Economic Benchmarking Results for the Australian Energy Regulator's 2019 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	Evoenergy	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

OTHER ABBREVIATIONS

Abbreviation	*Description*
AEMO	Australian Energy Market Operator
AUC	Annual user cost of capital
CAM	Cost allocation methodology
CMOS	Customer minutes off supply
DNSP	Distribution network service provider
EBRIN	Economic Benchmarking Regulatory Information Notice
LSECD	Least squares econometrics Cobb–Douglas model
LSETLG	Least squares econometrics translog model
MPFP	Multilateral partial factor productivity
MTFP	Multilateral total factor productivity
MVA	Megavolt ampere
MVAkms	Megavolt ampere kilometres
NEM	National Electricity Market
PFP	Partial factor productivity
RMD	Ratcheted maximum demand
SFACD	Stochastic frontier analysis Cobb–Douglas model
SFATLG	Stochastic frontier analysis translog model
TFP	Total factor productivity
VCR	Value of customer reliability

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 2018 DNSP Benchmarking Report (AER 2018). 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 2017–18 financial and 2018 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 corrections to 2017 opex data for one group of DNSPs and further refinement of MVA factors for lines and cables.

We also update and expand the opex cost function econometric results presented in Economic Insights (2014a, 2015a,b, 2017, 2018) to include 2017–18 or 2018 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 13–year period from 2006 onwards as well as for the 7–year period from 2012 onwards.

1.1 Methods used for productivity and efficiency measurement

In this report we use three broad types of economic benchmarking techniques to measure DNSPs' productivity growth and efficiency levels: time–series TFP indexes; time–series, cross–section MTFP indexes; and, econometric opex cost functions.

We use the Törnqvist time–series TFP index to measure productivity growth at the Australian industry, State and individual DNSP levels. This index provides a second order approximation to any underlying production structure. This means it can accurately model both the level and shape of the underlying production function. It provides the most accurate measure of productivity growth over time and provides a convenient way of decomposing overall TFP growth into components due to changes in individual outputs and inputs. However, it cannot be used to measure productivity levels across DNSPs because it does not satisfy some other technical properties required for invariant cross–sectional comparisons.

The Multilateral TFP index was developed to satisfy these technical properties and, hence, allow invariant cross–sectional comparisons and this is the second economic benchmarking method used in this report. It is a more complex indexing procedure than the Törnqvist time–series index and makes all comparisons via the sample mean. This ensures that a comparison between any two observations in the sample is invariant to whether the comparison is made directly or indirectly via any number of other observations.

We adopt a 'functional' rather than 'billed' approach to measuring outputs in the TFP and MTFP methods. As DNSPs operate in largely non–competitive environments, charging practices have often evolved on an ease of implementation basis rather than being cost–

reflective of the key aspects of supply valued by customers or considered by regulators in establishing revenue requirements. As result items charged for by the DNSP and associated revenue shares do not necessarily provide a good guide to what customers value and what regulators allow funds for. The functional outputs approach identifies key high level outputs valued by customers and considered in the setting of building blocks revenue requirements. To weight these outputs together in the indexing method we require a set of cost–reflective output shares. These are derived from a simple Leontief cost function model with corroboration from separate estimation of a translog cost function model using the full sample of Australian DNSPs.

The DNSP TFP and MTFP 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 TFP and MTFP 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.

Technical details of the TFP and MTFP indexes are presented in appendix A.

The TFP and MTFP indexes are both non–parametric methods. This means they adopt a mechanical approach and so have the important advantage that they are not dependent on sample size and can be accurately applied to as few as two observations. To allow for noise in the data and to provide information on associated confidence intervals, we need to move to parametric or statistical methods and so our third economic benchmarking method is the estimation of econometric opex cost function models. We estimate opex cost function models rather than total cost function models as opex efficiency assessment is a key component of implementing building blocks regulation. To implement these parametric models sample size and data variation become important considerations.

The four opex cost function models estimated for this report are:

- 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)
- a stochastic frontier analysis model using the Cobb–Douglas functional form (SFACD), and
- a stochastic frontier analysis model using the translog functional form (SFATLG).

A technical description of the models can be found in appendix A and Economic Insights (2014a). 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.

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.

1.2 Data revisions

In line with previous practice, all Australian DNSPs' data for all years are based on the cost allocation methodologies (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.

This year a number of revisions have been made to the Australian, New Zealand and Ontario data.

For Australia, the AER was notified in December 2018 that three Victorian DNSPs – CIT, PCR and UED – had submitted incorrect opex data for the 2017 year in their April 2018 EBRINs.[1] The three DNSPs had incorrectly capitalised some inspection and maintenance costs instead of expensing them as required under their EBRIN reporting. This correction has led to CIT's 2017 opex being 10 per cent higher than initially reported, PCR's 2017 opex being 15 per cent higher than initially reported and UED's 2017 opex being 4 per cent lower than initially reported. Consequently, there are material differences between the 2017 productivity performance of these three DNSP's reported here compared to Economic Insights (2018).

Corrections have also been made to the opex data of a fourth Victorian DNSP, AND. The first change involves the exclusion of opex for connections services which AND had incorrectly included over 2006 to 2017. The second change reflects the exclusion of opex for transmission connection planning which AND had incorrectly included over 2006 to 2015. And the third change involves the addition of taxes and levies which AND had incorrectly omitted for 2016 and 2017. The first and second changes are relatively small but the third change leads to AND's opex increasing by around 7 per cent in 2016 and 2017.

There have also been further minor refinements to selected MVA factors for lines and cables, mainly for AND.

We have also undertaken an audit of the New Zealand and Ontario components of our database in conjunction with assessing how to best allow for an important amalgamation of several Ontario DNSPs which took place in 2017.

For New Zealand, it was noted that the Commerce Commission shifted from reporting end–year customer numbers to average customer numbers from 2013 onwards in its latest Information Disclosure Data and this had not been fully allowed for in our database. Consequently, we now include actual average customer numbers for New Zealand DNSPs for 2013 onwards and estimated average customer numbers for 2012 and earlier years. Estimated average customer numbers are formed by averaging the current and preceding year end–year customer numbers.

We also noted that until now we have updated the New Zealand DNSPs' opex series used in Economic Insights (2014b) by proportional changes in the Commerce Commission's Information Disclosure Data opex for 2013 onwards. To align our database with the latest official regulatory data, we now reverse this process by using the Commerce Commission's Information Disclosure Data opex series for 2013 onwards and index this back before 2013 using annual changes in the Economic Insights (2014b) opex series which corrected for inclusion of customer rebates and similar items in the opex reported in early versions of the Information Disclosure Data.

[1] Email from Powercor to the AER titled 'Restated RIN data' dated 7 December 2018.

We have also reviewed our treatment of the Vector (Auckland) and Wellington DNSPs. These were originally one DNSP but Vector spun off the Wellington network in 2009. Until now we have continued the treatment of these DNSPs adopted in Economic Insights (2014b) which involved aggregating them together from 2009 onwards to be consistent for all years with the situation that applied before 2009. This was done in Economic Insights (2014b) to maintain a balanced database and noting that the database in that case started in 1996. In our current database the aggregated entity only existed for the first three years, from 2006 to 2008. Given that these have now been separate DNSPs for 10 years, we think it is better to include them as separate entities. This involves splitting the first 3 years of the previous aggregate DNSP into current Vector and Wellington equivalents based on 2009 shares for each variable. This is consistent with our move to align the New Zealand data with current Information Disclosure Data reporting and reflects the current structure of the New Zealand industry as it has existed for the last decade. Consequently, we now have 19 New Zealand DNSPs instead of the previous 18.

Our audit of the Ontario DNSP data has identified one issue requiring correction for 2016 opex. For the Economic Insights (2018) update we drew on Ontario Energy Board (2017) Yearbook data. This did not include some minor adjustments to opex included in Pacific Economic Group (2018) which we have otherwise drawn on. These adjustments included removing items such as amortisation of smart meters. To be consistent with earlier years, these adjustments have now been included for 2016 and result in quite small reductions in 2016 opex for most Ontario DNSPs.

A more significant issue affecting Ontario DNSP data in recent years has been that of DNSP amalgamations. There have been three sets of amalgamations since 2015. Before considering these, it is worth noting that the 'medium' database used for our opex cost function estimation initially included the 37 largest Ontario DNSPs by customer number (based on 2012 data). The first set of amalgamations involved Hydro One, by far the largest Ontario DNSP, acquiring three quite small DNSPs – Norfolk (ranked 38th) in 2015, and then Haldimand (ranked 35th) and Woodstock (ranked 42nd) in 2016. The second amalgamation involved the mid–sized Cambridge and North Dumfries (ranked 16th) acquiring the very small Brant County (ranked 51st). The best way of handling these amalgamations has been to add the very small acquired DNSPs back into the large acquirers over the whole period as they generally only make a marginal difference to the much larger acquirers and would generally not otherwise be in our database. We continue this treatment for these first two sets of amalgamations.

The third set of amalgamations is of a very different nature. In 2017 four of the larger Ontario DNSP – Powerstream (ranked 3rd), Horizon (ranked 5th), Enersource (ranked 6th) and Hydro One Brampton (ranked 8th) – amalgamated to form Alectra which is now the second largest Ontario DNSP. Given that the difference between Alectra and each of its four component DNSPs is quite large, we include the four component DNSPs separately for 2005 to 2016 and then include Alectra from 2017 onwards.

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, 2006–2018**

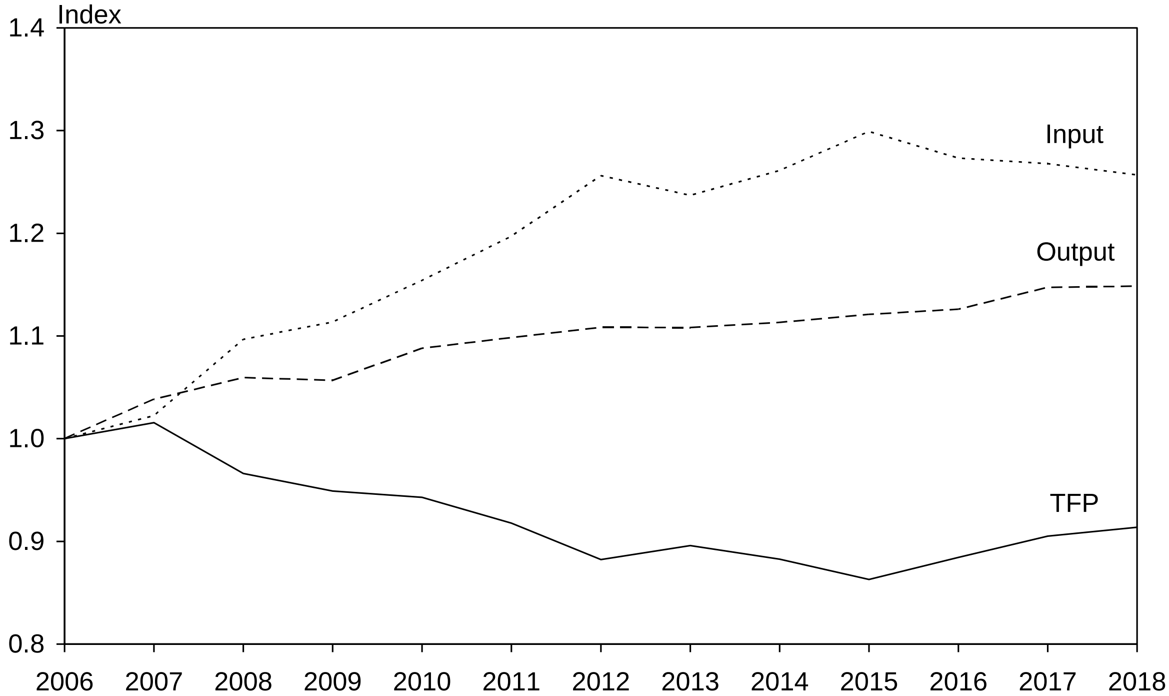


Table 2.1 **Industry–level distribution output, input and total factor productivity and partial productivity indexes, 2006–2018**

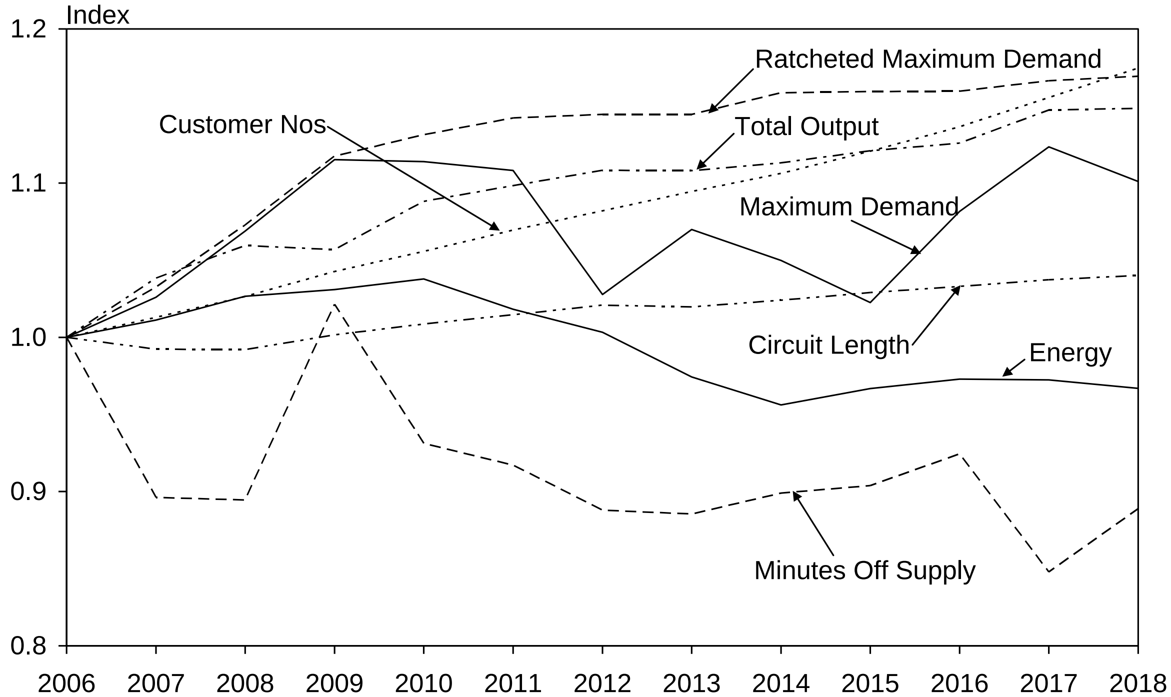
Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index Opex*	*PFP Index Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.038	1.022	1.016	1.042	0.999
2008	1.060	1.097	0.966	0.928	0.992
2009	1.057	1.114	0.949	0.938	0.957
2010	1.088	1.154	0.943	0.926	0.954
2011	1.098	1.197	0.918	0.881	0.940
2012	1.108	1.256	0.882	0.815	0.925
2013	1.108	1.237	0.896	0.884	0.905
2014	1.113	1.261	0.883	0.876	0.888
2015	1.121	1.299	0.863	0.838	0.881
2016	1.126	1.273	0.884	0.913	0.871
2017	1.147	1.268	0.905	0.957	0.880
2018	1.149	1.257	0.914	1.002	0.871
Growth Rate 2006–18	1.15%	1.91%	–0.75%	0.02%	–1.16%
Growth Rate 2006–12	1.72%	3.80%	–2.09%	–3.41%	–1.30%
Growth Rate 2012–18	0.59%	0.01%	0.58%	3.45%	–1.01%

Over the 13–year period 2006 to 2018, industry level TFP declined at an average annual rate of 0.8 per cent. Although total output increased at an average annual rate of 1.2 per cent, total input use increased faster, at a rate of 1.9 per cent. Since the average rate of change in TFP is the average rate of change in total output less the average rate of change in total inputs, this produced a negative average rate of productivity change. TFP change was, however, positive in five years – 2007, 2013, 2016, 2017 and again in 2018. In the first of these years, input use increased but at less of a rate than output increased, while in 2013, 2016, 2017 and 2018 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, 2006–2018**



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 18 per cent higher in 2018 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 2018 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, before reducing again in 2018. In 2018 overall ratcheted maximum demand was 17 per cent above its 2006 level.

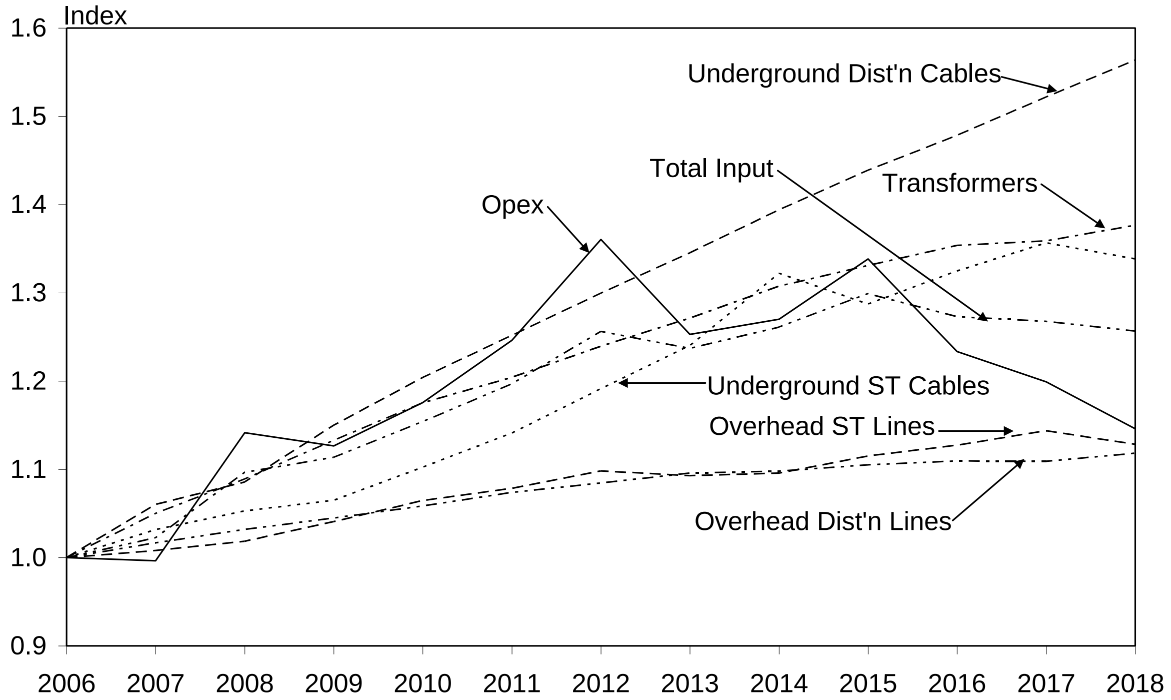
The circuit length output grew very modestly over the 13 years and by 2018 was only 4 per cent higher than it was in 2006. This reflects the fact that most of the increase in customer numbers over the period has been able to be accommodated by 'in fill' off the existing network that does not require 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 2018 CMOS was 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 2.2 we see that the total output index tends to lie close to 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 3 per cent in 2017 and by 4 per cent in 2018 at which time it was 15 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, 2006–2018**



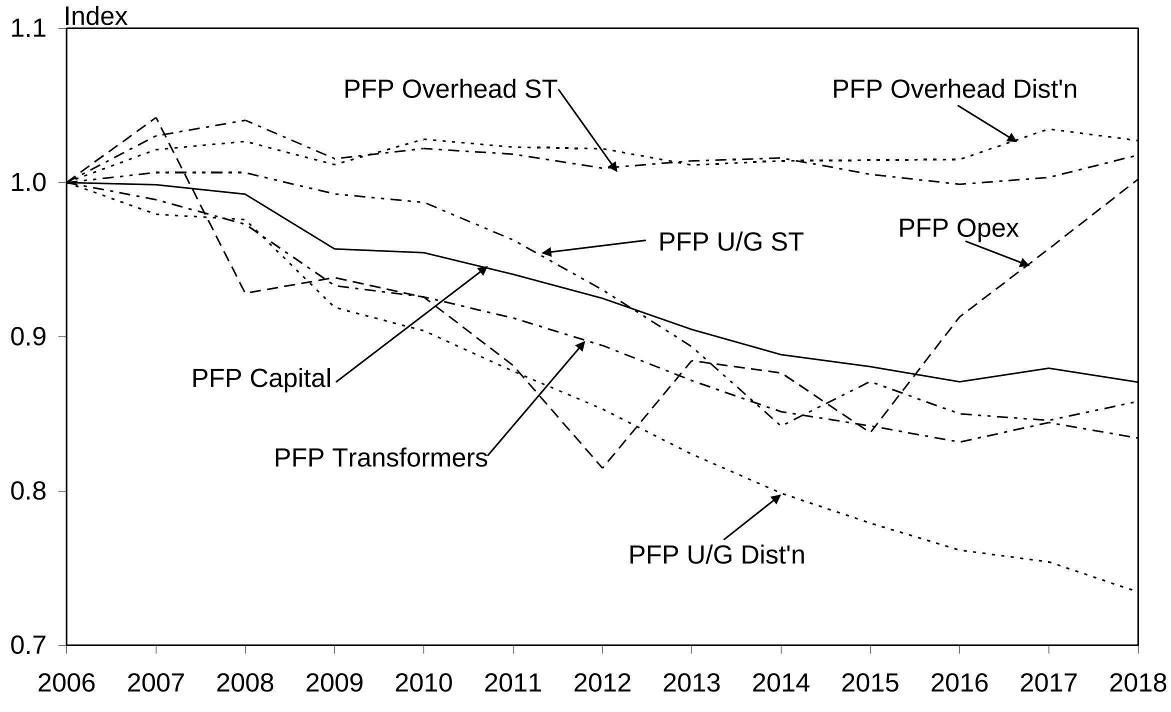
The other input component with a large average share of total cost, at 29 per cent, is transformers. The quantity of transformers has increased steadily over the period and by 2018 was 38 per cent above its 2006 level. It is by the use of more or larger transformers in zone substations and on the existing 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 2018 around 12 and 13 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 56 per cent higher in 2018 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, 2006–2018**

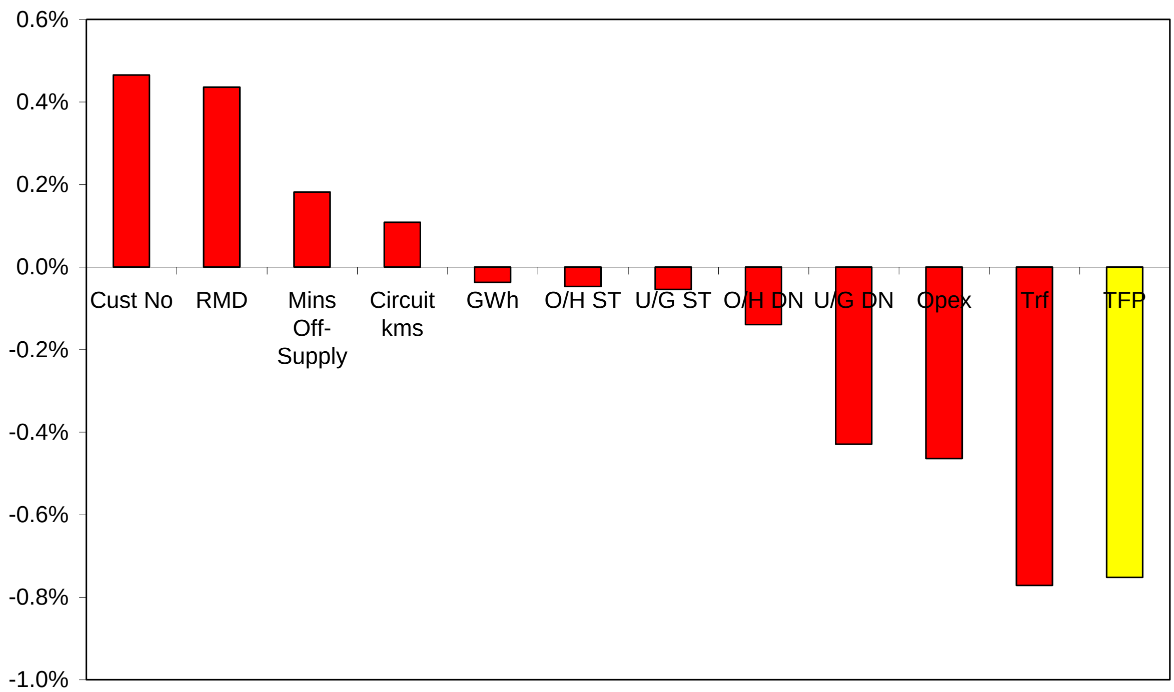


From figure 2.4 we see that movements in distribution industry–level partial productivity indexes follow an essentially inverse pattern to input quantities (since a partial productivity index is total output quantity divided by the relevant input quantity index). Overhead lines partial productivity indexes are consequently the highest over the period, although the level of overhead distribution lines partial productivity was only 3 per cent higher in 2018 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 26 per cent lower in 2018 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 17 per cent lower in 2018 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 2018 had recovered to regain 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[2].

Figure 2.5 **Distribution industry output and input percentage point contributions to average annual TFP change, 2006–2018**



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 –0.8 per cent over the 13–year period

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

2006 to 2018. 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 customer numbers and RMD provided the highest positive contributions to TFP change over the 13–year period. As noted in the previous section, customer numbers have grown steadily by over 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 second highest contribution to TFP change comes from ratcheted maximum demand which, despite flattening out after 2011, had the second highest average annual output growth rate over the period of 1.3 per cent. Combined with its weight of around 32 per cent, this led to RMD also contributing just over 0.4 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 –1.0 per cent (ie reduction in CMOS which increases output), contributed 0.2 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 35 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 13–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 13–year period. Overhead subtransmission and distribution lines have the lowest average annual input growth rates of 1.0 per cent and 0.9 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 2.4 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.

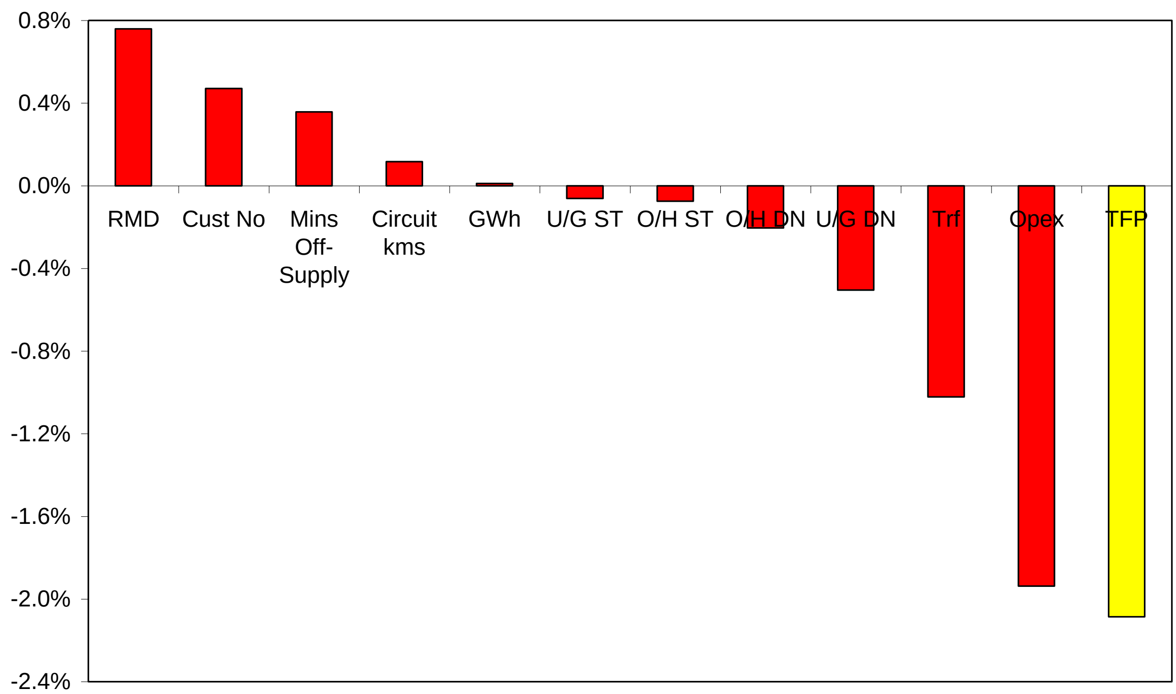
Underground distribution cables have the highest rate of average annual input growth over the period at 3.8 per cent but only get a weight of 12 per cent in the total input index. This gives them the third most negative contribution of –0.4 percentage points to TFP change.

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 2.7 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 1.1 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 –0.5 percentage points.

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

Year	*2006 to 2018*	*2006 to 2012*	*2012 to 2018*
Energy (GWh)	–0.04%	0.01%	–0.09%
Ratcheted Max Demand	0.44%	0.76%	0.11%
Customer Numbers	0.47%	0.47%	0.46%
Circuit Length	0.11%	0.12%	0.10%
CMOS	0.18%	0.36%	0.01%
Opex	–0.46%	–1.94%	1.01%
O/H Subtransmission Lines	–0.05%	–0.07%	–0.02%
O/H Distribution Lines	–0.14%	–0.20%	–0.08%
U/G Subtransmission Cables	–0.05%	–0.06%	–0.05%
U/G Distribution Cables	–0.43%	–0.51%	–0.35%
Transformers	–0.77%	–1.02%	–0.52%
TFP Change	–0.75%	–2.09%	0.58%

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

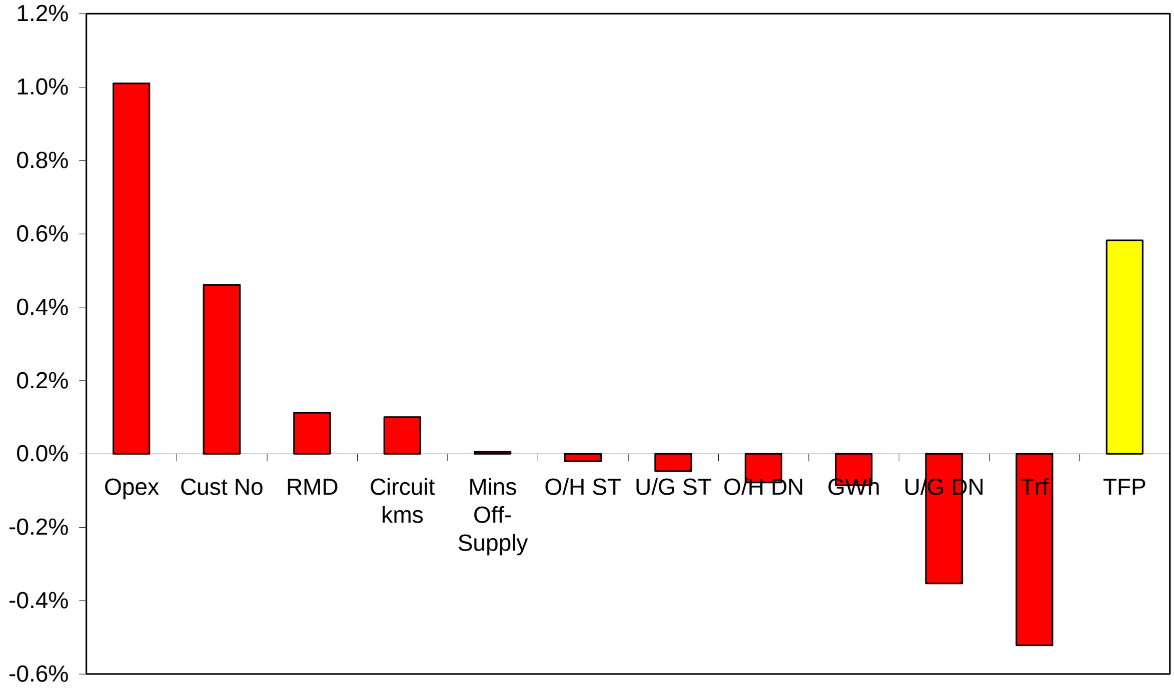


We next look at contributions to average annual TFP change for the period up to 2012 and then for the period after 2012. The results for the period from 2006 to 2012 are presented in figure 2.6 and table 2.2. Average annual TFP change for this period was more negative at

–2.1 per cent. 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, 2012–2018**



Contributions to average annual TFP change for the period from 2012 to 2018 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 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) determinations, 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 –0.5 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 zero 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, 2006–2018**

Year	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*
GWh	1.1%	1.5%	0.4%	0.7%	–1.9%	–1.5%	–2.9%	–1.9%	1.1%	0.6%	–0.1%	–0.6%
RMD	3.2%	3.8%	4.1%	1.2%	1.0%	0.2%	0.0%	1.2%	0.1%	0.0%	0.6%	0.3%
CustNo	1.3%	1.3%	1.6%	1.2%	1.3%	1.2%	1.1%	1.1%	1.3%	1.4%	1.7%	1.6%
Kms	–0.8%	0.0%	1.0%	0.7%	0.6%	0.6%	–0.1%	0.4%	0.5%	0.4%	0.4%	0.3%
CMOS	–11%	0%	13%	–9%	–2%	–3%	0%	2%	1%	2%	–9%	5%
Opex	–0.4%	13.6%	–1.3%	4.3%	5.8%	8.8%	–8.2%	1.4%	5.2%	–8.1%	–2.8%	–4.5%
O/HST	0.8%	1.0%	2.2%	2.3%	1.3%	1.8%	–0.5%	0.3%	1.7%	1.1%	1.4%	–1.3%
O/HDs	1.7%	1.5%	1.2%	1.3%	1.4%	1.0%	1.0%	0.2%	0.6%	0.4%	0.0%	0.8%
U/GST	3.1%	2.0%	1.1%	3.5%	3.4%	4.3%	4.0%	6.4%	–2.7%	2.9%	2.4%	–1.4%
U/GDs	5.8%	2.4%	5.8%	4.6%	3.9%	3.7%	3.5%	3.6%	3.2%	2.7%	2.9%	2.7%
Trform	4.9%	3.7%	3.9%	3.7%	2.4%	2.9%	2.5%	2.8%	1.8%	1.7%	0.4%	1.3%

Table 2.4 **Distribution industry output and input percentage point contributions to annual TFP change, 2006–2018**

Year	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*
GWh	0.2%	0.2%	0.1%	0.1%	–0.3%	–0.2%	–0.4%	–0.3%	0.2%	0.1%	0.0%	–0.1%
RMD	1.1%	1.3%	1.4%	0.4%	0.3%	0.1%	0.0%	0.4%	0.0%	0.0%	0.2%	0.1%
CustNo	0.5%	0.5%	0.6%	0.4%	0.5%	0.4%	0.4%	0.4%	0.4%	0.5%	0.6%	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%	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%	–0.5%
Opex	0.1%	–5.4%	0.5%	–1.6%	–2.1%	–3.2%	2.9%	–0.5%	–2.0%	3.0%	1.0%	1.6%
O/HST	0.0%	0.0%	–0.1%	–0.1%	–0.1%	–0.1%	0.0%	0.0%	–0.1%	–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%	–0.1%
U/GST	–0.1%	0.0%	0.0%	–0.1%	–0.1%	–0.1%	–0.1%	–0.2%	0.1%	–0.1%	–0.1%	0.0%
U/GDs	–0.7%	–0.3%	–0.7%	–0.5%	–0.5%	–0.4%	–0.4%	–0.4%	–0.3%	–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%	–0.4%
TFP	1.5%	–5.0%	–1.8%	–0.7%	–2.7%	–3.9%	1.5%	–1.5%	–2.3%	2.5%	2.3%	1.0%

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 2018. Taking 2018 as an example, the results are broadly similar to the average annual results for the period 2012 to 2018 described above, except for the contributions of opex and CMOS. Since there was a 4.5 per cent reduction in opex inputs in 2018 instead of the 2.9 per cent average annual reduction observed for the period after 2012, its percentage point contribution to TFP growth is considerably larger at 1.6 percentage points in 2018 instead of 1.0 percentage points. CMOS, on the other hand, increased by 4.7 per cent in 2018 compared to being relatively flat for the period after 2012 as a whole. This led to its contribution to TFP growth being –0.6 percentage points in 2018 compared to a marginally positive contribution for the period after 2012. TFP growth was itself higher in 2018 at 1.0 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 of the econometric opex cost function models in Economic Insights (2014, 2015a,b, 2018).

3.1 DNSP multilateral total and partial factor productivity indexes

Updated DNSP MTFP indexes are presented in figure 3.1 and table 3.1.

Figure 3.1 **DNSP multilateral total factor productivity indexes, 2006–2018**

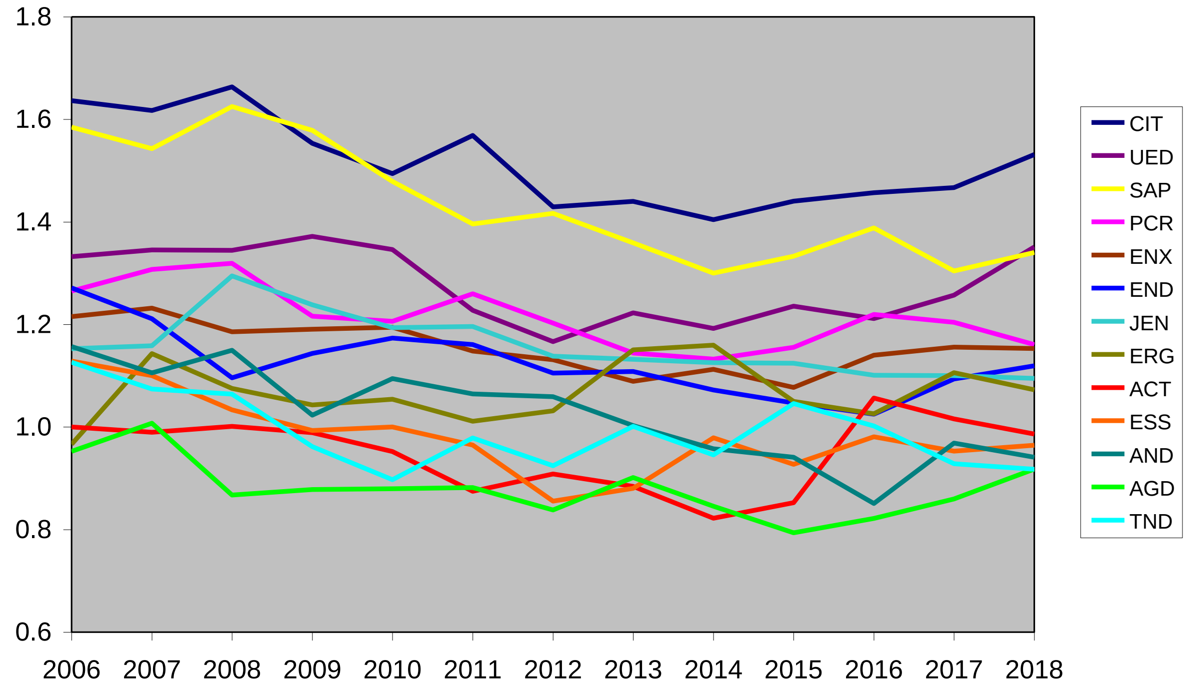


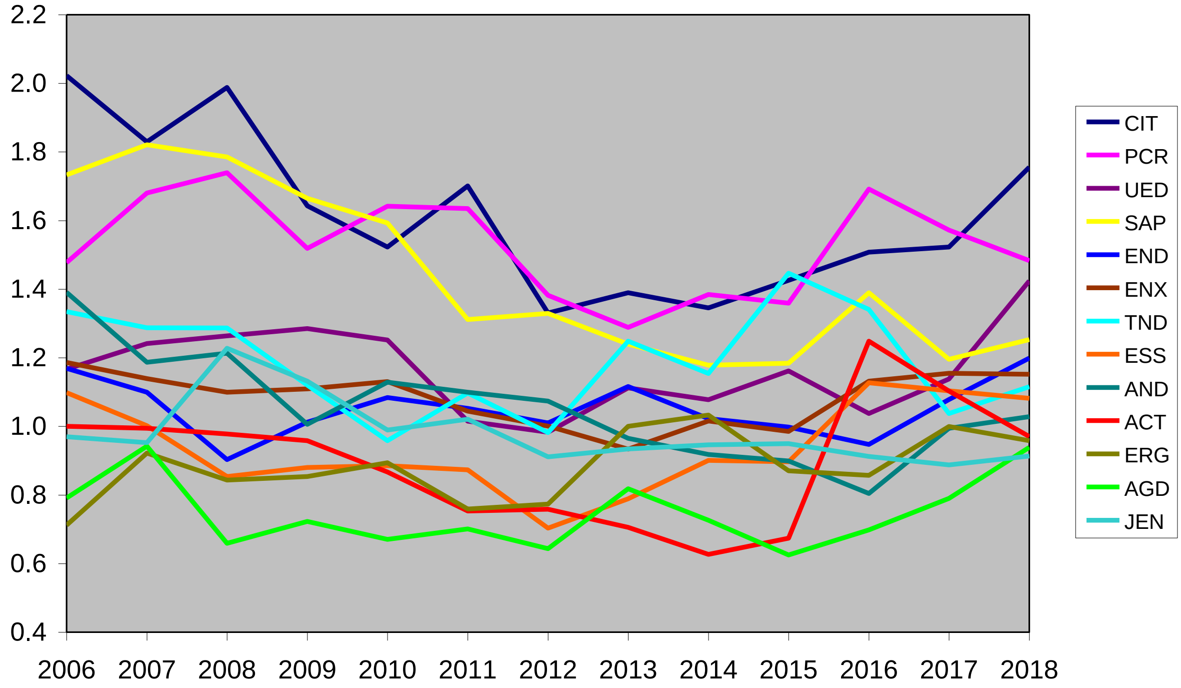
Table 3.1 **DNSP multilateral total factor productivity indexes, 2006–2018**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*
ACT	1.000	0.990	1.001	0.989	0.952	0.875	0.908	0.884	0.822	0.852	1.057	1.016	0.986
AGD	0.953	1.008	0.867	0.878	0.880	0.882	0.838	0.901	0.845	0.794	0.822	0.860	0.918
AND	1.157	1.106	1.150	1.023	1.095	1.065	1.059	1.003	0.958	0.941	0.851	0.969	0.941
CIT	1.637	1.617	1.664	1.553	1.494	1.569	1.430	1.440	1.404	1.440	1.457	1.467	1.532
END	1.271	1.211	1.096	1.144	1.174	1.161	1.105	1.108	1.072	1.047	1.025	1.094	1.120
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	1.153
ERG	0.966	1.143	1.075	1.043	1.054	1.011	1.032	1.151	1.160	1.050	1.026	1.106	1.073
ESS	1.129	1.100	1.034	0.993	1.000	0.965	0.856	0.880	0.979	0.927	0.981	0.953	0.964
JEN	1.153	1.159	1.295	1.239	1.194	1.196	1.138	1.132	1.126	1.125	1.101	1.100	1.095
PCR	1.265	1.307	1.319	1.216	1.206	1.260	1.203	1.144	1.132	1.155	1.220	1.204	1.161
SAP	1.585	1.543	1.625	1.579	1.479	1.396	1.417	1.359	1.300	1.333	1.389	1.305	1.341
TND	1.127	1.074	1.064	0.962	0.897	0.979	0.924	1.001	0.946	1.046	1.002	0.929	0.918
UED	1.333	1.345	1.345	1.372	1.346	1.228	1.167	1.223	1.192	1.236	1.212	1.257	1.351

In 2018 MTFP levels increased for six DNSPs and decreased for seven DNSPs. CIT, SAP, UED and END all lie in the upper half of MTFP levels and increased their productivity levels in 2018. ESS and AGD also increased their MTFP levels. In particular, all three NSW DNSPs increased their MTFP levels as earlier staffing reductions became more fully reflected in their opex with the reduction in redundancy payments. Relative to 2017, END improved its ranking by two places while ESS and AGD each improved their MTFP rankings by one place. On average, the increases in MTFP levels in 2018 were notably larger than the decreases, reflecting the positive TFP growth for the industry in 2018 of 1.0 per cent discussed in section 2.

