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

Report prepared for
Australian Energy Regulator

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DNSP NAME ABBREVIATIONS

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

Abbreviation	*DNSP name*	*State*
ACT	ActewAGL	Australian Capital Territory
AGD	Ausgrid	New South Wales
AND	AusNet Services Distribution	Victoria
CIT	CitiPower	Victoria
END	Endeavour Energy	New South Wales
ENX	Energex	Queensland
ERG	Ergon Energy	Queensland
ESS	Essential Energy	New South Wales
JEN	Jemena Electricity Networks	Victoria
PCR	Powercor	Victoria
SAP	SA Power Networks	South Australia
TND	TasNetworks Distribution	Tasmania
UED	United Energy	Victoria

1 INTRODUCTION

Economic Insights has been asked to update the electricity distribution network service provider (DNSP) multilateral total factor productivity (MTFP) and multilateral partial factor productivity (MPFP) results presented in the Australian Energy Regulator's 2017 DNSP Benchmarking Report (AER 2017). We also update the detailed analysis of the drivers of DNSP productivity change presented for the first time in Economic insights (2017). This analysis examines the contribution of each individual output and input to total factor productivity (TFP) change.

The update involves including data for the 2016–17 financial and 2017 calendar years (as relevant) reported by the DNSPs in their latest Economic Benchmarking Regulatory Information Notice (EBRIN) returns. It also includes a small number of revisions to DNSP data, mainly relating to further refinement of MVA factors for lines and cables, and updates to the output cost weights used in the index number analysis.

We also update and expand the three sets of opex cost function econometric results presented in Economic Insights (2014, 2015a,b, 2017) to include 2016–17 or 2017 data for the Australian DNSPs, as relevant, and to update the New Zealand and Ontario data by another year. This year we present results for the 6–year period from 2012 onwards as well as for the 12–year period from 2006 onwards.

1.1 Specification used for productivity measurement

Since we use a functional outputs approach to measuring DNSP productivity, we require estimates of the shares of total cost attributable to each of the included outputs. The output weights used in our DNSP productivity analyses reported to date were based on estimation of Leontief cost functions using Australian DNSP data for 2006 to 2012 outlined in Economic Insights (2014). In line with previous practice where a functional outputs specification is used, these weights have been held constant so that changes in productivity scores from year to year directly reflect changes in DNSP performance. However, the weights do need to be updated periodically to improve their currency and to take advantage of larger sample sizes which become available over time. We recognise there will be an inevitable trade–off between maintaining stability of the weights and maintaining their currency and accuracy. In our view, the best response to this trade–off will be to update the weights every several years.

Only 7 observations per DNSP were available to support estimation of the Leontief cost functions reported in Economic Insights (2014). As more data becomes available over time, it should be possible to obtain better and more current estimates of these output cost shares and to use more alternative functional forms to corroborate the estimates. We now have 12 observations available per DNSP – an increase of more than 50 per cent in the size of the Australian database – and there have also been some data revisions made since the original Leontief cost functions were estimated, including ACT's significant revision of its Cost Allocation Methodology (CAM) which brought it more into line with those of the other DNSPs. Since 5 years have passed since the original estimation was undertaken, we believe now is an appropriate time to update the output cost share weights. Consequently, we have re–estimated our Leontief cost function models and obtained updated output weights. We recommend these updated output weights be left in place for the next 5 years so that changes in annual productivity scores directly reflect changes in DNSP performance. The Leontief cost function methodology is outlined in appendix A.

The expanded Australian DNSP database now also supports estimation of a translog cost function across the whole sample. While the sample size and degree of data variation across DNSPs is still at the lower end of that required, the derived output cost shares are broadly similar to those obtained from the Leontief cost functions. The translog cost function methodology is also outlined in appendix A.

The output weights used up till now allocated approximately 13 per cent to energy, 18 per cent to ratcheted maximum demand (RMD), 46 per cent to customer numbers and 24 per cent to circuit length. The updated weights shift around 10 percentage points from customers to RMD and around 5 percentage points from customers to circuit length. It is likely that customer numbers were initially acting as a proxy for relatively fixed infrastructure–related costs as well as for directly customer–related costs. The expanded database allows the models to attribute infrastructure–related costs more directly. Using the updated weights does not make a large change to the productivity levels results although the rural DNSPs do somewhat better under the updated weights and some urban DNSPs do slightly less well.

In submissions on the draft version of this report, AGD (2018) and END (2018) expressed reservations about the output weights being updated without more extensive consultation. In particular, AGD (2018, p.5) noted that the increased weight given to RMD could discourage DNSPs' demand side response initiatives aimed at reducing peak demands. SAP (2018, p.4) also noted that facilitating increased solar generation was now a major focus of its operations and what customers expected but doing this actually reduced its output as currently measured by economic benchmarking.

As transformation of the electricity supply industry progresses, we agree that the economic benchmarking specification will need to be reviewed and outputs possibly included that reflect the increasing role distributed generation is expected to play. This would most appropriately be done as part of a broader review conducted by the AER. In the meantime, we believe it is appropriate to undertake ongoing refinements of the current specification including periodic updating of output weights.

The DNSP MTFP and TFP measures presented in this report have five outputs included:

- Energy throughput (with 12 per cent share of gross revenue)
- Ratcheted maximum demand (with 28 per cent share of gross revenue)
- Customer numbers (with 31 per cent share of gross revenue)
- Circuit length (with 29 per cent share of gross revenue), and
- (minus) Minutes off–supply (with the weight based on current AEMO VCRs).

The DNSP MTFP and TFP measures include six inputs:

- Opex (network services opex deflated by a composite labour, materials and services price index)

- Overhead subtransmission lines (quantity proxied by overhead subtransmission MVAkms)
- Overhead distribution lines (quantity proxied by overhead distribution MVAkms)
- Underground subtransmission cables (quantity proxied by underground subtransmission MVAkms)
- Underground distribution cables (quantity proxied by underground distribution MVAkms), and
- Transformers and other capital (quantity proxied by distribution transformer MVA plus the sum of single stage and the second stage of two stage zone substation level transformer MVA).

In all cases, the annual user cost (AUC) 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.

In the interests of maximum transparency, we also present MTFP and MPFP measures using the original output weights in appendix B.

1.2 Data revisions

Some further small refinements have been made to the database, the most notable of which is improved estimates to put CitiPower's and Powercor's connections opex on a more comparable basis with other DNSPs. This leads to an approximate 3 per cent reduction in these DNSPs' network services opex. TasNetworks' revenue has been revised to include only distribution use of system charges. There have also been further refinements to selected MVA factors for lines and cables, mainly for AusNet Services. Two DNSPs have proposed sizable changes to a small number of MVA factors for 2017 but these have not been included to maintain comparability within the database.

Submissions from some DNSPs, notably those of AND (2018) and SAP (2018), argued that further refinement of the treatment of CAM issues could be made at a more disaggregated level, particularly in relation to corporate overheads. We agree this is likely to be a worthwhile area to focus future data refinement on.

In line with previous practice, all DNSPs' data for all years are based on the CAMs that applied in 2014 rather than on more recently revised CAMs. The CAMs applying in 2014 (including ACT's revised CAM) led to opex/capex ratios being broadly consistent across DNSPs. 'Freezing' the CAMs at this point has minimised the scope for DNSPs to game the benchmarking results by reallocating costs between opex and capex and currently provides the best basis for like–with–like comparisons of overall network services opex.

2 INDUSTRY–LEVEL DISTRIBUTION PRODUCTIVITY RESULTS

Distribution 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 distribution output, input and total factor productivity indexes, 2006–2017**

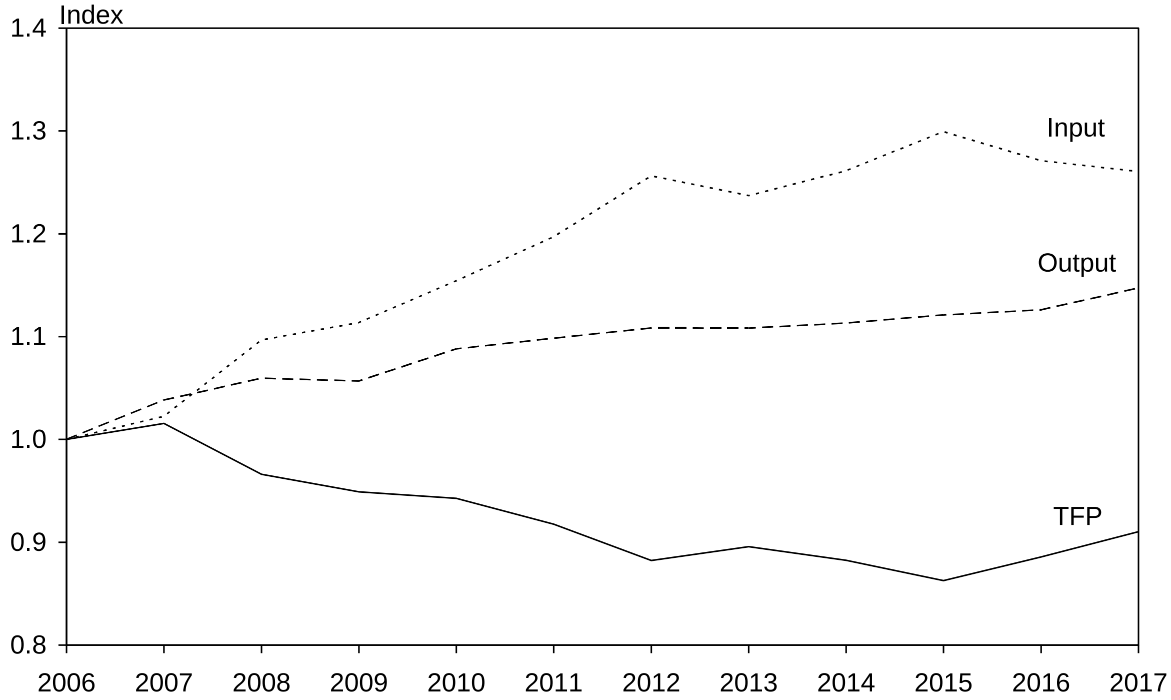


Table 2.1 **Industry–level distribution output, input and total factor productivity and partial productivity indexes, 2006–2017**

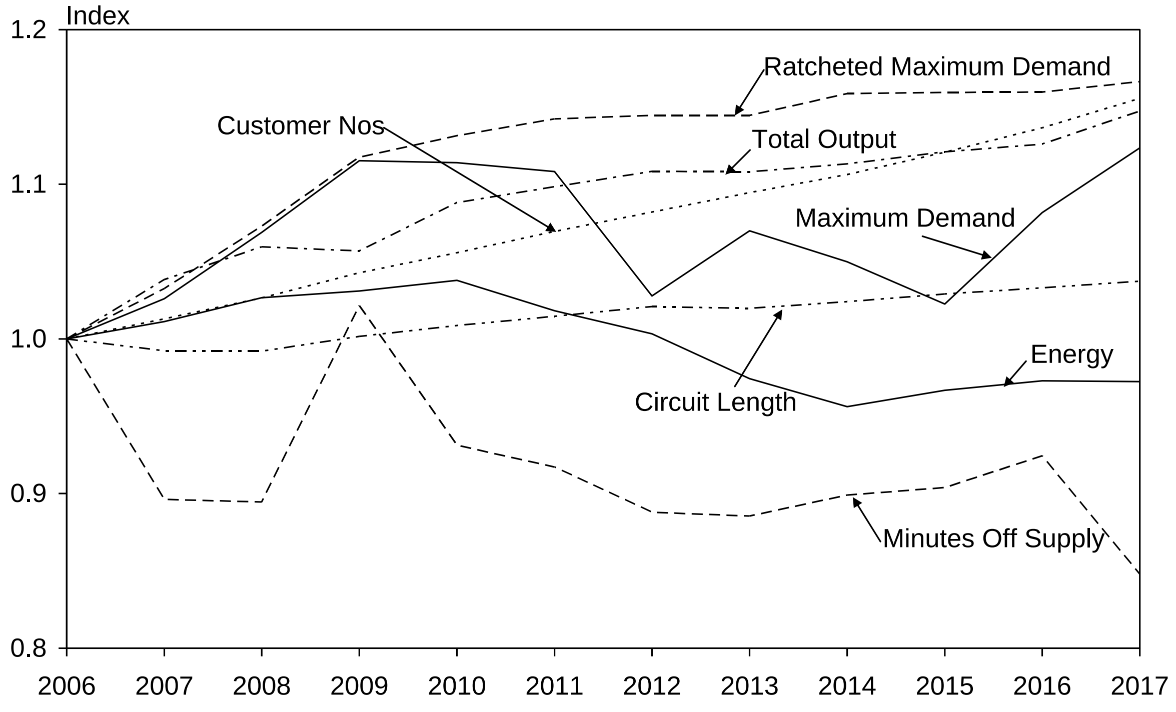
Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index Opex*	*PFP Index Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.038	1.022	1.016	1.042	0.998
2008	1.060	1.097	0.966	0.928	0.992
2009	1.057	1.114	0.949	0.938	0.957
2010	1.088	1.154	0.943	0.926	0.954
2011	1.098	1.197	0.918	0.882	0.940
2012	1.108	1.256	0.882	0.815	0.925
2013	1.108	1.237	0.896	0.885	0.904
2014	1.113	1.261	0.883	0.877	0.888
2015	1.121	1.299	0.863	0.838	0.880
2016	1.126	1.271	0.886	0.918	0.870
2017	1.147	1.261	0.910	0.973	0.879
Growth Rate 2006–17	1.25%	2.11%	–0.86%	–0.25%	–1.17%
Growth Rate 2006–12	1.72%	3.80%	–2.09%	–3.41%	–1.31%
Growth Rate 2012–17	0.69%	0.07%	0.62%	3.55%	–1.01%

Over the 12–year period 2006 to 2017, industry level TFP declined at an average annual rate of 0.9 per cent. Although total output increased at an average annual rate of 1.3 per cent, total input use increased faster, at a rate of 2.1 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 – 2007, 2013, 2016 and again in 2017. In the first of these years, input use increased but at less of a rate than output increased, while in 2013, 2016 and 2017 input use decreased.

2.1 Distribution 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 distribution output components and our six distribution 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 distribution 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, customer numbers, increased steadily over the period and was 16 per cent higher in 2017 than it was in 2006. This steady increase is to be expected as the number of electricity customers will increase roughly in line with growth in the population. However, we see that energy throughput for distribution peaked in 2010 and fell steadily through to 2014 and has increasing only marginally since then. In 2017 energy throughput was still 3 per cent 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. 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 and more energy efficient buildings and appliances. Distribution networks, thus, have to service a steadily increasing number of 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 DNSPs 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 lesser rate in 2010 and has been relatively flat since. We do observe some small increases in this output since 2009 as it is the sum of individual ratcheted maximum demands across the 13 DNSPs and maximum demand for some DNSPs increased above earlier peaks in some years even though aggregate maximum demand exceeded its 2009 peak for the first time in 2017. In 2017 overall ratcheted maximum demand was 17 per cent above its 2006 level.

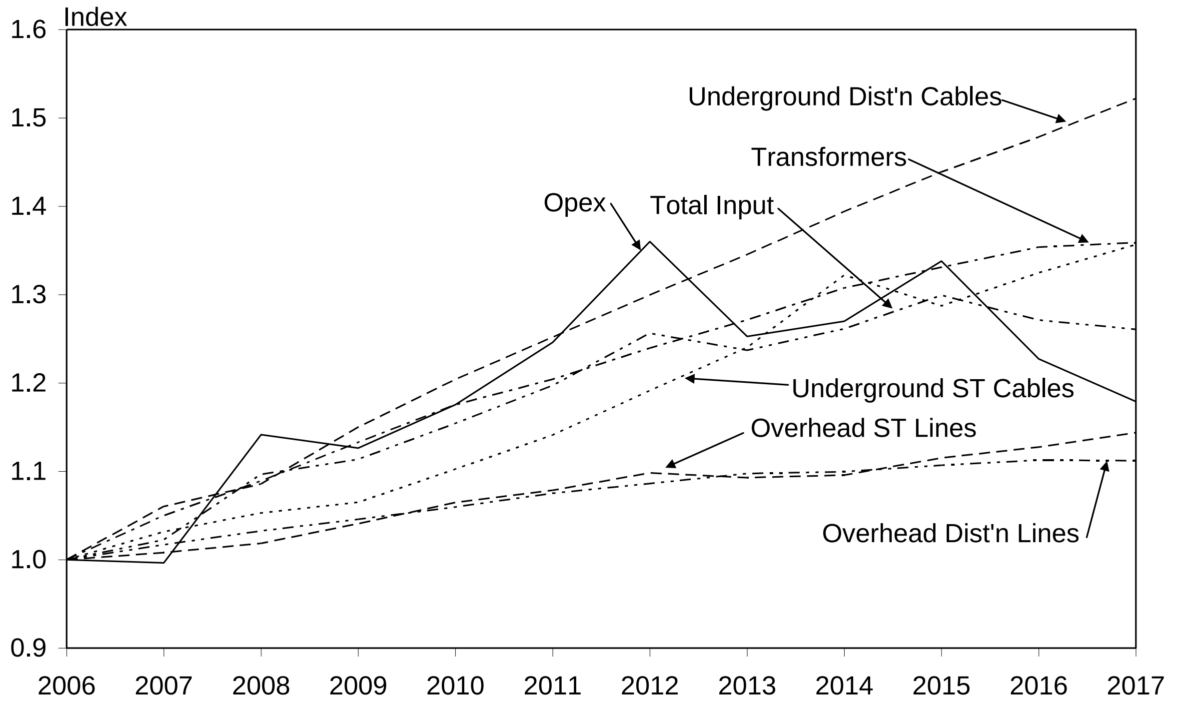
The circuit length output grew very modestly over the 12 years and by 2017 was only 4 per cent higher than it was in 2006. This reflects the fact that most of the increase in customer numbers over the period has been able to be accommodated by 'in fill' off the existing network that does not require large increases in 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 network length are modest compared to the increase in customer numbers being serviced.

The last output shown in figure 2.2 is total customer minutes off–supply (CMOS). This enters the total output index as a negative output since a reduction in CMOS represents an improvement and a higher level of service for customers. Conversely, an increase in CMOS reduces total output as customers are inconvenienced more by not having supply for a longer period. We see that, with the exception of 2009, CMOS has generally been lower and, hence, contributed more to total output than was the case in 2006. In 2017 CMOS was 15 per cent less than it was in 2006.

Since the customer numbers and ratcheted maximum demand outputs receive a weight of around 60 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 just above the customer numbers output index with movements influenced by the pattern of movement in the CMOS output (noting that an increase in CMOS has a negative impact on total output and is given a weight of around 15 per cent of gross revenue on average). Although circuit length also gets a weight of around 29 per cent of gross revenue, it changes little over the period. And throughput is given a smaller weight of 12 per cent of gross revenue in line with changes in throughput generally having relatively low marginal cost. Reductions in throughput after 2010, hence, have a more muted impact on total output.

Turning to the input side, we present quantity indexes for the six input components and total input in figure 2.3. The quantity of opex (ie opex in constant 2006 prices) increased sharply between 2006 and 2012, being 36 per cent higher in 2012 than it was in 2006. It then fell in 2013 – a year that coincided with price reviews of several large DNSPs – before increasing again in 2014 and 2015 and then falling by 8 per cent in 2016 and by 4 per cent in 2017, at which time it was 18 per cent above its 2006 level. Opex has the largest average share in total costs at 37 per cent and so is an important driver of the total input quantity index.

Figure 2.3 **Industry–level distribution input quantity indexes, 2006–2016**



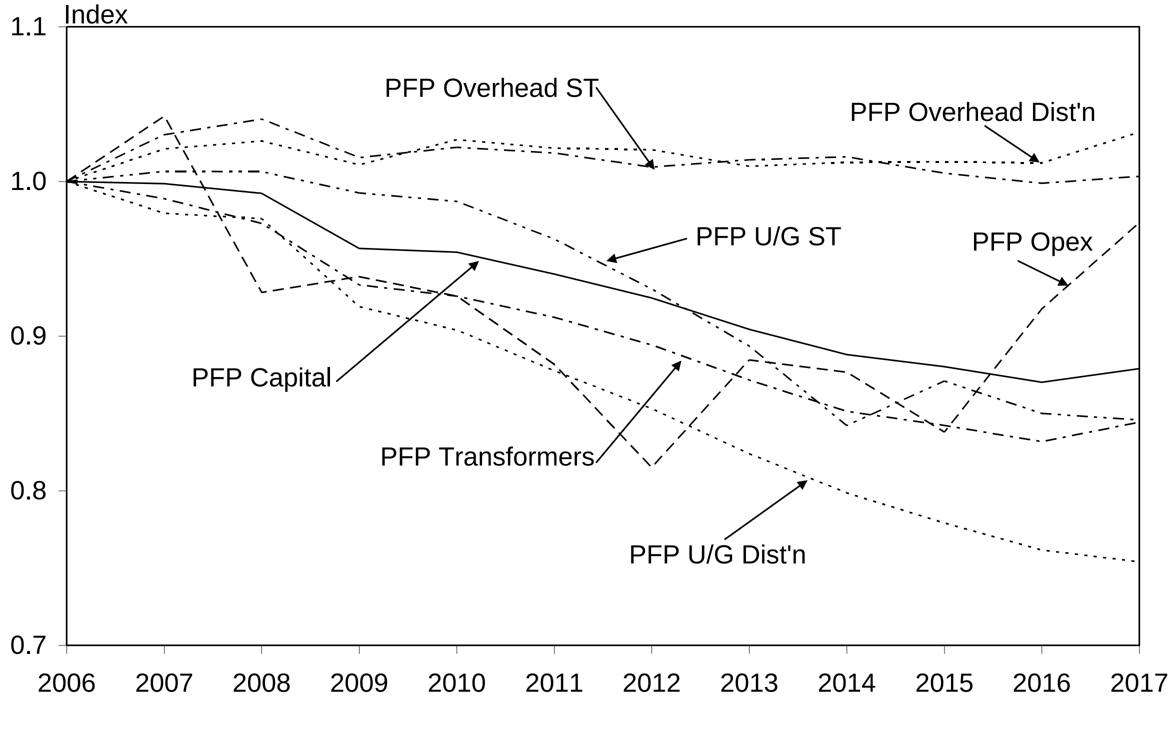
The other input component with a large average share of total cost, at 29 per cent, is transformers. The quantity of transformers has increased steadily over the period and by 2017 was 36 per cent above its 2006 level. It is by the use of more or larger transformers in zone substations and on the existing network that DNSPs can accommodate ongoing increases in customer numbers with only minimal increases in their overall network length.

The next key components of DNSP input are the quantities of overhead distribution and overhead subtransmission lines. These two input quantities have increased the least over the period with levels in 2017 around 11 and 14 per cent, respectively, higher than 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 both overhead distribution and subtransmission quantities have 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. This could partly reflect the need for higher capacity lines to meet the growth in customer numbers within the overall network footprint and the need to meet higher standards but could also reflect a degree of built–in overcapacity. Overhead distribution and subtransmission lines account for around 20 per cent of total DNSP costs on average.

The fastest growing input quantity is that of underground distribution cables whose quantity was 52 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, particularly seeing that many new land developments require the use of underground distribution and there is a push in some areas to make greater use of undergrounding for aesthetic reasons. Underground distribution quantity increases somewhat faster than underground subtransmission quantity, again likely reflecting the increasing use of undergrounding in new subdivisions and land developments. Although the length of overhead lines is several times higher than the length of underground cables, underground cables are considerably more expensive to install per kilometre. Consequently, underground distribution and subtransmission have a share in total costs of 14 per cent despite their relatively short length.

From figure 2.3 we see that the total input quantity index lies close to the quantity indexes for opex and transformers (which together have a weight of 67 per cent of total costs). The faster growing underground distribution cables quantity index generally lies above this group of quantity indexes which in turn lie above the slower growing overhead lines quantity indexes.

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

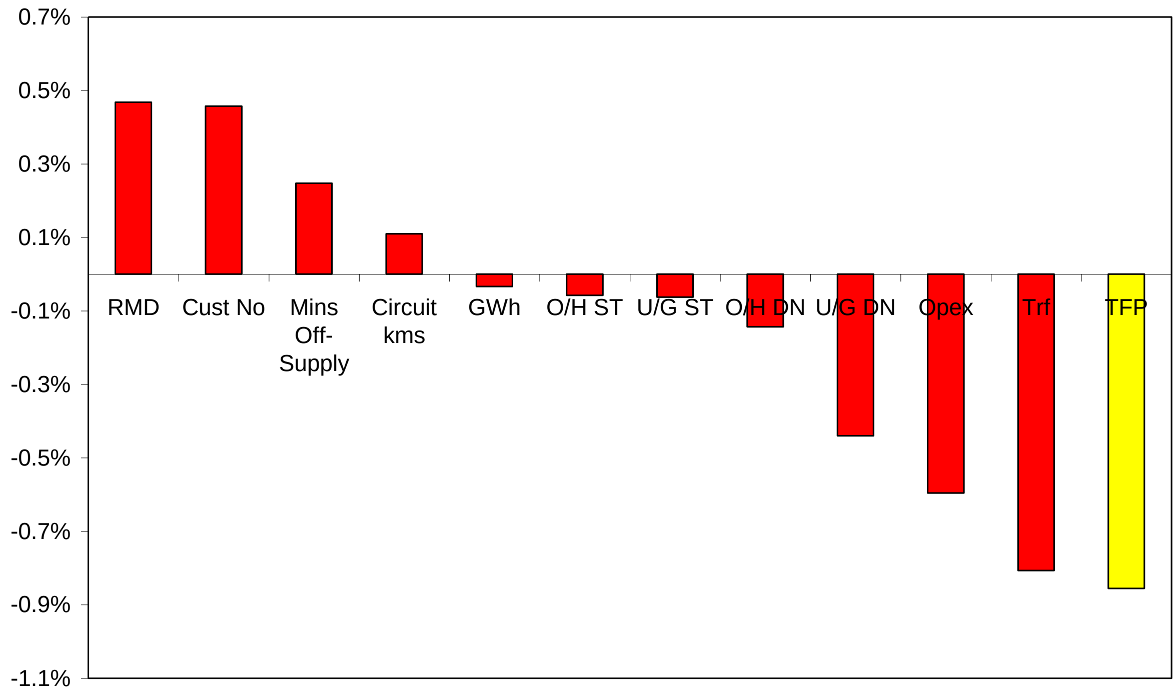


From figure 2.4 we see that movements in distribution industry–level partial productivity indexes follow an essentially inverse pattern to input quantities (since a partial productivity index is total output quantity divided by the relevant input quantity index). Overhead lines partial productivity indexes are consequently the highest over the period, although the level of overhead distribution lines partial productivity was only 3 per cent higher in 2017 than it was in 2006. Nearly all other partial productivity indexes decline over the period which means the quantities of those inputs have increased faster than total output. Underground distribution cables partial productivity declines the most over the period, being 25 per cent lower in 2017 than in 2006. As noted above, this is because underground distribution cables have increased rapidly from a small base. Transformer partial productivity has declined by the next largest amount, being 16 per cent lower in 2017 than in 2006. Opex partial productivity declined the most through to 2012 but has generally improved since as opex use has trended down from its 2012 peak. In 2012 opex partial productivity was 18 per cent below its 2006 level but by 2017 had recovered somewhat to be 3 per cent below its 2006 level.

2.2 Distribution 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].

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



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 –0.9 per cent over the 12–year period

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

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 (red bar) positive and negative contributions 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 RMD and customer numbers provided the highest positive contributions to TFP change over the 12–year period. As noted in the previous section, customer numbers have grown steadily by 1.3 per cent annually over the whole period as customer numbers generally increase in line with population growth. As customer numbers have the largest weight of the output components at around 35 per cent and the second highest growth rate of the output components, they contribute just under 0.5 percentage points to TFP change over the period.

The highest contribution to TFP change comes from ratcheted maximum demand which, despite flattening out after 2011, had the highest average annual output growth rate over the period of 1.4 per cent. Combined with its weight of around 33 per cent, this led to RMD also contributing just under 0.5 percentage points to TFP change over the period.

The third highest contributor was improvements in customer minutes off–supply performance. The CMOS output receives a weight of around minus 15 per cent in the total output index and, combined with an average annual change of –1.5 per cent (ie reduction in CMOS which increases output), contributed 0.3 percentage points to average annual TFP change.

Despite only increasing at an average annual rate of 0.3 per cent, circuit length receives a weight of around 33 per cent in total output so it made the fourth highest contribution to TFP change at 0.1 percentage points.

Since energy throughput fell over the 12–year period at an average annual rate of –0.3 per cent and it only has a weight of less than 15 per cent in total output, it made a marginal negative percentage point contribution to TFP change.

All six inputs made negative contributions to average annual TFP change. That is, the use of all six inputs increased over the 12–year period. Overhead subtransmission and distribution lines have the lowest average annual input growth rates of 1.2 per cent and 1.0 per cent, respectively. Because they also have low weights in total input of 5 per cent and 15 per cent, respectively, they have the least negative and third least negative contributions, respectively, to TFP change at around –0.1 percentage points. Despite having the third highest input average annual growth rate of 2.8 per cent, underground subtransmission cables only have a weight of 2 per cent in total inputs and so make the second least negative contribution to TFP change at –0.1 percentage points.

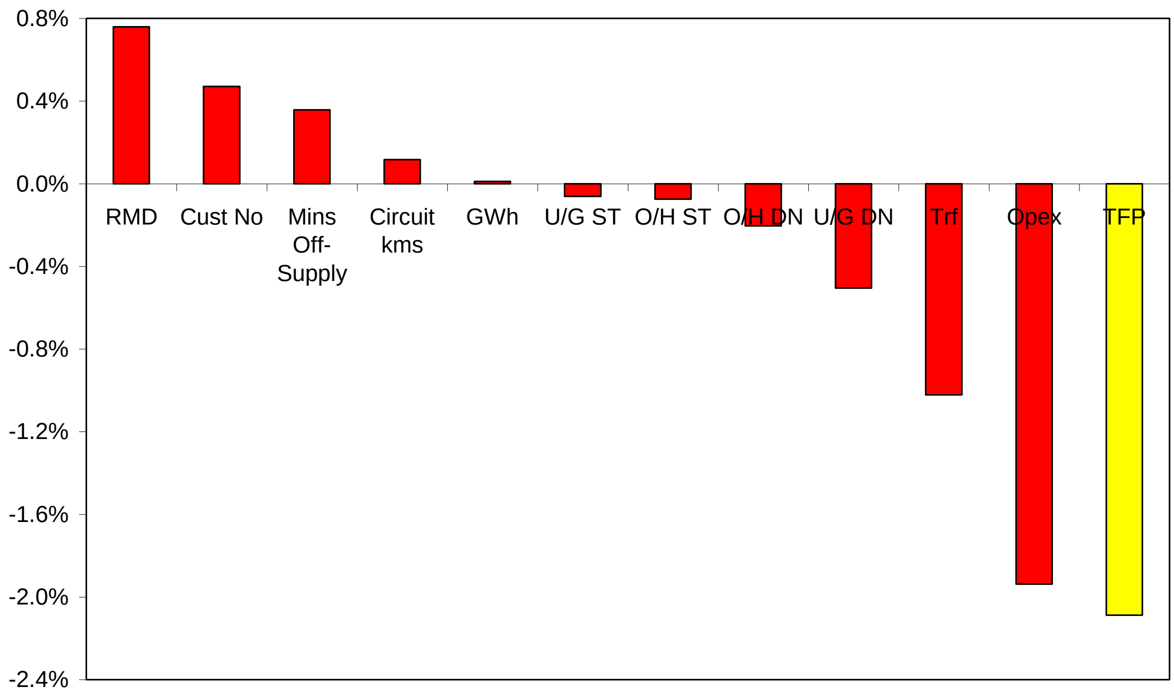
Underground distribution cables have the highest rate of average annual input growth over the period at 3.8 per cent but only get a weight of 12 per cent in the total input index. This gives them the third most negative contribution of –0.4 percentage points to TFP change.

The two inputs with the largest shares in the total input index are transformers and opex with shares of 29 per cent and 37 per cent, respectively. Since transformers have the second highest input average annual growth rate at 2.8 per cent, they make the largest negative contribution to TFP change at –0.8 percentage points. Opex has a lower average annual growth rate at 1.6 per cent but, when combined with its 37 per cent share of total inputs, it makes the second most negative contribution to TFP change at –0.6 percentage points.

Table 2.2 **Distribution 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)	–0.03%	0.01%	–0.09%
Ratcheted Max Demand	0.47%	0.76%	0.12%
Customer Numbers	0.46%	0.47%	0.44%
Circuit Length	0.11%	0.12%	0.10%
CMOS	0.25%	0.36%	0.12%
Opex	–0.60%	–1.94%	1.01%
O/H Subtransmission Lines	–0.06%	–0.07%	–0.04%
O/H Distribution Lines	–0.14%	–0.20%	–0.07%
U/G Subtransmission Cables	–0.06%	–0.06%	–0.06%
U/G Distribution Cables	–0.44%	–0.50%	–0.36%
Transformers	–0.81%	–1.02%	–0.55%
TFP Change	–0.86%	–2.09%	0.62%

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

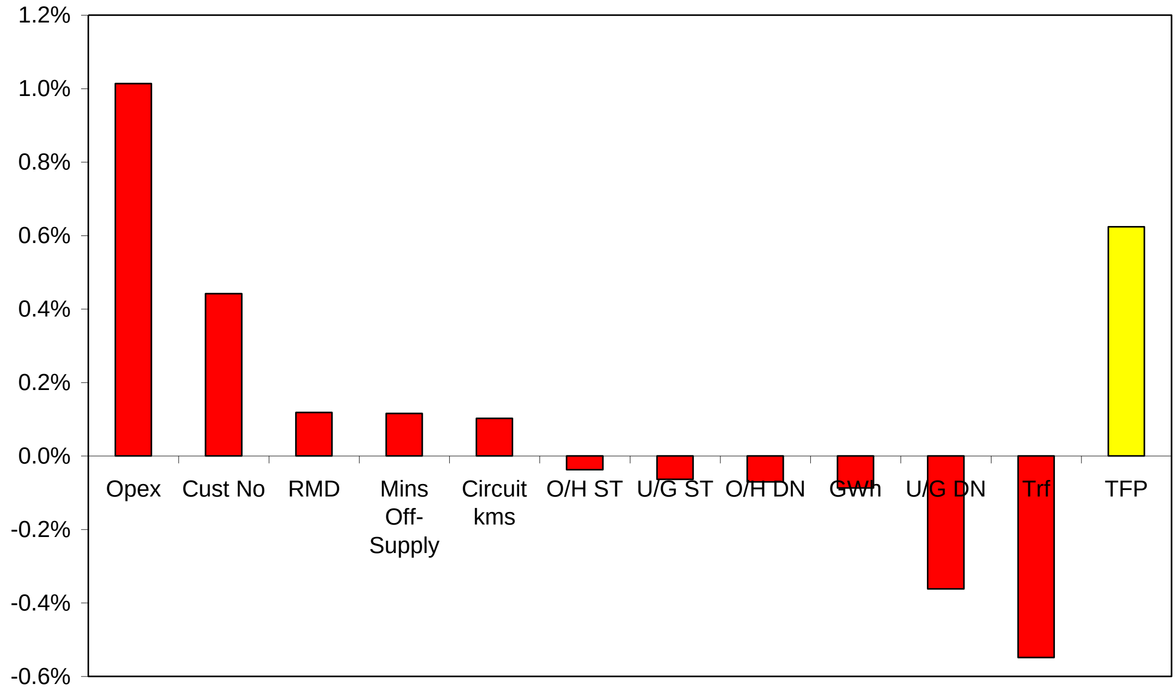


We next look at contributions to average annual TFP change for the period up to 2012 and then for the period after 2012. The results for the period from 2006 to 2012 are presented in figure 2.6 and table 2.2. Average annual TFP change for this period was more negative at

–2.1 per cent.[2] From figure 2.6 we can see a similar pattern of contributions to TFP change for most outputs and inputs for the period up to 2012 as for the whole period with two exceptions. The lesser of these relates to contributions from the RMD and CMOS outputs which are somewhat higher in the period up to 2012 at 0.8 percentage points and 0.4 percentage points, respectively. This coincides with the period where RMD was still increasing and CMOS was at close to its lowest point (ie most positive contribution to total output).

The most significant difference for the period up to 2012, however, relates to the contribution of opex to average annual TFP change. Opex increased rapidly from 2006 to 2012 and peaked in 2012. Its average annual growth rate over this period was a very high 5 per cent. This very high growth rate in opex likely reflects responses to meet new standards requirements, with many of those responses arguably being suboptimal, responses to changed conditions following the 2009 Victorian bushfires and lack of cost control from constraints imposed by government ownership. A detailed discussion of these issues can be found in AER (2015). This very high growth rate in the input with the highest share in total inputs made a very large negative contribution of –1.9 percentage points to average annual TFP change over this period.

Figure 2.7 **Distribution 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. The first thing to note for this period is that average annual TFP change is now positive with a growth rate of 0.6 per cent. The most significant change relative to the earlier period is the contribution of opex to TFP change which has changed

[2] Note there are some changes in results relative to Economic Insights (2017) due to output weighting changes.

from being the most negative contributor up to 2012 to being the most positive contributor after 2012. Since 2012 opex has fallen at an average annual rate of change of –2.9 per cent. This has led to opex now making a positive contribution of 1.0 percentage points to average annual TFP change over this period. Drivers of this turnaround in opex performance include efficiency improvements in response to the AER (2015) determination, improvements in vegetation management and preparation of some DNSPs for privatisation. The introduction of the AER's economic benchmarking program has likely also played a role.

Other contributors to improved TFP performance after 2012 are reductions in the negative contributions from transformers and overhead distribution cables whose contributions to TFP change have fallen from –1.0 per cent to –0.6 percentage points and from –0.2 to –0.1 percentage points, respectively, before and after 2012. However, offsetting this have been reductions in the contributions from some outputs with RMD's contribution to average annual TFP change falling from 0.8 to 0.1 percentage points before and after 2012 and CMOS's contribution falling from 0.4 to 0.1 percentage points as RMD flattened out and reliability performance again declined somewhat. And further reductions in energy throughput turned its contribution to average annual TFP change before and after 2012 from being marginally positive to –0.1 percentage points, respectively.

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

Year	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
GWh	1.1%	1.5%	0.4%	0.7%	–1.9%	–1.5%	–2.9%	–1.9%	1.1%	0.6%	–0.1%
RMD	3.2%	3.8%	4.1%	1.2%	1.0%	0.2%	0.0%	1.2%	0.1%	0.0%	0.6%
CustNo	1.3%	1.3%	1.6%	1.2%	1.3%	1.2%	1.1%	1.1%	1.3%	1.4%	1.7%
Kms	–0.8%	0.0%	1.0%	0.7%	0.6%	0.6%	–0.1%	0.4%	0.5%	0.4%	0.4%
CMOS	–11%	–0.2%	13.3%	–9.2%	–1.5%	–3.2%	–0.3%	1.5%	0.5%	2.2%	–8.6%
Opex	–0.4%	13.6%	–1.3%	4.3%	5.8%	8.8%	–8.2%	1.4%	5.2%	–8.6%	–4.0%
O/HST	0.8%	1.0%	2.2%	2.3%	1.3%	1.8%	–0.5%	0.3%	1.7%	1.1%	1.4%
O/HDs	1.7%	1.5%	1.3%	1.3%	1.5%	1.0%	1.0%	0.2%	0.7%	0.5%	–0.1%
U/GST	3.1%	2.0%	1.1%	3.5%	3.4%	4.3%	4.0%	6.4%	–2.7%	2.9%	2.4%
U/GDs	5.8%	2.4%	5.8%	4.6%	3.9%	3.7%	3.5%	3.6%	3.2%	2.7%	2.9%
Trform	4.9%	3.7%	3.9%	3.7%	2.4%	2.9%	2.5%	2.8%	1.8%	1.7%	0.4%

Table 2.4 **Distribution 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	0.2%	0.2%	0.1%	0.1%	-0.3%	-0.2%	-0.4%	-0.3%	0.2%	0.1%	0.0%
RMD	1.1%	1.3%	1.4%	0.4%	0.3%	0.1%	0.0%	0.4%	0.0%	0.0%	0.2%
CustNo	0.5%	0.5%	0.6%	0.4%	0.5%	0.4%	0.4%	0.4%	0.4%	0.5%	0.6%
Kms	-0.3%	0.0%	0.3%	0.2%	0.2%	0.2%	0.0%	0.1%	0.2%	0.1%	0.1%
CMOS	2.3%	0.0%	-2.6%	1.7%	0.2%	0.4%	0.0%	-0.2%	-0.1%	-0.3%	1.0%
Opex	0.1%	–5.4%	0.5%	–1.6%	–2.1%	–3.2%	2.9%	–0.5%	–2.0%	3.2%	1.4%
O/HST	0.0%	0.0%	–0.1%	–0.1%	–0.1%	–0.1%	0.0%	0.0%	–0.1%	–0.1%	–0.1%
O/HDs	–0.2%	–0.2%	–0.2%	–0.2%	–0.2%	–0.1%	–0.2%	0.0%	–0.1%	–0.1%	0.0%
U/GST	–0.1%	0.0%	0.0%	–0.1%	–0.1%	–0.1%	–0.1%	–0.2%	0.1%	–0.1%	–0.1%
U/GDs	–0.7%	–0.3%	–0.7%	–0.5%	–0.5%	–0.4%	–0.4%	–0.4%	–0.3%	–0.3%	–0.3%
Trform	–1.4%	–1.0%	–1.1%	–1.1%	–0.7%	–0.9%	–0.8%	–0.9%	–0.5%	–0.5%	–0.1%
TFP	1.5%	-5.0%	-1.8%	-0.7%	-2.7%	-3.9%	1.5%	-1.5%	-2.3%	2.6%	2.7%

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. Taking 2017 as an example, the results are broadly similar to the average annual results for the period 2012 to 2017 described above, except for the contribution of transformers. Since there was only a 0.4 per cent increase in transformer inputs in 2017 instead of 1.8 per cent average annual growth observed for the period after 2012, its percentage point contribution to TFP growth is considerably less negative at –0.1 percentage points in 2017 instead of –0.6 percentage points. TFP growth was itself considerably higher in 2017 at 2.7 per cent versus an average annual rate of 0.6 per cent for the period after 2012.

3 DNSP EFFICIENCY RESULTS

In this section we present updated DNSP MTFP and MPFP results followed by an update and extension of the econometric cost function models in Economic Insights (2014, 2015a,b).

3.1 DNSP multilateral total factor and opex partial productivity indexes using updated output weights

DNSP MTFP indexes using updated output weights are presented in figure 3.1 and table 3.1.

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

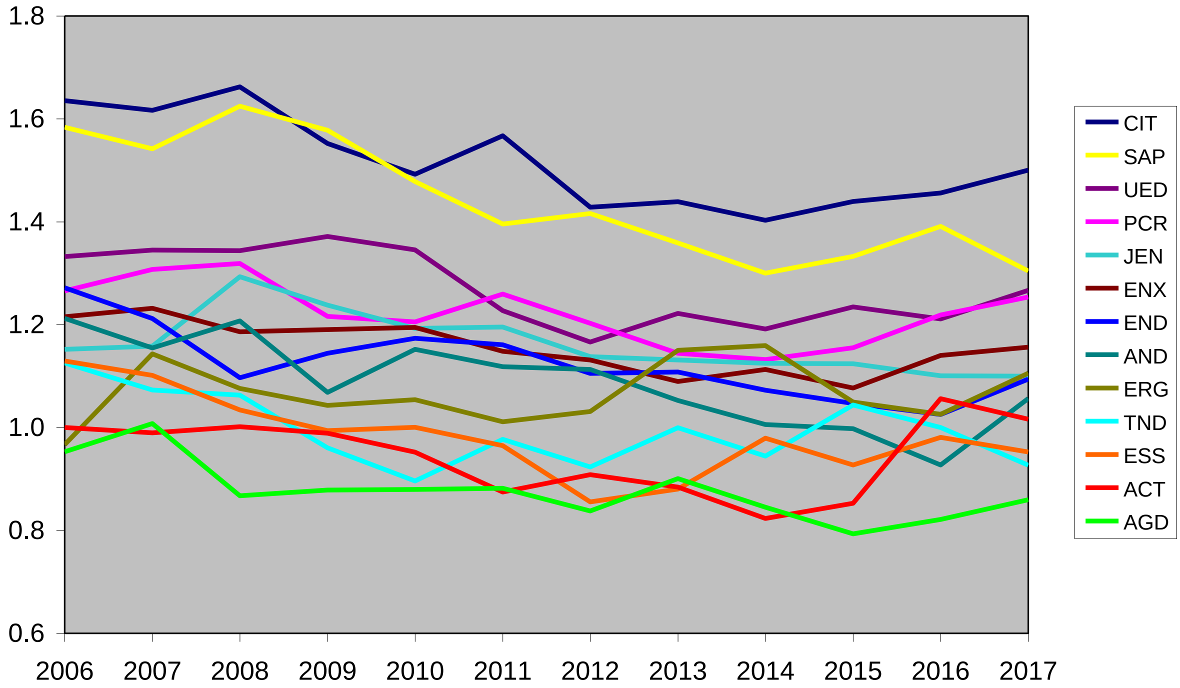


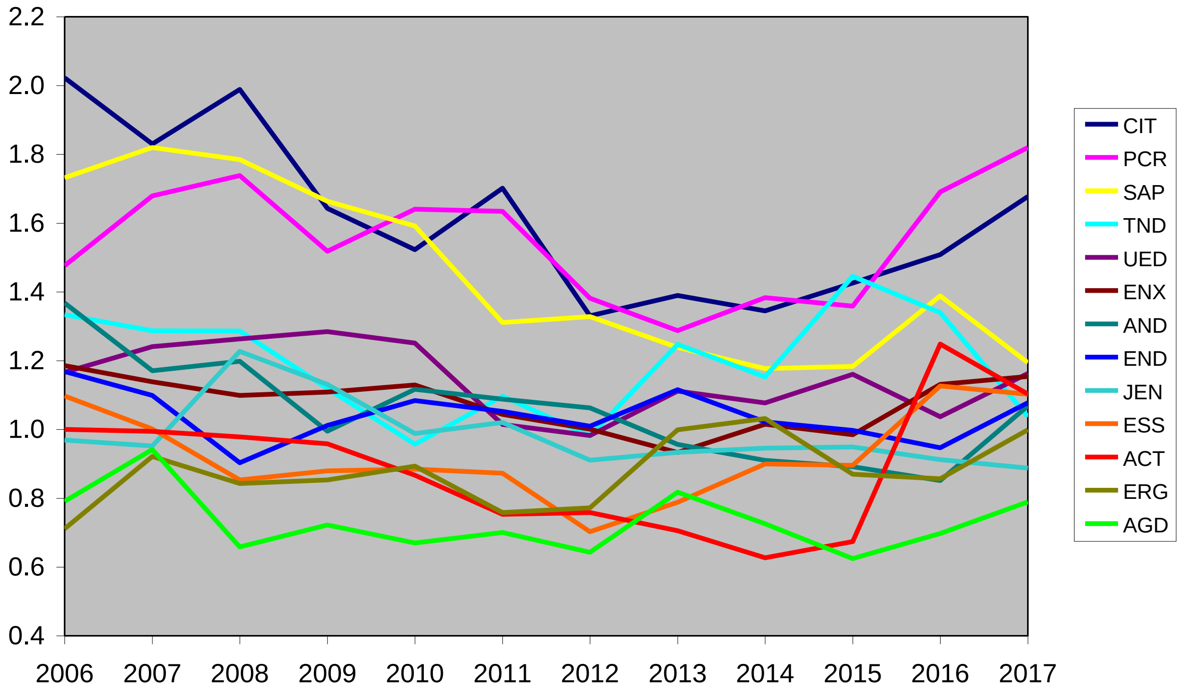
Table 3.1 **DNSP multilateral total factor productivity indexes, 2006–2017**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
ACT	1.000	0.990	1.002	0.989	0.952	0.875	0.908	0.884	0.823	0.853	1.056	1.016
AGD	0.953	1.008	0.868	0.878	0.880	0.882	0.838	0.901	0.845	0.793	0.821	0.860
AND	1.212	1.155	1.207	1.069	1.152	1.118	1.113	1.053	1.006	0.998	0.927	1.056
CIT	1.635	1.617	1.662	1.552	1.493	1.567	1.428	1.439	1.403	1.439	1.456	1.500
END	1.272	1.212	1.097	1.144	1.174	1.161	1.105	1.108	1.073	1.047	1.025	1.094
ENX	1.216	1.232	1.186	1.191	1.195	1.148	1.131	1.089	1.113	1.077	1.140	1.156
ERG	0.967	1.143	1.076	1.043	1.054	1.011	1.031	1.150	1.159	1.050	1.026	1.106
ESS	1.130	1.101	1.034	0.994	1.000	0.965	0.856	0.880	0.979	0.927	0.981	0.953
JEN	1.152	1.158	1.293	1.238	1.193	1.195	1.138	1.131	1.125	1.124	1.101	1.100
PCR	1.266	1.307	1.319	1.216	1.205	1.260	1.203	1.144	1.132	1.155	1.219	1.254
SAP	1.584	1.542	1.625	1.578	1.478	1.396	1.416	1.359	1.300	1.333	1.391	1.304
TND	1.126	1.073	1.063	0.961	0.896	0.977	0.923	1.000	0.945	1.044	1.000	0.927
UED	1.332	1.345	1.344	1.372	1.345	1.227	1.166	1.222	1.192	1.235	1.211	1.267

In 2017 MTFP levels increased for eight DNSPs and decreased for five DNSPs. CIT, UED, PCR, ENX and END all lie in the upper half of MTFP levels and increased their productivity levels in 2017. AND, ERG and AGD also increased their MTFP levels. In particular, AND made a large improvement in its MTFP level of 13 per cent. The increase in MTFP levels in 2017, including for some of the larger DNSPs, reflects the positive TFP growth for the industry discussed in section 2.

