Economic Benchmarking Results for the Australian Energy Regulator's 2021 DNSP Annual Benchmarking Report

Draft report prepared for
Australian Energy Regulator

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Michael Cunningham, Denis Lawrence and Tim Coelli

Economic Insights Pty Ltd
Ph +61 419 171 634
Email: john@economicinsights.com.au
WEB www.economicinsights.com.au
ABN 52 060 723 631

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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*
EVO	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
OMPP	Output multilateral partial productivity
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
TNSP	Transmission network service provider
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 2020 DNSP Benchmarking Report (AER 2020).

The annual update involves including data for the 2019-20 financial and 2020 calendar years (as relevant) reported by the DNSPs in their latest Economic Benchmarking Regulatory Information Notice (EBRIN) returns. It includes a small number of revisions to DNSP data, made by the AER in consultation with relevant DNSPs.

In addition to the presentation of updated productivity indexes, we also update:

- the detailed analysis of the drivers of DNSP productivity change presented annually since Economic insights (2017). This analysis examines the contribution of each individual output and input to total factor productivity (TFP) change.
- We also update and expand the opex cost function econometric results presented in Economic Insights (2014, 2015a, 2015b, 2017, 2018, 2019, 2020a). This uses a data sample which includes New Zealand and Ontario DNSPs, in addition to the Australian DNSPs. Results are presented for the 15-year period from 2006 to 2020 as well as for the 9-year period from 2012 to 2020.

1.1 Updates to Productivity Measurement Methods

The methods of analysis used in this report are the same as those used in Economic Insights (2020a), with the following exceptions.

- As with past studies, an opex price index is calculated from published ABS price indexes that approximate components of electricity DNSP costs, and it is used to deflate nominal opex and derive real opex. As applied to individual DNSPs, the approach used in this report is consistent with the previously used approach, whereby the opex price index differs depending on whether the DNSP reports data in financial or calendar years.[1] For the industry as a whole, this report uses a weighted average regulatory year opex price index, whereas previously the financial year opex price index was used for the industry.[2]
- Consistently with previous studies, customer minutes off-supply (CMOS) is a (negative) output and the weight given to this output in the output index depends on the cost of CMOS to consumers in proportion to a DNSP's total revenue. The cost to consumers depends on the value of customer reliability (VCR) per minute, which

[1] Victorian DNSPs report on a calendar year basis, and all other NEM DNSPs report on a financial year (ending 30 June) basis.
[2] The weights attached to the financial and calendar being based on the opex quantities of each of the DNSPs. The weighted average opex price index is such that both: the sum of all DNSPs' nominal opex equals industry nominal opex; and the sum of all DNSPs' real opex equals industry real opex.

differs for each DNSP, and the CMOS. For the industry as a whole, past practice has been to average the VCRs of the DNSPs using customer numbers as weights, and multiply this by total CMOS of all DNSPs. In this report, the cost of CMOS is calculated as the sum of the estimated costs of CMOS for all DNSPs. In addition, in calculating the weight of the reliability output based on the value of customer reliability, we have recognised that the state-based value of customer reliability estimates published by the AER are the September 2019 value (AER 2019b:71), which are adjusted by CPI to the mid-point of each regulatory year of the DNSP.

- The annual user cost of capital (the return on and of capital) is used to determine the cost (and hence cost shares) of physical capital inputs. We have updated the calculation of the weighted average cost of capital for 2020 to reflect the AER's Rate of Return Instrument 2018 (AER 2018:13–16 Table 1, col. 3).[3] For earlier years (2006-2019), the annual user cost of capital calculations broadly reflect the 2013 rate of return guideline (AER 2018:13–16 Table 1, col. 2).

1.2 Specifications Used for Productivity Measurement

This report uses two broad types of economic benchmarking techniques to measure DNSPs' productivity growth and efficiency levels: productivity index numbers and econometric opex cost functions. The latter are discussed in section 1.3.

We use total factor productivity (TFP) indexes and partial factor productivity (PFP) indexes to measure productivity growth of electricity distribution at the Australian industry, State and individual DNSP levels. TFP is measured using the multilateral Törnqvist TFP (MTFP) index method developed by Caves, Christensen and Diewert (1982), and explained in Appendix A. These indexes provide a second order approximation to any underlying production structure. This means they can accurately model both the level and shape of the underlying production function. They provide an accurate measure of productivity growth over time and provide a convenient way of decomposing overall TFP growth into components due to changes in individual outputs and inputs. We also use the multilateral productivity indexes for time–series, cross–section (or panel data) comparisons of productivity levels. 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.

The MTFP method is used for the industry TFP indexes presented in chapter 2, the multilateral comparisons of productivity in chapter 3 (section 3.1), the State-level TFP indexes presented in chapter 4, and the individual DNSP indexes in chapter 5. When the MTFP method is applied to data for a single DNSP, it provides information on the *changes over time* in productivity for the DNSP. The industry-level and State-level analyses in chapters 2 and 4, and the analysis of individual DNSPs in chapter 5, examine patterns of output, input and productivity over time. These chapters do not provide a basis for comparing productivity levels between DNSPs. An analysis of *comparative productivity levels* of TNSPs is presented in chapter 3.

[3] We have applied the 2018 Rate of return Instrument in full, that is: Risk free rate – Yield from 10 year CGS; MRP – 6.1%; Equity beta – 0.6; Gamma – 0.585; Return on debt – Weighted average of A and BBB curves from RBA, Bloomberg and Thomson Reuters.

1.2.1 Defining Outputs

The output index for DNSPs is defined to include five outputs:

(a) Energy throughput in GWh (with 8.6 per cent share of gross revenue,[4] equivalent to 9.8 per cent of total revenue on average)

(b) Ratcheted maximum demand (RMD) in Megavolt amperes (MVA) (with 33.8 per cent share of gross revenue, equivalent to 38.4 per cent of total revenue on average)

(c) Customer numbers (with 18.5 per cent share of gross revenue, equivalent to 21.1 per cent of total revenue on average)

(d) Circuit length in kms (with 39.1 per cent share of gross revenue, equivalent to 44.5 per cent of total revenue on average), and

(e) (minus) Customer Minutes Off–supply (CMOS) (with the weight based on current AER VCRs, being –12.0 per cent of gross revenue on average and equivalent to –13.7 per cent of total revenue on average).[5]

Outputs (a) to (d) are referred to as the 'non-reliability outputs', and output (e) is the 'reliability' output. With the exception of RMD, the outputs are all directly reported by the DNSPs, which also report Maximum Demand for each year in MVA from which RMD is derived. RMD, in any given year *t*, is the maximum of the series of maximum demands from 2006 up to and including year *t*.

The weights applied to the non-reliability outputs are based on estimated shares of marginal cost which the provision of each output accounts for. These are derived from the coefficients of an econometrically-estimated Leontief cost function. This cost analysis was carried out by Economic Insights (2020a) and the method is described in Appendix A. This report does not repeat that analysis because the resulting weights are intended to be held constant for several years before updating them (Economic Insights 2020a:3–6).

1.2.2 Defining Inputs

The DNSP MTFP measures include six inputs:

(a) Opex (network services opex deflated by a composite labour, materials and services price index), making up 37.2 per cent of total costs on average

(b) Overhead subtransmission lines (quantity proxied by overhead subtransmission MVAkms), making up 4.1 per cent of total costs on average

(c) Overhead distribution lines (quantity proxied by overhead distribution MVAkms) , making up 17.3 per cent of total costs on average

[4] 'Gross revenue' is defined as the sum of total revenue plus the value of energy not supplied. See Appendix A.

[5] The weights of the first four outputs sum to more than 100 per cent as reliability enters as a negative output and the sum of all five outputs is 100 per cent.

(d) Underground subtransmission cables (quantity proxied by underground subtransmission MVAkms), making up 1.8 per cent of total costs on average

(e) Underground distribution cables (quantity proxied by underground distribution MVAkms), making up 13.0 per cent of total costs on average, and

(f) 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), making up 26.6 per cent of total costs on average.

These inputs are grouped into two broader categories: input (a) is referred to as 'non-capital inputs', or 'opex input', whilst inputs (b) to (f) are together the 'capital inputs'. The capital inputs are aggregated for the purpose of calculating indexes of capital inputs and partial factor productivities (PFPs) for capital inputs.

The weights applied to each input are based on estimated shares of total cost which each input accounts for. The cost of the non-capital input is measured by nominal Opex. For the capital inputs taken together, the annual user cost of capital (AUC) is taken to be the return on capital, the return of capital and the benchmark tax liability, all calculated in a broadly similar way to that used in forming the building blocks revenue requirement. This aggregate cost of capital inputs is decomposed into the separate capital inputs using estimated shares of each capital asset type in the RAB for each TNSP in each year. See appendix A for further information.