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

Figure 3.2 **DNSP multilateral opex partial productivity indexes, 2006–2018**



From figure 3.2 we see six DNSPs – UED, AGD, CIT, END, TND and SAP – increased their 2018 opex MPFP levels by 5 per cent or more. The first three of these – UED, AGD and CIT – increased their opex MPFP levels by over 15 per cent while END increased its opex MPFP level by over 11 per cent. Another two DNSPs – AND and JEN – increased their opex MPFP levels by more than 2 per cent. ENX's opex MPFP level was relatively flat in 2018 while the opex MPFP levels of another two DNSPs – ESS and ERG – fell by less than 5 per cent. Only the remaining two DNSPs – ACT and PCR – had opex MPFP reductions of over 5 per cent.

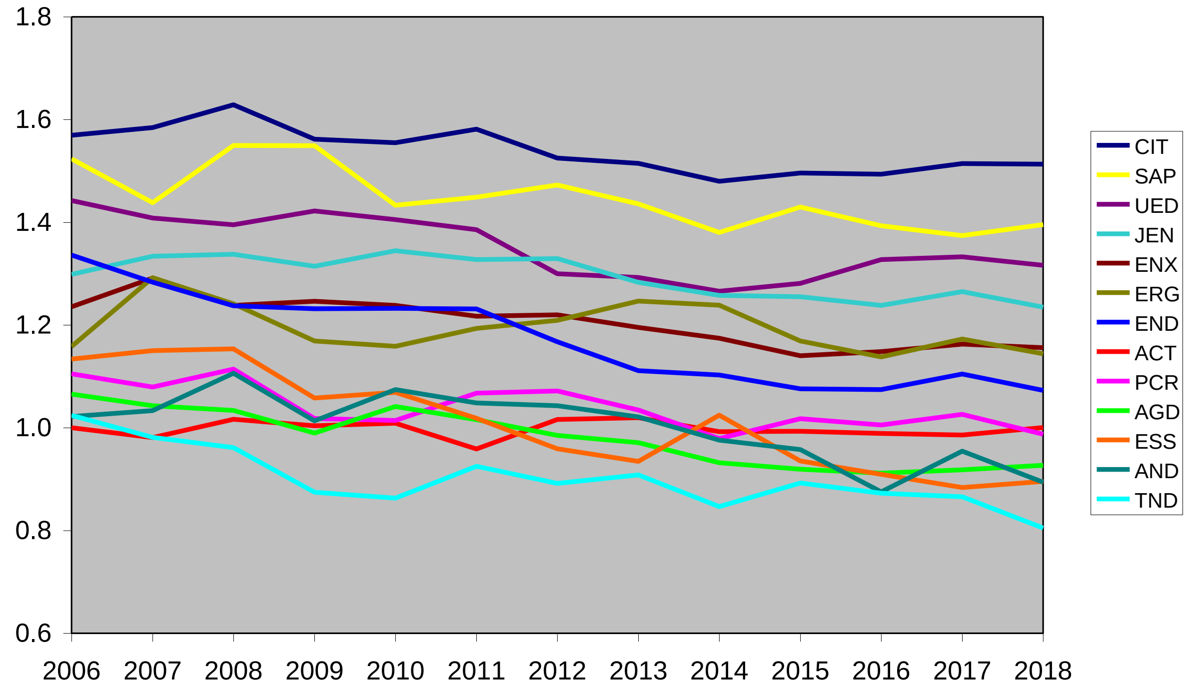
The impact of corrections to 2017 opex for four of the Victorian DNSPs – CIT, PCR, UED and AND – and of smaller corrections to AND's opex for earlier years can be seen in figure 3.2 relative to the corresponding figure in Economic Insights (2018). PCR's opex MPFP now declines in 2017 instead of increasing that year while the 2017 opex MPFP increases previously reported for CIT and AND are now reduced. Conversely, UED's 2017 opex level is now higher than previously reported. CIT and PCR retain their top two positions rankings for 2017 with the corrections while UED increases its ranking from fifth to fourth and AND's 2017 ranking falls from ninth to eleventh.

Table 3.2 **DNSP multilateral opex partial productivity indexes, 2006–2018**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*
ACT	1.000	0.995	0.978	0.958	0.867	0.753	0.758	0.705	0.627	0.674	1.248	1.103	0.970
AGD	0.791	0.942	0.659	0.723	0.670	0.701	0.644	0.818	0.726	0.625	0.698	0.790	0.939
AND	1.391	1.187	1.213	1.006	1.129	1.100	1.074	0.965	0.918	0.899	0.804	0.995	1.029
CIT	2.022	1.830	1.988	1.643	1.523	1.701	1.331	1.389	1.345	1.426	1.508	1.523	1.756
END	1.169	1.099	0.903	1.012	1.084	1.053	1.010	1.116	1.023	0.998	0.948	1.078	1.199
ENX	1.186	1.139	1.100	1.109	1.130	1.045	1.001	0.934	1.016	0.985	1.132	1.155	1.152
ERG	0.712	0.922	0.844	0.854	0.894	0.759	0.773	1.000	1.033	0.871	0.857	1.000	0.958
ESS	1.098	1.002	0.854	0.880	0.886	0.873	0.704	0.789	0.901	0.897	1.127	1.104	1.082
JEN	0.970	0.953	1.228	1.132	0.989	1.021	0.911	0.934	0.946	0.949	0.913	0.888	0.913
PCR	1.477	1.680	1.739	1.519	1.642	1.635	1.382	1.288	1.385	1.359	1.692	1.573	1.483
SAP	1.733	1.821	1.786	1.665	1.593	1.312	1.329	1.240	1.178	1.184	1.390	1.196	1.253
TND	1.334	1.287	1.287	1.120	0.958	1.098	0.982	1.248	1.154	1.446	1.341	1.038	1.115
UED	1.167	1.242	1.264	1.285	1.252	1.015	0.983	1.112	1.078	1.161	1.038	1.138	1.424

Looking at changes in rankings between 2017 and 2018 of two or more positions, UED improves its ranking from fifth to third, TND moves from ninth to seventh and AND regains ninth position after being in eleventh in 2017. For those DNSPs whose rankings slipped, ENX moved from fourth to sixth position despite its opex MPFP level effectively remaining constant across the two years, ESS moved from sixth to eighth while ACT had the largest downward movement from seventh to tenth.

Figure 3.3 **DNSP multilateral capital partial productivity indexes, 2006–2018**



If we exclude CIT, PCR and UED which sit well above the rest of the pack in 2018, the spread of opex MPFP levels has further narrowed with the spread between SAP and the

DNSP with the lowest opex MPFP level reducing by 16 per cent between 2017 and 2018.

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. Five DNSPs improved their capital MPFP levels in 2018 with three of these – those of SAP, ESS and ACT – being by more than 1 per cent. Of the eight DNSPs with reductions in capital MPFP levels in 2018, three of these – TND, AND and PCR – had reductions of 4 per cent or more. Contributions of each of the five components making up overall capital productivity will be examined further in sections 4 and 5.

3.2 Econometric opex cost function efficiency scores

In this report we further update the models in Economic Insights (2018) to include data for 2017–18 (or 2018, as relevant) for the Australian and New Zealand DNSPs and 2017 data for the Ontario DNSPs. As outlined in section 1.2, we have also included a number of revisions to data this year and reassessed our treatment of DNSP amalgamations in New Zealand and Ontario.

The econometric cost function models produce average opex efficiency scores for the period over which the models are estimated. As noted in section 1.2, four opex cost function models are estimated for this report:

- 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)
- a stochastic frontier analysis model using the Cobb–Douglas functional form (SFACD), and
- a stochastic frontier analysis model using the translog functional form (SFATLG).

We present the average opex efficiency scores for two periods – 2006 to 2018 and 2012 to 2018 – in this section. The corresponding regression results are presented in appendix B. With the updated and revised database, the four econometric models now perform relatively well for both estimation periods.

The two Cobb–Douglas models impose the important monotonicity property as part of their simpler structure. The monotonicity property requires that an increase in output can only be achieved with an increase in cost. However, this property is not automatically imposed with the more flexible translog functional form and, instead, the translog models have to be checked for compliance with this property. In earlier modelling the SFATLG model has not performed well on this property for the period from 2006 onwards but did perform well for the period from 2012 onwards in Economic Insights (2018). With the current data updates and revisions, the SFATLG model now also performs relatively well for the full period and is also included in the full period results. However, for the 2012 onwards period, the LSETLG model now presents monotonicity violations for one output for three DNSPs – AGD, JEN and UED – for all their observations and its results are excluded for these three DNSPs when forming an overall average efficiency score across models for the shorter period. No monotonicity violations are present for the LSETLG model for the full period.

Figure 3.4 **DNSP opex cost efficiency scores, 2006–2018**

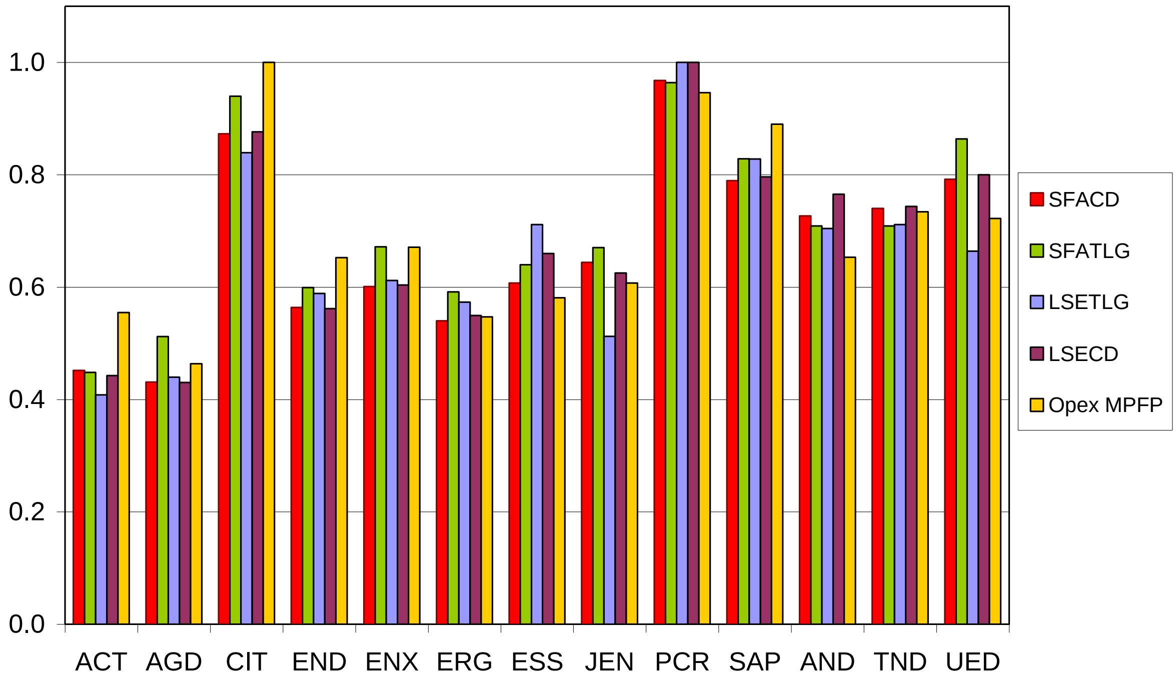
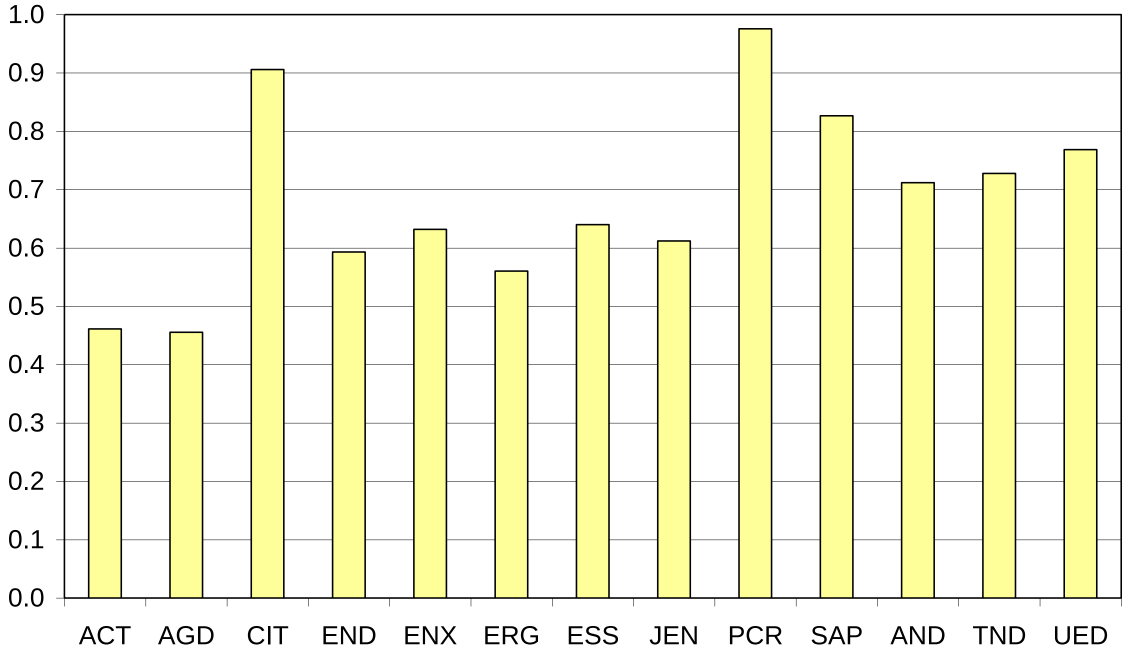


Figure 3.5 **DNSP opex cost efficiency scores, 2006–2018, average of models**



Opex efficiency scores for each of the 13 NEM DNSPs across the 13–year period 2006 to 2018 for the four opex cost function models and, for comparison, opex MPFP are presented in figure 3.4 and table 3.3. Average opex efficiency scores across the five economic benchmarking models are presented in figure 3.5 and table 3.3.

Table 3.3 **DNSP average opex cost efficiency scores, 2006–2018**

DNSP	*SFACD*	*SFATLG*	*LSETLG*	*LSECD*	*Opex MPFP*	*Average*
ACT	0.452	0.448	0.408	0.443	0.555	0.461
AGD	0.431	0.512	0.440	0.430	0.464	0.455
CIT	0.873	0.940	0.839	0.877	1.000	0.906
END	0.564	0.599	0.589	0.562	0.653	0.593
ENX	0.601	0.672	0.612	0.604	0.671	0.632
ERG	0.540	0.592	0.573	0.549	0.547	0.560
ESS	0.607	0.640	0.711	0.660	0.581	0.640
JEN	0.644	0.670	0.512	0.625	0.607	0.612
PCR	0.968	0.964	1.000	1.000	0.946	0.976
SAP	0.790	0.828	0.828	0.796	0.890	0.826
AND	0.727	0.709	0.704	0.765	0.653	0.712
TND	0.740	0.709	0.712	0.744	0.734	0.728
UED	0.792	0.864	0.664	0.800	0.722	0.768

The opex efficiency scores in figures 3.4 and 3.5 fall into three distinct groups. Six DNSPs – PCR, CIT, SAP, UED, TND and AND – form the top performing group with average efficiency scores above 0.7. Another five DNSPs – ESS, ENX, JEN, END and ERG – form the middle performing group with average efficiency scores between 0.55 and 0.65. And the remaining two DNSPs – ACT and AGD – form the low performing group for the period as a whole with average opex efficiency scores between 0.45 and 0.5.

These results are broadly similar to the corresponding results presented in Economic Insights (2018, p.24) for the period up to 2017. If the averages of the same four models presented for this period in Economic Insights (2018) are compared, there have been upward movements in average performance for seven DNSPs – ACT, END, ERG, ESS, SAP, AND and TND. This will in part reflect the addition of another year of higher opex efficiency performance levels in forming the average over the period for these DNSPs and in part reflect a small worsening in the average of the performance of the leader, PCR, with the downward correction of its 2017 opex data. The reduction in performance of PCR will be reflected in a closing of the gap by other DNSPs rather than a reduction in PCR's efficiency score as PCR remains the leader in the cost function models overall.

Efficiency scores across the four econometric models are broadly similar. The SFATLG model produces slightly higher scores than the SFACD model for the majority of DNSPs. We note that the LSETLG model produces noticeably lower efficiency scores for JEN and UED compared to the other cost function models but there are no monotonicity issues present. The opex MPFP efficiency scores are also broadly within the range of scores for the four cost function models but are somewhat higher than the opex cost function efficiency score range for four DNSPs – ACT, CIT, END and SAP – and somewhat below the range for AND. Relative to the opex cost function models, the opex MPFP model includes an additional two outputs – energy and reliability – but excludes the impact of undergrounding.

We turn now to the opex efficiency scores from the more recent period, 2012 to 2018. Opex efficiency scores for each of the 13 NEM DNSPs across the 7–year period for the four opex cost function models and opex MPFP are presented in figure 3.6 and table 3.4. Average opex efficiency scores across the five economic benchmarking models for the 7–year period are presented in figure 3.7 and table 3.4.

Figure 3.6 **DNSP opex cost efficiency scores, 2012–2018**

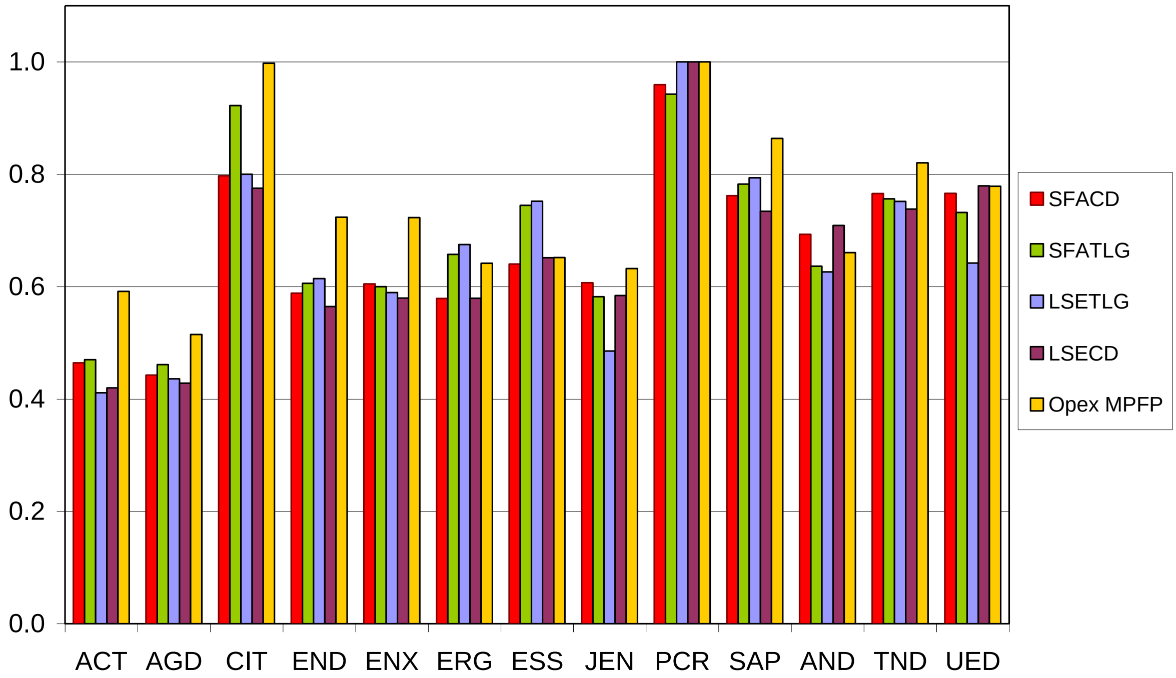


Figure 3.7 **DNSP opex cost efficiency scores, 2012–2018, average of models**

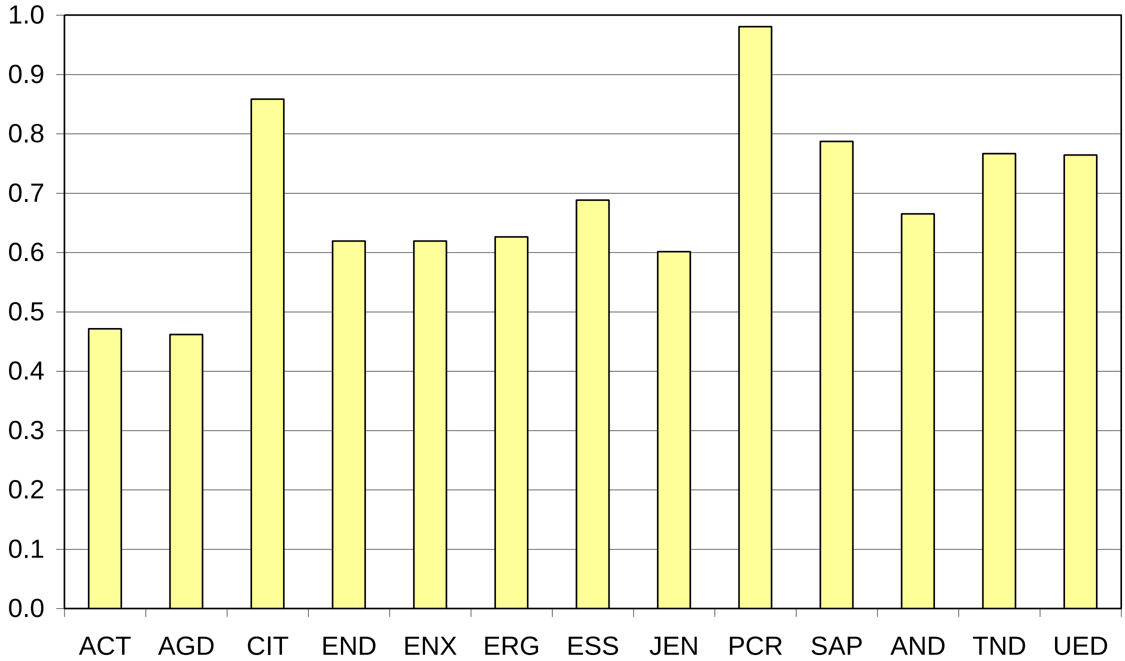


Table 3.4 **DNSP average opex cost efficiency scores, 2012–2018**

DNSP	*SFACD*	*SFATLG*	*LSETLG*	*LSECD*	*Opex MPFP*	*Average*
ACT	0.464	0.470	0.411	0.420	0.591	0.471
AGD	0.443	0.461	0.436	0.428	0.515	0.462*
CIT	0.797	0.922	0.800	0.775	0.998	0.858
END	0.588	0.606	0.614	0.565	0.724	0.619
ENX	0.605	0.600	0.589	0.580	0.723	0.619
ERG	0.579	0.657	0.675	0.579	0.642	0.626
ESS	0.640	0.745	0.752	0.652	0.652	0.688
JEN	0.607	0.582	0.485	0.584	0.632	0.601*
PCR	0.959	0.943	1.000	1.000	1.000	0.980
SAP	0.762	0.783	0.794	0.734	0.864	0.787
AND	0.693	0.636	0.626	0.709	0.661	0.665
TND	0.766	0.756	0.752	0.738	0.820	0.766
UED	0.766	0.732	0.642	0.779	0.779	0.764*

* Average excludes LSETLG as monotonicity requirement violated for this DNSP using this model.

From figures 3.6 and 3.7 we see that there are still three reasonably distinct efficiency groups although there is less distinction between the bottom of the top group and the top of the middle group with, for example, ESS now having a higher average efficiency score than AND. Compared to corresponding average scores across the models for the full time period, average scores improve by more than one percentage point for five DNSPs – AGD, END, ERG, ESS and TND – reflecting improved relative performance. On the other hand, compared to the full time period, corresponding average scores across the models decline by more than one percentage point for four DNSPs – CIT, JEN, SAP and AND – reflecting a relative worsening in performance.

To fully understand these movements in relative performance, it is important to recognise that they are period averages for each DNSP. It is instructive to refer back to figure 3.2 which shows the annual movements in opex MPFP over the whole period. Although the opex MPFP model has a broader inclusion of outputs and different output weights, it will still provide a good guide to interpreting the opex cost function efficiency score movements. Two patterns of movements in the annual scores are noteworthy.

Firstly, there has been a general upward movement in opex productivity since 2012. This means that although the performance of a DNSP may be improving in absolute terms since 2012, the performance of the leading DNSPs has also improved leading to little change in relative performance. Taking ENX as an example, its average efficiency score remained virtually unchanged between the full period and the more recent period. However, its opex MPFP has grown at an average annual rate of 2.4 per cent since 2012. But offsetting this, of the two leading DNSPs, CIT's opex MPFP has grown at an average rate of 4.6 per cent and PCR's has grown at 1.2 per cent since 2012. Thus, a DNSP can be improving its opex productivity at a reasonable rate while its relative opex efficiency remains relatively constant. In other words, a DNSP has to effectively 'run to stand still'.

The second noteworthy pattern is that the average efficiency scores of some of the leading DNSPs can fall over time despite them having strong opex productivity growth since 2012. Taking CIT and as an example, its average score fell by nearly 4 percentage points in the recent period compared to the full period despite having had high average annual opex productivity growth in the recent period. This is because its opex productivity levels had been higher for most of the period before 2012 compared to the period after 2012. Hence, its post 2012 average productivity level will be lower than its full period average level and its efficiency score will have fallen.

Another variation of this effect is AND. Despite having had relatively high productivity growth in 2017, it is yet to regain its 2012 productivity level and its 2012 productivity level was lower than for all but one of the years prior to 2012. Thus, despite impressive recent short–term productivity growth, its opex efficiency score has declined for the recent 7–year period compared to the full 13–year period.

And the third noteworthy effect is the converse of the second. Despite having had large productivity falls in the most recent few years, a DNSP's efficiency score can still improve for the post 2012 period compared to the full period. Taking ACT as an example, its opex productivity fell at an average annual rate of 13 per cent over the last two years. But its average opex efficiency score still increased by 1 percentage point for the post 2012 period compared to the full period. This is due to its large productivity jump in 2016 which has kept its average productivity level for the period from 2012 onwards higher than its average for the period before 2012, despite large falls in the last few years. In a regulatory context, performance changes between the average of the period and the end of the period, whether they be improvements or worsening, are allowed for in the efficient opex target roll–forward mechanism applied in Economic Insights (2014a).

Turning to the comparison of model scores, the four opex cost function models generally produce broadly similar efficiency scores for the post 2012 period. Two differences are noteworthy. Firstly, the two translog models now produce notably higher opex efficiency scores for the two sparsest DNSPs – ESS and ERG – compared to the corresponding Cobb Douglas models. This could indicate these two DNSPs have different characteristics which the more flexible translog model is better able to capture. And, secondly, we see that the LSETLG model again gives notably lower opex efficiency scores to JEN and UED. Because monotonicity is also not satisfied for this model for all seven observations for these DNSPs, we exclude its scores in calculating these DNSPs' overall average scores. Similarly, monotonicity is not satisfied for AGD's seven observations in the LSETLG model. Although there is no obvious anomaly with AGD's score for this model, for consistency we also exclude it in calculating AGD's average score.

Opex MPFP efficiency scores now lie above the range of the cost function efficiency scores for the same four DNSPs as in the full sample plus another four – AGD, ENX, JEN and TND. They do not lie below the cost function range for any of the DNSPs. The inclusion of reliability in the opex MPFP efficiency scores will explain but of the better performance of these DNSPs. While volatile, PCR's customer minutes off supply has generally trended up over the period while the other DNSPs have either trended down or remained relatively constant on average. This would tend to narrow the gap in average efficiency scores when reliability is allowed for.

Relative to the 2012 to 2017 corresponding average efficiency scores presented in Economic Insights (2018, p.23), the scores of nearly all DNSPs are higher for the 2012 to 2018 average although this will in part reflect a narrowing of the gap following the significant correction to PCR's 2017 opex value.

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, 2006–2018**

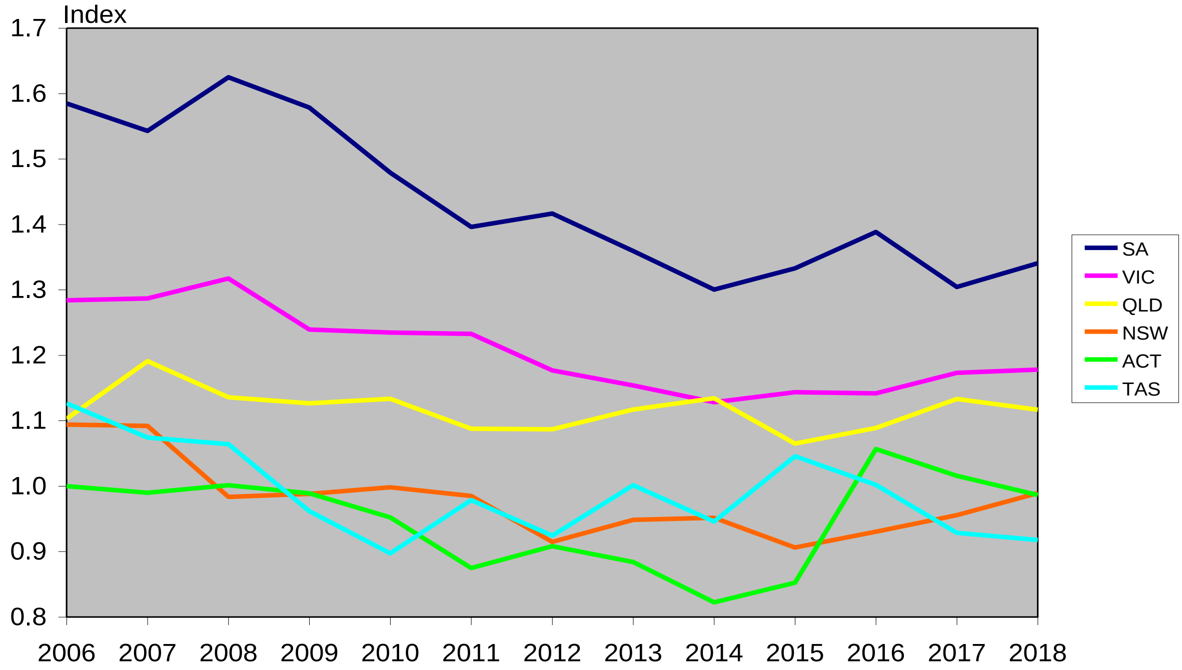
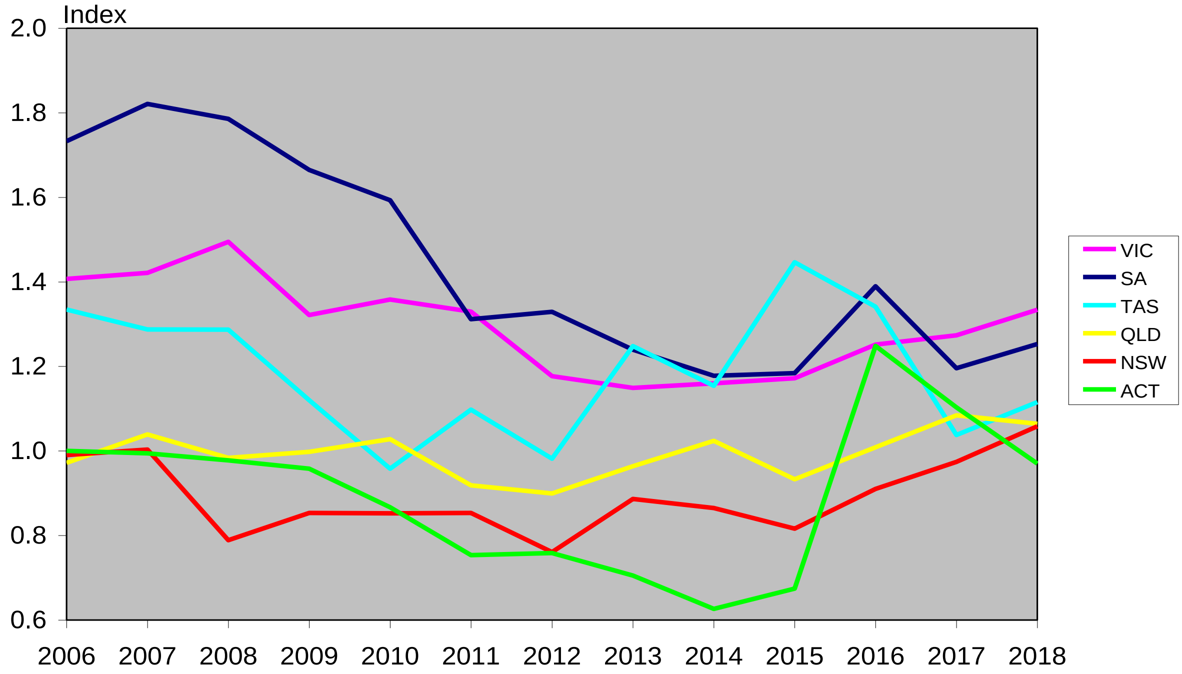


Figure 4.2 **State–level DNSP multilateral opex PFP indexes, 2006–2018**



State–level MTFP indexes are presented in figure 4.1. Rankings have remained the same as in 2017 with the exception of the ACT which has moved from fourth place to fifth place among the six states. This is the result of a further fall in the ACT's MTFP and a further increase in NSW's MTFP in 2018. South Australia's and Victoria's MTFP both increased in 2018 while those of Queensland and Tasmania both fell somewhat. Victoria's MTFP in 2017 has been revised downwards with corrections to the opex figures supplied by four of the Victorian DNSPs. This has widened the gap between South Australia and Victoria at the top of the table in the last two years.

Opex MPFP levels are shown in figure 4.2. Victoria's and South Australia's opex MPFP levels both increased by just under 5 per cent in 2018 leading to Victoria retaining top place despite the revisions to its DNSPs' opex for 2017 reducing its lead over South Australia. Tasmania's opex fell by 8 per cent in 2018 following a large increase in 2017. This led to it regaining third position in opex MPFP rankings in 2018. After its large increase in opex MPFP in 2016, the ACT's opex MPFP fell by 12 per cent in 2017 and by another 12 per cent in 2018. This led to its opex MPFP ranking falling from third in 2017 to sixth in 2018. NSW achieved the largest increase in opex MPFP in 2018 with a 9 per cent improvement but its ranking in 2018 was still fifth, just behind Queensland.

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 2,852 GWh to 197,537 customers over 5,384 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.

Figure 4.3 **ACT output, input and total factor productivity indexes, 2006–2018**

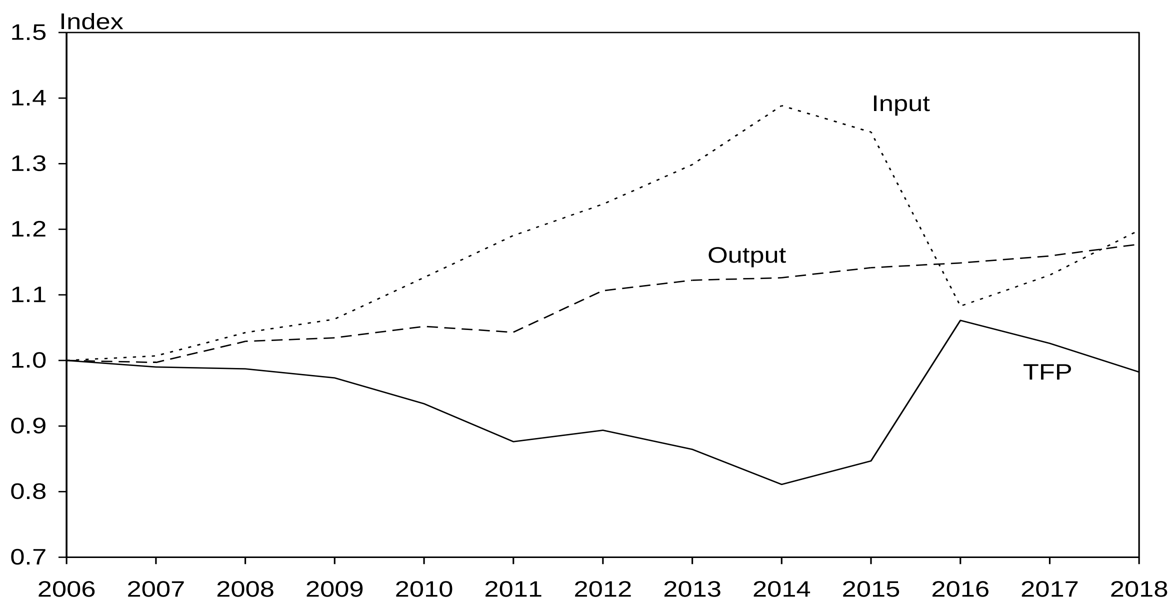


Table 4.1 **ACT output, input and total factor productivity and partial productivity indexes, 2006–2018**

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
2018	1.177	1.198	0.982	0.979	0.988
Growth Rate 2006–18	1.36%	1.51%	–0.15%	–0.17%	–0.10%
Growth Rate 2006–12	1.69%	3.56%	–1.87%	–4.54%	–0.10%
Growth Rate 2012–18	1.03%	–0.54%	1.58%	4.19%	–0.11%

Over the 13–year period 2006 to 2018, ACT's average annual rate TFP change was –0.2 per cent. TFP levels had fallen 19 per cent between 2006 and 2014 and then increased by 25 per cent in 2016 before falling back by 3 per cent in 2017 and 4 per cent in 2018. Total output increased steadily over the period at an average annual rate of 1.4 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 and 2018 leading to ACT's TFP level in 2018 being 2 per cent below 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

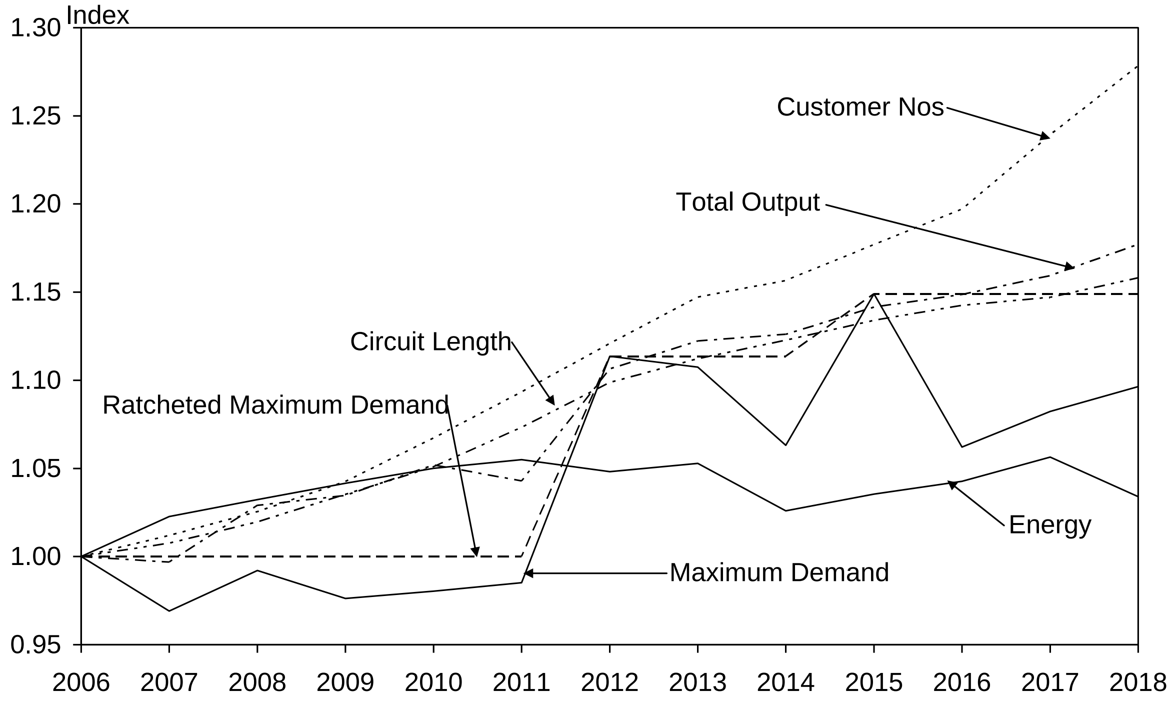
We graph the quantity indexes for ACT's five individual outputs in figure 4.4 and for its six individual inputs in figure 4.5, respectively.