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 **DNSP multilateral opex partial productivity indexes, 2006–2017**



From figure 3.2 we see six DNSPs – AND, ERG, END, AGD, UED and CIT – increased their 2017 opex MPFP levels by more than 10 per cent while PCR increased its opex MPFP level by 8 per cent. ENX also increased its opex MPFP level in 2017.

Three DNSPs – TND, SAP and ACT – reported reductions in opex MPFP levels of greater than 10 per cent. TND's opex MPFP decreased by 23 per cent. TND noted that its large increase in opex 'has been necessary to address emerging risks on our distribution network, such as the bushfire risks posed by vegetation, especially in light of experiences interstate'.[3] TND indicated it expected this higher level of opex to continue for some years. SAP's opex MPFP fell by 14 per cent in 2015. However, SAP indicated this was the result of increased emergency response costs and Guaranteed Service Level payments 'due to an unprecedented number of severe weather events during the year'.[4]

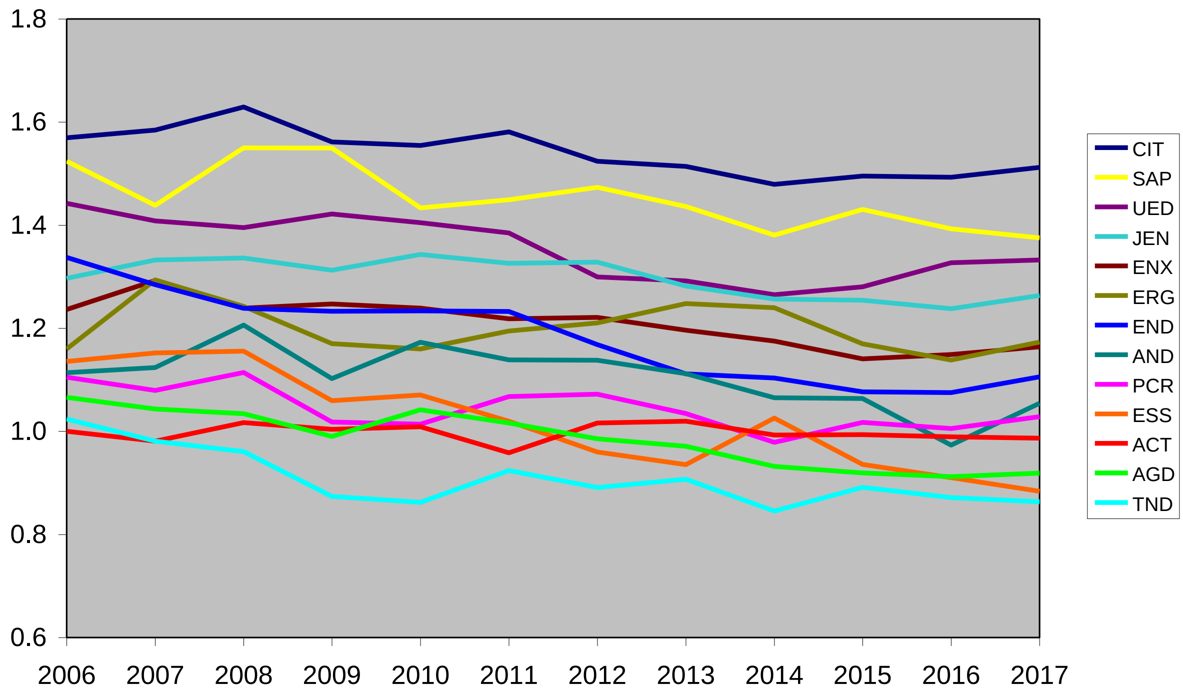
[3] Email from TND dated 14 June 2018 responding to AER questions.
[4] Email from SAP dated 15 June 2018 responding to AER questions.

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

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
ACT	1.000	0.994	0.978	0.958	0.867	0.753	0.758	0.705	0.627	0.674	1.248	1.103
AGD	0.791	0.942	0.658	0.722	0.670	0.701	0.643	0.818	0.725	0.625	0.698	0.789
AND	1.368	1.171	1.198	0.995	1.117	1.088	1.063	0.956	0.910	0.892	0.851	1.069
CIT	2.023	1.830	1.989	1.643	1.523	1.701	1.331	1.390	1.345	1.426	1.508	1.677
END	1.169	1.099	0.903	1.012	1.084	1.052	1.009	1.116	1.022	0.997	0.947	1.078
ENX	1.186	1.138	1.099	1.109	1.130	1.044	1.001	0.933	1.015	0.985	1.131	1.154
ERG	0.711	0.921	0.843	0.853	0.894	0.759	0.772	0.999	1.032	0.870	0.857	0.999
ESS	1.097	1.001	0.853	0.879	0.885	0.873	0.703	0.788	0.900	0.896	1.126	1.103
JEN	0.969	0.952	1.227	1.131	0.988	1.020	0.910	0.933	0.946	0.949	0.912	0.888
PCR	1.476	1.679	1.739	1.518	1.641	1.634	1.382	1.288	1.384	1.358	1.691	1.820
SAP	1.732	1.820	1.785	1.664	1.592	1.311	1.328	1.239	1.177	1.183	1.389	1.195
TND	1.334	1.287	1.286	1.120	0.957	1.097	0.981	1.247	1.153	1.445	1.340	1.037
UED	1.166	1.241	1.263	1.285	1.251	1.015	0.982	1.112	1.077	1.161	1.037	1.163

In 2017 PCR and CIT further increased their lead in opex MPFP levels while there was some tendency for the remaining DNSPs' opex MPFP levels to show signs of convergence. This apparent convergence would be further increased if redundancy and associated expenses were excluded from AGD's opex in 2017. Despite including a large redundancy and associated expenses component, AGD's opex MPFP still improved by 13 per cent in 2017.

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



From figure 3.3 we can see that movements in capital MPFP levels have been much more modest, as is to be expected given the largely sunk and long–lived nature of DNSP capital assets. Seven DNSPs improved their capital MPFP levels in 2017 by more than 1 per cent with AND, ERG, END, PCR and JEN showing improvements of more than 2 per cent. Contributions of each of the five components making up overall capital productivity will be examined further in sections 4 and 5.

For comparison purposes, MTFP and MPFP results using the original output cost share weights are presented in appendix B.

3.2 Econometric opex cost function results

As well as calculating MTFP and opex MPFP index–based efficiency results, Economic Insights (2014, 2015a,b) also estimated three econometric opex cost function models to examine DNSP opex efficiency. These models were updated in Economic Insights (2017) and AER (2017). The three models estimated were:

- a least squares econometrics model using the Cobb–Douglas functional form (LSECD)
- a least squares econometrics model using the more flexible translog functional form (LSETLG), and
- a stochastic frontier analysis model using the Cobb–Douglas functional form (SFACD).

Unlike the non–parametric index–based MTFP and opex MPFP methods, econometric opex cost function models allow for statistical noise in the data and produce confidence intervals.

A technical description of the models can be found in Economic Insights (2014). DNSP–specific dummy variables are included in the LSE models and opex efficiency scores are derived from these. In the SFA models opex efficiency scores are calculated in the model relative to the directly estimated efficient frontier.

Because there is insufficient time–series variation in the Australian data and an inadequate number of cross–sections to produce robust parameter estimates, we include data on New Zealand and Ontario DNSPs. We include country dummy variables for New Zealand and Ontario to pick up systematic differences across the jurisdictions, including particularly differences in opex coverage and systematic differences in operating environment factors (OEFs), such as the impact of harsher winter conditions in Ontario. Because we include country dummy variables, it is not possible to benchmark the Australian DNSPs against DNSPs in New Zealand or Ontario. Rather, the inclusion of the overseas data was used to increase the number of observations in the sample to improve the robustness and accuracy of the parameter estimates.

The models include three outputs – ratcheted maximum demand, customer numbers and circuit length – along with the proportion of undergrounding and a time trend.

In this report we further update the models in Economic Insights (2017) to include data for 2016–17 (or 2017, as relevant) for the Australian and New Zealand DNSPs and 2016 data for the Ontario DNSPs. These models differ from the models in Economic Insights (2014, 2015a) in using non–coincident maximum demand as the basis for forming the ratcheted maximum demand output for all included DNSPs whereas the earlier models used coincident maximum demand in the calculation for Australian and New Zealand DNSPs. The effect of this change on efficiency scores was generally not material as there were offsetting changes in the country dummy variables.

The EBRIN data are used to update the database for the Australian DNSPs.

The econometric cost function models produce average opex efficiency scores for the period over which the models are estimated. It will hence take some time for improvements in efficiency by previously poorly performing DNSPs to be reflected in the efficiency scores produced by the models. Furthermore, as illustrated in Economic Insights (2014, 2015a,b), it is necessary to roll the model results forward to the end of the period using a rate of change process to assess base year opex efficiency for regulatory determinations for the next period. The longer the estimation period becomes, the further average opex efficiency results would need to be rolled forward to undertake base year efficiency assessments. For these reasons, in this report we present results based on estimation for the period from 2012 onwards (2011 onwards for Ontario). This improves the currency of the results and reduces the extent of roll forward necessary to undertake base year assessments. We also present results based on estimation over the whole time period later in this section for comparability with previous years' results.

The year 2012 is chosen as the first year of the shorter estimation period because it still allows six years to be included for each DNSP and does not lead to loss of statistical robustness of the estimates. It can also be seen from figure 3.2 above that the period from 2012 onwards represents for Australian DNSPs a period of more settled performance following earlier reform initiatives and unusual events such as the aftermath of the 2009 Victorian bushfires. This should aid statistical estimation of the models.

The improved conditions for statistical estimation using the period from 2012 onwards are reflected in the difference in required properties satisfied by the estimated translog stochastic frontier analysis (SFATLG) model. The key required property we use in assessing the translog econometric models (both LSETLG and SFATLG) is that of monotonicity. This property states that it should not be possible to increase output without increasing costs. Hence, violations of the monotonicity requirement are cause for concern. When the LSETLG model is estimated across the entire sample, there are only minor monotonicity violations for one output for around five NZ DNSPs. Importantly, there are no monotonicity violations for Australian DNSPs. However, estimation of the SFATLG model over the entire sample leads to monotonicity violations in all years for four Australian DNSPs – AGD, CIT, JEN and UED – and for nearly 60 per cent of the Ontario observations. Overall, 31 per cent of the Australian observations and 36 per cent of the total sample violate monotonicity. Furthermore, for one Australian DNSP in all years and for 8 per cent of the sample in total there are monotonicity violations for two of the three outputs. For this reason we consider the SFATLG model estimated over the entire sample does not produce useable results.

When we move to estimating the translog models on the sample from 2012 onwards, the LSETLG model still performs well with no Australian observations violating monotonicity. And, the SFATLG model now performs much better with only one Australian DNSP's observations for one output not satisfying monotonicity – those of CIT. Only 8 per cent of the Australian sample now has monotonicity issues and, for the sample as a whole, the proportion of observations with monotonicity issues is halved to 20 per cent and no observations have monotonicity violations for two outputs. Given this improvement in the SFATLG's model's properties with the more recent sample, we are of the view that it is now worth presenting its results for the shorter period and it should be considered for inclusion in any averaging of model results for base year assessment purposes.

Table 3.3 **SFA Cobb–Douglas cost frontier estimates using 2012–2017 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.708	0.096	7.350
ln(CircLen)	0.168	0.052	3.210
ln(RMDemand)	0.124	0.086	1.440
ln(ShareUGC)	–0.113	0.049	–2.290
Year	0.015	0.003	5.690
Country dummy variables:			
New Zealand	0.068	0.103	0.660
Ontario	0.316	0.094	3.370
Constant	–21.176	5.396	–3.920
Variance parameters:			
Mu	0.447	0.143	3.130
SigmaU squared	0.031	0.007	4.558
SigmaV squared	0.008	0.001	12.926
LLF			298.337

Table 3.4 **LSE Cobb–Douglas cost function estimates using 2012–2017 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.681	0.068	10.090
ln(CircLen)	0.119	0.034	3.460
ln(RMDemand)	0.208	0.074	2.820
ln(ShareUGC)	–0.195	0.027	–7.190
Year	0.017	0.004	3.910
Country dummy variables:			
New Zealand	–0.296	0.198	–1.490
Ontario	–0.120	0.198	–0.610
DNSP dummy variables:			
AGD	–0.015	0.221	–0.070
CIT	–0.661	0.207	–3.190
END	–0.295	0.204	–1.450
ENX	–0.332	0.206	–1.610
ERG	–0.304	0.218	–1.400
ESS	–0.401	0.232	–1.730
JEN	–0.370	0.198	–1.870
PCR	–0.910	0.217	–4.190
SAP	–0.526	0.206	–2.550
AND	–0.511	0.206	–2.480
TND	–0.562	0.225	–2.500
UED	–0.623	0.207	–3.010
Constant	–24.239	8.814	–2.750
R–Square			0.995

Table 3.5 **LSE translog cost function estimates using 2012–2017 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.505	0.075	6.730
ln(CircLen)=x2	0.136	0.030	4.510
ln(RMDemand)=x3	0.340	0.067	5.050
x1*x1/2	–0.565	0.273	–2.070
x1*x2	0.175	0.095	1.840
x1*x3	0.317	0.213	1.490
x2*x2/2	0.039	0.043	0.910
x2*x3	–0.204	0.072	–2.830
x3*x3/2	0.005	0.183	0.030
ln(ShareUGC)	–0.159	0.027	–5.980
Year	0.018	0.004	4.410
Country dummy variables:			
New Zealand	–0.417	0.180	–2.320
Ontario	–0.229	0.179	–1.280
DNSP dummy variables:			
AGD	–0.126	0.208	–0.600
CIT	–0.713	0.187	–3.800
END	–0.417	0.187	–2.230
ENX	–0.423	0.193	–2.190
ERG	–0.443	0.215	–2.060
ESS	–0.541	0.235	–2.300
JEN	–0.258	0.183	–1.410
PCR	–0.940	0.205	–4.590
SAP	–0.632	0.194	–3.260
AND	–0.460	0.197	–2.340
TND	–0.581	0.205	–2.830
UED	–0.528	0.193	–2.730
Constant	–26.812	8.399	–3.190
R–Square			0.995

Energy Queensland Group (2018, p.11) noted in their submission on the draft report that they had advice that the monotonicity violations for the SFATLG model over the period 2006–2017 were ‘minor’ and they requested its consideration for inclusion in the economic benchmarking results. When such a large proportion of the sample suffers from these violations and a number of DNSPs have violations for two outputs at the same time, we retain our view that this model is not suitable for inclusion for the whole 12 year period but it is worth considering for the more recent period where its performance is much improved. Our view is reinforced by the increased variability in efficiency scores the inclusion of the 12–year SFATLG results would produce.

The parameter estimates and statistics for the updated SFACD, LSECD and LSETLG models and for the SFATLG model, all estimated over the 2012 to 2017 sample, are presented in tables 3.3, 3.4, 3.5 and 3.6, respectively.

Table 3.6 **SFA translog cost function estimates using 2012–2017 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.656	0.120	5.460
ln(CircLen)=x2	0.170	0.049	3.450
ln(RMDemand)=x3	0.154	0.110	1.400
x1*x1/2	–0.232	0.408	–0.570
x1*x2	–0.092	0.161	–0.570
x1*x3	0.319	0.295	1.080
x2*x2/2	0.175	0.076	2.300
x2*x3	–0.102	0.113	–0.900
x3*x3/2	–0.155	0.247	–0.630
ln(ShareUGC)	–0.065	0.048	–1.340
Year	0.015	0.003	5.260
Country dummy variables:			
New Zealand	–0.023	0.104	–0.220
Ontario	0.287	0.091	3.170
Constant	–20.482	5.706	–3.590
Variance parameters:			
Mu	0.391	0.070	5.560
SigmaU squared	0.027	0.006	4.410
SigmaV squared	0.008	0.001	12.778
LLF			306.107

Average opex efficiency scores for each of the 13 NEM DNSPs across the 6–year period for the four opex cost function models are presented in figure 3.4 and table 3.7. Average opex MPFP efficiency scores across the same 6–year period are also included in the figure and table for reference.

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

The opex efficiency scores in figure 3.4 and table 3.7 for 2012 to 2017 are also broadly consistent with comparable results for 2006 to 2016 presented in Economic Insights (2017, p.21). The most notable difference is that CIT’s efficiency scores are somewhat lower in the more recent period and PCR becomes the best performer in the opex MPFP model as well as the econometric models in the more recent period. This reflects, in part, a downward drift in

CIT's opex MPFP scores up to 2012 (see figure 3.2) and the effect of the updated index output weights which tends to favour rural DNSPs relative to some urban DNSPs.

Figure 3.4 **DNSP average opex cost efficiency scores, 2012–2017**

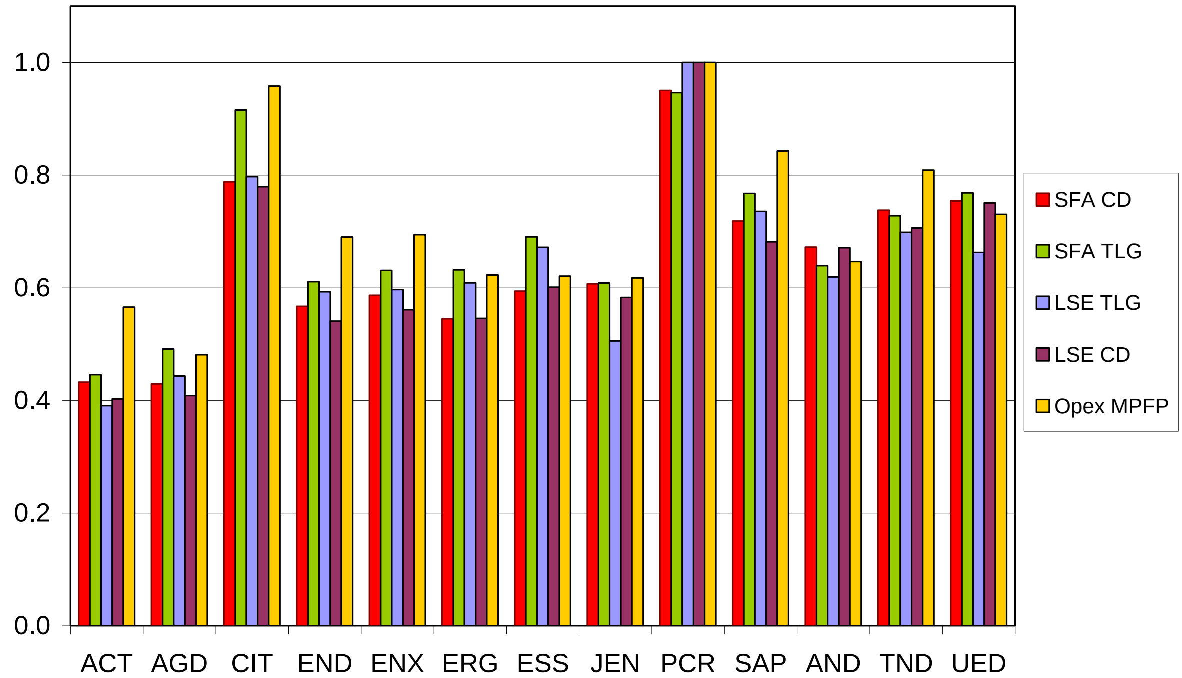


Table 3.7 **DNSP average opex cost efficiency scores, 2012–2017**

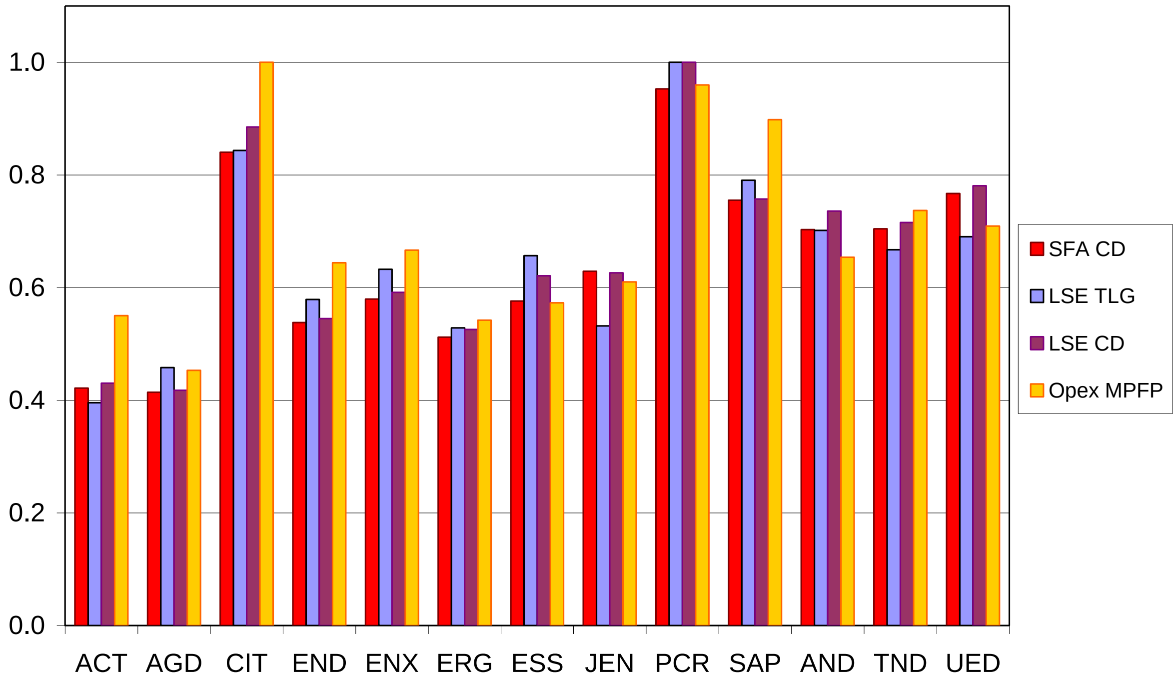
DNSP	*SFACD*	*SFATLG*	*LSETLG*	*LSECD*	*Opex MPFP*
ACT	0.432	0.446	0.391	0.403	0.566
AGD	0.429	0.491	0.443	0.408	0.481
CIT	0.788	0.916	0.797	0.779	0.958
END	0.567	0.611	0.593	0.541	0.690
ENX	0.587	0.631	0.597	0.561	0.694
ERG	0.545	0.632	0.609	0.546	0.623
ESS	0.594	0.690	0.672	0.601	0.621
JEN	0.607	0.608	0.506	0.583	0.618
PCR	0.950	0.946	1.000	1.000	1.000
SAP	0.718	0.767	0.736	0.681	0.843
AND	0.672	0.639	0.619	0.671	0.646
TND	0.738	0.728	0.698	0.706	0.809
UED	0.754	0.769	0.663	0.751	0.730

Some downward movement in opex efficiency scores in the more recent period is also seen for AND, SAP, JEN and UED, and, to a lesser extent, for ENX. The opex efficiency of these DNSPs has also tended to drift lower in general over the period as can be seen from figure 3.2 – although this figure presents annual opex MPFP results which have a broader output specification, it provides a graphic depiction of trends in efficiency over time and, hence, how average efficiency levels for different periods are likely to compare. The DNSP that shows a noticeable improvement in the more recent period relative to the period up to 2016 is ERG. In this case there was a general upward trend in opex efficiency for this DNSP over the period (see figure 3.2).

In its submission on the draft report, Jemena (2018) noted that it was concerned by the apparent volatility in its ranking across the econometric models and the two time periods. As noted above, we consider the results to be broadly consistent given the different properties and coverage of the econometric and index number–based models. And differences across the time periods need to be interpreted by reference to relative movements in figure 3.2. Given that the different models have different strengths, there is a strong argument for considering an average of the model results.

For some of the DNSPs that have recently undertaken significant reforms in their use of opex, such as ACT and ESS, the differences between efficiency scores from the more recent period and the period to 2016 presented in Economic Insights (2017) are not as great as might be expected. Again, the drivers of this can be understood by reference to figure 3.2. In both these cases opex productivity drifted downwards prior to the reforms being undertaken – in the case of ACT this occurred up to 2014 and in the case of ESS up to 2012. Hence, despite impressive improvements in opex efficiency in 2016, in both cases the average opex efficiency level for 2012 to 2017 is not that different to the average for 2006 to 2016. Provided higher levels of opex efficiency are maintained, the average for the period after 2012 will increase as more years are added.

Figure 3.5 **DNSP average opex cost efficiency scores, 2006–2017**



In the case of other DNSPs to have recently introduced significant reforms in opex usage, such as AGD, it should be noted that redundancy and associated transformation costs are still included in the opex series used in the modelling. Once these costs cease, we would expect to see sizable improvements in the opex efficiency results for these DNSPs, all else equal.

The results obtained from the SFATLG model are generally similar to those obtained from the LSETLG model. The main exception is for CIT, the DNSP whose observations did not satisfy the monotonicity property in the case of the SFATLG model.

Table 3.8 **DNSP average opex cost efficiency scores, 2006–2017**

DNSP	*SFACD*	*LSETLG*	*LSECD*	*Opex MPFP*
ACT	0.421	0.396	0.430	0.550
AGD	0.414	0.458	0.418	0.453
CIT	0.840	0.843	0.885	1.000
END	0.538	0.579	0.545	0.644
ENX	0.579	0.632	0.591	0.667
ERG	0.512	0.529	0.526	0.542
ESS	0.576	0.657	0.621	0.573
JEN	0.629	0.532	0.626	0.610
PCR	0.953	1.000	1.000	0.960
SAP	0.755	0.791	0.757	0.898
AND	0.703	0.701	0.736	0.654
TND	0.704	0.667	0.716	0.737
UED	0.767	0.690	0.781	0.709

We present results for the models using data for the period 2006 to 2017 in figure 3.5 and table 3.8. These models include one extra year of data compared to those presented in Economic Insights (2017, p.21) and the results are generally similar. The revised output weights used here lead to somewhat higher opex MPFP efficiency scores for most DNSPs with significant rural components including ESS, ERG, PCR, SAP and TND.

For comparison purposes, analogous results using the original index number output cost share weights are presented in appendix B.

4 STATE–LEVEL DISTRIBUTION PRODUCTIVITY RESULTS

In this section we present MTFP and opex MPFP results for each of the NEM jurisdictions before analysing outputs, inputs and drivers of productivity change for each jurisdiction.

4.1 State–level distribution MTFP and opex MPFP indexes

Figure 4.1 **State–level DNSP multilateral TFP indexes, 2006–2017**

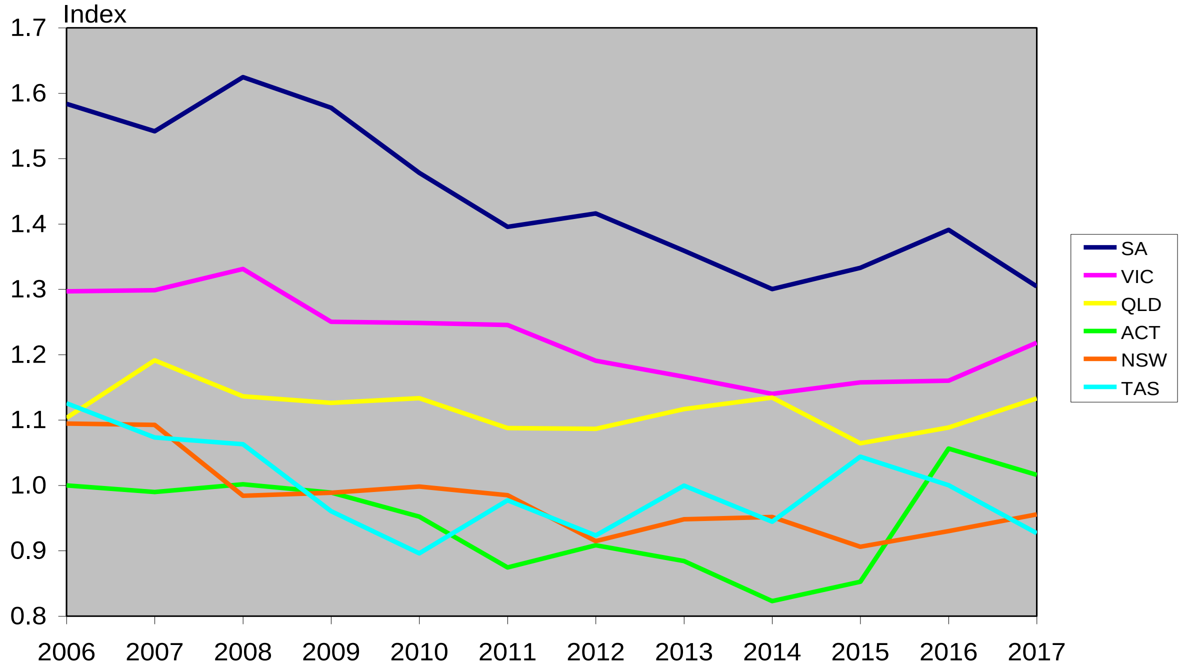
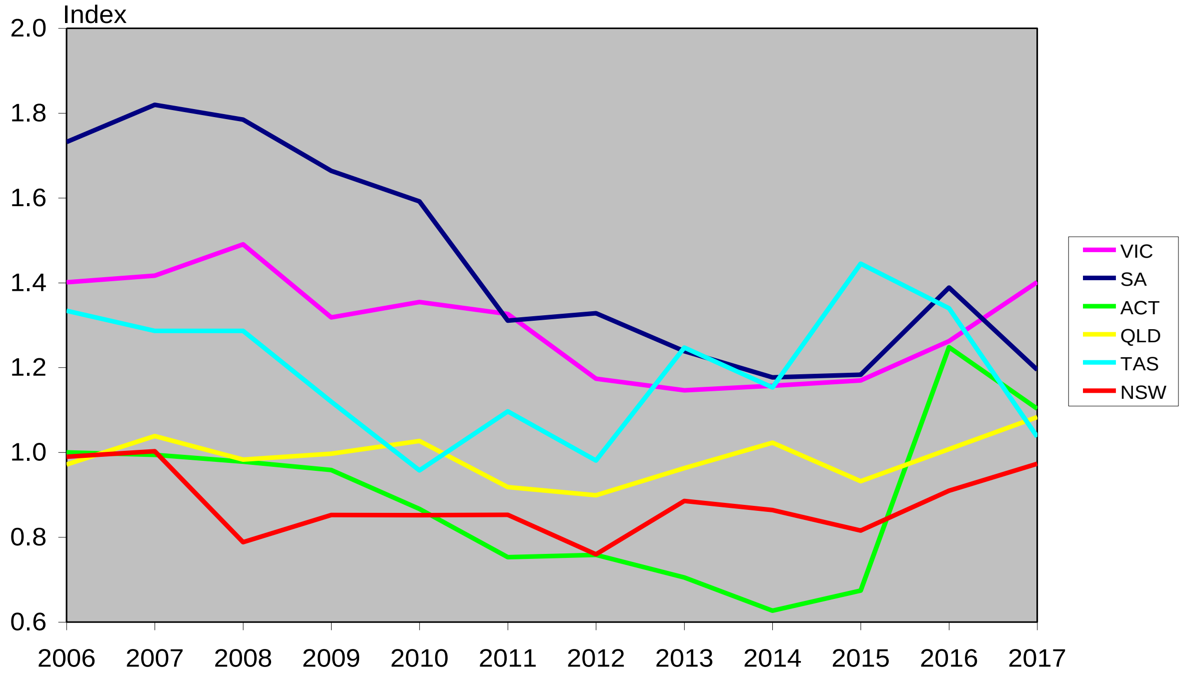


Figure 4.2 **State–level DNSP multilateral opex PFP indexes, 2006–2017**



State–level MTFP indexes are presented in figure 4.1. Rankings have remained the same as in 2016 with the exception of Tasmania which has moved from fifth place to last place among the six states. The large increase in Tasmania's opex in 2017 is the main cause of its fall in MTFP ranking. The large increase in South Australia's opex in 2017 reduced its lead over Victoria at the top of the table in 2017. Victoria, Queensland and NSW all improved their performance somewhat in 2017 while the ACT's worsened relative to 2016.

Opex MPFP levels are shown in figure 4.2. The large increase in South Australia's opex in 2017 led to its opex MPFP falling by 14 per cent that year and its ranking falling from first to second. Similarly, Tasmania's large increase in opex in 2017 led to its opex MPFP falling by 23 per cent that year and its ranking falling from second to fifth. After its large increase in opex MPFP in 2016, the ACT's opex MPFP fell by 12 per cent in 2017 but it retained third place, just ahead of Queensland. Victoria's opex MPFP increased by 11 per cent in 2017 to take it to first place. Queensland's opex MPFP improved by 8 per cent in 2017 while NSW's improved by 7 per cent.

4.2 State–level distribution outputs, inputs and productivity change

4.2.1 Australian Capital Territory

The Australian Capital Territory (ACT) is the smallest of the NEM jurisdictions and is served by one DNSP, Evoenergy (formerly ActewAGL). In 2017 ACT delivered 2,914 GWh to 191,482 customers over 5,333 circuit kilometres of lines and cables.

ACT productivity performance

ACT's total output, total input and TFP indexes are presented in figure 4.3 and table 4.1. Opex and capital partial productivity indexes are also presented in table 4.1.

Figure 4.3 **ACT output, input and total factor productivity indexes, 2006–2017**

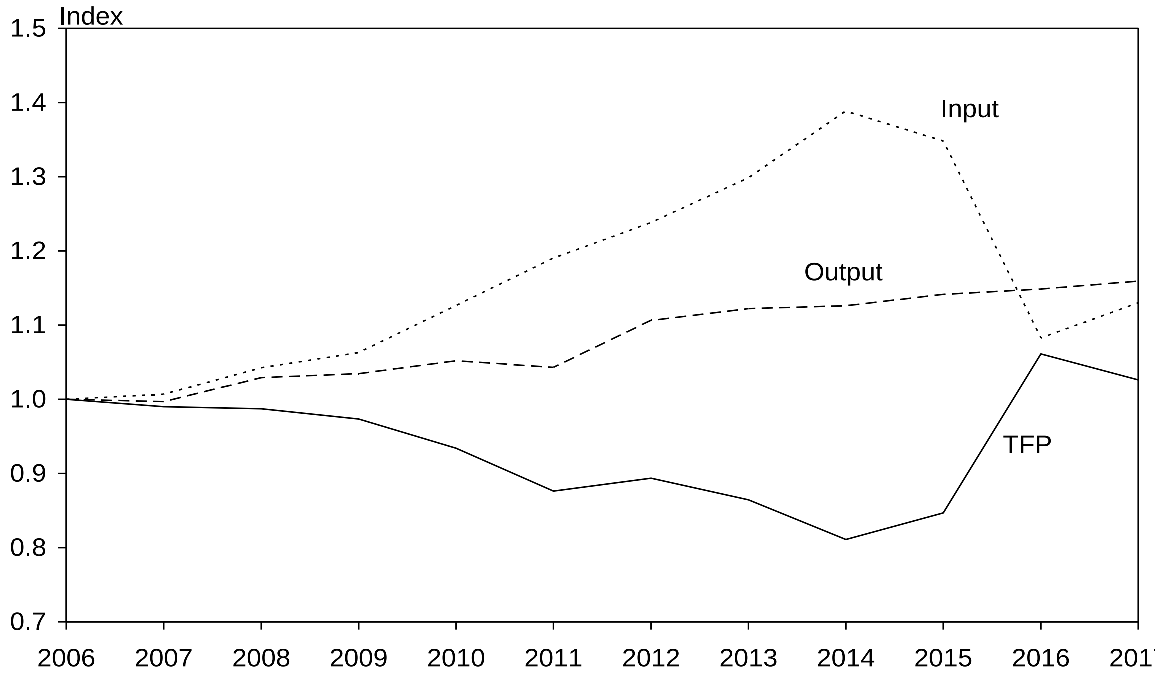


Table 4.1 **ACT output, input and total factor productivity and partial productivity indexes, 2006–2017**

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	0.997	1.007	0.990	1.001	0.983
2008	1.029	1.043	0.987	0.970	0.999
2009	1.035	1.063	0.973	0.956	0.985
2010	1.052	1.126	0.934	0.862	0.985
2011	1.043	1.190	0.876	0.767	0.956
2012	1.106	1.238	0.894	0.762	0.994
2013	1.122	1.298	0.864	0.706	0.992
2014	1.126	1.389	0.811	0.626	0.976
2015	1.141	1.348	0.847	0.680	0.984
2016	1.149	1.083	1.061	1.264	0.980
2017	1.159	1.130	1.026	1.124	0.983
Growth Rate 2006–17	1.34%	1.11%	0.23%	1.06%	–0.16%
Growth Rate 2006–12	1.69%	3.56%	–1.87%	–4.54%	–0.10%
Growth Rate 2012–17	0.93%	–1.83%	2.76%	7.78%	–0.23%

Over the 12–year period 2006 to 2017, ACT's TFP increased at an average annual rate of 0.2 per cent. TFP levels had fallen by nearly 20 per cent between 2006 and 2014 and then increased by 25 per cent in 2016 before falling back by 3 per cent in 2017. Total output increased steadily over the period at an average annual rate of 1.3 per cent, somewhat higher than the industry average rate. However, total input use increased at a much faster rate than the industry average up to 2014 before falling dramatically in the following two years. It increased again in 2017 leading to ACT's TFP level in 2017 being 3 per cent above its 2006 level. The partial productivity indexes in table 4.1 show that swings in opex usage have been the main driver of the ACT's TFP changes over the last few years.

ACT output and input quantity changes

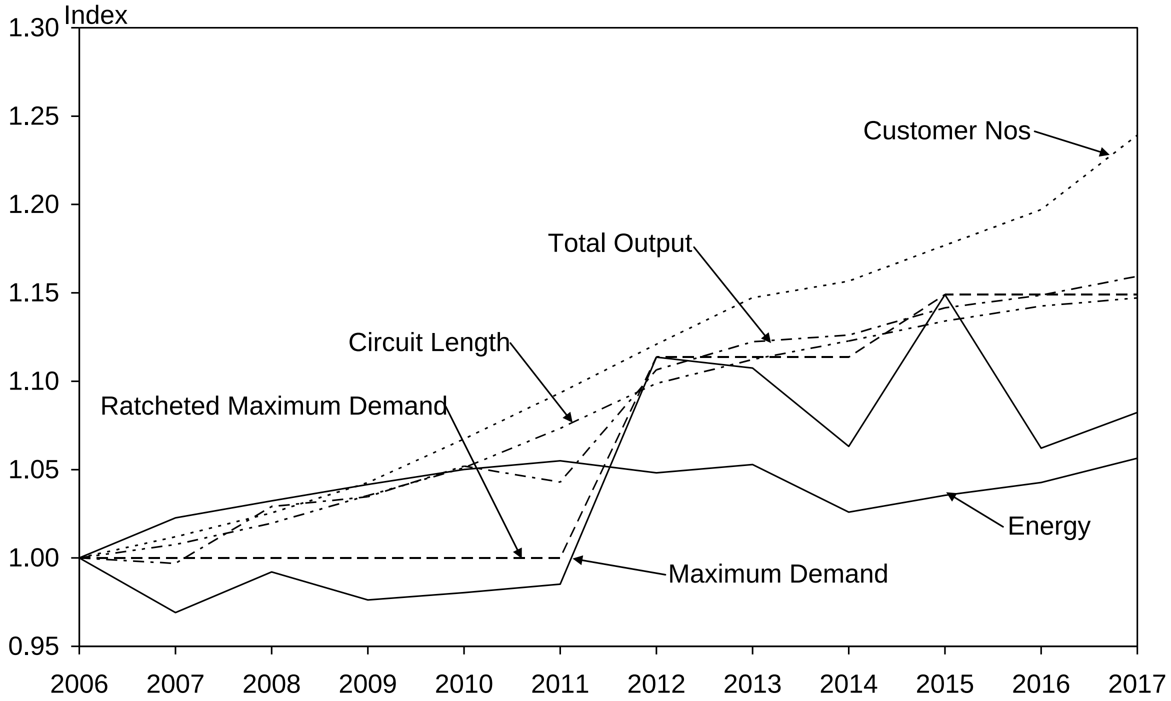
We graph the quantity indexes for ACT's five individual outputs in figure 4.4 and for its six individual inputs in figure 4.5, respectively.

From figure 4.4 we see that the output component of customer numbers increased steadily over the period and was 24 per cent higher in 2017 than it was in 2006 reflecting ACT's relatively strong output growth. Energy throughput for distribution peaked in 2011 and fell less after that than it did for the industry as a whole. In 2017 energy throughput was at its highest level since 2006, being 6 per cent above what it was in 2006.

Unlike the case for the industry as a whole, ACT's maximum demand did not exceed its 2006 level until 2012 and has been relatively volatile since then. Ratcheted maximum demand in 2017 was 15 per cent above its 2006 level – a similar result as for the industry overall although ACT's growth in this output has been concentrated in the second half of the period whereas growth in demand for most other DNSPs mainly occurred in the first half of the period.

ACT's circuit length output grew much more over the 12 years than occurred for the industry overall and by 2017 was 15 per cent higher than it was in 2006 compared to an increase of only 4 per cent for the industry. This reflects the Territory's higher increase in customer numbers over the period and the ongoing expansion of the city and development of new areas on the fringes of the city as well as by 'in fill'.

Figure 4.4 **ACT output quantity indexes, 2006–2017**



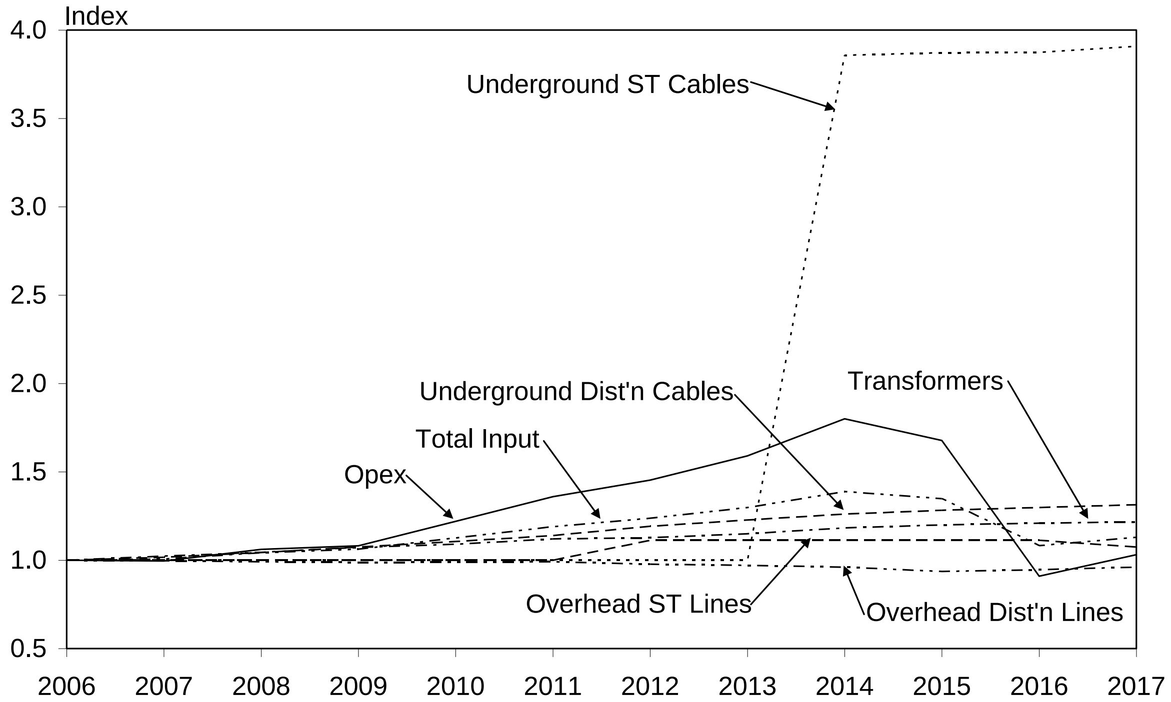
We do not show ACT's total customer minutes off–supply in figure 4.4. ACT's CMOS performance is the best of the 13 DNSPs in the NEM and CMOS receives only a negative 3 per cent weight on average in ACT's total output. Because ACT's CMOS levels are very low, fluctuations in CMOS come off a low base and so swings tend to be quite large in relative terms. However, given its low levels, its inclusion in figure 4.4 would provide a misleading picture.

Since the customer numbers, ratcheted maximum demand and circuit length outputs receive a weight of around 88 per cent of gross revenue in forming the total output index, in figure 4.4 we see that the total output index tends to lie just below the customer numbers output index and just above the RMD and circuit length indexes which follow a similar pattern to each other.

Turning to the input side, we see from ACT's six input components and total input in figure 4.5 that the quantity of opex increased rapidly between 2009 and 2014, being 80 per cent higher in 2014 than it was in 2006. It then fell sharply in 2015 and 2016 following the AER's price determination for ACT before increasing by 13 per cent in 2017. In 2017 ACT's opex input quantity was 3 per cent above its 2006 level. Opex has the largest average share in ACT's total costs at 40 per cent and so is an important driver of its total input quantity index.

With the exception of underground subtransmission cables, ACT's other input component quantities increase at much more modest and steady rates over the period. ACT's underground subtransmission cables length doubled in 2012 and its capacity rating increased three fold but the total length was then only 6 kilometres and this input has a negligible share in total cost. The quantity of transformer inputs, which have a share of 26 per cent in total cost, increased by 22 per cent over the 12–year period.

Figure 4.5 **ACT input quantity indexes, 2006–2017**



From figure 4.5 we see that the total input quantity index lies between the quantity indexes for opex and transformers (which together have a weight of 66 per cent of total costs). Total input quantity fell by 22 per cent between 2014 and 2016 but increased by 4 per cent in 2017 in line with the movements in opex usage.