1.3 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 allow for statistical noise and potentially allow the direct inclusion of, and hence control for, a wider range of operating environment factors. The econometric approach also allows the calculation of confidence intervals for efficiency estimates. 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, which involves separate efficiency assessments of, and determinations on, DNSP's opex and capex.

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, nor is this the objective of the AER's benchmarking. 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.

Alternative specifications used for the econometric opex cost function are based on:

- *Functional form*: The two most commonly used functional forms in econometric estimation of cost functions are the Cobb–Douglas and translog functional forms. The simpler Cobb-Douglas function is linear in logs and implies that the elasticities of real opex to each output are constant at all levels of outputs. The more flexible translog function is quadratic in logs, allowing the elasticities of real opex to each output to vary with different output levels.

- *Method of identifying firm-specific inefficiency*: Two alternative methods are used. One method is to use a variant of ordinary least squares (OLS) regression, incorporating dummy variables for 12 of the 13 Australian DNSPs.[6] The parameters of these dummy variables are interpreted as measures of comparative inefficiency among these DNSPs. The other method uses stochastic frontier analysis (SFA). In the SFA models opex efficiency scores are calculated in the model relative to the directly estimated efficient frontier.

The combinations of these methods yield four different econometric models. Details of the methods used are provided in appendix A (section A4). The opex cost efficiency measures from these four models are then averaged. Efficiency measures are obtained using the sample period from 2006 to 2020, and also using the sample period from 2012 to 2020. The results of this analysis are presented in chapter 3 (section 3.2) and Appendix C.

1.4 DNSP comments on draft report

The AER made the draft version of this report available to the thirteen included DNSPs for comment. Feedback was received from seven DNSPs: Evoenergy (EVO), Ausgrid (AGD), AusNet Services (AND), Jemena (JEN), Powercor (PCR), SA Power Networks (SAP), and TasNetworks (TND). Where specific corrections have been highlighted with regard to data, these have been corrected in the analysis. Some specific drafting suggestions have also been incorporated. Some submitters had no concerns with the draft report, or no further comment beyond confirming the accuracy of the data used. This section discusses the critical issues raised by submitters.

Some submitters, such as AusNet, considered that it would be timely for the AER to reassess the suitability of the current benchmarking methodology, including in light of recent changes and current developments in the power system. For example, Evoenergy raised the possibility of treating DER integration as an output. As part of this year's benchmarking exercise, a scoping paper relating to DNSP benchmarking is being prepared which will address opportunities to improve the benchmarking methods to account for new responsibilities of network operators arising in relation to current market reforms, including new responsibilities relating to DER access.

[6] That is, one DNSP is treated as the 'base' and the estimated coefficients on the dummy variables for other Australian DNSPs represent their systematic variation against the base. Overseas DNSPs do not have individual dummy variables, but rather a dummy variable for each country (with Australia as the 'base country', and hence with no such dummy variable). It is immaterial which DNSP is chosen as the base since comparative efficiency measures are subsequently scaled against the DNSP with greatest efficiency.

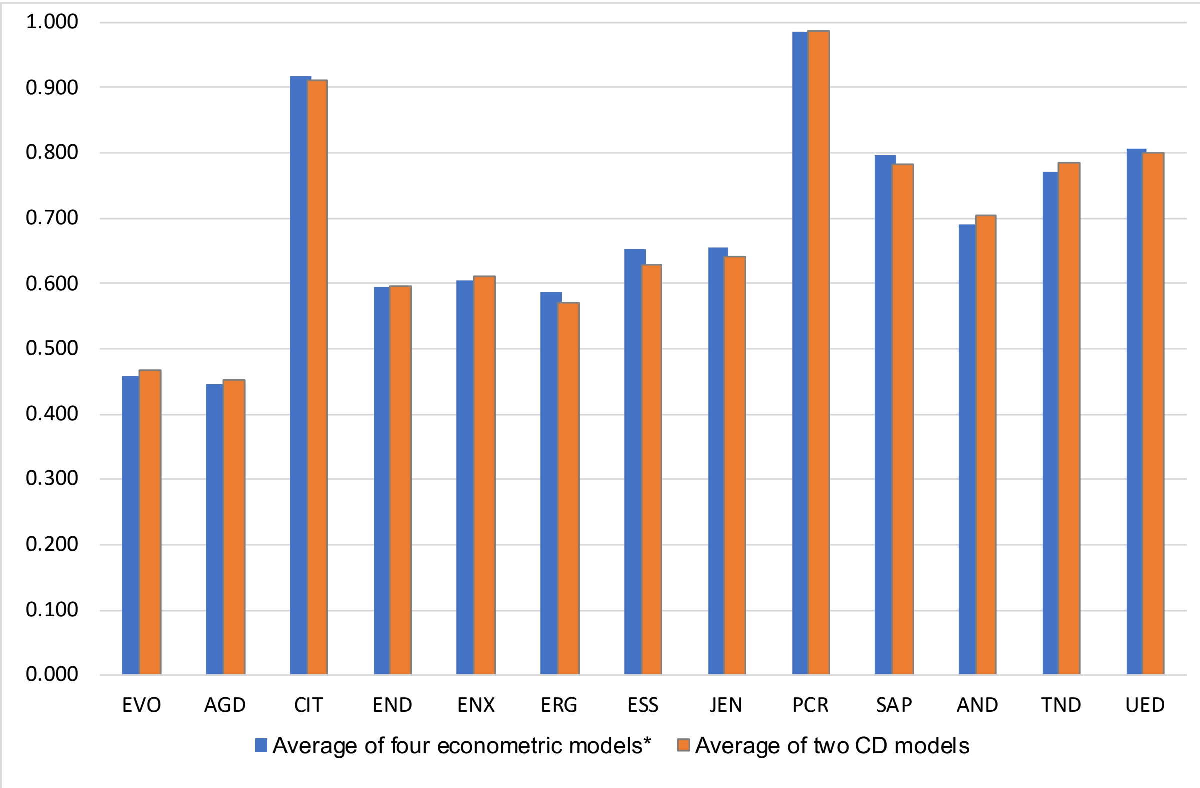
Some submitters are concerned about the output weights used in the multilateral TFP index analysis. For example, AusNet said "the corrected output weights are skewed toward circuit length", and customer numbers "should be represented with a higher weighting". However, the reasons for this claim are not made clear. Ausgrid questioned the methodology used for deriving the output weights for the MTFP analysis. The output weights for the non-reliability outputs were estimated in Economic Insights (2020a), using the method described in appendix A (section A3.1). It is not within the scope of this year's benchmarking exercise to re-estimate those output weights. Similar questions were previously raised by Ausgrid, and addressed in Economic Insights (2020b:1–2). Measurement of total factor productivity of regulated utilities using index analysis typically requires outputs to be defined functionally, and because these functional outputs differ from the basis on which DNSPs charge customers we require estimates of the cost shares attributable to each functional output. Since the weights on the functional outputs are econometrically derived from data on Australian DNSPs (see section A1 of Appendix A on index methodology), this necessarily implies that the degrees of freedom for the econometric analysis of output weights are limited by the sample size for Australian DNSPs. Economic Insights noted that the Leontief function is the simplest available and involves DNSP–by–DNSP estimation of a basic fixed proportions model, which is considered more reliable than the alternatives, even though it may not perform as well on standard statistical indicators designed to assess the fitting of smooth curves.

AusNet also maintained that its Opex partial factor productivity outcomes relative to PCR were implausible, and suggested that this may be due to OEFs. However, this comparative outcome is due to divergent trends in opex input use between 2006 and 2020, and could not be explained by comparatively stable factors such as topographical differences or differences in customer mix.

In relation to the opex cost function analysis, comments were made on the AER's use of the econometric results to derive output weights for forecasting output as part of its rate of change formula for forecasting opex when making distribution determinations. Evoenergy questioned whether the output weights should be calculated using the sample of Australian DNSPs or using the three-country sample. The AER recently addressed this question with respect to its Jemena distribution determination (2021:46–47). It will re-examine this issue, as needed, when considering its determinations for individual DNSPs.