From figure 4.4 we see that the output component of customer numbers increased steadily over the period and was 28 per cent higher in 2018 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 2018 energy throughput fell by just over 2 per cent to be 3 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 2018 was 15 per cent above its 2006 level – a similar result as for the industry overall although ACT's growth in this output was concentrated between 2011 and 2015 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 13 years than occurred for the industry overall and by 2018 was 16 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, 2006–2018**



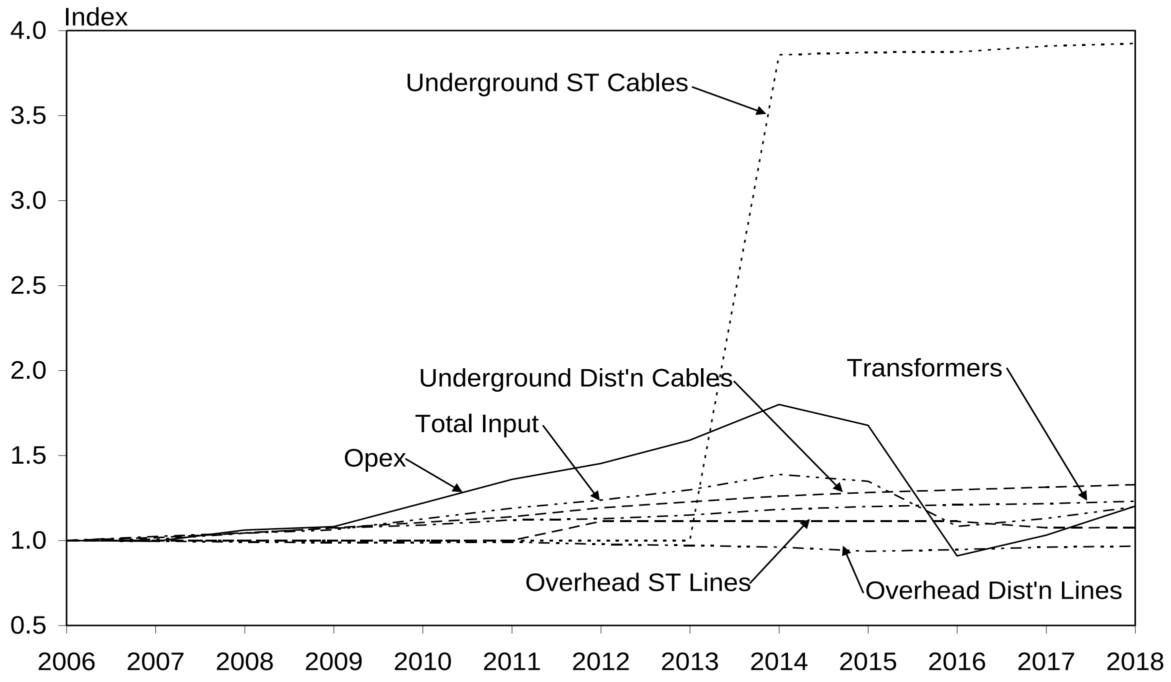
We do not show ACT's total customer minutes off–supply in figure 4.4. ACT's CMOS performance is the best of the 13 DNSPs in the NEM and CMOS receives only a negative 3 per cent weight on average in ACT's total output. Because ACT's CMOS levels are very low, fluctuations in CMOS come off a low base and 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 90 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 ACT price determination before increasing by 13 per cent in 2017 and 16 per cent in 2018. In an email to the AER dated 22 August 2019, Evoenergy noted the main reasons for its increase in opex in 2018 were complying with new ring–fencing requirements and Power of Choice reforms and preparation of its 2019–24 regulatory period proposal. In 2018 ACT's opex input quantity was 20 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 23 per cent over the 13–year period.

Figure 4.5 **ACT input quantity indexes, 2006–2018**



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 and by 6 per cent in 2018 in line with the movements in opex usage.

ACT output and input contributions to TFP change

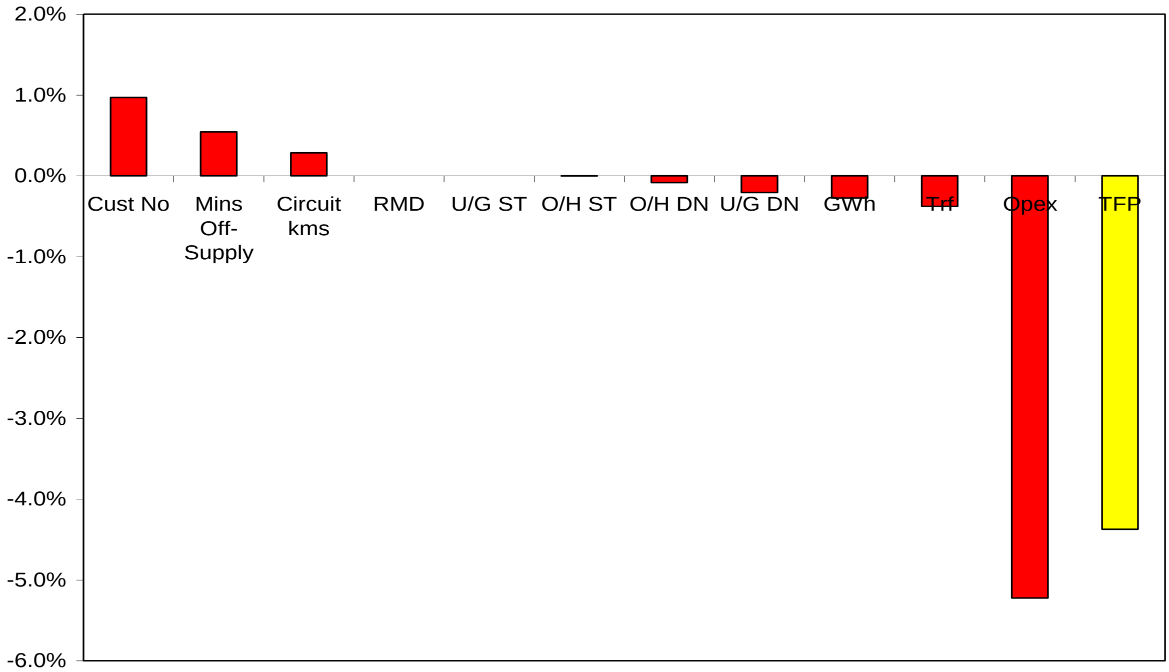
In table 4.2 we decompose ACT's TFP change into its constituent output and input parts for the whole 13–year period and for the periods up to and after 2012. ACT's drivers of TFP change for the whole 13–year period are broadly similar to the industry as a whole. Customer numbers and circuit length output 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. Opex usage now makes a somewhat more negative contribution of 0.6 percentage points on average and is the most negative contributor to ACT's –0.2 per cent average annual TFP change over the 13–year period. For the industry opex has the second most negative contribution of 0.5 percentage points over the whole period and this is also a major reason for the industry's negative TFP growth rate over the 13 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. The large reductions made in ACT's opex in 2015 and 2016 led to opex contributing 1.2 percentage points to ACT's positive average annual TFP change of 1.6 per cent for the period after 2012, despite the sizable increases in opex in 2017 and 2018. 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: 2006–2018, 2006–2012 and 2012–2018**

Year	*2006 to 2018*	*2006 to 2012*	*2012 to 2018*
Energy (GWh)	0.04%	0.10%	–0.03%
Ratcheted Max Demand	0.34%	0.53%	0.15%
Customer Numbers	0.64%	0.60%	0.68%
Circuit Length	0.37%	0.47%	0.26%
CMOS	–0.02%	–0.01%	–0.03%
Opex	–0.63%	–2.49%	1.22%
O/H Subtransmission Lines	–0.02%	–0.06%	0.02%
O/H Distribution Lines	0.03%	0.05%	0.01%
U/G Subtransmission Cables	0.00%	0.00%	–0.01%
U/G Distribution Cables	–0.45%	–0.59%	–0.31%
Transformers	–0.43%	–0.47%	–0.39%
TFP Change	–0.15%	–1.87%	1.58%

Figure 4.6 **ACT output and input percentage point contributions to annual TFP change, 2017–18**



The 16 per cent increase in opex usage in 2018 contributed –5.2 percentage points to ACT's TFP change of –4.4 per cent that year as shown in figure 4.6. Above average growth in customer numbers in 2018 contributed 1.0 percentage points to TFP growth and an improvement in CMOS contributed 0.5 percentage points.

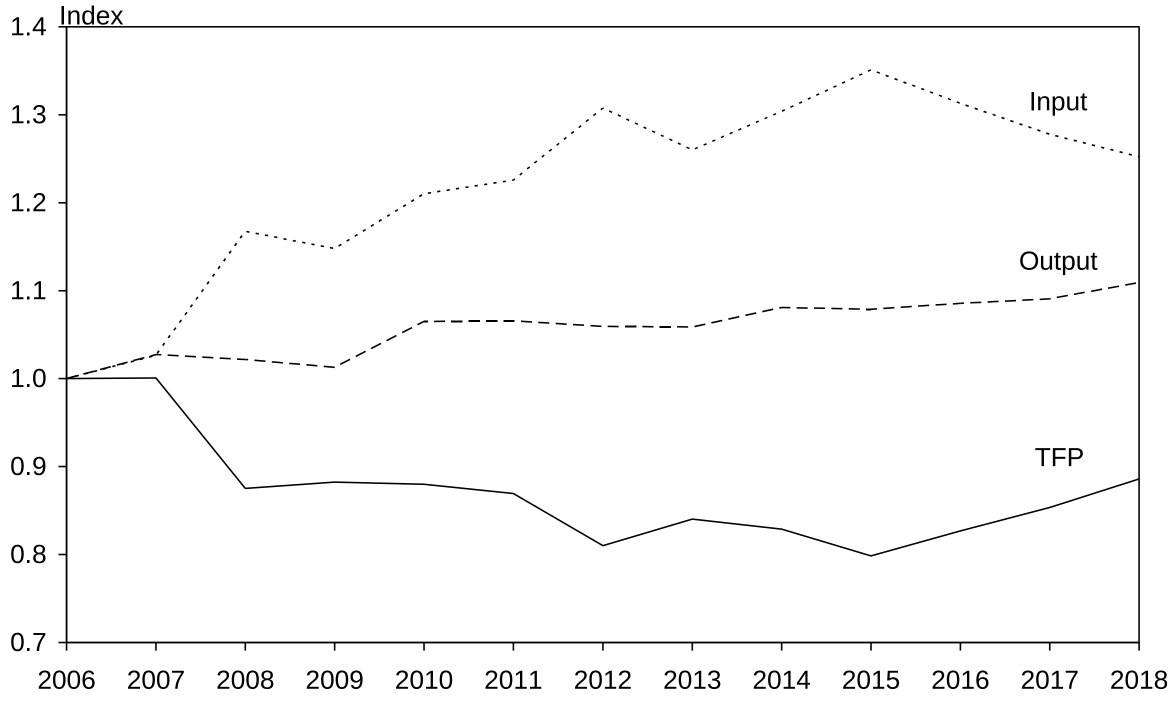
4.2.2 New South Wales

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 2018 the three NSW DNSPs delivered 54,559 GWh to 3.64 million customers over 271,594 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, 2006–2018**



Over the 13–year period 2006 to 2018, the NSW DNSPs' TFP decreased at an average annual rate of 1.0 per cent. Although total output increased by an average annual rate of 0.9 per cent, total input use increased faster, at a rate of 1.9 per cent. NSW thus had slower output growth and similar input growth compared to 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, 2017 and 2018. TFP fell markedly in 2008 and 2012 but TFP change was positive in five years – 2009, 2013, 2016, 2017 and 2018. TFP average annual change was sharply negative for the period up to 2012 but has been positive at 1.5 per cent for the period since 2012.

Table 4.3 **NSW DNSP output, input and total factor productivity and partial productivity indexes, 2006–2018**

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
2018	1.109	1.252	0.886	1.057	0.815
Growth Rate 2006–18	0.86%	1.87%	–1.01%	0.46%	–1.70%
Growth Rate 2006–12	0.96%	4.47%	–3.51%	–4.79%	–2.59%
Growth Rate 2012–18	0.77%	–0.72%	1.49%	5.71%	–0.81%

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.

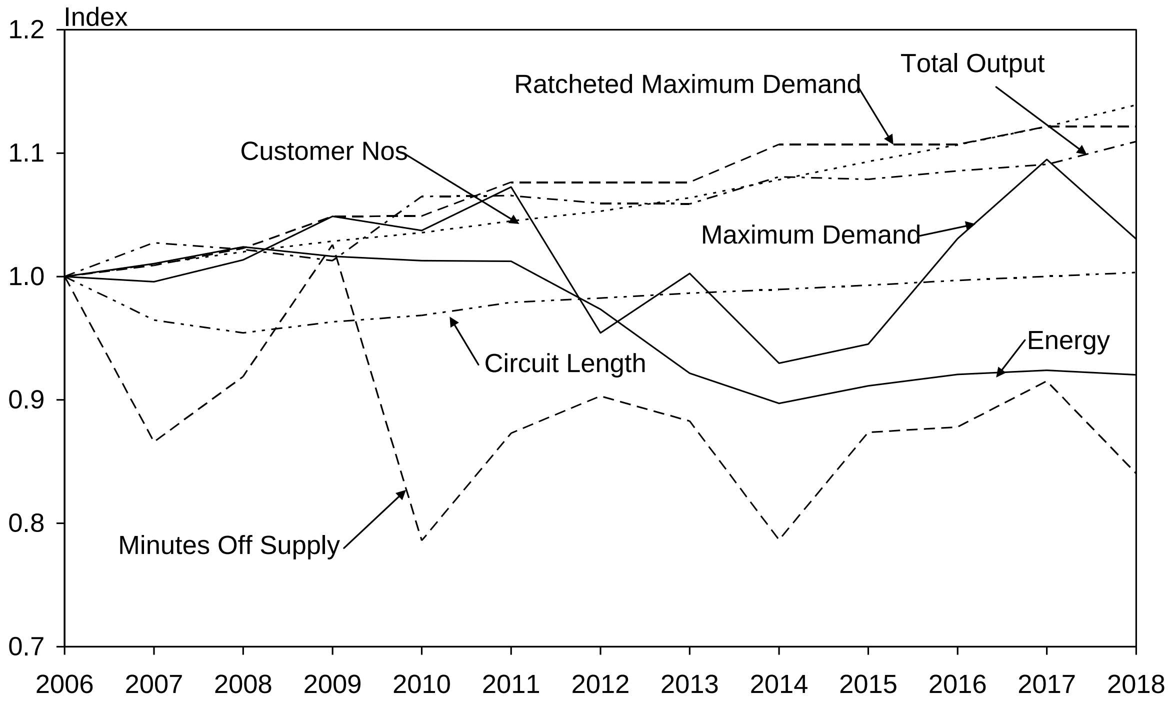
From figure 4.8 we see that NSW's output components showed a similar pattern of change to the industry as a whole except that there was much less growth in outputs for NSW between 2006 and 2009, likely reflecting the impact of the global financial crisis and the initial negative effects of the mining boom on NSW. Customer numbers increased steadily over the period and were 14 per cent higher in 2018 than they were 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 2018 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 2018 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 13 years than occurred for the industry overall and by 2018 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 2018 CMOS was 16 per cent less than it was in 2006.

Figure 4.8 **NSW output quantity indexes, 2006–2018**



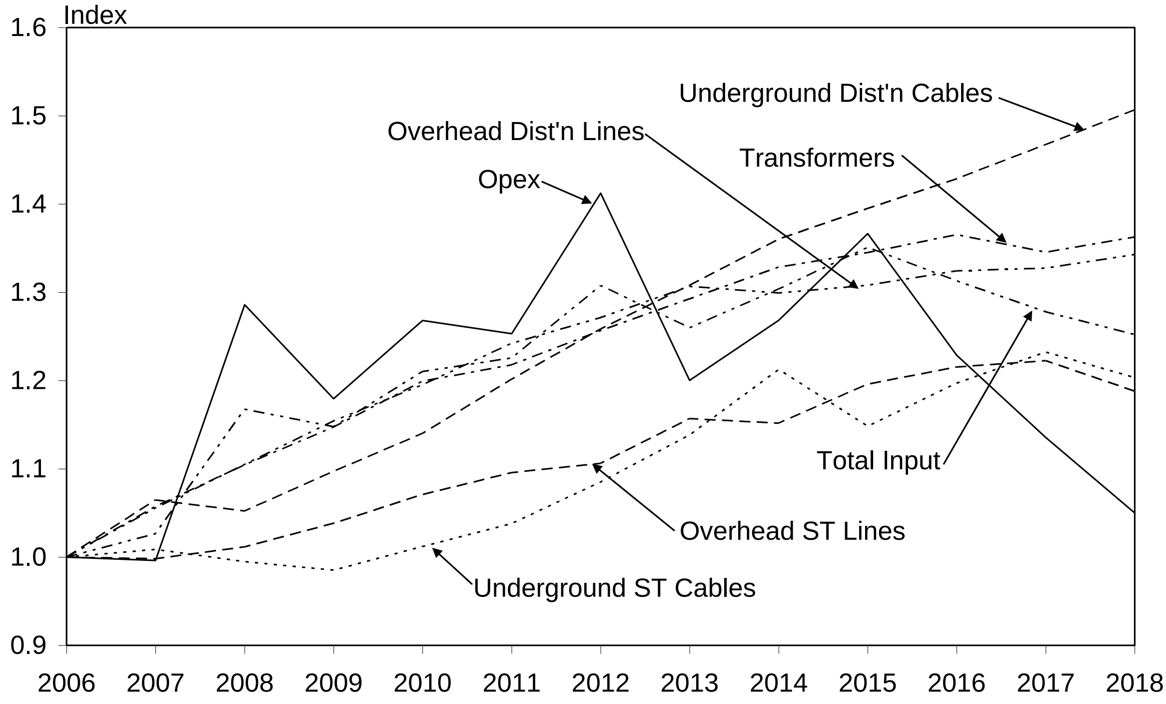
Since the customer numbers and ratcheted maximum demand outputs receive a weight of around 60 per cent of gross revenue in forming the total output index, in figure 4.8 we see that the total output index tends to lie very close to these two output indexes. The circuit length index lies at a lower level 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, 2017 and 2018 but was only 5 per cent above its 2006 level in 2018.[3] Opex has the largest average share in NSW's total costs at 38 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 34 per cent compared to only 12 per cent for the industry.

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

Figure 4.9 **NSW DNSP input quantity indexes, 2006–2018**



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 13–year period and for the periods up to and after 2012. NSW's drivers of TFP change for the whole 13–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 now makes a less 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.

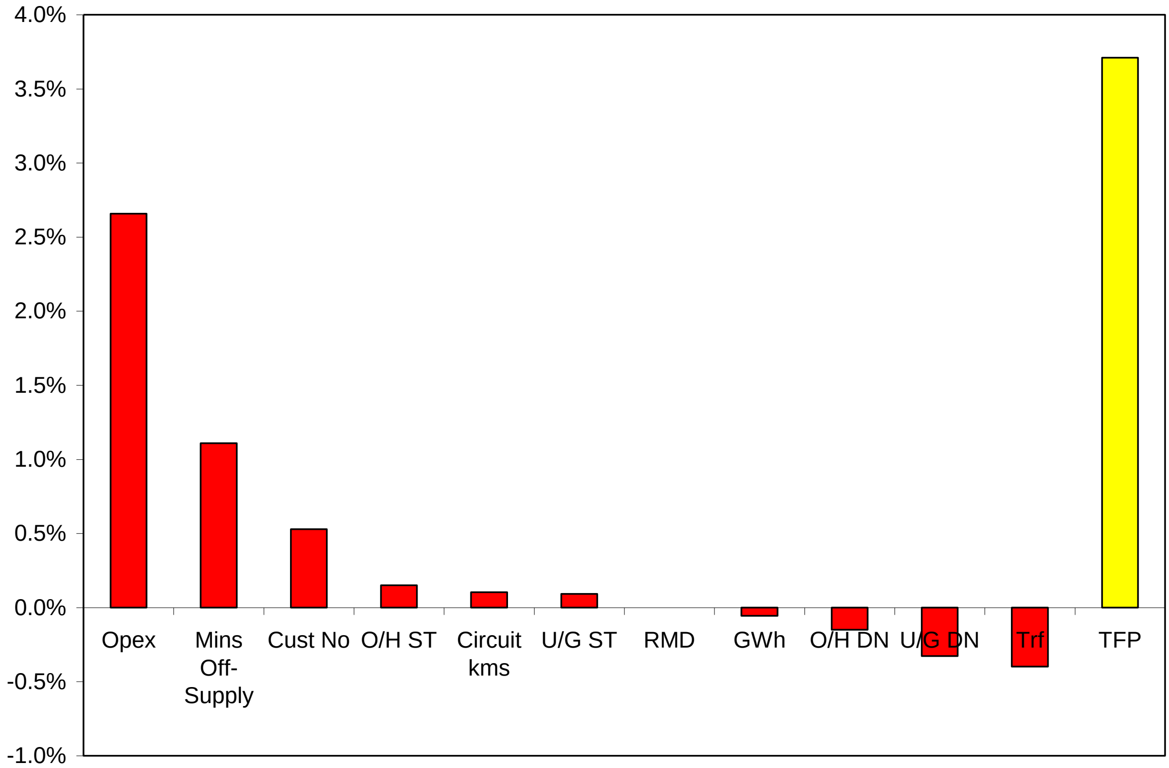
The NSW situation is again a tale of two distinct periods. For the period up to 2012, rapid opex growth made a larger negative percentage point contribution to TFP growth for NSW than for the industry, at –2.4 percentage points for NSW versus –1.9 percentage points for the industry. But the reductions made in NSW's opex after 2012 led to opex contributing 1.7 percentage points to NSW's average annual TFP change of 1.5 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 2018 is highlighted in figure 4.10 where the 2.7 percentage point contribution of opex to TFP change of 3.7 per cent in the 2018 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: 2006–2018, 2006–2012 and 2012–2018**

Year	*2006 to 2018*	*2006 to 2012*	*2012 to 2018*
Energy (GWh)	–0.09%	–0.06%	–0.13%
Ratcheted Max Demand	0.31%	0.41%	0.21%
Customer Numbers	0.37%	0.31%	0.44%
Circuit Length	0.00%	–0.11%	0.11%
CMOS	0.27%	0.41%	0.13%
Opex	–0.32%	–2.38%	1.74%
O/H Subtransmission Lines	–0.06%	–0.08%	–0.05%
O/H Distribution Lines	–0.25%	–0.40%	–0.11%
U/G Subtransmission Cables	–0.05%	–0.04%	–0.05%
U/G Distribution Cables	–0.38%	–0.42%	–0.35%
Transformers	–0.80%	–1.16%	–0.45%
TFP Change	–1.01%	–3.51%	1.49%

Figure 4.10 **NSW output and input percentage point contributions to annual TFP change, 2017–18**



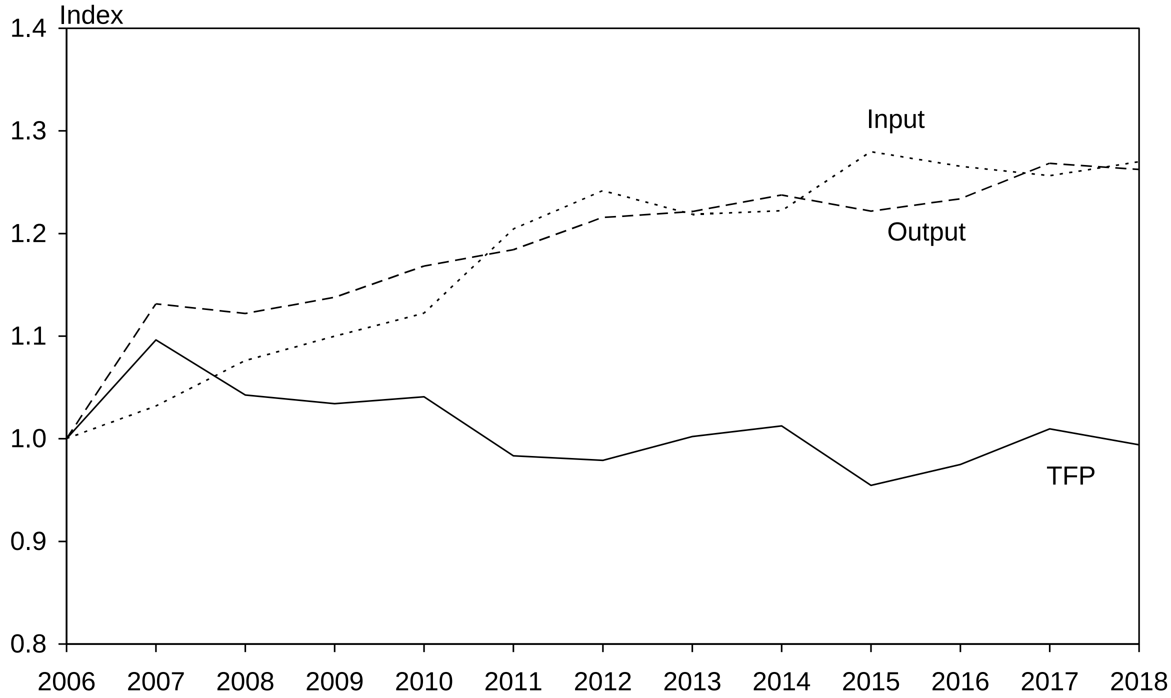
4.2.3 Queensland

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 2018 the two Queensland DNSPs delivered 34,505 GWh to 2.23 million customers over 206,242 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, 2006–2018**



Over the 13–year period 2006 to 2018, the Queensland DNSPs' TFP decreased at an average annual rate of 0.1 per cent. Queensland's total output increased by an average annual rate of 1.9 per cent – considerably higher than the output growth rates in ACT and NSW. Queensland's total input use increased a little faster, at a rate of 2.0 per cent – only slightly higher 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 those years. A small reduction in output and a small increase in input use has led to a fall in TFP in 2018. TFP average annual change was negative for the period up to 2012 at – 0.4 per cent but has been positive at 0.3 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.

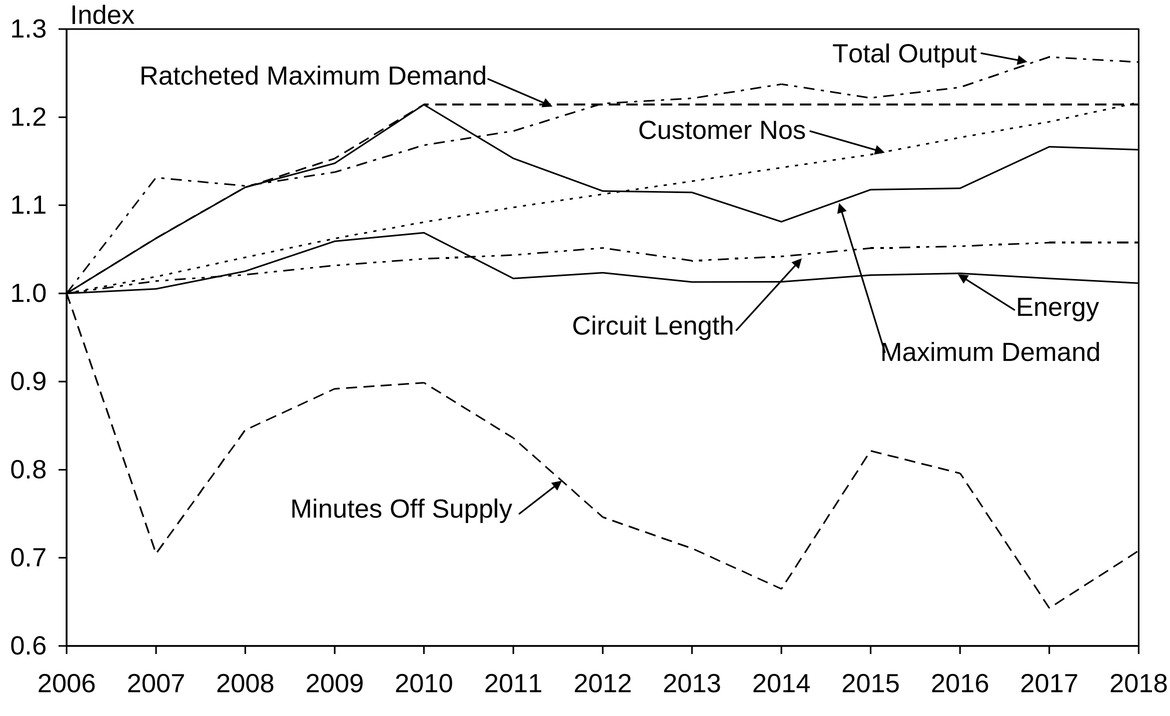
Table 4.5 **Qld DNSP output, input and total factor productivity and partial productivity indexes, 2006–2018**

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
2018	1.262	1.270	0.994	1.121	0.931
Growth Rate 2006–18	1.94%	1.99%	–0.05%	0.95%	–0.59%
Growth Rate 2006–12	3.25%	3.61%	–0.36%	–0.92%	–0.07%
Growth Rate 2012–18	0.63%	0.37%	0.26%	2.82%	–1.12%

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, 2006–2018**



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 were 22 per cent higher in 2018 than they were in 2006 reflecting Queensland's relatively strong output growth. Energy throughput for distribution peaked in 2010 but was still 1 per cent higher in 2018 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 2018 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 13 years than occurred for the industry overall and by 2018 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 2018 CMOS was 30 per cent less than it was in 2006.

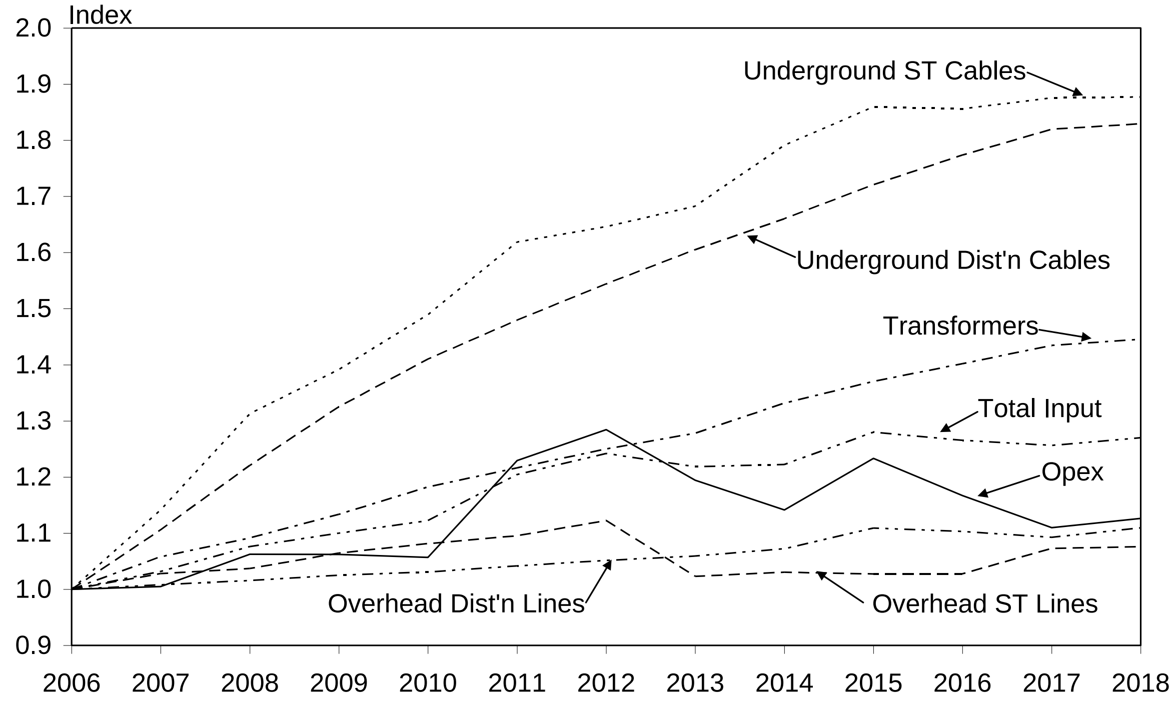
Since the customer numbers and ratcheted maximum demand outputs receive a weight of around 60 per cent of gross revenue in forming the total output index, in figure 4.12 we see that the total output index tends to lie close to these two output indexes. The circuit length and energy output indexes lie 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 –16 per cent of gross revenue in forming the total output index.

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 13 per cent above its 2006 level in 2018.[4] 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 increased by 1.1 per cent in 2018 with increases in all six input categories, including a 1.5 per cent increase in opex usage.

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

Figure 4.13 **Qld DNSP input quantity indexes, 2006–2018**



Queensland output and input contributions to TFP change

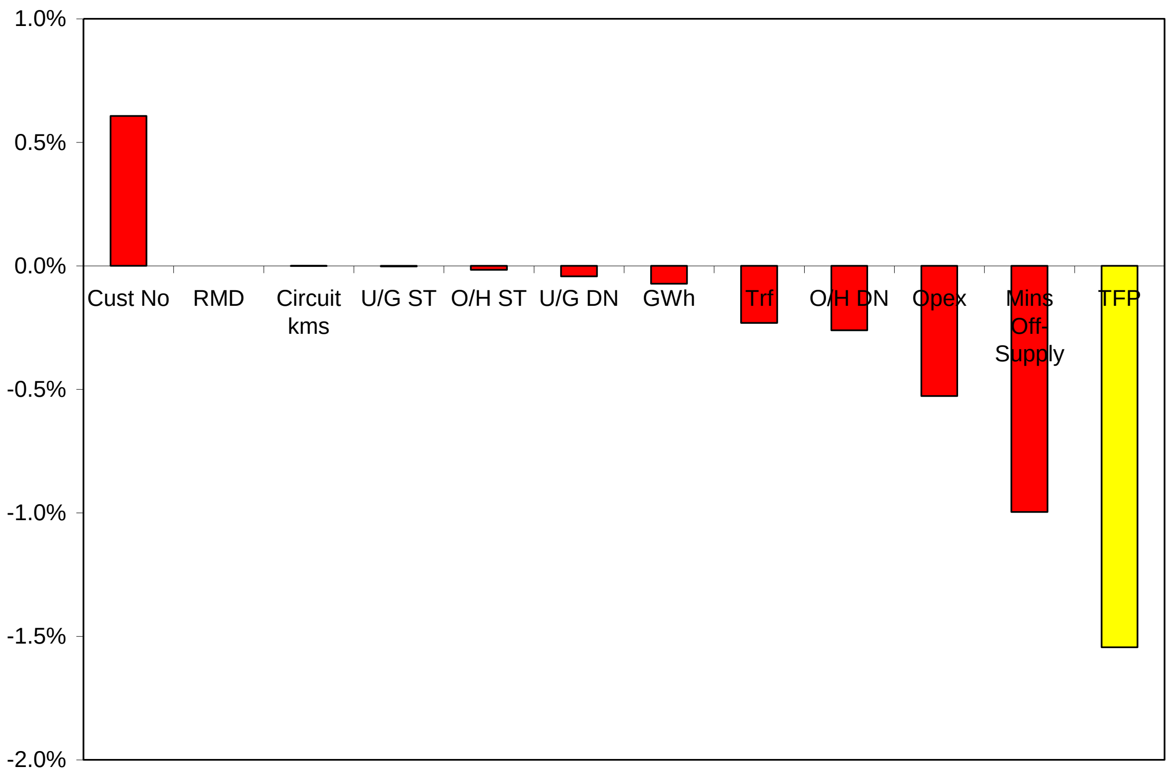
Table 4.6 **Qld output and input percentage point contributions to average annual TFP change: 2006–2018, 2006–2012 and 2012–2018**

Year	*2006 to 2018*	*2006 to 2012*	*2012 to 2018*
Energy (GWh)	0.02%	0.06%	–0.03%
Ratcheted Max Demand	0.56%	1.13%	0.00%
Customer Numbers	0.58%	0.66%	0.50%
Circuit Length	0.16%	0.30%	0.03%
CMOS	0.62%	1.12%	0.13%
Opex	–0.37%	–1.49%	0.75%
O/H Subtransmission Lines	–0.04%	–0.14%	0.06%
O/H Distribution Lines	–0.14%	–0.14%	–0.15%
U/G Subtransmission Cables	–0.13%	–0.20%	–0.06%
U/G Distribution Cables	–0.38%	–0.53%	–0.23%
Transformers	–0.93%	–1.12%	–0.74%
TFP Change	–0.05%	–0.36%	0.26%

In table 4.6 we decompose Queensland's TFP change into its constituent output and input parts for the whole 13–year period and for the periods up to and after 2012. Queensland's drivers of TFP change for the whole 13–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.

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 –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 0.8 percentage points to Queensland's average annual TFP change, somewhat less than the 1.0 percentage point contribution for the industry. After 2012, Queensland's outputs all contributed somewhat smaller amounts to TFP growth compared to the period before 2012 but its inputs generally 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, 2017–18**



A worsening in CMOS performance contributed –1.0 percentage points and an increase in opex contributed –0.5 percentage points to the TFP change of –1.5 per cent in 2018 as shown in figure 4.14. Increases in transformer and overhead distribution inputs and a reduction in energy throughput slightly more than offset the main positive contribution from customer numbers.

4.2.4 South Australia

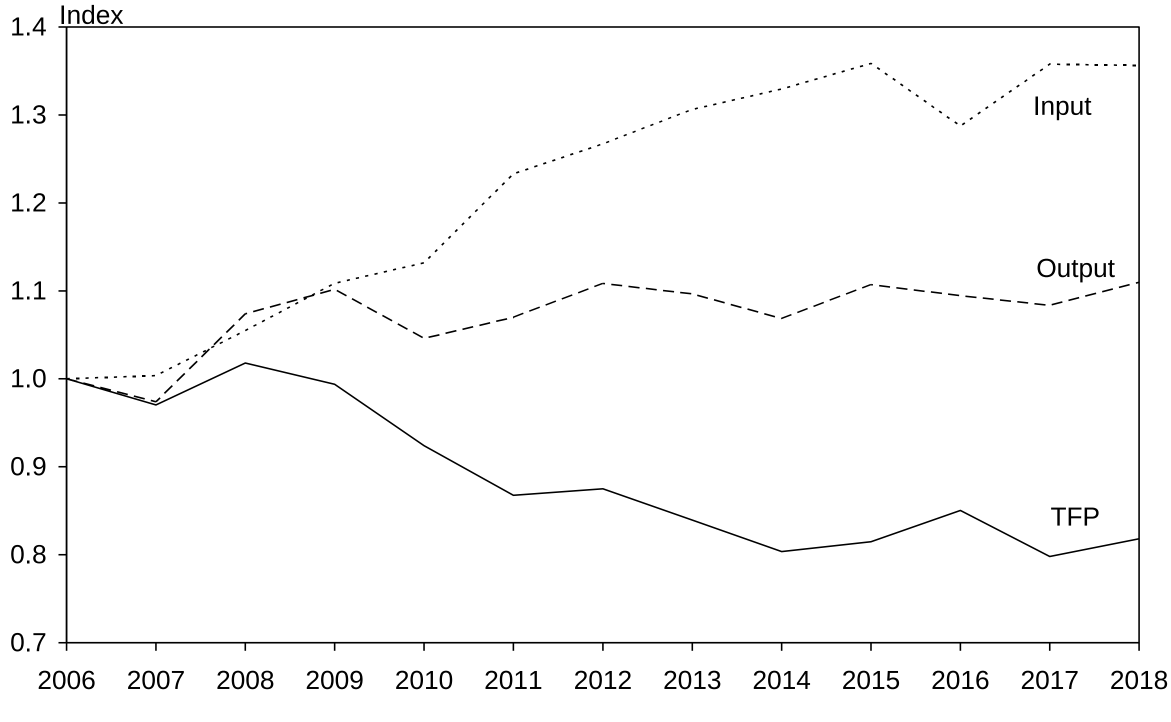
South Australia (SA) is the fourth largest of the NEM jurisdictions (by customer numbers) and is served by one DNSP, SA Power Networks (SAP). In 2018 the SA DNSP delivered 10,154 GWh to 894,397 customers over 89,311 circuit kilometres of lines and cables.

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 13–year period 2006 to 2018, the SA DNSP's TFP decreased at an average annual rate of 1.7 per cent. Although total output increased by an average annual rate of 0.9 per cent, total input use increased faster, at a rate of 2.5 per cent. SA thus had somewhat lower output growth and 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, 2006–2018**



In 2018 SA's output surpassed its previous peak in 2012. TFP change was positive in 2008, 2012, 2015, 2016 and 2018. Compared to the whole 13–year period TFP average annual change was more negative for the period up to 2012 at –2.2 per cent but has been less negative at –1.1 per cent for the period since 2012.

The partial productivity indexes in table 4.7 show that opex productivity growth for South Australia was considerably more negative than capital productivity growth for the period up to 2012 and both have declined at around 1.1 per cent per annum on average since 2012.