ACT output and input contributions to TFP change

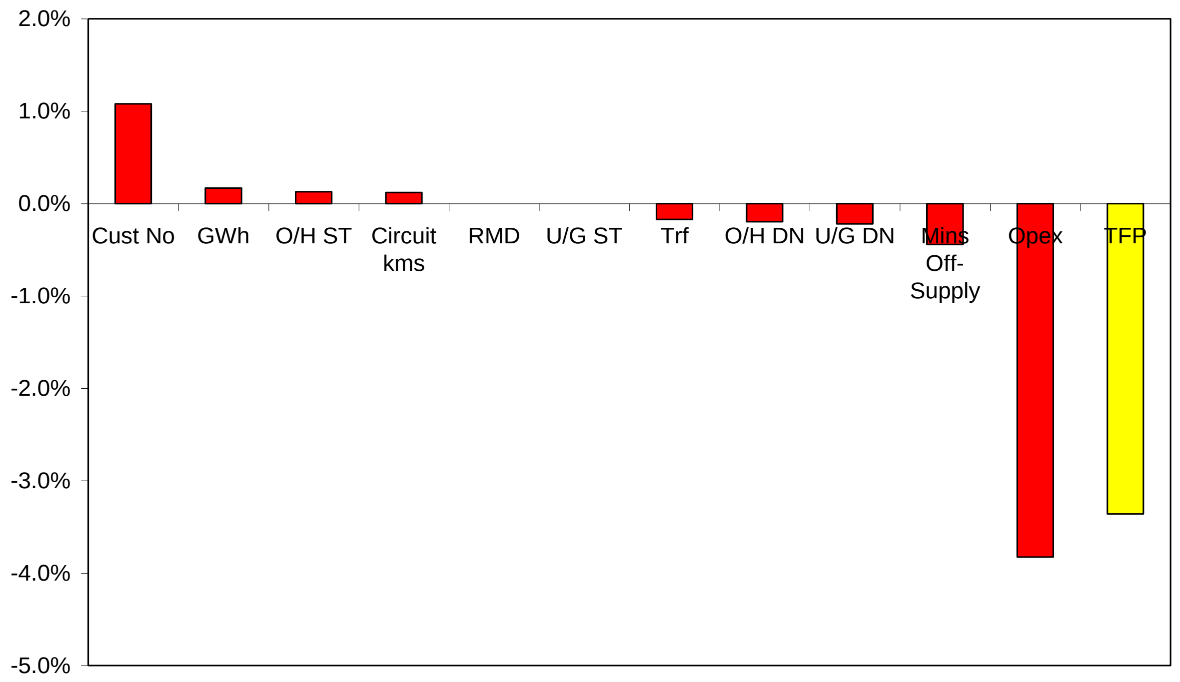
In table 4.2 we decompose ACT's TFP change into its constituent output and input parts for the whole 12–year period and for the periods up to and after 2012. ACT's drivers of TFP change for the whole 12–year period are broadly similar to the industry as a whole with the exception of the role played by opex. Customer numbers and circuit length output growth both contribute more to TFP growth for ACT than for the industry given their higher rates of growth for ACT. And transformer input growth makes a less negative contribution to TFP growth for ACT than it does for the industry. However, the main difference is that over the whole period opex usage makes a less negative contribution of 0.2 percentage points on average to ACT's TFP change which is 0.2 per cent. This contrasts with the industry where opex has the second most negative contribution of 0.6 percentage points over the whole period and this is a major reason for the industry's negative TFP growth rate over the 12 years.

The ACT situation is, however, very much a tale of two distinct periods. For the period up to 2012, rapid opex growth made a larger negative percentage point contribution to TFP growth for ACT than for the industry, at –2.5 percentage points for ACT versus –1.9 percentage points for the industry. But the large reductions made in ACT's opex in 2015 and 2016 led to opex contributing 2.5 percentage points to ACT's average annual TFP change of 2.8 per cent for the period after 2012, despite the sizable increase in opex in 2017. This compares to an opex contribution of 1.0 percentage points to the industry TFP average annual change of 0.6 per cent after 2012.

Table 4.2 **ACT 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)	0.06%	0.10%	0.02%
Ratcheted Max Demand	0.37%	0.53%	0.18%
Customer Numbers	0.61%	0.60%	0.62%
Circuit Length	0.37%	0.47%	0.26%
CMOS	–0.07%	–0.01%	–0.15%
Opex	–0.22%	–2.49%	2.51%
O/H Subtransmission Lines	–0.02%	–0.06%	0.03%
O/H Distribution Lines	0.04%	0.05%	0.02%
U/G Subtransmission Cables	–0.01%	0.00%	–0.01%
U/G Distribution Cables	–0.47%	–0.59%	–0.33%
Transformers	–0.43%	–0.47%	–0.39%
TFP Change	0.23%	–1.87%	2.76%

Figure 4.6 **ACT output and input percentage point contributions to annual TFP change, 2016–17**



Despite its strong performance in 2016, the 15 per cent increase in opex usage in 2017 contributed –3.8 percentage points to ACT's TFP change of –3.4 per cent that year as shown in figure 4.6. Above average growth in customer numbers in 2017 contributed 1.1 percentage points to TFP growth.

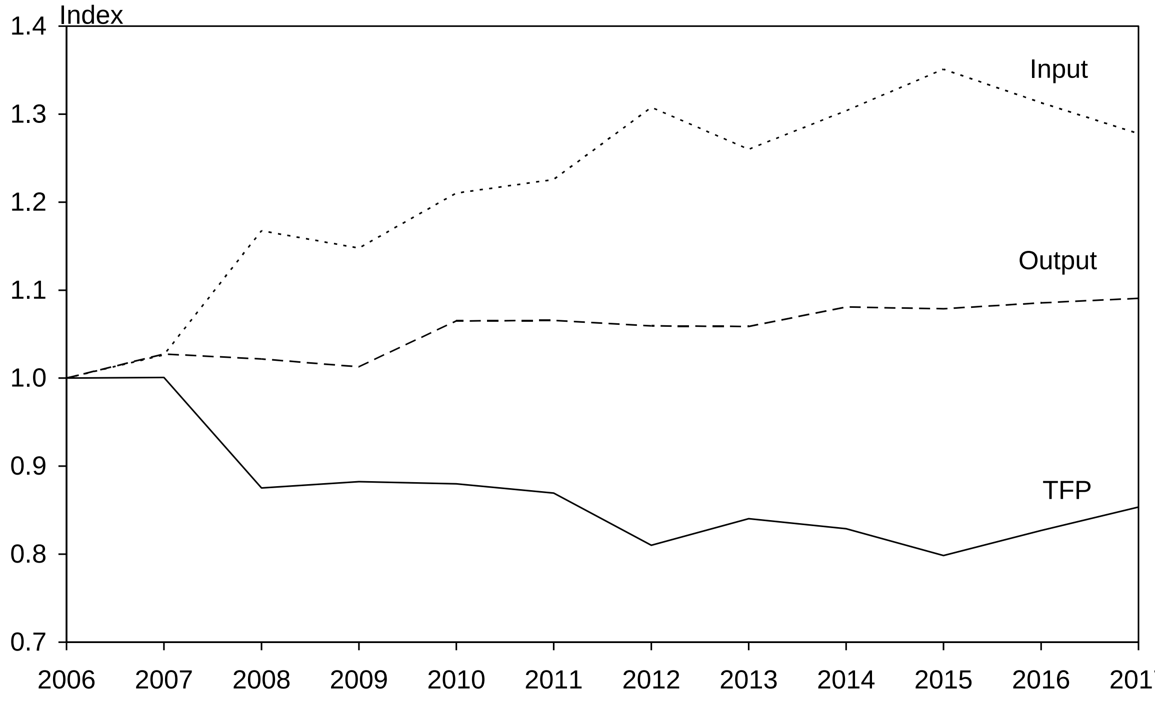
4.2.2 New South Wales

New South Wales is the largest of the NEM jurisdictions and is served by three DNSPs: Ausgrid (AGD), Endeavour Energy (END) and Essential Energy (ESS). In 2017 the three NSW DNSPs delivered 54,774 GWh to 3.54 million customers over 270,728 circuit kilometres of lines and cables.

NSW DNSP productivity performance

NSW's total output, total input and TFP indexes are presented in figure 4.7 and table 4.3. Opex and capital partial productivity indexes are also presented in table 4.3.

Figure 4.7 **NSW DNSP output, input and total factor productivity indexes, 2006–2017**



Over the 12–year period 2006 to 2017, the NSW DNSPs' TFP decreased at an average annual rate of 1.4 per cent. Although total output increased by an average annual rate of 0.8 per cent, total input use increased faster, at a rate of 2.2 per cent. NSW thus had slower output growth and faster input growth than the industry as whole, leading to a more negative TFP growth rate. Input use increased sharply in 2008 and 2012, to be followed each time by a small reduction the following year. Input use again fell in 2016 and 2017. TFP fell markedly in 2008 and 2012 but TFP change was positive in four years – 2009, 2013, 2016 and 2017. TFP average annual change was sharply negative for the period up to 2012 but has been positive at 1.1 per cent for the period since 2012.

Table 4.3 **NSW DNSP 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	1.027	1.027	1.001	1.031	0.978
2008	1.022	1.168	0.875	0.795	0.945
2009	1.013	1.148	0.882	0.859	0.904
2010	1.065	1.210	0.880	0.840	0.913
2011	1.066	1.226	0.869	0.850	0.889
2012	1.059	1.308	0.810	0.750	0.856
2013	1.059	1.260	0.840	0.882	0.829
2014	1.081	1.304	0.829	0.852	0.827
2015	1.079	1.351	0.799	0.789	0.815
2016	1.086	1.313	0.827	0.883	0.806
2017	1.091	1.278	0.854	0.961	0.810
Growth Rate 2006–17	0.79%	2.23%	–1.44%	–0.36%	–1.92%
Growth Rate 2006–12	0.96%	4.47%	–3.51%	–4.79%	–2.59%
Growth Rate 2012–17	0.59%	–0.46%	1.05%	4.95%	–1.12%

The partial productivity indexes in table 4.3 show that reduced opex usage was the main driver of the improved TFP performance after 2012.

NSW DNSP output and input quantity changes

We graph the quantity indexes for the NSW DNSPs' five individual outputs in figure 4.8 and for their six individual inputs in figure 4.9.

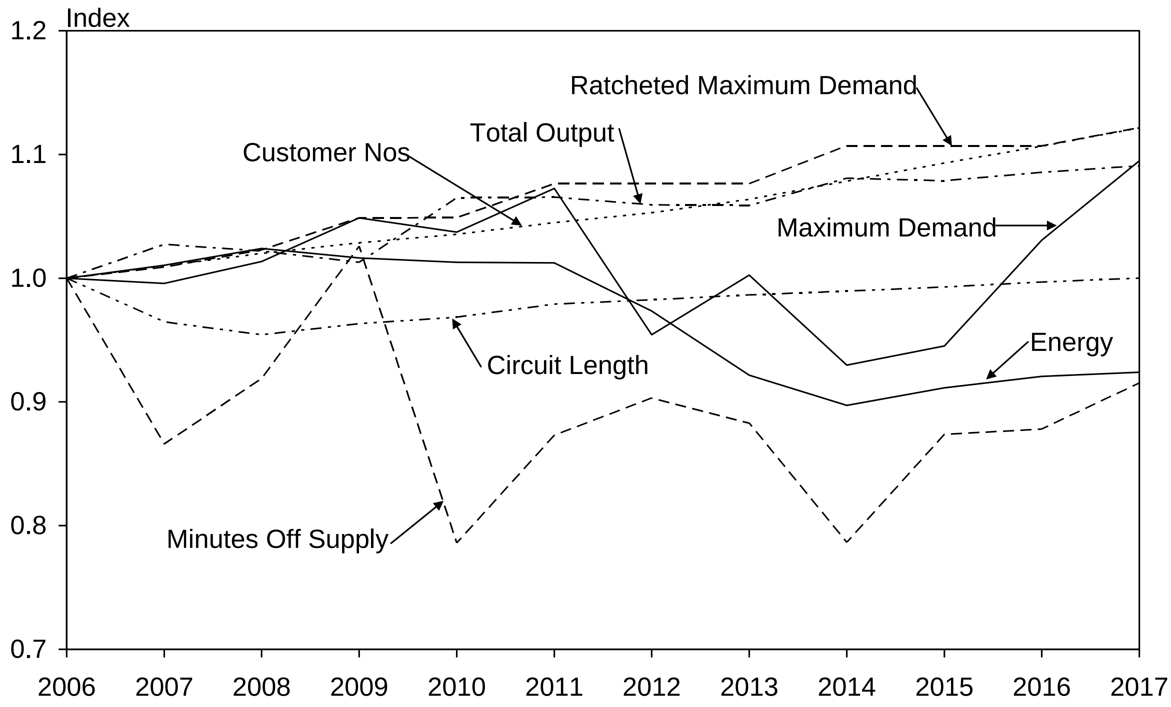
From figure 4.8 we see that NSW's output components showed a similar pattern of change to the industry as a whole except that there was much less growth in outputs for NSW between 2006 and 2009, likely reflecting the impact of the global financial crisis and the initial negative effects of the mining boom on NSW. Customer numbers increased steadily over the period and was 12 per cent higher in 2017 than it was in 2006 reflecting NSW's relatively weak output growth. Energy throughput for distribution peaked in 2008 and has fallen since to be 8 per cent lower in 2017 than it was in 2006.

NSW's maximum demand peaked in 2011 – two to three years later than in most other states and has been relatively volatile since then. It did not exceed its 2006 level again until 2016. Ratcheted maximum demand in 2017 was 12 per cent above its 2006 level – a smaller increase than for the industry overall.

NSW's circuit length output grew less over the 12 years than occurred for the industry overall and by 2017 was at the same level it was in 2006 compared to an increase of 4 per cent for the industry. NSW's circuit length actually declined somewhat between 2006 and 2008.

The last output shown in figure 4.8 is total CMOS. NSW's CMOS has generally followed a similar pattern to that of the industry although it has been more volatile in NSW. With the exception of 2009, CMOS has generally been lower and, hence, contributed more to total output than was the case in 2006. In 2017 CMOS was 8 per cent less than it was in 2006.

Figure 4.8 **NSW output quantity indexes, 2006–2017**



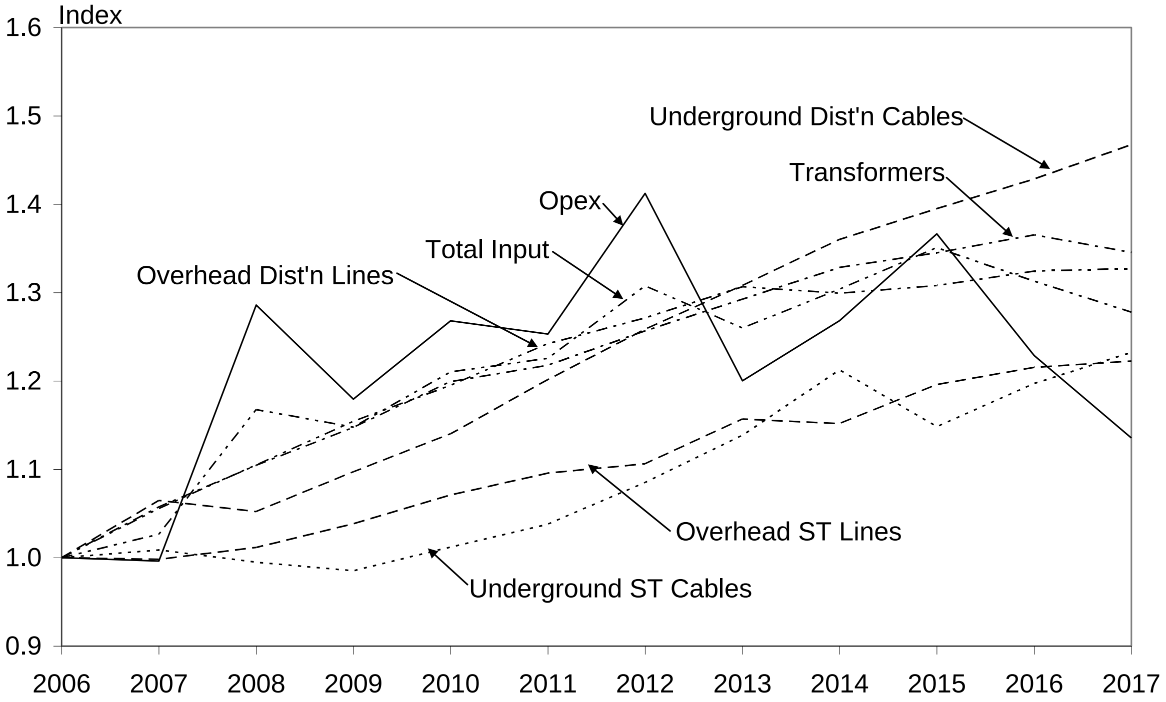
Since the customer numbers and ratcheted maximum demand outputs receive a weight of around 60 per cent of gross revenue in forming the total output index, in figure 4.8 we see that the total output index tends to lie very close to these two output indexes. The circuit length index lies at a lower level but this is largely offset by the CMOS index which would generally lie above the other output indexes when it enters the formation of total output as a negative output (ie the reduction in CMOS over the period makes a positive contribution to total output).

Turning to the input side, we see from NSW's six input components and total input in figure 4.9 that the quantity of NSW's opex increased more rapidly between 2006 and 2012 than the corresponding increase for the industry. For NSW, opex increased by 41 per cent up to 2012 whereas the corresponding increase for the industry was 36 per cent. NSW's opex input has also been somewhat more volatile over the whole period, with another peak in opex in 2015. However, opex again fell in 2016 and 2017 but was still 14 per cent above its 2006 level in 2017.[5] Opex has the largest average share in NSW's total costs at 39 per cent and so is an important driver of its total input quantity index.

NSW's underground distribution cables and transformers inputs increase more steadily over the period and at a similar rate to the industry as a whole. Its overhead distribution lines input, however, increases much more rapidly over the period with an increase of 33 per cent compared to only 11 per cent for the industry.

[5] Note that redundancy payments are included in the opex figures presented here.

Figure 4.9 **NSW DNSP input quantity indexes, 2006–2017**



From figure 4.9 we see that the total input quantity index lies between the quantity indexes for opex and transformers (which together have a weight of 70 per cent of total costs). Total input quantity falls in 2016 and 2017 in line with the reductions in opex usage.

NSW output and input contributions to TFP change

In table 4.4 we decompose NSW's TFP change into its constituent output and input parts for the whole 12–year period and for the periods up to and after 2012. NSW's drivers of TFP change for the whole 12–year period are broadly similar to the industry as a whole except that the major outputs of customer numbers and RMD contribute somewhat less due to their weaker growth in NSW and opex makes a larger negative contribution. Circuit length output growth contributes less to TFP growth for NSW than for the industry given circuit length's lower rate of growth for NSW. And the overhead distribution input makes a more negative contribution to TFP growth for NSW than it does for the industry.

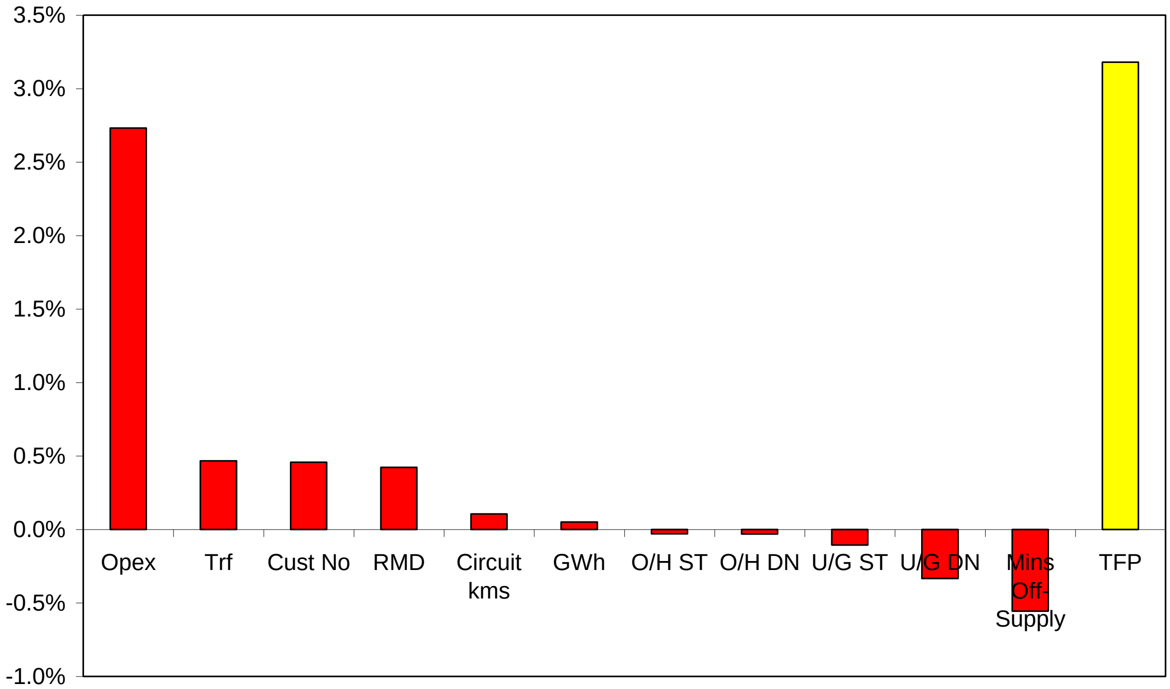
The NSW situation is again a tale of two distinct periods. For the period up to 2012, rapid opex growth made a larger negative percentage point contribution to TFP growth for NSW than for the industry, at –2.4 percentage points for NSW versus –1.9 percentage points for the industry. But the reductions made in NSW's opex after 2012 led to opex contributing 1.6 percentage points to NSW's average annual TFP change of 1.1 per cent for the period after 2012. This compares to an opex contribution of 1.0 percentage points to the industry TFP average annual change of 0.6 per cent after 2012.

The importance of the reduction in opex in 2017 is highlighted in figure 4.10 where the 2.7 percentage point contribution of opex to TFP change of 3.2 per cent in the 2017 year is considerably larger than the contributions of other outputs and inputs.

Table 4.4 **NSW 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)	–0.10%	–0.06%	–0.14%
Ratcheted Max Demand	0.34%	0.41%	0.26%
Customer Numbers	0.36%	0.31%	0.42%
Circuit Length	–0.01%	–0.11%	0.11%
CMOS	0.20%	0.41%	–0.06%
Opex	–0.60%	–2.38%	1.55%
O/H Subtransmission Lines	–0.08%	–0.08%	–0.09%
O/H Distribution Lines	–0.26%	–0.40%	–0.10%
U/G Subtransmission Cables	–0.06%	–0.04%	–0.08%
U/G Distribution Cables	–0.39%	–0.42%	–0.36%
Transformers	–0.84%	–1.16%	–0.46%
TFP Change	–1.44%	–3.51%	1.05%

Figure 4.10 **NSW output and input percentage point contributions to annual TFP change, 2016–17**



4.2.3 Queensland

Queensland (Qld) is the third largest of the NEM jurisdictions in terms of customer numbers and the second largest in terms of circuit length. It is served by two DNSPs: Energex (ENX) and Ergon Energy (ERG). In 2017 the two Queensland DNSPs delivered 34,687 GWh to 2.19 million customers over 206,248 circuit kilometres of lines and cables.

Queensland DNSP productivity performance

Queensland's total output, total input and TFP indexes are presented in figure 4.11 and table 4.5. Opex and capital partial productivity indexes are also presented in table 4.5.

Figure 4.11 **Qld DNSP output, input and total factor productivity indexes, 2006–2017**

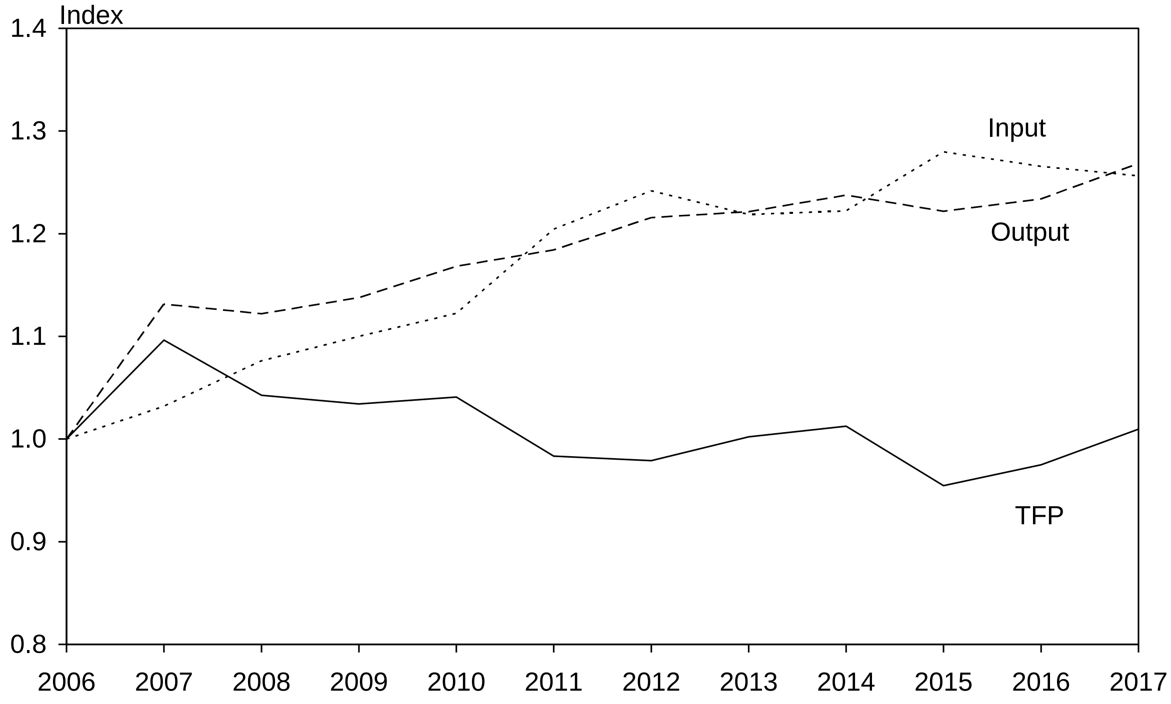


Table 4.5 **Qld DNSP output, input and total factor productivity and partial productivity indexes, 2006–2017**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.131	1.032	1.096	1.126	1.079
2008	1.122	1.076	1.043	1.056	1.035
2009	1.138	1.100	1.034	1.071	1.014
2010	1.168	1.122	1.041	1.105	1.007
2011	1.184	1.204	0.983	0.963	0.994
2012	1.216	1.242	0.979	0.946	0.996
2013	1.221	1.219	1.002	1.023	0.993
2014	1.238	1.222	1.012	1.084	0.975
2015	1.222	1.280	0.955	0.991	0.936
2016	1.234	1.266	0.975	1.057	0.933
2017	1.268	1.256	1.010	1.143	0.944
Growth Rate 2006–17	2.16%	2.07%	0.09%	1.21%	–0.53%
Growth Rate 2006–12	3.25%	3.61%	–0.36%	–0.92%	–0.07%
Growth Rate 2012–17	0.85%	0.23%	0.62%	3.77%	–1.08%

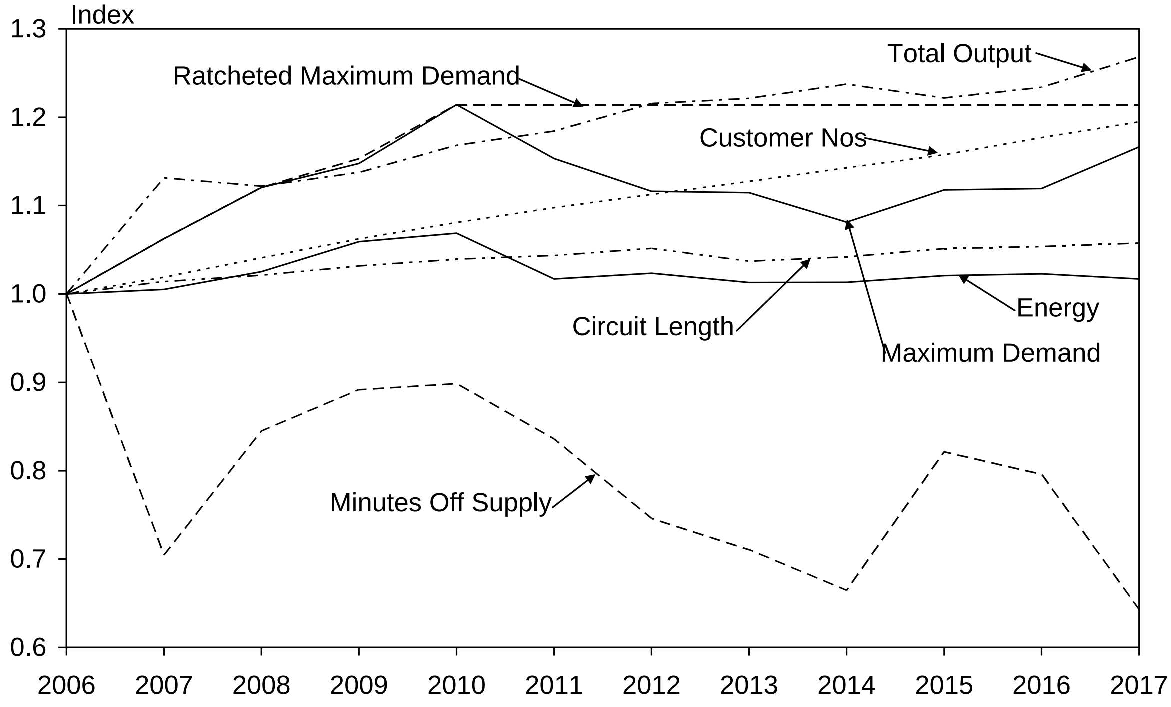
Over the 12–year period 2006 to 2017, the Queensland DNSPs' TFP increased at an average annual rate of 0.1 per cent. Queensland's total output increased by an average annual rate of 2.2 per cent – considerably higher than the output growth rates in ACT and NSW. Queensland's total input use increased a little slower, at a rate of 2.1 per cent – lower than the rate of input growth in NSW despite Queensland's much higher output growth. Queensland has also had much higher output growth than the industry as a whole but its input growth has been very similar to the industry's input growth. Input use increased at an above average rate in 2011 and 2015. The increase in 2015 coincided with a small reduction in output that year which lead to a marked fall in TFP. However, output recovered in 2016 and 2017 and, combined with a marginal reduction in input use, led to positive TFP growth in the latest year. TFP average annual change was negative for the period up to 2012 at –0.4 per cent but has been positive at 0.6 per cent for the period since 2012.

The partial productivity indexes in table 4.5 show that reduced opex usage was the main driver of the improved TFP performance after 2012 although this was offset somewhat by a worsening in capital partial productivity performance.

Queensland DNSP output and input quantity changes

We graph the quantity indexes for the Queensland DNSPs' five individual outputs in figure 4.12 and for their six individual inputs in figure 4.13.

Figure 4.12 **Qld output quantity indexes, 2006–2017**



From figure 4.12 we see that Queensland's output components showed a generally similar pattern of change to the industry as a whole except that there was more growth in outputs for Queensland over the period. Queensland's energy and maximum demand outputs showed less of a downturn after 2010, likely reflecting the effects of the mining boom. Customer numbers increased steadily over the period and was 20 per cent higher in 2017 than it was in 2006 reflecting Queensland's relatively strong output growth. Energy throughput for distribution peaked in 2010 but was still 2 per cent higher in 2017 than it was in 2006.

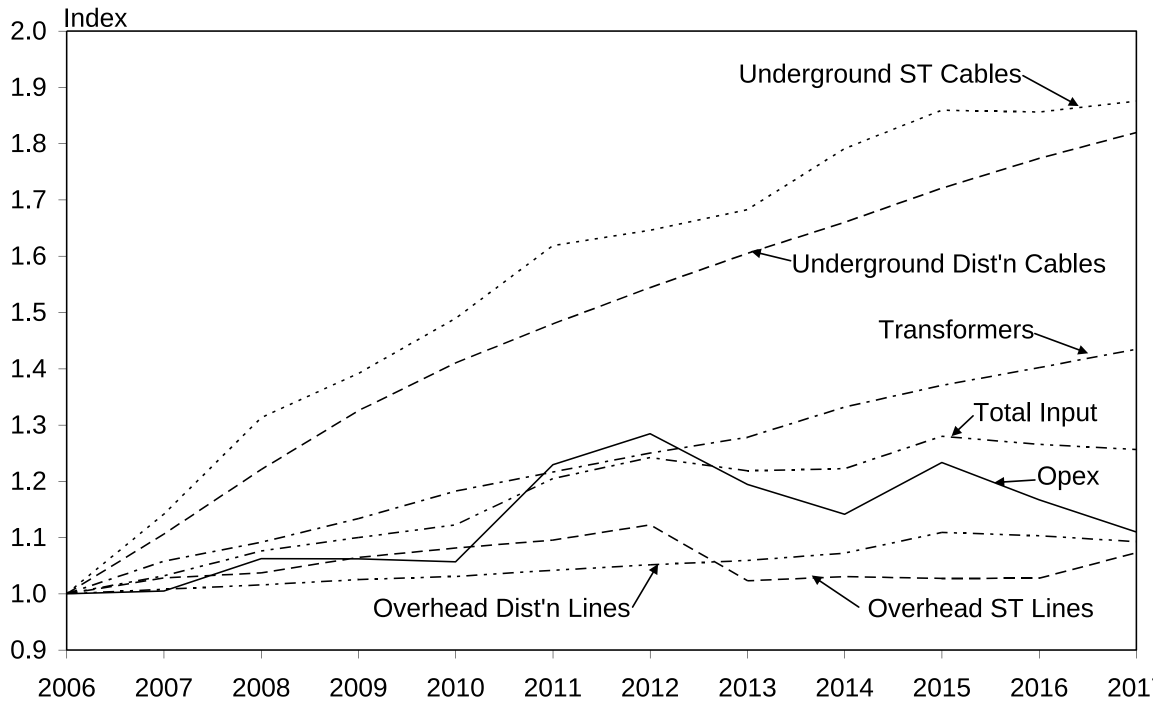
Queensland's maximum demand also peaked in 2010 and then declined through to 2014. However, unlike NSW, Queensland's maximum demand has stayed above its 2006 level for the remainder of the period. In 2017 RMD was 21 per cent above its 2006 level – a larger increase than for the industry overall.

Queensland's circuit length output also grew more over the 11 years than occurred for the industry overall and by 2017 was 6 per cent above the level it was in 2006 compared to an increase of 4 per cent for the industry.

The last output shown in figure 4.12 is total CMOS. Queensland's CMOS has generally followed a similar pattern to that of the industry although it increased markedly in 2015. CMOS has been lower and, hence, contributed more to total output for all other years than was the case in 2006. In 2017 CMOS was 36 per cent less than it was in 2006.

Since the customer numbers and ratcheted maximum demand outputs receive a weight of around 60 per cent of gross revenue in forming the total output index, in figure 4.12 we see that the total output index tends to lie close to these two output indexes. The circuit length and energy output indexes lie at a lower level but this is largely offset by the CMOS index which would generally lie above the other output indexes when it enters the formation of total output as a negative output (ie the reduction in CMOS over the period makes a positive contribution to total output). In Queensland CMOS receives an average weight of –17 per cent of gross revenue in forming the total output index.

Figure 4.13 **Qld DNSP input quantity indexes, 2006–2017**



Turning to the input side, we see from Queensland's six input components and total input in figure 4.13 that the quantity of Queensland's underground distribution and subtransmission cables and transformers inputs have increased more than for the industry as a whole while its opex and overhead lines increased somewhat less. Again, not too much should be read into the higher increase in underground cables as this was starting from a small base and reflects Queensland's higher rate of customer numbers growth. For Queensland, opex increased by 28 per cent up to 2012 which was less than the corresponding increases for the industry of 36 per cent and for NSW of 41 per cent. After an increase in 2015, Queensland's opex again fell in 2016 and 2017 to be 11 per cent above its 2006 level in 2017.[6] Opex has the largest average share in Queensland's total costs at 36 per cent and so is an important driver of its total input quantity index.

From figure 4.13 we see that the total input quantity index generally lies between the quantity indexes for opex and transformers (which together have a weight of 66 per cent of total costs). Total input quantity fell only a small amount in 2017 with the reduction in opex usage being offset by increases in transformers and underground distribution cables.

Queensland output and input contributions to TFP change

In table 4.6 we decompose Queensland's TFP change into its constituent output and input parts for the whole 12–year period and for the periods up to and after 2012. Queensland's drivers of TFP change for the whole 12–year period are broadly similar to the industry as a whole except that most outputs make a larger percentage point contribution to TFP growth in Queensland and opex makes a smaller negative contribution. And the transformers input makes a somewhat more negative contribution to TFP growth for Queensland than it does for the industry. However, the stronger output growth and lower opex growth for Queensland lead to its TFP performance being considerably better than that for the industry.

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

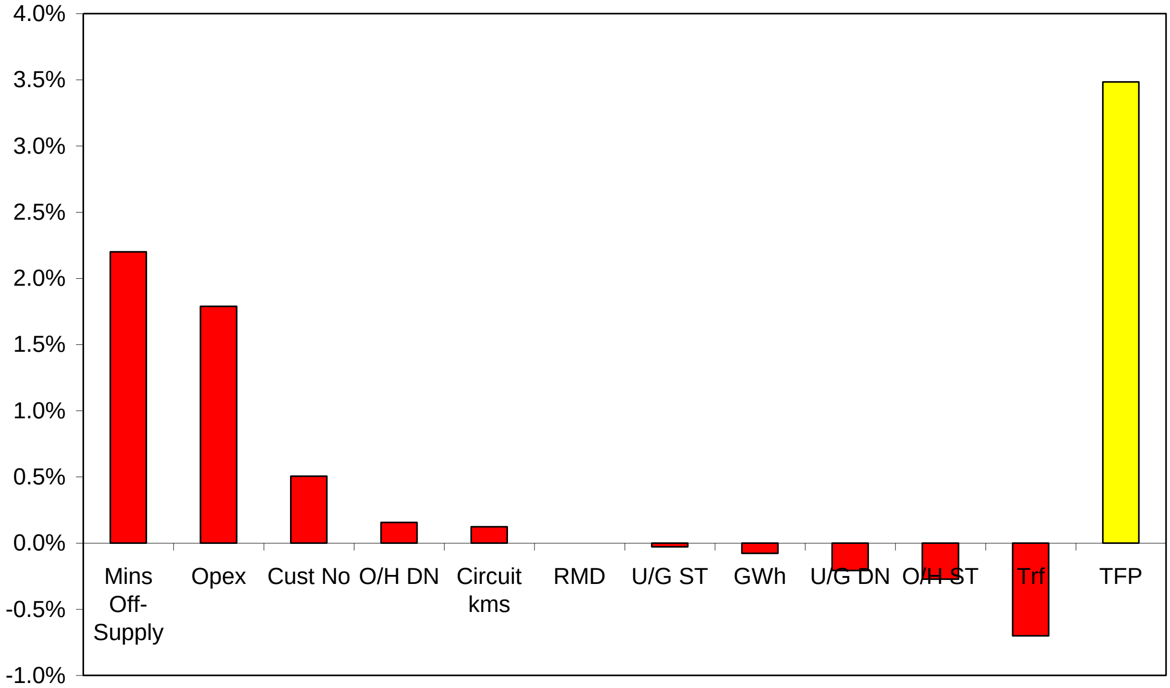
Year	*2006 to 2017*	*2006 to 2012*	*2012 to 2017*
Energy (GWh)	0.03%	0.06%	–0.02%
Ratcheted Max Demand	0.61%	1.13%	0.00%
Customer Numbers	0.57%	0.66%	0.48%
Circuit Length	0.18%	0.30%	0.03%
CMOS	0.77%	1.12%	0.36%
Opex	–0.35%	–1.49%	1.01%
O/H Subtransmission Lines	–0.04%	–0.14%	0.07%
O/H Distribution Lines	–0.13%	–0.14%	–0.12%
U/G Subtransmission Cables	–0.14%	–0.20%	–0.08%
U/G Distribution Cables	–0.41%	–0.53%	–0.27%
Transformers	–1.00%	–1.12%	–0.85%
TFP Change	0.09%	–0.36%	0.62%

The Queensland situation is also a tale of two distinct periods although the differences are less marked than for NSW and ACT. For the period up to 2012, opex growth made a smaller negative percentage point contribution to TFP growth for Queensland than for the industry, at

[6] Note that redundancy payments are included in the opex figures presented here.

–1.5 percentage points for Queensland versus –1.9 percentage points for the industry. The reductions made in Queensland's opex after 2012 led to opex contributing 1.0 percentage points to Queensland's average annual TFP change, similar to the industry. After 2012, Queensland's outputs all contributed somewhat smaller amounts to TFP growth compared to the period before 2012 but its inputs all made either positive or somewhat less negative percentage point contributions to TFP growth.

Figure 4.14 **Qld output and input percentage point contributions to annual TFP change, 2016–17**



The importance of the improvement in reliability and reduction in opex in 2017 is highlighted in figure 4.14 where they make 2.2 and 1.8 percentage point contribution to TFP change, respectively. Increases in transformer inputs somewhat more than offset positive contributions from customer numbers and the percentage point contributions from other outputs and inputs largely offset each other to produce a TFP increase of 3.5 per cent in 2017.

4.2.4 South Australia

South Australia (SA) is the fourth largest of the NEM jurisdictions (by customer numbers) and is served by one DNSP, SA Power Networks (SAP). In 2017 the SA DNSP delivered 10,215 GWh to 878,300 customers over 88,971 circuit kilometres of lines and cables.

SA DNSP productivity performance

SA's total output, total input and TFP indexes are presented in figure 4.15 and table 4.7. Opex and capital partial productivity indexes are also presented in table 4.7.

Over the 12–year period 2006 to 2017, the SA DNSP's TFP decreased at an average annual rate of 1.4 per cent. Although total output increased by an average annual rate of 1.4 per cent, total input use increased faster, at a rate of 2.8 per cent. SA thus had somewhat higher output growth but considerably higher input growth and hence lower TFP growth compared to the industry as whole. Input use increased at a faster rate in 2011 but otherwise grew at a steady rate through to 2015 before falling in 2016 but then increasing again in 2017.

Figure 4.15 **SA DNSP output, input and total factor productivity indexes, 2006–2017**

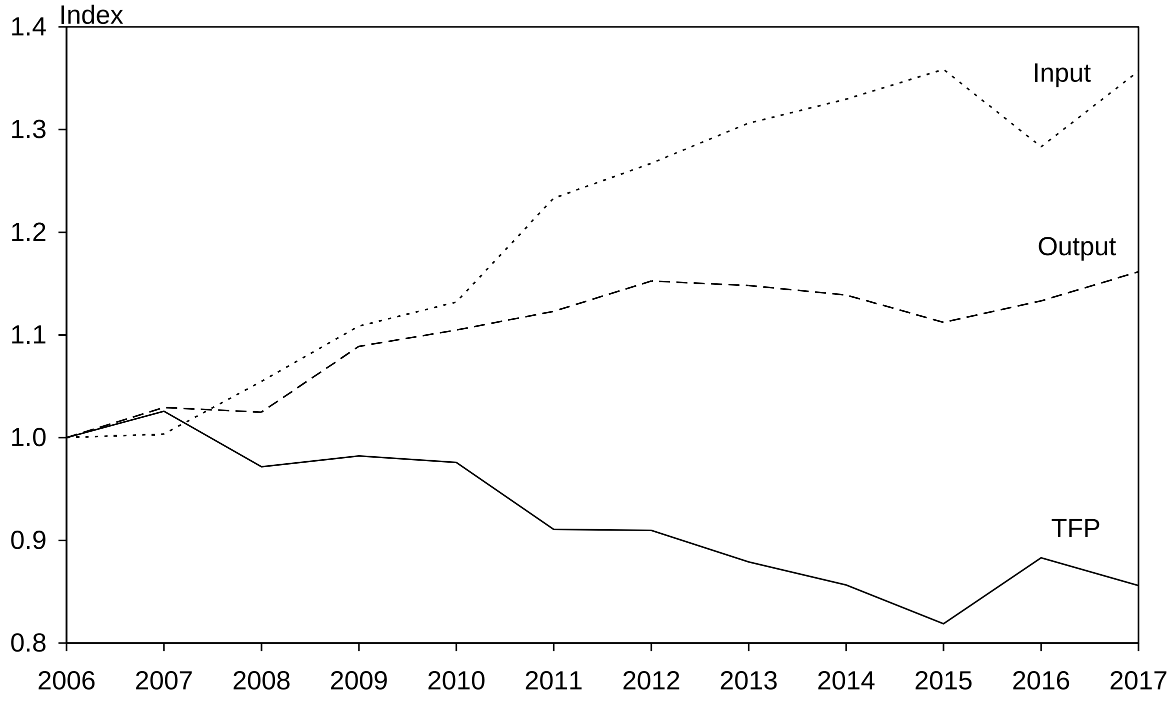


Table 4.7 **SA DNSP output, input and total factor productivity and partial productivity indexes, 2006–2017**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.029	1.004	1.026	1.111	0.994
2008	1.025	1.055	0.972	0.988	0.967
2009	1.089	1.109	0.982	0.952	0.999
2010	1.105	1.132	0.976	0.972	0.981
2011	1.123	1.233	0.911	0.792	0.980
2012	1.153	1.267	0.910	0.790	0.979
2013	1.148	1.306	0.879	0.743	0.960
2014	1.139	1.330	0.857	0.720	0.939
2015	1.112	1.359	0.819	0.677	0.907
2016	1.133	1.283	0.883	0.822	0.913
2017	1.161	1.357	0.856	0.732	0.930
Growth Rate 2006–17	1.36%	2.77%	–1.41%	–2.84%	–0.66%
Growth Rate 2006–12	2.37%	3.94%	–1.58%	–3.93%	–0.35%
Growth Rate 2012–17	0.15%	1.37%	–1.22%	–1.53%	–1.03%

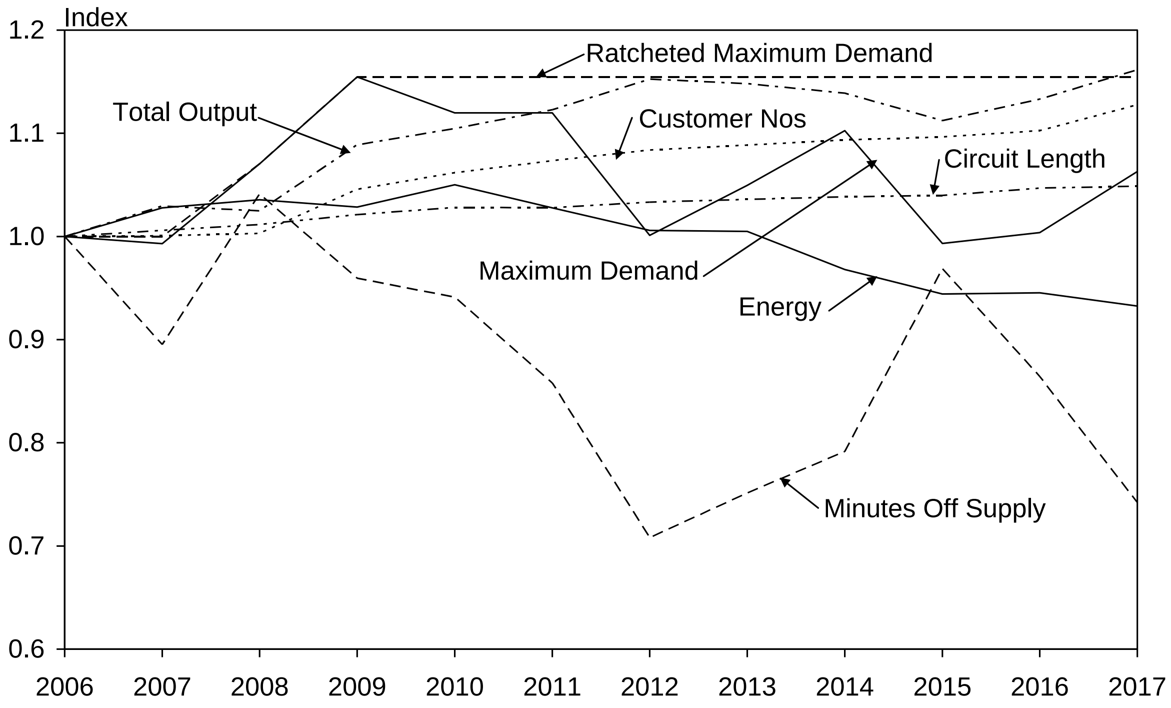
In 2017 SA's output surpassed its previous peak in 2012. TFP change was positive in 2007, 2009 and 2016. Compared to the whole 12–year period TFP average annual change was more negative for the period up to 2012 at –1.6 per cent but has been less negative at –1.2 per cent for the period since 2012.

The partial productivity indexes in table 4.7 show that opex productivity growth for South Australia has generally been more negative than capital productivity growth.

SA DNSP output and input quantity changes

We graph the quantity indexes for the SA DNSP's five individual outputs in figure 4.16 and for their six individual inputs in figure 4.17.