Some submitters were concerned about aspects of the opex cost function estimation reported in section 3.2 and Appendix C. These models are used to yield econometric estimates of the comparative (opex) cost efficiency of the DNSPs. The concerns expressed by some submitters relate to the reliability of the translog (TLG) models. Economic theory implies that the elasticities of opex with respect to each output should be non-negative (here called the 'monotonicity' requirement), and in some of the TLG models, in a proportion of the observations, this requirement is not satisfied. In this report, when a TLG model has violations for more than half of the observations for a DNSP, it is excluded for the purpose of calculating the average efficiency score for that DNSP. In addition, we have chosen to exclude TLG results for all Australian DNSPs for the short period as the monotonicity violations affect most of the Australian DNSPs. Generally, we prefer to retain the TLG model where there are not too many monotonicity violations. The TLG specification is a second-order approximation to any functional form, whereas the Cobb-Douglas (CD) specification is first-order approximation to any functional form. Being more flexible, the TLG model can better capture functional forms that are not as well approximated by the CD model. The downside of this flexibility is that the monotonicity requirement is not necessarily satisfied for all observations in the data sample. The monotonicity violations are most likely the result of the greater flexibility in the TLG functional form in which the edges of the isoquants can 'bend backwards' in places because the data is thinner in those extreme regions and hence the shape of the production surface could be more influenced by a handful of atypical observations. When the efficiency estimates derived using both specifications are averaged, this allows some of the benefits of greater flexibility to be reflected in the results without undue reliance on the TLG models. An important point to note, however, is that the average efficiency scores of DNSPs when the TLG models are included in the averages are broadly similar to the average efficiency scores obtained when only the CD models are included in the averages.[7] This is shown in figure 3.6, reproduced as figure 1.1 below.

Figure 1.1 **DNSP opex cost efficiency scores, 2006–2020, average of four econometric models compared to the average of CD models**



* Average of three models for CIT, JEN and UED.

Jemena is concerned about the procedure used for averaging efficiency scores. For any given DNSP, the "translog models could be included in the average efficiency assessment in one year but excluded in another depending on whether the model violates the monotonicity requirement

[7] The average for four models (or three models for CIT, JEN and UED) differ from the average of the two CD models by an amount which ranges from 0.001 to 0.023.

in that particular year". This, it says, may introduce volatility into the efficiency assessment. Whilst this observation needs to be kept in perspective given the general proximity of efficiency averages shown in figure 1.1, it would be desirable to minimise such effects. To this end, section C3 explores alternative specifications, and identifies a specification which is hybrid between the TLG and CD specifications. That is, by imposing selected constraints on the TLG model (by setting the coefficients on some squared terms to be zero), thereby making it somewhat less flexible, this may make its curvature more 'well behaved' in the face of atypical or outlying observations. It is concluded that the performance of the preferred hybrid specification should be tested again with additional data in 2022, to see if it performs adequately. If so, then in circumstances where the TLG model is inadequate due to excessive monotonicity violations, and if the hybrid specification does not have excessive violations for the same DNSPs, then it might possibly be used as a substitute for the TLG model for the purpose of calculating an average efficiency score over four models.

With reference to the TLG models used in the opex cost function analysis, Jemena says: "Our analysis also shows that there are significant discrepancies between the output weights estimated by the two translog models". These comments reflect observations made by CEPA (2020), which highlighted some differences between estimated elasticities of opex with respect to customers. Given the differences in model specification and estimation technique, it is to be expected that there will be differences in the estimated output elasticities. In our view this does not imply that the models are unreliable, but does highlight the benefit of averaging these models to derive efficiency scores, and of the AER's practice of averaging these elasticities to obtain output weights for forecasting output. While multicollinearity can lead to discrepancies in estimates of the correlated output variables, the impact on efficiency scores of these discrepancies in customer number elasticities can be limited when the joint effect of all outputs is considered. Since one of the principal criteria of model acceptability is the conformity of the estimated coefficients with requirements of economic theory, the elasticities do partly serve a diagnostic purpose; however, it is important to note that the consistency of the cost efficiency scores of DNSPs, estimated directly in the different econometric opex cost function models, is an important indicator of reliability. The substantial degree of consistency of efficiency scores is shown in section 3.2, and is exemplified by figure 1.1 above, which shows the consistency between averages from the CD models and averages across both the CD and TLG models.

Some of the further issues raised will require investigation and consultation that could not be completed within the timeframes for this year's benchmarking report. The AER has identified a number of these issues as areas for benchmarking development and will provide an update on progress and next steps in this year's report. These include:

- Evoenergy noted a need to improve the consistency of measures of quantities of lines and cables across DNSPs. This presumably refers to methods of calculating the MVA ratings of lines;
- AusNet argues that Victorian GSL scheme payments should be excluded from opex;
- AusNet, Evoenergy and Jemena seek clarification on how differences between DNSPs' cost allocation and capitalisation policies might affect the benchmarking results;

- Jemena suggests that the labour proportion of opex used in deriving the opex price index should use more current data.
- AusNet states that guaranteed service level (GSL) payments are included in opex, whereas they are “essentially another measure of reliability performance, and therefore double counts reliability in the analysis”. We understand that the AER will investigate this issue, including whether GSL payments should be reported as a separate line item in EBRIN data.

It is important to note that the productivity measures in this report do not take account of operating environment factors (OEFs) except the degree of undergrounding of electricity lines. However, when the results of this analysis are used by the AER, it does take OEFs into account and makes adjustments when forming its efficiency assessments (see AER 2020 ch.6).

2 INDUSTRY–LEVEL DISTRIBUTION PRODUCTIVITY RESULTS

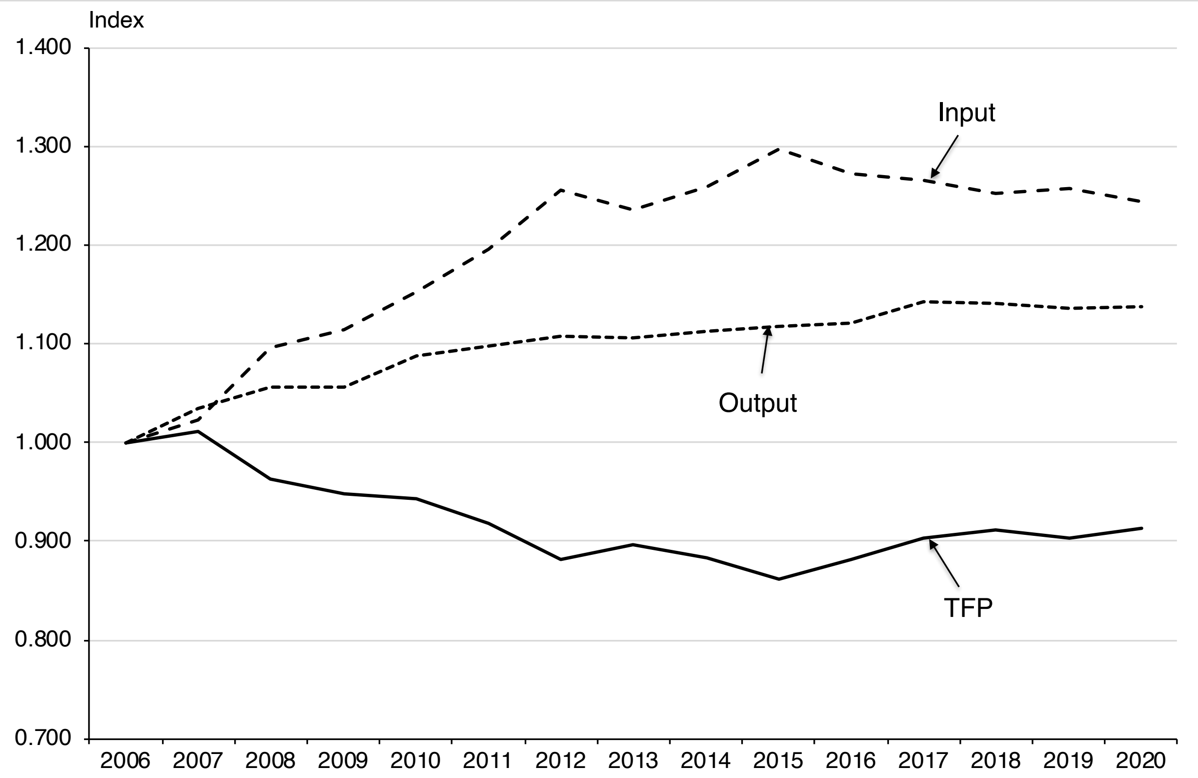
This chapter presents productivity results for the electricity distribution industry across the NEM states and territories in aggregate.

2.1 Industry TFP

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.

Over the 15-year period 2006 to 2020, industry level TFP declined at an average annual rate of 0.6 per cent.[8] Although total output increased at an average annual rate of 0.9 per cent, total input use increased faster at a rate of 1.6 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 six years – 2007, 2013, 2016, 2017, 2018, and 2020. Between 2019 and 2020, TFP increased by 1.2 per cent. Over the period 2006 to 2012, TFP *decreased* at an average annual rate of 2.1 per cent. From 2012 to 2020, TFP *increased* at an average annual rate of 0.4 per cent.