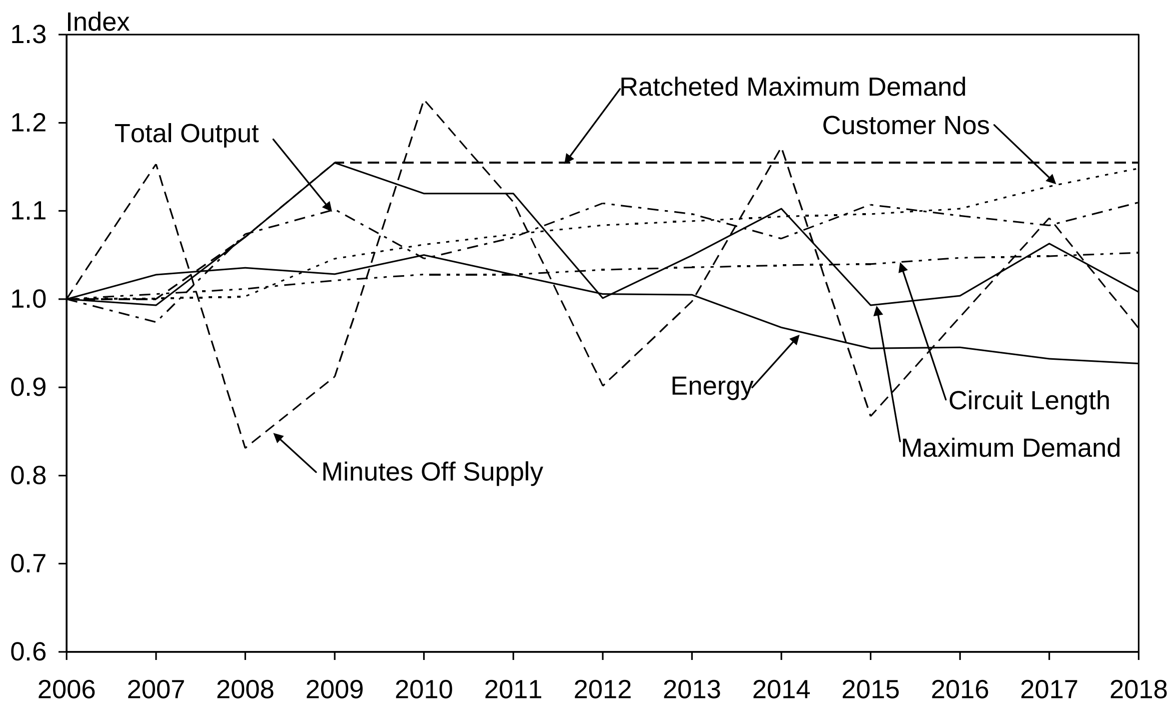
Table 4.7 **SA DNSP output, input and total factor productivity and partial productivity indexes, 2006–2018**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	0.974	1.004	0.970	1.051	0.940
2008	1.074	1.055	1.018	1.035	1.013
2009	1.102	1.109	0.994	0.964	1.010
2010	1.046	1.132	0.924	0.920	0.929
2011	1.070	1.233	0.868	0.754	0.934
2012	1.108	1.267	0.875	0.760	0.942
2013	1.096	1.306	0.839	0.710	0.917
2014	1.069	1.330	0.804	0.676	0.881
2015	1.107	1.359	0.815	0.674	0.902
2016	1.095	1.287	0.850	0.794	0.882
2017	1.084	1.358	0.798	0.683	0.868
2018	1.110	1.356	0.818	0.714	0.880
Growth Rate 2006–18	0.87%	2.54%	–1.67%	–2.81%	–1.07%
Growth Rate 2006–12	1.72%	3.94%	–2.23%	–4.58%	–1.00%
Growth Rate 2012–18	0.02%	1.14%	–1.12%	–1.05%	–1.14%

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 its six individual inputs in figure 4.17.

Figure 4.16 **SA output quantity indexes, 2006–2018**



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 15 per cent higher in 2018 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 9 per cent lower in 2018 than it was in 2006.

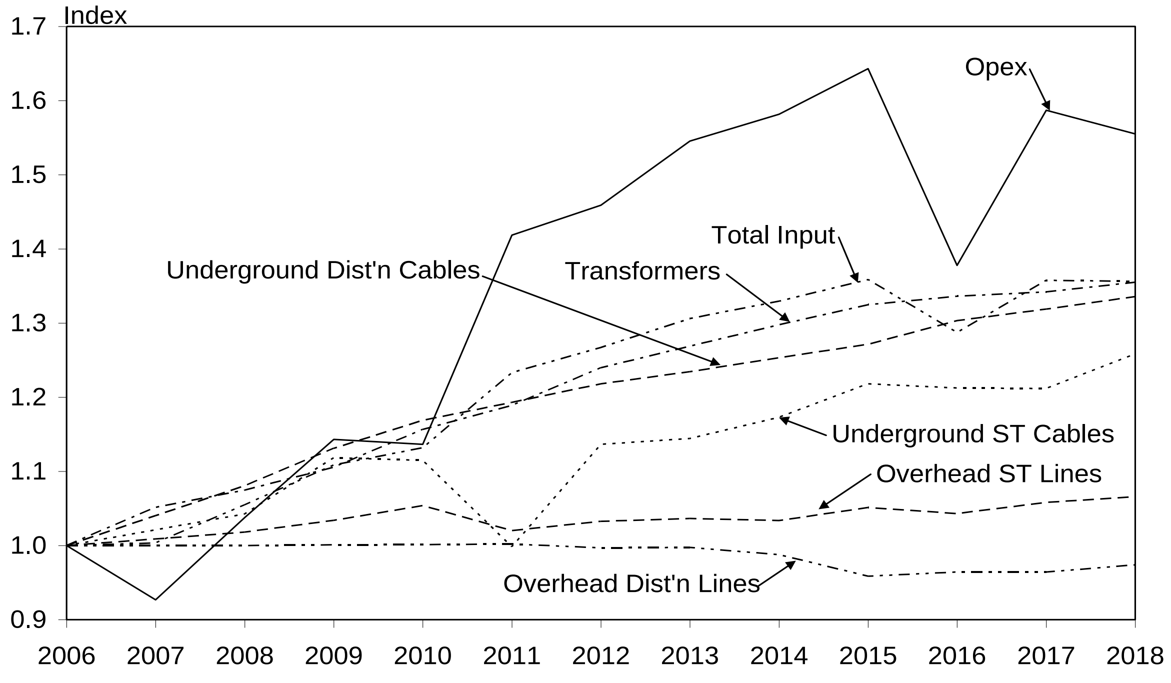
SA's maximum demand peaked in 2009 and has been relatively volatile since then. It has trended down since 2009 and in 2018 was 1 per cent above its 2006 level. Ratcheted maximum demand in 2018 was 16 per cent above its 2006 level – close to the same increase as for the industry overall.

SA's circuit length output grew somewhat more over the 13 years than occurred for the industry overall and by 2018 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, finishing the period at near the same level as it started despite considerable volatility around this level in the intervening years. By 2008 SA's CMOS was at its lowest level for the period being 17 per cent lower than it was in 2006 but in 2010 it was at its highest being 23 per cent higher than it was in 2006. CMOS fell by 11 per cent in 2018.

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 close to these output indexes in most years. The circuit length index lies at a lower level. Fluctuations in the total output index are mainly driven by the frequent movements in CMOS. The reduction in CMOS in 2018 contributed to the increase in the total output index in the latest year.

Figure 4.17 **SA DNSP input quantity indexes, 2006–2018**



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. 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. It then fell by 2 per cent in 2018. 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 3 per cent by 2018 relative to 2006 compared to a 12 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 was flat in 2018 with the decrease in opex usage offsetting small increases in the other inputs.

SA output and input contributions to TFP change

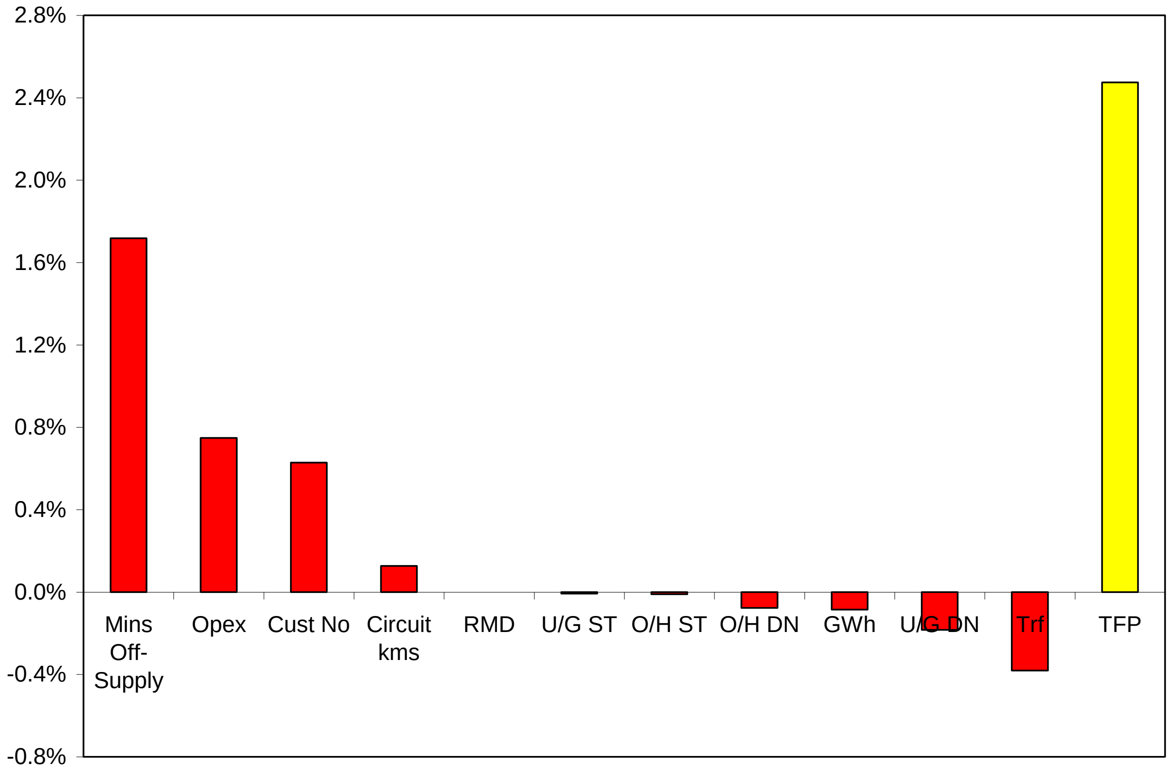
In table 4.8 we decompose SA's TFP change into its constituent output and input parts for the whole 13–year period and for the periods up to and after 2012. SA's drivers of TFP change for the whole 13–year period are broadly similar to the industry as a whole except that the output of customer numbers contributes somewhat less due to its weaker growth in SA and opex makes a larger negative contribution. CMOS contributes less to TFP growth for SA than for the industry given SA's CMOS changed little between the start and end of the period, despite considerable volatility around this level in the intervening years.

Table 4.8 **SA output and input percentage point contributions to average annual TFP change: 2006–2018, 2006–2012 and 2012–2018**

Year	*2006 to 2018*	*2006 to 2012*	*2012 to 2018*
Energy (GWh)	–0.09%	0.02%	–0.19%
Ratcheted Max Demand	0.41%	0.81%	0.00%
Customer Numbers	0.41%	0.48%	0.33%
Circuit Length	0.15%	0.19%	0.10%
CMOS	–0.01%	0.21%	–0.23%
Opex	–1.24%	–2.07%	–0.41%
O/H Subtransmission Lines	–0.01%	–0.01%	–0.01%
O/H Distribution Lines	0.02%	0.01%	0.04%
U/G Subtransmission Cables	–0.01%	–0.01%	–0.01%
U/G Distribution Cables	–0.48%	–0.71%	–0.25%
Transformers	–0.83%	–1.15%	–0.51%
TFP Change	–1.67%	–2.23%	–1.12%

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 reduced considerably for SA after 2012, although at –0.4 percentage points it was well below the 1.0 percentage points for the industry after 2012.

Figure 4.18 **SA output and input percentage point contributions to annual TFP change, 2017–18**



The importance of the decrease in CMOS in 2018 is highlighted in figure 4.18 where it makes a 1.7 percentage point contribution to TFP change. This adds to contributions of 0.8 and 0.6 percentage points from the reduction in opex and growth in customer numbers, respectively. SA's TFP growth in 2018 was 2.5 per cent.

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 2018 the Tasmania DNSP delivered 4,293 GWh to 287,936 customers over 22,767 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.

Figure 4.19 **TAS DNSP output, input and total factor productivity indexes, 2006–2018**

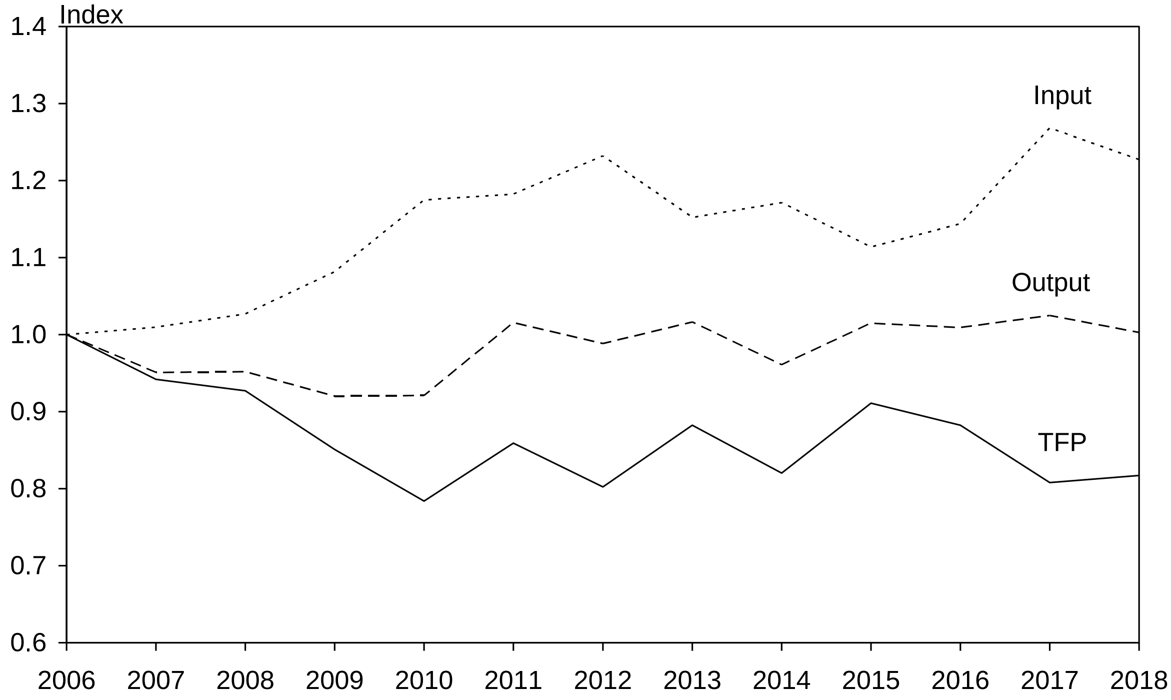


Table 4.9 **TAS DNSP output, input and total factor productivity and partial productivity indexes, 2006–2018**

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	0.951	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	1.268	0.808	0.742	0.855
2018	1.003	1.227	0.817	0.803	0.827
Growth Rate 2006–18	0.02%	1.71%	–1.68%	–1.82%	–1.58%
Growth Rate 2006–12	–0.20%	3.48%	–3.67%	–5.80%	–2.40%
Growth Rate 2012–18	0.24%	–0.07%	0.31%	2.15%	–0.76%

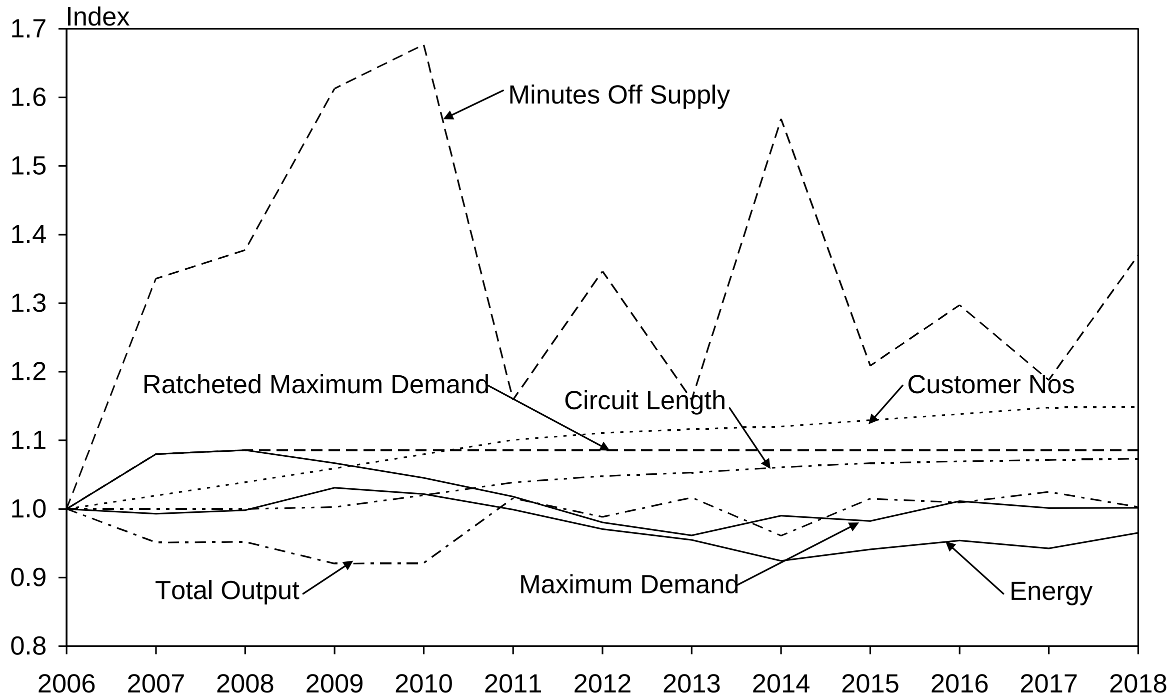
Over the 13–year period 2006 to 2018, the Tasmanian DNSP's TFP decreased at an average annual rate of 1.7 per cent. Total output has increased only marginally and actually decreased by 8 per cent between 2006 and 2010. Total input use, on the other hand, has increased at an average annual rate of 1.7 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 and then reducing in 2018. TFP change was positive in four years: 2011, 2013, 2015 and 2018. In 2011 output grew strongly while input increase moderated. In 2015 output grew more strongly and input use was also cut significantly while in 2018 input use was reduced while output reduced by a lesser amount. Compared to the whole 13–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 0.3 per cent.

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, 2006–2018**



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 2018 than they were in 2006, somewhat less than the industry's increase over the 13 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 3 per cent lower in 2018 than it was in 2006.

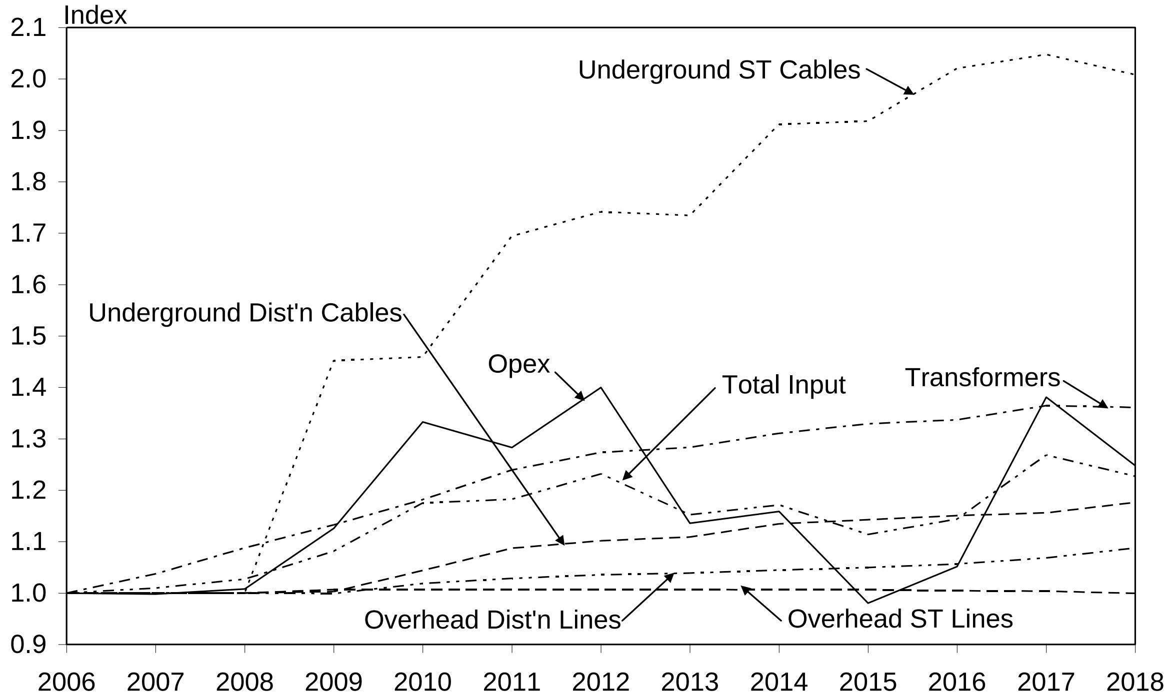
Tasmania's maximum demand reached its highest level in 2008 then declined through to 2013 before recovering somewhat subsequently. In 2018 it was around the same level as it was in 2006. Ratcheted maximum demand in 2018 was 9 per cent above its 2006 level – a much smaller increase than the industry's 17 per cent.

Tasmania's circuit length output grew faster over the 13 years than occurred for the industry overall and by 2018 was 7 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 2018 Tasmania's CMOS was 37 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.

Figure 4.21 **TAS DNSP input quantity indexes, 2006–2018**



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 sharply in 2017 before again being reduced in 2018. In 2018 it was 25 per cent above its 2006 level. As noted in Economic Insights (2018), TND 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 higher levels 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.

Tasmania's transformer inputs have increased at a similar annual rate to the industry's 2.7 per cent for the 13 year period as a whole. However, Tasmania's transformer input use increased somewhat more rapidly than for the industry up to 2012 but somewhat 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 2018 underground distribution cables inputs were 18 per cent higher in Tasmania than they were in 2006 compared to a corresponding increase of 56 per cent for the industry. Tasmania's overhead distribution lines input increased over the period with an increase of 9 per cent by 2018 relative to 2006 compared to a corresponding 12 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 decreased by over 3 per cent in 2018, mainly due to the 10 per cent reduction in opex.

Tasmanian output and input contributions to TFP change

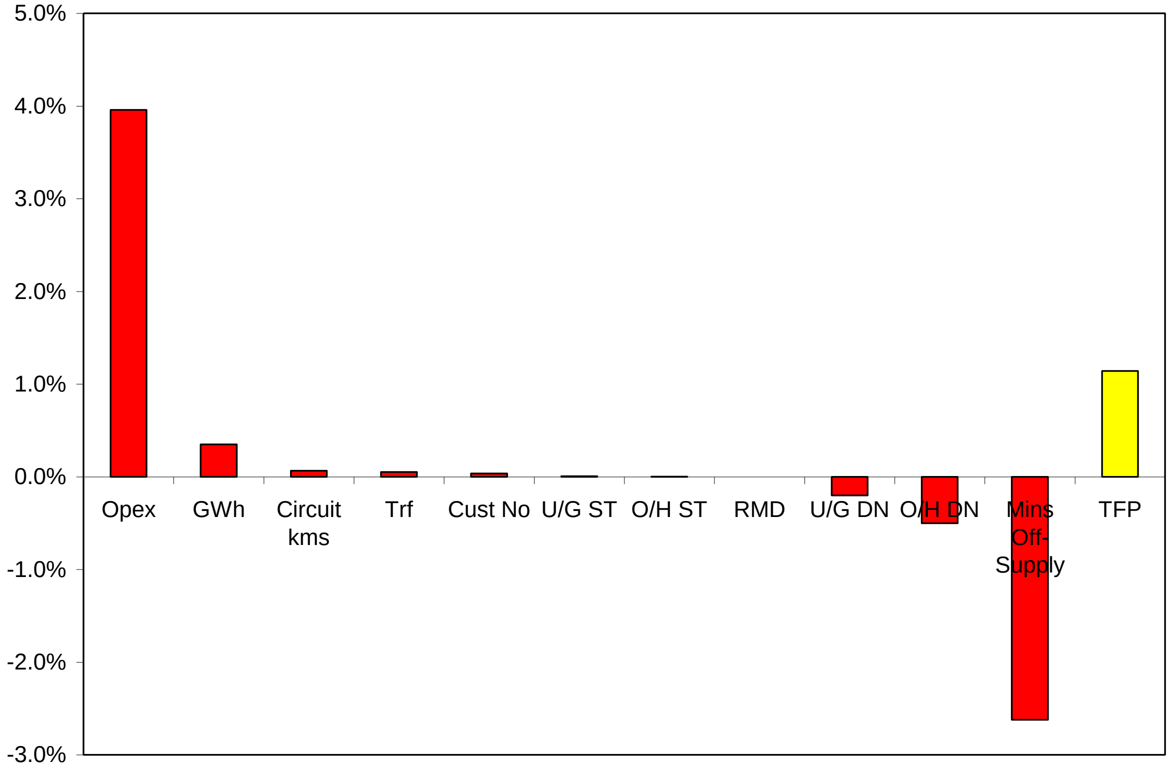
In table 4.10 we decompose Tasmania's TFP change into its constituent output and input parts for the whole 13–year period and for the periods up to and after 2012. Tasmania's drivers of TFP change for the whole 13–year period are somewhat similar to the industry as a whole except that CMOS makes a negative 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 –0.7 per cent compared to –0.5 per cent for the industry.

Table 4.10 **TAS output and input percentage point contributions to average annual TFP change: 2006–2018, 2006–2012 and 2012–2018**

Year	*2006 to 2018*	*2006 to 2012*	*2012 to 2018*
Energy (GWh)	–0.04%	–0.07%	–0.01%
Ratcheted Max Demand	0.25%	0.50%	0.00%
Customer Numbers	0.44%	0.68%	0.20%
Circuit Length	0.21%	0.28%	0.14%
CMOS	–0.83%	–1.59%	–0.08%
Opex	–0.67%	–2.06%	0.72%
O/H Subtransmission Lines	0.00%	0.00%	0.00%
O/H Distribution Lines	–0.19%	–0.16%	–0.23%
U/G Subtransmission Cables	–0.02%	–0.04%	–0.01%
U/G Distribution Cables	–0.17%	–0.21%	–0.13%
Transformers	–0.65%	–1.02%	–0.28%
TFP Change	–1.68%	–3.67%	0.31%

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 2.8 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 0.7 percentage points.

Figure 4.22 **TAS output and input percentage point contributions to annual TFP change, 2017–18**



The impact of the reduction in opex in 2018 on Tasmanian TFP performance is highlighted in figure 22 where opex made a 4.0 percentage point contribution to TFP change in the 2018 year. This more than offset the contribution of –2.6 percentage points from a worsening in CMOS. Contributions from other outputs and inputs were all relatively small leading to Tasmanian TFP change of 1.1 per cent in 2018, somewhat above the industry TFP change of 1.0 per cent in the latest year.

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 36,032 GWh to 2.9 million customers over 145,012 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.

Figure 4.23 **VIC DNSP output, input and total factor productivity indexes, 2006–2018**

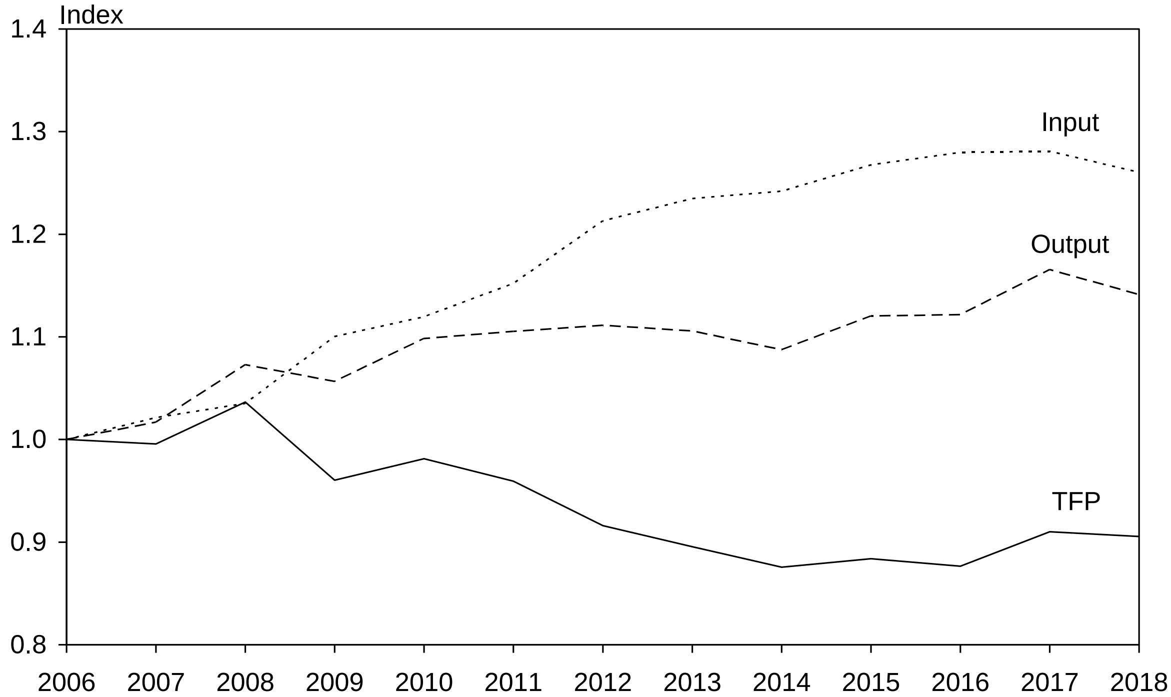


Table 4.11 **VIC DNSP output, input and total factor productivity and partial productivity indexes, 2006–2018**

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	1.017	1.021	0.996	1.002	0.991
2008	1.073	1.035	1.037	1.059	1.022
2009	1.057	1.100	0.960	0.944	0.971
2010	1.099	1.120	0.981	0.969	0.989
2011	1.105	1.152	0.959	0.926	0.979
2012	1.111	1.213	0.916	0.842	0.965
2013	1.106	1.235	0.895	0.825	0.942
2014	1.087	1.242	0.876	0.823	0.909
2015	1.120	1.268	0.884	0.824	0.922
2016	1.122	1.280	0.877	0.825	0.909
2017	1.166	1.281	0.910	0.878	0.931
2018	1.141	1.260	0.905	0.928	0.895
Growth Rate 2006–18	1.10%	1.93%	–0.83%	–0.63%	–0.92%
Growth Rate 2006–12	1.76%	3.22%	–1.46%	–2.87%	–0.60%
Growth Rate 2012–18	0.44%	0.63%	–0.19%	1.62%	–1.24%

Over the 13–year period 2006 to 2018, the Victorian DNSPs' TFP decreased at an average annual rate of 0.8 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 1.9 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 2018. Victoria's output declined in four years: 2009, 2013, 2014 and 2018. 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 levelled off at the same time there was a return to strong output growth. Compared to the whole 13–year period TFP average annual change of –0.8 per cent, TFP average annual change was more negative for the period up to 2012 at –1.5 per cent but has been –0.2 per cent for the period since 2012.

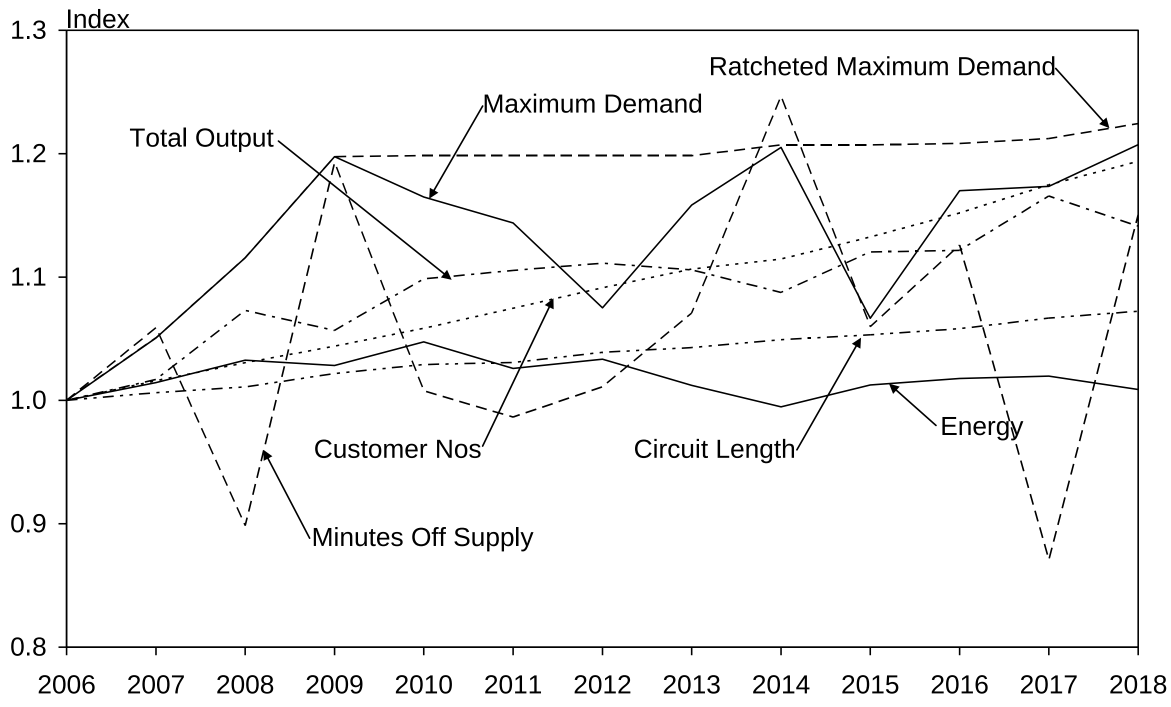
The partial productivity indexes in table 4.11 show that better opex PFP performance was the main driver of the improved TFP performance after 2012.

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 19 per cent higher in 2018 than they were in 2006, slightly higher than the industry's increase of 18 per cent. Energy throughput for distribution peaked in 2010 and was only 1 per cent higher in 2018 than it was in 2006.

Figure 4.24 **VIC output quantity indexes, 2006–2018**



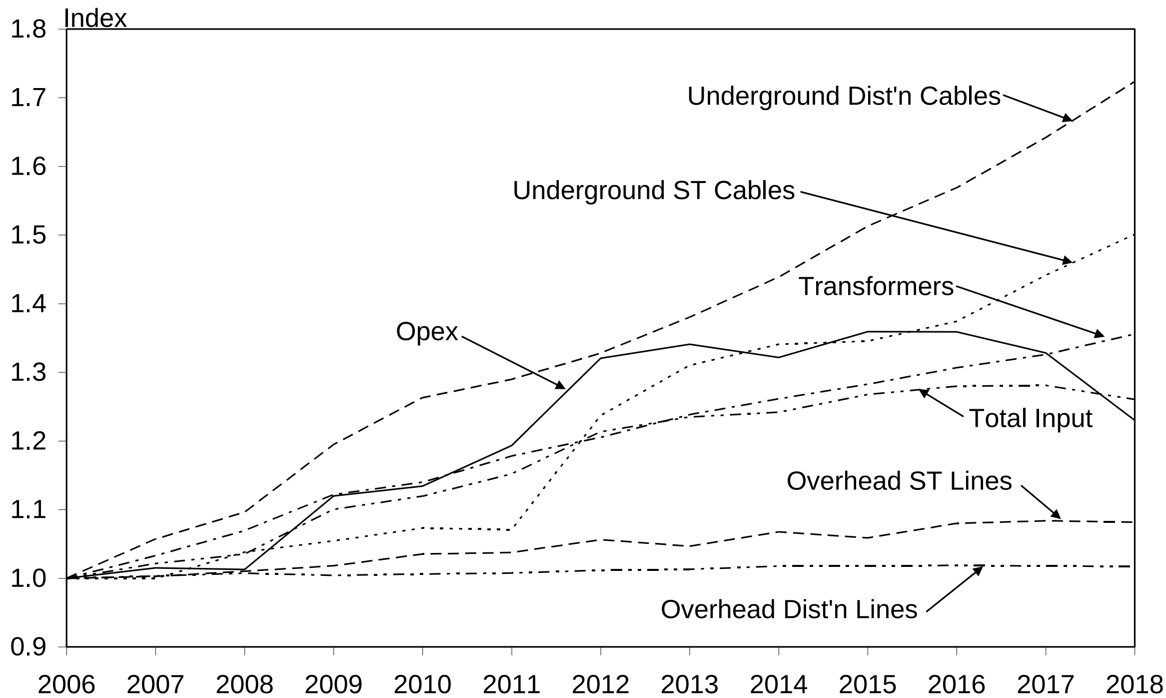
In 2018 Victoria's maximum demand marginally exceeded its previous highest level in 2014 but has been relatively volatile since 2009. In 2018 it was around 21 per cent above its 2006 level. Ratcheted maximum demand in 2018 was 22 per cent above its 2006 level – a larger increase than the industry's 17 per cent.

Victoria's circuit length output grew somewhat more over the 13 years than occurred for the industry overall and by 2018 was 7 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 4.24 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 before again increasing by 32 per cent in 2018 to be 15 per cent higher 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 increase in 2018 is the main reason for the reduction in total output in the latest year.

Figure 4.25 **VIC DNSP input quantity indexes, 2006–2018**



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 2017 before decreasing by 7 per cent in 2018. This brought Victoria's opex reduction after 2012 to less than half that for the industry which reduced by 16 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 slowly over the period with an increase of 2 per cent by 2018 relative to 2006 compared to a 4 per cent increase for the industry.

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 1.6 per cent in 2018 with the reduction in opex usage of 8 per cent more than offsetting increases in transformer and underground cables inputs.

Victorian output and input contributions to TFP change

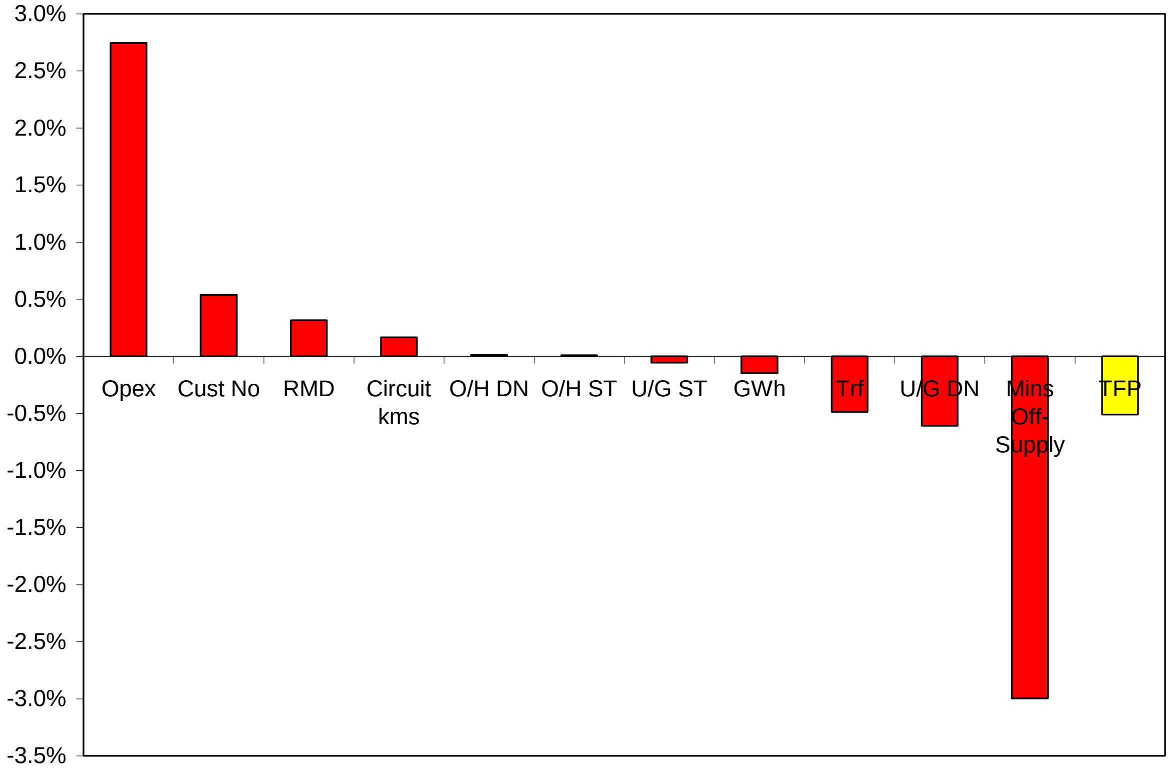
In table 4.12 we decompose Victoria's TFP change into its constituent output and input parts for the whole 13–year period and for the periods up to and after 2012. Victoria's drivers of TFP change for the whole 13–year period are broadly similar to the industry as a whole except that CMOS makes a negative contribution to TFP growth for Victoria as opposed to a positive contribution for the industry. Opex also makes a somewhat more negative contribution over the period for Victoria at –0.7 per cent compared to –0.5 per cent for the industry. However, transformer inputs make a lees negative contribution to Victoria's TFP at –0.5 percentage points compared to –0.8 for the industry.

Table 4.12 **VIC output and input percentage point contributions to average annual TFP change: 2006–2018, 2006–2012 and 2012–2018**

Year	*2006 to 2018*	*2006 to 2012*	*2012 to 2018*
Energy (GWh)	0.01%	0.08%	–0.06%
Ratcheted Max Demand	0.55%	0.99%	0.11%
Customer Numbers	0.51%	0.51%	0.51%
Circuit Length	0.19%	0.21%	0.17%
CMOS	–0.16%	–0.03%	–0.29%
Opex	–0.69%	–1.78%	0.40%
O/H Subtransmission Lines	–0.02%	–0.03%	–0.02%
O/H Distribution Lines	–0.03%	–0.04%	–0.02%
U/G Subtransmission Cables	–0.05%	–0.05%	–0.04%
U/G Distribution Cables	–0.60%	–0.64%	–0.55%
Transformers	–0.54%	–0.68%	–0.41%
TFP Change	–0.83 %	–1.46%	–0.19%

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 customer numbers. And the contribution of most inputs remains relatively unchanged except for opex and transformers whose contributions improve by 2.2 percentage points and 0.3 percentage points, respectively. Opex change went from a negative percentage point contribution to TFP to a positive contribution of 0.4 percentage points for Victoria as opex usage reduced, although this was concentrated in 2018. This was broadly in line with changes for the industry as a whole.