Figure 4.16 **SA output quantity indexes, 2006–2017**



From figure 4.16 we see that, with the exception of CMOS, SA's output components exhibit a similar pattern of change to the industry as a whole. Customer numbers increase steadily over the period and were only 10 per cent higher in 2017 than they were in 2006 reflecting SA's somewhat weaker economic conditions, particularly since 2012. Energy throughput for distribution peaked in 2010 and has fallen since to be 7 per cent lower in 2017 than it was in 2006.

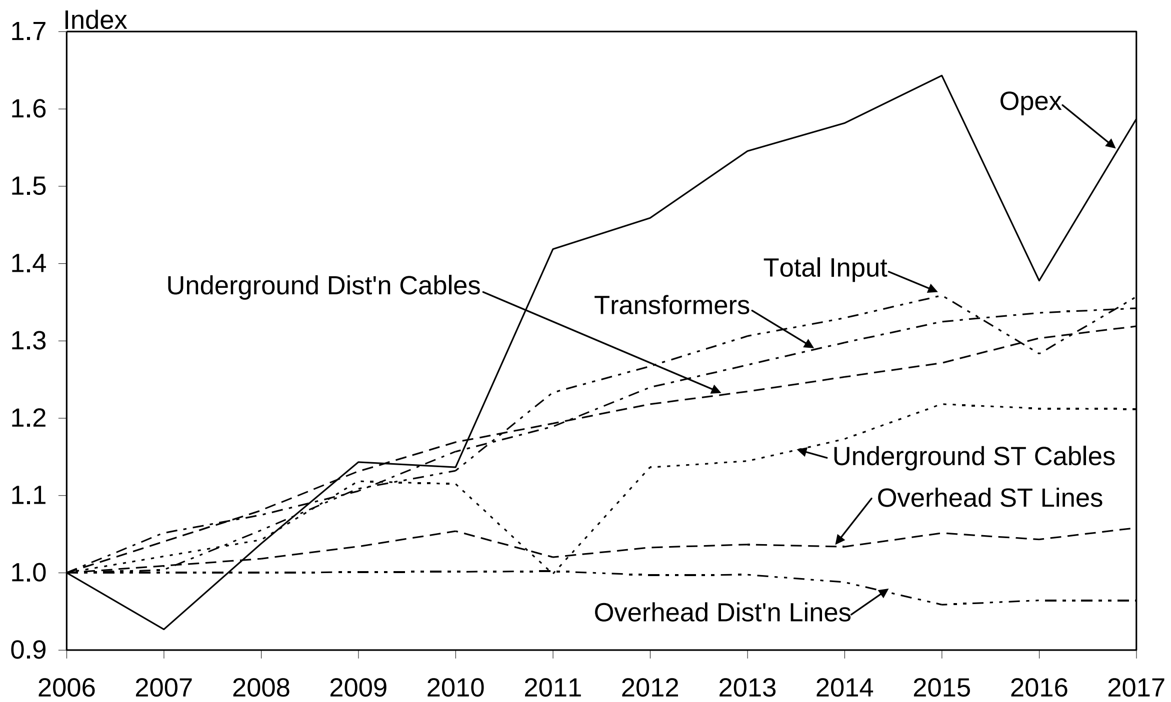
SA's maximum demand peaked in 2009 and has been relatively volatile since then. It has trended down since 2009 and in 2017 was 6 per cent above its 2006 level. Ratcheted maximum demand in 2017 was 16 per cent above its 2006 level – close to the same increase as for the industry overall.

SA's circuit length output grew somewhat more over the 12 years than occurred for the industry overall and by 2017 was 5 per cent the level it was in 2006 compared to an increase of 4 per cent for the industry.

The last output shown in figure 4.16 is total CMOS. SA's CMOS has been more volatile than for the industry. By 2012 SA's CMOS was 30 per cent lower than it was in 2006 but then increased through to 2015 to be within 3 per cent of its 2006 level before again falling in 2016 and 2017. In 2017 CMOS was 26 per cent less than it was in 2006.

Since the customer numbers and ratcheted maximum demand outputs receive a weight of around 60 per cent of gross revenue in forming the total output index, in figure 4.16 we see that the total output index lies between these two output indexes. The circuit length index lies at a lower level but this is largely offset by the CMOS index which would generally lie above the other output indexes when it enters the formation of total output as a negative output (ie the reduction in CMOS over the period makes a positive contribution to total output). The CMOS increase in 2015 is the main reason for a fall in total output in that year.

Figure 4.17 **SA DNSP input quantity indexes, 2006–2017**



Turning to the input side, we see from SA's six input components and total input in figure 4.17 that the quantity of SA's opex increased more rapidly between 2006 and 2015 than the corresponding increase for the industry. For SA, opex increased by 64 per cent up to 2015 whereas the corresponding increase for the industry was 34 per cent. A major driver of this difference was an increase in SA's opex input of 22 per cent in 2011. However, opex fell sharply in 2016 but was still 38 per cent above its 2006 level compared to 23 per cent for the industry. As noted in section 3.1, SA's opex increased sharply in 2017 as a result of increased emergency response costs and Guaranteed Service Level payments due to severe weather events. Opex has the largest average share in SA's total costs at 34 per cent and so is an important driver of its total input quantity index.

SA's transformers and underground distribution cables inputs increase more steadily over the period, the latter at a somewhat slower rate than for the industry as a whole. Its overhead distribution lines input decreased over the period with a fall of 4 per cent by 2017 relative to 2006 compared to an 11 per cent increase for the industry.

From figure 4.17 we see that the total input quantity index lies between the quantity indexes for opex, transformers and underground distribution cables (which together account for 86 per cent of total costs). Total input quantity increased in 2017 in line with the increase in opex usage.

SA output and input contributions to TFP change

In table 4.8 we decompose SA's TFP change into its constituent output and input parts for the whole 12–year period and for the periods up to and after 2012. SA's drivers of TFP change for the whole 12–year period are broadly similar to the industry as a whole except that the output of customer numbers contributes somewhat less due to its weaker growth in SA and opex makes a larger negative contribution. CMOS contributes more to TFP growth for SA than for the industry given the larger reduction in CMOS for SA.

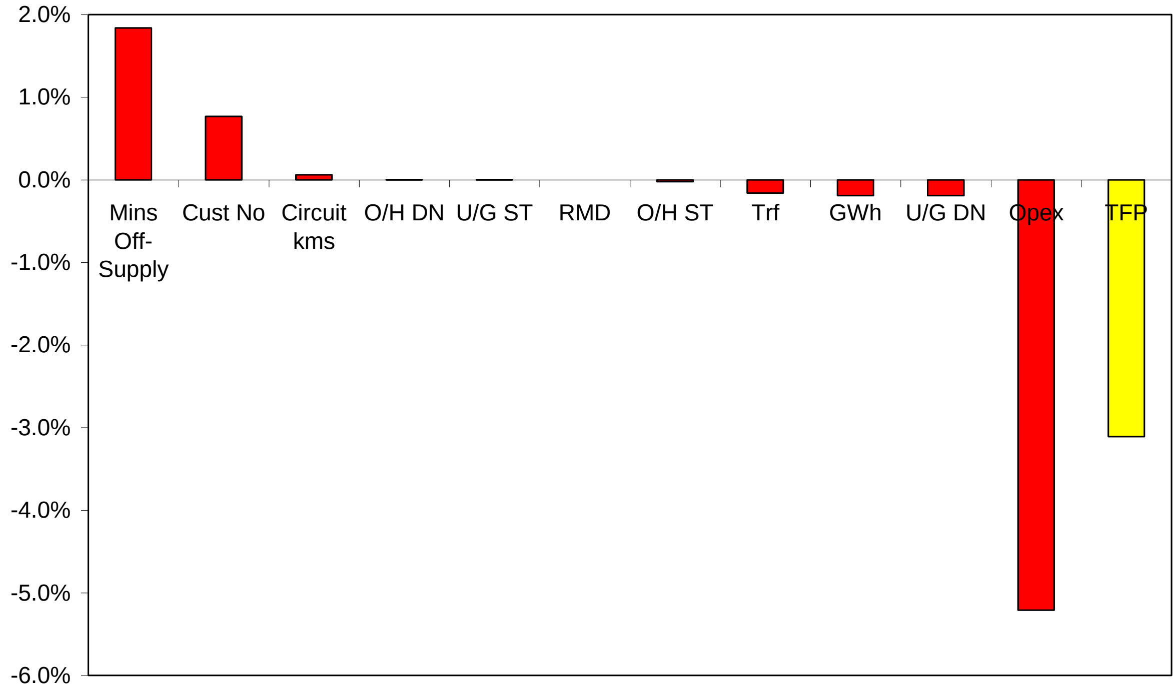
The SA situation is again a tale of two distinct periods. For the period up to 2012, all outputs made a positive contribution to TFP change but after 2012 this fell to near zero or negative for all outputs other than customer numbers. The negative percentage point contribution of opex to TFP more than halved for SA after 2012, although at –0.6 percentage points it was well below the 0.9 percentage points for the industry after 2012.

Table 4.8 **SA 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%	0.02%	–0.21%
Ratcheted Max Demand	0.45%	0.82%	0.00%
Customer Numbers	0.39%	0.48%	0.27%
Circuit Length	0.15%	0.19%	0.10%
CMOS	0.47%	0.86%	0.00%
Opex	–1.41%	–2.07%	–0.63%
O/H Subtransmission Lines	–0.01%	–0.01%	–0.01%
O/H Distribution Lines	0.03%	0.01%	0.06%
U/G Subtransmission Cables	–0.01%	–0.01%	0.00%
U/G Distribution Cables	–0.51%	–0.71%	–0.26%
Transformers	–0.87%	–1.15%	–0.53%
TFP Change	–1.41%	–1.58%	–1.22%

The importance of the increase in opex in 2017 is highlighted in figure 4.18 where the –5.2 percentage point contribution of opex to TFP change in the 2017 year dwarfs the contributions of other outputs and inputs. In fact, with the exception of CMOS which made a 1.8 percentage point contribution, the contributions of the other output and inputs were mainly small and almost offset each other to produce a TFP change of –3.1 per cent in 2017.

Figure 4.18 **SA output and input percentage point contributions to annual TFP change, 2016–17**



4.2.5 Tasmania

Tasmania (TAS) is the second smallest of the NEM jurisdictions (by customer numbers) and is served by one DNSP, TasNetworks Distribution (TND). In 2017 the Tasmania DNSP delivered 4,192 GWh to 287,652 customers over 22,725 circuit kilometres of lines and cables.

Tasmanian DNSP productivity performance

Tasmania's total output, total input and TFP indexes are presented in figure 4.19 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, the Tasmanian DNSP's TFP decreased at an average annual rate of 1.9 per cent. Total output has increased by an average annual rate of only 0.2 per cent and actually decreased by 8 per cent between 2006 and 2010. Total input use, on the other hand, has increased at a faster average annual rate of 2.2 per cent. Input use increased at a much faster rate between 2006 and 2012. Input use decreased in 2013 and again in 2015 but increased again in 2016 before increasing sharply in 2017. TFP change was positive in three years: 2011, 2013 and 2015. In 2011 output grew strongly while input increase moderated. In 2013 input use was reduced while output grew modestly and in 2015 output grew more strongly and input use was also cut significantly. Compared to the whole 12–year period TFP average annual change was more negative for the period up to 2012 at –3.7 per cent but this reversed after 2012 to an average annual growth rate of 0.1 per cent.

Figure 4.19 **TAS DNSP output, input and total factor productivity indexes, 2006–2017**

Table 4.9 **TAS DNSP output, input and total factor productivity and partial productivity indexes, 2006–2017**

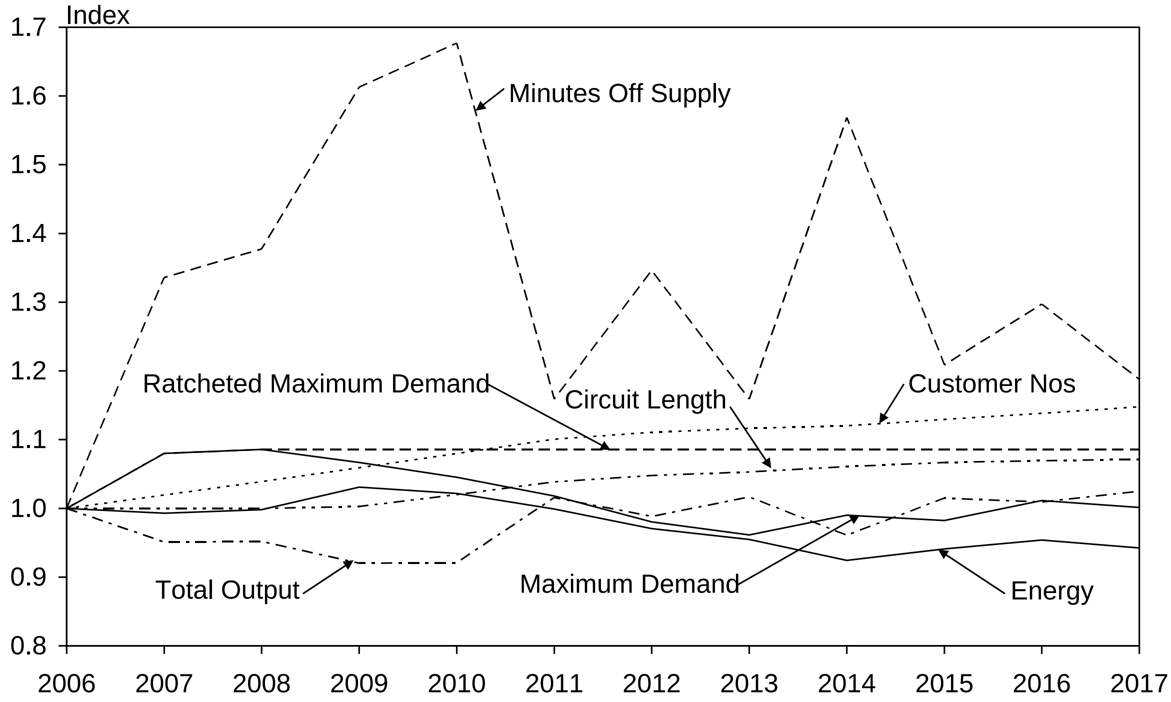
Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	0.951	1.010	0.942	0.953	0.936
2008	0.952	1.027	0.927	0.945	0.918
2009	0.920	1.082	0.851	0.817	0.871
2010	0.921	1.175	0.784	0.691	0.845
2011	1.016	1.182	0.859	0.792	0.904
2012	0.988	1.232	0.802	0.706	0.866
2013	1.016	1.152	0.882	0.895	0.885
2014	0.961	1.171	0.820	0.829	0.824
2015	1.015	1.114	0.911	1.035	0.863
2016	1.009	1.144	0.882	0.960	0.853
2017	1.025	1.269	0.808	0.742	0.855
Growth Rate 2006–17	0.22%	2.16%	–1.94%	–2.71%	–1.43%
Growth Rate 2006–12	–0.20%	3.48%	–3.67%	–5.80%	–2.40%
Growth Rate 2012–17	0.72%	0.59%	0.14%	0.99%	–0.26%

The partial productivity indexes in table 4.9 show that reduced opex usage was the main driver of the improved TFP performance after 2012 although improved capital productivity also played a role.

Tasmanian DNSP output and input quantity changes

We graph the quantity indexes for the Tasmania DNSP's five individual outputs in figure 4.20 and its six individual inputs in figure 4.21.

Figure 4.20 **TAS output quantity indexes, 2006–2017**



From figure 4.20 we see that, with the exception of CMOS, Tasmania's output components exhibit a similar pattern of change to the industry as a whole except that there has been considerably less growth in some of Tasmania's outputs. Customer numbers increased steadily over the period and were 15 per cent higher in 2017 than they were in 2006, similar to the industry's increase over the 12 years. Energy throughput for distribution peaked in 2009 and decreased each year through to 2014 before recovering somewhat in the last few years. It was still 6 per cent lower in 2017 than it was in 2006.

Tasmania's maximum demand reached its highest level in 2008 then declined through to 2013 before recovering somewhat subsequently. In 2017 it was around the same level as it was in 2006. Ratcheted maximum demand in 2017 was 9 per cent above its 2006 level – a much smaller increase than the industry's 17 per cent.

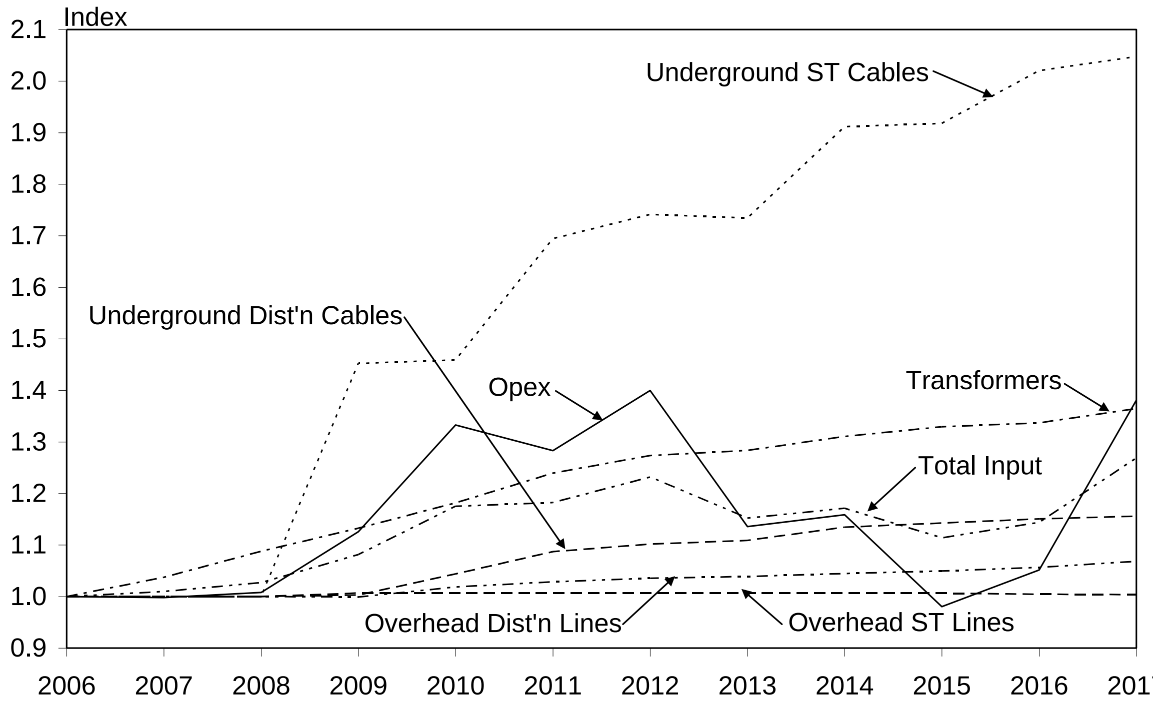
Tasmania's circuit length output grew around the same over the 12 years as occurred for the industry overall and by 2017 was 4 per cent above the level it was in 2006.

The last output shown in figure 4.20 is total CMOS. Tasmania's CMOS has been more volatile than for the industry and has trended upwards over the period. By 2017 Tasmania's CMOS was 19 per cent higher than it was in 2006 but this was down from 68 per cent above its 2006 level in 2010 and 57 per cent above its 2006 level in 2014.

Although the customer numbers, ratcheted maximum demand and circuit length outputs receive most of the weight in forming the total output index, in figure 4.20 we see that the total output index lies below these three output indexes. This is because the CMOS variable enters the formation of total output as a negative output (ie the large increase in CMOS over the period makes a substantial negative contribution to total output). Movements in the total output index generally mirror movements in CMOS.

Turning to the input side, we see from Tasmania's six input components and total input in figure 4.21 that the quantity of Tasmania's opex increased somewhat more between 2006 and 2012 than the corresponding increase for the industry. For Tasmania, opex increased by 40 per cent up to 2012 whereas the corresponding increase for the industry was 36 per cent. Since then Tasmania's opex usage was reduced sharply through to 2015 but increased moderately in 2016 and then very sharply in 2017. In 2017 it almost regained its earlier peak level in 2012 and was 38 per cent above its 2006 level. As noted in section 3.1, TND has indicated the 33 per cent increase in opex in 2017 was used to address bushfire and other risks that had recently been identified. It expected this high level of opex usage to continue for some time. Opex has the largest average share in Tasmania's total costs at 35 per cent and so is an important driver of its total input quantity index.

Figure 4.21 **TAS DNSP input quantity indexes, 2006–2017**



Tasmania's transformer inputs have increased at a similar annual rate to the industry's 2.8 per cent for the 12 year period as a whole. However, Tasmania's transformer input use increased more rapidly than for the industry up to 2012 but less rapidly than for the industry after 2012.

Tasmania's underground distribution cables inputs increased more modestly over the period at a lower rate than for the industry as a whole. By 2017 underground distribution cables inputs were 16 per cent higher in Tasmania than they were in 2006 compared to a corresponding increase of 52 per cent for the industry. Tasmania's overhead distribution lines input increased over the period with an increase of 7 per cent by 2017 relative to 2006 compared to a corresponding 11 per cent increase for the industry.

From figure 4.21 we see the total input quantity index lies below the quantity indexes for opex and transformers and above the quantity index for overhead distribution lines (having a combined weight of 87 per cent of total costs). Total input quantity increased by 10 per cent in 2017, mainly due to the 31 per cent increase in opex.

Tasmanian output and input contributions to TFP change

In table 4.10 we decompose Tasmania's TFP change into its constituent output and input parts for the whole 12–year period and for the periods up to and after 2012. Tasmania's drivers of TFP change for the whole 12–year period are somewhat similar to the industry as a whole except that CMOS makes a negative contribution to TFP growth for Tasmania whereas it is positive for the industry. Opex also makes a more negative contribution over the period for Tasmania at –1.1 per cent compared to –0.6 per cent for the industry.

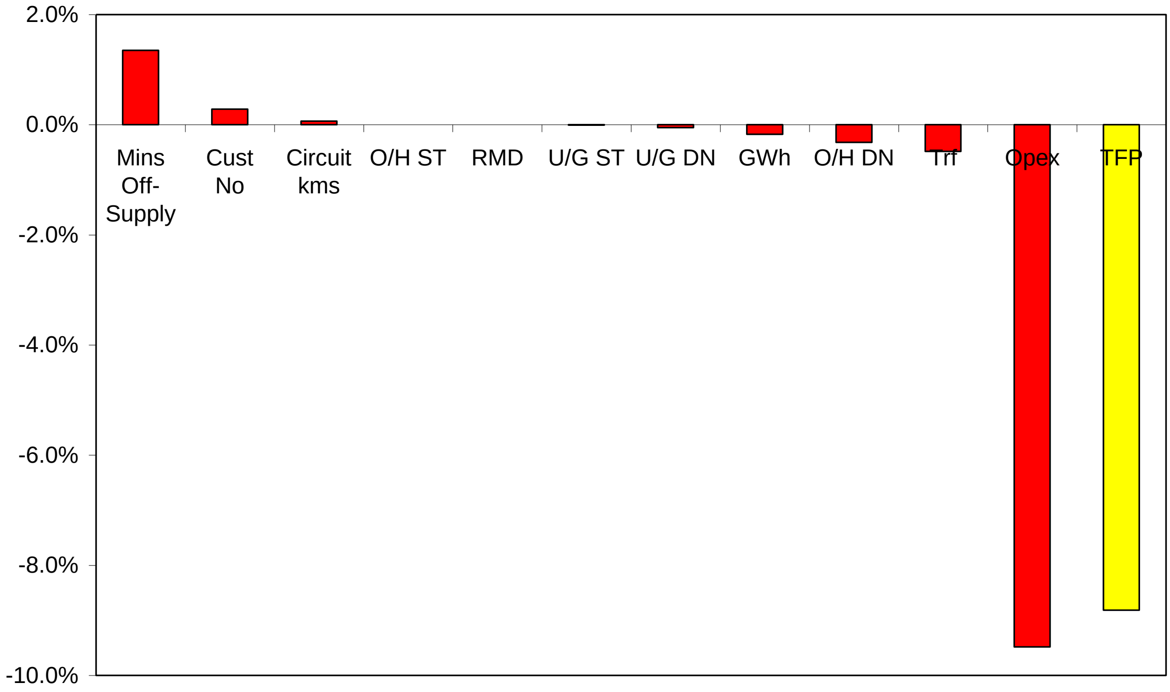
Table 4.10 **TAS output and input percentage point contributions to average annual TFP change: 2006–2017, 2006–2012 and 2012–2017**

Year	*2006 to 2017*	*2006 to 2012*	*2012 to 2017*
Energy (GWh)	–0.08%	–0.07%	–0.09%
Ratcheted Max Demand	0.27%	0.50%	0.00%
Customer Numbers	0.48%	0.68%	0.23%
Circuit Length	0.22%	0.28%	0.15%
CMOS	–0.67%	–1.59%	0.43%
Opex	–1.09%	–2.06%	0.07%
O/H Subtransmission Lines	0.00%	0.00%	0.00%
O/H Distribution Lines	–0.17%	–0.16%	–0.18%
U/G Subtransmission Cables	–0.03%	–0.04%	–0.01%
U/G Distribution Cables	–0.17%	–0.21%	–0.12%
Transformers	–0.71%	–1.02%	–0.34%
TFP Change	–1.94%	–3.67%	0.14%

The Tasmanian situation is again a tale of two distinct periods. With the exception of CMOS, the contribution of most outputs to TFP falls after 2012 compared to the period before 2012. And the contribution of most inputs remains relatively unchanged except for opex and transformers whose contributions improve by 2.1 percentage points and 0.7 percentage points, respectively. Opex change went from a contribution to TFP of –2.1 percentage points to a contribution of around zero percentage points.

The impact of the very large increase in opex in 2017 on Tasmanian TFP performance is highlighted in figure 22 where opex made a –9.5 percentage point contribution to TFP change in the 2017 year. Despite a contribution of 1.4 percentage points from an improvement in CMOS and of 0.3 percentage points from growth in customer numbers, the negative impact of the large increase in opex and smaller increases in other inputs led to Tasmanian TFP change of –8.8 per cent. This contrasts with positive industry TFP change of 2.7 per cent in the latest year.

Figure 4.22 **TAS output and input percentage point contributions to annual TFP change, 2016–17**



4.2.6 Victoria

Victoria (VIC) is the second largest of the NEM jurisdictions (by customer numbers) and is served by five DNSPs: AusNet Services Distribution (AND), CitiPower (CIT), Jemena Electricity Networks (JEN), Powercor (PCR) and United Energy (UED). In 2017 the Victorian DNSPs delivered 36,419 GWh to 2.9 million customers over 144,265 circuit kilometres of lines and cables.

Victorian DNSP productivity performance

Victoria's total output, total input and TFP indexes are presented in figure 4.23 and table 4.11. Opex and capital partial productivity indexes are also presented in table 4.11.

Over the 12–year period 2006 to 2017, the Victorian DNSPs' TFP decreased at an average annual rate of 0.6 per cent. Although total output increased by an average annual rate of 1.4 per cent, total input use increased faster, at a rate of 2.0 per cent. Victoria thus had similar output growth, input growth and TFP growth to the industry as a whole. Input use increased at a faster rate in 2009 and 2012 but otherwise grew at a steady rate through to 2015 before levelling off in 2016 and decreasing in 2017. Victoria's output declined in three years: 2009, 2013 and 2014. TFP change was positive in four years: 2008, 2010, 2015 and 2017. In the first three of these years there was stronger output growth and in 2017 input use fell at the same time there was a return to strong output growth. Compared to the whole 12–year period TFP average annual change of –0.6 per cent, TFP average annual change was more negative for the period up to 2012 at –1.5 per cent but has been positive at 0.4 per cent for the period since 2012.

Figure 4.23 **VIC DNSP output, input and total factor productivity indexes, 2006–2017**

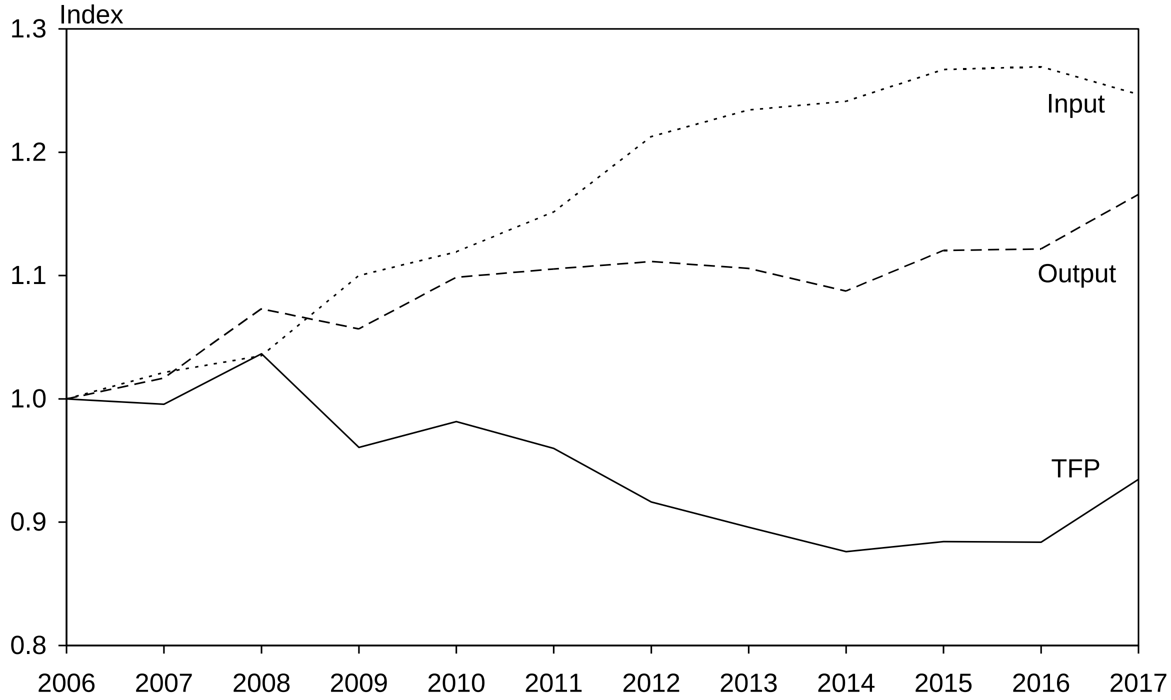


Table 4.11 **VIC DNSP output, input and total factor productivity and partial productivity indexes, 2006–2017**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.017	1.021	0.996	1.002	0.991
2008	1.073	1.035	1.037	1.060	1.022
2009	1.057	1.100	0.961	0.944	0.971
2010	1.099	1.119	0.982	0.969	0.989
2011	1.105	1.152	0.960	0.927	0.979
2012	1.111	1.213	0.916	0.843	0.965
2013	1.106	1.234	0.896	0.826	0.942
2014	1.087	1.241	0.876	0.824	0.909
2015	1.120	1.267	0.884	0.825	0.922
2016	1.122	1.269	0.884	0.845	0.908
2017	1.166	1.247	0.935	0.948	0.930
Growth Rate 2006–17	1.39%	2.01%	–0.61%	–0.48%	–0.66%
Growth Rate 2006–12	1.76%	3.21%	–1.45%	–2.85%	–0.59%
Growth Rate 2012–17	0.95%	0.56%	0.40%	2.36%	–0.74%

The partial productivity indexes in table 4.11 show that strong opex MPFP performance was the main driver of the improved TFP performance after 2012.

Victorian DNSP output and input quantity changes

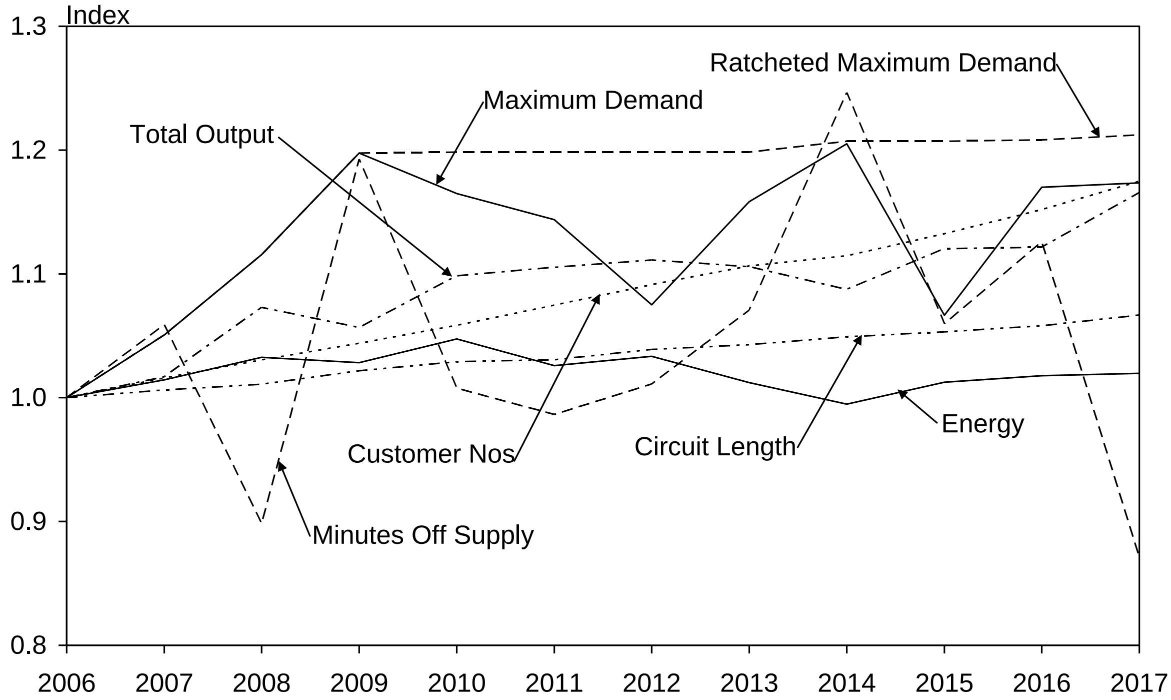
We graph the quantity indexes for the Victorian DNSPs' five individual outputs in figure 4.24 and for their six individual inputs in figure 4.25.

From figure 4.24 we see that, with the exception of CMOS, Victoria's output components exhibit a similar pattern of change to the industry as a whole. Customer numbers increased steadily over the period and were 18 per cent higher in 2017 than they were in 2006, a little higher than the industry's increase of 16 per cent. Energy throughput for distribution peaked in 2010 and was only 2 per cent higher in 2017 than it was in 2006.

Victoria's maximum demand reached its highest level in 2014 but has been relatively volatile since 2009. In 2017 it was around 17 per cent above its 2006 level. Ratcheted maximum demand in 2017 was 21 per cent above its 2006 level – a larger increase than the industry's 17 per cent.

Victoria's circuit length output grew somewhat more over the 12 years than occurred for the industry overall and by 2017 was 7 per cent above the level it was in 2006 compared to an increase of 4 per cent for the industry.

Figure 4.24 **VIC output quantity indexes, 2006–2017**



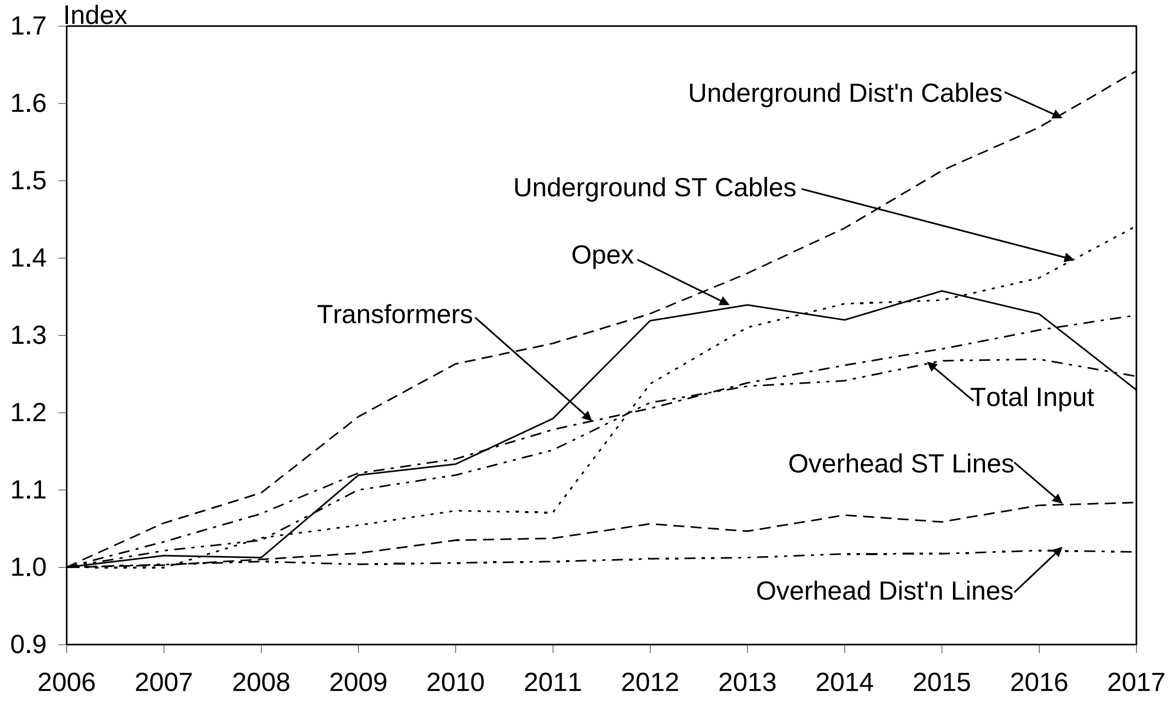
The last output shown in figure 4.24 is total CMOS. Victoria's CMOS has been more volatile than for the industry and trended upwards till 2016 but then fell by 23 per cent in 2017 to be 13 per cent lower than it was in 2006. But in 2014 it had been 25 per cent above its 2006 level.

Since the customer numbers, circuit length and ratcheted maximum demand outputs receive a weight of around 88 per cent of gross revenue in forming the total output index, in figure 4.24 we see that the total output index lies close to these output indexes. The energy output index lies at a lower level and the CMOS index would also generally lie below the other output indexes when it enters the formation of total output as a negative output. The CMOS decrease in 2017 is the main reason for the stronger total output growth in that year.

Turning to the input side, we see from Victoria's six input components and total input in figure 4.25 that the quantity of Victoria's opex increased somewhat less rapidly between 2006 and 2012 than the corresponding increase for the industry. For Victoria, opex increased by 32 per cent up to 2012 whereas the corresponding increase for the industry was 36 per cent. Since then Victoria's opex usage was relatively flat through to 2016 before decreasing 7 by per cent in 2017. This brought Victoria's opex reduction after 2012 to around half that for the industry which reduced by 13 per cent. Opex has the largest average share in Victoria's total costs at 38 per cent and so is an important driver of its total input quantity index.

Victoria's underground distribution cables and transformers inputs increased more steadily over the period at somewhat higher and lower rates, respectively, than for the industry as a whole. Its overhead distribution lines input increased over the period with an increase of 2 per cent by 2017 relative to 2006 compared to a 4 per cent increase for the industry.

Figure 4.25 **VIC DNSP input quantity indexes, 2006–2017**



From figure 4.25 we see that the total input quantity index lies close to the quantity indexes for opex and transformers (which have a combined weight of 60 per cent of total costs). Total input quantity decreased by 1.8 per cent in 2017 with the reduction in opex usage more than offsetting increases in the other inputs.

Victorian output and input contributions to TFP change

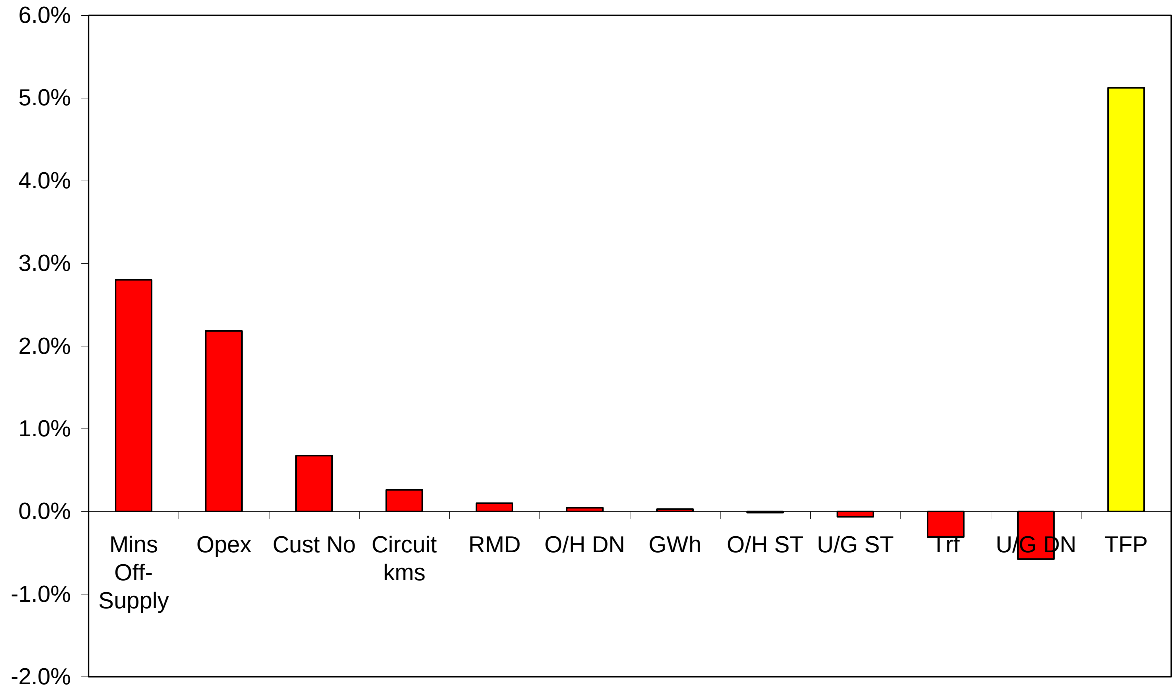
In table 4.12 we decompose Victoria's TFP change into its constituent output and input parts for the whole 12–year period and for the periods up to and after 2012. Victoria's drivers of TFP change for the whole 12–year period are broadly similar to the industry as a whole except that CMOS makes a slightly less positive contribution to TFP growth for Victoria.

Opex also makes a somewhat more negative contribution over the period for Victoria at –0.8 per cent compared to –0.6 per cent for the industry. However, transformer inputs make a lees negative contribution to Victoria's TFP at –0.6 percentage points compared to –0.8 for the industry.

Table 4.12 **VIC 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)	0.03%	0.08%	–0.04%
Ratcheted Max Demand	0.57%	0.99%	0.07%
Customer Numbers	0.51%	0.51%	0.50%
Circuit Length	0.19%	0.21%	0.17%
CMOS	0.09%	–0.03%	0.25%
Opex	–0.75%	–1.78%	0.48%
O/H Subtransmission Lines	–0.03%	–0.03%	–0.02%
O/H Distribution Lines	–0.04%	–0.04%	–0.04%
U/G Subtransmission Cables	–0.05%	–0.05%	–0.04%
U/G Distribution Cables	–0.60%	–0.64%	–0.54%
Transformers	–0.55%	–0.67%	–0.39%
TFP Change	–0.61 %	–1.45%	0.40%

Figure 4.26 **VIC output and input percentage point contributions to annual TFP change, 2017**



The Victorian situation is again a tale of two distinct periods. The contribution of all outputs to TFP falls after 2012 compared to the period before 2012, with the exception of CMOS. And the contribution of most inputs remains relatively unchanged except for opex and transformers whose contributions improve by 2.3 percentage points and 0.3 percentage points, respectively. Opex change went from a negative percentage point contribution to TFP to a positive contribution of 0.5 percentage points for Victoria as opex usage reduced, although this was concentrated in 2017. This was broadly in line with changes for the industry as a whole.

The importance of the recent falls in opex usage and in CMOS is highlighted in figure 4.26 where CMOS made a 2.8 percentage point contribution and opex made a 2.7 percentage point contribution to TFP change in the 2017 year. Customer numbers growth contributed 0.7 percentage points to TFP. This was offset by the transformers input contribution of –0.6 percentage points and the other outputs and inputs made smaller contributions which largely offset each other. Victorian TFP growth in 2017 was 5.6 per cent compared to industry TFP growth of 2.7 per cent in that year.

5 DNSP OUTPUTS, INPUTS AND PRODUCTIVITY CHANGE

In this section we review the outputs, inputs and productivity change results for the remaining 10 NEM DNSPs – three of the NEM jurisdictions covered in the preceding section have only one DNSP so we have already covered the ACT's ActewAGL, South Australia's SA Power Networks and Tasmania's TasNetworks Distribution.

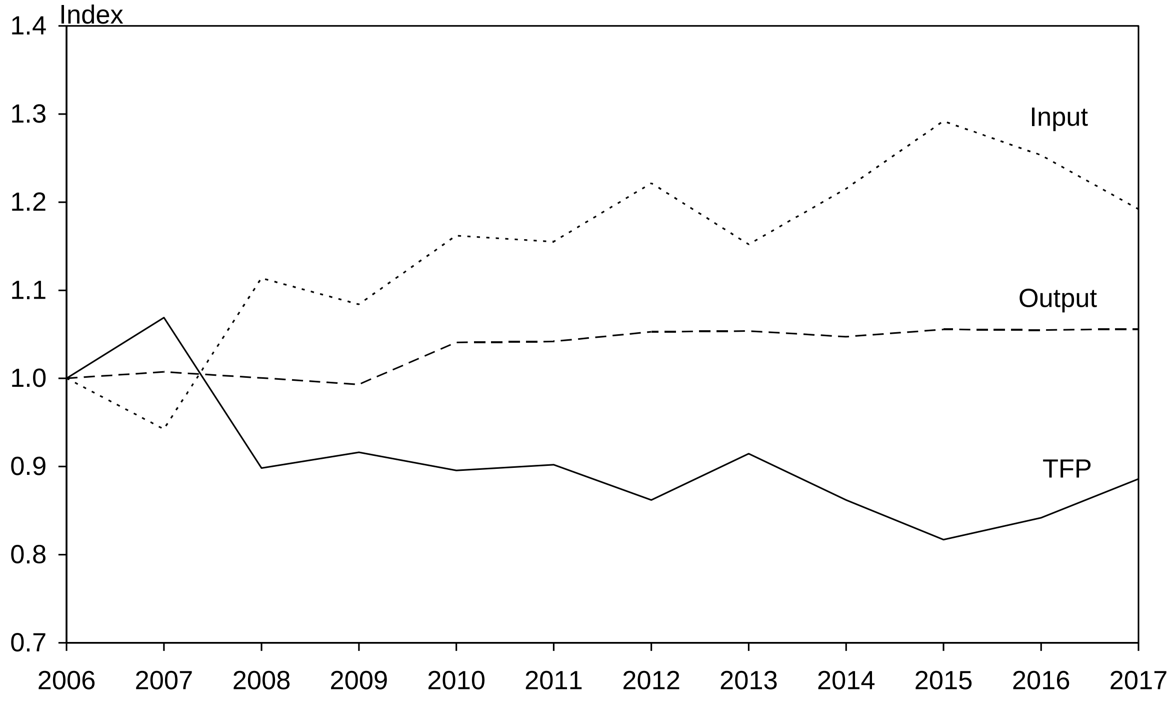
5.1 Ausgrid

In 2017 Ausgrid (AGD) delivered 25,669 GWh to 1.71 million customers over 41,642 circuit kilometres of lines and cables. AGD distributes electricity to the eastern half of Sydney (including the Sydney CBD), the NSW Central Coast and the Hunter region across an area of 22,275 square kilometres. It is the largest of the three NSW DNSPs in terms of customer numbers and energy throughput.

AGD's productivity performance

AGD's total output, total input and TFP indexes are presented in figure 5.1 and table 5.1. Opex and capital partial productivity indexes are also presented in table 5.1.