Figure 2.1 **DNSP industry output, input and TFP indexes, 2006–2020**



[8] In keeping with common practice in productivity studies, reported growth rates are generally calculated on a natural logarithm basis. This approach is based on a continuous time growth framework rather than a discrete time framework. It also more readily facilitates identification of the contributors to a given growth rate when the multilateral Törnqvist indexing method is used (see appendix A).

Table 2.1 **DNSP industry output, input, TFP and PFP indexes, 2006–2020**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.035	1.023	1.011	1.037	0.996
2008	1.056	1.096	0.963	0.924	0.989
2009	1.057	1.114	0.949	0.934	0.957
2010	1.087	1.153	0.943	0.923	0.954
2011	1.098	1.196	0.918	0.879	0.941
2012	1.108	1.256	0.882	0.812	0.925
2013	1.107	1.235	0.896	0.881	0.905
2014	1.112	1.259	0.883	0.873	0.890
2015	1.118	1.297	0.862	0.832	0.881
2016	1.121	1.273	0.881	0.901	0.870
2017	1.143	1.266	0.903	0.947	0.878
2018	1.142	1.252	0.912	0.992	0.868
2019	1.135	1.258	0.903	0.990	0.856
2020	1.138	1.245	0.914	1.041	0.846
Growth Rate 2006-2020	0.9%	1.6%	-0.6%	0.3%	-1.2%
Growth Rate 2006-2012	1.7%	3.8%	-2.1%	-3.5%	-1.3%
Growth Rate 2012-2020	0.3%	-0.1%	0.4%	3.1%	-1.1%
Growth Rate 2020	0.2%	-1.1%	1.2%	5.1%	-1.1%

2.2 Partial productivity trends

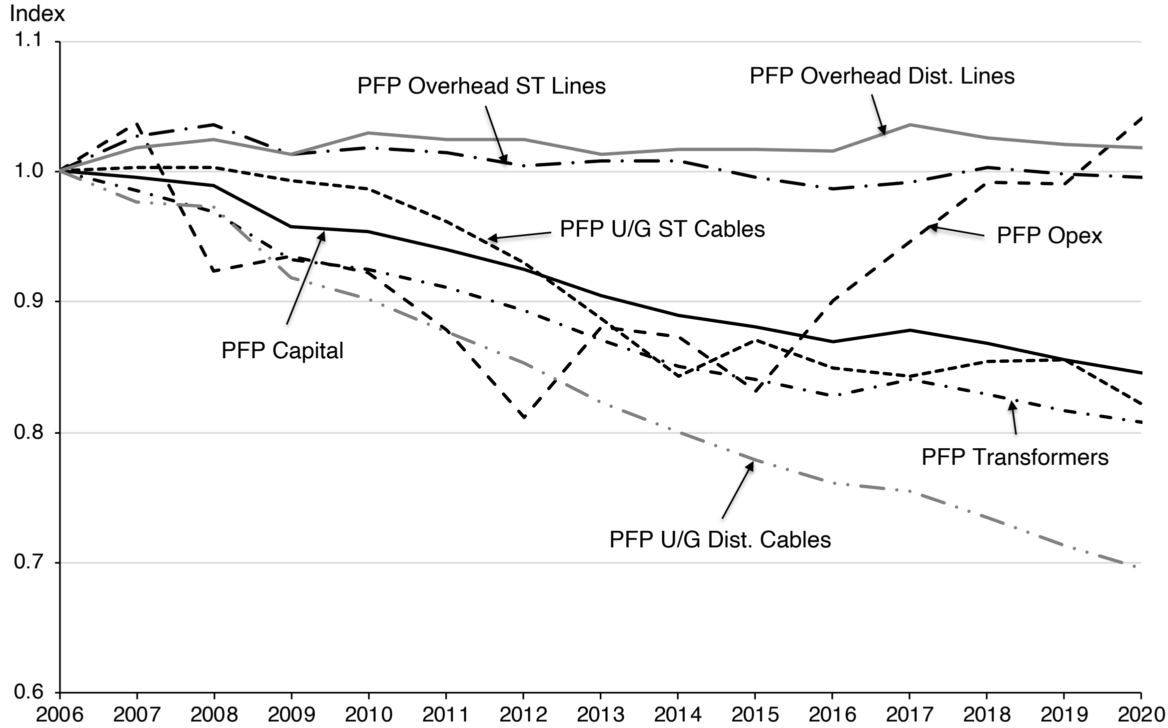
Partial factor productivity (PFP) is a measure of output relative to a single input. The partial productivity indexes in figure 2.2 represent ratios of the total output index to each individual input. Movements in distribution industry-level input partial productivity indexes follow an essentially inverse pattern to input quantities (since as figure 2.1 shows, the total output index has a reasonably stable upward trend).

The partial productivity of opex inputs increased slightly between 2006 and 2020, whereas the partial productivity indexes for most capital inputs decreased over the same period. Opex PFP declined through to 2012 but has generally improved since then, as opex use has trended down. In 2020, opex PFP was 4.1 per cent above its 2006 level. Among the capital inputs:

- Overhead distribution lines PFP in 2020 was 1.8 per cent higher than in 2006, and the overhead sub-transmission lines were 0.5 per cent lower over the same period.
- Underground distribution cables PFP was 30.5 per cent lower in 2020 than in 2006, and underground sub-transmission PFP declined by 17.8 per cent over this period. As noted above, this is because underground cables have increased rapidly from a small base.
- Transformer PFP declined by 19.2 per cent between 2006 and 2020.

Tables showing that average growth rates of individual outputs and inputs, and average growth rates for PFP by individual input are presented in Appendix D, for the industry overall and for individual DNSPs.

Figure 2.2 **DNSP industry partial productivity indexes, 2006–2020**

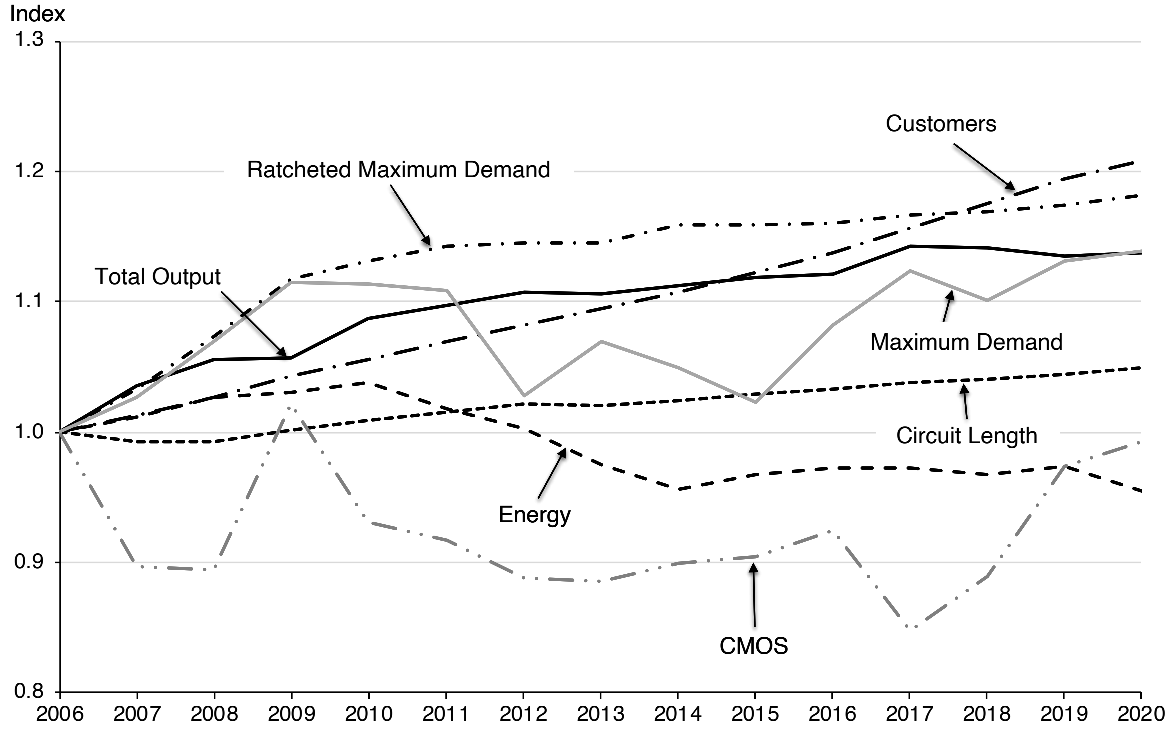


2.3 Distribution industry output and input quantity changes

This section considers the changes in the quantities of the five separate outputs that make up the output index, and the six inputs that make up the input index. Quantity indexes for individual outputs are shown in figure 2.3 and for individual inputs in figure 2.4. In each case the quantities are converted to index format with a value of one in 2006 for ease of comparison. Later, in section 2.4, we 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.

