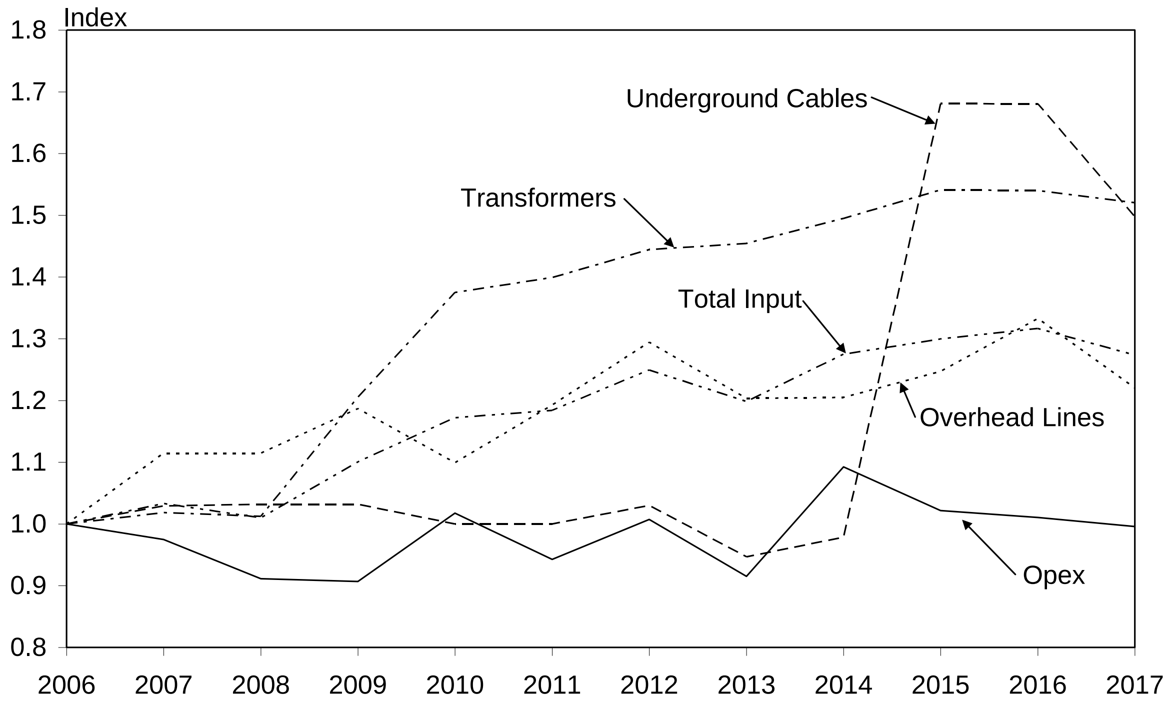
Similarly, we see that TRG's energy throughput increased by 2 per cent in 2007 but then fell by around 18 per cent through to 2014. In 2017 it was 8 per cent below its 2006 level compared to the industry's throughput then being around the same as it was in 2006.

The output that increased the most over the period for TRG is end–user numbers with an increase of 13 per cent between 2006 and 2017, less than the increase of 16 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 has 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. 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 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 3 per cent of gross revenue on average for TRG).

Figure 4.19 **TRG's input quantity indexes, 2006–2017**



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. 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.

The quantity of opex increased the least of TRG's four inputs over the 12–year period, being around the same level in 2017 as 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 three years. TRG's marginal opex change between 2006 and 2017 compares to an increase for the industry of 11 per cent. Opex has the second largest average share in TRG's total costs at 31 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 in 2016 and declining slightly in 2017. By 2017 it was 52 per cent above its 2006 level – a larger increase that the industry's 46 per cent. Given its large share of total costs, transformer inputs is 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 present the percentage point contributions of each output and each input to TRG's average annual rate of TFP change of –1.8 per cent over the 12–year period 2006 to 2017.

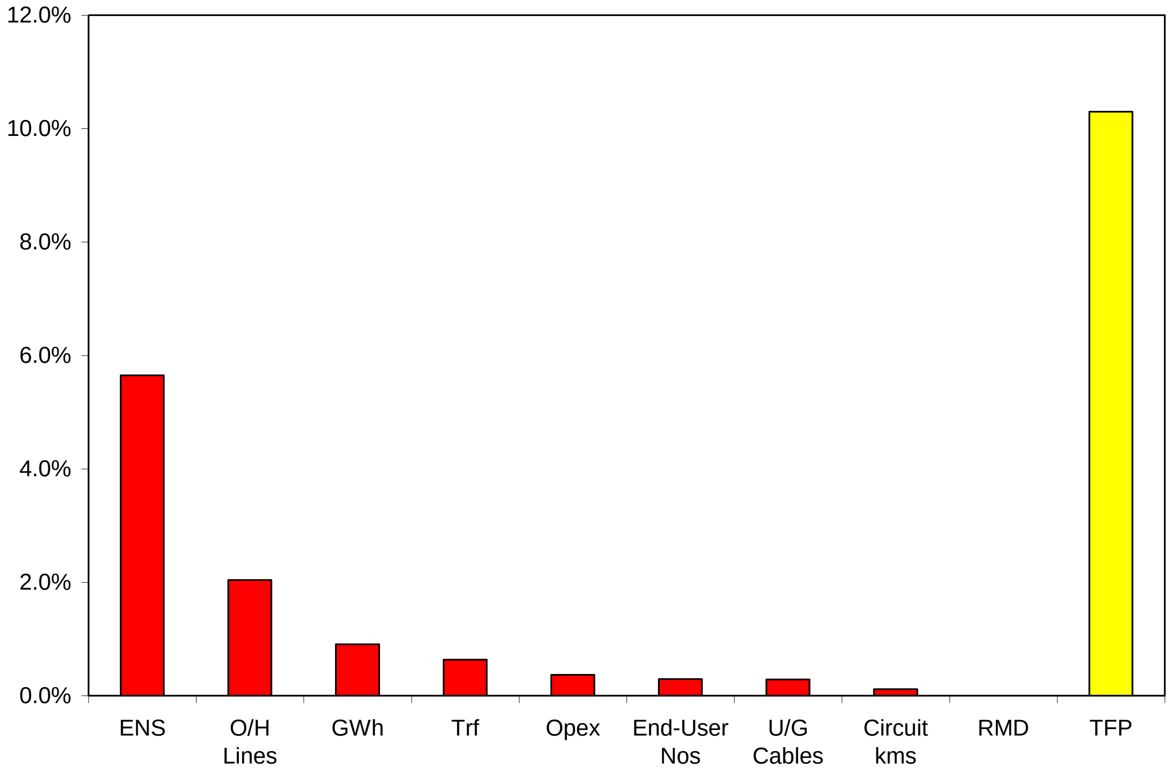
Table 4.10 **TRG's output and input percentage point contributions to average annual TFP change: 2006–2017, 2006–2012 and 2012–2017**