Figure 5.1 **AGD output, input and total factor productivity indexes, 2006–2017**



Over the 12–year period 2006 to 2017, AGD's TFP decreased with an average annual change of –1.1 per cent. Although total output increased by an average annual rate of 0.5 per cent, total input use increased faster, at a rate of 1.6 per cent. AGD thus had much slower output growth than the industry as a whole. Despite also having slower input growth, this led to AGD having a more negative TFP growth rate. Input use increased sharply in 2008 and 2012, to be followed each time by a small reduction the following year. Input use again fell in 2016 and 2017 after solid increases in 2014 and 2015. TFP fell markedly in 2008, 2012, 2014 and 2015 but TFP change was positive in six years – 2007, 2009, 2011, 2013, 2016 and 2017. TFP average annual change was sharply negative for the period up to 2012 at –2.5 per cent but has reversed for the period since 2012 with a rate of 0.5 per cent.

Table 5.1 **AGD 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	1.007	0.942	1.069	1.190	0.983
2008	1.001	1.114	0.898	0.832	0.953
2009	0.993	1.084	0.916	0.912	0.920
2010	1.041	1.162	0.896	0.843	0.934
2011	1.042	1.155	0.902	0.883	0.918
2012	1.053	1.221	0.862	0.808	0.900
2013	1.054	1.152	0.915	1.024	0.876
2014	1.047	1.215	0.862	0.913	0.848
2015	1.056	1.292	0.817	0.784	0.850
2016	1.055	1.253	0.842	0.877	0.836
2017	1.056	1.192	0.886	0.994	0.849
Growth Rate 2006–17	0.50%	1.60%	–1.10%	–0.06%	–1.49%
Growth Rate 2006–12	0.86%	3.33%	–2.47%	–3.55%	–1.76%
Growth Rate 2012–17	0.06%	–0.49%	0.54%	4.13%	–1.16%

The partial productivity indexes in table 5.1 show that reduced opex usage was the main driver of the improved TFP performance after 2012.

AGD's output and input quantity changes

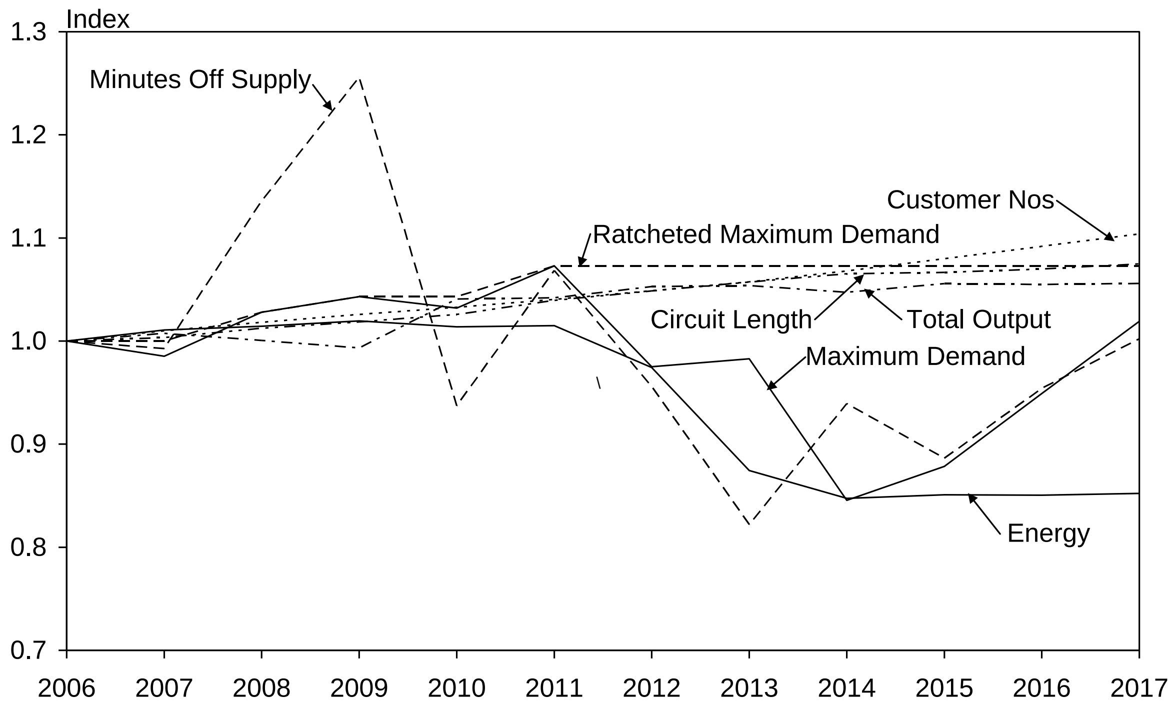
We graph the quantity indexes for AGD's five individual outputs in figure 5.2 and for its six individual inputs in figure 5.3.

From figure 5.2 we see that AGD's output components showed a similar pattern of change to the industry as a whole except that there was much less growth in outputs for AGD between 2006 and 2009, likely reflecting the impact of the global financial crisis and the initial negative effects of the mining boom on NSW. Customer numbers increased steadily over the period and were 10 per cent higher in 2017 than they were in 2006 reflecting AGD's relatively weak output growth. Energy throughput for distribution peaked in 2009 and has fallen considerably since to be a quite large 15 per cent lower in 2017 than it was in 2006.

AGD's maximum demand peaked in 2011 – two to three years later than in most other states and then declined through to 2014 before increasing in the subsequent three years. In 2017 it was 2 per cent above its 2006 level. Ratcheted maximum demand in 2017 was 7 per cent above its 2006 level – a considerably smaller increase than for the industry overall.

AGD's circuit length output grew more over the 12 years than occurred for the industry overall and by 2017 it was 8 per cent above its 2006 level compared to an increase of 4 per cent for the industry.

Figure 5.2 **AGD output quantity indexes, 2006–2017**



The last output shown in figure 5.2 is total CMOS. AGD's CMOS has generally followed a similar pattern to that of the industry although it has been considerably more volatile. AGD's CMOS increased by 26 per cent between 2007 and 2009 and has fluctuated since, but on a downward trajectory to 2013 and then an upward trend subsequently. In 2017 CMOS was around the same level it was in 2006.

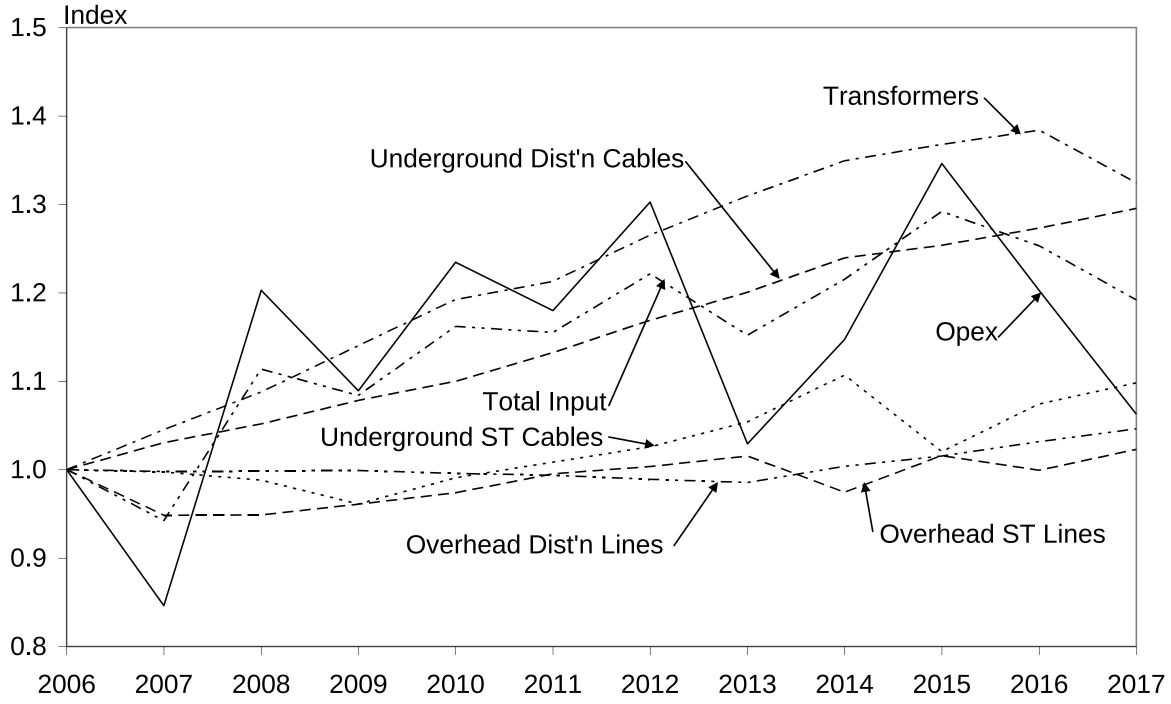
Since the customer numbers, circuit length and ratcheted maximum demand outputs receive the bulk of the weight in forming the total output index, in figure 5.2 we see that the total output index tends to lie very close to these three output indexes. The total output index lies slightly below these three indexes after 2012 as it is pulled down by AGD's weak throughput output and generally upward movement in CMOS since 2013.

Turning to the input side, we see from AGD's six input components and total input in figure 5.3 that the quantity of AGD's opex has been subject to wide swings over the 12–year period. AGD's opex increased by 30 per cent up to 2012 whereas the corresponding increase for the industry was 36 per cent. However, AGD's opex input has also been more volatile over the whole period, with a subsequent higher peak in opex in 2015. However, opex then fell in 2016 and 2017 but was still 6 per cent above its 2006 level in 2017.[7] Opex has the largest average share in AGD's total costs at 38 per cent and so is an important driver of its total input quantity index.

[7] Note that redundancy payments are included in the opex figures presented here.

AGD's transformers and underground distribution cables inputs increased more steadily over the period, although transformer inputs were reduced in 2017. While AGD's transformer inputs increased at a similar rate to the industry as a whole, its underground distribution cable inputs increased at a considerably lower rate than for the industry, probably reflecting the fact AGD operates in Australia's largest city and so undergrounding is growing from a high initial base. Similarly, AGD's overhead distribution lines input increases much more slowly over the period with an increase of only 5 per cent compared to 11 per cent for the industry.

Figure 5.3 **AGD input quantity indexes, 2006–2017**



From figure 5.3 we see that the total input quantity index lies between the quantity indexes for opex and transformers (which have a combined weight of 71 per cent of total costs). Total input quantity falls in 2017 in line with the reductions in opex usage and transformer inputs.

AGD's output and input contributions to TFP change

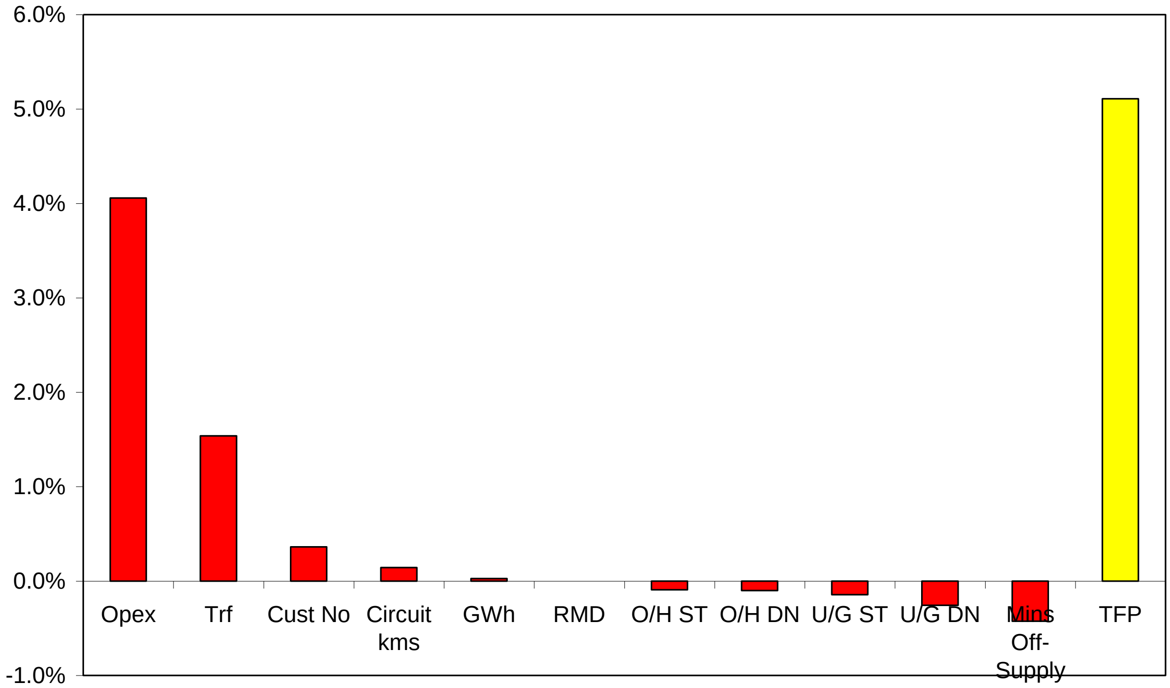
In table 5.2 we decompose AGD's TFP change into its constituent output and input parts for the whole 12–year period and for the periods up to and after 2012. AGD's drivers of TFP change for the whole 12–year period are broadly similar to the industry as a whole except that the major outputs of customer numbers and RMD contribute somewhat less due to their weaker growth in NSW. Circuit length output growth contributes more to TFP growth for AGD than for the industry given circuit length's higher rate of growth for AGD. And CMOS makes less of a contribution to AGD's TFP change than for the industry given AGD's small increase in CMOS over the period.

AGD's situation is again a tale of two distinct periods. For the period up to 2012, opex growth made a similar negative percentage point contribution to TFP growth for AGD as it did for the industry, at around –1.8 percentage points. But the larger reductions made in AGD's opex after 2012 led to opex contributing 1.3 percentage points to AGD's average annual TFP change of 0.5 per cent for the period after 2012. This compares to an opex contribution of 1.0 percentage points to the industry's similar TFP average annual change of 0.6 per cent after 2012.

Table 5.2 **AGD 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)	–0.19%	–0.06%	–0.35%
Ratcheted Max Demand	0.21%	0.38%	0.00%
Customer Numbers	0.30%	0.27%	0.33%
Circuit Length	0.21%	0.26%	0.15%
CMOS	–0.03%	0.00%	–0.07%
Opex	–0.39%	–1.79%	1.30%
O/H Subtransmission Lines	–0.01%	0.00%	–0.01%
O/H Distribution Lines	–0.03%	0.01%	–0.08%
U/G Subtransmission Cables	–0.05%	–0.02%	–0.08%
U/G Distribution Cables	–0.32%	–0.34%	–0.29%
Transformers	–0.81%	–1.20%	–0.34%
TFP Change	–1.10%	–2.47%	0.54%

Figure 5.4 **AGD output and input percentage point contributions to annual TFP change, 2016–17**



The importance of the reduction in AGD's opex in 2017 is highlighted in figure 5.4 where the 4.1 percentage point contribution of opex to TFP change in the 2017 year and the 1.5 percentage point contribution from the reduction in transformer inputs dwarf the contributions of other outputs and inputs. In fact, apart from the worsening in CMOS performance in 2017 which has the largest negative impact on TFP change, the contributions of the other output and inputs almost offset each other to produce a TFP increase of 5.1 per cent in 2017.

5.2 AusNet Services Distribution

In 2017 AusNet Services Distribution (AND) delivered 7,673 GWh to 734,644 customers over 44,907 circuit kilometres of lines and cables. AND distributes electricity to eastern Victoria (including Melbourne's outer northern and eastern suburbs) across an area of 80,000 square kilometres.

AND's productivity performance

AND's total output, total input and TFP indexes are presented in figure 5.5 and table 5.3. Opex and capital partial productivity indexes are also presented in table 5.3.

Figure 5.5 **AND's output, input and total factor productivity indexes, 2006–2017**

Over the 12–year period 2006 to 2017, AND's TFP decreased with an average annual change of –1.3 per cent. Although total output increased by an average annual rate of 2.0 per cent, total input use increased faster, at a rate of 3.3 per cent. AND had much faster output growth than the industry as a whole up to 2012 at an average annual rate of 3.0 per cent compared to the industry's 1.7 per cent. However, since 2012 AND's output has increased at a reduced average annual rate of 0.7 per cent, the same as that for the industry's output over this period. AND's pattern of input use has also been quite different to the industry as a whole. Whereas the industry saw rapid growth in input use up to 2012 followed by flattening out after that, AND's input use increased more rapidly than the industry up to 2012 and continued to grow strongly after 2012, albeit at a somewhat lower rate, before reducing in 2017. AND's TFP change was positive in three years: 2008, 2010 and 2017. In the first two of these years there was strong output growth and in 2017 output growth was higher than usual while input use declined. Compared to the whole 12–year period, AND’s TFP average annual change was more negative for the period up to 2012 at –1.8 per cent than for the period after 2012 when it was –0.7 per cent. AND’s service area was badly affected by the 2009 ‘Black Saturday’ bushfires and this will have played a role in its pattern of input use.

Table 5.3 **AND’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	1.039	1.115	0.932	0.852	0.997
2008	1.142	1.159	0.985	0.871	1.080
2009	1.103	1.275	0.865	0.727	0.986
2010	1.186	1.263	0.939	0.808	1.053
2011	1.163	1.288	0.903	0.787	1.005
2012	1.198	1.333	0.899	0.765	1.015
2013	1.192	1.404	0.849	0.688	0.991
2014	1.171	1.434	0.817	0.656	0.959
2015	1.206	1.481	0.814	0.638	0.973
2016	1.174	1.507	0.779	0.617	0.925
2017	1.240	1.430	0.867	0.763	0.968
Growth Rate 2006–17	1.96%	3.25%	–1.30%	–2.46%	–0.29%
Growth Rate 2006–12	3.01%	4.79%	–1.78%	–4.47%	0.24%
Growth Rate 2012–17	0.69%	1.41%	–0.72%	–0.05%	–0.93%

The partial productivity indexes in table 5.3 show that opex PFP growth improved but remained negative after 2012 while capital PFP growth worsened in the more recent period.

AND’s output and input quantity changes

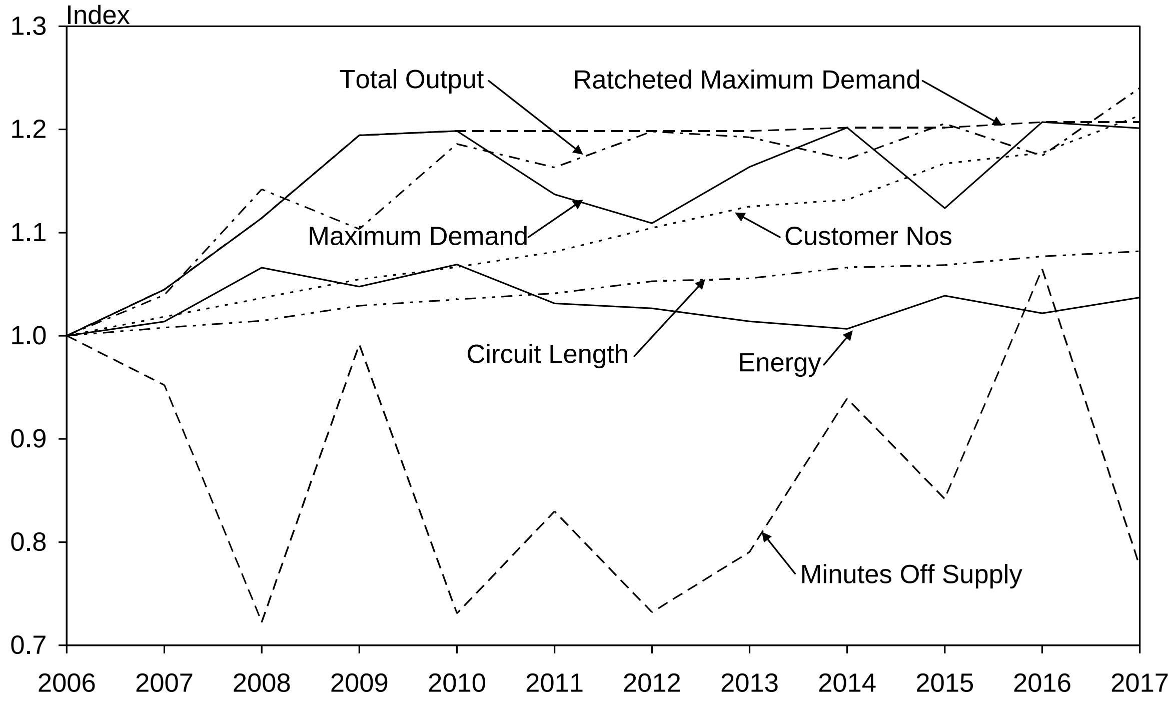
We graph the quantity indexes for AND’s five individual outputs in figure 5.6 and for their six individual inputs in figure 5.7.

From figure 5.6 we see that, with the exception of CMOS, AND’s output components exhibit a broadly similar pattern of change to the industry as a whole. Customer numbers increased steadily over the period and were 21 per cent higher in 2017 than they were in 2006, higher than the industry’s increase of 16 per cent. Energy throughput for distribution peaked in 2010 and was only 4 per cent higher in 2017 than it was in 2006.

AND’s maximum demand reached its initial peak in 2010 but then marginally exceeded this level in 2014 and again in 2016. This is a different pattern to the industry where maximum demand is still well short of its peak in 2009. In 2017 AND’s maximum demand was around 20 per cent above its 2006 level. Ratcheted maximum demand in 2017 was 21 per cent above its 2006 level – a larger increase than the industry’s 17 per cent.

AND's circuit length output grew somewhat more over the 12 years than occurred for the industry overall and by 2017 was 8 per cent above the level it was in 2006 compared to an increase of 4 per cent for the industry.

Figure 5.6 **AND's output quantity indexes, 2006–2017**



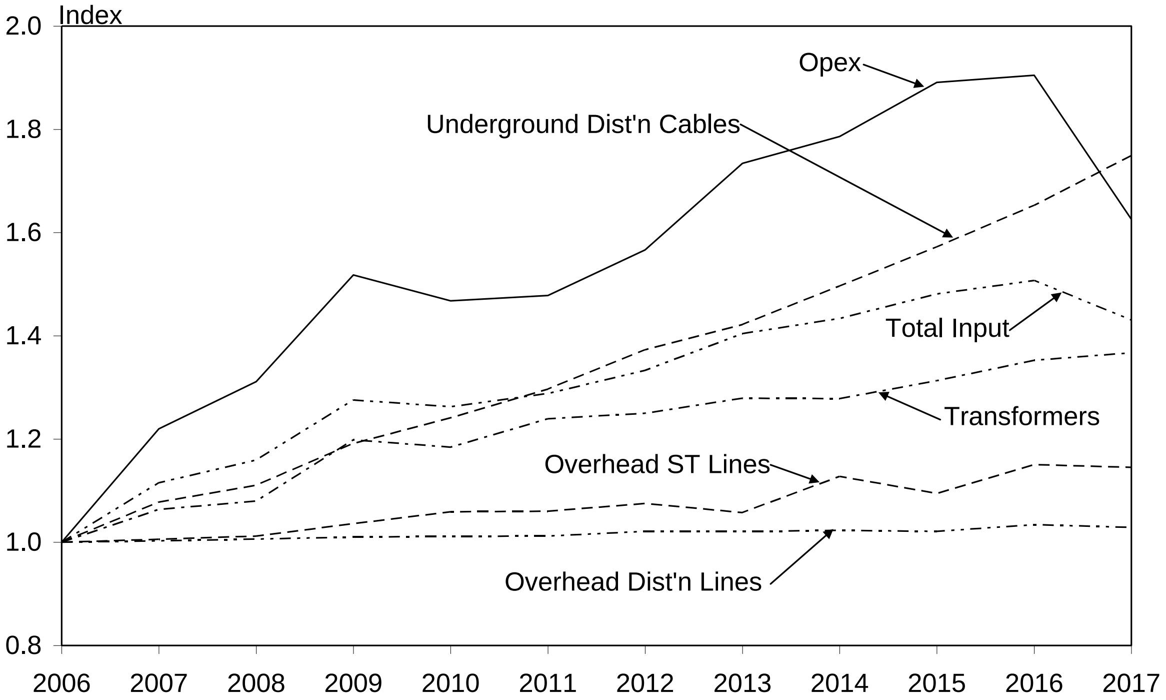
The last output shown in figure 5.6 is total CMOS. AND's CMOS has been more volatile than for the industry and, after trending downwards to 2012 (at which point it was 27 per cent below its 2006 level), it trended upwards strongly from 2012 to 2016 before falling back to near its 2012 level in 2017. By 2017 Victoria's CMOS was 13 per cent lower than it was in 2006.

Since the customer numbers and ratcheted maximum demand outputs receive a combined weight of around 60 per cent of gross revenue in forming the total output index, in figure 5.6 we see that the total output index mostly lies between these two output indexes. The circuit length and energy output indexes lie at a lower level. The downward trend in the CMOS index up to 2012 would generally contribute to positive growth in the output index but the steep upwards trend in CMOS between 2012 and 2016 would suppress output growth significantly over this period. Similarly, the sharp reduction in CMOS in 2017 made a positive contribution to total output growth in the most recent year.

Turning to the input side, we see from AND's six input components and total input in figure 5.7 that the quantity of AND's opex has increased more rapidly than the corresponding increase for the industry. For AND, opex increased by 57 per cent up to 2012 whereas the corresponding increase for the industry was 36 per cent. Since then AND's opex usage continued to increase by another 22 per cent through to 2016 before falling by 15 per cent in 2017. In 2017 AND's opex was still 4 per cent above its 2012 level whereas that for the industry was 13 per cent lower than its 2012 peak. Opex has the largest average share in AND's total costs at 40 per cent and so is an important driver of its total input quantity index.

AND’s underground distribution cables inputs increased steadily over the period at a higher rates than for the industry as a whole while its transformers increased at a similar rate to the industry. Its overhead distribution lines input increased slower over the period with an increase of 2.9 per cent by 2017 relative to 2006 compared to an 11 per cent increase for the industry.

Figure 5.7 **AND’s input quantity indexes, 2006–2017**



From figure 5.7 we see that the total input quantity index lies between the quantity indexes for opex and transformers (which have a combined weight of 60 per cent of total costs). Total input quantity fell by 5.2 per cent in 2017 driven by the 15 per cent fall in opex usage.

AND’s output and input contributions to TFP change

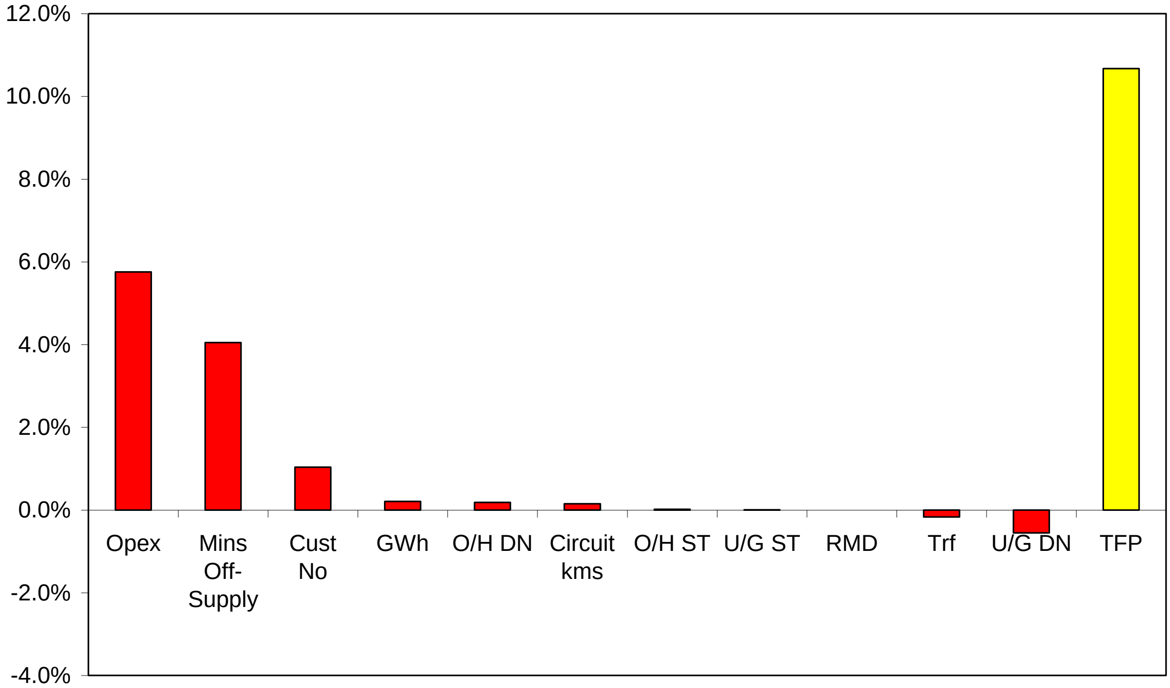
In table 5.4 we decompose AND’s TFP change into its constituent output and input parts for the whole 12–year period and for the periods up to and after 2012. AND’s drivers of TFP change for the whole 12–year period are broadly similar to the industry as a whole except that opex makes far and away the largest negative contribution to TFP growth for AND and relatively much larger than for the industry. Opex makes a negative contribution over the period for AND of –1.9 percentage points compared to –0.6 percentage points for the industry. Transformer inputs make a smaller negative contribution to AND’s TFP change at –0.6 percentage points than they do for the industry’s at –0.8 percentage points.

AND’s situation is again a tale of two distinct periods. The contribution of all outputs to TFP falls after 2012 compared to the period before 2012 except for customer numbers. And the contribution of most inputs remains relatively unchanged except for opex and transformers whose contributions improve by 2.7 percentage points and 0.5 percentage points, respectively, but still remain negative as both their quantities continued to trend upwards after 2012. This differs to the industry–wide result where opex makes a positive contribution to TFP change after 2012 as opex usage declines overall.

Table 5.4 **AND'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)	0.05%	0.07%	0.03%
Ratcheted Max Demand	0.59%	1.04%	0.05%
Customer Numbers	0.62%	0.60%	0.64%
Circuit Length	0.24%	0.30%	0.18%
CMOS	0.46%	1.01%	–0.20%
Opex	–1.92%	–3.16%	–0.44%
O/H Subtransmission Lines	–0.03%	–0.02%	–0.04%
O/H Distribution Lines	–0.06%	–0.07%	–0.05%
U/G Subtransmission Cables	–0.02%	0.00%	–0.04%
U/G Distribution Cables	–0.63%	–0.71%	–0.53%
Transformers	–0.59%	–0.82%	–0.32%
TFP Change	–1.30%	–1.78%	–0.72%

Figure 5.8 **AND's output and input percentage point contributions to annual TFP change, 2017**



AND's opex usage reduction of 15 per cent in 2017 means it makes the largest positive contribution to TFP change in 2017 of 5.8 percentage points as shown in figure 5.8. The substantial improvement in CMOS performance that year also contributed 4.1 percentage points. Customer numbers growth made a contribution of 1.1 percentage points while small positive and negative contributions from the other outputs and inputs largely offset each other. As a result, AND's TFP change in 2017 was a very strong 10.7 per cent compared to industry TFP change of 2.7 per cent that year.

5.3 CitiPower

In 2017, CitiPower (CIT) delivered 5,917 GWh to 339,400 customers over 4,550 circuit kilometres of lines and cables. CIT is the second smallest of the Victorian DNSPs (in terms of customer numbers) and covers central Melbourne, including the Melbourne CBD.

CIT's productivity performance

CIT's total output, total input and TFP indexes are presented in figure 5.9 and table 5.5. Opex and capital partial productivity indexes are also presented in table 5.5.

Over the 12–year period 2006 to 2017, CIT's TFP decreased with an average annual change of –1.2 per cent. Although total output increased by an average annual rate of 1.1 per cent, total input use increased faster, at a rate of 2.3 per cent. CIT thus had lower output growth, higher input growth and, hence, lower TFP growth compared to the industry as a whole. Input use increased at a faster rate in 2012 but has subsequently levelled off. CIT's output declined in three years: 2009, 2012 and 2014. TFP change was positive in six years: 2008, 2011, 2013, 2015, 2016 and 2017. In all of these years, input change was either a smaller increase than otherwise or there was a reduction in input use. Compared to the whole 12–year period TFP average annual change was more negative for the period up to 2012 at –3.1 per cent but has been positive for the period since 2012 at 1.1 per cent as input use has levelled off and output has continued growing.

Figure 5.9 **CIT's output, input and total factor productivity indexes, 2006–2017**

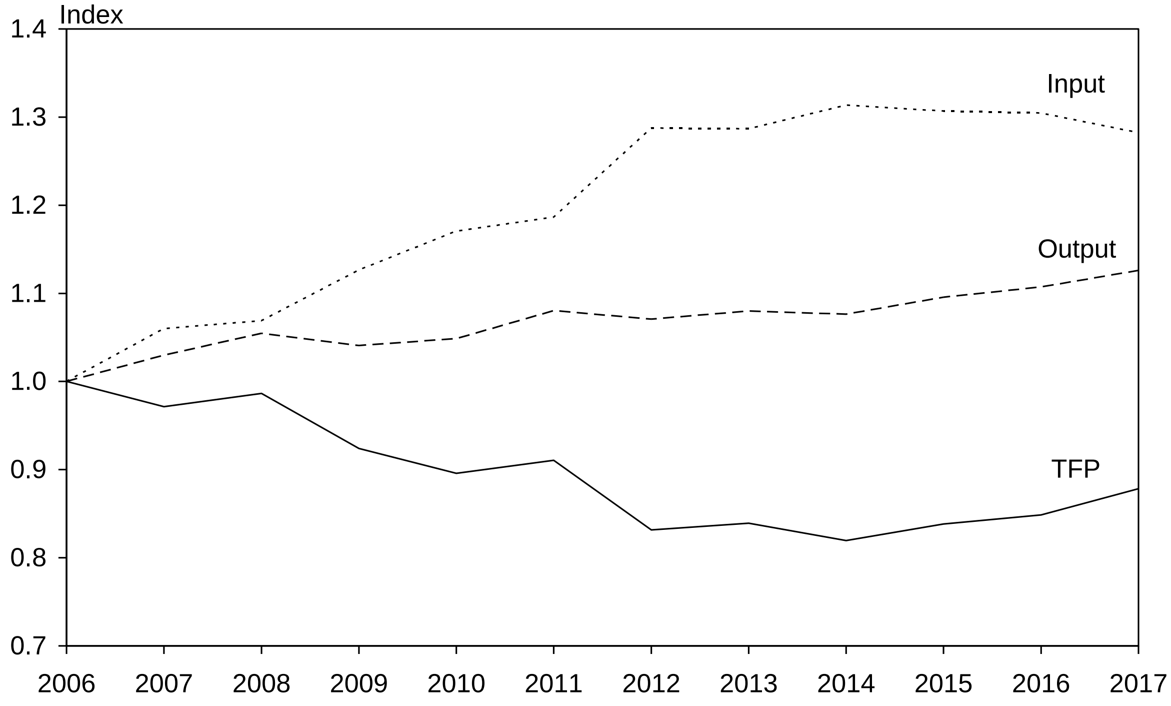


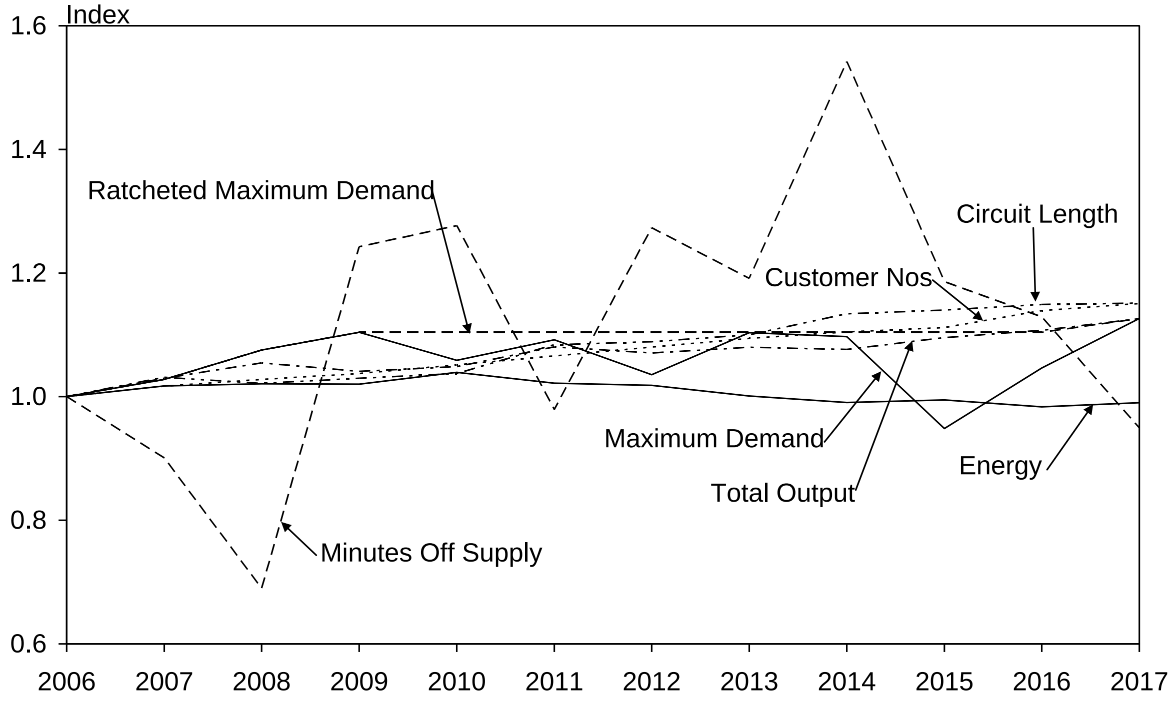
Table 5.5 **CIT's output, input and total factor productivity and partial productivity indexes, 2006–2017**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.030	1.060	0.971	0.901	0.996
2008	1.055	1.069	0.987	0.971	0.993
2009	1.041	1.127	0.924	0.812	0.965
2010	1.049	1.171	0.896	0.753	0.951
2011	1.080	1.187	0.911	0.835	0.940
2012	1.071	1.288	0.831	0.657	0.909
2013	1.080	1.287	0.839	0.687	0.904
2014	1.076	1.314	0.819	0.669	0.883
2015	1.096	1.307	0.838	0.706	0.892
2016	1.107	1.305	0.849	0.746	0.888
2017	1.126	1.282	0.878	0.824	0.900
Growth Rate 2006–17	1.08%	2.26%	–1.18%	–1.76%	–0.96%
Growth Rate 2006–12	1.14%	4.21%	–3.08%	–7.00%	–1.59%
Growth Rate 2012–17	1.01%	–0.09%	1.09%	4.53%	–0.21%

The partial productivity indexes in table 5.5 show that reduced opex usage was the main driver of the improved TFP performance after 2012 although capital partial productivity also made a less negative contribution.

CIT's output and input quantity changes

Figure 5.10 **CIT's output quantity indexes, 2006–2017**



We graph the quantity indexes for CIT's five individual outputs in figure 5.10 and for its six individual inputs in figure 5.11.

From figure 5.10 we see that, with the exception of CMOS, CIT's output components exhibit a similar pattern of change to the industry as a whole. Customer numbers increased steadily over the period and were 15 per cent higher in 2017 than they were in 2006, similar to the industry's increase over this period. Energy throughput for distribution peaked in 2010 and has trended down since then to be 1 per cent lower in 2017 than it was in 2006.

CIT's maximum demand reached its highest level in 2009 but has been somewhat volatile since then and almost regained its 2009 peak in 2013 before surpassing it in 2017. In 2017 it was around 13 per cent above its 2006 level. Ratcheted maximum demand in 2017 was therefore also 13 per cent above its 2006 level – a smaller increase than the industry's 17 per cent.

CIT's circuit length output grew considerably more over the 12 years than occurred for the industry overall and by 2017 was 15 per cent above the level it was in 2006 compared to an increase of only 4 per cent for the industry.

The last output shown in figure 5.10 is total CMOS. CIT's CMOS has been more volatile than for the industry and trended upwards to 2014 before starting to trend downwards. By 2017 CIT's CMOS was 5 per cent lower than it was in 2006 but it was 54 per cent above its 2006 level in 2014.

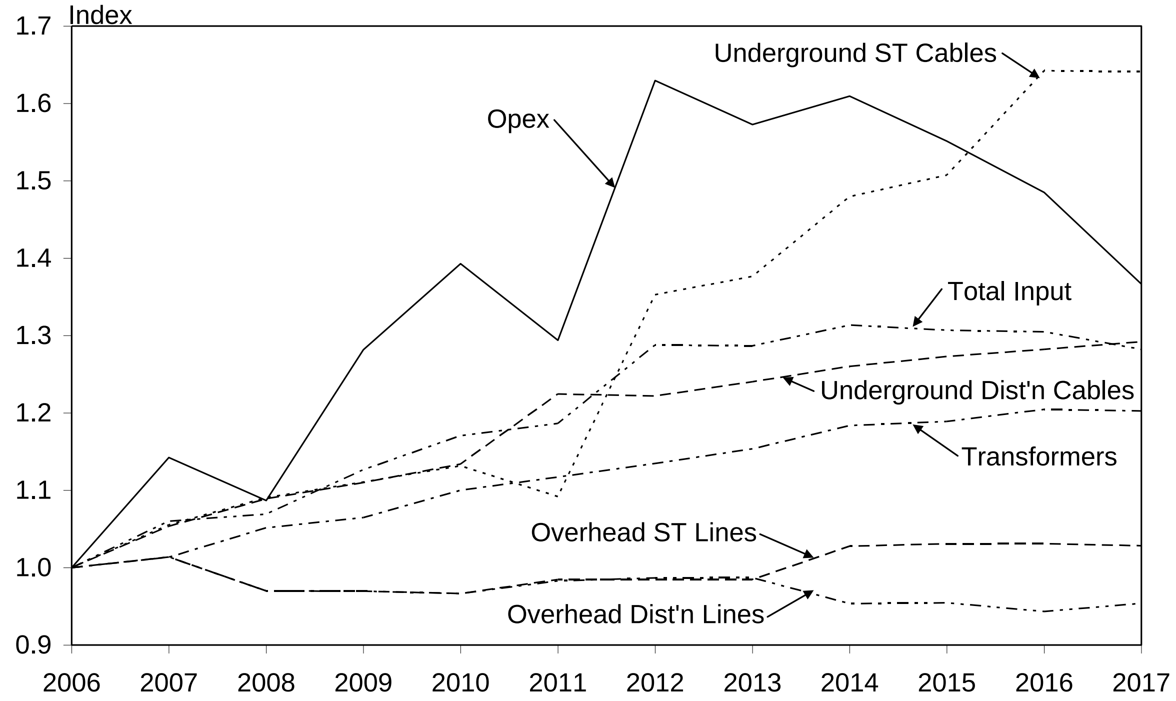
Since the customer numbers and ratcheted maximum demand outputs receive a combined weight of around 60 per cent of gross revenue in forming the total output index, in figure 5.10 we see that the total output index lies close to these two output indexes. In this case the circuit length index lies above the customer number and RMD indexes. The energy output index lies at a lower level and the CMOS index would also generally lie below the other output indexes when it enters the formation of total output as a negative output (ie the increase in CMOS up to 2014 makes a negative contribution to total output).

Turning to the input side, we see from CIT's six input components and total input in figure 5.11 that the quantity of CIT's opex increased more rapidly between 2006 and 2012 than the corresponding increase for the industry. For CIT, opex increased by 64 per cent up to 2012 whereas the corresponding increase for the industry was 36 per cent. Since then CIT's opex usage has decreased by 16 per cent, slightly more than for the industry as a whole. Opex has the second largest average share in CIT's total costs at 26 per cent and so is an important driver of its total input quantity index.

CIT's underground distribution cables and transformers inputs increased more steadily over the period at somewhat lower rates than for the industry as a whole. CIT's overhead distribution lines input decreased over the period and was 5 per cent lower by 2017 than it was in 2006. This compares to an 11 per cent increase for the industry.

From figure 5.11 we see that the total input quantity index lies close to the quantity indexes for opex, underground distribution cables and transformers (which have a combined weight of 86 per cent of total costs). Total input quantity decreased by 1.4 per cent in 2017 in line with the 6.8 per cent reduction in opex usage slightly more than offsetting a very small increase in capital inputs.

Figure 5.11 **CIT's input quantity indexes, 2006–2017**



CIT's output and input contributions to TFP change

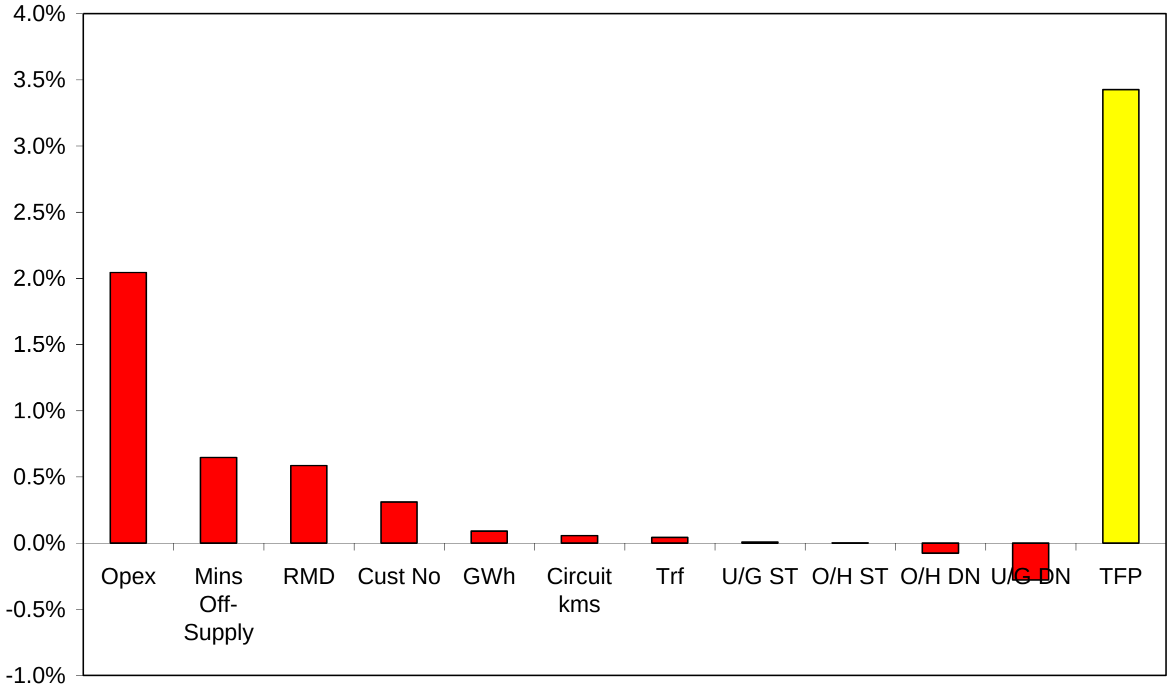
Table 5.6 **CIT's output and input percentage point contributions to average annual TFP change: 2006–2017, 2006–2012 and 2012–2017**

Year	*2006 to 2017*	*2006 to 2012*	*2012 to 2017*
Energy (GWh)	–0.01%	0.04%	–0.07%
Ratcheted Max Demand	0.32%	0.49%	0.12%
Customer Numbers	0.40%	0.41%	0.40%
Circuit Length	0.39%	0.43%	0.34%
CMOS	–0.02%	–0.23%	0.23%
Opex	–0.75%	–2.17%	0.95%
O/H Subtransmission Lines	0.00%	0.00%	0.00%
O/H Distribution Lines	0.03%	0.01%	0.05%
U/G Subtransmission Cables	–0.31%	–0.35%	–0.27%
U/G Distribution Cables	–0.82%	–1.17%	–0.39%
Transformers	–0.40%	–0.54%	–0.24%
TFP Change	–1.18%	–3.08%	1.09%

In table 5.6 we decompose CIT's TFP change into its constituent output and input parts for the whole 12–year period and for the periods up to and after 2012. CIT's drivers of TFP change for the whole 12–year period are broadly similar to the industry as a whole except that CMOS makes a small negative contribution to TFP growth for CIT whereas it is positive for the industry. Circuit length makes a larger contribution to CIT's TFP change at 0.4 percentage points compared to 0.1 percentage points for the industry, given CIT's high circuit length growth rate. Opex also makes a somewhat more negative contribution over the period for CIT at –0.8 percentage point compared to –0.6 percentage points for the industry. However, transformer inputs make a less negative contribution to CIT's TFP at –0.4 percentage points compared to –0.8 percentage points for the industry.