From figure 2.3 we see that circuit length—the output component with the largest weight in the output index—grew very modestly over the 15 years and by 2020 was only 4.9 per cent higher than in 2006. This reflects the fact that most of the increase in customer numbers over the period has been through 'in fill' development (i.e. new dwellings which could be supplied off the existing network), not requiring large increases in network length. The bulk of population growth has occurred on the fringes of cities and towns, in areas already supplied with electricity and in higher density development of cities, so that required increases in network length are modest compared to the increase in customer numbers being serviced.

Figure 2.3 **DNSP industry output quantity indexes, 2006–2020**



The customer numbers index increased steadily over the period and was 20.8 per cent higher in 2020 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 although there was a marginal increase since then, in 2020 energy throughput was the same as that in 2014 and 4.5 per cent less than it was in 2006. This broadly reflects the increasing impact of energy conservation initiatives and more energy–efficient buildings and appliances.

Ratcheted maximum demand (RMD) (i.e. the highest maximum demand up to a particular date) is used as a measure of the capacity supplied to users. It has the second highest weight in forming the output index. This measure reflects the fact that the provision of capacity to service the earlier higher maximum demands does not diminish with decreases in maximum demand or necessarily vary with year-to-year variations in maximum demand. RMD shown in figure 2.3 is the sum of ratcheted maximum demands across the 13 DNSPs (rather than first summing the maximum demands and then calculating the ratcheted quantity).[9] RMD increased rapidly in the period up to 2009, and more slowly since then, even though energy throughput declined after 2010. By 2020, RMD was 18.1 per cent higher than in 2006. Also shown in figure 2.3 is (non-ratcheted) maximum demand. It decreased over the period from 2010 to 2015, in line with energy demand, but maximum demand has since increased. Over the period from 2006 to 2020, the ratio of maximum demand to energy throughput increased overall by 19.3 per cent.

[9] For this reason, the RMD for the industry can increase in a year when aggregate maximum demands did not increase as seen for 2010 and 2011 in Figure 2.3.

Similarly, the ratio between RMD and energy use continued to increase steadily and by 2020 was 23.7 per cent higher than it was in 2006.

Distribution networks, thus, have to service a steadily increasing number of customers and, at least in aggregate, need to meet a slowly growing maximum demand, at a time of weak or falling annual energy throughput.

The last output shown in figure 2.3 is aggregate 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 appears to have generally trended downward up to 2017, hence contributing more to total output than was the case in 2006. However, since 2017 there appears to be an upward trend, and by 2020, CMOS was only 0.8 per cent below the 2006 level.

Since the circuit length and ratcheted maximum demand outputs receive an average weight of 83.9 per cent of total revenue in forming the total output index (see Table A.2 in appendix A), in figure 2.3 we see that the total output index is largely bounded by these two output indexes. The total output index also lies close to the customer numbers output index which received the third highest weight. The output index is also significantly influenced by the comparatively volatile movements in the CMOS output (noting again that an increase in CMOS has a negative impact on total output and is given an average weight of –15.1 per cent of total revenue on average for the industry in aggregate (see Table A.2, Appendix A). For example, the large increases in CMOS since 2017 caused total output to decline slightly despite increases in the other four outputs. Energy throughput is given a comparatively small average weight of 9.9 per cent of total revenue, since changes in throughput generally have relatively low marginal cost. Reductions in throughput after 2010, hence, have had a more muted impact on total output.

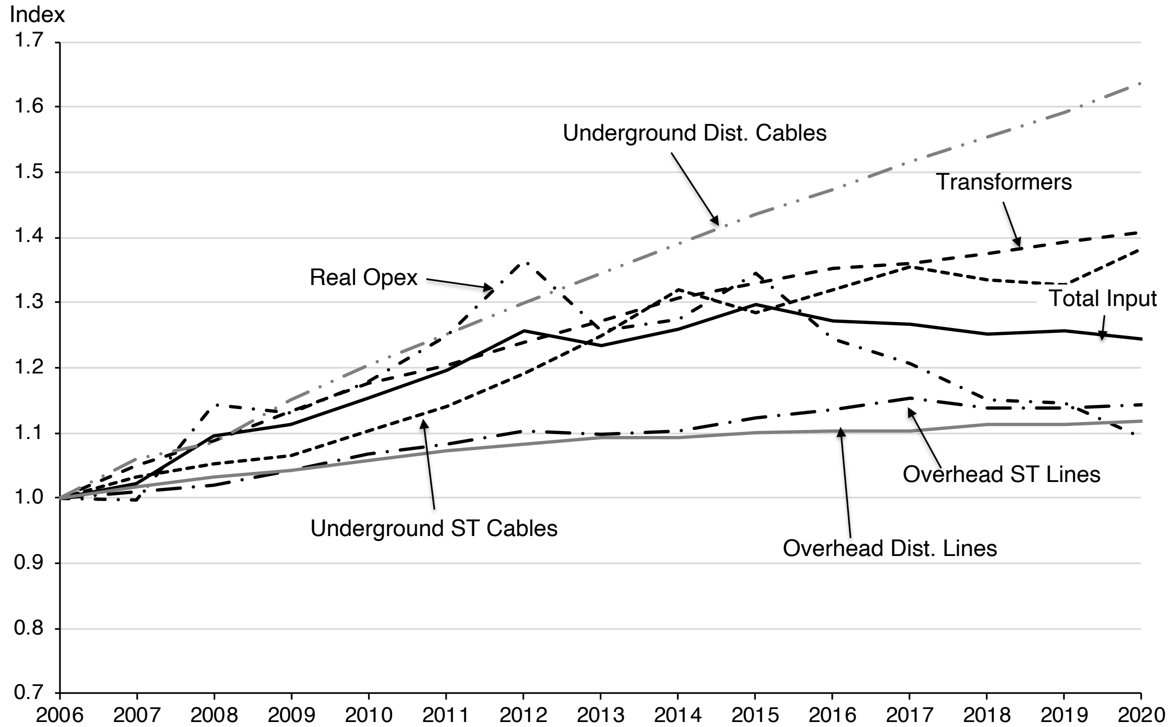
Turning to the input side, quantity indexes for the six individual inputs and the total input index are presented in figure 2.4. Opex has the largest average share in total costs at 37.2 per cent and so is an important driver of the total input quantity index (where weights are based on cost shares; see Table A.3 in appendix A). The quantity of opex (i.e. opex in constant 2006 prices) increased sharply between 2006 and 2012, being 36.4 per cent higher in 2012 than it was in 2006. It then fell in 2013 – a year that coincided with revenue determinations of several large DNSPs – before increasing again in 2014 and 2015. Since then it has decreased consistently, so that by 2020 real opex was 9.2 per cent higher than in 2006.

Another input with a large weight is transformers, which accounts for 28.9 per cent of total cost for the industry. The quantity of transformers has increased steadily over the period and by 2020 was 40.8 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 small increases in their overall network length.

The next key components of DNSP input are the quantities of overhead distribution and overhead sub-transmission lines (measured in MVA-km). These two input quantities have increased over the period from 2006 to 2020 to be 11.7 and 14.3 per cent respectively of the

2006 level. Overhead line input quantities take account of both the length of lines (in km) and the overall 'carrying capacity' of the lines (in MVA). The fact that both overhead distribution and sub-transmission quantities have increased substantially more than circuit length reflects the fact that the average capacity of overhead lines has increased over the period as new or upgraded lines have higher carrying capacity than older lines. Overhead distribution and sub-transmission lines account for 20.1 per cent of total DNSP costs on average.

Figure 2.4 **DNSP industry input quantity indexes, 2006–2020**



The fastest growing input quantity is that of underground distribution cables whose quantity was 63.7 per cent higher in 2020 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 faster than underground sub-transmission quantity (which increased by 38.3 per cent over the period), 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, despite their relatively short length, underground distribution and sub-transmission have an average share in total costs of 13.8 per cent.

From figure 2.4 we see that the total input quantity index lies close to the quantity indexes for opex and transformers (which together have a weight of 66.1 per cent of total costs on average). 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.

2.4 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.