Figure 4.26 **VIC output and input percentage point contributions to annual TFP change, 2018**



The importance of the recent falls in opex usage and the increase in CMOS is highlighted in figure 4.26 where opex made a 2.8 percentage point contribution and CMOS made a –3.0 percentage point contribution to TFP change in the 2018 year. Customer numbers growth contributed 0.5 percentage points to TFP. Victorian TFP growth in 2018 was –0.5 per cent compared to industry TFP growth of 1.0 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 Evoenergy, South Australia's SA Power Networks and Tasmania's TasNetworks Distribution.

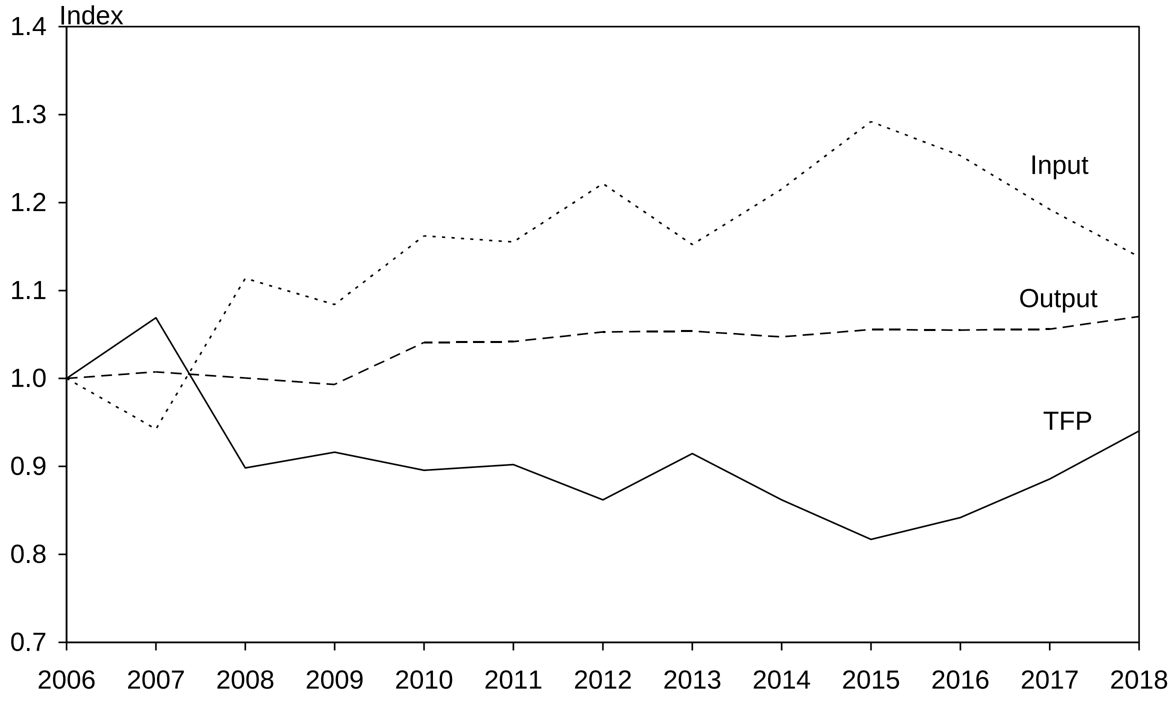
5.1 Ausgrid

In 2018 Ausgrid (AGD) delivered 25,387 GWh to 1.72 million customers over 41,847 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, 2006–2018**



Over the 13–year period 2006 to 2018, AGD's TFP decreased with an average annual change of –0.5 per cent. Although total output increased by an average annual rate of 0.6 per cent, total input use increased faster, at a rate of 1.1 per cent. AGD thus had much slower output growth than the industry as a whole. However, it has also now had slower input growth leading to AGD having a less negative TFP growth rate than the industry. 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, 2017 and 2018 after solid increases in 2014 and 2015. TFP fell markedly in 2008, 2012, 2014 and 2015 but TFP change was positive in seven years – 2007, 2009, 2011, 2013, 2016, 2017 and 2018. 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 an average annual rate of 1.5 per cent.

Table 5.1 **AGD output, input and total factor productivity and partial productivity indexes, 2006–2018**

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
2018	1.070	1.138	0.940	1.177	0.858
Growth Rate 2006–18	0.57%	1.08%	–0.51%	1.36%	–1.28%
Growth Rate 2006–12	0.86%	3.33%	–2.47%	–3.55%	–1.76%
Growth Rate 2012–18	0.27%	–1.17%	1.45%	6.27%	–0.80%

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

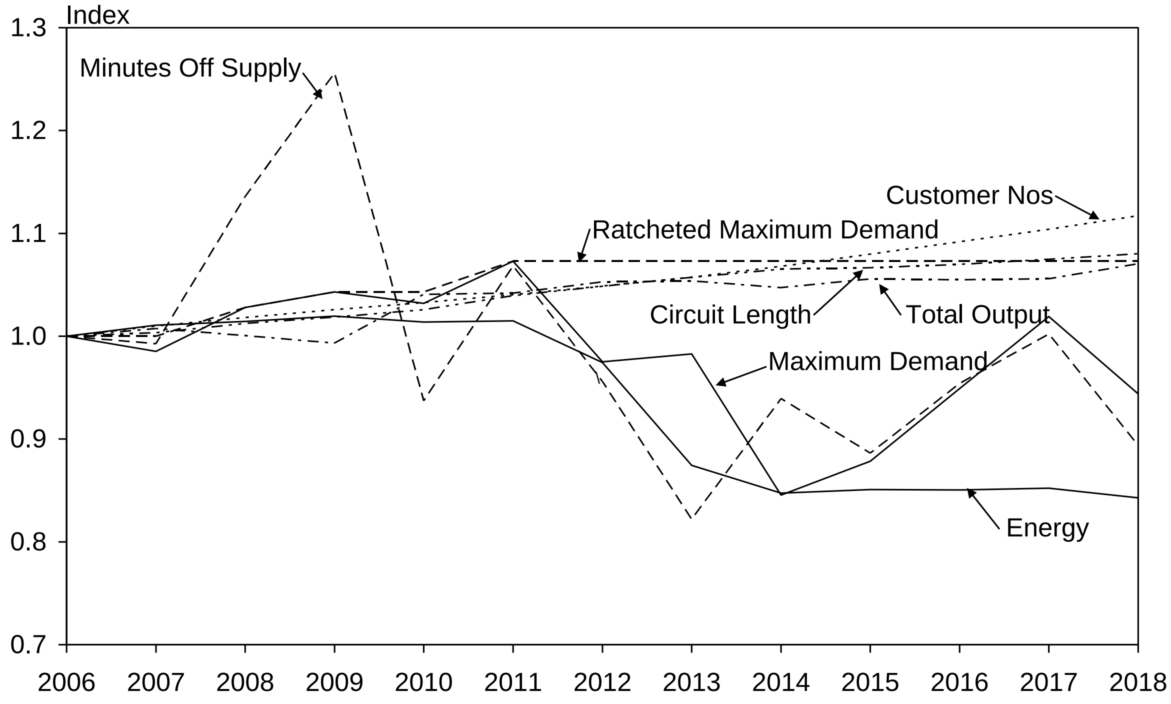
We graph the quantity indexes for AGD’s five individual outputs in figure 5.2 and for its six individual inputs in figure 5.3.

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 12 per cent higher in 2018 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 16 per cent lower in 2018 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 and falling again in 2018. In 2018 it was 6 per cent below its 2006 level. Ratcheted maximum demand in 2018 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 2018 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, 2006–2018**



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 generally downward trajectory. In 2018 CMOS was 11 per cent below its 2006 level.

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 was slightly below these three indexes between 2012 and 2017 as it is pulled down by AGD's weak throughput output and an upward movement in CMOS between 2013 and 2017.

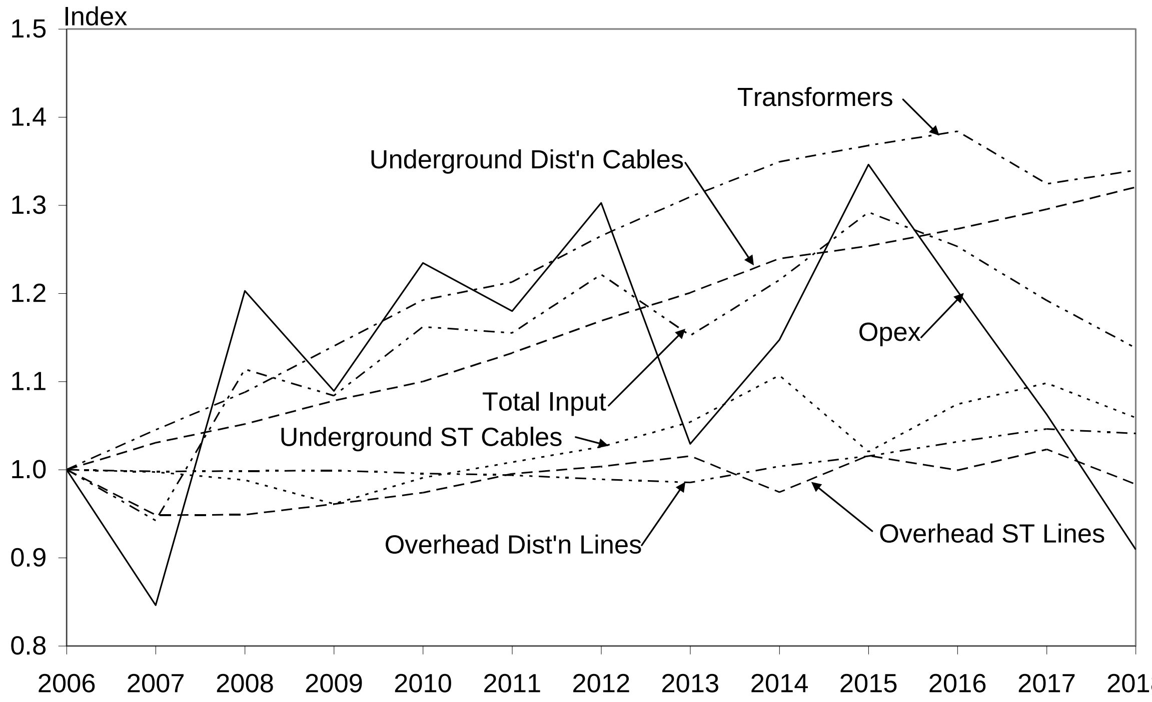
Turning to the input side, we see from AGD's six input components and total input in figure 5.3 that the quantity of AGD's opex has been subject to wide swings over the 13–year period. AGD's opex increased by 30 per cent up to 2012 whereas the corresponding increase for the industry was 36 per cent. 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 substantially in 2016, 2017 and 2018 to be 9 per cent below its 2006 level in 2018.[5] Opex has the largest average share in AGD's total costs at 37 per cent and so is an important driver of its total input quantity index.

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

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

inputs increased at a broadly 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 4 per cent compared to 12 per cent for the industry.

Figure 5.3 **AGD input quantity indexes, 2006–2018**



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 70 per cent of total costs). Total input quantity fell by 5 per cent in 2018 in line with the substantial reduction in reported opex usage that year.

AGD's output and input contributions to TFP change

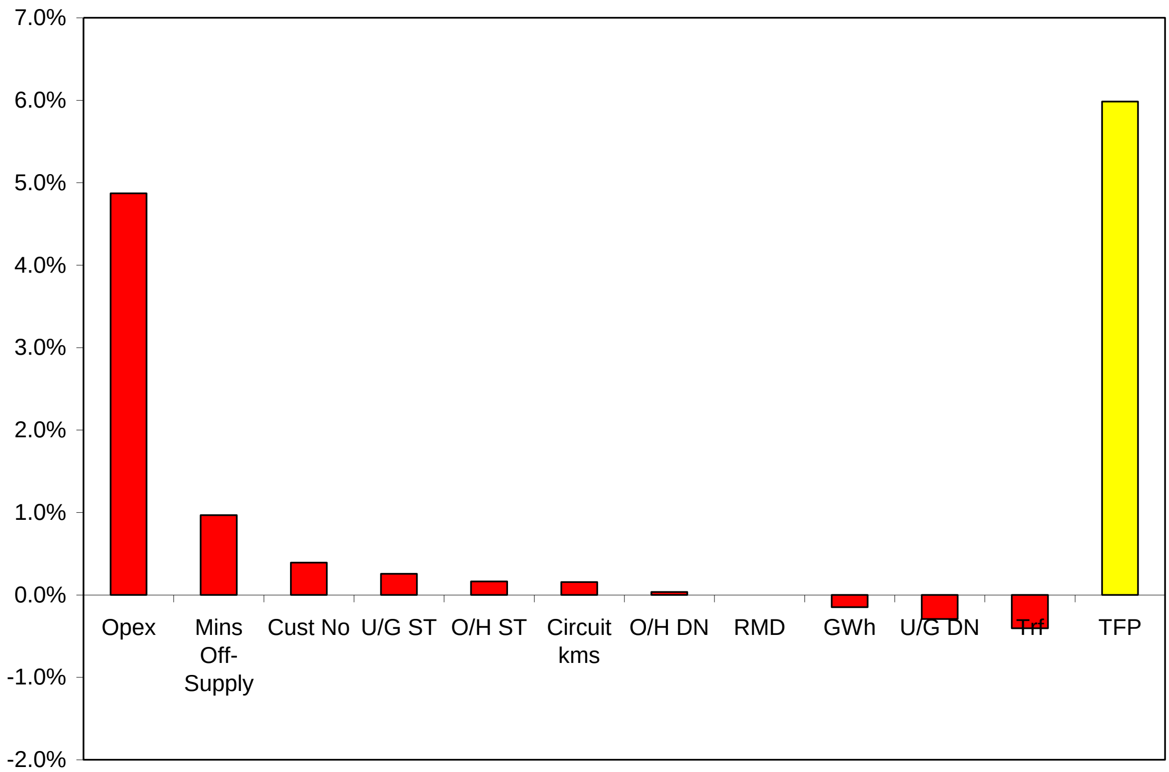
In table 5.2 we decompose AGD's TFP change into its constituent output and input parts for the whole 13–year period and for the periods up to and after 2012. AGD's drivers of TFP change for the whole 13–year period are broadly similar to the industry as a whole except that the major outputs of customer 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 decrease in CMOS over the period and its smaller weight in recent years.

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 1.9 percentage points to AGD's average annual TFP change of 1.5 per cent for the period after 2012. This compares to an opex contribution of 1.0 percentage points to the industry's lower 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: 2006–2018, 2006–2012 and 2012–2018**

Year	*2006 to 2018*	*2006 to 2012*	*2012 to 2018*
Energy (GWh)	–0.19%	–0.06%	–0.32%
Ratcheted Max Demand	0.19%	0.38%	0.00%
Customer Numbers	0.31%	0.27%	0.34%
Circuit Length	0.21%	0.26%	0.15%
CMOS	0.05%	0.00%	0.10%
Opex	0.05%	–1.79%	1.89%
O/H Subtransmission Lines	0.01%	0.00%	0.01%
O/H Distribution Lines	–0.02%	0.01%	–0.06%
U/G Subtransmission Cables	–0.02%	–0.02%	–0.03%
U/G Distribution Cables	–0.32%	–0.34%	–0.29%
Transformers	–0.78%	–1.20%	–0.35%
TFP Change	–0.51%	–2.47%	1.45%

Figure 5.4 **AGD output and input percentage point contributions to annual TFP change, 2017–18**



The importance of the reduction in AGD's reported opex in 2018 is highlighted in figure 5.4 where the 4.9 percentage point contribution of opex to TFP change in the 2018 year and the

1.0 percentage point contribution from the reduction in CMOS dwarf the contributions of other outputs and inputs. The contributions of the other output and inputs almost offset each other to produce a TFP increase of 6.0 per cent in 2018.

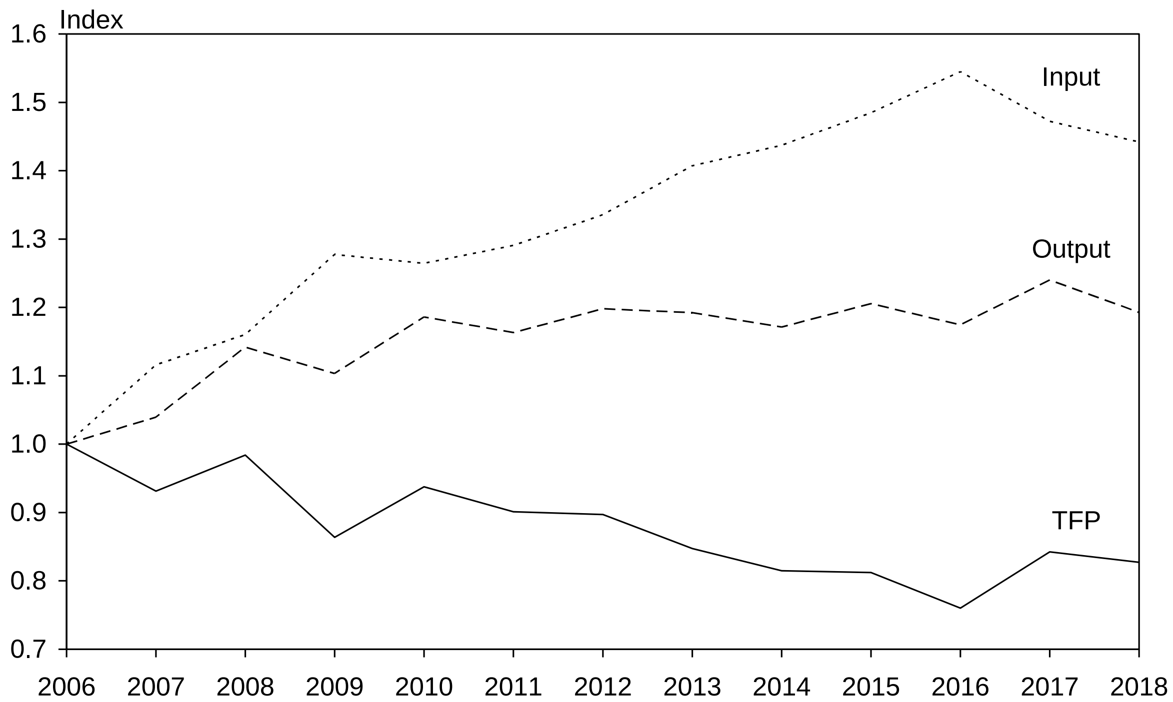
5.2 AusNet Services Distribution

In 2018 AusNet Services Distribution (AND) delivered 7,570 GWh to 741,836 customers over 45,115 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, 2006–2018**



Over the 13–year period 2006 to 2018, AND's TFP decreased with an average annual change of –1.6 per cent. Although total output increased by an average annual rate of 1.5 per cent, total input use increased considerably faster, at a rate of 3.5 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 remained flat while the industry's output increased annually at 0.6 per cent. 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 2018. 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 13–year period, AND's TFP average annual change was somewhat more negative for the period up to 2012 at –1.8 per cent than for the period after 2012 when it was –1.4 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, 2006–2018**

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	1.116	0.931	0.850	0.997
2008	1.142	1.160	0.984	0.867	1.080
2009	1.103	1.278	0.864	0.723	0.986
2010	1.186	1.265	0.938	0.803	1.053
2011	1.163	1.291	0.901	0.782	1.005
2012	1.198	1.336	0.897	0.760	1.015
2013	1.192	1.407	0.847	0.682	0.991
2014	1.171	1.437	0.815	0.650	0.959
2015	1.206	1.485	0.812	0.632	0.973
2016	1.174	1.545	0.760	0.573	0.932
2017	1.240	1.472	0.842	0.698	0.974
2018	1.193	1.442	0.827	0.732	0.922
Growth Rate 2006–18	1.47%	3.05%	–1.58%	–2.60%	–0.68%
Growth Rate 2006–12	3.01%	4.82%	–1.81%	–4.58%	0.24%
Growth Rate 2012–18	–0.07%	1.27%	–1.35%	–0.62%	–1.60%

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

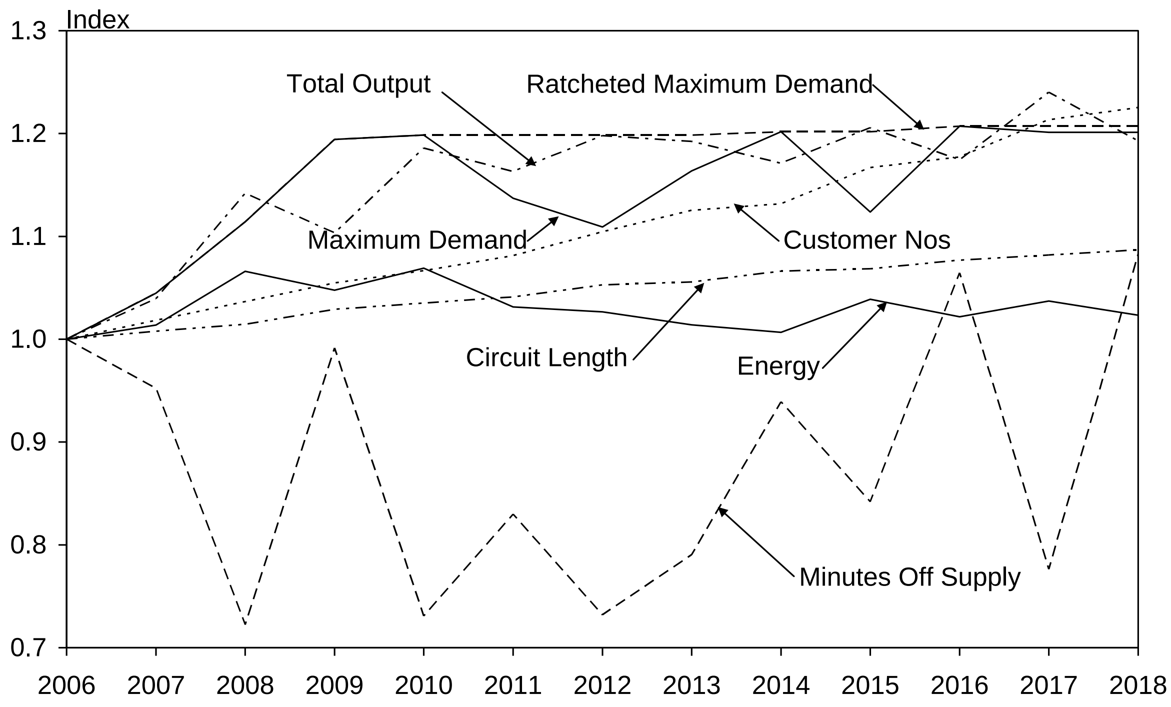
We graph the quantity indexes for AND's five individual outputs in figure 5.6 and for their six individual inputs in figure 5.7.

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 23 per cent higher in 2018 than they were in 2006, higher than the industry's increase of 18 per cent. Energy throughput for distribution peaked in 2010 and was only 2 per cent higher in 2018 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 2018 AND's maximum demand was around 20 per cent above its 2006 level. Ratcheted maximum demand in 2018 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 13 years than occurred for the industry overall and by 2018 was 9 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, 2006–2018**



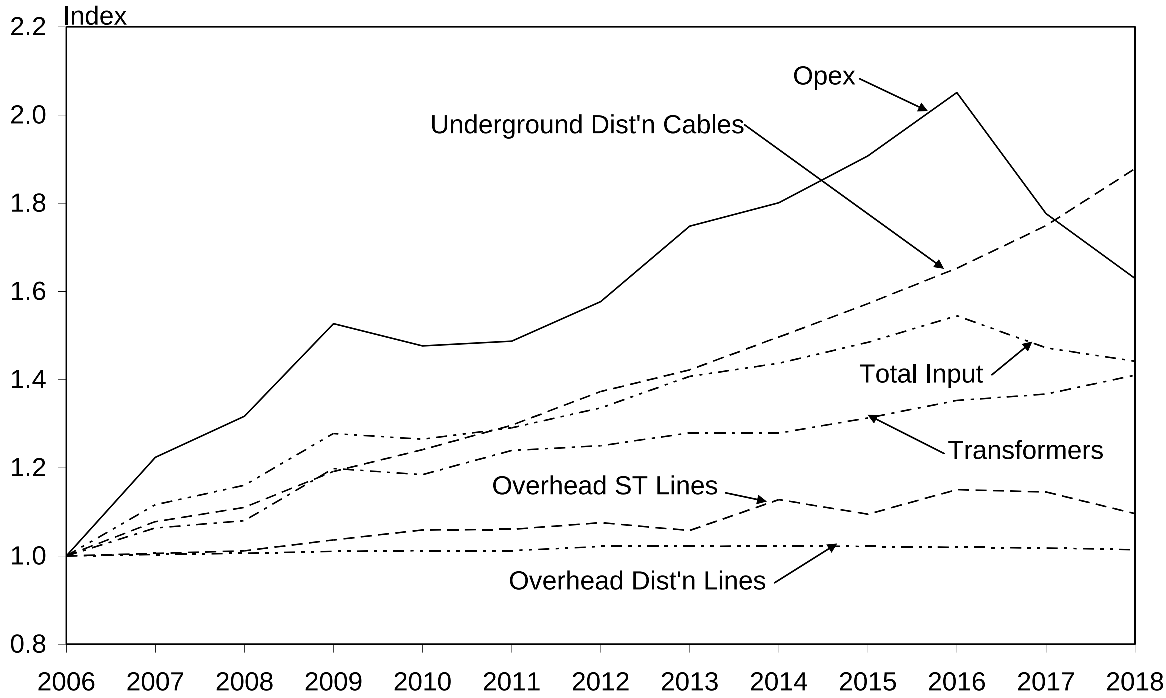
The last output shown in figure 5.6 is total CMOS. AND's CMOS has been more volatile than for the industry and, after trending downwards to 2012 (at which point it was 27 per cent below its 2006 level), it has trended upwards since. By 2018 AND's CMOS was 8 per cent higher than it was in 2006.

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 since 2012 has suppressed output growth significantly over this period, particularly in 2018.

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. We also note that AND's opex has been revised this year to exclude connections opex and transmission planning opex for most years but to include taxes and levies costs for 2016 and 2017. This led to opex increasing by around 7 per cent in 2016 and 2017. For AND, opex increased by 58 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 30 per cent through to 2016 before falling by 21 per cent over the last two years. In 2018 AND's opex was still 3 per cent above its 2012 level whereas that for the industry was 16 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 rate than for the industry as a whole while its transformers increased at a somewhat higher rate compared to the industry. Its overhead distribution lines input increased slower over the period with an increase of 1.4 per cent by 2018 relative to 2006 compared to an 12 per cent increase for the industry.

Figure 5.7 **AND's input quantity indexes, 2006–2018**



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 2.1 per cent in 2018 driven by the 9 per cent fall in opex usage.

AND's output and input contributions to TFP change

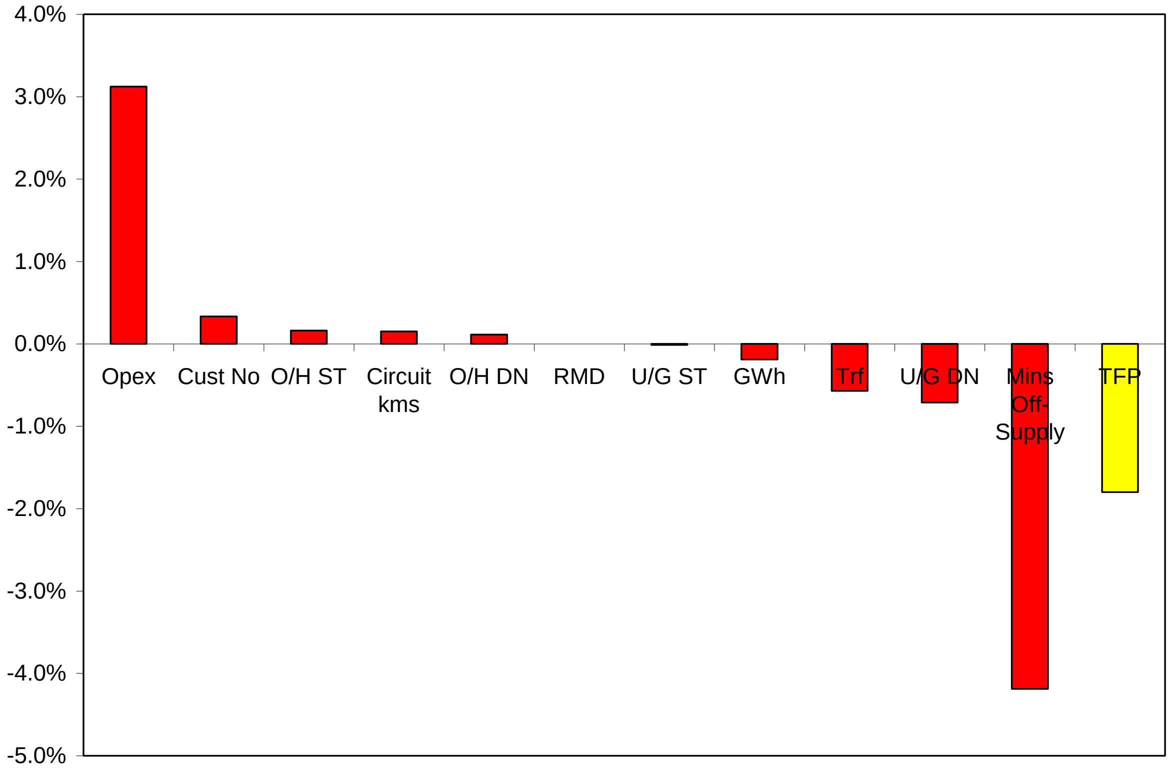
In table 5.4 we decompose AND's TFP change into its constituent output and input parts for the whole 13–year period and for the periods up to and after 2012. AND's drivers of TFP change for the whole 13–year period are broadly similar to the industry as a whole except that opex makes far and away the 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 –1.8 percentage points compared to –0.5 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. And the contribution of most inputs remains relatively unchanged except for opex and transformers whose contributions improve by 3.5 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: 2006–2018, 2006–2012 and 2012–2018**

Year	*2006 to 2018*	*2006 to 2012*	*2012 to 2018*
Energy (GWh)	0.03%	0.07%	–0.01%
Ratcheted Max Demand	0.54%	1.04%	0.04%
Customer Numbers	0.60%	0.60%	0.59%
Circuit Length	0.24%	0.30%	0.17%
CMOS	0.07%	1.01%	–0.87%
Opex	–1.77%	–3.18%	–0.36%
O/H Subtransmission Lines	–0.01%	–0.02%	0.00%
O/H Distribution Lines	–0.02%	–0.08%	0.04%
U/G Subtransmission Cables	–0.02%	0.00%	–0.03%
U/G Distribution Cables	–0.64%	–0.72%	–0.56%
Transformers	–0.59%	–0.82%	–0.36%
TFP Change	–1.58%	–1.81%	–1.35%

Figure 5.8 **AND's output and input percentage point contributions to annual TFP change, 2018**



AND's opex usage reduction of 9 per cent in 2018 means it makes the largest positive contribution to TFP change in 2018 of 3.1 percentage points as shown in figure 5.8. The substantial worsening in CMOS performance that year contributed –4.2 percentage points. Customer numbers growth made a contribution of 0.3 percentage points while small positive and negative contributions from the other outputs and inputs made a net contribution of –1.1 per cent. As a result, AND's TFP change in 2018 was –1.8 per cent compared to industry TFP change of 1.0 per cent that year.

5.3 CitiPower

In 2018, CitiPower (CIT) delivered 5,823 GWh to 342,669 customers over 4,536 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

As noted in section 1.3, CIT is one of three Victorian DNSPs that submitted incorrect opex data for the 2017 year in their April 2018 EBRINs. The AER was notified in December 2018 that CIT had incorrectly capitalised some inspection and maintenance costs instead of expensing them as required under CIT's EBRIN reporting. This correction has led to CIT's 2017 opex being 10 per cent higher than initially reported. Consequently, there are material differences between CIT's 2017 productivity performance reported in this report compared to Economic Insights (2018).

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.

Figure 5.9 **CIT's output, input and total factor productivity indexes, 2006–2018**

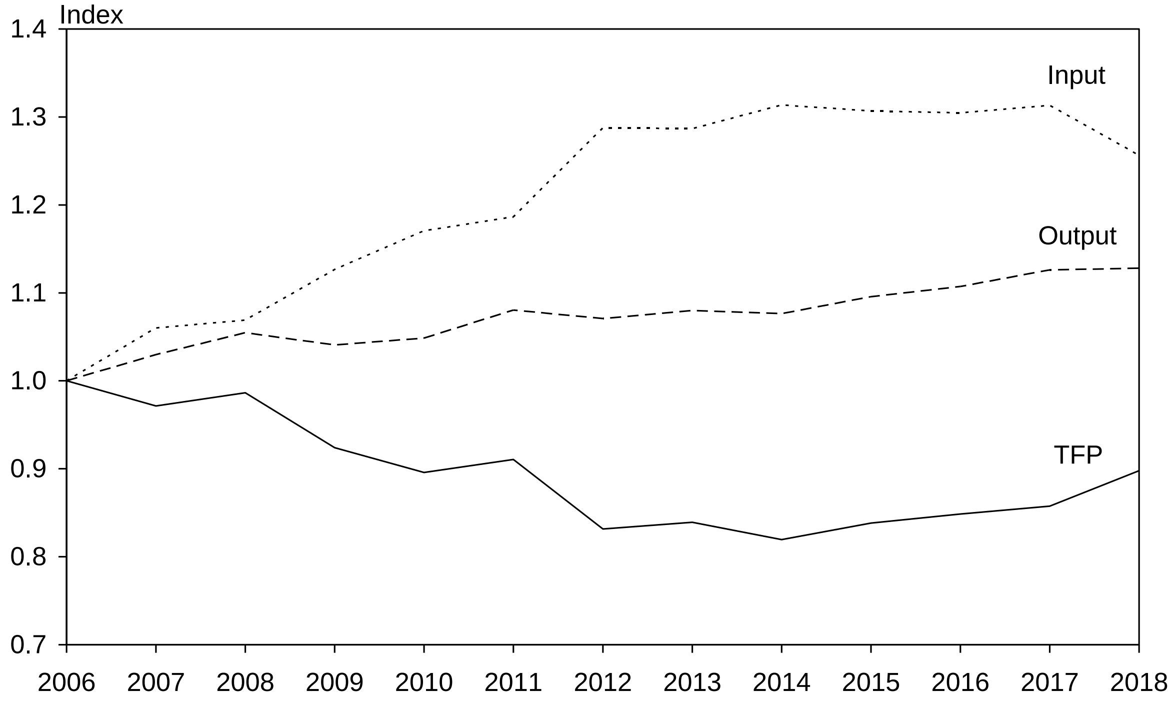


Table 5.5 **CIT's output, input and total factor productivity and partial productivity indexes, 2006–2018**

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	1.313	0.858	0.748	0.900
2018	1.128	1.256	0.898	0.869	0.911
Growth Rate 2006–18	1.00%	1.90%	–0.90%	–1.17%	–0.78%
Growth Rate 2006–12	1.14%	4.21%	–3.08%	–7.00%	–1.59%
Growth Rate 2012–18	0.87%	–0.41%	1.28%	4.65%	0.04%

Over the 13–year period 2006 to 2018, CIT's TFP decreased with an average annual change of –0.9 per cent. Although total output increased by an average annual rate of 1.0 per cent, total input use increased faster, at a rate of 1.9 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 before declining in 2018. CIT's output declined in three years: 2009, 2012 and 2014. TFP change was positive in seven years: 2008, 2011, 2013, 2015, 2016, 2017 and 2018. 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 13–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 1.3 per cent as input use has levelled off and then declined recently and output has continued growing.

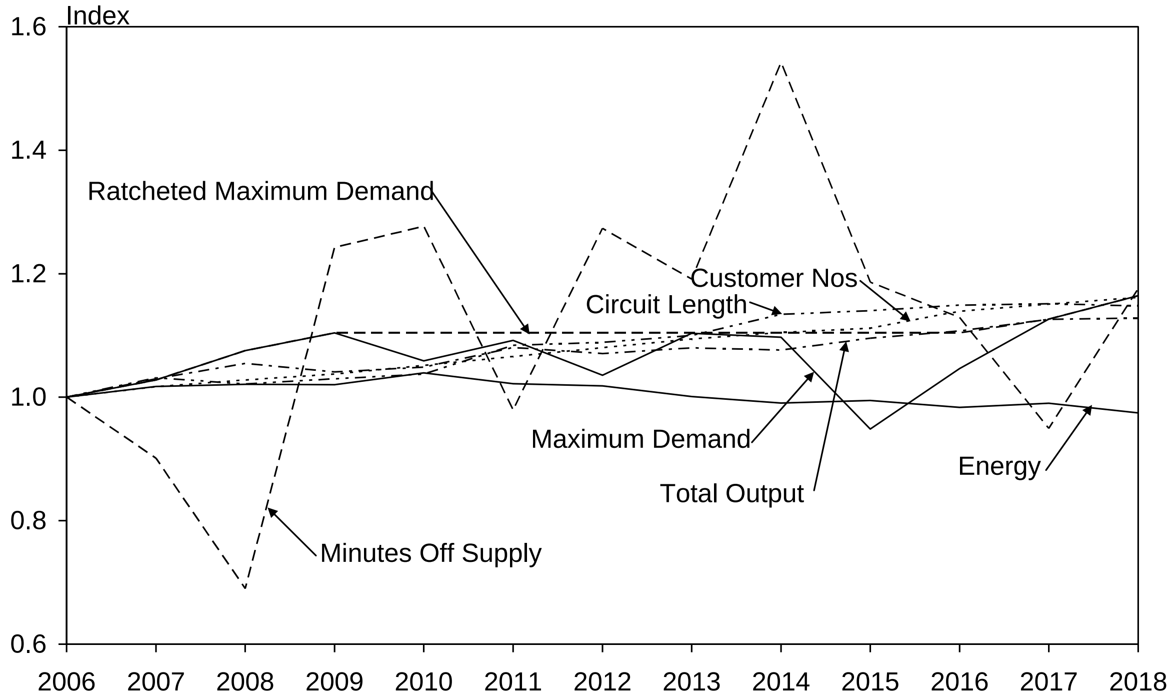
The partial productivity indexes in table 5.5 show that reduced opex usage was the main driver of the improved TFP performance after 2012 although capital partial productivity also made a less negative contribution.

CIT's output and input quantity changes

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 16 per cent higher in 2018 than they were in 2006, somewhat less than the industry's increase over this period. Energy throughput for distribution peaked in 2010 and has trended down since then to be 3 per cent lower in 2018 than it was in 2006.

Figure 5.10 **CIT's output quantity indexes, 2006–2018**



CIT's maximum demand reached its initial highest level in 2009 but has been somewhat volatile since then and almost regained its 2009 peak in 2013 before surpassing it in 2017 and 2018. In 2018 it was around 17 per cent above its 2006 level. Ratcheted maximum demand in 2017 was therefore also 17 per cent above its 2006 level – a similar increase to that of the industry.

CIT's circuit length output grew considerably more over the 13 years than occurred for the industry overall and by 2018 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 has trended upwards over the period. By 2018 CIT's CMOS was 18 per cent higher than it was in 2006 but it was 54 per cent above its 2006 level in 2014.

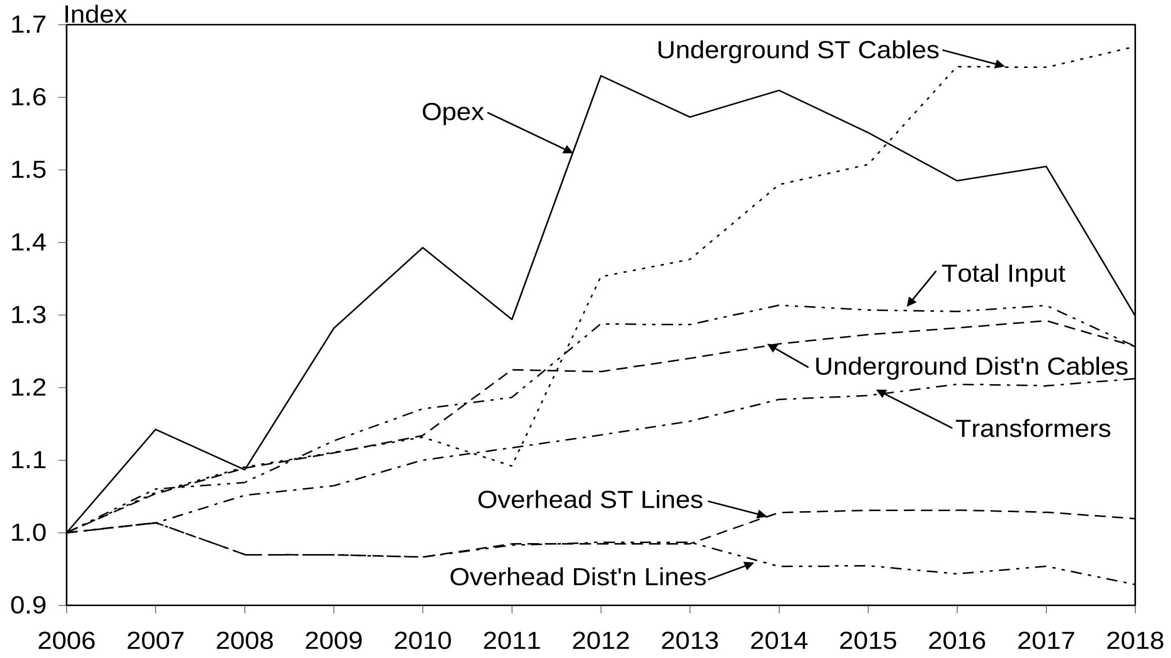
Since the customer numbers and ratcheted maximum demand outputs receive a combined weight of around 60 per cent of gross revenue in forming the total output index, in figure 5.10 we see that the total output index lies close to these two output indexes. In this case the circuit length index lies above 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 over the period generally 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 20 per cent, somewhat 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 8 per cent lower by 2017 than it was in 2006. This compares to an 12 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 4.4 per cent in 2018 in line with the 15 per cent reduction in opex usage more than offsetting small increase and decreases in the various capital inputs.