CIT's situation is again a tale of two distinct periods. The contribution of customer numbers and circuit length growth to TFP remains strong after 2012 compared to before 2012 and CMOS changes from making a negative contribution before 2012 to making a positive one after 2012. The contribution of opex change went from a negative contribution to TFP of –2.2 percentage point before 2012 to a positive contribution of 1.0 percentage points after 2012 with the turnaround in opex usage. The underground distribution cable growth rate reduced markedly after 2012 which reduced underground distribution cables' contribution to TFP from –1.2 percentage points before 2012 to –0.4 percentage points after 2012.

Figure 5.12 **CIT's output and input percentage point contributions to annual TFP change, 2017**



CIT's opex usage fell by 8 per cent in 2017. The importance of this is highlighted in figure 5.12 where opex made a 2.0 percentage point contribution to TFP change in the 2017 year. Along with strong contributions of 0.7 and 0.6 percentage points from CMOS and RMD growth also occurring in 2017, this led to CIT's TFP growth in 2017 being 3.4 per cent.

5.4 Endeavour Energy

In 2017 Endeavour Energy (END) delivered 16,716 GWh to 984,230 customers over 36,993 circuit kilometres of lines and cables. END distributes electricity to Sydney's Greater West, the Blue Mountains, Southern Highlands, the Illawarra and the South Coast regions of NSW. It is the second largest of the three NSW DNSPs in terms of customer numbers and energy throughput.

END's productivity performance

END's total output, total input and TFP indexes are presented in figure 5.13 and table 5.7. Opex and capital partial productivity indexes are also presented in table 5.7.

Figure 5.13 **END's output, input and total factor productivity indexes, 2006–2017**

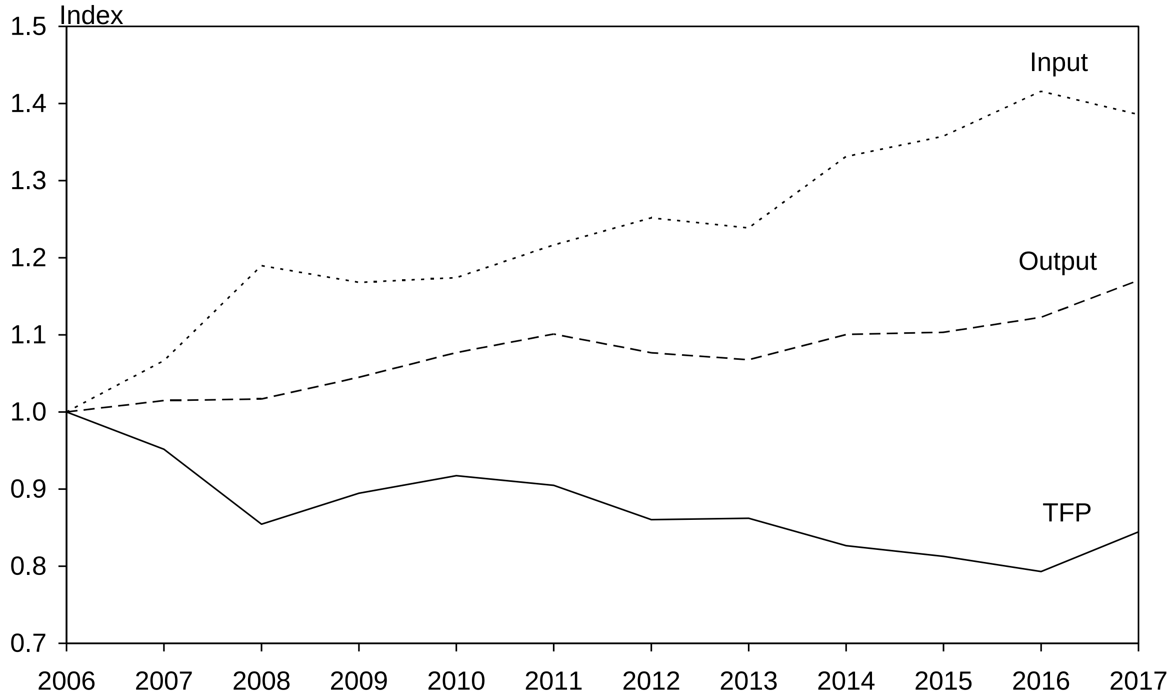


Table 5.7 **END's output, input and total factor productivity and partial productivity indexes, 2006–2017**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.015	1.067	0.952	0.941	0.959
2008	1.017	1.190	0.855	0.772	0.921
2009	1.045	1.168	0.895	0.866	0.917
2010	1.077	1.174	0.917	0.929	0.915
2011	1.101	1.217	0.905	0.903	0.910
2012	1.077	1.252	0.860	0.869	0.859
2013	1.068	1.239	0.862	0.962	0.815
2014	1.101	1.331	0.827	0.878	0.804
2015	1.103	1.358	0.813	0.858	0.794
2016	1.123	1.416	0.793	0.814	0.790
2017	1.170	1.386	0.845	0.926	0.806
Growth Rate 2006–17	1.43%	2.97%	–1.54%	–0.70%	–1.96%
Growth Rate 2006–12	1.23%	3.74%	–2.51%	–2.34%	–2.54%
Growth Rate 2012–17	1.67%	2.04%	–0.37%	1.27%	–1.27%

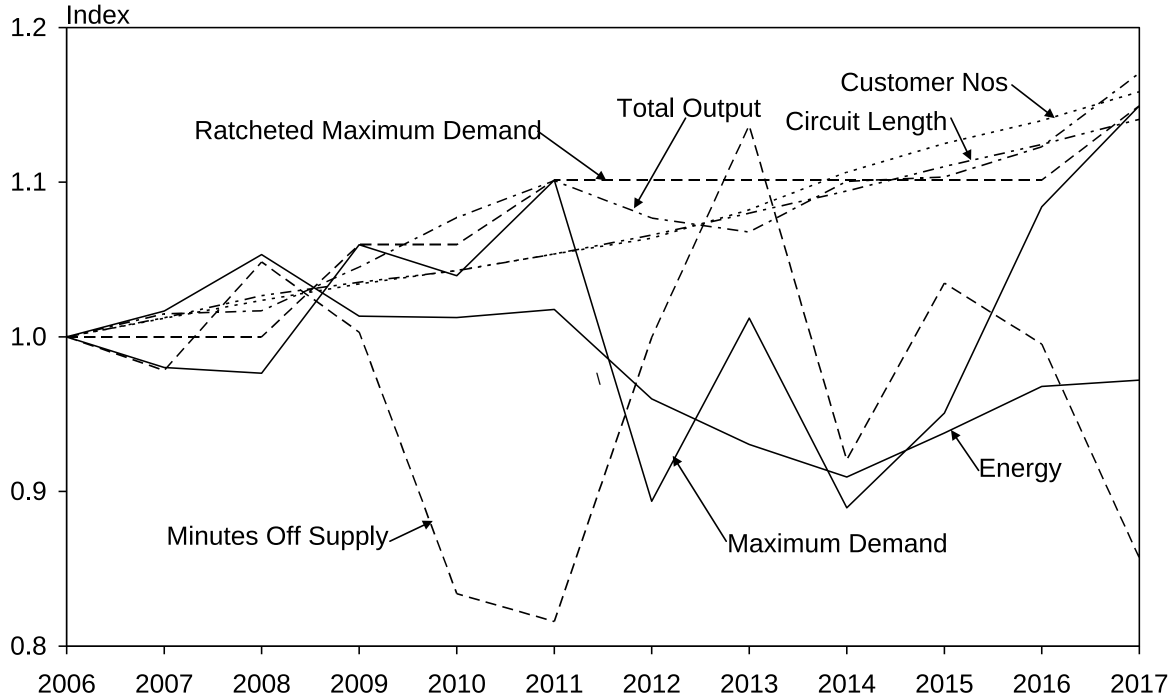
Over the 12–year period 2006 to 2017, END's TFP decreased at an average annual rate of 1.5 per cent. Although total output increased by an average annual rate of 1.4 per cent, total input use increased faster, at a rate of 3.0 per cent. END thus had somewhat faster output growth but considerably faster input growth than the industry as a whole, leading to a more negative TFP growth rate. Input use increased sharply in 2008 and 2014, to be followed by a small reduction in 2009 but continued increases in input use from 2014 to 2016. TFP fell markedly in 2008, 2012 and 2014 but TFP change was positive in four years – 2009, 2010, 2013 and 2017. TFP average annual change was more negative for the period up to 2012 at –2.5 per cent but less negative at –0.4 per cent for the period since 2012.

The partial productivity indexes in table 5.7 show that a turnaround in opex PFP growth and a less negative growth rate for capital PFP accounted for the improvement in TFP performance after 2012.

END's output and input quantity changes

We graph the quantity indexes for END's five individual outputs in figure 5.14 and for its six individual inputs in figure 5.15.

Figure 5.14 **END's output quantity indexes, 2006–2017**



From figure 5.14 we see that END's output components showed a broadly similar pattern of change to the industry as a whole except that there was much less growth in some outputs for END between 2006 and 2009, likely reflecting the impact of the global financial crisis and the initial negative effects of the mining boom on NSW. END also has a more volatile CMOS pattern compared to the industry as a whole. Customer numbers increased steadily over the period and were 16 per cent higher in 2017 than they were in 2006, around the same growth as for the industry and more than was seen for AGD. END's energy throughput peaked in 2008 and has fallen since to be 3 per cent lower in 2017 than it was in 2006, despite a partial recovery in 2015 and 2016.

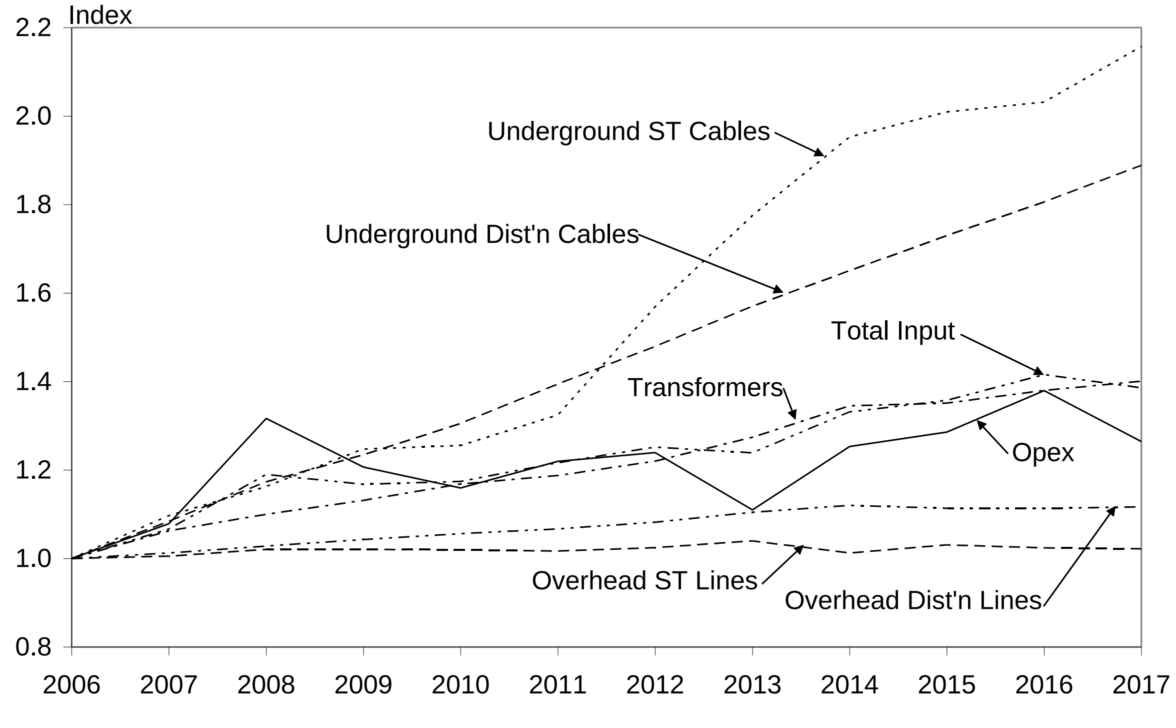
END's maximum demand peaked in 2011 and has been relatively volatile since then. It then briefly exceeded its 2006 level in 2013 and again in 2016 and 2017 with the 2017 level being he highest for the period. Ratcheted maximum demand in 2017 was 15 per cent above its 2006 level – just behind the increase for the industry overall.

END's circuit length output grew considerably more over the 12 years than occurred for the industry overall and by 2017 was 14 per cent above the level it was in 2006 compared to an increase of only 4 per cent for the industry. This likely reflects the ongoing development of new areas to Sydney's west.

The last output shown in figure 5.14 is total CMOS. Despite a high degree of volatility. END's CMOS had a relatively flat trend through to 2016 before a substantial reduction in 2017. In 2017 CMOS was 14 per cent below its 2006 level.

Since the customer numbers and ratcheted maximum demand outputs receive a combined weight of around 60 per cent of gross revenue in forming the total output index, in figure 5.14 we see that the total output index tends to lie very close to these two output indexes, as well as the circuit length index. Fluctuations of total output away from these three output indexes are driven by the large swings in CMOS.

Figure 5.15 **END's input quantity indexes, 2006–2017**



Turning to the input side, we see from END's six input components and total input in figure 5.15 that the quantity of END's opex follows a quite different pattern to both the industry as a whole and its Sydney–based sister DNSP, AGD. END's opex increased more rapidly between 2006 and 2008 than the corresponding increase for the industry but it then declined through to 2013 before again increasing through to 2016. By 2008 END's opex was 32 per cent above its 2006 level then fell back to within 11 per cent of its 2006 level in 2013. However, in 2016

END’s opex was 38 per cent above its 2006 level before falling back to 26 per cent of its 2006 level in 2017.[8] Opex has the largest average share in END’s total costs at 39 per cent and so is an important driver of its total input quantity index.

END’s underground distribution cables and transformers inputs increase more steadily over the period with transformers increasing at a similar rate to the industry as a whole. However, END’s underground distribution cables increased at a considerably faster rate and in 2017 were 89 per cent above their 2006 level compared to an increase of 52 per cent for the industry as a whole. END’s overhead distribution lines input increased by 12 per cent over the period, similar to the increase for the industry.

From figure 5.15 we see that END’s total input quantity index lies close to the quantity indexes for opex and transformers (which have a combined weight of 70 per cent of total costs). Total input quantity fell 2.1 per cent in 2017 in line with the reduction in opex usage.

END’s output and input contributions to TFP change

In table 5.8 we decompose END’s TFP change into its constituent output and input parts for the whole 12–year period and for the periods up to and after 2012. END’s drivers of TFP change for the whole 12–year period are broadly similar to the industry as a whole except that the circuit length output makes a larger positive contribution and opex makes a larger negative contribution, as do underground distribution cables and transformer inputs.

Table 5.8 **END’s output and input percentage point contributions to average annual TFP change: 2006–2017, 2006–2012 and 2012–2017**

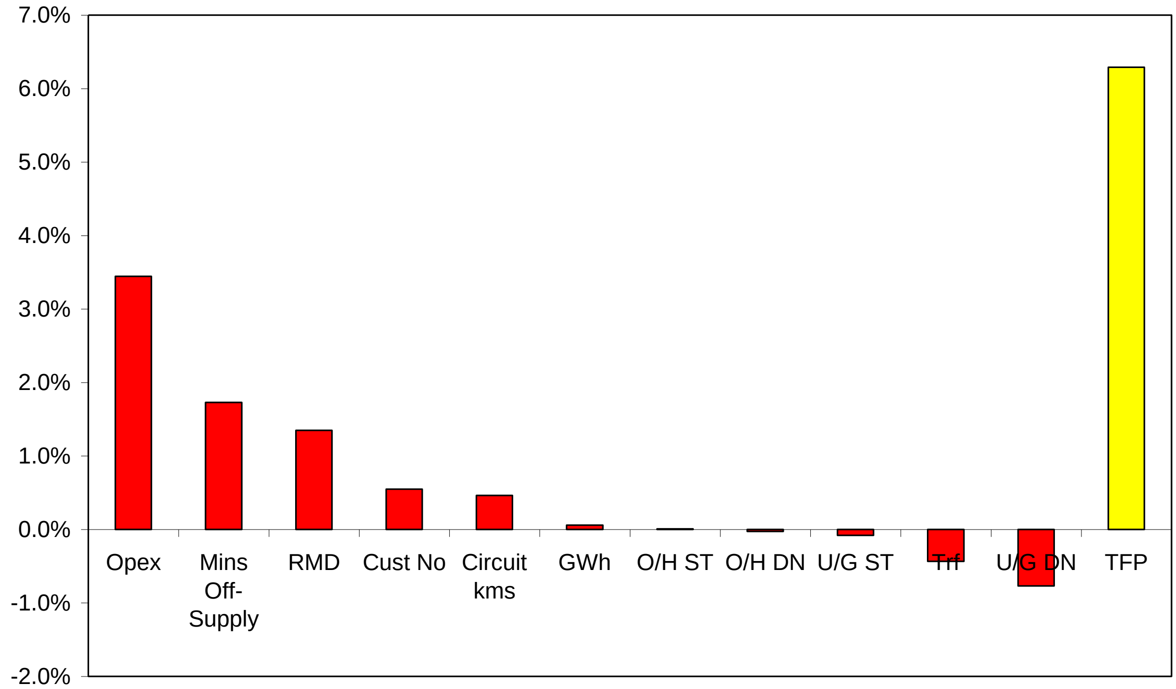
Year	*2006 to 2017*	*2006 to 2012*	*2012 to 2017*
Energy (GWh)	–0.03%	–0.09%	0.04%
Ratcheted Max Demand	0.41%	0.52%	0.27%
Customer Numbers	0.46%	0.36%	0.57%
Circuit Length	0.39%	0.35%	0.44%
CMOS	0.21%	0.09%	0.35%
Opex	–0.89%	–1.47%	–0.21%
O/H Subtransmission Lines	–0.01%	–0.01%	0.00%
O/H Distribution Lines	–0.10%	–0.12%	–0.06%
U/G Subtransmission Cables	–0.09%	–0.11%	–0.07%
U/G Distribution Cables	–0.93%	–1.03%	–0.82%
Transformers	–0.95%	–1.00%	–0.88%
TFP Change	–1.54%	–2.51%	–0.37%

END’s situation is less obviously a tale of two distinct periods compared to other DNSPs. The contribution of the growth in opex usage moderated after 2012, as did that of growth in underground distribution cables and transformers. The contributions of customer numbers and circuit length growth increased somewhat while the contribution of RMD moderated and the contribution of the other outputs and inputs changes little between the periods before and after 2012. Increases in END’s opex between 2013 and 2016 led to opex contributing –0.2

[8] Note that redundancy payments are included in the opex figures presented here.

percentage points to END's average annual TFP change of –0.4 per cent for the period after 2012. This compares to a positive opex contribution of 1.0 percentage points to the industry TFP average annual change of 0.6 per cent after 2012 as most DNSPs reduced opex use over this period.

Figure 5.16 **END's output and input percentage point contributions to annual TFP change, 2016–17**



The importance of END's reduction in opex in 2017 is highlighted in figure 5.16. The 3.5 percentage point contribution of opex is the largest contribution to END's TFP change of 6.3 per cent in the 2017 year. Contributions of 1.7 and 1.4 percentage points from CMOS and RMD, respectively, were also important.

5.5 Energex

In 2017 Energex (ENX) delivered 21,355 GWh to 1.45 million customers over 53,757 circuit kilometres of lines and cables. ENX distributes electricity in South East Queensland including the major urban areas of Brisbane, Gold Coast, Sunshine Coast, Logan, Ipswich, Redlands and Moreton Bay. ENX's electricity distribution area runs from the NSW border north to Gympie and west to the base of the Great Dividing Range. It is the second largest DNSP in the NEM in terms of customer numbers and energy throughput.

ENX's productivity performance

ENX's total output, total input and TFP indexes are presented in figure 5.17 and table 5.9. Opex and capital partial productivity indexes are also presented in table 5.9.

Over the 12–year period 2006 to 2017, ENX's TFP decreased with an average annual change of –0.5 per cent. ENX's total output increased by an average annual rate of 2.4 per cent – almost double the output growth rate that the industry as a whole. ENX's total input use increased faster at a rate of 2.9 per cent. Input use increased at a steady rate through to 2013 and has fluctuated since then.

Figure 5.17 **ENX's output, input and total factor productivity indexes, 2006–2017**

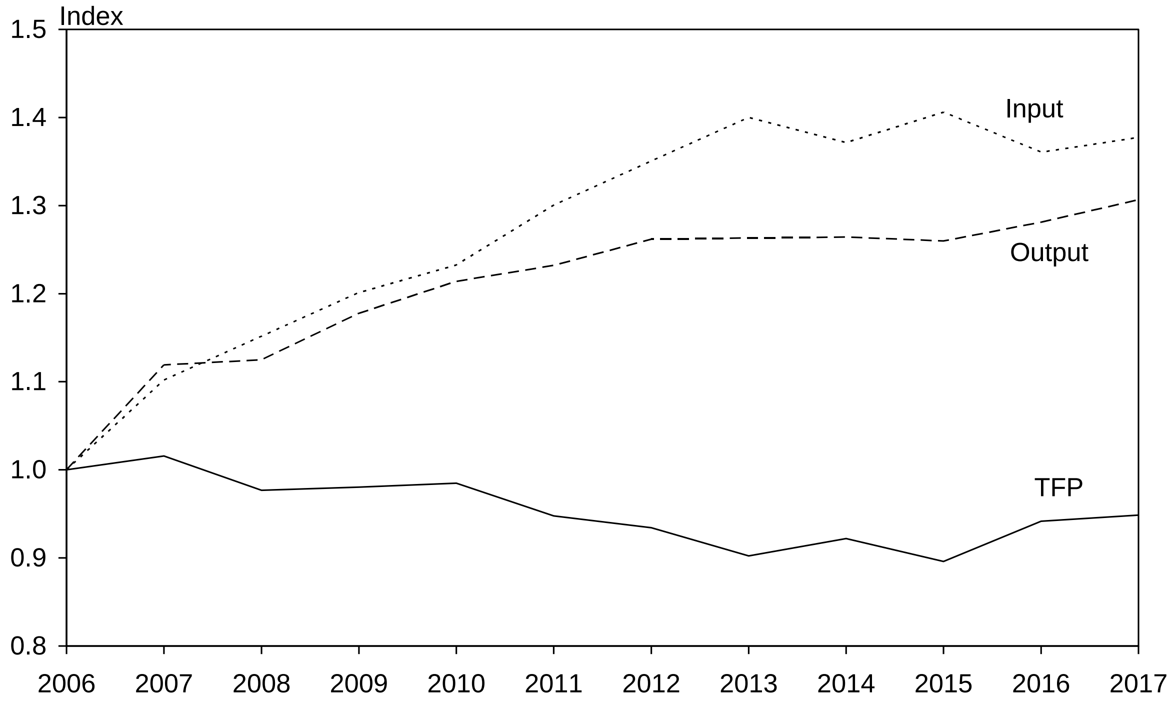


Table 5.9 **ENX's output, input and total factor productivity and partial productivity indexes, 2006–2017**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.119	1.102	1.016	0.963	1.047
2008	1.125	1.152	0.977	0.929	1.005
2009	1.178	1.201	0.980	0.936	1.006
2010	1.214	1.233	0.985	0.954	1.003
2011	1.232	1.300	0.948	0.881	0.987
2012	1.262	1.351	0.934	0.843	0.988
2013	1.263	1.400	0.902	0.789	0.970
2014	1.264	1.372	0.922	0.860	0.951
2015	1.260	1.406	0.896	0.840	0.922
2016	1.281	1.360	0.942	0.961	0.925
2017	1.307	1.377	0.949	0.975	0.928
Growth Rate 2006–17	2.43%	2.91%	–0.48%	–0.23%	–0.68%
Growth Rate 2006–12	3.88%	5.01%	–1.13%	–2.84%	–0.21%
Growth Rate 2012–17	0.70%	0.39%	0.30%	2.90%	–1.24%

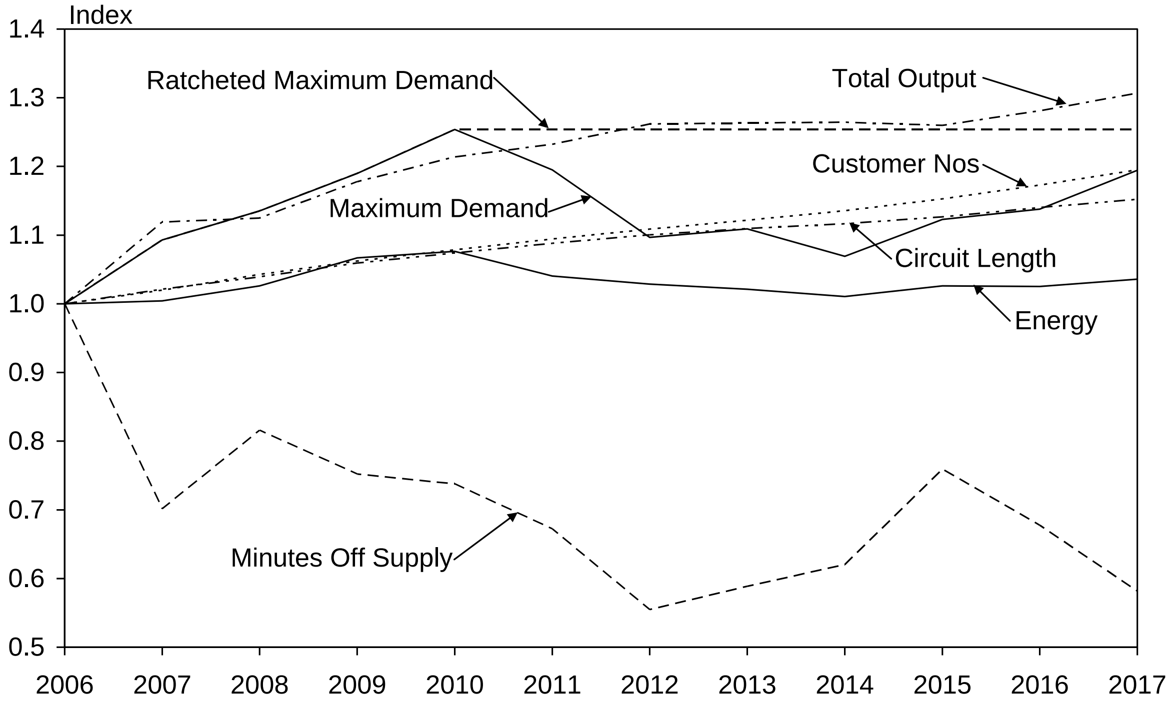
Output increased steadily from 2006 to 2012 before remaining flat for the following three years and then increasing again in 2016 and 2017. The increase in 2016 coincided with a reduction in input that year which lead to a marked upturn in TFP. However, an increase in input use led to TFP growth being flat in 2017. TFP average annual change was more negative for the period up to 2012 at –1.1 per cent but has been positive for the period since 2012 at 0.3 per cent.

The partial productivity indexes in table 5.9 show that substantially improved opex PFP performance was the main driver of the improved TFP performance after 2012 although this was offset somewhat by a worsening in capital partial productivity performance.

ENX's output and input quantity changes

We graph the quantity indexes for ENX's five individual outputs in figure 5.18 and for its six individual inputs in figure 5.19.

Figure 5.18 **ENX's output quantity indexes, 2006–2017**



From figure 5.18 we see that ENX's output components showed a generally similar pattern of change to the industry as a whole except that there was more growth in outputs for ENX over the period. ENX's energy output showed less of a downturn after 2010, likely reflecting the effects of the mining boom and continuing growth in SE Queensland. Customer numbers increased steadily over the period and were 20 per cent higher in 2017 than they were in 2006 reflecting Queensland's relatively strong output growth. Energy throughput for distribution peaked in 2010 but was still 4 per cent higher in 2017 than it was in 2006.

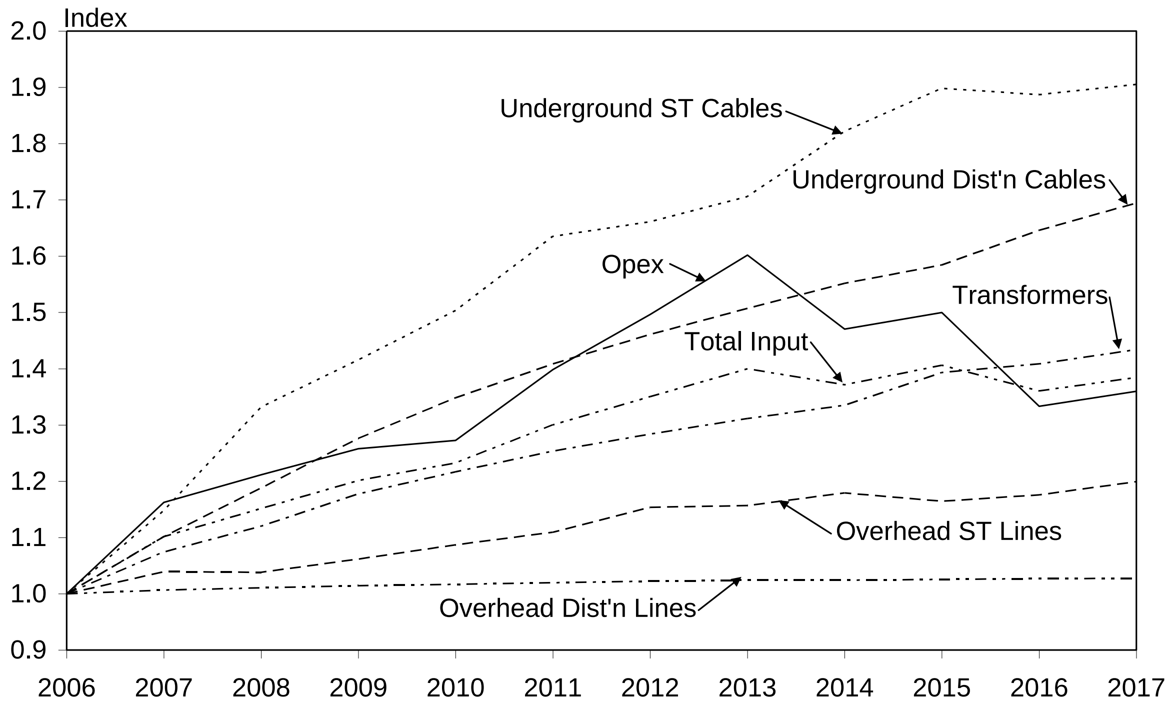
Queensland's maximum demand also peaked in 2010 and then declined through to 2014. However, unlike many DNSPs, ENX's maximum demand has stayed above its 2006 level for the remainder of the period. In 2017 RMD was 25 per cent above its 2006 level – a larger increase than for the industry overall.

Queensland's circuit length output also grew more over the 12 years than occurred for the industry overall and by 2017 was 15 per cent above the level it was in 2006 compared to an increase of only 4 per cent for the industry.

The last output shown in figure 5.18 is total CMOS. ENX's CMOS has generally followed a similar pattern to that of the industry and has trended downwards although it increased in 2015. CMOS has been lower and, hence, contributed more to total output for all other years than was the case in 2006. In 2017 CMOS was 42 per cent less than it was in 2006.

Since the customer numbers and ratcheted maximum demand outputs receive a combined weight of around 60 per cent of gross revenue in forming the total output index, in figure 5.18 we see that the total output index tends to lie close to these two output indexes. In ENX's case the circuit length output index also lies very close to the customer numbers index. And the CMOS index would generally lie above the other output indexes when it enters the formation of total output as a negative output (ie the reduction in CMOS over the period makes a positive contribution to total output).

Figure 5.19 **ENX's input quantity indexes, 2006–2017**



Turning to the input side, we see from ENX's six input components and total input in figure 5.19 that the quantity of ENX's underground distribution and subtransmission cables and opex inputs have increased more than for the industry as a whole while its transformers input increased around the same as for the industry but its overhead distribution lines increased considerably less. Again, not too much should be read into the higher increase in underground cables as this was starting from a smaller base and reflects ENX's higher rate of customer numbers growth. For ENX, opex increased by 60 per cent up to 2013 which was more than the corresponding increase for the industry of 36 per cent (up to 2012). However, ENX's opex has trended down since 2013 and was 34 per cent above its 2006 level in 2017.[9] Opex has the largest average share in ENX's total costs at 36 per cent and so is an important driver of its total input quantity index.

From figure 5.19 we see that the total input quantity index generally lies between the quantity indexes for opex and transformers (which have a combined weight of 68 per cent of total costs). Total input quantity increased by 1.2 per cent in 2017 driven by small increases in the use of all input components that year.

ENX's output and input contributions to TFP change

In table 5.10 we decompose ENX's TFP change into its constituent output and input parts for the whole 12–year period and for the periods up to and after 2012. ENX's drivers of TFP change for the whole 12–year period are broadly similar to the industry as a whole except that all five outputs make a larger percentage point contribution to TFP growth for ENX and opex and transformers make a somewhat more negative contribution. However, the stronger output growth for ENX, particularly from improvements in CMOS, lead to its TFP performance being better than that for the industry.

Table 5.10 **ENX'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)	0.05%	0.07%	0.02%
Ratcheted Max Demand	0.68%	1.24%	0.00%
Customer Numbers	0.54%	0.60%	0.48%
Circuit Length	0.42%	0.53%	0.28%
CMOS	0.75%	1.44%	–0.09%
Opex	–0.93%	–2.41%	0.84%
O/H Subtransmission Lines	–0.06%	–0.08%	–0.03%
O/H Distribution Lines	–0.03%	–0.04%	–0.01%
U/G Subtransmission Cables	–0.27%	–0.38%	–0.14%
U/G Distribution Cables	–0.57%	–0.75%	–0.37%
Transformers	–1.04%	–1.35%	–0.68%
TFP Change	–0.48%	–1.13%	0.30%

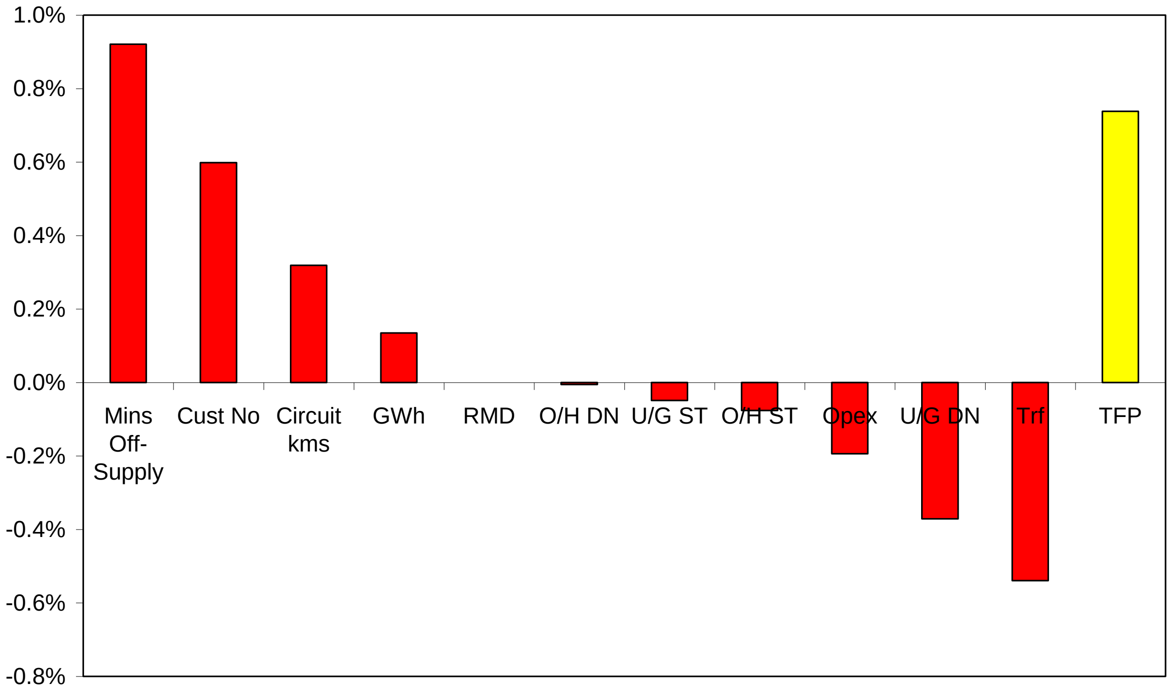
The Queensland situation is also a tale of two distinct periods. For the period up to 2012, all five outputs made a larger positive contribution to TFP change but all six inputs, and particularly opex, made a more negative percentage point contribution to TFP growth compared to the period after 2012. Up to 2012 ENX's average annual TFP change was –1.1 per cent compared to –2.1 per cent for the industry. The reductions made in ENX's opex after 2012 led to opex contributing 0.7 percentage points to ENX's average annual TFP change compared to 1.0 percentage points for the industry.

The importance of the reduction in CMOS in 2017 is highlighted in figure 5.20 where it makes a 0.9 percentage point contribution to TFP change in the 2017 year. Growth in

[9] Note that redundancy payments are included in the opex figures presented here.

customer numbers and circuit length make positive contributions of 0.6 and 0.3 percentage points, respectively, while growth in transformers, underground distribution and opex usage make contributions of–0.5,–0.4 and –0.2 percentage points, respectively. These changes combine to produce a TFP increase of 0.7 per cent in 2017.

Figure 5.20 **ENX's output and input percentage point contributions to annual TFP change, 2016–17**



5.6 Ergon Energy

In 2017 Ergon Energy (ERG) delivered 13,332 GWh to 745,501 customers over 152,491 circuit kilometres of lines and cables. ERG distributes electricity throughout regional Queensland, excluding South East Queensland. ERG is around the seventh largest DNSP in the NEM in terms of customer numbers but is the second largest in terms of network length.

ERG's productivity performance

ERG's total output, total input and TFP indexes are presented in figure 5.21 and table 5.11. Opex and capital partial productivity indexes are also presented in table 5.11.

Over the 12–year period 2006 to 2017, ERG's TFP increased at an average annual rate of 0.7 per cent. ERG's total output increased by an average annual rate of 2.0 per cent – considerably higher than for most other DNSPs. ERG's total input use increased at a rate of 1.3 per cent – considerably slower than for the industry as a whole. The combination of higher output growth and slower input growth has led to ERG having better TFP performance than the industry over the 12–year period. Input use increased at an above average rate in 2011 but fell in 2007, 2013 and 2017. The increase in 2007 coincided with a sizable increase in output that year which lead to a marked increase in TFP. Similarly, the reduction in input use in 2013 was accompanied by strong output growth leading to a jump in TFP. However, a reduction in output in 2015 combined with strong input growth that year led to a fall in TFP. ERG's TFP average annual change was 0.5 per cent for the period up to 2012 and 1.1 per cent for the period since 2012. Faster output growth in 2017 combined with a reduction in input use contributed to stronger TFP growth in the latest year.

Figure 5.21 **ERG's output, input and total factor productivity indexes, 2006–2017**

Table 5.11 **ERG's output, input and total factor productivity and partial productivity indexes, 2006–2017**

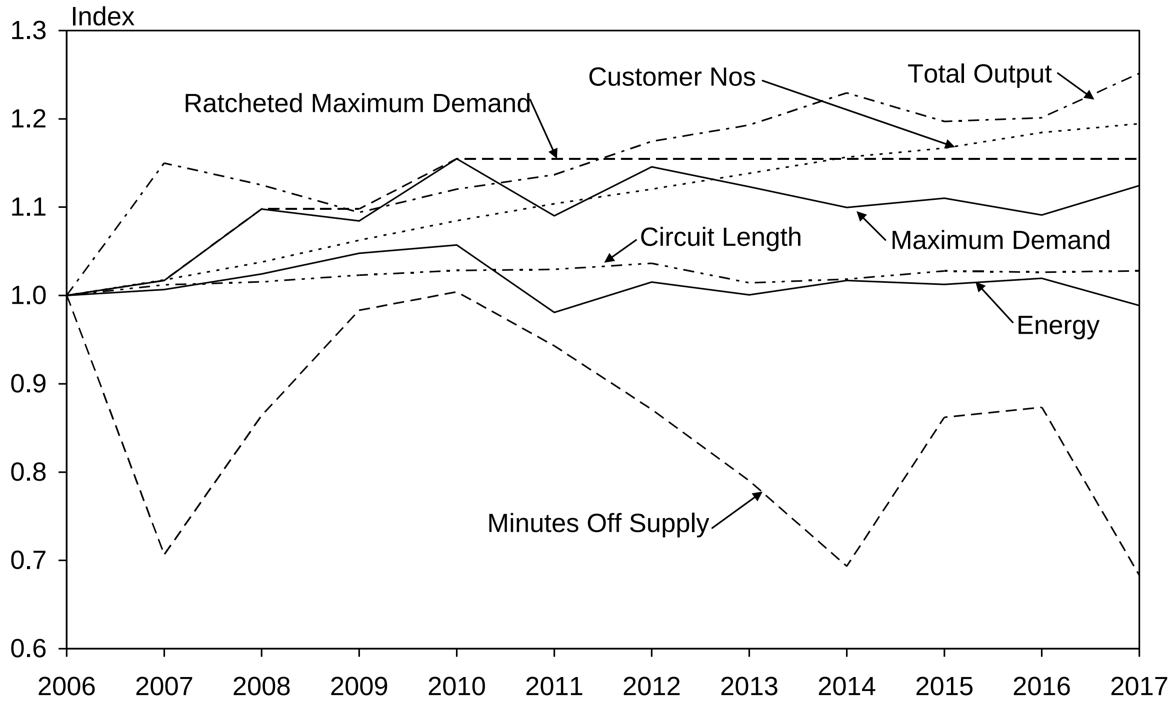
Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index Opex*	*PFP Index Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.150	0.971	1.184	1.292	1.123
2008	1.125	1.007	1.117	1.180	1.081
2009	1.094	1.007	1.087	1.190	1.029
2010	1.120	1.024	1.095	1.246	1.018
2011	1.137	1.116	1.019	1.028	1.011
2012	1.174	1.143	1.028	1.039	1.018
2013	1.193	1.057	1.128	1.329	1.041
2014	1.230	1.094	1.124	1.364	1.022
2015	1.197	1.165	1.027	1.152	0.975
2016	1.201	1.183	1.016	1.149	0.960
2017	1.252	1.154	1.084	1.329	0.980
Growth Rate 2006–17	2.04%	1.30%	0.74%	2.58%	–0.18%
Growth Rate 2006–12	2.68%	2.22%	0.46%	0.64%	0.30%
Growth Rate 2012–17	1.27%	0.20%	1.07%	4.91%	–0.76%

The partial productivity indexes in table 5.11 show that improvements in opex PFP after 2012 have been the driver of improved TFP growth and have more than offset a worsening in capital PFP.

ERG's output and input quantity changes

We graph the quantity indexes for ERG's five individual outputs in figure 5.22 and for its six individual inputs in figure 5.23.

Figure 5.22 **ERG's output quantity indexes, 2006–2017**



From figure 5.22 we see that ERG's output components showed a generally similar pattern of change to the industry as a whole except that there was more growth in outputs for ERG over the period. ERG's energy and maximum demand outputs showed less of a downturn after 2010, likely reflecting the effects of the mining boom. Customer numbers increased steadily over the period and were 19 per cent higher in 2017 than they were in 2006 reflecting regional Queensland's relatively strong growth. Energy throughput for distribution peaked in 2010 and was 1 per cent lower in 2017 than it was in 2006.

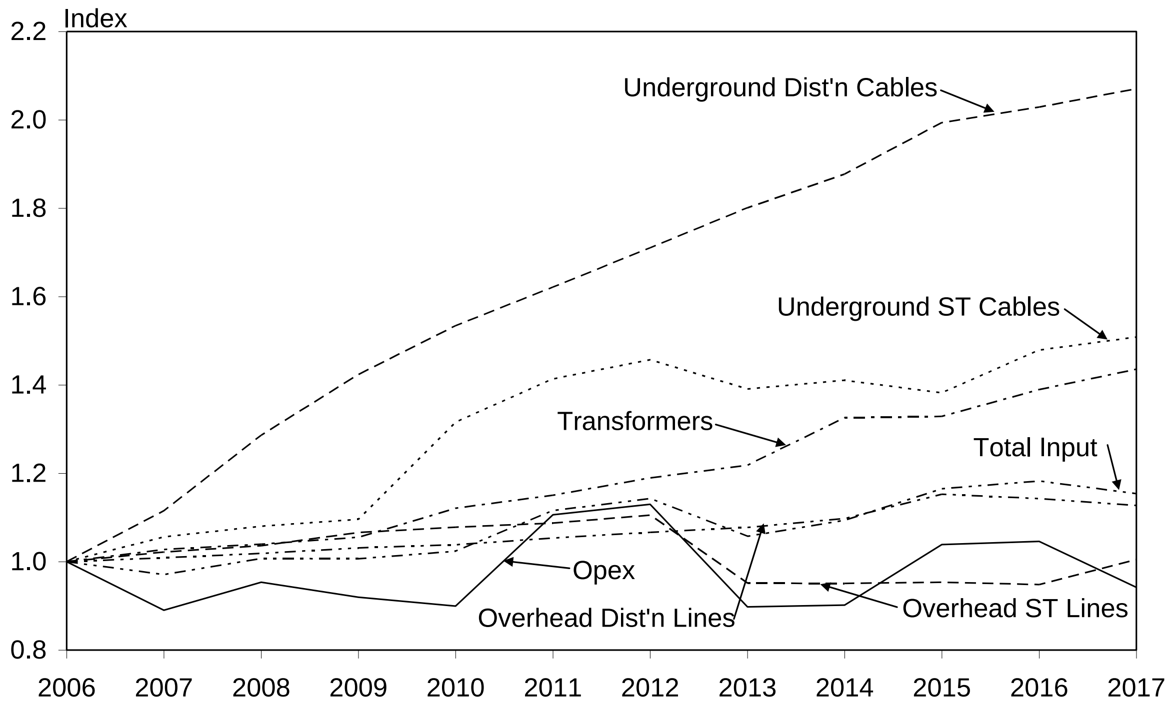
ERG's maximum demand also peaked in 2010 before recovering in 2012 and then declining through to 2016 before increasing in 2017. However, unlike many DNSPs in the NEM, ERG's maximum demand has stayed above its 2006 level for the remainder of the period. In 2017 RMD was 16 per cent above its 2006 level – a similar increase to the industry overall.

ERG's circuit length output also grew at a similar rate to the industry over the 12 years and by 2017 was 3 per cent above the level it was in 2006.

The last output shown in figure 5.22 is total CMOS. ERG's CMOS has generally followed a similar pattern to that of the industry although it increased markedly in 2015. With the exception of 2010, CMOS has been lower and, hence, contributed more to total output for all other years than was the case in 2006. In 2016 CMOS was 32 per cent less than it was in 2006.

Since the customer numbers and ratcheted maximum demand outputs receive a combined weight of around 60 per cent of gross revenue in forming the total output index, in figure 5.22 we see that the total output index tends to lie close to but often above these two output indexes. The circuit length and energy output indexes lie at a lower level but this is more than offset by the CMOS index which would generally lie above the other output indexes when it enters the formation of total output as a negative output (ie the reduction in CMOS over the period makes a positive contribution to total output). CMOS receives a higher weight for ERG as, being a remote regional DNSP and having a low network density, it has a higher level of CMOS.

Figure 5.23 **ERG's input quantity indexes, 2006–2017**



Turning to the input side, we see from ERG's six input components and total input in figure 5.23 that the quantity of ERG's underground distribution and subtransmission cables inputs have increased more than for the industry as a whole, its transformers overhead distribution lines inputs have increased around the same as for the industry while its opex has increased much less. Again, not too much should be read into the higher increase in underground cables as this was starting from a very small base and reflects Queensland's higher rate of customer numbers growth. For ERG, opex increased by 13 per cent up to 2012 which was much less than the corresponding increase for the industry of 36 per cent. After a substantial fall in 2013, ERG's opex subsequently increased through to 2016 before falling in 2017. In 2017 it was 6 per cent below its 2006 level.[10] Opex has the largest average share in ERG's total costs at 35 per cent and so is an important driver of its total input quantity index.

[10] Note that redundancy payments are included in the opex figures presented here.