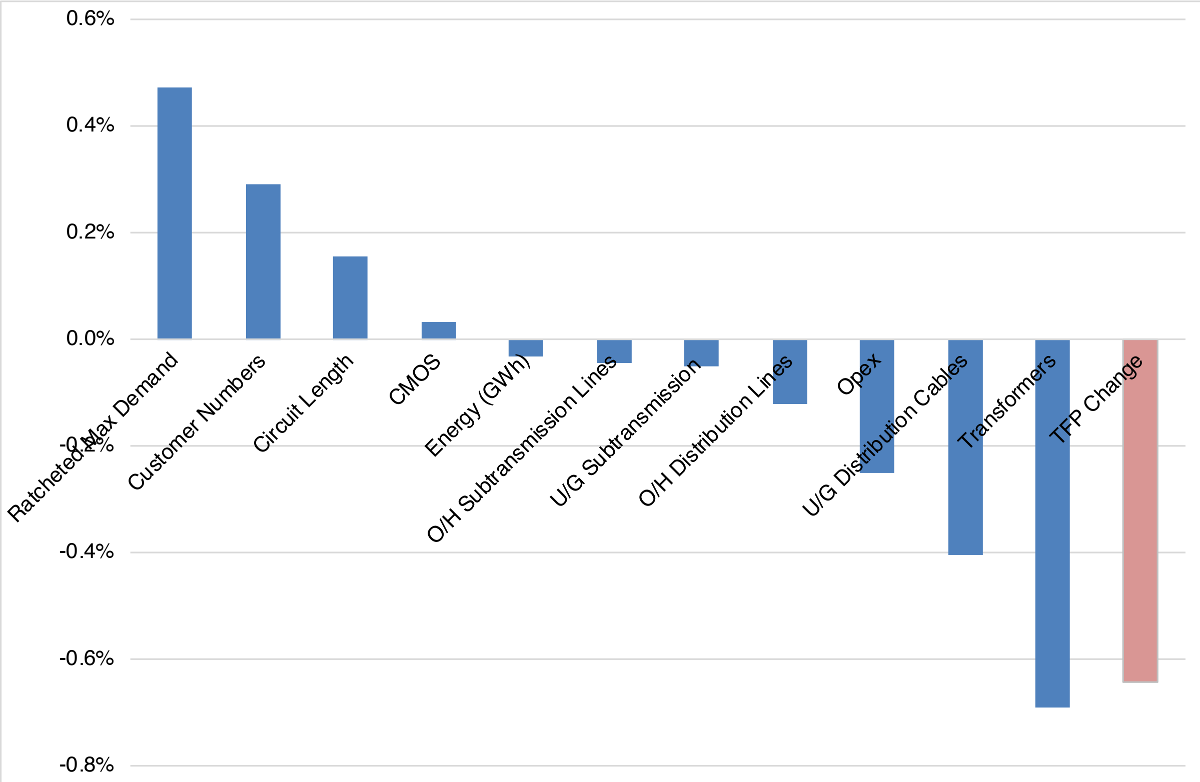
In figure 2.5 and table 2.2 we present the percentage point contributions of each output and each input to the average annual rate of TFP change of –0.64 per cent over the 15–year period 2006 to 2020. In figure 2.5 the blue bars represent the percentage point contributions of each of the outputs and inputs to average annual TFP change which is given in the orange 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 (blue bar) positive and negative contributions in figure 2.5 are added together, the sum will equal the orange bar of TFP change at the far right.

In figure 2.5 we see that the highest (i.e. most positive) contribution to TFP change over the 15-year period comes from RMD which, despite weaker growth after 2011, had the second highest average annual output growth rate over the period of 1.2 per cent. Combined with its average total revenue weight of 38.9 per cent (see: Table A.2, Appendix A), this led to RMD contributing 0.47 percentage points to TFP change over the period.

The second highest contribution to TFP change comes from customer numbers which have grown steadily by 1.3 per cent annually over the whole period. Customer numbers have the third largest weight of the output components at 21.3 per cent on average and the highest growth rate of the output components, and contributed 0.29 percentage points to TFP change over the period.

Despite only increasing at an average annual rate of 0.3 per cent, circuit length receives an average weight of 45.1 per cent of the total output index, and so it made the third highest contribution to TFP change at 0.16 percentage points. Customer minutes off-supply performance effectively made no significant contribution to TFP improvement. The CMOS output receives a weight of –15.1 per cent on average in the total output index and, combined with an average annual change of –0.1 per cent (i.e. reduction in CMOS which increases output), contributed 0.03 percentage points to average annual TFP change. Since energy throughput fell over the 15-year period at an average annual rate of –0.3 per cent and it only has an average weight of 9.9 per cent in total revenue, it made a marginal negative percentage point contribution to TFP change of –0.03 percentage points.

Figure 2.5 **Distribution industry output and input percentage point contributions to average annual TFP change, 2006–2020**



All six inputs made negative contributions to average annual TFP change. That is, the use of all six inputs increased over the 15-year period. Overhead sub-transmission and distribution lines had average annual input growth rates of 1.0 and 0.8 per cent respectively, and because they also have low weights in total input of 4.7 per cent and 15.4 per cent on average respectively, they made among the smallest negative contributions to TFP change: –0.05 and –0.12 percentage points respectively. Despite having a high average annual growth rate of 2.3 per cent, the underground sub-transmission cables input only has a weight of 2.3 per cent in total inputs and so made only a negligible negative contribution to TFP change at –0.05 percentage points.

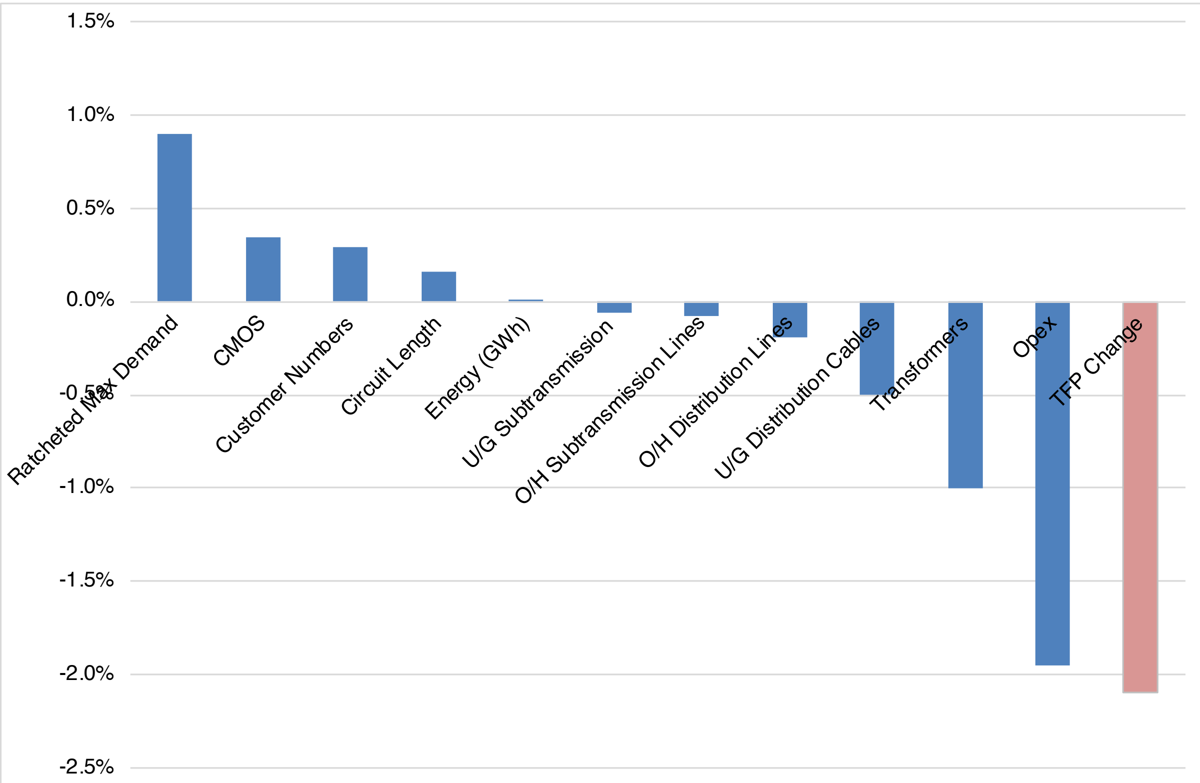
Underground distribution cables had the highest rate of average annual input growth over the period at 3.5 per cent and having a weight of 11.5 per cent in the total input index; they made a substantial negative contribution of –0.40 percentage points to TFP change. The two inputs with the largest average shares in the total input index are transformers and opex, with shares of 28.9 per cent and 37.2 per cent, respectively. Since transformers have the second highest input average annual growth rate at 2.4 per cent, they make the largest negative contribution to TFP change at –0.69 percentage points. Opex has a lower average annual growth rate at 0.6 per cent and makes the third most negative contribution to TFP change at –0.25 percentage points.

We next look at contributions to average annual TFP change for the period up to 2012 and then for the period after 2012. Table 2.2 also shows the contributions to TFP growth in these two sub-periods. The results for the period from 2006 to 2012 are also presented in figure 2.6, and those for the period from 2012 to 2020 are presented in figure 2.7.