Year	*2006 to 2017*	*2006 to 2012*	*2012 to 2017*
Energy (GWh)	–0.17%	–0.24%	–0.09%
Ratcheted Max Demand	0.11%	0.21%	0.00%
Customer Numbers	0.22%	0.18%	0.26%
Circuit Length	0.15%	0.09%	0.23%
ENS	0.05%	–0.06%	0.18%
Opex	0.03%	0.08%	–0.03%
O/H Lines	–0.53%	–1.23%	0.31%
U/G Cables	–0.10%	–0.02%	–0.19%
Transformers	–1.60%	–2.54%	–0.46%
TFP Change	–1.83%	–3.53%	0.20%

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 has near zero impact on TRG's TFP whereas it has an effect of –0.3 percentage points for the industry. And, transformer input growth contributes –1.6 percentage points to TRG's TFP change compared to –1.4 percentage points for the industry, reflecting the faster growth in TRG's transformer input quantity.

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 0.2 percentage points after 2012. The contribution of transformers goes from –2.5 percentage points before 2012 to –0.5 after 2012 as growth in transformer inputs moderates. And the contribution of overhead lines input changes from –1.2 percentage points before 2012 to 0.3 percentage points after 2012 as overhead lines input increased more rapidly in the earlier period before flattening out and declining by a small amount in the more recent period. Overall, TFP average annual change improves from –3.5 per cent before 2012 to 0.2 per cent after 2012.

Figure 4.20 **TRG's output and input percentage point contributions to annual TFP change, 2016–17**



In figure 4.20 we present the contributions of outputs and inputs to TRG's 10.3 per cent TFP change in the 2017 year. The large reduction in ENS in 2017 leads to it making the largest positive contribution to TFP change at 5.7 percentage points. The second largest positive contribution at 2.0 percentage points comes from the reduction in overhead lines input. Small reductions in the other input components lead tot hem also making small positive contributions to TFP change in 2017. And growth in energy throughput in 2017 leads to it making the third largest positive contribution at 0.9 percentage points. TRG's large positive TFP change in 2017, just half of which was due to the reduction in ENS, was better than TFP change for the industry as a whole which was itself a quite high 5.8 per cent.

APPENDIX A METHODOLOGY

A1 Time–series TFP index

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 benchmarking reports we have used the Fisher ideal index, one of a family of index number methods that have desirable properties such as providing second–order approximations to underlying technologies (see Economic Insights 2014). In this report we use another of those indexes, the Törnqvist index, because it allows more convenient identification of the contribution of individual outputs and inputs to productivity change.

The Törnqvist TFP change index is given by the following equation:

$$(1) \qquad \ln(TFP_t / TFP_{t-1}) = \sum_{i=1}^{N} \left(\frac{r_{it} + r_{it-1}}{2} \right) [\ln y_{it} - \ln y_{it-1}] - \sum_{j=1}^{M} \left(\frac{s_{jt} + s_{jt-1}}{2} \right) [\ln x_{jt} - \ln x_{jt-1}]$$

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 and ln is the natural logarithm operator.

A2 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 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 is given by the following equation:

(2) $$Contribution\ of\ output\ i = \left(\frac{r_{it}+r_{it-1}}{2}\right)[\ln y_{it} - \ln y_{it-1}]$$

And, the contribution of input *j* to productivity change is given by the following equation:

(3) $$Contribution\ of\ input\ j = -\left(\frac{s_{jt}+s_{jt-1}}{2}\right)[\ln x_{jt} - \ln x_{jt-1}]$$

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).

A3 Multilateral TFP comparisons

Traditional measures of TFP, such as that presented in sections A1 and A2 above, 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 translog 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.

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

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

where the variables have the same definition as in equation (1) and R_i^* (S_j^*) is the revenue (cost) share of the *i*–th output (*j*–th input) averaged over all utilities and time periods 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 average NSP with output vector Y_i^*, input vector X_j^*, revenue shares R_i^* and cost shares S_j^*.

Because the MTFP index focuses on preserving comparability of productivity levels over time, there may sometimes be minor differences in the pattern of productivity change for a particular firm derived from the MTFP results as compared to the time–series Törnqvist TFP results for the same firm. 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 over time. Detailed examination of a firm's productivity performance over time is usually done using a time–series index such as the Törnqvist or Fisher index since the comparison being made is then unilateral in nature rather than multilateral.

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