From figure 5.23 we see that the total input quantity index generally lies between the quantity indexes for opex and transformers (which have a combined weight of 65 per cent of total costs). Total input quantity fell by 1.9 cent in 2017 driven by a decrease in opex usage of 9 per cent.

ERG's output and input contributions to TFP change

In table 5.12 we decompose ERG's TFP change into its constituent output and input parts for the whole 12–year period and for the periods up to and after 2012. ERG's drivers of TFP change for the whole 12–year period are broadly similar to the industry as a whole except that the customer numbers and CMOS outputs make a larger percentage point contribution to TFP growth in regional Queensland and opex makes a small positive contribution rather than a negative contribution. And the transformers input makes a somewhat more negative contribution to TFP growth for ERG than it does for the industry. However, the stronger output growth and lower opex growth for ERG lead to its TFP performance being considerably better than that for the industry.

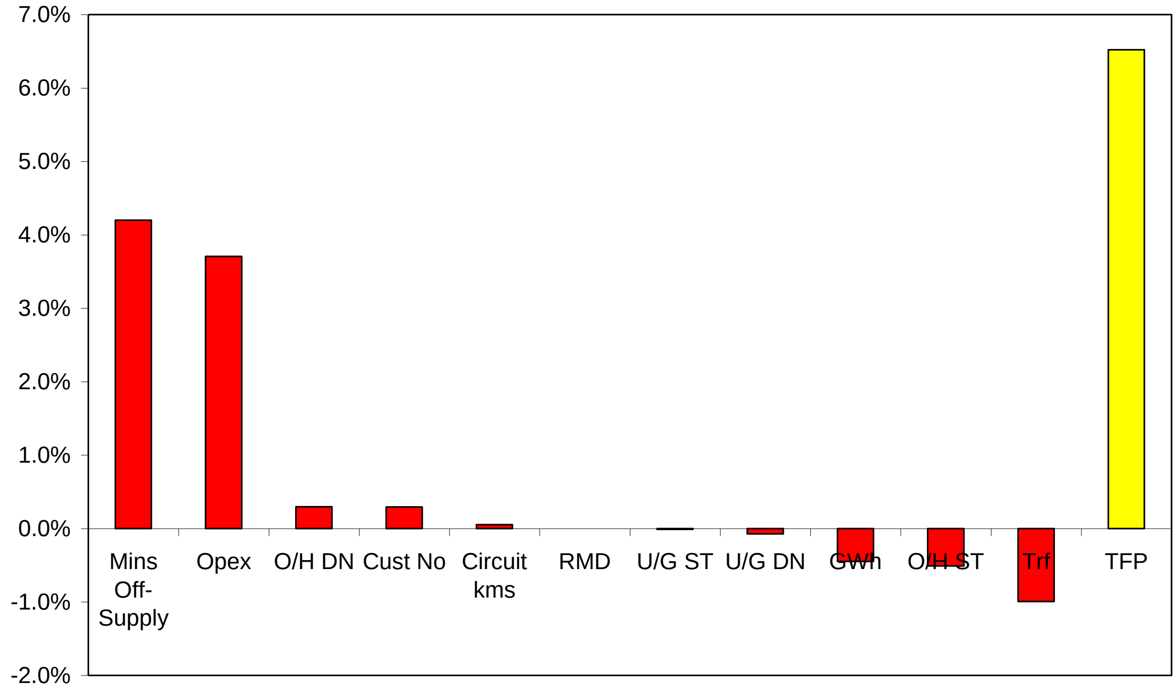
Table 5.12 **ERG's output and input percentage point contributions to average annual TFP change: 2006–2017, 2006–2012 and 2012–2017**

Year	*2006 to 2017*	*2006 to 2012*	*2012 to 2017*
Energy (GWh)	–0.01%	0.04%	–0.08%
Ratcheted Max Demand	0.49%	0.90%	0.00%
Customer Numbers	0.62%	0.76%	0.46%
Circuit Length	0.10%	0.23%	–0.06%
CMOS	0.85%	0.75%	0.96%
Opex	0.13%	–0.69%	1.12%
O/H Subtransmission Lines	0.01%	–0.17%	0.22%
O/H Distribution Lines	–0.23%	–0.23%	–0.23%
U/G Subtransmission Cables	–0.02%	–0.03%	0.00%
U/G Distribution Cables	–0.22%	–0.27%	–0.15%
Transformers	–0.98%	–0.83%	–1.16%
TFP Change	0.74%	0.46%	1.07%

ERG's situation is also a tale of two distinct periods. For the period up to 2012, opex growth made a smaller negative percentage point contribution to TFP growth for ERG than for the industry, at –0.7 percentage points for ERG versus –1.9 percentage points for the industry. The reductions made in ERG's opex after 2012 led to opex making a similar percentage point contribution to ERG's average annual TFP change as that for the industry. After 2012, with the exception of CMOS, ERG's outputs mostly contributed somewhat smaller amounts to TFP growth compared to the period before 2012 but its inputs, with the exception of transformers, made either positive or somewhat less negative percentage point contributions to TFP growth.

The importance of the improvement in CMOS and reduction in opex in 2017 is highlighted in figure 5.24 where they make 4.2 and 3.7 percentage point contributions, respectively, to TFP change in the 2017 year of 6.5 per cent.

Figure 5.24 **ERG's output and input percentage point contributions to annual TFP change, 2016–17**



5.7 Essential Energy

In 2017 Essential Energy (ESS) delivered 12,389 GWh to 891,935 customers over 192,103 circuit kilometres of lines and cables. ESS distributes electricity throughout 95 per cent of New South Wales' land mass and parts of southern Queensland. ESS is the third largest NEM DNSP in terms of customer numbers but by far the largest in terms of network length.

ESS's productivity performance

ESS's total output, total input and TFP indexes are presented in figure 5.25 and table 5.13. Opex and capital partial productivity indexes are also presented in table 5.13.

Over the 12–year period 2006 to 2017, ESS's TFP decreased at an average annual rate of 1.4 per cent. Although total output increased by an average annual rate of 1.2 per cent, total input use increased faster, at a rate of 2.6 per cent. ESS thus had somewhat similar output growth and somewhat higher input growth than the industry, leading to a lower TFP growth rate than that for the industry. Input use increased sharply in 2007, 2008 and 2012. Input use flattened out in 2009 before increasing through to 2012 and then falling in subsequent years. Input use then fell markedly in 2016 before increasing marginally in 2017. Apart from a small increase in 2010, TFP fell each year through to 2012 but, except for 2015, TFP change was positive each year from 2012 to 2016. TFP fell by 2.4 per cent in 2017. TFP average annual change was sharply negative for the period up to 2012 but has been strongly positive at 3.3 per cent for the period since 2012.

Figure 5.25 **ESS's output, input and total factor productivity indexes, 2006–2017**

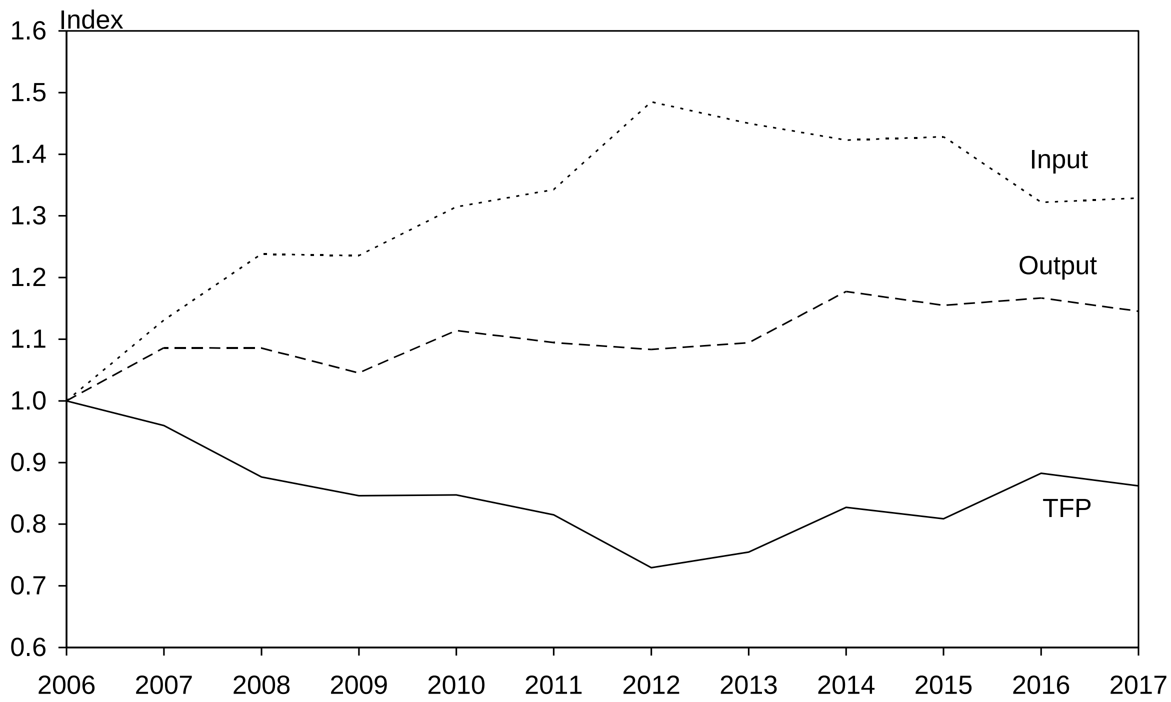


Table 5.13 **ESS's output, input and total factor productivity and partial productivity indexes, 2006–2017**

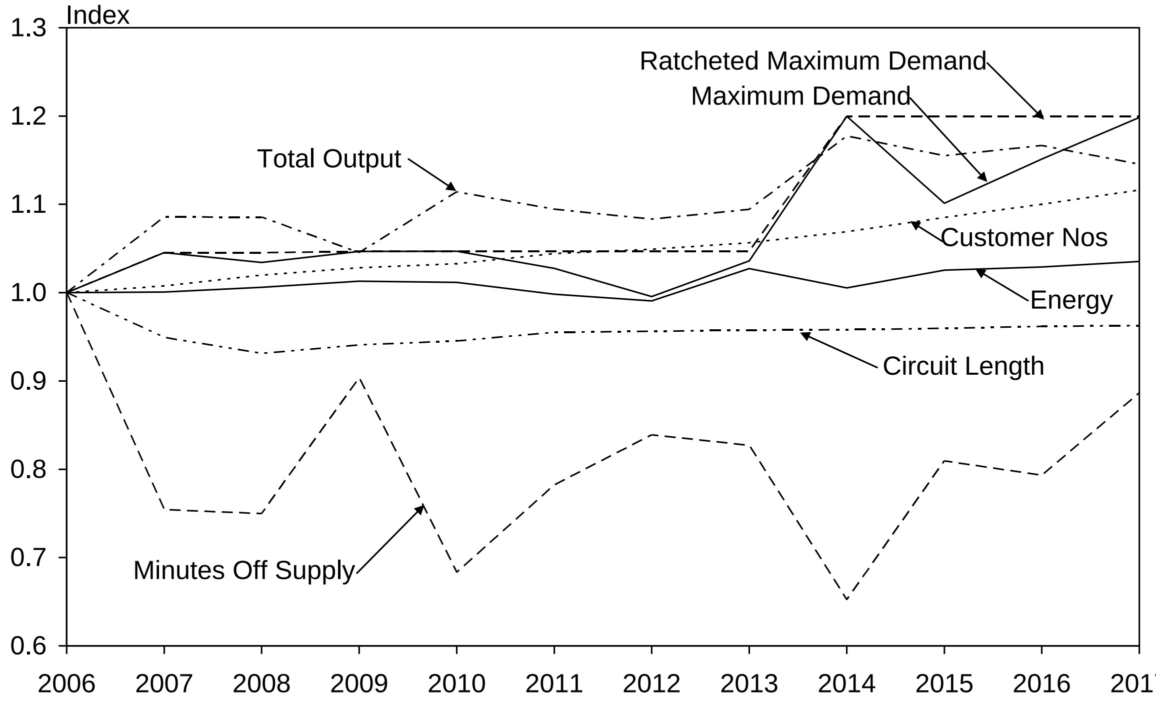
Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index Opex*	*PFP Index Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.086	1.131	0.960	0.904	1.007
2008	1.085	1.238	0.877	0.769	0.977
2009	1.045	1.235	0.846	0.792	0.896
2010	1.114	1.314	0.848	0.788	0.902
2011	1.094	1.343	0.815	0.775	0.855
2012	1.083	1.485	0.729	0.620	0.825
2013	1.094	1.450	0.755	0.692	0.810
2014	1.177	1.423	0.827	0.786	0.870
2015	1.155	1.428	0.809	0.787	0.837
2016	1.167	1.322	0.883	1.008	0.829
2017	1.145	1.329	0.862	0.984	0.810
Growth Rate 2006–17	1.23%	2.58%	–1.35%	–0.15%	–1.92%
Growth Rate 2006–12	1.33%	6.59%	–5.26%	–7.96%	–3.21%
Growth Rate 2012–17	1.12%	–2.22%	3.34%	9.22%	–0.37%

The partial productivity indexes in table 5.13 show that reduced opex usage was the main driver of the improved TFP performance after 2012 although capital partial productivity also improved.

ESS's output and input quantity changes

We graph the quantity indexes for ESS's five individual outputs in figure 5.26 and for its six individual inputs in figure 5.27.

Figure 5.26 **ESS's output quantity indexes, 2006–2017**



From figure 5.26 we see that ESS's output components showed a quite different pattern of change to the industry with energy and demand outputs effectively being flat through to 2012 but increasing subsequently. This likely reflects the negative impact of the global financial crisis and then progressively positive economic effects of the mining boom on regional NSW. Customer numbers increased more steadily over the period and were 12 per cent higher in 2017, a lower increase than that for the industry. Energy throughput for distribution peaked in 2009 and again in 2013 but has increased since 2014 to be 4 per cent higher in 2017 than it was in 2006.

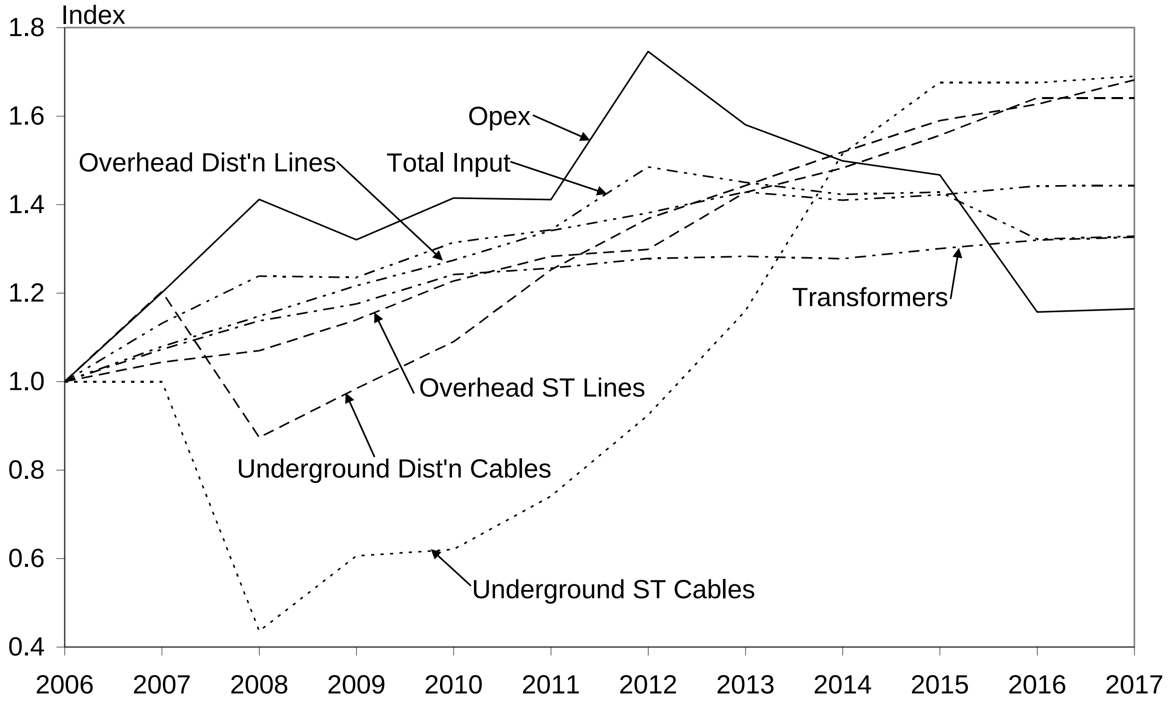
ESS's maximum demand peaked in 2014 – several years later than for most other DNSPs. Ratcheted maximum demand in 2017 was 20 per cent above its 2006 level – a larger increase than for the industry overall.

ESS's circuit length output declined in 2007 and 2008 and increased gradually since then. By 2017 it was still 4 per cent lower than it was in 2006 compared to an increase of 4 per cent for the industry.

The last output shown in figure 5.26 is total CMOS. ESS's CMOS has generally followed a similar pattern to that of the industry although it has been somewhat more volatile. CMOS has generally trended downwards over the period and, hence, contributed more to total output than was the case in 2006. Although CMOS increased by 12 per cent in 2017 it was still 11 per cent less than it was in 2006.

Since the customer numbers and ratcheted maximum demand outputs receive a weight of around 60 per cent of gross revenue in forming the total output index, in figure 5.26 we see that the total output index tends to lie close to but often above these two output indexes. The circuit length and energy indexes lie at a lower level but do not offset the CMOS index which would generally lie above the other output indexes when it enters the formation of total output as a negative output (ie the reduction in CMOS over the period makes a positive contribution to total output). As was the case for ERG, CMOS receives a higher weight for ESS as, being a remote regional DNSP and having a low network density, ESS also has a higher level of CMOS.

Figure 5.27 **ESS's input quantity indexes, 2006–2017**



Turning to the input side, we see from ESS's six input components and total input in figure 5.27 that the quantity of ESS's opex increased considerably more rapidly between 2006 and 2012 than the corresponding increase for the industry. For ESS, opex increased by 75 per cent up to 2012 whereas the corresponding increase for the industry was 36 per cent. However, ESS's opex then fell significantly through to 2016 before a small increase in 2017 when it was 17 per cent above its 2006 level.[11] This compares to the industry's 2017 opex usage being 18 per cent above its 2006 level. Opex has the largest average share in ESS's total costs at 40 per cent and so is an important driver of its total input quantity index.

ESS's underground distribution cables and transformers inputs increase more steadily over the period and at rates somewhat higher and lower, respectively, than for the industry as a whole. Its overhead distribution lines input, however, increases much more rapidly over the period with an increase of 44 per cent compared to only 11 per cent for the industry.

[11] Note that redundancy payments are included in the opex figures presented here.

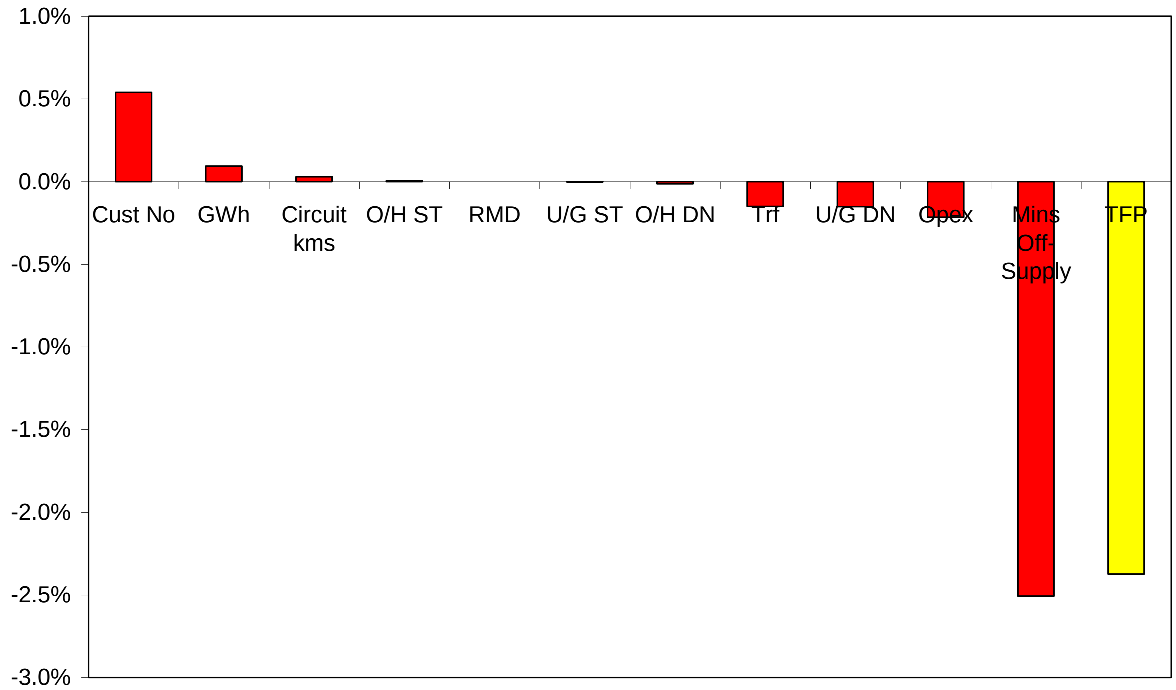
From figure 5.27 we see that the total input quantity index lies between the quantity indexes for opex and transformers (which have a combined weight of 70 per cent of total costs). Total input quantity increased by 1.0 per cent in 2017 driven by an increase of 2.1 per cent in opex usage.

ESS's output and input contributions to TFP change

Table 5.14 **ESS'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)	0.05%	–0.02%	0.13%
Ratcheted Max Demand	0.54%	0.28%	0.86%
Customer Numbers	0.36%	0.30%	0.44%
Circuit Length	–0.13%	–0.28%	0.05%
CMOS	0.42%	1.06%	–0.36%
Opex	–0.75%	–3.97%	3.13%
O/H Subtransmission Lines	–0.30%	–0.28%	–0.33%
O/H Distribution Lines	–0.56%	–0.87%	–0.18%
U/G Subtransmission Cables	–0.01%	0.00%	–0.02%
U/G Distribution Cables	–0.19%	–0.22%	–0.17%
Transformers	–0.78%	–1.25%	–0.21%
TFP Change	–1.35%	–5.26%	3.34%

Figure 5.28 **ESS's output and input percentage point contributions to annual TFP change, 2016–17**



In table 5.14 we decompose ESS's TFP change into its constituent output and input parts for the whole 12–year period and for the periods up to and after 2012. ESS's drivers of TFP change for the whole 12–year period are broadly similar to the industry as a whole except that the CMOS output makes the second largest positive contribution with RMD making the largest positive contribution and customer numbers growth coming in third. Circuit length output growth contributes less to TFP growth for ESS than for the industry given circuit length's lower rate of growth for ESS.

ESS's situation is again a tale of two distinct periods but with the opposite relativities compared to most other DNSPs. For the period up to 2012, output growth (except for the CMOS output) made less of a contribution to TFP growth than it did after 2012. ESS's rapid opex growth up to 2012 made a larger negative percentage point contribution to TFP growth than it did for the industry, at –4.0 percentage points for ESS versus –1.9 percentage points for the industry. But the reductions made in ESS's opex after 2012 led to opex contributing 3.1 percentage points to ESS's average annual TFP change of 3.3 per cent for the period after 2012. This compares to an opex contribution of 1.0 percentage points to the industry TFP average annual change of 0.6 per cent after 2012.

The importance of the increase in CMOS in 2017 is highlighted in figure 5.28 where the –2.5 percentage point contribution of CMOS is the main driver of TFP change of –2.4 per cent in 2017. The increase in opex in 2017 contributed –0.7 percentage points to TFP change in that year.

5.8 Jemena Electricity Networks

In 2017 Jemena Electricity Networks (JEN) delivered 4,264 GWh to 334,840 customers over 6,345 circuit kilometres of lines and cables. JEN distributes electricity across 950 square kilometres of north–west greater Melbourne. JEN's network footprint incorporates a mix of major industrial areas, residential growth areas, established inner suburbs and Melbourne International Airport.

JEN's productivity performance

JEN's total output, total input and TFP indexes are presented in figure 5.29 and table 5.15. Opex and capital partial productivity indexes are also presented in table 5.15.

Over the 12–year period 2006 to 2017, JEN's TFP decreased at an average annual rate of 0.2 per cent. Although total output increased by an average annual rate of 1.5 per cent, total input use increased slightly faster, at a rate of 1.7 per cent. JEN thus had a similar but slightly higher output growth rate compared to the industry but it had a considerably lower input growth rate than the industry leading to a small downward trend in TFP growth overall for JEN compared to a decline in TFP at the rate of –0.9 per cent per annum for the industry as a whole. JEN's input use decreased in 2008 before then increasing at a higher rate through to 2012 and flattening off through to 2014 before again increasing over the last three years. TFP change was positive in 2007, 2008 and 2011, negative in 2009, 2010, 2012, 2016 and 2017 and relatively flat in the other years. In 2008 output growth was strong while input usage fell markedly leading to a TFP increase of 11 per cent. In 2017 output growth improved somewhat while input use increased leading to a TFP change of –0.6 per cent. Compared to the whole 12–year period TFP average annual change was slightly positive for the period up to 2012 at 0.1 per cent but has been more negative at –0.5 per cent for the period since 2012.

Figure 5.29 **JEN's output, input and total factor productivity indexes, 2006–2017**

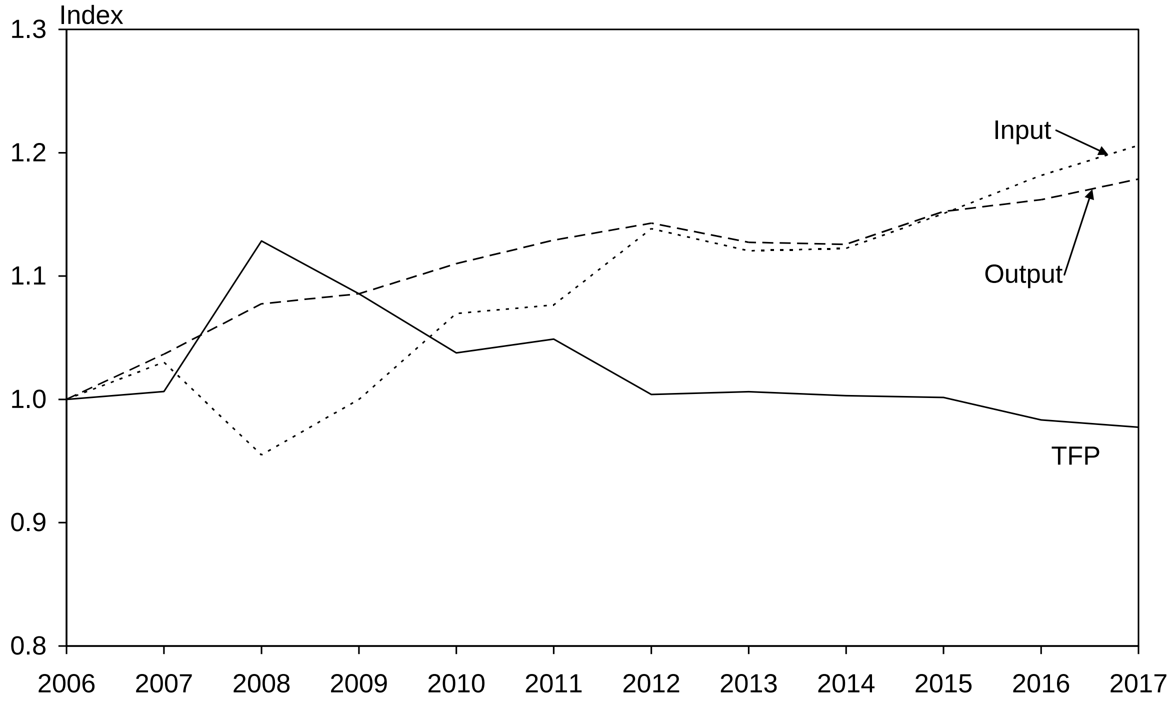


Table 5.15 **JEN's output, input and total factor productivity and partial productivity indexes, 2006–2017**

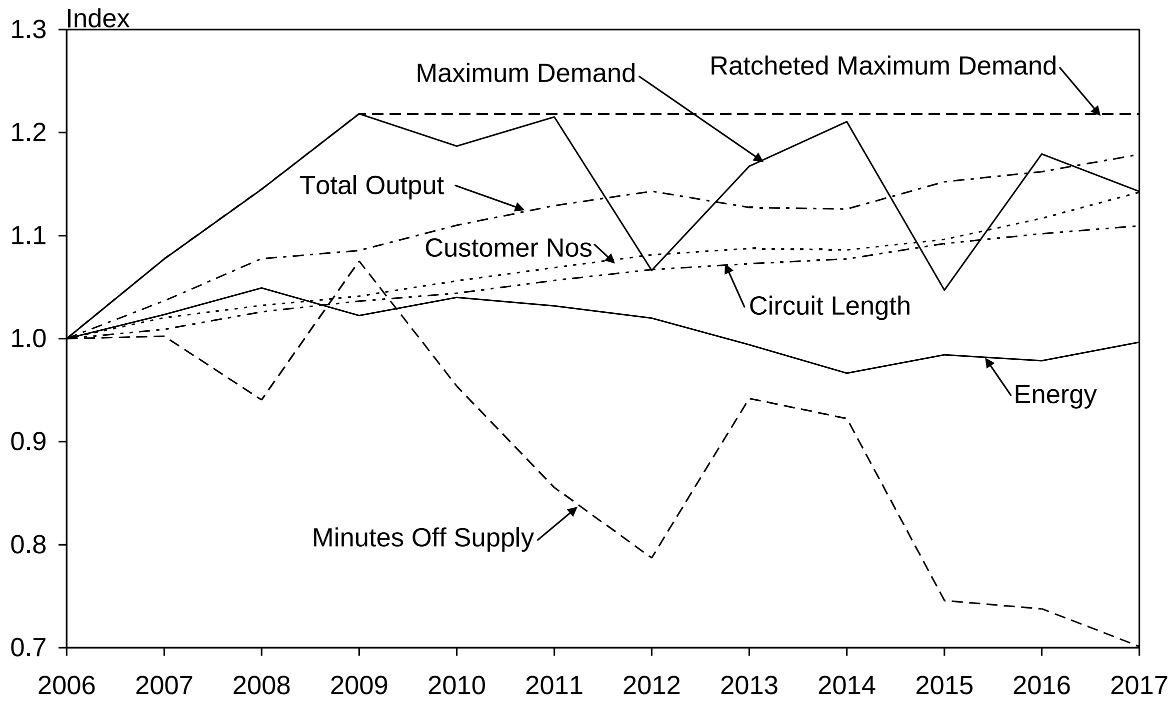
Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index Opex*	*PFP Index Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.037	1.030	1.006	0.982	1.030
2008	1.077	0.955	1.128	1.264	1.039
2009	1.086	1.000	1.086	1.167	1.029
2010	1.110	1.070	1.038	1.018	1.054
2011	1.129	1.077	1.049	1.049	1.050
2012	1.143	1.138	1.004	0.935	1.064
2013	1.127	1.120	1.006	0.964	1.043
2014	1.126	1.122	1.003	0.977	1.028
2015	1.152	1.150	1.002	0.974	1.028
2016	1.162	1.182	0.983	0.935	1.024
2017	1.179	1.206	0.977	0.908	1.034
Growth Rate 2006–17	1.49%	1.70%	–0.21%	–0.87%	0.30%
Growth Rate 2006–12	2.23%	2.16%	0.07%	–1.11%	1.03%
Growth Rate 2012–17	0.62%	1.15%	–0.54%	–0.58%	–0.57%

The partial productivity indexes in table 5.15 show that while opex PFP improved after 2012, this was more than offset by a worsening in capital PFP.

JEN's output and input quantity changes

We graph the quantity indexes for the JEN's five individual outputs in figure 5.30 and for its six individual inputs in figure 5.31.

Figure 5.30 **JEN's output quantity indexes, 2006–2017**



From figure 5.30 we see that JEN's output components exhibit a similar pattern of change to the industry as a whole. Customer numbers increased steadily over the period and were 14 per cent higher in 2017 than they were in 2006, somewhat lower than the industry's increase of 16 per cent. Energy throughput for distribution peaked in 2008 – a year or two earlier than for most DNSPs – and was around the same level in 2017 as it was in 2006.

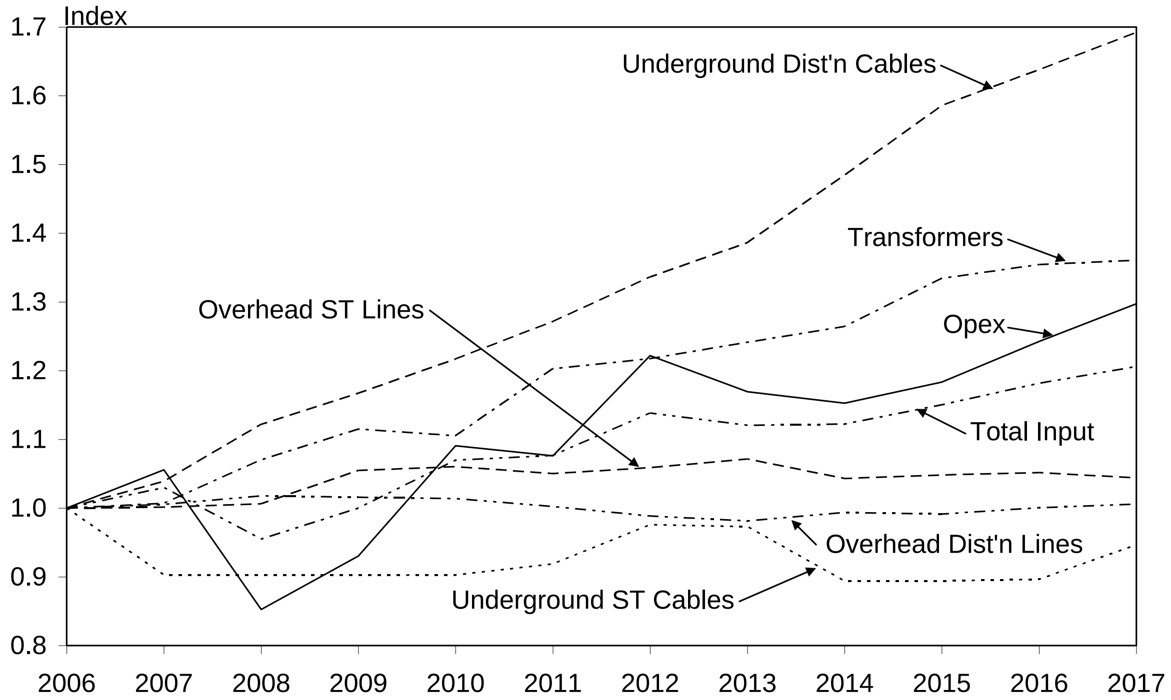
JEN's maximum demand reached its highest level in 2009 but has been relatively volatile since then. It almost regained its 2009 level in 2011 and again in 2014. In 2017 it was around 14 per cent above its 2006 level. Ratcheted maximum demand in 2017 was 22 per cent above its 2006 level – a larger increase than the industry's 17 per cent.

JEN's circuit length output grew somewhat more over the 12 years than occurred for the industry overall and by 2017 was 11 per cent above the level it was in 2006 compared to an increase of only 4 per cent for the industry.

The last output shown in figure 5.30 is total CMOS. JEN's CMOS has been more volatile than for the industry but has similarly trended downwards over the period. By 2017 JEN's CMOS was 30 per cent lower than it was in 2006 but it had been only 6 per cent below its 2006 level in 2013.

Since the customer numbers and ratcheted maximum demand outputs receive a combined weight of around 60 per cent of gross revenue in forming the total output index, in figure 5.30 we see that the total output index lies between these two output indexes. The circuit length output index also lies close to the customer numbers index while the energy output index lies at a lower level. The CMOS index would lie above the other output indexes in most years when it enters the formation of total output as a negative output (ie the decrease in CMOS over the period makes a positive contribution to total output). The CMOS increase in 2013 and 2014 is the main reason for the dip in total output in those years.

Figure 5.31 **JEN's DNSP input quantity indexes, 2006–2017**



Turning to the input side, we see from JEN's six input components and total input in figure 5.31 that the quantity of JEN's opex decreased sharply in 2008 and was the driver of the fall in total inputs in that year. Opex usage then increased again through to 2012. However, for JEN, opex increased by 22 per cent up to 2012 whereas the corresponding increase for the industry was 36 per cent. Since then JEN's opex usage initially decreased but then increased to be 30 per cent above its 2006 level in 2017 – an increase of 6 per cent on its 2012 level. This compared to a reduction in opex usage for the industry of 13 per cent between 2012 and 2017. Opex has the largest average share in JEN's total costs at 43 per cent and so is an important driver of its total input quantity index.

JEN's underground distribution cables and transformers inputs increased more steadily over the period at somewhat higher and similar rates, respectively, compared to the industry as a whole. Its overhead distribution lines input remained virtually unchanged over the period compared to a 11 per cent increase for the industry.

From figure 5.31 we see that JEN's total input quantity index lies close to the quantity indexes for opex and overhead distribution lines (with the latter receiving a higher weight for

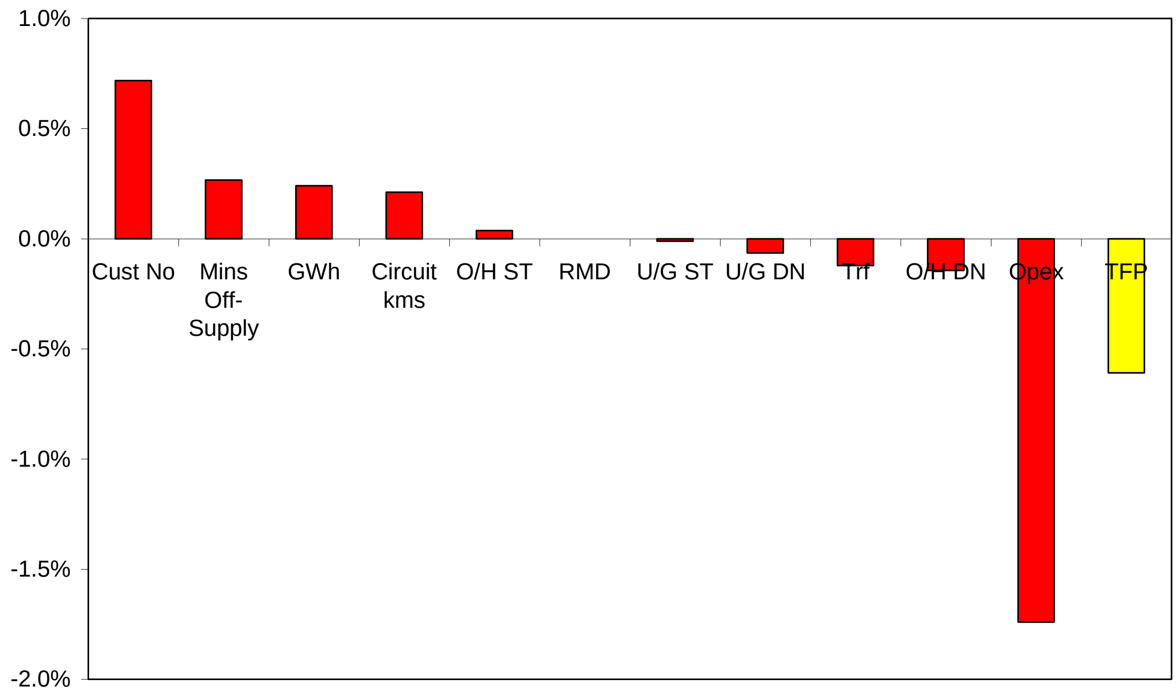
JEN than for most DNSPs). Total input quantity increased by 2.0 per cent in 2017, driven mainly by the increase in opex usage.

JEN's output and input contributions to TFP change

Table 5.16 **JEN'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)	0.00%	0.05%	–0.06%
Ratcheted Max Demand	0.56%	1.03%	0.00%
Customer Numbers	0.40%	0.44%	0.35%
Circuit Length	0.30%	0.35%	0.24%
CMOS	0.24%	0.37%	0.09%
Opex	–1.01%	–1.48%	–0.45%
O/H Subtransmission Lines	–0.02%	–0.04%	0.01%
O/H Distribution Lines	–0.01%	0.06%	–0.09%
U/G Subtransmission Cables	0.00%	0.00%	0.00%
U/G Distribution Cables	–0.10%	–0.11%	–0.09%
Transformers	–0.56%	–0.59%	–0.53%
TFP Change	–0.21%	0.07%	–0.54%

Figure 5.32 **JEN's output and input percentage point contributions to annual TFP change, 2017**



In table 5.16 we decompose JEN's TFP change into its constituent output and input parts for the whole 12–year period and for the periods up to and after 2012. JEN's drivers of TFP change for the whole 12–year period are broadly similar to the industry as a whole except that circuit length makes a larger positive contribution to TFP growth for JEN, opex makes a larger negative contribution and the underground distribution cables and transformers inputs make a smaller negative contribution. Opex makes a considerably more negative contribution over the period for JEN at –1.0 per cent compared to –0.6 per cent for the industry.

JEN's situation is again a tale of two distinct periods. The contribution of all outputs to TFP falls after 2012 compared to the period before 2012. And the contribution of most inputs remains relatively unchanged except for opex whose contribution improves by 1.0 percentage points. Opex change went from –1.5 percentage points contribution to TFP to –0.5 percentage points contribution for JEN. This differs to the industry–wide result where opex makes a positive contribution to TFP change after 2012 as opex usage declines overall.

The importance of JEN's increase in opex usage in 2017 is highlighted in figure 5.32 where opex made a –1.7 percentage point contribution to TFP change in the 2017 year. Despite a strong contribution of 0.7 percentage points from customer numbers growth also occurring in 2017, combined with negative contributions from each of transformers and underground distribution cable, the increase in opex usage led to JEN's TFP growth in 2017 being –0.6 per cent compared to industry TFP growth of 2.7 per cent in that year.

5.9 Powercor

In 2017 Powercor (PCR) delivered 10,720 GWh to 816,349 customers over 75,121 circuit kilometres of lines and cables. PCR distributes electricity to the western half of Victoria, including the western suburbs of Melbourne and stretching west to the border of South Australia and north to New South Wales.

PCR's productivity performance

PCR's total output, total input and TFP indexes are presented in figure 5.33 and table 5.17. Opex and capital partial productivity indexes are also presented in table 5.17.

Over the 12–year period 2006 to 2017, PCR's TFP grew at an average annual rate of 0.3 per cent. Total output increased by an average annual rate of 1.4 per cent while total input use increased at a rate of 1.1 per cent. PCR thus had a similar but slightly lower output growth rate compared to the industry but it had a considerably lower input growth rate than the industry leading to positive TFP growth for PCR compared to a fall in TFP at the rate of –0.9 per cent per annum for the industry as a whole. PCR's input use decreased in 2007 before then increasing at a higher rate through to 2013 and flattening off through to 2015 before decreasing significantly in 2016 and increasing slightly in 2017. TFP change was positive in 2007, 2008, 2010, 2011, 2015, 2016 and 2017, negative in 2009, 2012 and 2013 and relatively flat in 2014. In 2008, 2010 and 2011 output growth was strong while input usage moderated. In 2016 input use decreased by 7.2 per cent while output growth continued albeit at a moderated rate leading to a TFP change of 8.3 per cent. A return to strong output growth in 2017 led to TFP growth of 3.9 per cent. TFP average annual change reversed from –0.8 per cent for the period up to 2012 to a positive rate of 1.6 per cent for the period after 2012.

Figure 5.33 **PCR's output, input and total factor productivity indexes, 2006–2017**

Table 5.17 **PCR's output, input and total factor productivity and partial productivity indexes, 2006–2017**

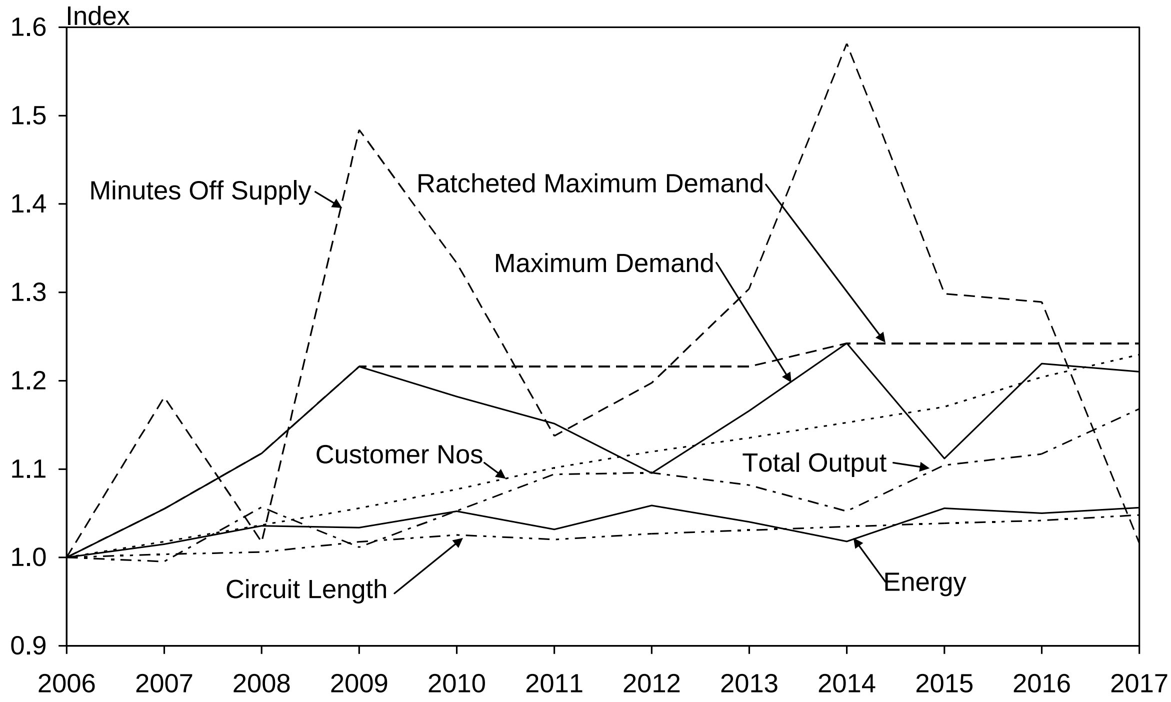
Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index Opex*	*PFP Index Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	0.995	0.955	1.042	1.136	0.974
2008	1.057	0.973	1.086	1.180	1.017
2009	1.011	1.050	0.964	1.023	0.916
2010	1.052	1.052	1.000	1.111	0.924
2011	1.094	1.064	1.028	1.110	0.966
2012	1.096	1.149	0.954	0.937	0.956
2013	1.082	1.196	0.905	0.870	0.921
2014	1.052	1.161	0.906	0.932	0.877
2015	1.104	1.209	0.913	0.913	0.904
2016	1.117	1.126	0.992	1.137	0.898
2017	1.168	1.132	1.032	1.223	0.918
Growth Rate 2006–17	1.41%	1.12%	0.29%	1.83%	–0.78%
Growth Rate 2006–12	1.53%	2.31%	–0.78%	–1.09%	–0.74%
Growth Rate 2012–17	1.27%	–0.30%	1.57%	5.33%	–0.82%

The partial productivity indexes in table 5.17 show that greatly improved opex PFP growth after 2012 more than offset a small worsening in capital PFP change to be the main driver of the improved TFP performance after 2012.

PCR's output and input quantity changes

We graph the quantity indexes for the PCR's five individual outputs in figure 5.34 and for its six individual inputs in figure 5.35.

Figure 5.34 **PCR's output quantity indexes, 2006–2017**



From figure 5.34 we see that PCR's output components exhibit a similar pattern of change to the industry as a whole, except that CMOS is more volatile and exhibits an upward rather than a downward trend over the period as a whole although there was a large improvement in CMOS in 2017. Customer numbers increased steadily over the period and were 23 per cent higher in 2017 than it was in 2006, a larger increase than the industry's increase of 16 per cent. Energy throughput for distribution peaked in 2012 – a little later than for most DNSPs – and was 6 per cent higher in 2017 than it was in 2006.