Table 2.2 **Distribution industry output and input percentage point contributions to average annual TFP change: 2006–2020, 2006–2012, 2012–2020 and 2020**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2020*
Energy (GWh)	-0.03%	0.00%	-0.06%	-0.19%
Ratcheted Max Demand	0.47%	0.90%	0.15%	0.23%
Customer Numbers	0.29%	0.29%	0.29%	0.24%
Circuit Length	0.16%	0.16%	0.15%	0.19%
CMOS	0.03%	0.34%	-0.20%	-0.28%
Opex	-0.25%	-1.95%	1.03%	1.82%
O/H Subtransmission Lines	-0.05%	-0.08%	-0.02%	-0.02%
O/H Distribution Lines	-0.12%	-0.20%	-0.07%	-0.07%
U/G Subtransmission	-0.05%	-0.06%	-0.04%	-0.09%
U/G Distribution Cables	-0.40%	-0.50%	-0.33%	-0.30%
Transformers	-0.69%	-1.01%	-0.45%	-0.29%
TFP Change	-0.64%	-2.10%	0.45%	1.23%

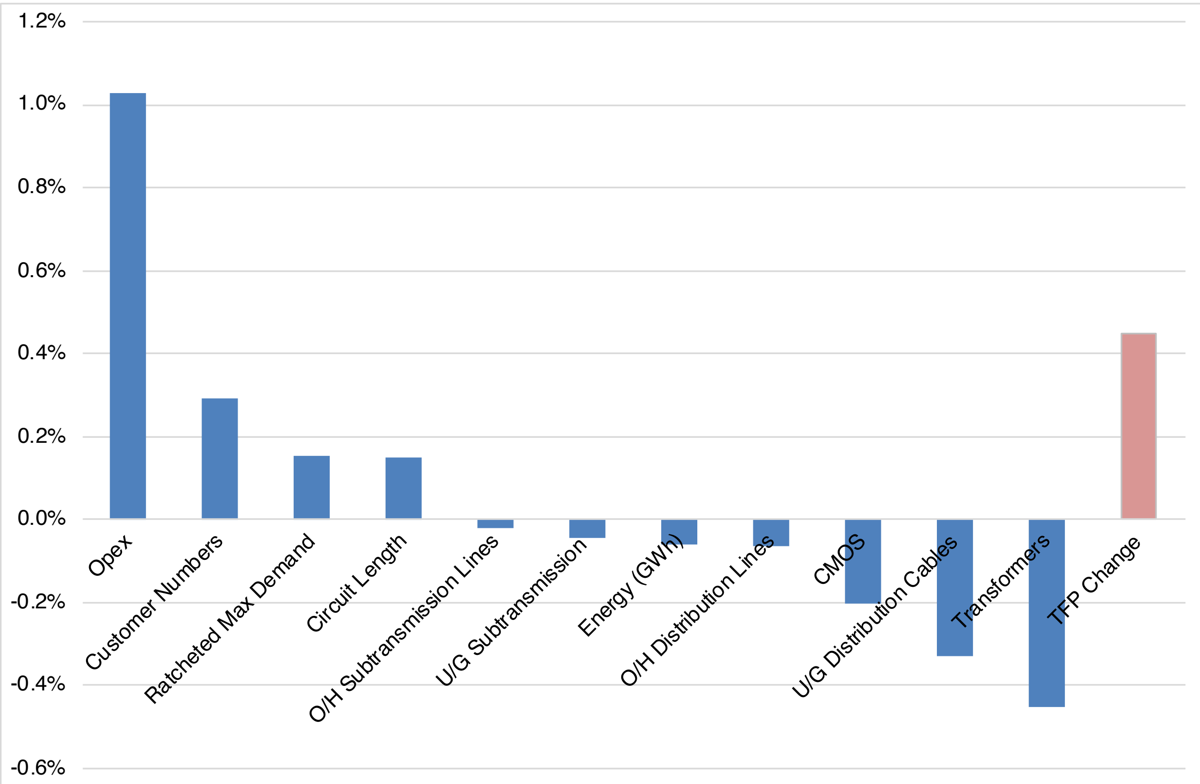
Figure 2.6 **Distribution industry output and input percentage point contributions to average annual TFP change, 2006–2012**



Average annual TFP change for the 2006 to 2012 period was more negative at –2.10 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 main exceptions. The contributions from the RMD and CMOS outputs are somewhat higher in the period up to 2012 at 0.90 percentage points and 0.34 percentage points, respectively. This coincides with the period where RMD was increasing most strongly and CMOS was at close to its lowest point (i.e. most positive contribution to total output).

The second, and most significant, difference of the period up to 2012 relates to the contribution of opex to average annual TFP change. Opex increased rapidly from 2006 to 2012, and its average annual growth rate over this period was 5.2 per cent. This high growth rate in opex likely reflects responses to meet new standards requirements, with many of those responses relating 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 high growth rate of opex, together with its large weight in the total input index, made for a very large negative contribution of –1.95 percentage points to average annual TFP change over the period up to 2012.

Figure 2.7 **Distribution industry output and input percentage point contributions to average annual TFP change, 2012–2020**



In the period from 2012 to 2020, TFP change was positive with an annual average growth rate of 0.45 per cent, and the contributions to this growth are presented in figure 2.7 and table 2.2. The most significant change relative to the earlier period is the contribution of opex to TFP change, which 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 –2.8 per cent. This has led to opex making a positive contribution of 1.03 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 to TFP change from: (i) transformers whose contribution fell from –1.01 percentage points (pre-2012) to –0.45 after 2012; and (ii) underground distribution cables, which decreased from –0.50 to –0.33 percentage points. However, offsetting this has been reductions in the contributions from some outputs, with RMD's contribution to average annual TFP change falling from 0.90 (up to 2012) to 0.15 percentage points after 2012 and CMOS's contribution falling from 0.34 to –0.20 percentage points. Reductions in energy throughput made its contribution to average annual TFP change marginally negative (by comparison its contribution was zero pre-2012 and –0.06 after 2012).

Table 2.2 also shows the contributions to TFP growth in 2020. The outputs tend to have broadly similar contributions to the average annual results for the period 2012 to 2020 described above, with energy throughput and CMOS making small negative contributions and the other outputs making small positive contributions. The higher TFP growth in 2020 is driven by inputs. Opex reductions made a particularly strong contribution to TFP growth of 1.82 percentage points, which is stronger than the average for the period 2012 to 2020. Transformers made a smaller negative contribution in 2020 (–0.29 percentage points).

Tables 2.3 and 2.4 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 2020.

Table 2.3 **Distribution industry output and input annual changes, 2006–2020**

Year	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*
Energy	1.11%	1.52%	0.42%	0.67%	-1.92%	-1.48%	-2.92%
RMD	3.20%	3.83%	4.08%	1.24%	0.95%	0.20%	0.00%
CustomerNo	1.30%	1.32%	1.57%	1.24%	1.23%	1.19%	1.20%
Cct Length	-0.76%	-0.04%	0.97%	0.69%	0.60%	0.62%	-0.11%
CMOS	-10.95%	-0.19%	13.27%	-9.23%	-1.57%	-3.23%	-0.25%
Opex	-0.22%	13.57%	-1.06%	4.08%	5.87%	8.80%	-8.21%
O/H SubTrn	0.84%	1.08%	2.28%	2.36%	1.38%	1.88%	-0.44%
O/H Distrib	1.62%	1.45%	1.18%	1.25%	1.41%	0.95%	0.93%
U/G SubTrn	3.13%	2.01%	1.13%	3.48%	3.44%	4.33%	4.65%
U/G Distrib	5.85%	2.31%	5.80%	4.60%	3.86%	3.73%	3.44%
Transformer	4.87%	3.66%	3.93%	3.69%	2.45%	2.87%	2.53%

Table 2.3 **(cont.)**

Year	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
Energy	-1.88%	1.10%	0.63%	-0.06%	-0.56%	0.69%	-1.95%
RMD	1.23%	0.06%	0.02%	0.58%	0.25%	0.43%	0.59%
CustomerNo	1.13%	1.34%	1.41%	1.66%	1.61%	1.55%	1.12%
Cct Length	0.42%	0.48%	0.39%	0.42%	0.27%	0.41%	0.41%
CMOS	1.55%	0.56%	2.24%	-8.65%	4.71%	9.13%	1.86%
Opex	1.40%	5.33%	-7.64%	-3.11%	-4.79%	-0.32%	-4.87%
O/H SubTrn	0.39%	1.80%	1.16%	1.50%	-1.29%	0.02%	0.43%
O/H Distrib	0.11%	0.64%	0.38%	-0.05%	0.89%	-0.09%	0.45%
U/G SubTrn	5.49%	-2.69%	2.85%	2.58%	-1.46%	-0.62%	4.16%
U/G Distrib	3.40%	3.13%	2.59%	2.84%	2.53%	2.49%	2.71%
Transformer	2.77%	1.80%	1.69%	0.40%	1.27%	1.11%	1.20%