Figure 5.11 **CIT's input quantity indexes, 2006–2018**



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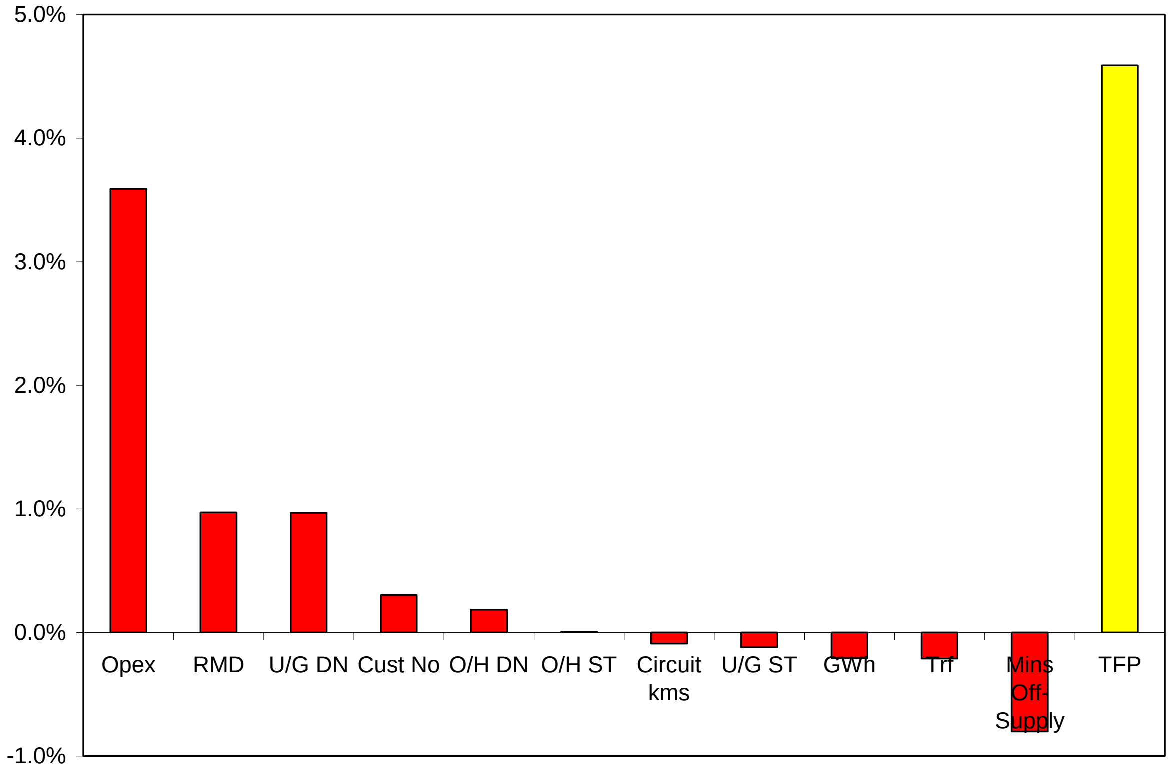
CIT's output and input contributions to TFP change

In table 5.6 we decompose CIT's TFP change into its constituent output and input parts for the whole 13–year period and for the periods up to and after 2012. CIT's drivers of TFP change for the whole 13–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. 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. Overhead lines make a marginally positive contribution to CIT's TFP change compared to small negative contributions for the industry. And, CIT's underground cables inputs make more negative contributions for CIT than for the industry reflecting CIT's higher proportion of undergrounding.

Table 5.6 **CIT's output and input percentage point contributions to average annual TFP change: 2006–2018, 2006–2012 and 2012–2018**

Year	*2006 to 2018*	*2006 to 2012*	*2012 to 2018*
Energy (GWh)	–0.03%	0.04%	–0.10%
Ratcheted Max Demand	0.37%	0.49%	0.26%
Customer Numbers	0.40%	0.41%	0.38%
Circuit Length	0.35%	0.43%	0.27%
CMOS	–0.09%	–0.23%	0.05%
Opex	–0.59%	–2.17%	0.99%
O/H Subtransmission Lines	0.00%	0.00%	0.00%
O/H Distribution Lines	0.04%	0.01%	0.07%
U/G Subtransmission Cables	–0.30%	–0.35%	–0.24%
U/G Distribution Cables	–0.67%	–1.17%	–0.17%
Transformers	–0.39%	–0.54%	–0.24%
TFP Change	–0.90%	–3.08%	1.28%

Figure 5.12 **CIT's output and input percentage point contributions to annual TFP change, 2018**



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 very small 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 –0.2 percentage points after 2012.

CIT's opex usage fell by 15 per cent in 2018. The importance of this is highlighted in figure 5.12 where opex made a 3.6 percentage point contribution to TFP change in the 2018 year. Along with positive contributions of around 1.0 percentage points from RMD and underground distribution input changes also occurring in 2018 more than offsetting the worsening CMOS contribution of –0.8 percentage points, this led to CIT's TFP growth in 2018 being 4.6 per cent.

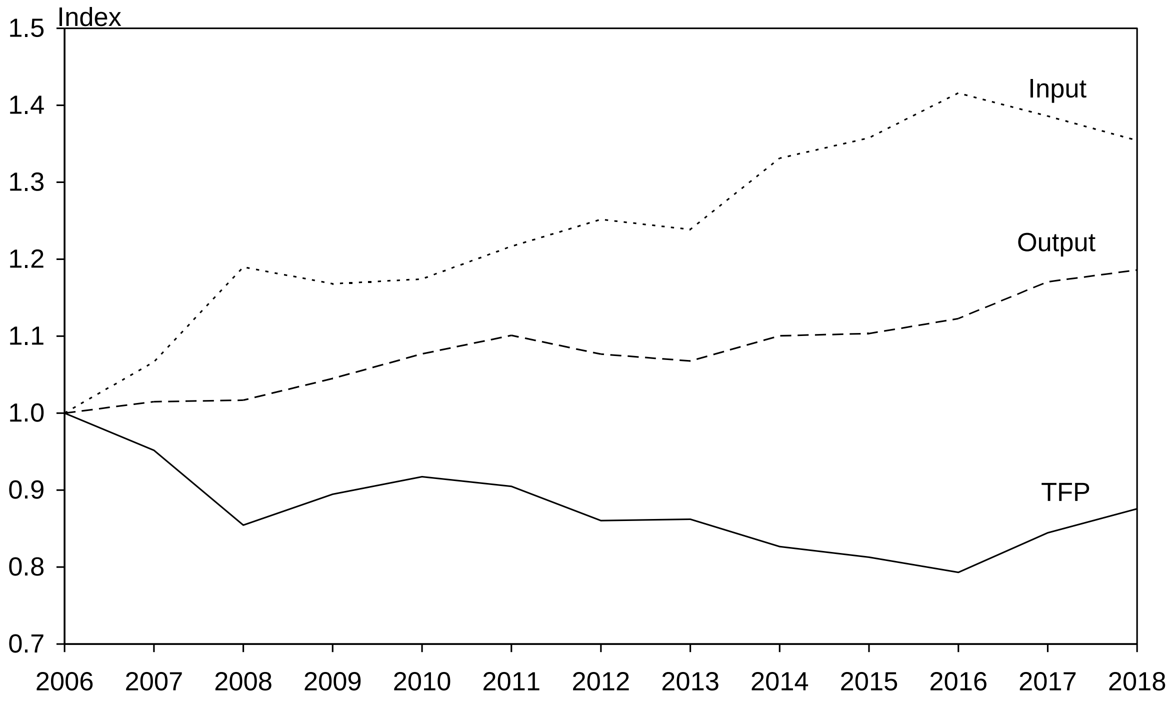
5.4 Endeavour Energy

In 2018 Endeavour Energy (END) delivered 16,639 GWh to 1.0 million customers over 37,534 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, 2006–2018**



Over the 13–year period 2006 to 2018, END's TFP decreased at an average annual rate of 1.1 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 2.5 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 five years – 2009, 2010, 2013, 2017 and 2018. TFP average annual change was negative for the period up to 2012 at –2.5 per cent but positive at 0.3 per cent for the period since 2012.

Table 5.7 **END's output, input and total factor productivity and partial productivity indexes, 2006–2018**

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
2018	1.186	1.354	0.876	1.029	0.801
Growth Rate 2006–18	1.42%	2.53%	–1.11%	0.24%	–1.85%
Growth Rate 2006–12	1.23%	3.74%	–2.51%	–2.34%	–2.54%
Growth Rate 2012–18	1.61%	1.31%	0.30%	2.82%	–1.17%

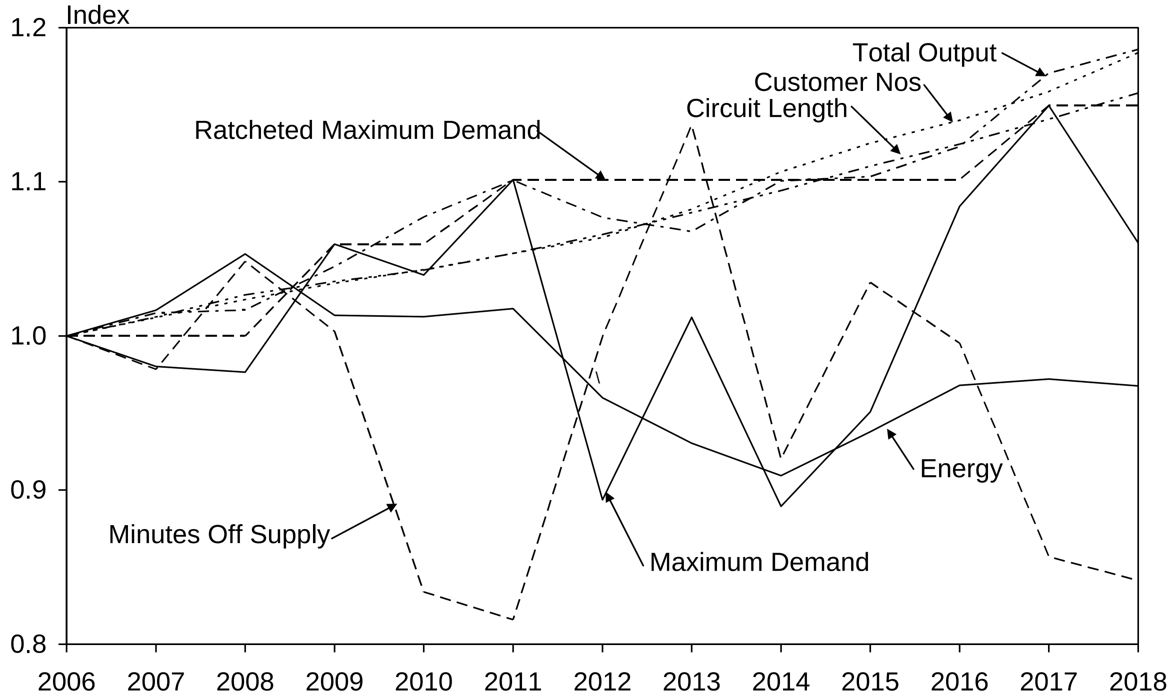
The partial productivity indexes in table 5.7 show that a turnaround in opex PFP growth and a less negative growth rate for capital PFP accounted for the improvement in TFP performance after 2012.

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.

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 18 per cent higher in 2018 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 2018 than it was in 2006, despite a partial recovery in 2015 and 2016.

Figure 5.14 **END's output quantity indexes, 2006–2018**



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 the highest for the period. Ratcheted maximum demand in 2018 was 15 per cent above its 2006 level – just behind the increase for the industry overall.

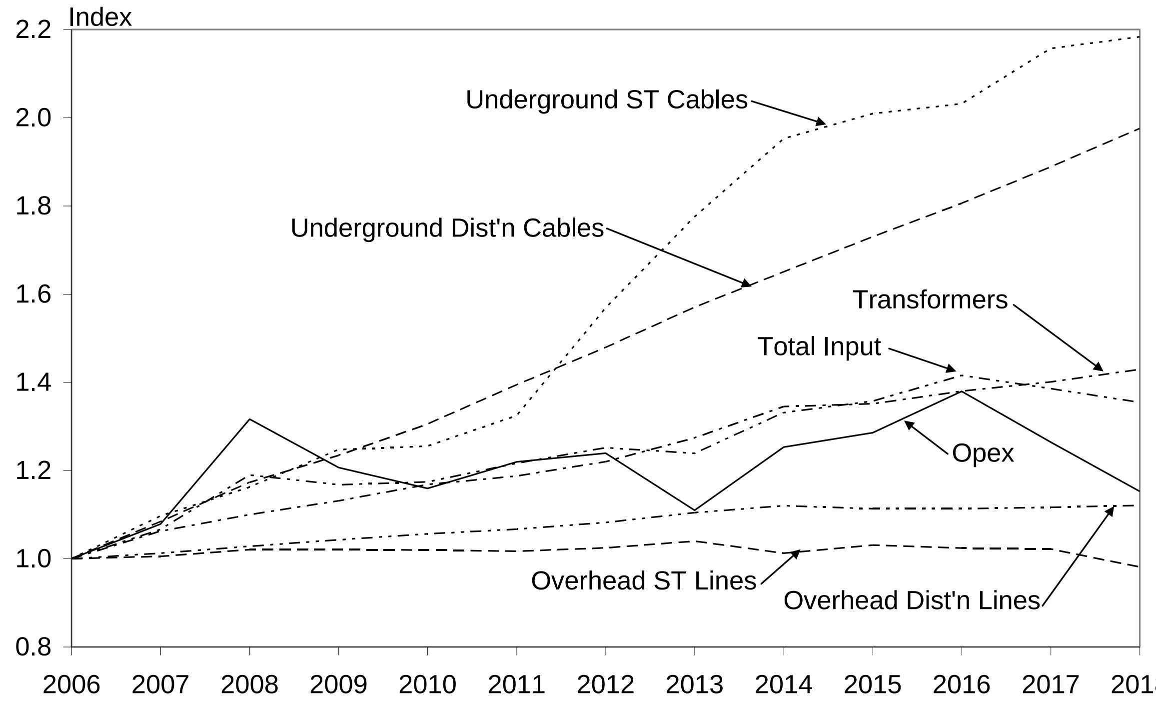
END's circuit length output grew considerably more over the 13 years than occurred for the industry overall and by 2018 was 16 per cent above the level it was in 2006 compared to an increase of only 4 per cent for the industry. This likely reflects the ongoing development of new areas to Sydney's west.

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 and a further reduction in 2018. In 2018 CMOS was 16 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.

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 but 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 15 per cent of its 2006 level in 2018.[6] 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.

Figure 5.15 **END's input quantity indexes, 2006–2018**



END's underground distribution cables and transformers inputs increase more steadily over the period with transformers increasing at a somewhat higher rate than the industry as a whole. However, END's underground distribution cables increased at a considerably faster rate and in 2018 were 98 per cent above their 2006 level compared to an increase of 56 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 69 per cent of total costs). Total input quantity fell 2.3 per cent in 2018, driven largely by a reduction in opex usage of over 9 per cent.

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 13–year period and for the periods up to and after 2012. END's drivers of TFP change for the whole 13–year period are broadly similar to the industry as a whole except that the circuit length output makes a larger positive contribution and underground distribution cables and transformer inputs make a larger negative contribution.

END's situation is less obviously a tale of two distinct periods compared to other DNSPs. The contribution of the growth in opex usage reversed after 2012, while that of growth in underground distribution cables and transformers moderated. The contributions of customer

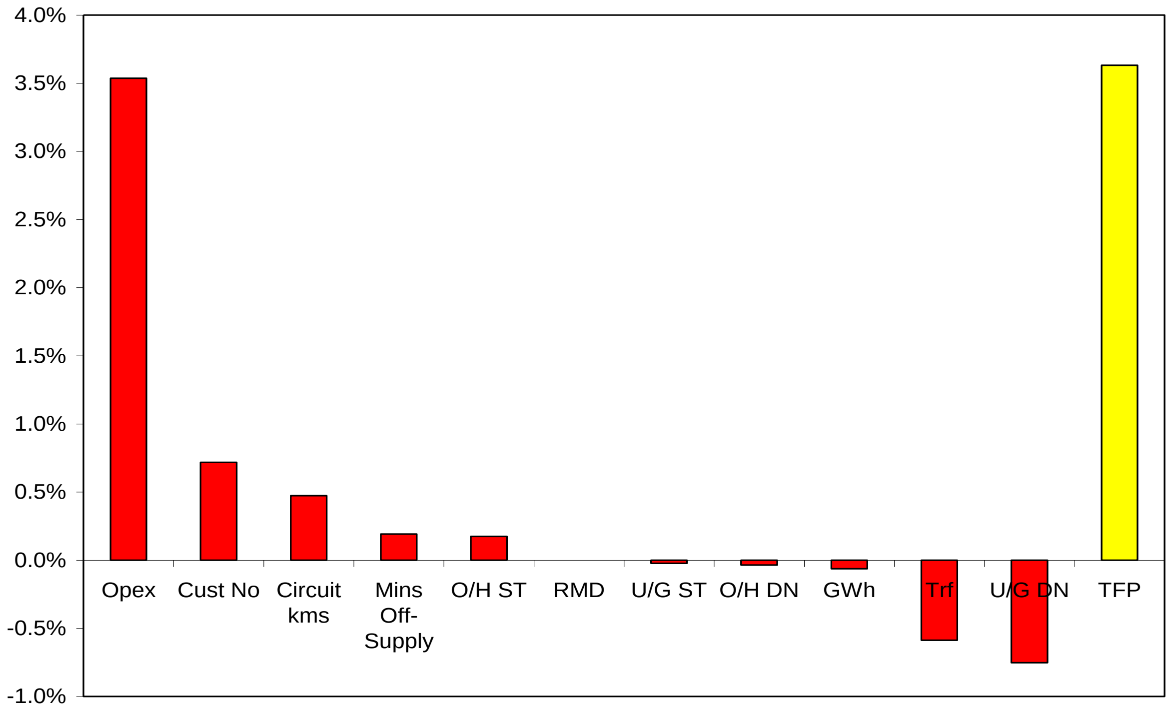
[6] Note that redundancy payments are included in the opex figures presented here.

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 were largely offset by reductions in 2017 and 2018 leading to opex contributing 0.4 percentage points to END's average annual TFP change of –0.3 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.

Table 5.8 **END's output and input percentage point contributions to average annual TFP change: 2006–2018, 2006–2012 and 2012–2018**

Year	*2006 to 2018*	*2006 to 2012*	*2012 to 2018*
Energy (GWh)	–0.04%	–0.09%	0.02%
Ratcheted Max Demand	0.37%	0.52%	0.22%
Customer Numbers	0.48%	0.36%	0.60%
Circuit Length	0.40%	0.35%	0.44%
CMOS	0.21%	0.09%	0.33%
Opex	–0.52%	–1.47%	0.42%
O/H Subtransmission Lines	0.01%	–0.01%	0.03%
O/H Distribution Lines	–0.09%	–0.12%	–0.06%
U/G Subtransmission Cables	–0.08%	–0.11%	–0.06%
U/G Distribution Cables	–0.92%	–1.03%	–0.81%
Transformers	–0.92%	–1.00%	–0.83%
TFP Change	–1.11%	–2.51%	–0.30%

Figure 5.16 **END's output and input percentage point contributions to annual TFP change, 2017–18**



The importance of END's reduction in opex in 2018 is highlighted in figure 5.16. The 3.5 percentage point contribution of opex is the largest contribution to END's TFP change of 3.6 per cent in the 2018 year with the contributions of other outputs and inputs largely offsetting each other.

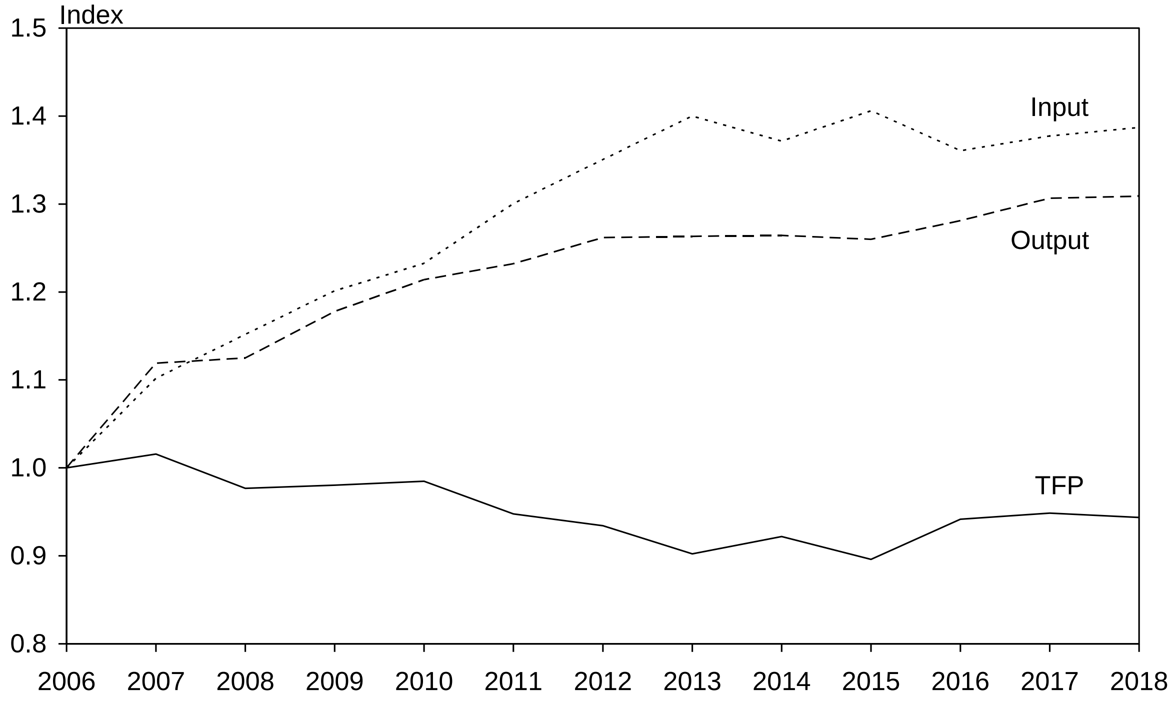
5.5 Energex

In 2018 Energex (ENX) delivered 21,262 GWh to 1.47 million customers over 54,266 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.

Figure 5.17 **ENX's output, input and total factor productivity indexes, 2006–2018**



Over the 13–year period 2006 to 2018, 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 2.2 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 2.7 per cent. Input use increased at a steady rate through to 2013 and has fluctuated since then.

Output increased steadily from 2006 to 2012 before remaining flat for the following three years and then increasing again in 2016 and 2017 and levelling off again in 2018. The increase in 2016 coincided with a reduction in input that year which lead to a marked upturn in TFP. However, increases in input use led to TFP growth being flat in 2017 and negative in 2018. 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 0.2 per cent.

Table 5.9 **ENX's output, input and total factor productivity and partial productivity indexes, 2006–2018**

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
2018	1.309	1.387	0.944	0.973	0.922
Growth Rate 2006–18	2.24%	2.73%	–0.48%	–0.22%	–0.68%
Growth Rate 2006–12	3.88%	5.01%	–1.13%	–2.84%	–0.21%
Growth Rate 2012–18	0.61%	0.44%	0.17%	2.39%	–1.15%

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.

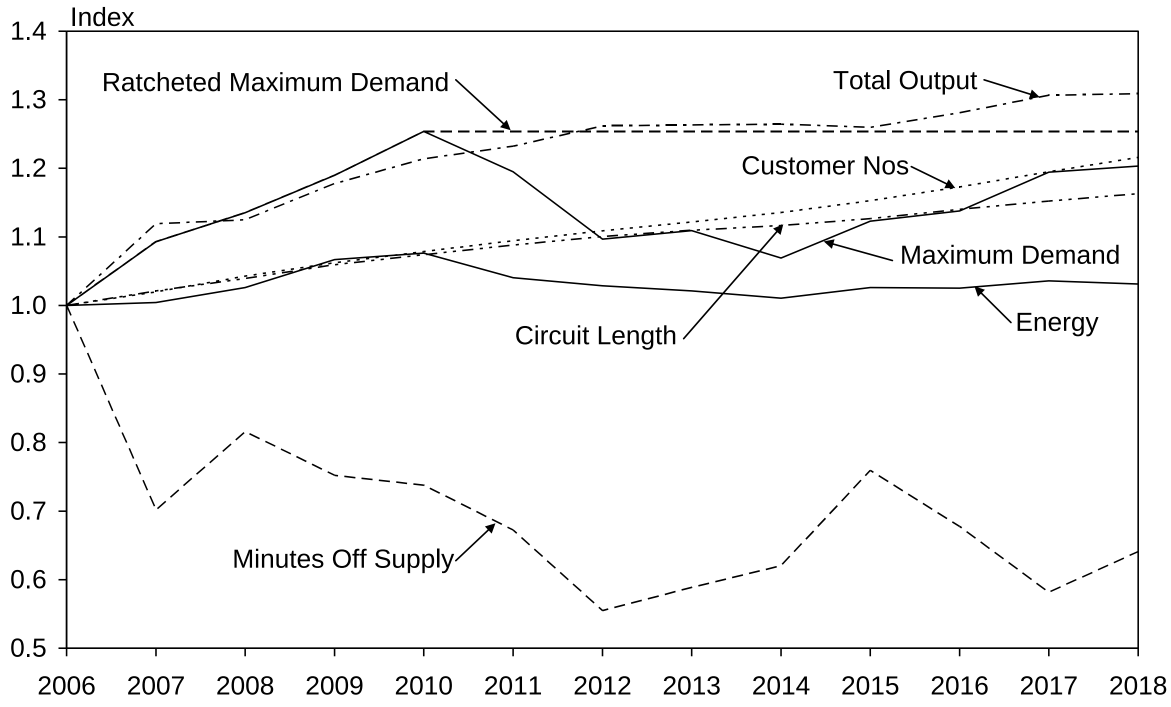
ENX's output and input quantity changes

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.

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 22 per cent higher in 2018 than they were in 2006 reflecting Queensland's relatively strong output growth. Energy throughput for distribution peaked in 2010 but was still 3 per cent higher in 2018 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 2018 RMD was 25 per cent above its 2006 level – a larger increase than for the industry overall.

Figure 5.18 **ENX's output quantity indexes, 2006–2018**



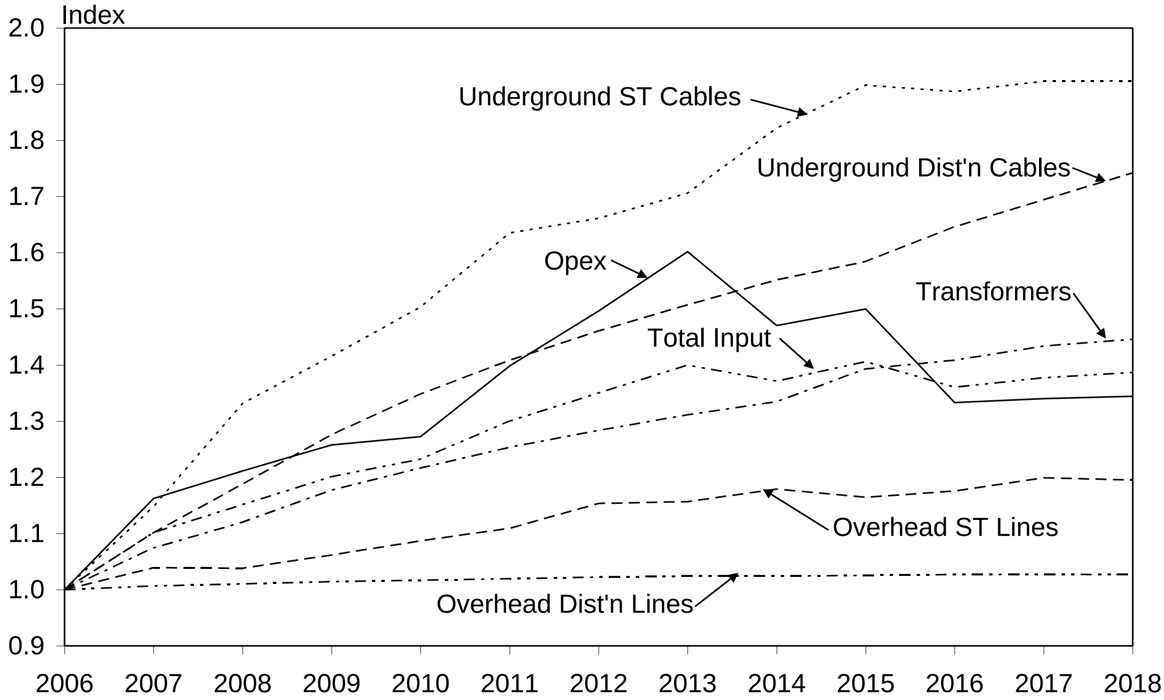
Queensland's circuit length output also grew more over the 13 years than occurred for the industry overall and by 2018 was 16 per cent above the level it was in 2006 compared to an increase of only 4 per cent for the industry.

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 from 2012 to 2015 and again in 2018. CMOS has been lower and, hence, contributed more to total output for all other years than was the case in 2006. In 2018 CMOS was 36 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).

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 somewhat more than 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 35 per cent above its 2006 level in 2018.[7] 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.

Figure 5.19 **ENX's input quantity indexes, 2006–2018**



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 0.7 per cent in 2018 driven by increases in the use of underground distribution cables and transformers inputs 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 13–year period and for the periods up to and after 2012. ENX's drivers of TFP change for the whole 13–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 somewhat better than that for the industry.

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

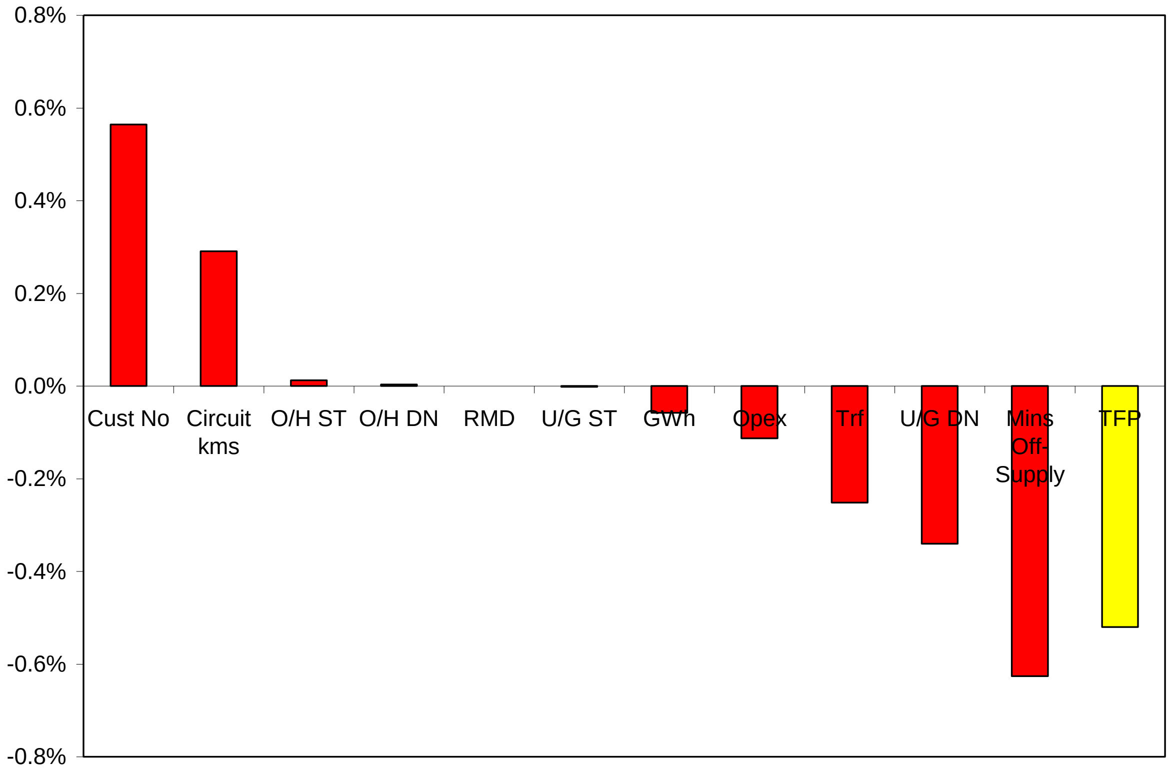
[7] Note that redundancy payments are included in the opex figures presented here.

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.

Table 5.10 **ENX's output and input percentage point contributions to average annual TFP change: 2006–2018, 2006–2012 and 2012–2018**

Year	*2006 to 2018*	*2006 to 2012*	*2012 to 2018*
Energy (GWh)	0.04%	0.07%	0.01%
Ratcheted Max Demand	0.62%	1.24%	0.00%
Customer Numbers	0.55%	0.60%	0.50%
Circuit Length	0.41%	0.53%	0.29%
CMOS	0.63%	1.44%	–0.18%
Opex	–0.86%	–2.41%	0.68%
O/H Subtransmission Lines	–0.05%	–0.08%	–0.02%
O/H Distribution Lines	–0.03%	–0.04%	–0.01%
U/G Subtransmission Cables	–0.25%	–0.38%	–0.12%
U/G Distribution Cables	–0.56%	–0.75%	–0.36%
Transformers	–0.98%	–1.35%	–0.61%
TFP Change	–0.48%	–1.13%	0.17%

Figure 5.20 **ENX's output and input percentage point contributions to annual TFP change, 2017–18**



The importance of the increase in CMOS in 2018 is highlighted in figure 5.20 where it makes a –0.6 percentage point contribution to TFP change in the 2018 year. Growth in customer numbers and circuit length make positive contributions of 0.6 and 0.3 percentage points, respectively, while growth in underground distribution, transformers and opex usage make contributions of –0.3, –0.3 and –0.1 percentage points, respectively. These changes combine to produce a TFP change of –0.5 per cent in 2018.

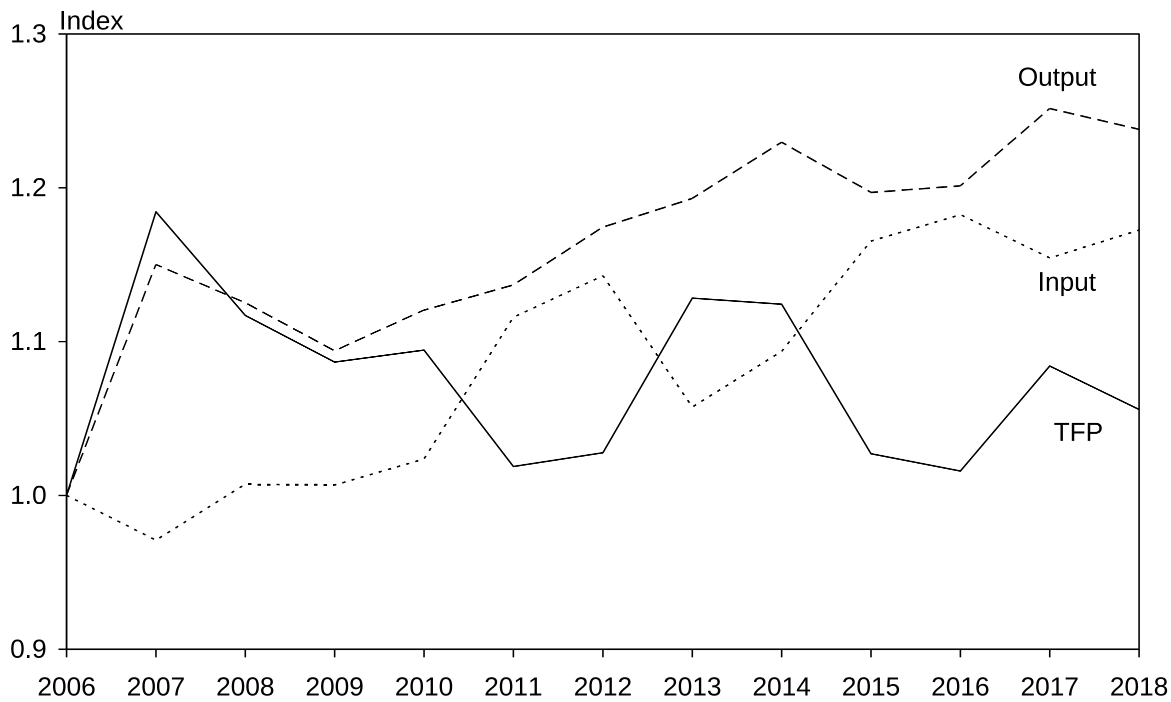
5.6 Ergon Energy

In 2018 Ergon Energy (ERG) delivered 13,243 GWh to 760,122 customers over 151,976 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.

Figure 5.21 **ERG's output, input and total factor productivity indexes, 2006–2018**



Over the 13–year period 2006 to 2018, ERG's TFP increased at an average annual rate of 0.5 per cent. ERG's total output increased by an average annual rate of 1.8 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 13–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 also 0.5 per cent for the period since 2012. Negative output growth in 2018 combined with an increase in input use contributed to negative TFP growth in the latest year.

Table 5.11 **ERG's output, input and total factor productivity and partial productivity indexes, 2006–2018**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*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
2018	1.238	1.173	1.056	1.280	0.960
Growth Rate 2006–18	1.78%	1.33%	0.45%	2.06%	–0.34%
Growth Rate 2006–12	2.68%	2.22%	0.46%	0.64%	0.30%
Growth Rate 2012–18	0.88%	0.43%	0.45%	3.47%	–0.97%

The partial productivity indexes in table 5.11 show that improvements in opex PFP after 2012 have been largely offset by a worsening in capital PFP leading to little change in TFP growth.

ERG's output and input quantity changes

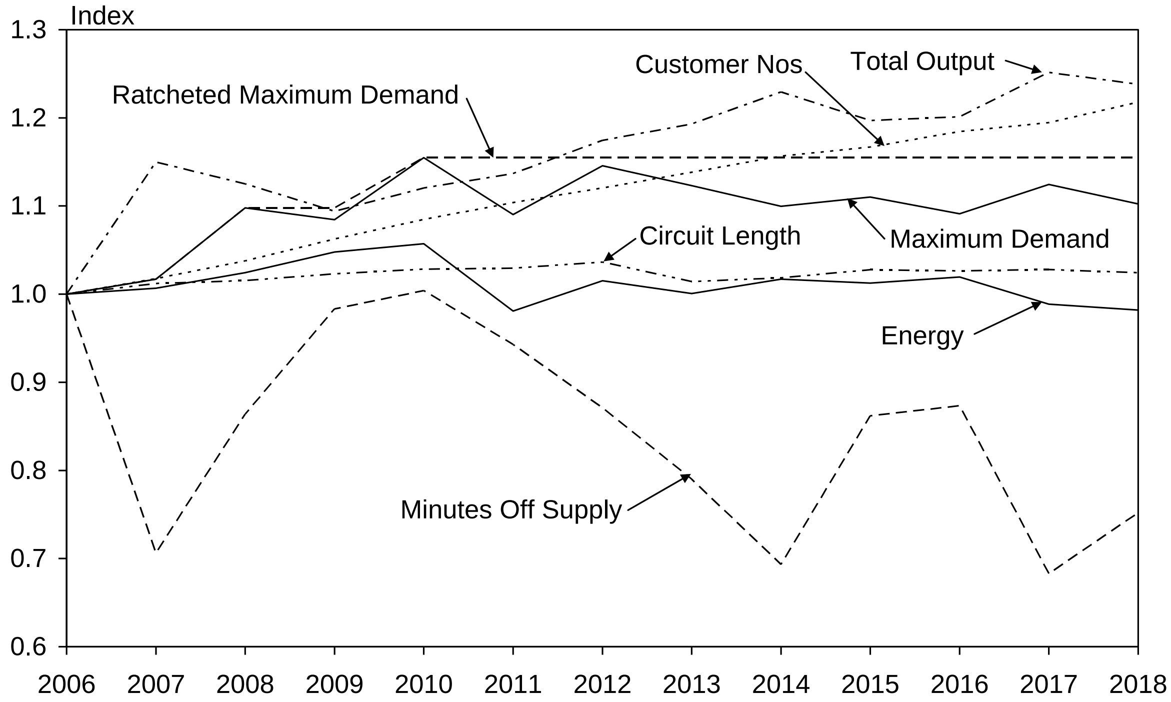
We graph the quantity indexes for ERG's five individual outputs in figure 5.22 and for its six individual inputs in figure 5.23.

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 22 per cent higher in 2018 than they were in 2006 reflecting regional Queensland's relatively strong growth. Energy throughput for distribution peaked in 2010 and was 2 per cent lower in 2018 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 and falling again in 2018. However, unlike many DNSPs in the NEM, ERG's maximum demand has stayed above its 2006 level for the remainder of the period. In 2018 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 slightly slower rate than for the industry over the 13 years and by 2018 was 2 per cent above the level it was in 2006.