PCR's maximum demand reached its highest level in 2014 – again later than for most DNSPs – but has been relatively volatile since a slightly lower peak in 2009. In 2017 it was around 21 per cent above its 2006 level. Ratcheted maximum demand in 2016 was 24 per cent above its 2006 level – a larger increase than the industry's 17 per cent.

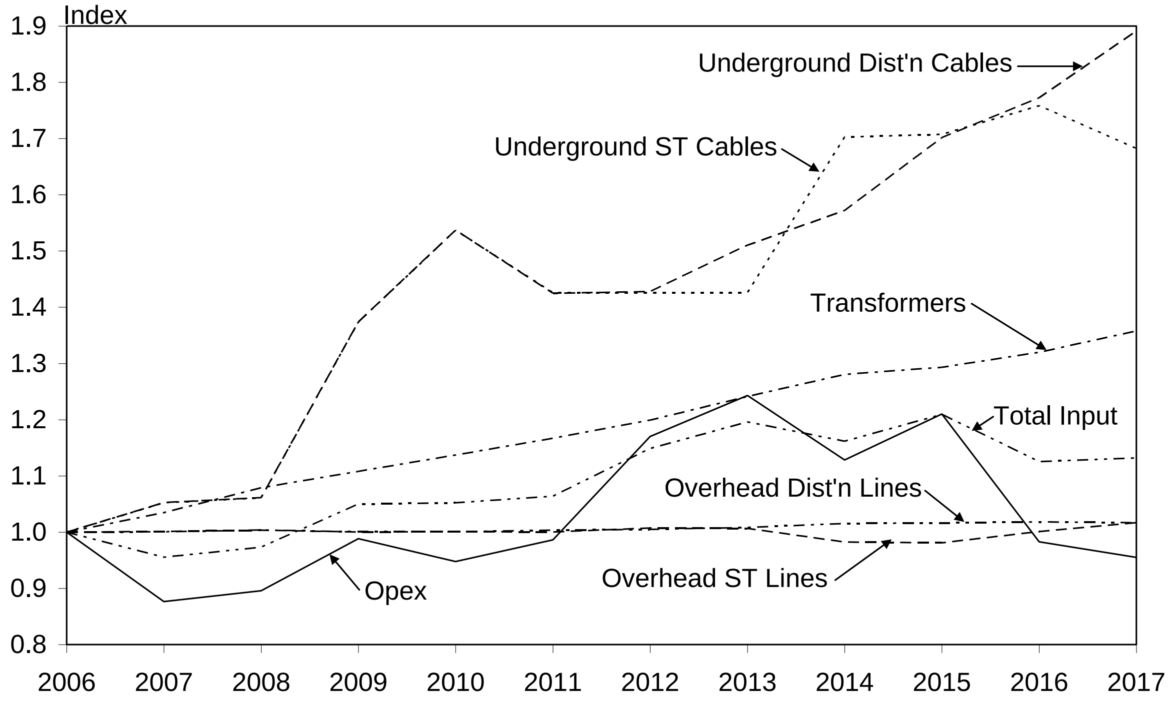
PCR's circuit length output grew slightly more over the 12 years than occurred for the industry overall and by 2017 was 5 per cent above the level it was in 2006 compared to an increase of 4 per cent for the industry.

The last output shown in figure 5.34 is total CMOS. PCR's CMOS has been more volatile than for the industry and has trended upwards to 2014 before trending downwards after that. In 2017 PCR's CMOS was only 2 per cent higher than it was in 2006 but it had been 58 per cent higher than its 2006 level in 2014.

Since the customer numbers and ratcheted maximum demand outputs receive a combined weight of around 60 per cent of gross revenue in forming the total output index, in figure 5.34

we see that the total output index lies close to but below these two output indexes. The circuit length output index and energy output index lie below the total output index. In this case, the CMOS index would lie well below the other output indexes in most years when it enters the formation of total output as a negative output (ie the increase in CMOS over the period makes a negative contribution to total output). The CMOS increases in 2009 and 2014 are the main reason for dips in total output in those years. Conversely, the marked improvement in CMOS in 2017 contributes to the increase in total output in the latest year.

Figure 5.35 **PCR's DNSP input quantity indexes, 2006–2017**



Turning to the input side, we see from PCR's six input components and total input in figure 5.35 that the quantity of PCR's opex decreased sharply in 2014 and again in 2016. It was the driver of the fall in total inputs in those years. For PCR, opex increased by 24 per cent up to 2013 whereas the corresponding increase for the industry was 36 per cent up to 2012. Since 2013 PCR's opex usage has decreased sharply to be 4 per cent below its 2006 level in 2017. This compared to the industry's opex usage in 2017 still being 18 per cent above its 2006 level. Opex has the largest average share in PCR's total costs at 40 per cent and so is an important driver of its total input quantity index.

PCR's underground distribution cables and transformers inputs increased more steadily over the period at somewhat higher and similar rates, respectively, compared to the industry as a whole. Its overhead distribution lines input only increased a little over the period to be 2 per cent above its 2006 level in 2017 compared to a 4 per cent increase for the industry.

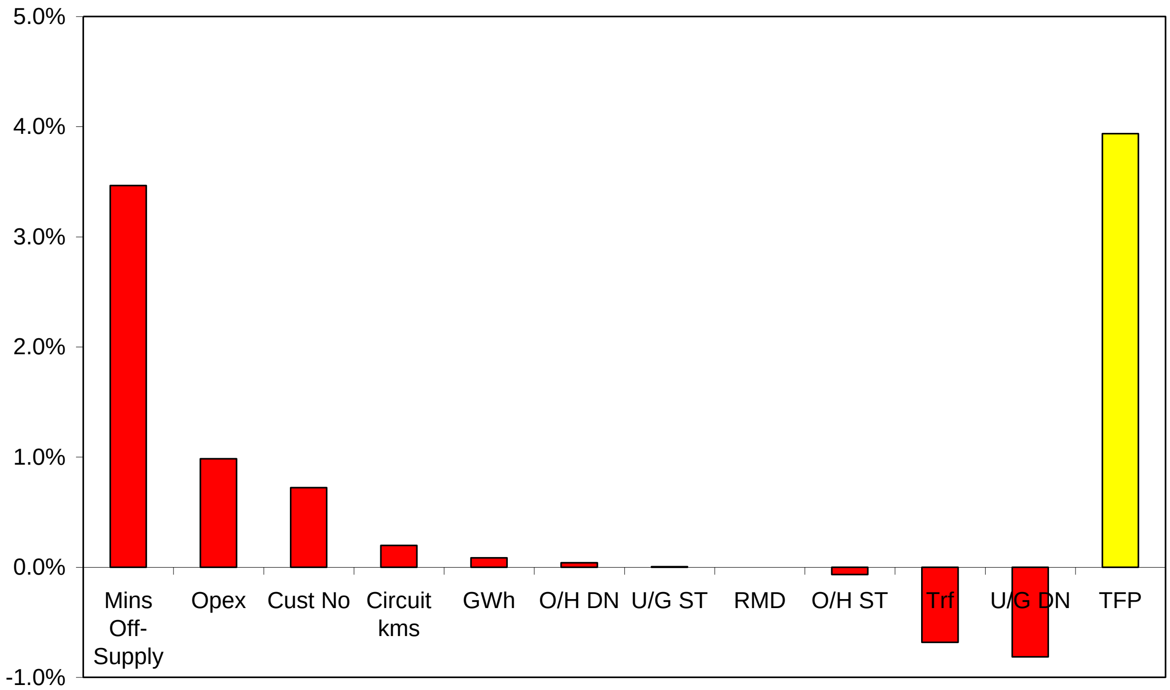
From figure 5.35 we see that PCR's total input quantity index generally lies between the quantity indexes for opex and transformers. Total input quantity increased by 0.5 per cent in 2017, driven mainly by increases in underground distribution cables and transformer inputs that year.

PCR's output and input contributions to TFP change

Table 5.18 **PCR'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)	0.07%	0.14%	–0.01%
Ratcheted Max Demand	0.67%	1.11%	0.15%
Customer Numbers	0.68%	0.69%	0.66%
Circuit Length	0.15%	0.16%	0.14%
CMOS	–0.16%	–0.58%	0.33%
Opex	0.17%	–0.97%	1.55%
O/H Subtransmission Lines	–0.01%	0.00%	–0.01%
O/H Distribution Lines	–0.03%	–0.02%	–0.05%
U/G Subtransmission Cables	0.00%	–0.01%	0.00%
U/G Distribution Cables	–0.67%	–0.70%	–0.64%
Transformers	–0.58%	–0.61%	–0.55%
TFP Change	0.29%	–0.78%	1.57%

Figure 5.36 **PCR's output and input percentage point contributions to annual TFP change, 2016–17**



In table 5.18 we decompose PCR's TFP change into its constituent output and input parts for the whole 12–year period and for the periods up to and after 2012. PCR's drivers of TFP change for the whole 12–year period differ from those for the industry as a whole in a number of ways. The customer numbers and RMD outputs make a larger positive contribution for PCR. Importantly, opex makes a positive rather than a negative contribution for PCR, as does energy throughput. Transformers input makes a smaller negative contribution for PCR but

CMOS makes a negative contribution for PCR instead of the positive one it makes for the industry. Opex makes a positive contribution over the period for PCR of 0.2 per cent compared to –0.6 per cent for the industry.

PCR's situation is also a tale of two distinct periods. With the exception of CMOS, the contribution of all outputs to TFP falls after 2012 compared to the period before 2012, although to less of an extent for PCR compared to most DNSPs. And the contribution of most inputs remains relatively unchanged except for opex whose contribution improves by a very large 2.5 percentage points. Opex change went from a –1.0 percentage point contribution to TFP to 1.6 for PCR as opex usage reduced after 2013.

The importance of PCR's large decrease in CMOS in 2017 is highlighted in figure 5.36 where CMOS made a 3.5 percentage point contribution to TFP change in the 2017 year. Strong positive contributions from customer numbers growth and opex reductions also occurring in 2017 more than offset the larger negative contributions from transformers and underground distribution cables growth, leading to PCR's TFP growth in 2017 being 3.9 per cent compared to industry TFP growth of 2.7 per cent in that year.

5.10 United Energy

In 2017 United Energy (UED) delivered 7,844 GWh to 676,807 customers over 13,342 circuit kilometres of lines and cables. UED distributes electricity across east and south–east Melbourne and the Mornington Peninsula.

UED's productivity performance

UED's total output, total input and TFP indexes are presented in figure 5.37 and table 5.19. Opex and capital partial productivity indexes are also presented in table 5.19.

Over the 12–year period 2006 to 2017, UED's TFP decreased with an average annual change of –0.5 per cent. Although total output increased by an average annual rate of 1.1 per cent, total input use increased faster, at a rate of 1.6 per cent. UED thus had slower output growth, slower input growth and somewhat less negative TFP growth compared to the industry as a whole. Input use increased at a faster rate in 2011 and 2016. It decreased in 2013 and then levelled off for two years. It decreased again in 2017. UED's output declined in three years: 2011, 2012 and 2014. TFP change was positive in five years: 2007, 2009, 2013, 2015 and 2017. In the first, third and fourth of these years there were input decreases and in the second there was stronger output growth. In 2017 there was stronger output growth combined with a reduction in input use. Compared to the whole 12–year period TFP average annual change was much more negative for the period up to 2012 at –2.1 per cent but has been positive at 1.5 per cent for the period since 2012.

The partial productivity indexes in table 5.19 show that improvements in both opex PFP and capital PFP have played a role in the improved TFP performance after 2012.

Figure 5.37 **UED's output, input and total factor productivity indexes, 2006–2017**

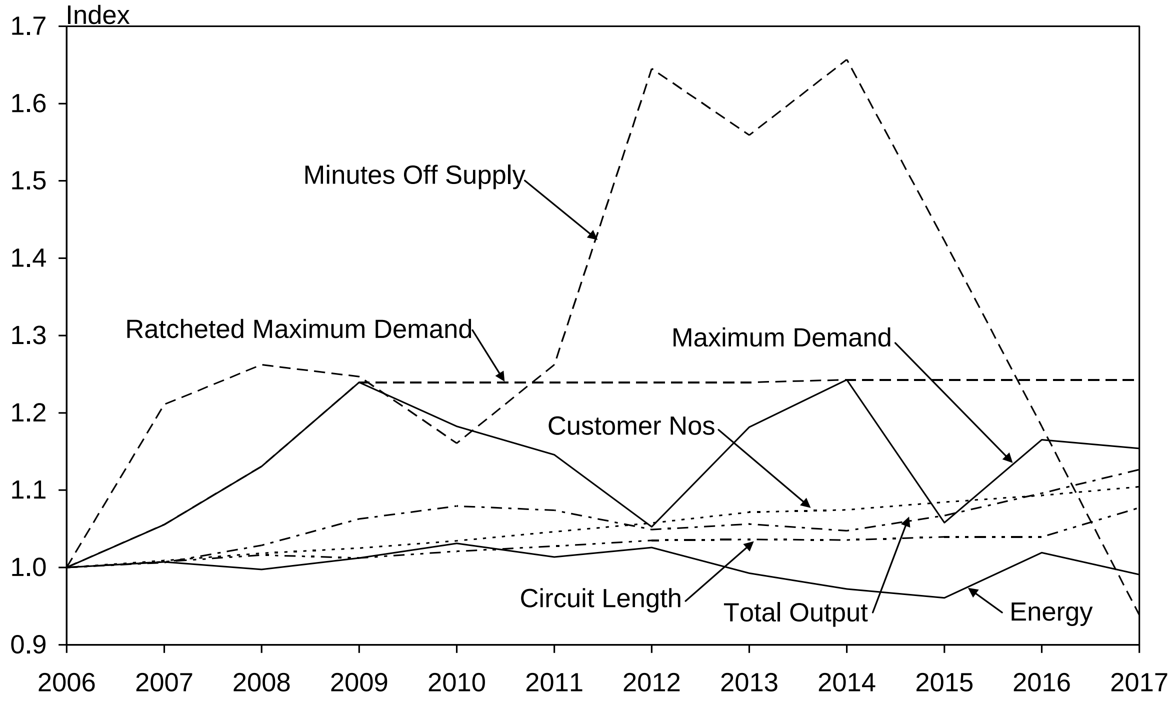
Table 5.19 **UED's output, input and total factor productivity and partial productivity indexes, 2006–2017**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.006	0.992	1.014	1.068	0.979
2008	1.029	1.014	1.015	1.087	0.970
2009	1.063	1.028	1.034	1.104	0.990
2010	1.079	1.066	1.013	1.074	0.973
2011	1.074	1.167	0.920	0.872	0.951
2012	1.049	1.192	0.880	0.847	0.899
2013	1.056	1.143	0.924	0.957	0.897
2014	1.048	1.160	0.903	0.928	0.880
2015	1.067	1.142	0.934	0.997	0.890
2016	1.096	1.197	0.916	0.886	0.925
2017	1.127	1.185	0.951	0.989	0.920
Growth Rate 2006–17	1.08%	1.55%	–0.46%	–0.10%	–0.76%
Growth Rate 2006–12	0.80%	2.93%	–2.13%	–2.77%	–1.77%
Growth Rate 2012–17	1.43%	–0.11%	1.54%	3.10%	0.46%

UED's output and input quantity changes

We graph the quantity indexes for UED's five individual outputs in figure 5.38 and for their six individual inputs in figure 5.39.

Figure 5.38 **UED's output quantity indexes, 2006–2017**



From figure 5.38 we see that, with the exception of CMOS, UED's output components exhibit a similar pattern of change to the industry as a whole. Customer numbers increased steadily over the period and were 11 per cent higher in 2017 than they were in 2006, a noticeably smaller increase than the industry's increase of 16 per cent. Energy throughput for distribution peaked in 2012 and was 1 per cent lower in 2017 than it was in 2006.

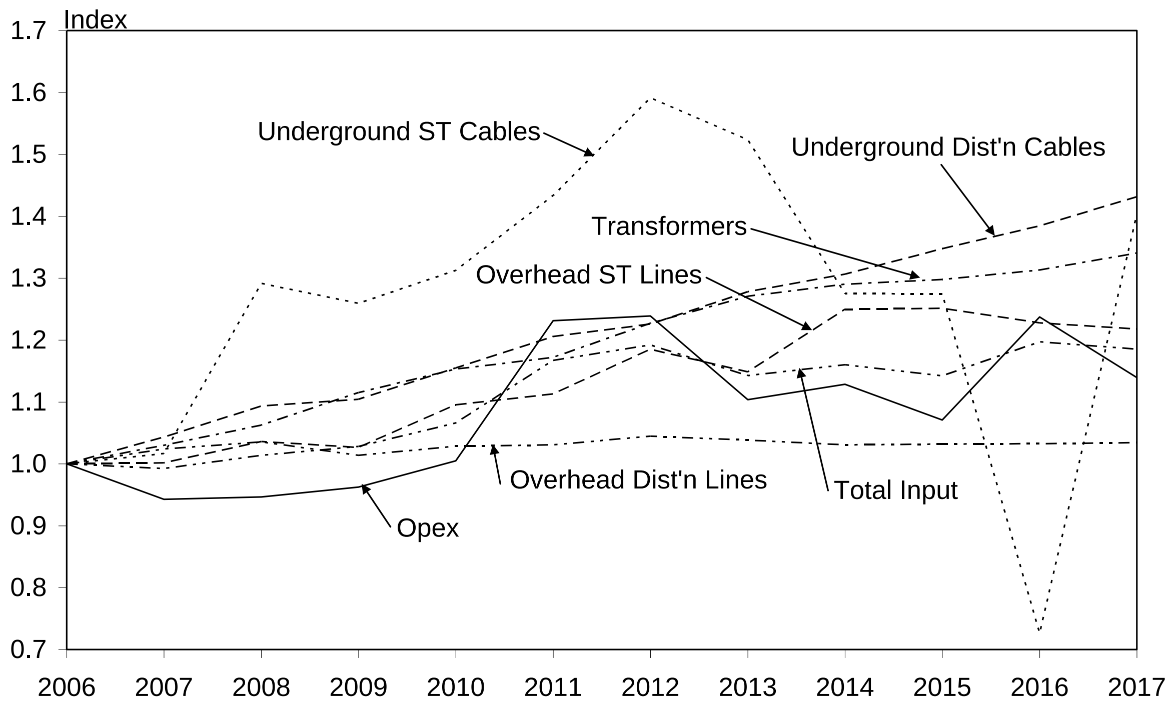
UED's maximum demand reached its highest level in 2014 but has been relatively volatile since a slightly lower peak in 2009. In 2017 it was around 15 per cent above its 2006 level. Ratcheted maximum demand in 2017 was 24 per cent above its 2006 level – a larger increase than the industry's 17 per cent.

UED's circuit length output grew slightly more over the 12 years than occurred for the industry overall and by 2016 was 8 per cent above the level it was in 2006 compared to an increase of 4 per cent for the industry.

The last output shown in figure 5.38 is total CMOS. UED's CMOS has been more volatile than for the industry and has trended upwards over the period as a whole. It trended upwards strongly from 2006 to 2014 but has trended downwards since then. In 2017 UED's CMOS was 6 per cent lower than it was in 2006 but it had been 66 per cent above its 2006 level in 2014.

Since the customer numbers and ratcheted maximum demand outputs receive a weight of around 60 per cent of gross revenue in forming the total output index, in figure 5.38 we see that the total output index lies close to but mostly below these two output indexes. The circuit length and energy output indexes lie at a lower level in some years and the CMOS index would generally lie well below the other output indexes when it enters the formation of total output as a negative output (ie the increase in CMOS over the period makes a negative contribution to total output). The CMOS decrease in 2017 and a coinciding increase in circuit length are the main reasons for stronger total output growth in the latest year.

Figure 5.39 **UED's input quantity indexes, 2006–2017**



Turning to the input side, we see from UED's six input components and total input in figure 5.39 that the quantity of UED's opex was relatively flat through to 2010 but then increased sharply in 2011. For UED, opex increased by 24 per cent up to 2012 – considerably less than the corresponding increase for the industry of 36 per cent. Since then UED's opex initially decreased but then returned to its 2012 level in 2016 and then decreased again in 2017. This took UED's opex change between 2006 and 2017 to be a little better than for the industry, albeit with a different pattern between these two endpoints. Opex has the largest average share in UED's total costs at 39 per cent and so is an important driver of its total input quantity index.

UED's underground distribution cables and transformers inputs increased more steadily over the period but at somewhat lower rates than for the industry as a whole. Its overhead distribution lines input increased over the period with an increase of 3 per cent by 2017 relative to 2006, similar to the increase for the industry.

From figure 5.39 we see that the total input quantity index lies close to the quantity indexes for opex, transformers and overhead distribution lines (which have a total share of 82 per cent of total costs). Total input quantity decreased by 1.0 per cent in 2017, driven mainly by the change in opex usage of 8.2 per cent.

UED's output and input contributions to TFP change

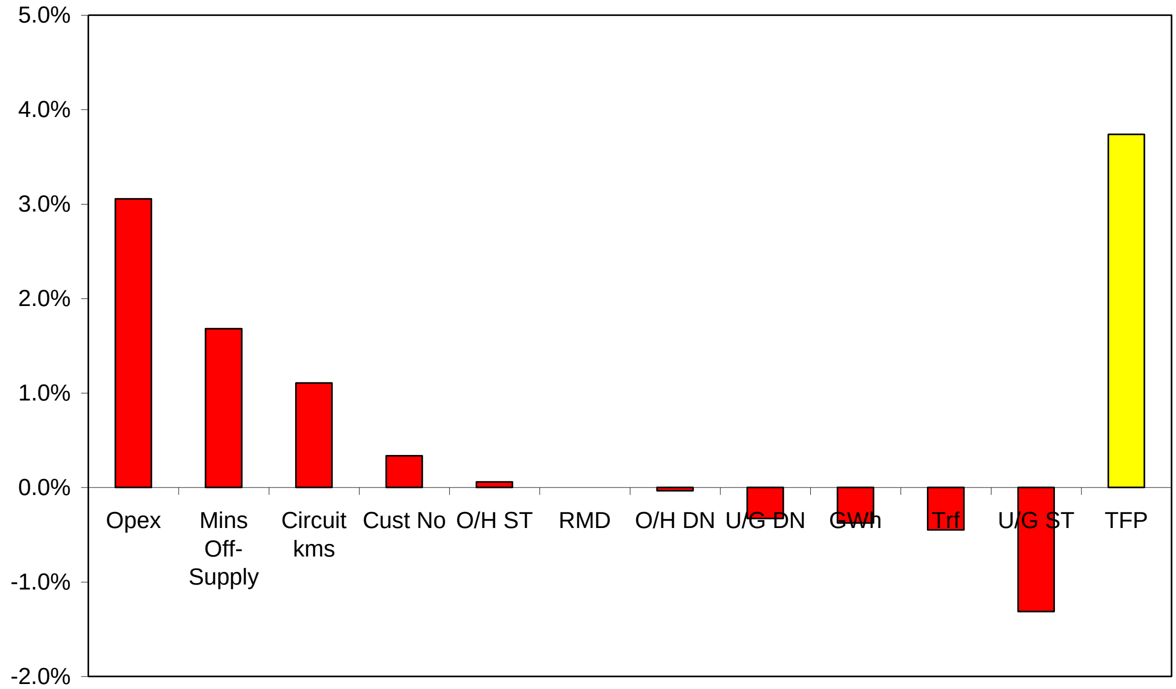
In table 5.20 we decompose UED's TFP change into its constituent output and input parts for the whole 12–year period and for the periods up to and after 2012. UED's drivers of TFP change for the whole 12–year period are broadly similar to the industry as a whole except that

CMOS makes a small negative contribution to TFP growth for UED whereas it is positive for the industry. Opex makes a smaller negative contribution over the period for UED at –0.4 percentage points compared to –0.6 for the industry. And transformer inputs make a less negative contribution to UED's TFP at –0.6 percentage points compared to –0.8 for the industry.

Table 5.20 **UED'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)	–0.01%	0.06%	–0.10%
Ratcheted Max Demand	0.61%	1.11%	0.02%
Customer Numbers	0.30%	0.31%	0.29%
Circuit Length	0.21%	0.18%	0.25%
CMOS	–0.03%	–0.86%	0.97%
Opex	–0.43%	–1.38%	0.71%
O/H Subtransmission Lines	–0.13%	–0.20%	–0.05%
O/H Distribution Lines	–0.06%	–0.15%	0.04%
U/G Subtransmission Cables	–0.05%	–0.14%	0.06%
U/G Distribution Cables	–0.31%	–0.32%	–0.30%
Transformers	–0.56%	–0.74%	–0.35%
TFP Change	–0.46%	–2.13%	1.54%

Figure 5.40 **UED's output and input percentage point contributions to annual TFP change, 2017**



The UED situation is again a tale of two distinct periods. With the exceptions of CMOS and circuit length, the contribution of outputs to TFP falls after 2012 compared to the period before 2012. And the contribution of all inputs becomes either positive or less negative. Opex change went from a negative percentage point contribution to TFP of –1.4 percentage points to a positive contribution of 0.7 percentage points.

The importance of UED's reductions in opex and in CMOS in 2017 is highlighted in figure 5.40 where opex made a 3.1 percentage point contribution to TFP change in the 2017 year and CMOS made a 1.7 percentage point contribution. Circuit length output also made a 1.1 percentage point contribution. The main negative contribution was from underground subtransmission inputs with –1.3 percentage points. UED's TFP change in 2017 was 3.7 per cent compared to industry TFP growth of 2.7 per cent in that year.

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

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.

A4 Leontief cost function output cost shares

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

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

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

The estimating equations were the M input demand equations:

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

where the i's represent the M inputs, the j's the N outputs and t is a time trend representing the 12 years, 2006 to 2017.

The input demand equations were estimated separately for each of the 24 DNSPs using the non–linear regression facility in Shazam (Northwest Econometrics 2007) and data for the years 2006 to 2017. Given the absence of cross equation restrictions, each input demand equation is estimated separately.

We then derive the output cost shares for each output and each observation as follows:

(7) $$h_j^t = \{\sum_{i=1}^{M} w_i^t [(a_{ij})^2 y_j^t (1 + b_i t)]\} / \{\sum_{i=1}^{M} w_i^t [\sum_{j=1}^{N} (a_{ij})^2 y_j^t (1 + b_i t)]\} .$$

We then form a weighted average of the estimated output cost shares for each observation to form an overall estimated output cost share where the weight for each observation, b, is given by:

(8) $$s_b^t = C(b, y_b^t, w_b^t, t) / \sum_{b,t} C(b, y_b^t, w_b^t, t) .$$

A4 Translog cost function output cost shares

To obtain extra information on output cost shares we also estimate a translog cost function across the Australian DNSP sample. This function has four outputs, one operating environment variable and a time trend. It has the following form:

(9) $$\ln C_{it} = b_0 + \sum_{m=1}^{4} b_m \ln y_{mit} + 0.5 \sum_{m=1}^{4} \sum_{l=1}^{4} b_{ml} \ln y_{mit} \ln y_{lit} + b_z \ln Z_{it} + b_t T + v_{it}$$

Where *i* is DNSP *i*, *t* is time period *t*, y_m is an output, *Z* is the operating environment variable and *T* is a time trend representing technological change.

The translog cost function is estimated using the POOL regression facility in Shazam (Northwest Econometrics 2007) and data for the 13 DNSPs for the years 2006 to 2017. This regression employs a set of assumptions on the disturbance covariance matrix that gives a cross–sectionally heteroskedastic and timewise autoregressive model using the Parks (1967) method. Parameter estimates are obtained by applying OLS to data transformed to correct for serial correlation. Panel corrected standard errors are then calculated and reported. A common cross–section autocorrelation coefficient, as recommended by Beck and Katz (1995), is used.

Output cost shares are derived from the share of the relevant first–order output coefficient in the sum of the first–order output coefficients.

APPENDIX B MTFP/MPFP RESULTS USING ORIGINAL WEIGHTS

In this appendix we present MTFP and MPFP index results using the original output cost share weights derived in Economic Insights (2014) for the information of those interested in comparing them with the results in section 3 using updated output cost share weights.

Figure B.1 **DNSP multilateral total factor productivity indexes using original output weights, 2006–2017**

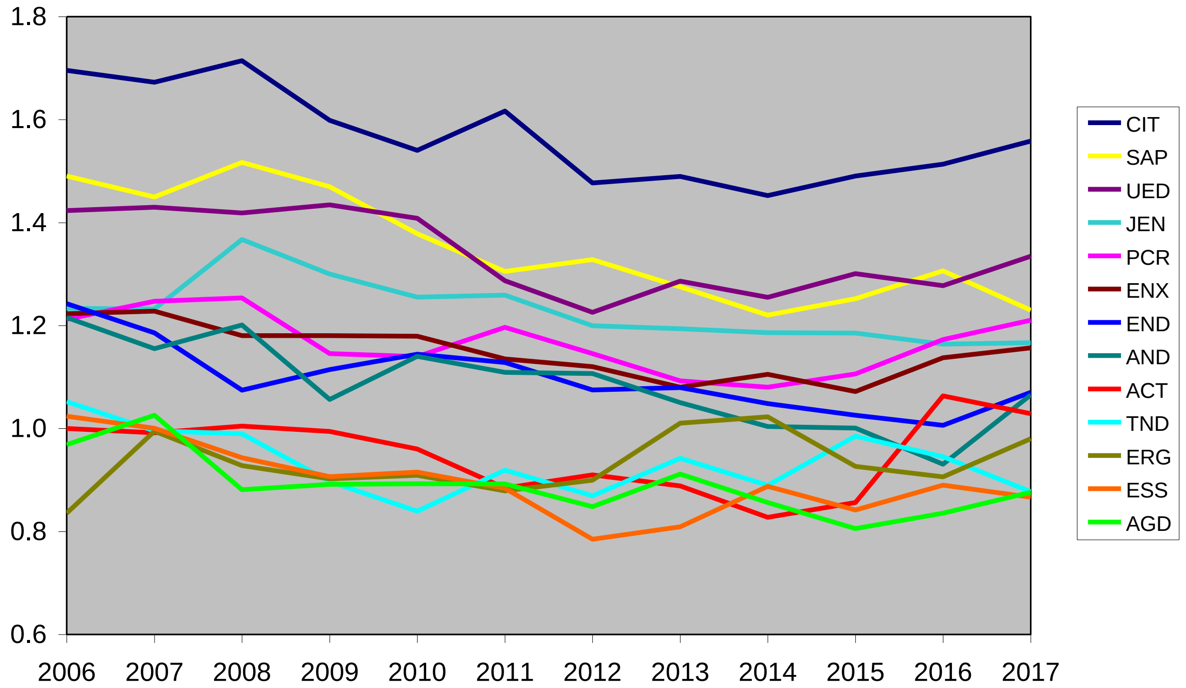


Table B.1 **DNSP multilateral total factor productivity indexes using original output weights, 2006–2017**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
ACT	1.000	0.992	1.005	0.994	0.960	0.884	0.910	0.889	0.828	0.856	1.063	1.029
AGD	0.969	1.026	0.881	0.892	0.893	0.892	0.848	0.912	0.856	0.806	0.836	0.876
AND	1.216	1.155	1.201	1.057	1.140	1.109	1.107	1.050	1.004	1.001	0.931	1.065
CIT	1.696	1.673	1.715	1.599	1.540	1.617	1.477	1.490	1.453	1.491	1.513	1.558
END	1.243	1.186	1.074	1.114	1.144	1.128	1.075	1.080	1.049	1.026	1.006	1.070
ENX	1.223	1.228	1.181	1.181	1.179	1.135	1.120	1.080	1.105	1.072	1.137	1.157
ERG	0.836	0.995	0.928	0.902	0.909	0.879	0.900	1.010	1.023	0.926	0.906	0.980
ESS	1.024	1.001	0.943	0.907	0.915	0.884	0.785	0.809	0.888	0.842	0.890	0.867
JEN	1.233	1.232	1.367	1.300	1.255	1.259	1.200	1.194	1.186	1.186	1.164	1.167
PCR	1.212	1.247	1.254	1.146	1.140	1.197	1.146	1.093	1.080	1.106	1.173	1.211
SAP	1.491	1.450	1.517	1.470	1.379	1.305	1.328	1.275	1.220	1.252	1.306	1.230
TND	1.052	0.996	0.990	0.897	0.840	0.919	0.869	0.942	0.890	0.985	0.945	0.877
UED	1.423	1.430	1.419	1.434	1.408	1.287	1.226	1.286	1.255	1.301	1.278	1.335

Figure B.2 **DNSP multilateral opex partial productivity indexes using original output weights, 2006–2017**

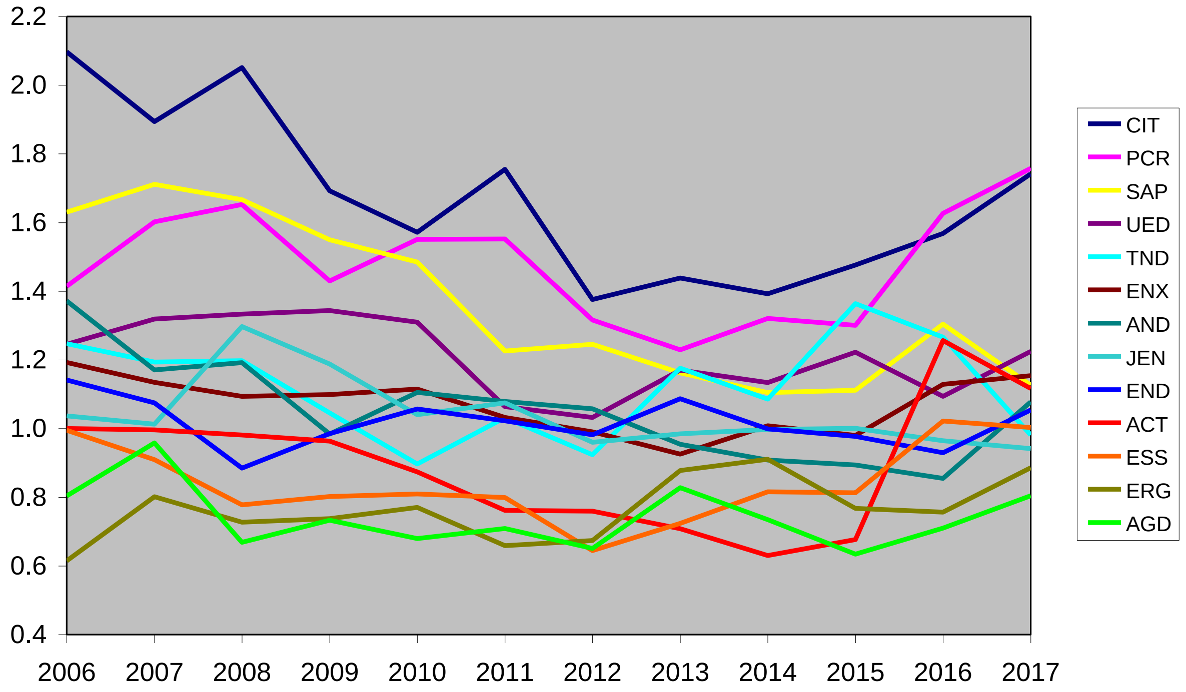


Table B.2 **DNSP multilateral opex partial productivity indexes using original output weights, 2006–2017**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
ACT	1.000	0.996	0.981	0.963	0.874	0.762	0.760	0.709	0.630	0.677	1.257	1.117
AGD	0.804	0.959	0.669	0.733	0.680	0.709	0.651	0.828	0.735	0.634	0.710	0.805
AND	1.372	1.171	1.192	0.984	1.105	1.079	1.057	0.954	0.908	0.894	0.855	1.078
CIT	2.097	1.894	2.051	1.692	1.572	1.755	1.376	1.439	1.393	1.477	1.568	1.742
END	1.142	1.075	0.885	0.986	1.057	1.023	0.982	1.087	0.999	0.977	0.929	1.054
ENX	1.193	1.135	1.094	1.099	1.115	1.032	0.991	0.925	1.008	0.980	1.129	1.154
ERG	0.615	0.802	0.727	0.738	0.771	0.659	0.674	0.878	0.911	0.768	0.757	0.886
ESS	0.995	0.910	0.778	0.802	0.809	0.799	0.645	0.724	0.816	0.813	1.022	1.003
JEN	1.037	1.013	1.297	1.188	1.040	1.075	0.960	0.985	0.997	1.001	0.965	0.942
PCR	1.414	1.602	1.653	1.430	1.551	1.552	1.316	1.230	1.320	1.301	1.627	1.758
SAP	1.630	1.712	1.667	1.550	1.485	1.226	1.246	1.162	1.105	1.112	1.304	1.126
TND	1.247	1.194	1.198	1.046	0.897	1.032	0.924	1.176	1.086	1.364	1.266	0.981
UED	1.246	1.319	1.333	1.343	1.310	1.064	1.032	1.170	1.134	1.223	1.094	1.225

Figure B.3 **DNSP multilateral capital partial productivity indexes using original output weights, 2006–2017**

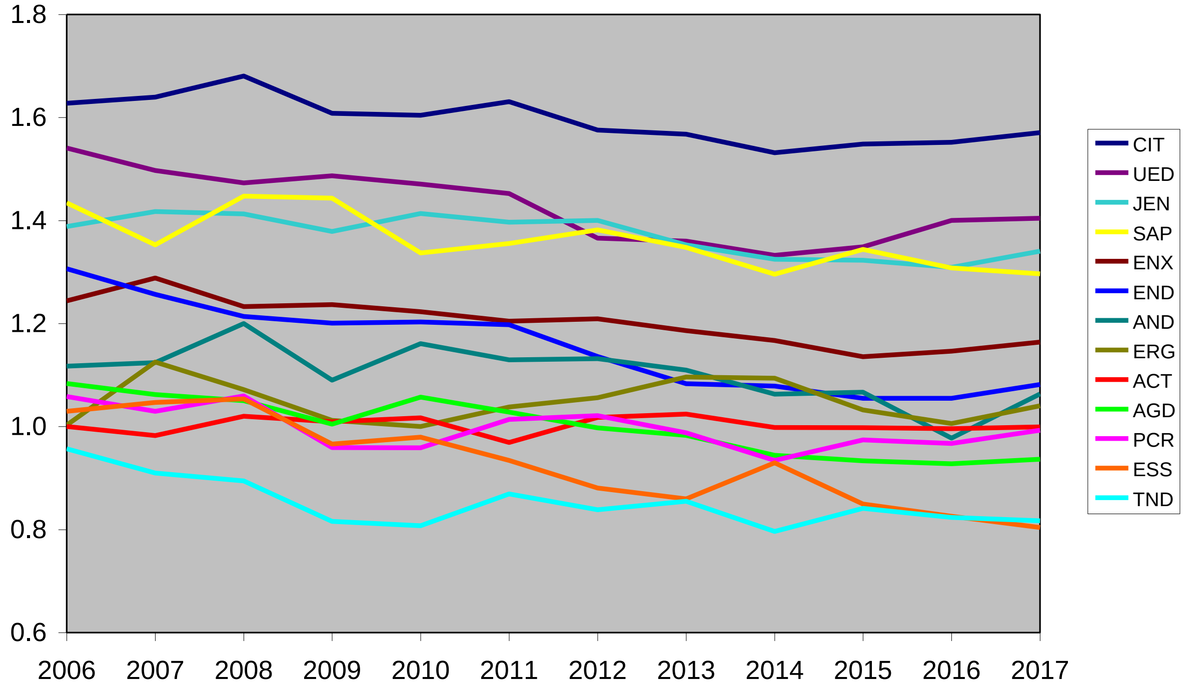


Table B.3 **DNSP multilateral capital partial productivity indexes using original output weights, 2006–2017**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
ACT	1.000	0.983	1.020	1.009	1.017	0.969	1.018	1.024	0.998	0.998	0.996	0.999
AGD	1.084	1.062	1.050	1.005	1.057	1.028	0.997	0.983	0.944	0.934	0.928	0.937
AND	1.117	1.124	1.200	1.090	1.161	1.130	1.132	1.110	1.063	1.067	0.977	1.063
CIT	1.628	1.640	1.681	1.608	1.604	1.631	1.576	1.568	1.532	1.549	1.552	1.571
END	1.307	1.257	1.214	1.201	1.203	1.198	1.136	1.083	1.079	1.055	1.055	1.082
ENX	1.244	1.289	1.233	1.237	1.223	1.205	1.209	1.186	1.167	1.136	1.146	1.164
ERG	1.003	1.126	1.072	1.012	1.000	1.038	1.056	1.096	1.094	1.032	1.006	1.040
ESS	1.030	1.047	1.054	0.966	0.979	0.934	0.881	0.860	0.930	0.850	0.826	0.804
JEN	1.388	1.418	1.413	1.379	1.414	1.397	1.400	1.353	1.325	1.323	1.309	1.341
PCR	1.058	1.030	1.059	0.959	0.959	1.014	1.021	0.988	0.934	0.974	0.967	0.993
SAP	1.434	1.353	1.447	1.444	1.337	1.356	1.382	1.348	1.296	1.344	1.308	1.297
TND	0.957	0.910	0.895	0.816	0.808	0.869	0.839	0.855	0.796	0.841	0.824	0.817
UED	1.541	1.497	1.473	1.487	1.471	1.452	1.366	1.360	1.332	1.349	1.400	1.404

Figure B.4 **DNSP average opex cost efficiency scores using original output weights for MPFP, 2012–2017**

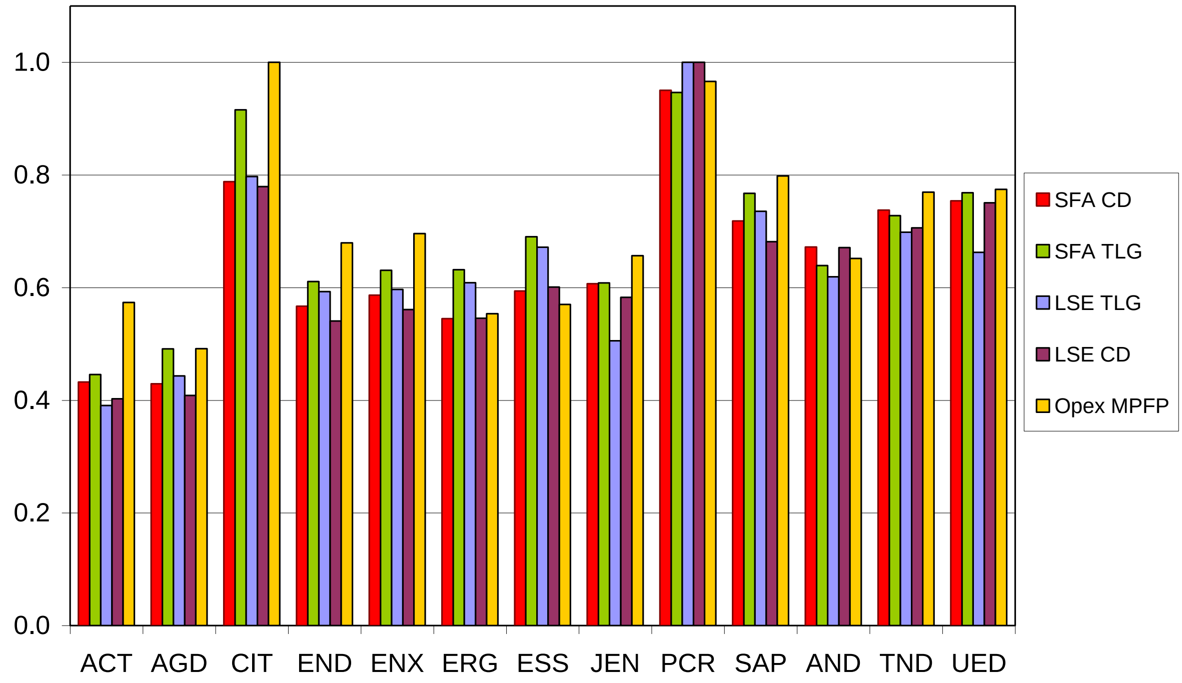


Table B.4 **DNSP average opex cost efficiency scores using original output weights for MPFP, 2012–2017**

DNSP	*SFACD*	*SFATLG*	*LSETLG*	*LSECD*	*Opex MPFP*
ACT	0.432	0.446	0.391	0.403	0.574
AGD	0.429	0.491	0.443	0.408	0.492
CIT	0.788	0.916	0.797	0.779	1.000
END	0.567	0.611	0.593	0.541	0.679
ENX	0.587	0.631	0.597	0.561	0.696
ERG	0.545	0.632	0.609	0.546	0.554
ESS	0.594	0.690	0.672	0.601	0.570
JEN	0.607	0.608	0.506	0.583	0.657
PCR	0.950	0.946	1.000	1.000	0.966
SAP	0.718	0.767	0.736	0.681	0.798
AND	0.672	0.639	0.619	0.671	0.652
TND	0.738	0.728	0.698	0.706	0.770
UED	0.754	0.769	0.663	0.751	0.775

Figure B.5 **DNSP average opex cost efficiency scores using original output weights for MPFP, 2006–2017**

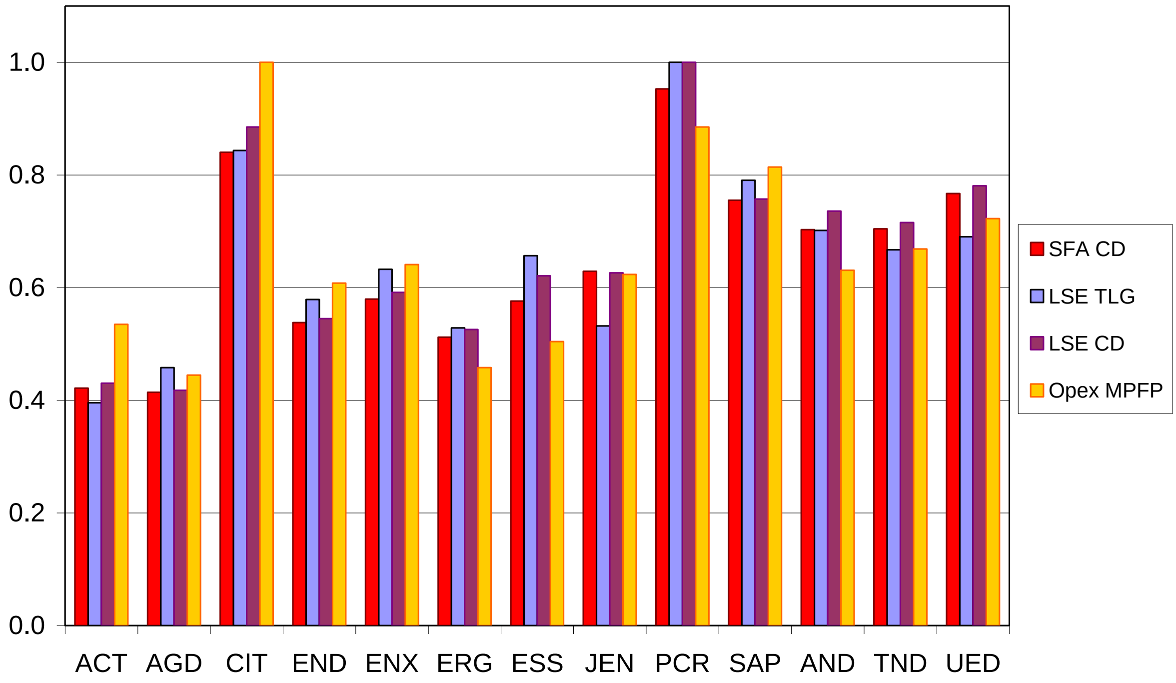


Table B.5 **DNSP average opex cost efficiency scores using original output weights for MPFP, 2006–2017**

DNSP	*SFACD*	*SFATLG*	*LSETLG*	*LSECD*	*Opex MPFP*
ACT	0.432	0.446	0.391	0.403	0.535
AGD	0.429	0.491	0.443	0.408	0.445
CIT	0.788	0.916	0.797	0.779	1.000
END	0.567	0.611	0.593	0.541	0.608
ENX	0.587	0.631	0.597	0.561	0.641
ERG	0.545	0.632	0.609	0.546	0.458
ESS	0.594	0.690	0.672	0.601	0.504
JEN	0.607	0.608	0.506	0.583	0.623
PCR	0.950	0.946	1.000	1.000	0.885
SAP	0.718	0.767	0.736	0.681	0.814
AND	0.672	0.639	0.619	0.671	0.631
TND	0.738	0.728	0.698	0.706	0.669
UED	0.754	0.769	0.663	0.751	0.723

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