Figure 5.22 **ERG's output quantity indexes, 2006–2018**

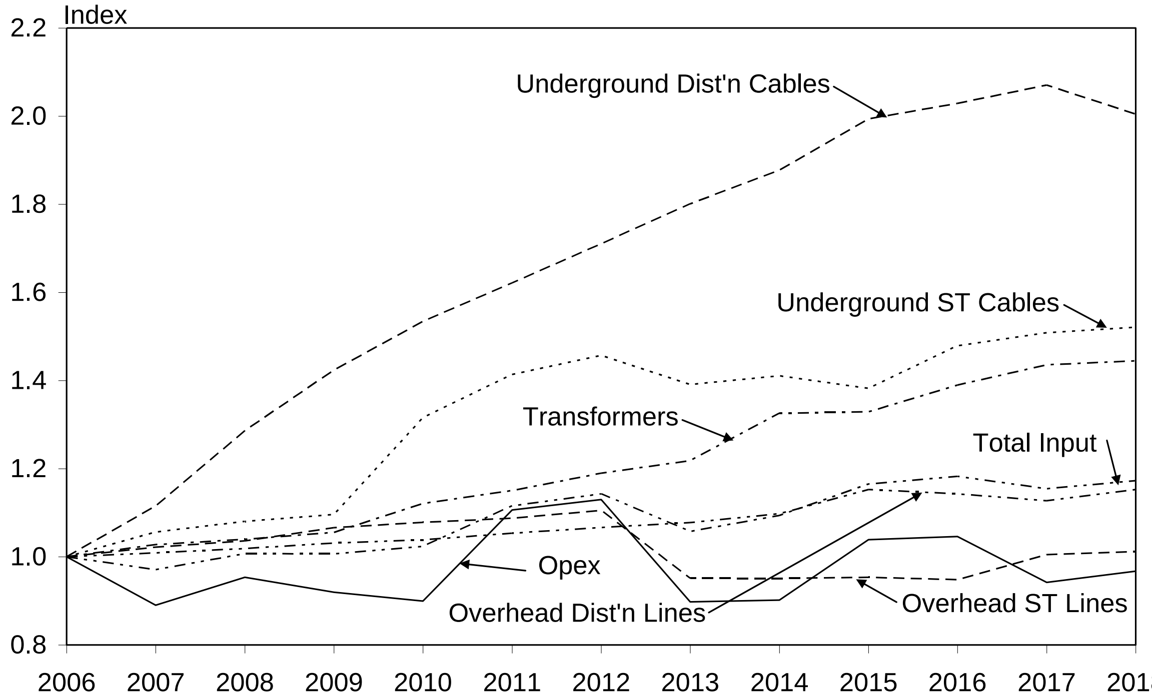


The last output shown in figure 5.22 is total CMOS. ERG's CMOS has generally followed a similar pattern to that of the industry although it increased markedly in 2015. With the exception of 2010, CMOS has been lower and, hence, contributed more to total output for all other years than was the case in 2006. In 2018 CMOS was 25 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.

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 and overhead distribution lines inputs have increased somewhat more than 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 and increasing somewhat in 2018. In 2018 it was 3 per cent below its 2006 level.[8] 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.

Figure 5.23 **ERG's input quantity indexes, 2006–2018**



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 increased by 1.6 cent in 2018 driven by small increases in all inputs except underground cables.

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 13–year period and for the periods up to and after 2012. ERG's drivers of TFP change for the whole 13–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.

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.

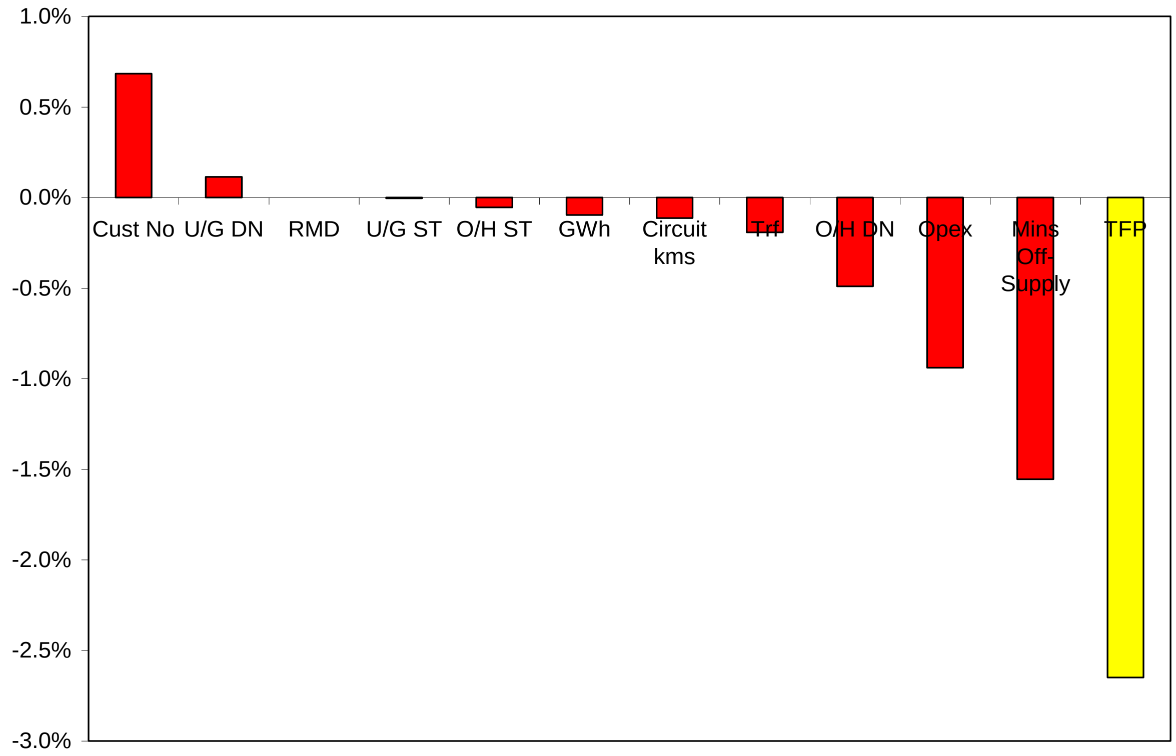
[8] Note that redundancy payments are included in the opex figures presented here.

The reductions made in ERG's opex after 2012 led to opex making a somewhat smaller positive percentage point contribution to ERG's average annual TFP change than that for the industry. After 2012, 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 and overhead distribution lines, made either positive or somewhat less negative percentage point contributions to TFP growth.

Table 5.12 **ERG's output and input percentage point contributions to average annual TFP change: 2006–2018, 2006–2012 and 2012–2018**

Year	*2006 to 2018*	*2006 to 2012*	*2012 to 2018*
Energy (GWh)	–0.02%	0.04%	–0.08%
Ratcheted Max Demand	0.45%	0.90%	0.00%
Customer Numbers	0.63%	0.76%	0.49%
Circuit Length	0.08%	0.23%	–0.07%
CMOS	0.65%	0.75%	0.54%
Opex	0.04%	–0.69%	0.77%
O/H Subtransmission Lines	0.00%	–0.17%	0.18%
O/H Distribution Lines	–0.25%	–0.23%	–0.27%
U/G Subtransmission Cables	–0.02%	–0.03%	0.00%
U/G Distribution Cables	–0.19%	–0.27%	–0.10%
Transformers	–0.92%	–0.83%	–1.00%
TFP Change	0.45%	0.46%	0.45%

Figure 5.24 **ERG's output and input percentage point contributions to annual TFP change, 2017–18**



The importance of the worsening in CMOS and increase in opex in 2018 is highlighted in figure 5.24 where they make –1.6 and –0.9 percentage point contributions, respectively, to TFP change in the 2018 year of –2.7 per cent.

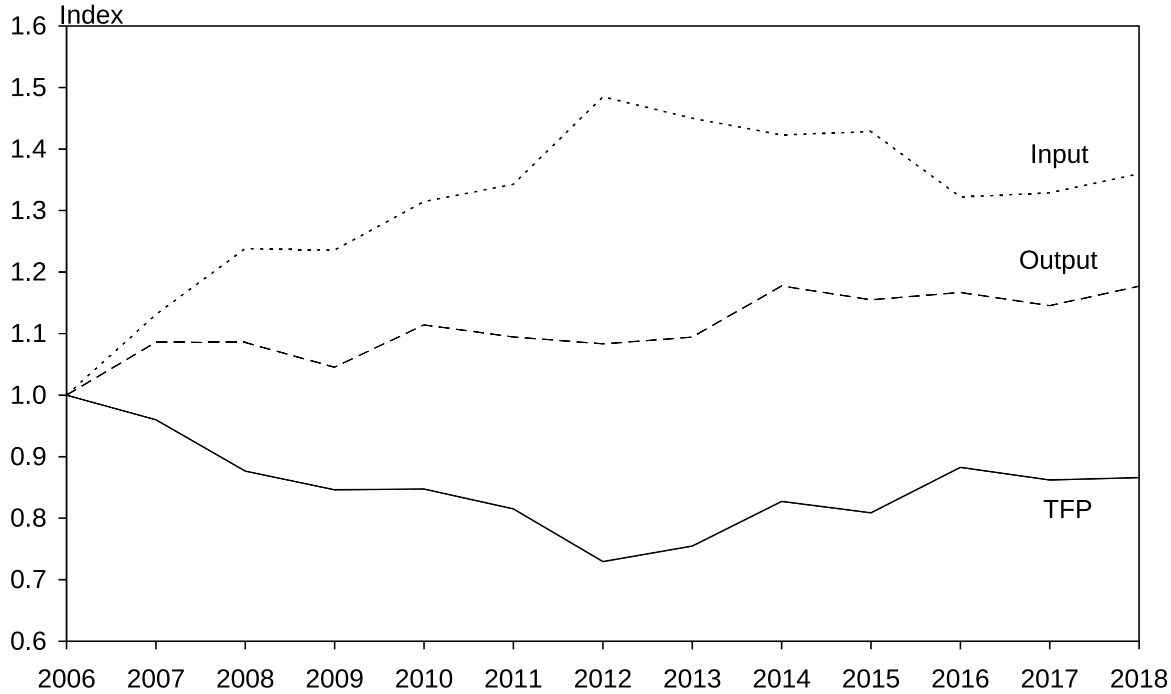
5.7 Essential Energy

In 2018 Essential Energy (ESS) delivered 12,533 GWh to 905,970 customers over 192,203 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.

Figure 5.25 **ESS's output, input and total factor productivity indexes, 2006–2018**



Over the 13–year period 2006 to 2018, ESS's TFP decreased at an average annual rate of 1.2 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 2.6 per cent. ESS thus had a somewhat higher output growth but considerably 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 and somewhat more in 2018. 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 before increasing by 0.5 per cent in 2018. TFP average annual change was sharply negative for the period up to 2012 but has been strongly positive at 2.9 per cent for the period since 2012.

Table 5.13 **ESS's output, input and total factor productivity and partial productivity indexes, 2006–2018**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*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
2018	1.177	1.359	0.866	0.963	0.825
Growth Rate 2006–18	1.36%	2.56%	–1.20%	–0.31%	–1.61%
Growth Rate 2006–12	1.33%	6.59%	–5.26%	–7.96%	–3.21%
Growth Rate 2012–18	1.39%	–1.47%	2.86%	7.33%	0.00%

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.

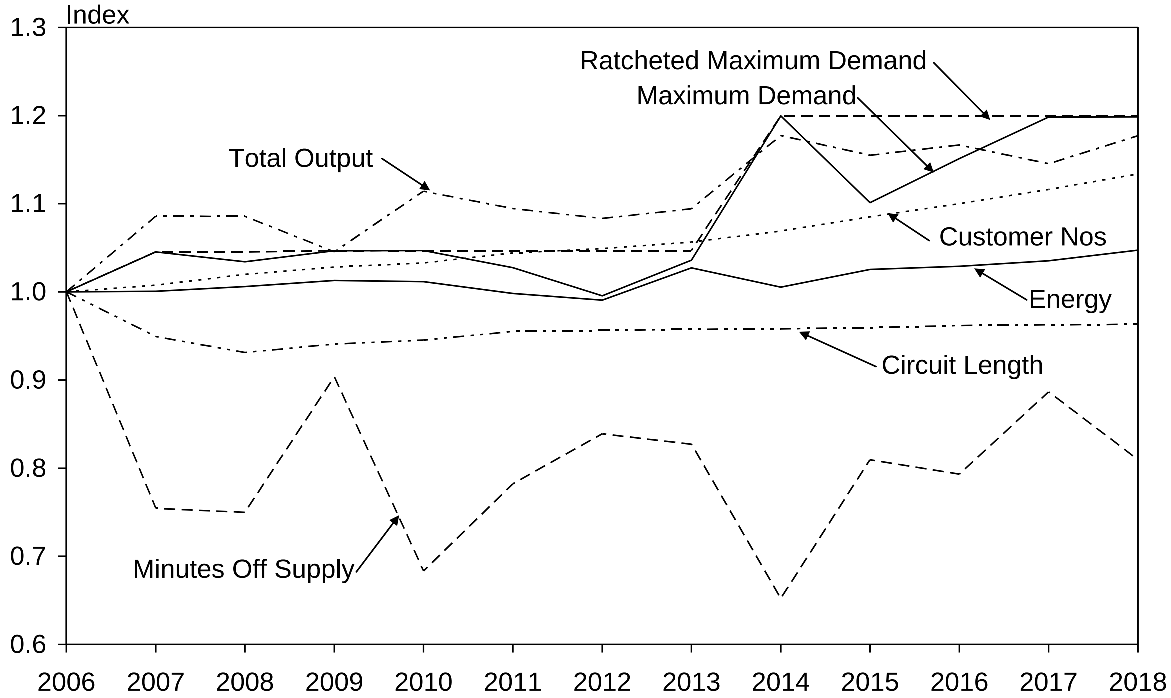
ESS's output and input quantity changes

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.

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 13 per cent higher in 2018, 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 5 per cent higher in 2018 than it was in 2006.

ESS's maximum demand peaked in 2014 – several years later than for most other DNSPs. Ratcheted maximum demand in 2018 was 20 per cent above its 2006 level – a larger increase than for the industry overall.

Figure 5.26 **ESS's output quantity indexes, 2006–2018**



ESS's circuit length output declined in 2007 and 2008 and increased gradually since then. By 2018 it was still 4 per cent lower than it was in 2006 compared to an increase of 4 per cent for the industry.

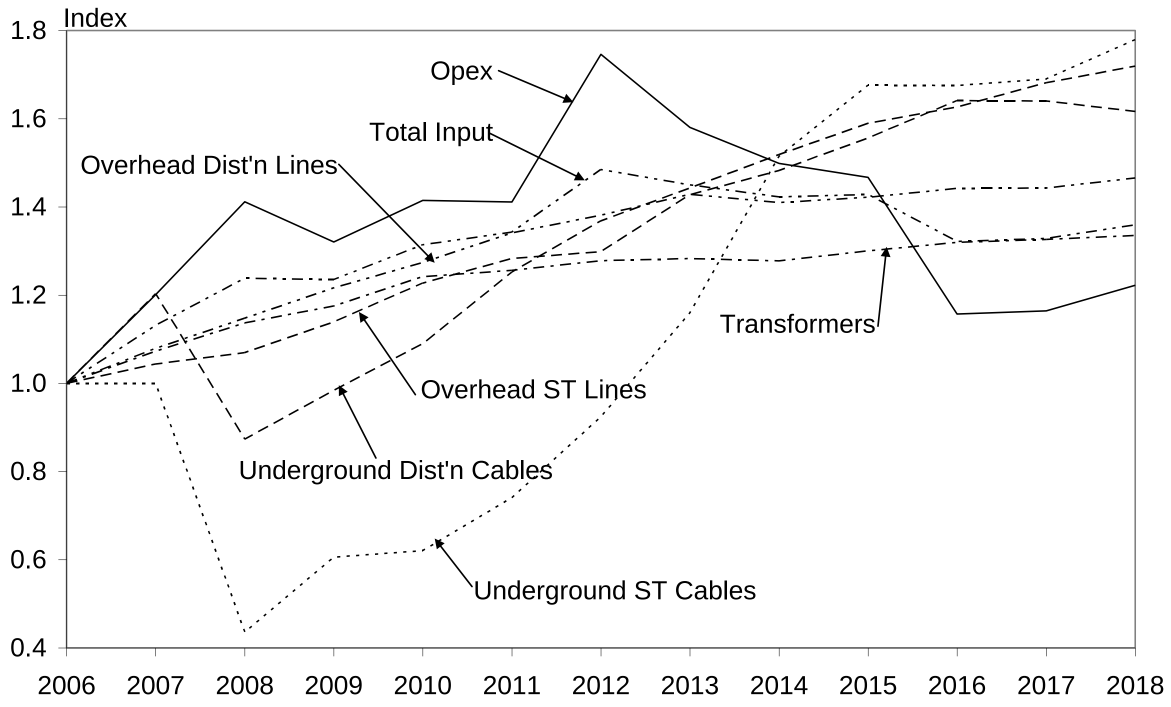
The last output shown in figure 5.26 is total CMOS. ESS's CMOS has generally followed a similar pattern to that of the industry although it has been somewhat more volatile. CMOS has generally trended downwards over the period and, hence, contributed more to total output than was the case in 2006. CMOS decreased by 9 per cent in 2018 and was 19 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.

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 increasing in 2017 and

2018 at which point it was 22 per cent above its 2006 level.[9] This compares to the industry's 2018 opex usage being 15 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.

Figure 5.27 **ESS's input quantity indexes, 2006–2018**



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 47 per cent compared to only 11 per cent for the industry.

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 2.3 per cent in 2018 driven by an increase of 4.9 per cent in opex usage and increases in four of the other five inputs.

ESS's output and input contributions to TFP change

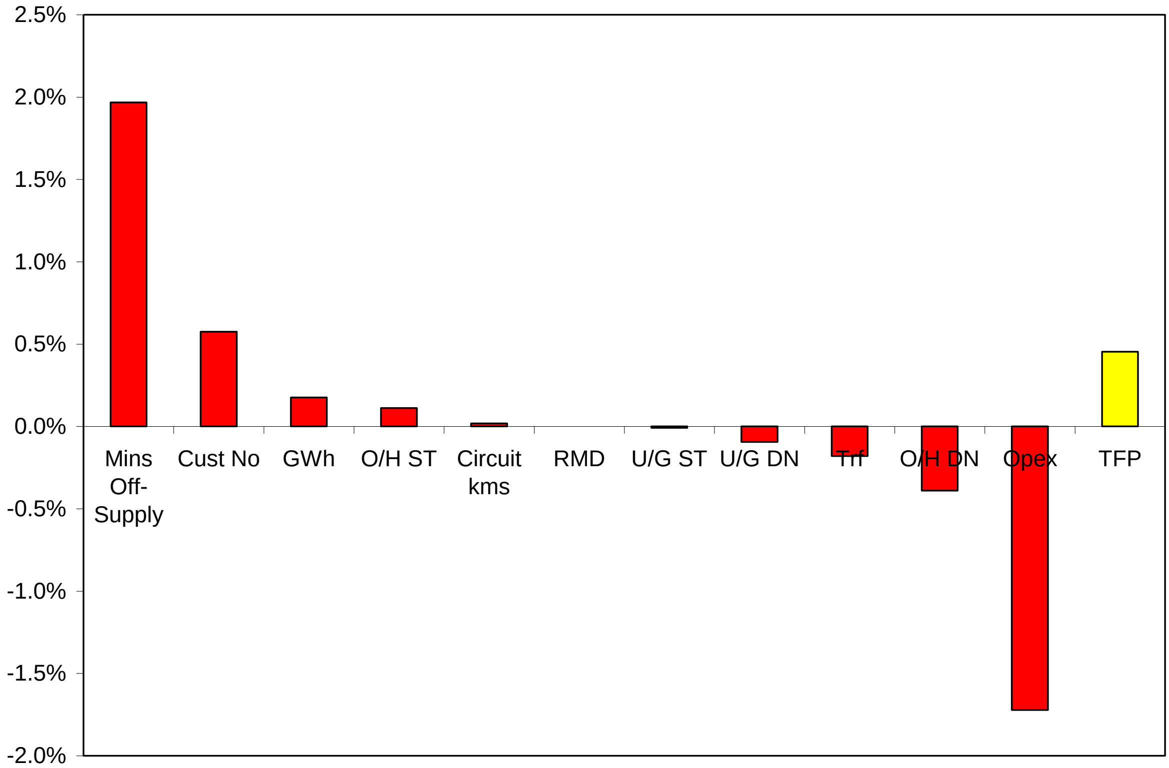
In table 5.14 we decompose ESS's TFP change into its constituent output and input parts for the whole 13–year period and for the periods up to and after 2012. ESS's drivers of TFP change for the whole 13–year period are broadly similar to the industry as a whole except that the CMOS output makes the largest positive contribution with RMD making the second 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. Opex usage contributes –0.8 percentage points to ESS's TFP growth compared to –0.5 percentage points for the industry.

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

Table 5.14 ESS's output and input percentage point contributions to average annual TFP change: 2006–2018, 2006–2012 and 2012–2018

Year	*2006 to 2018*	*2006 to 2012*	*2012 to 2018*
Energy (GWh)	0.06%	–0.02%	0.14%
Ratcheted Max Demand	0.50%	0.28%	0.72%
Customer Numbers	0.38%	0.30%	0.46%
Circuit Length	–0.12%	–0.28%	0.04%
CMOS	0.55%	1.06%	0.03%
Opex	–0.83%	–3.97%	2.32%
O/H Subtransmission Lines	–0.27%	–0.28%	–0.25%
O/H Distribution Lines	–0.54%	–0.87%	–0.21%
U/G Subtransmission Cables	–0.01%	0.00%	–0.02%
U/G Distribution Cables	–0.19%	–0.22%	–0.16%
Transformers	–0.73%	–1.25%	–0.21%
TFP Change	–1.20%	–5.26%	2.86%

Figure 5.28 ESS's output and input percentage point contributions to annual TFP change, 2017–18



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 2.3 percentage points to ESS's average annual TFP change of 2.9 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 CMOS in 2018 is highlighted in figure 5.28 where the 2.0 percentage point contribution of CMOS more than offsets the –1.7 percentage point contribution from increased opex usage. Customer numbers growth also contributes 0.6 percentage points to produce TFP change of 0.5 per cent in 2018.

5.8 Jemena Electricity Networks

In 2018 Jemena Electricity Networks (JEN) delivered 4,219 GWh to 343,655 customers over 6,568 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.

Figure 5.29 **JEN's output, input and total factor productivity indexes, 2006–2018**

Over the 13–year period 2006 to 2018, JEN's TFP decreased at an average annual rate of 0.1 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 1.6 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 –0.8 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 four years. TFP change was positive in 2007, 2008, 2011 and 2018, 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 2018 output growth improved somewhat while the increase in input use moderated leading to a TFP change of 0.6 per cent. Compared to the whole 13–year period TFP average annual change was slightly positive for the period up to 2012 at 0.1 per cent but has been somewhat negative at –0.4 per cent for the period since 2012.

Table 5.15 **JEN's output, input and total factor productivity and partial productivity indexes, 2006–2018**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*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
2018	1.197	1.217	0.983	0.934	1.023
Growth Rate 2006–18	1.50%	1.64%	–0.14%	–0.57%	0.19%
Growth Rate 2006–12	2.23%	2.16%	0.07%	–1.11%	1.03%
Growth Rate 2012–18	0.76%	1.11%	–0.35%	–0.02%	–0.65%

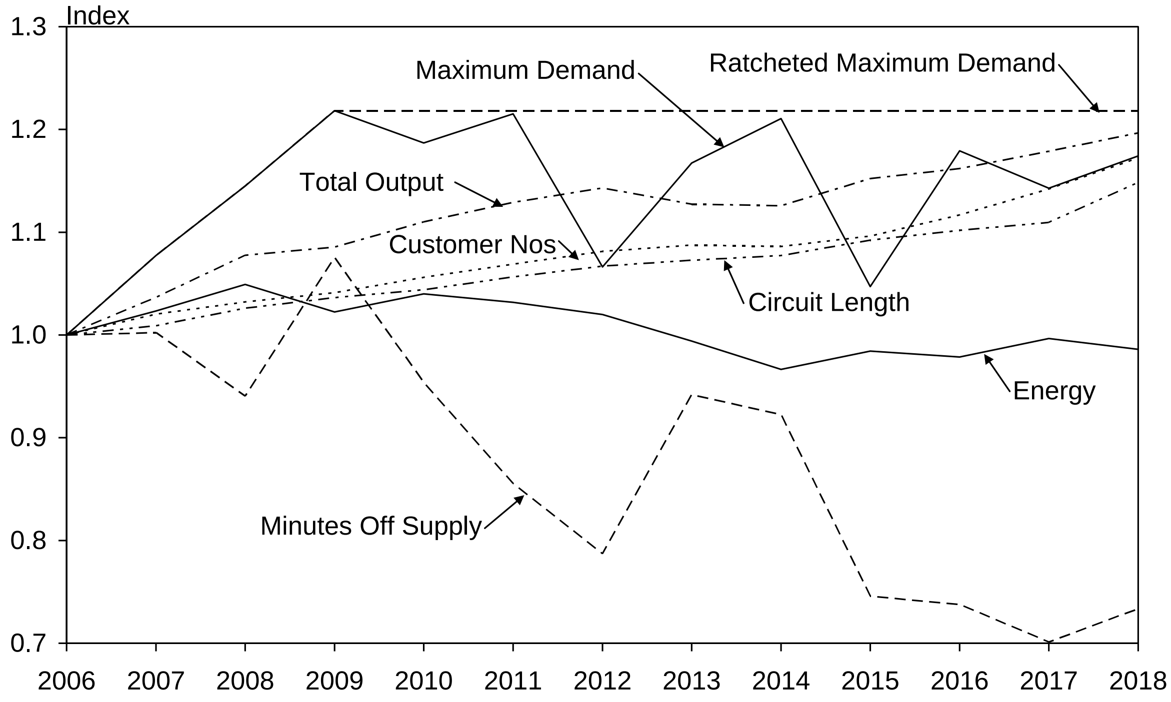
The partial productivity indexes in table 5.15 show that while opex PFP improved after 2012, this was more than offset by a worsening in capital PFP.

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.

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 17 per cent higher in 2018 than they were in 2006, close to the same as for the industry. Energy throughput for distribution peaked in 2008 – a year or two earlier than for most DNSPs – and was 1 per cent lower in 2018 than it was in 2006.

Figure 5.30 **JEN's output quantity indexes, 2006–2018**



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 2018 it was around 17 per cent above its 2006 level. Ratcheted maximum demand in 2018 was 22 per cent above its 2006 level – a larger increase than the industry's 17 per cent.

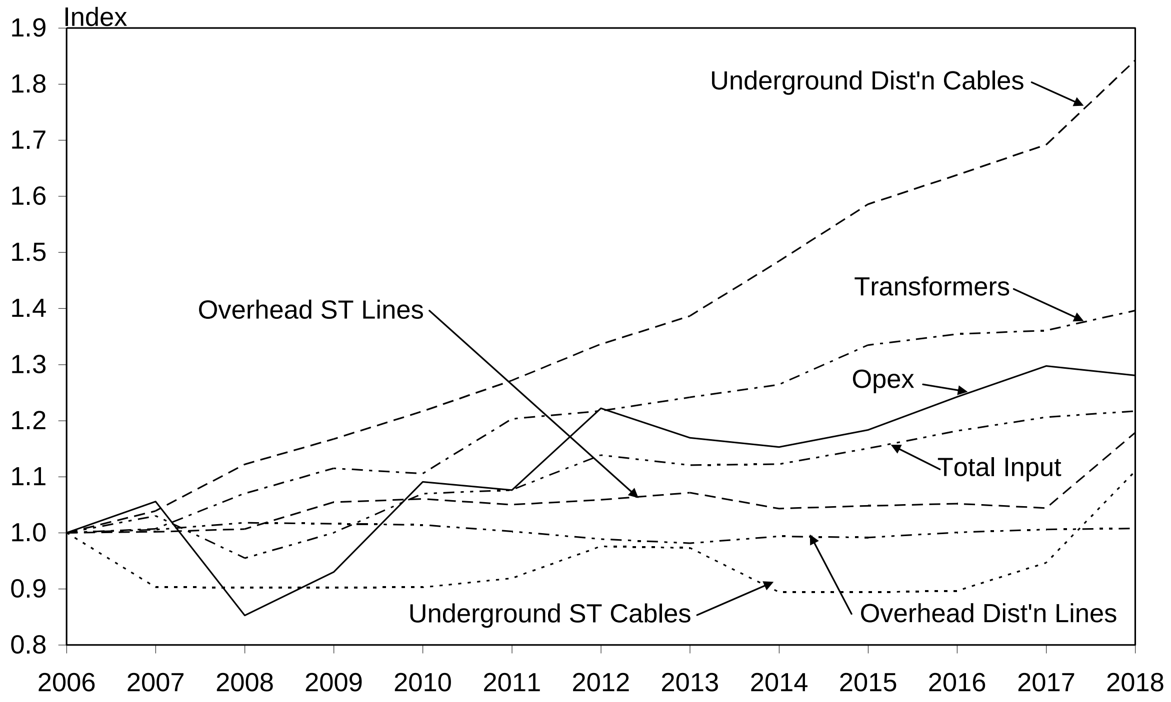
JEN's circuit length output grew more over the 13 years than occurred for the industry overall and by 2018 was 15 per cent above the level it was in 2006 compared to an increase of only 4 per cent for the industry.

The last output shown in figure 5.30 is total CMOS. JEN's CMOS has been more volatile than for the industry but has similarly trended downwards over the period. By 2018 JEN's CMOS was 27 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.

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 before falling by just over 1 per cent in 2018. This compared to a reduction in opex usage for the industry of 16 per cent between 2012 and 2018. 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.

Figure 5.31 **JEN's DNSP input quantity indexes, 2006–2018**



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 an 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 0.9 per cent in 2018, driven by increases in all inputs other than opex usage.

JEN's output and input contributions to TFP change

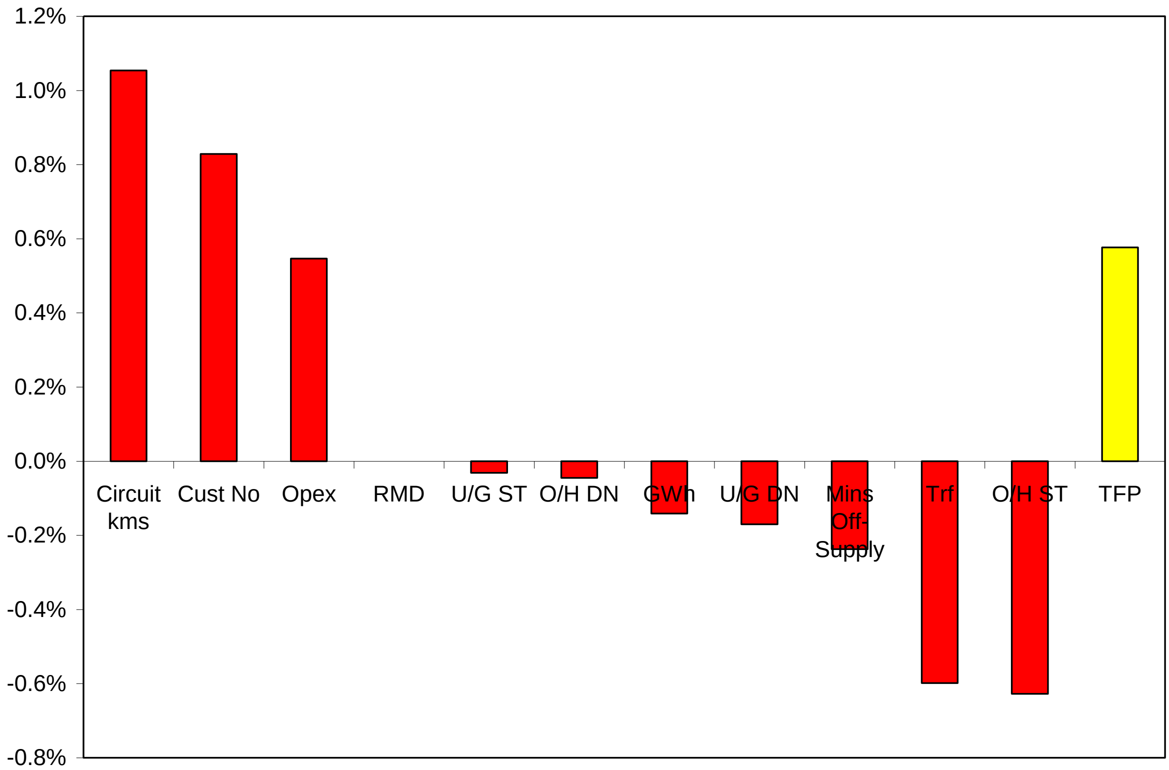
In table 5.16 we decompose JEN's TFP change into its constituent output and input parts for the whole 13–year period and for the periods up to and after 2012. JEN's drivers of TFP change for the whole 13–year period are broadly similar to the industry as a whole except that circuit length makes a larger 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 –0.9 per cent compared to –0.5 per cent for the industry.

JEN's situation is again a tale of two distinct periods. Except for circuit length, 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 1.2 percentage points. Opex change went from –1.5 percentage points contribution to TFP before 2012 to –0.3 percentage points contribution for JEN after 2012. This differs to the industry–wide result where opex makes a positive contribution to TFP change of 1.0 percentage points after 2012 as opex usage declines overall.

Table 5.16 **JEN's output and input percentage point contributions to average annual TFP change: 2006–2018, 2006–2012 and 2012–2018**

Year	*2006 to 2018*	*2006 to 2012*	*2012 to 2018*
Energy (GWh)	–0.01%	0.05%	–0.08%
Ratcheted Max Demand	0.52%	1.03%	0.00%
Customer Numbers	0.43%	0.44%	0.43%
Circuit Length	0.36%	0.35%	0.38%
CMOS	0.20%	0.37%	0.04%
Opex	–0.88%	–1.48%	–0.29%
O/H Subtransmission Lines	–0.07%	–0.04%	–0.09%
O/H Distribution Lines	–0.01%	0.06%	–0.09%
U/G Subtransmission Cables	0.00%	0.00%	0.00%
U/G Distribution Cables	–0.11%	–0.11%	–0.11%
Transformers	–0.56%	–0.59%	–0.54%
TFP Change	–0.14%	0.07%	–0.35%

Figure 5.32 **JEN's output and input percentage point contributions to annual TFP change, 2018**



The importance of JEN's increases in circuit length and customer numbers and decrease in opex usage in 2018 is highlighted in figure 5.32 with 1.1, 0.8 and 0.6 percentage point contributions to TFP change, respectively, in the 2018 year. These more than offset contributions from each of transformers and overhead subtransmission of –0.6 percentage points. JEN's TFP growth in 2018 was 0.6 per cent compared to industry TFP growth of 1.0 per cent in that year.

5.9 Powercor

In 2018 Powercor (PCR) delivered 10,753 GWh to 835,781 customers over 75,412 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

As noted in section 1.3, PCR is one of three Victorian DNSPs that submitted incorrect opex data for the 2017 year in their April 2018 EBRINs. The AER was notified in December 2018 that PCR had incorrectly capitalised some inspection and maintenance costs instead of expensing them as required under PCR's EBRIN reporting. This correction has led to PCR's 2017 opex being 15 per cent higher than initially reported. Consequently, there are material differences between PCR's 2017 productivity performance reported in this report compared to Economic Insights (2018).

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.

Figure 5.33 **PCR's output, input and total factor productivity indexes, 2006–2018**

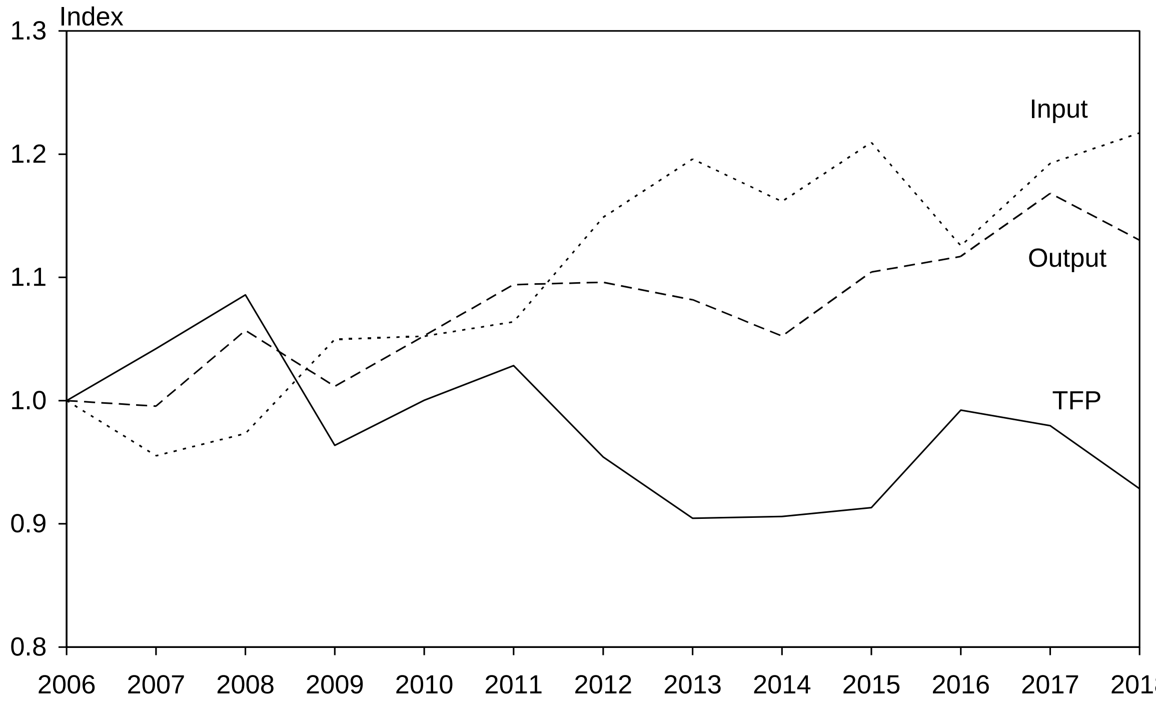


Table 5.17 **PCR's output, input and total factor productivity and partial productivity indexes, 2006–2018**

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	1.192	0.980	1.056	0.918
2018	1.130	1.217	0.929	0.996	0.872
Growth Rate 2006–18	1.02%	1.64%	–0.62%	–0.03%	–1.14%
Growth Rate 2006–12	1.53%	2.31%	–0.78%	–1.09%	–0.74%
Growth Rate 2012–18	0.51%	0.97%	–0.46%	1.03%	–1.53%

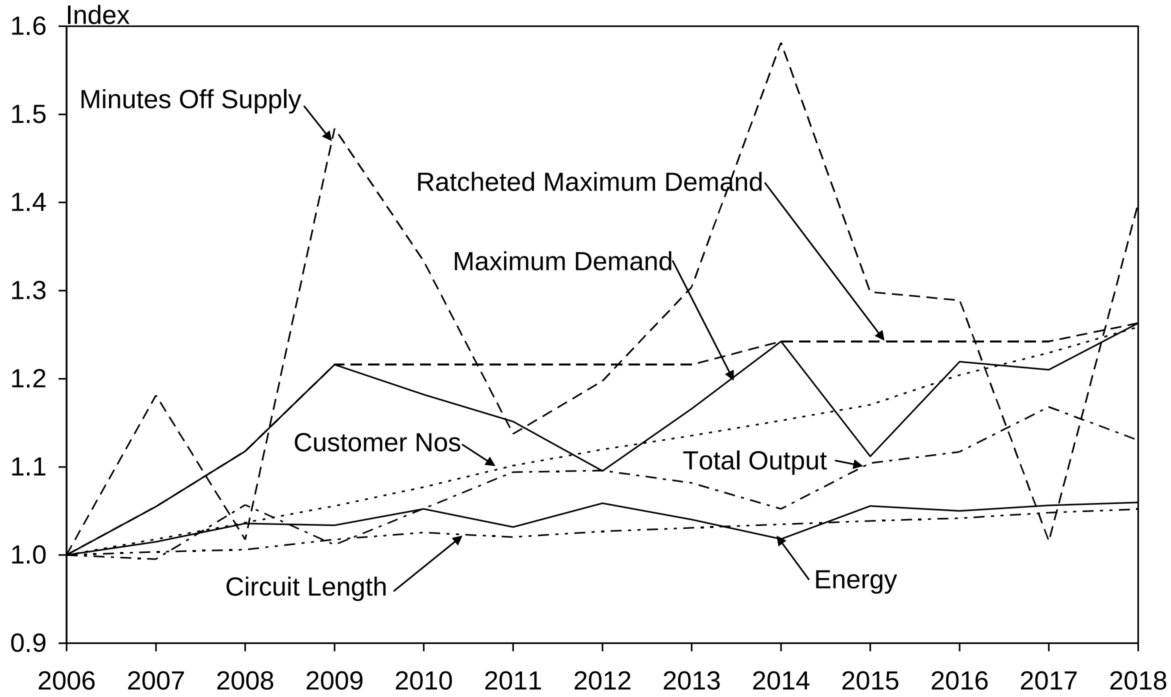
Over the 13–year period 2006 to 2018, PCR's TFP grew at an average annual rate of –0.6 per cent. Total output increased by an average annual rate of 1.0 per cent while total input use increased at a rate of 1.6 per cent. PCR thus had a similar but slightly lower output growth rate compared to the industry but it also had a lower input growth rate than the industry leading to a somewhat less negative TFP growth for PCR compared to the TFP growth rate of –0.8 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 then increasing again in 2017 and 2018. TFP change was positive in 2007, 2008, 2010, 2011, 2015 and 2016, negative in 2009, 2012, 2013, 2017 and 2018, 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 was more than offset by an increase in input use of 5.8 per cent leading to TFP growth of –1.3 per cent. In 2018 total output fell substantially while input use continued to increase, albeit at a reduced rate, to produce TFP change of –5.4 per cent. TFP average annual change was –0.8 per cent for the period up to 2012 and –0.5 per cent for the period after 2012.

The partial productivity indexes in table 5.17 show that opex PFP growth improved after 2012 but this was partly offset by a worsening in capital PFP change 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, 2006–2018**



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. Customer numbers increased steadily over the period and were 26 per cent higher in 2018 than they were in 2006, a larger increase than the industry's increase of 18 per cent. Energy throughput for distribution peaked in 2012 – a little later than for most DNSPs – and was 6 per cent higher in 2018 than it was in 2006.

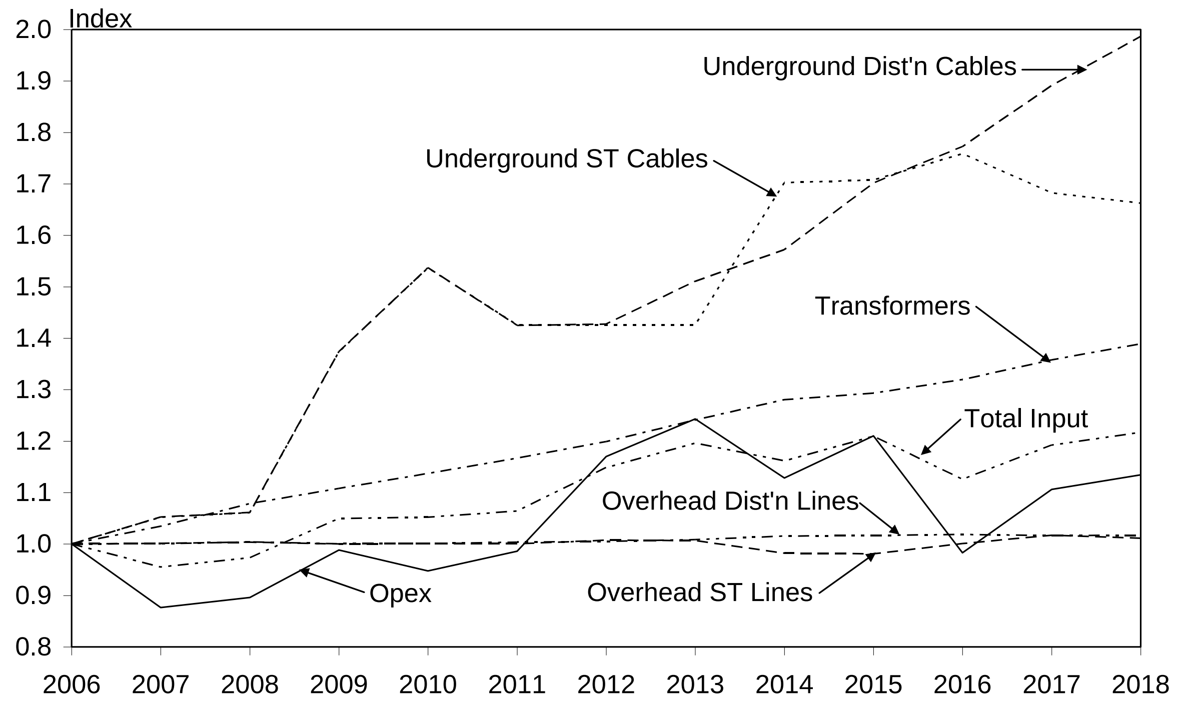
PCR's maximum demand reached its highest level in 2018 – later than for most DNSPs – but has been relatively volatile since a lower peaks in 2009 and 2014. In 2018 it was around 26 per cent above its 2006 level. Ratcheted maximum demand in 2018 was also 26 per cent above its 2006 level – a larger increase than the industry's 17 per cent.

PCR's circuit length output grew slightly more over the 13 years than occurred for the industry overall and by 2018 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 instead of trending downwards as it has for the industry. In 2018 PCR's CMOS was 40 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, 2014 and 2018 are the main reason for dips in total output in those years.

Figure 5.35 **PCR's DNSP input quantity indexes, 2006–2018**



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 decreased sharply in 2016 but has increased again in 2017 and 2018 to be 13 per cent above its 2006 level in 2018. This was similar to the industry's opex usage in 2018 which was 15 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 2018 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 2.1 per cent in 2018, driven mainly by increases in opex, underground distribution cables and transformer inputs that year.

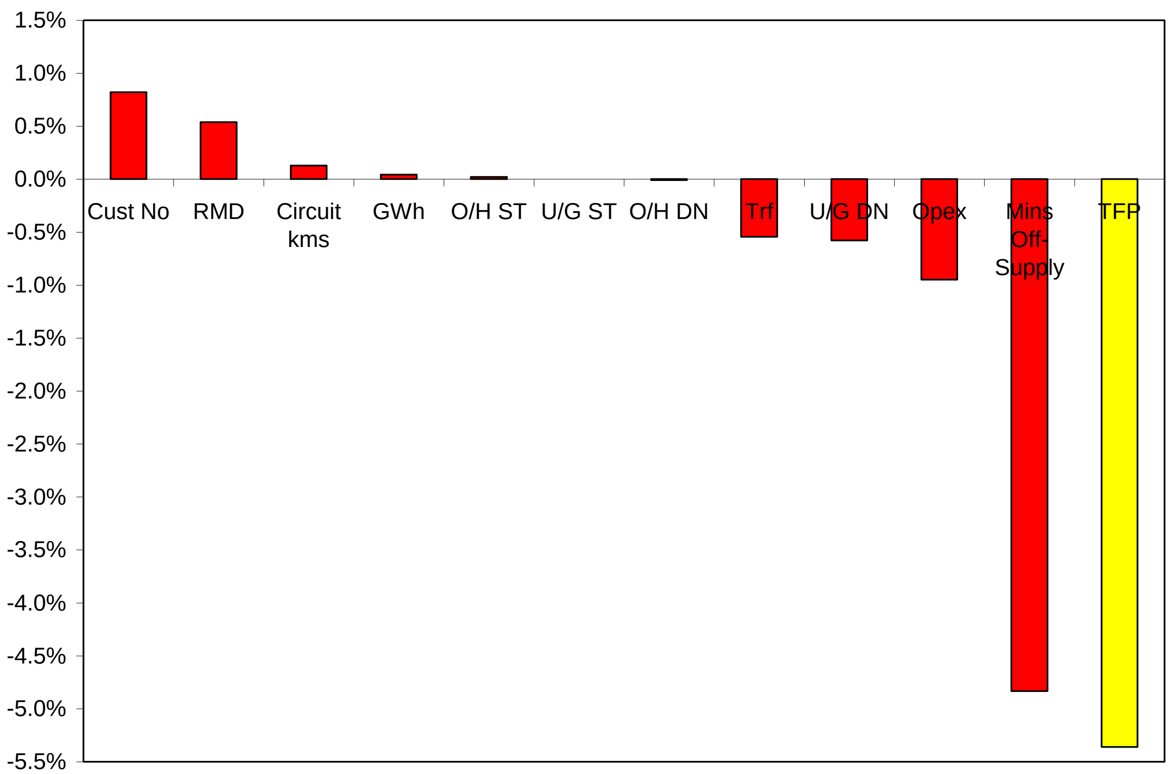
PCR's output and input contributions to TFP change

In table 5.18 we decompose PCR's TFP change into its constituent output and input parts for the whole 13–year period and for the periods up to and after 2012. PCR's drivers of TFP change for the whole 13–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. 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 contribution over the period for PCR of –0.4 per cent compared to –0.5 per cent for the industry.

Table 5.18 **PCR's output and input percentage point contributions to average annual TFP change: 2006–2018, 2006–2012 and 2012–2018**

Year	*2006 to 2018*	*2006 to 2012*	*2012 to 2018*
Energy (GWh)	0.07%	0.14%	0.00%
Ratcheted Max Demand	0.66%	1.11%	0.21%
Customer Numbers	0.69%	0.69%	0.69%
Circuit Length	0.15%	0.16%	0.14%
CMOS	–0.55%	–0.58%	–0.53%
Opex	–0.36%	–0.97%	0.25%
O/H Subtransmission Lines	0.00%	0.00%	0.00%
O/H Distribution Lines	–0.03%	–0.02%	–0.04%
U/G Subtransmission Cables	0.00%	–0.01%	0.00%
U/G Distribution Cables	–0.66%	–0.70%	–0.62%
Transformers	–0.58%	–0.61%	–0.55%
TFP Change	–0.62%	–0.78%	–0.46%

Figure 5.36 **PCR's output and input percentage point contributions to annual TFP change, 2018**



PCR's situation is also a tale of two distinct periods. With the exception of CMOS and customer numbers, the contribution of 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 1.3 percentage points. Opex change went from a –1.0 percentage point contribution to TFP to 0.3 for PCR as opex usage reduced somewhat after 2013.

The importance of PCR's large 38 per cent increase in CMOS in 2018 is highlighted in figure 5.36 where CMOS made a –4.8 percentage point contribution to TFP change in the 2018 year. There was also a –1.0 percentage point contribution from the 2.5 per cent increase in opex that year. These more than offset contributions from customer numbers and RMD growth of 0.8 and 0.5 percentage points, respectively, leading to PCR's TFP change in 2018 being –5.4 per cent compared to industry TFP growth of 1.0 per cent in that year.

5.10 United Energy

In 2018 United Energy (UED) delivered 7,667 GWh to 685,025 customers over 13,382 circuit kilometres of lines and cables. UED distributes electricity across east and south–east Melbourne and the Mornington Peninsula.

UED's productivity performance

As noted in section 1.3, UED is one of three Victorian DNSPs that submitted incorrect opex data for the 2017 year in their April 2018 EBRINs. The AER was notified in December 2018 that UED had made errors in capitalisation calculations required under its EBRIN reporting. This correction has led to UED's 2017 opex being 4 per cent lower than initially reported. Consequently, there are some differences between UED's 2017 productivity performance reported in this report compared to Economic Insights (2018).

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 13–year period 2006 to 2018, UED's TFP increased with an average annual change of 0.1 per cent. Total output increased by an average annual rate of 1.0 per cent while total input use increased at a rate of 0.8 per cent. UED thus had slower output growth, considerably slower input growth and positive instead of 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 and 2018. UED's output declined in three years: 2011, 2012 and 2014. TFP change was positive in six years: 2007, 2009, 2013, 2015, 2017 and 2018. In all but the second of these years there were input decreases and in the second there was stronger output growth. In 2018 there was a small reduction in total output but a sizable reduction in input use driven by a substantial reduction in opex. Compared to the whole 13–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 2.4 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, 2006–2018**

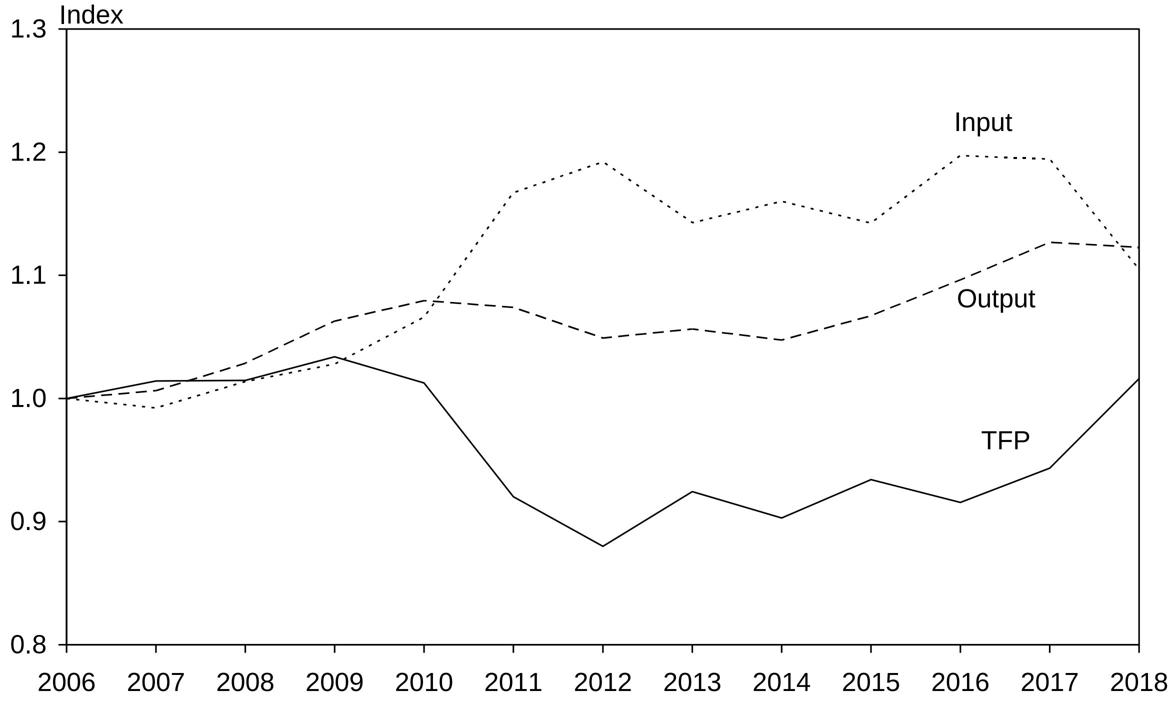


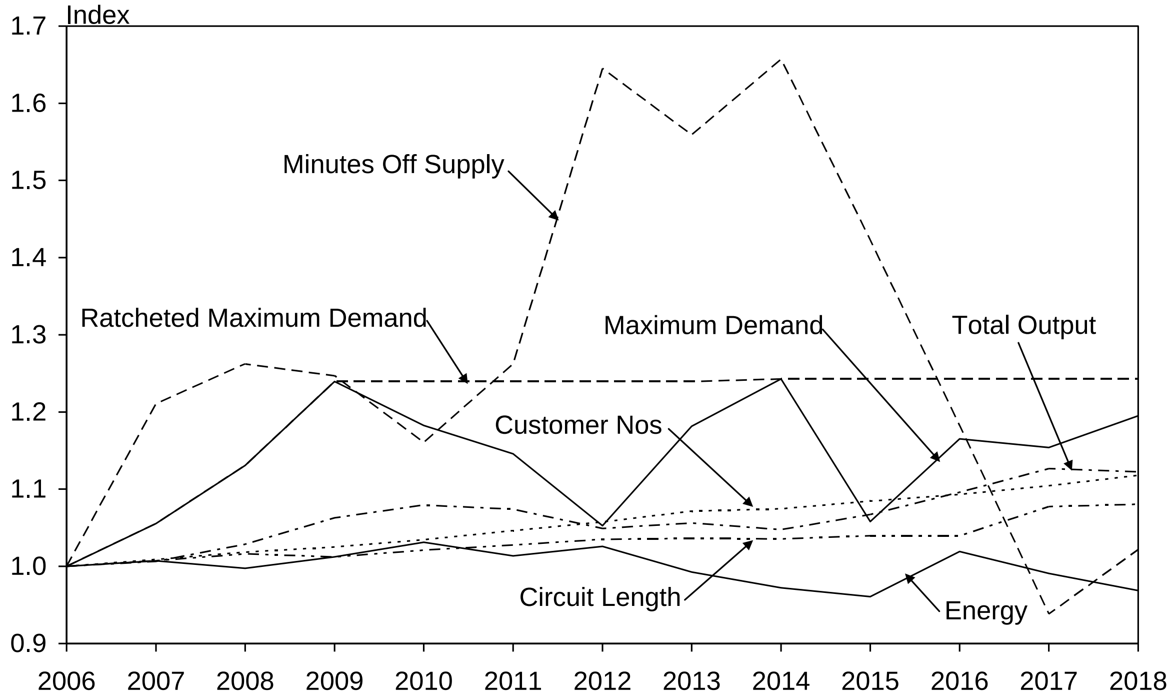
Table 5.19 **UED's output, input and total factor productivity and partial productivity indexes, 2006–2018**

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	1.006	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	1.194	0.943	0.968	0.920
2018	1.123	1.105	1.016	1.214	0.911
Growth Rate 2006–18	0.96%	0.83%	0.13%	1.62%	–0.77%
Growth Rate 2006–12	0.80%	2.93%	–2.13%	–2.77%	–1.77%
Growth Rate 2012–18	1.13%	–1.27%	2.40%	6.00%	0.22%

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, 2006–2018**



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 12 per cent higher in 2018 than they were in 2006, a noticeably smaller increase than the industry's increase of 18 per cent. Energy throughput for distribution peaked in 2012 and was 3 per cent lower in 2018 than it was in 2006.

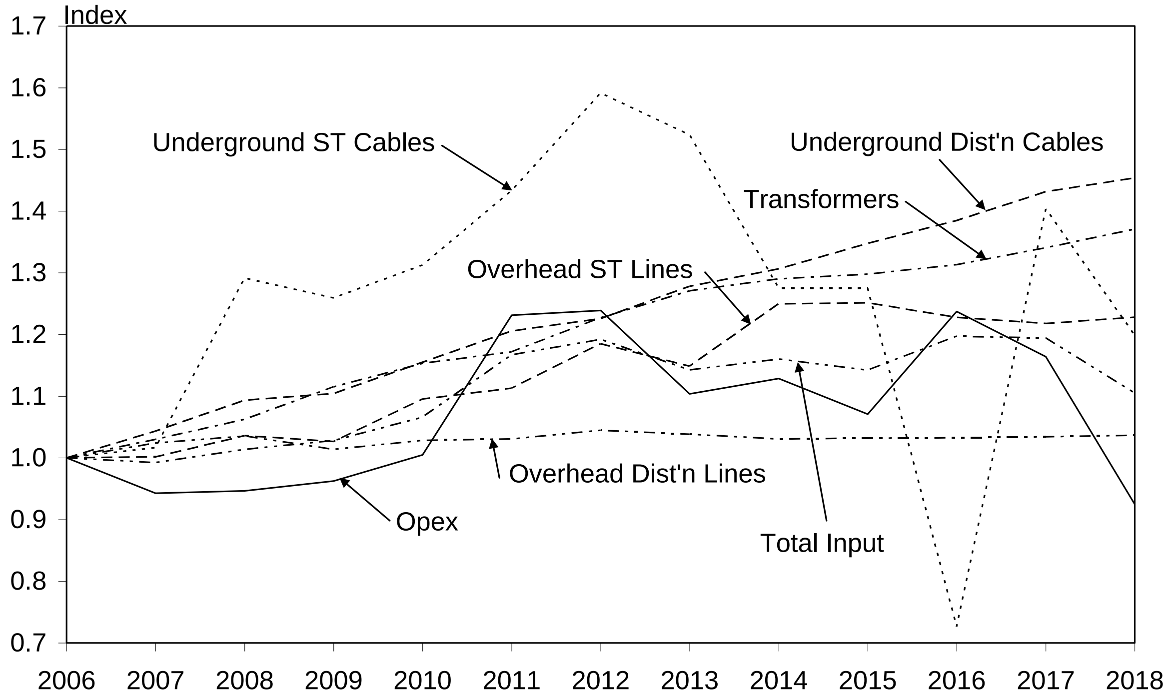
UED's maximum demand reached its highest level in 2014 but has been relatively volatile since a slightly lower peak in 2009. In 2018 it was around 20 per cent above its 2006 level. Ratcheted maximum demand in 2017 was 24 per cent above its 2006 level – a larger increase than the industry's 17 per cent.

UED's circuit length output grew more over the 13 years than occurred for the industry overall and by 2018 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 considerably 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 declining substantially through to 2017 before again increasing somewhat. In 2018 UED's CMOS was 2 per cent higher 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 increase in 2018 combined with weak growth in the other outputs is the main reason for the negative total output growth in the latest year.

Figure 5.39 **UED's input quantity indexes, 2006–2018**



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 and 2018. This took UED's opex change between 2006 and 2018 to be a considerably better than for the industry, with UED's 2018 opex being 8 per cent below its 2006 level compared to 13 per cent higher for the industry. 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 and similar rates, respectively, than for the industry as a whole. Its overhead distribution lines input increased over the period with an increase of 3 per cent by 2018 relative to 2006, substantially less than the increase for the industry of 12 per cent.

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 7.8 per cent in 2018, driven mainly by the large change in opex usage of –23 per cent.

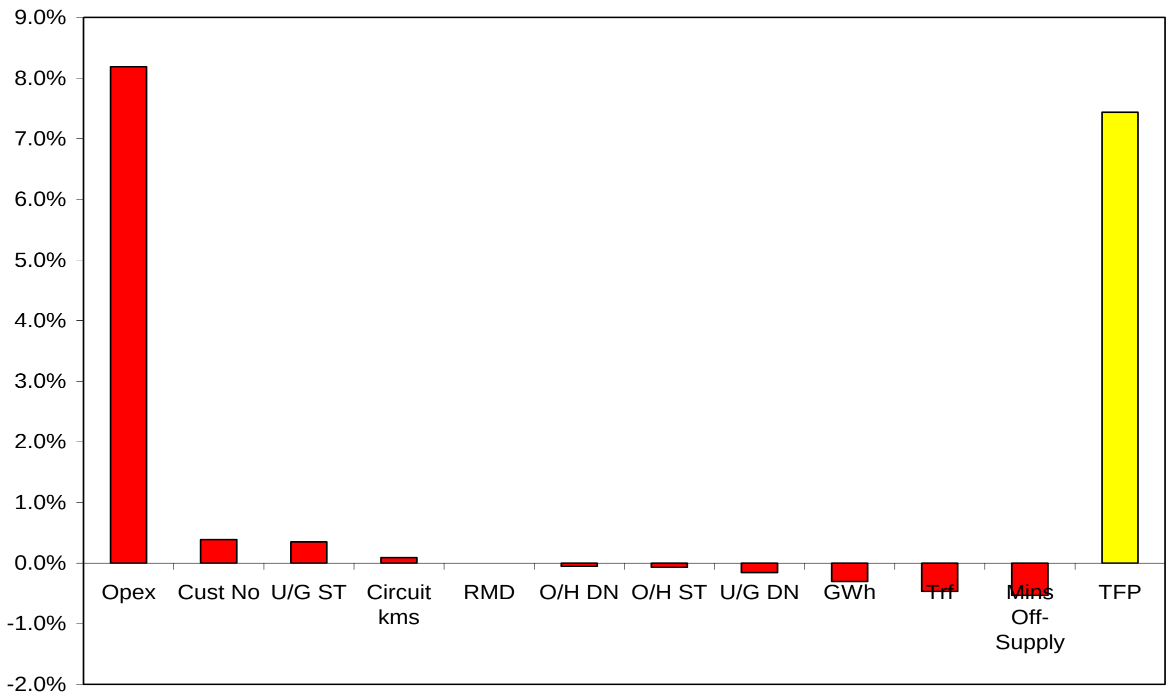
UED's output and input contributions to TFP change

In table 5.20 we decompose UED's TFP change into its constituent output and input parts for the whole 13–year period and for the periods up to and after 2012. UED's drivers of TFP change for the whole 13–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, however, makes a positive contribution over the period for UED at 0.2 percentage points compared to –0.5 for the industry. Transformer inputs make a less negative contribution to UED's TFP at –0.6 percentage points compared to the industry's –0.8 .

Table 5.20 **UED's output and input percentage point contributions to average annual TFP change: 2006–2018, 2006–2012 and 2012–2018**

Year	*2006 to 2018*	*2006 to 2012*	*2012 to 2018*
Energy (GWh)	–0.04%	0.06%	–0.13%
Ratcheted Max Demand	0.56%	1.11%	0.01%
Customer Numbers	0.31%	0.31%	0.31%
Circuit Length	0.20%	0.18%	0.22%
CMOS	–0.07%	–0.86%	0.72%
Opex	0.22%	–1.38%	1.83%
O/H Subtransmission Lines	–0.13%	–0.20%	–0.05%
O/H Distribution Lines	–0.06%	–0.15%	0.03%
U/G Subtransmission Cables	–0.02%	–0.14%	0.11%
U/G Distribution Cables	–0.30%	–0.32%	–0.28%
Transformers	–0.55%	–0.74%	–0.37%
TFP Change	0.13%	–2.13%	2.40%

Figure 5.40 **UED's output and input percentage point contributions to annual TFP change, 2018**



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 1.8 percentage points, a turnaround of 3.2 percentage points.

The importance of UED's reduction in opex in 2018 is highlighted in figure 5.40 where opex made an 8.2 percentage point contribution to TFP change in the 2018 year. CMOS and transformers each made a –0.5 percentage point contribution while customer numbers and underground subtransmission each made a 0.4 percentage point contribution. UED's TFP change in 2017 was 7.4 per cent compared to industry TFP growth of 1.0 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 2014a). 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)
$$\begin{aligned}\ln (TFP_m/TFP_n) = {} & \textstyle\sum_i (r_{im}+R_i^*)(\ln y_{im} - \ln Y_i^*)/2 - \\ & \textstyle\sum_i (r_{in}+R_i^*)(\ln y_{in} - \ln Y_i^*)/2 - \\ & \textstyle\sum_j (s_{jm}+S_j^*)(\ln x_{jm} - \ln X_j^*)/2 + \\ & \textstyle\sum_j (s_{jn}+S_j^*)(\ln x_{jn} - \ln X_j^*)/2\end{aligned}$$

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

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

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.

A5 Opex cost function methodologies

While the opex MPFP analysis presented in the preceding sections has the advantage of producing robust results even with small datasets, it is a deterministic method that does not facilitate the calculation of confidence intervals. We thus also include econometric operating cost functions which do facilitate this and which potentially allow the direct inclusion of adjustment for a wider range of operating environment factors.

To outline our methods we begin by defining the following notation:

C = nominal opex;

$Y = (Y_1, Y_2, ..., Y_G)$ = a G×1 vector of output quantities;

$K = (K_1, K_2, ..., K_H)$ = an H×1 vector of capital quantities;

$Z = (Z_1, Z_2, ..., Z_R)$ = an R×1 vector of operating environment factors; and

$W = (W_1, W_2, ..., W_S)$ = an S×1 vector of input prices.

To simplify our notation we define a vector (X) of length M=G+H+R+S which contains these four vectors together:

$X = (Y, K, Z, W) = (X_1, X_2, ..., X_M)$ = an M×1 vector of output quantities, capital quantities, operating environment factors and input prices.

We use lower case notation to define the natural logarithms of variables. For example, $x_1 = \log(X_1)$.

A5.1 Least squares opex cost function methods

The two most commonly used functional forms in econometric estimation of cost functions are the Cobb–Douglas and translog functional forms. These functions are linear in logs and quadratic in logs, respectively.

The Cobb–Douglas cost function may be written as:

$$(10) \qquad c_{it} = \beta_0 + \sum_{m=1}^{M} \beta_m x_{mit} + \lambda_1 t + v_{it} \,,$$

while the translog cost frontier may be specified as:

$$(11) \qquad c_{it} = \beta_0 + \sum_{m=1}^{M} \beta_m x_{mit} + 0.5 \sum_{m=1}^{M} \sum_{l=1}^{M} \beta_{ml} x_{mit} x_{lit} + \lambda_1 t + v_{it},$$

where subscripts i and t denote DNSP and year, respectively. Furthermore, the regressor variable 't' is a time trend variable used to capture the effects of year to year technical change (and other factors not modelled that have changed over time such as increasing regulatory obligations), v_{it} is a random disturbance term and the Greek letters denote the unknown parameters that are to be estimated.

One can then include a set of N–1 dummy variables into this model to capture efficiency differences across the N firms in the sample (see Pitt and Lee 1981 and Kumbhakar and Lovell 2000). These dummy variables are defined as:

(12) $\quad D_{nit} = 1$ when $n = i$, and is 0 otherwise, $(n = 2,...,N)$.

Including these dummy variables into models (10) and (11) we obtain

$$(13) \qquad c_{it} = \beta_0 + \sum_{m=1}^{M} \beta_m x_{mit} + \sum_{n=2}^{N} \delta_n D_{nit} + \lambda_1 t + v_{it}$$

and

$$(14) \qquad c_{it} = \beta_0 + \sum_{m=1}^{M} \beta_m x_{mit} + 0.5 \sum_{m=1}^{M} \sum_{l=1}^{M} \beta_{ml} x_{mit} x_{lit} + \sum_{n=2}^{N} \delta_n D_{nit} + \lambda_1 t + v_{it},$$

respectively.

In this study, the models in equations (13) and (14) are estimated using a variant of *ordinary least squares* (OLS) regression, where OLS is applied to data that has been transformed to correct for serial correlation (assuming a common autoregressive parameter across the DNSPs). We have also chosen to report *panel–corrected standard errors*, where the standard errors have been corrected for cross–sectional heteroskedasticity. The estimation methods used follow those described in Beck and Katz (1995) and Greene (2000, Ch15) and have been calculated using the *xtpcse* command in *Stata Release 13* (StataCorp 2013).

The estimated coefficients of the dummy variables are then used to predict firm–level cost efficiency scores as:

$$(15) \qquad CE_n = \exp[\min(\hat{\delta}_n) - \hat{\delta}_n] \,, \qquad (n = 1, 2,...,N),$$

where $\delta_1 = 0$ by definition because it is arbitrarily chosen as the base firm.

These cost efficiency scores vary between zero and one with a value of one indicating full cost efficiency, while a value of 0.8 (for example) would imply that the inefficient firm could reduce its opex by 20 per cent and still produce the same level of output.

A5.2 Stochastic frontier analysis opex cost function methods

The above least squares dummy variables approach to estimating cost functions and predicting firm–level cost efficiencies requires access to panel data and an assumption that cost inefficiencies are invariant over time. An alternative approach (that can also be applied to cross–sectional data) is the stochastic frontier analysis (SFA) method proposed by Aigner, Lovell and Schmidt (1977), which we outline below. Following Pitt and Lee (1981), Battese and Coelli (1988) and Kumbhakar and Lovell (2000), we add a one–sided, time–invariant inefficiency disturbance term to the cost function models in (13) and (14) to obtain a Cobb–Douglas stochastic cost frontier:

(16) $$c_{it} = \beta_0 + \sum_{m=1}^{M} \beta_m x_{mit} + \lambda_1 t + v_{it} + u_i ,$$

and a translog stochastic cost frontier:

(17) $$c_{it} = \beta_0 + \sum_{m=1}^{M} \beta_m x_{mit} + 0.5 \sum_{m=1}^{M} \sum_{l=1}^{M} \beta_{ml} x_{mit} x_{lit} + \lambda_1 t + v_{it} + u_i ,$$

where it is assumed that the random disturbance term v_{it} is normally distributed $N(0, \sigma_v^2)$ and independent of the one–sided inefficiency disturbance term u_i, which is assumed to have a truncated normal distribution $\left| N(\mu, \sigma_u^2) \right|$.

Given these distributional assumptions, the unknown parameters in models (16) and (17) can be estimated using Maximum Likelihood Estimation (MLE) methods. In this study we do this using the *xtfrontier* command in *Stata Release 13*.

The cost efficiency score of the *n*–th firm is defined as:

(18) $$CE_n = \exp[u_n], \quad (n = 1, 2,...,N).$$

However, given that u_n is unobservable, *Stata* makes use of the results in Battese and Coelli (1988) to predict the cost efficiency scores using the conditional expectation:

(19) $$CE_n = E[\exp(u_n) \,|\, (v_n + u_n)], \quad (n = 1, 2,...,N),$$

where $v_n = (v_{n1}, v_{n2} ... v_{nT})$.

Confidence intervals for these predictions can be obtained using the formula presented in Horrace and Schmidt (1996). We have calculated these using the *frontier_teci* Stata ado code written by Merryman (2010).

APPENDIX B OPEX COST FUNCTION REGRESSION RESULTS

Table B1 **SFA Cobb–Douglas cost frontier estimates using 2006–2018 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.665	0.072	9.220
ln(CircLen)	0.149	0.046	3.200
ln(RMDemand)	0.173	0.062	2.780
ln(ShareUGC)	–0.134	0.033	–4.060
Year	0.016	0.001	14.530
Country dummy variables:			
New Zealand	0.110	0.101	1.090
Ontario	0.294	0.090	3.260
Constant	–22.877	2.239	–10.220
Variance parameters:			
Mu	0.383	0.079	4.850
SigmaU squared	0.038	0.010	3.999
SigmaV squared	0.011	0.001	20.157
LLF			595.981

Table B2 **SFA translog cost function estimates using 2006–2018 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.673	0.087	7.760
ln(CircLen)=x2	0.144	0.048	3.000
ln(RMDemand)=x3	0.152	0.077	1.980
x1*x1/2	0.095	0.284	0.330
x1*x2	–0.228	0.112	–2.030
x1*x3	0.217	0.208	1.040
x2*x2/2	0.113	0.062	1.840
x2*x3	0.100	0.092	1.090
x3*x3/2	–0.335	0.180	–1.850
ln(ShareUGC)	–0.103	0.037	–2.790
Year	0.015	0.001	12.260
Country dummy variables:			
New Zealand	0.134	0.121	1.110
Ontario	0.322	0.079	4.050
Constant	–20.553	2.454	–8.370
Variance parameters:			
Mu	0.333	0.079	4.200
SigmaU squared	0.044	0.014	3.223
SigmaV squared	0.011	0.001	19.979
LLF			602.556

Table B3 **LSE Cobb–Douglas cost function estimates using 2006–2018 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.682	0.060	11.370
ln(CircLen)	0.154	0.029	5.220
ln(RMDemand)	0.153	0.058	2.650
ln(ShareUGC)	–0.156	0.022	–7.090
Year	0.016	0.002	8.320
Country dummy variables:			
New Zealand	–0.310	0.132	–2.340
Ontario	–0.089	0.132	–0.680
DNSP dummy variables:			
AGD	0.028	0.171	0.160
CIT	–0.683	0.149	–4.570
END	–0.238	0.145	–1.650
ENX	–0.310	0.139	–2.230
ERG	–0.216	0.155	–1.390
ESS	–0.399	0.165	–2.430
JEN	–0.345	0.143	–2.420
PCR	–0.815	0.151	–5.410
SAP	–0.587	0.147	–3.980
AND	–0.547	0.148	–3.700
TND	–0.519	0.155	–3.350
UED	–0.592	0.153	–3.880
Constant	–22.528	3.928	–5.740
R–Square			0.992

Table B4 **LSE translog cost function estimates using 2006–2018 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.512	0.066	7.730
ln(CircLen)=x2	0.152	0.028	5.400
ln(RMDemand)=x3	0.303	0.056	5.380
x1*x1/2	–0.618	0.273	–2.270
x1*x2	0.271	0.091	2.990
x1*x3	0.271	0.210	1.290
x2*x2/2	–0.013	0.038	–0.360
x2*x3	–0.235	0.073	–3.220
x3*x3/2	0.069	0.168	0.410
ln(ShareUGC)	–0.145	0.025	–5.850
Year	0.018	0.002	9.300
Country dummy variables:			
New Zealand	–0.394	0.122	–3.220
Ontario	–0.218	0.121	–1.800
DNSP dummy variables:			
AGD	–0.074	0.165	–0.450
CIT	–0.720	0.138	–5.230
END	–0.366	0.136	–2.680
ENX	–0.404	0.134	–3.020
ERG	–0.339	0.162	–2.090
ESS	–0.555	0.170	–3.270
JEN	–0.227	0.138	–1.650
PCR	–0.895	0.142	–6.290
SAP	–0.707	0.141	–5.000
AND	–0.545	0.142	–3.850
TND	–0.555	0.143	–3.880
UED	–0.486	0.149	–3.260
Constant	–25.033	3.790	–6.600
R–Square			0.993

Table B5 **SFA Cobb–Douglas cost frontier estimates using 2012–2018 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.660	0.098	6.750
ln(CircLen)	0.217	0.055	3.990
ln(RMDemand)	0.107	0.087	1.220
ln(ShareUGC)	–0.084	0.046	–1.810
Year	0.010	0.002	4.640
Country dummy variables:			
New Zealand	0.039	0.101	0.380
Ontario	0.320	0.092	3.480
Constant	–10.909	4.411	–2.470
Variance parameters:			
Mu	0.400	0.071	5.610
SigmaU squared	0.035	0.008	4.478
SigmaV squared	0.008	0.001	14.213
LLF			356.951

Table B6 **SFA translog cost function estimates using 2012–2018 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.587	0.118	4.960
ln(CircLen)=x2	0.202	0.050	4.010
ln(RMDemand)=x3	0.183	0.106	1.730
x1*x1/2	–0.435	0.397	–1.090
x1*x2	0.014	0.155	0.090
x1*x3	0.362	0.294	1.230
x2*x2/2	0.170	0.078	2.180
x2*x3	–0.195	0.111	–1.760
x3*x3/2	–0.082	0.249	–0.330
ln(ShareUGC)	–0.054	0.048	–1.110
Year	0.011	0.002	4.510
Country dummy variables:			
New Zealand	–0.076	0.103	–0.730
Ontario	0.235	0.087	2.690
Constant	–11.896	4.762	–2.500
Variance parameters:			
Mu	0.393	0.065	6.060
SigmaU squared	0.029	0.007	4.347
SigmaV squared	0.008	0.001	13.979
LLF			367.144

Table B7 **LSE Cobb–Douglas cost function estimates using 2012–2018 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.684	0.070	9.760
ln(CircLen)	0.179	0.036	5.010
ln(RMDemand)	0.134	0.073	1.840
ln(ShareUGC)	–0.161	0.028	–5.790
Year	0.011	0.004	3.010
Country dummy variables:			
New Zealand	–0.333	0.196	–1.700
Ontario	–0.091	0.196	–0.460
DNSP dummy variables:			
AGD	–0.020	0.230	–0.090
CIT	–0.614	0.209	–2.940
END	–0.296	0.206	–1.440
ENX	–0.323	0.204	–1.580
ERG	–0.322	0.217	–1.490
ESS	–0.440	0.227	–1.940
JEN	–0.331	0.196	–1.690
PCR	–0.868	0.213	–4.080
SAP	–0.559	0.205	–2.730
AND	–0.524	0.206	–2.540
TND	–0.565	0.225	–2.510
UED	–0.619	0.220	–2.820
Constant	–12.682	7.612	–1.670
R–Square			0.995

Table B8 **LSE translog cost function estimates using 2012–2018 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.443	0.073	6.050
ln(CircLen)=x2	0.195	0.029	6.800
ln(RMDemand)=x3	0.332	0.063	5.250
x1*x1/2	–0.799	0.259	–3.090
x1*x2	0.248	0.097	2.540
x1*x3	0.416	0.197	2.110
x2*x2/2	0.038	0.042	0.910
x2*x3	–0.265	0.075	–3.550
x3*x3/2	0.006	0.164	0.040
ln(ShareUGC)	–0.129	0.025	–5.110
Year	0.014	0.004	3.860
Country dummy variables:			
New Zealand	–0.450	0.155	–2.900
Ontario	–0.225	0.155	–1.450
DNSP dummy variables:			
AGD	–0.059	0.190	–0.310
CIT	–0.666	0.167	–4.000
END	–0.402	0.165	–2.430
ENX	–0.361	0.169	–2.140
ERG	–0.496	0.193	–2.570
ESS	–0.604	0.206	–2.930
JEN	–0.167	0.160	–1.040
PCR	–0.889	0.175	–5.070
SAP	–0.658	0.169	–3.890
AND	–0.421	0.175	–2.410
TND	–0.604	0.179	–3.380
UED	–0.446	0.179	–2.490
Constant	–17.181	7.116	–2.410
R–Square			0.995

REFERENCES

Aigner, D.J., C.A.K Lovell and P. Schmidt (1977), 'Formulation and Estimation of Stochastic Frontier Production Function Models', *Journal of Econometrics*, 6, 21–37.

Australian Energy Regulator (AER) (2015), *Final Decision: Ausgrid Distribution Determination 2014–15 to 2018–19 – Attachment 7: Operating Expenditure*, Melbourne, April.

Australian Energy Regulator (AER) (2018), *Electricity distribution network service providers – Annual benchmarking repor*t, Melbourne, November.

Battese, G.E., and T.J. Coelli (1988), 'Prediction of Firm–Level Technical Efficiencies with a Generalised Frontier Production Function and Panel Data', *Journal of Econometrics*, 38, 387–399.

Beck, N. and Katz, J.N. (1995), "What to do (and not to do) with time–series cross–section data", *American Political Science Review*, 89, 634–641.

Caves, D.W., L.R. Christensen and W.E. Diewert (1982), "Multilateral Comparisons of Output, Input, and Productivity Using Superlative Index Numbers", *The Economic Journal* 92, 73–86.

Economic Insights (2014a), *Economic Benchmarking Assessment of Operating Expenditure for NSW and ACT Electricity DNSPs*, Report prepared by Denis Lawrence, Tim Coelli and John Kain for the Australian Energy Regulator, Eden, 17 November.

Economic Insights (2014b), *Electricity Distribution Industry Productivity Analysis: 1996–2014*, Report prepared by Denis Lawrence and John Kain for the Commerce Commission, Eden, 30 October.

Economic Insights (2015a), *Response to Consultants' Reports on Economic Benchmarking of Electricity DNSPs*, Report prepared by Denis Lawrence, Tim Coelli and John Kain for the Australian Energy Regulator, Eden, 22 April.

Economic Insights (2015b), *DNSP MTFP and Opex Cost Function Results*, Memorandum prepared by Denis Lawrence, Tim Coelli and John Kain for the Australian Energy Regulator, Eden, 13 November.

Economic Insights (2017), *Economic Benchmarking Results for the Australian Energy Regulator's 2017 DNSP Benchmarking Report*, Report prepared by Denis Lawrence, Tim Coelli and John Kain for the Australian Energy Regulator, Eden, 31 October.

Economic Insights (2018), *Economic Benchmarking Results for the Australian Energy Regulator's 2018 DNSP Benchmarking Report*, Report prepared by Denis Lawrence, Tim Coelli and John Kain for the Australian Energy Regulator, Eden, 9 November.

Greene, W.H, (2000), *Econometric Analysis*, 4th Ed., Prentice–Hall.

Horrace, W. and P.Schmidt (1996) 'Confidence Statements for Efficiency Estimates from Stochastic Frontier Models', *Journal of Productivity Analysis*, 7, 257–282.

Kumbhakar, S. and C.A.K. Lovell, (2000), *Stochastic Frontier Analysis*, Cambridge: Cambridge University Press.

Lawrence, D. (2003), *Regulation of Electricity Lines Businesses, Analysis of Lines Business Performance – 1996–2003*, Report prepared by Meyrick and Associates for the New Zealand Commerce Commission, Canberra, 19 December.

Merryman, S. (2010), 'Confidence Intervals for Technical Efficiency Estimates using the *frontier_teci*', Stata code written by Scott Merryman, Risk Management Agency, USDA, USA.

Northwest Econometrics (2007), *SHAZAM User's Reference Manual Version 10*, Vancouver.

Ontario Energy Board (OEB) (2017), 2016 Yearbook of Electricity Distributors, Toronto, 17 August.

Pacific Economics Group Research (PEG) (2018), *Empirical Research in Support of Incentive Rate–Setting: 2017 Benchmarking Update*, Report to the Ontario Energy Board (Revised), Madison, August.

Parks, R.W., (1967), 'Efficient Estimation of a System of Regression Equations when Disturbances are Both Serially and Contemporaneously Correlated', *Journal of the American Statistical Association* 62, 500–509.

Pitt, M. and L. Lee (1981), 'The Measurement and Sources of Technical Inefficiency in Indonesian Weaving Industry', *Journal of Development Economics*, 9, pp. 43–64.

StataCorp (2013), *Stata Statistical Software: Release 13*, College Station, Texas.