Table 2.4 **Distribution industry output and input percentage point contributions to annual TFP change, 2006–2020**

Year	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*
Energy	0.11%	0.15%	0.05%	0.06%	-0.19%	-0.15%	-0.28%
RMD	1.33%	1.52%	1.61%	0.49%	0.37%	0.07%	0.00%
CustomerNo	0.31%	0.29%	0.33%	0.28%	0.27%	0.26%	0.25%
Cct Length	-0.34%	-0.01%	0.44%	0.32%	0.28%	0.28%	-0.05%
CMOS	2.04%	0.03%	-2.36%	1.67%	0.25%	0.44%	0.00%
Opex	0.07%	-5.19%	0.38%	-1.55%	-2.16%	-3.26%	3.08%
O/H SubTrn	-0.04%	-0.06%	-0.10%	-0.11%	-0.07%	-0.09%	0.02%
O/H Distrib	-0.24%	-0.22%	-0.18%	-0.18%	-0.22%	-0.14%	-0.14%
U/G SubTrn	-0.07%	-0.05%	-0.01%	-0.08%	-0.07%	-0.10%	-0.11%
U/G Distrib	-0.73%	-0.23%	-0.67%	-0.48%	-0.47%	-0.44%	-0.40%
Transformer	-1.29%	-1.10%	-1.05%	-1.03%	-0.71%	-0.84%	-0.75%
TFP Change	1.14%	-4.86%	-1.56%	-0.60%	-2.73%	-3.97%	1.61%

Year	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
Energy	-0.18%	0.11%	0.06%	0.00%	-0.06%	0.07%	-0.19%
RMD	0.47%	0.02%	0.02%	0.21%	0.10%	0.17%	0.23%
CustomerNo	0.24%	0.28%	0.30%	0.34%	0.34%	0.34%	0.24%
Cct Length	0.19%	0.21%	0.18%	0.18%	0.12%	0.19%	0.19%
CMOS	-0.21%	-0.07%	-0.29%	1.16%	-0.61%	-1.30%	-0.28%
Opex	-0.62%	-1.99%	2.91%	1.16%	1.74%	0.11%	1.82%
O/H SubTrn	-0.02%	-0.09%	-0.06%	-0.07%	0.06%	0.00%	-0.02%
O/H Distrib	-0.01%	-0.10%	-0.07%	0.00%	-0.14%	0.01%	-0.07%
U/G SubTrn	-0.12%	0.05%	-0.06%	-0.07%	0.03%	0.02%	-0.09%
U/G Distrib	-0.37%	-0.36%	-0.31%	-0.36%	-0.24%	-0.29%	-0.30%
Transformer	-0.80%	-0.49%	-0.49%	-0.15%	-0.33%	-0.33%	-0.29%
TFP Change	-1.45%	-2.43%	2.18%	2.41%	1.03%	-1.01%	1.23%

3 DNSP EFFICIENCY RESULTS

This chapter presents summary MTFP and MPFP results for each DNSP followed by an update of the econometric opex cost function models in Economic Insights (2014, 2015a, 2015b, 2020a).

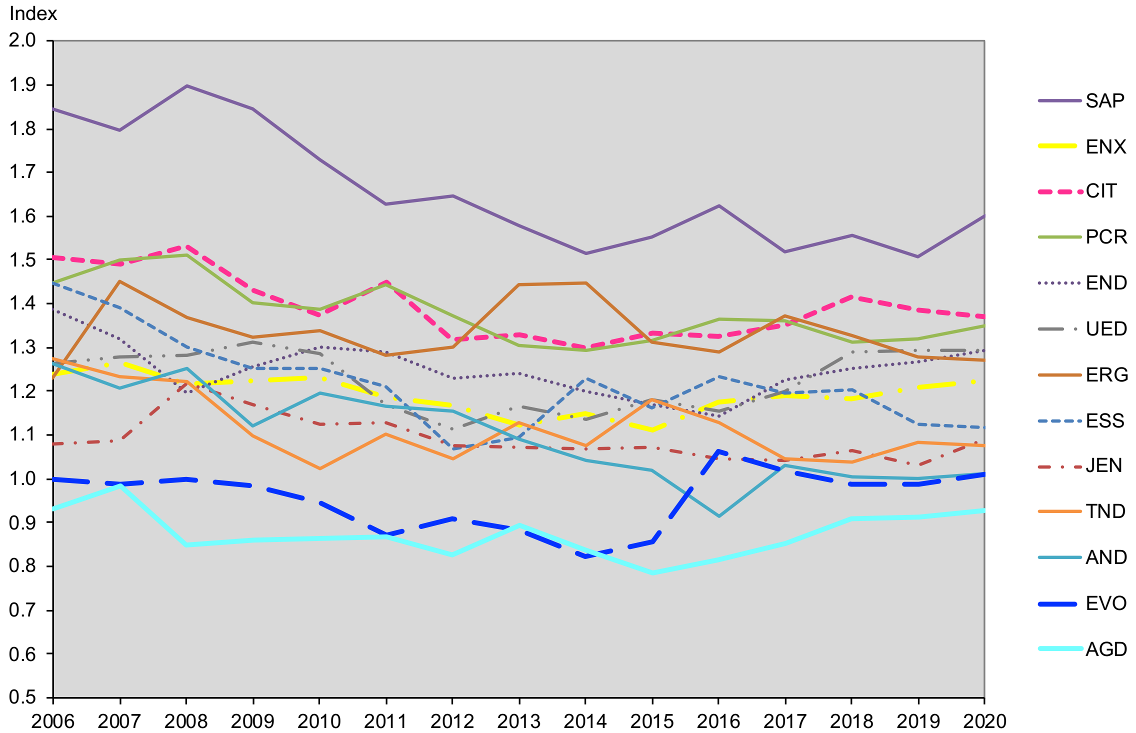
3.1 DNSP multilateral total and partial factor productivity indexes

As outlined in chapter 1, MTFP and MPFP indexes can allow comparisons of productivity levels as well as productivity growth to be made when a panel of businesses is included in the index analysis. The following two subsections examine MTFP and MPFP indexes in turn.

3.1.1 Multilateral TFP Indexes

Updated DNSP MTFP indexes are presented in figure 3.1 and table 3.1. For convenience, index results are presented relative to EVO in 2006 having a value of one. The results are invariant to which observation is used as the base. In figures 3.1 to 3.3, DNSPs are ordered in the legend according to their 2020 MTFP scores.

Figure 3.1 **DNSP multilateral total factor productivity indexes, 2006–2020**



In 2006 the average MTFP index (relative to EVO in 2006) was 1.30, and it reduced to 1.20 in 2020, reflecting the average industry decrease in TFP over the intervening period. There was also a narrowing on MTFP scores, in that the difference between the highest and lowest MTFP indexes decreased from 0.91 in 2006 to 0.67 in 2020. Comparing MTFP levels in 2020:

- SAP has the highest MTFP level followed by CIT and PCR. AGD ranks lowest in terms of MTFP followed by EVO and AND;
- the DNSPs with above-average MTFP indexes were SAP (with an MTFP index of 1.60), CIT (1.37), PCR (1.35), END (1.29), UED (1.29), ERG (1.27) and ENX (1.23);
- those with below-average MTFP indexes were (from smallest to largest) AGD (0.93), AND (1.01), EVO (1.01), TND (1.08), JEN (1.09) and ESS (1.12).

Table 3.1 **DNSP multilateral total factor productivity indexes, 2006–2020**

Year	EVO	AGD	CIT	END	ENX	ERG	ESS
2006	1.000	0.932	1.504	1.389	1.239	1.229	1.446
2007	0.988	0.984	1.489	1.321	1.264	1.452	1.391
2008	0.999	0.849	1.533	1.196	1.217	1.370	1.301
2009	0.986	0.860	1.430	1.257	1.225	1.323	1.252
2010	0.948	0.863	1.374	1.300	1.231	1.339	1.253
2011	0.870	0.868	1.448	1.288	1.185	1.282	1.210
2012	0.909	0.827	1.317	1.231	1.169	1.302	1.069
2013	0.883	0.895	1.328	1.243	1.123	1.443	1.096
2014	0.823	0.840	1.298	1.201	1.148	1.449	1.229
2015	0.857	0.787	1.332	1.169	1.110	1.312	1.161
2016	1.064	0.814	1.327	1.143	1.174	1.289	1.233
2017	1.017	0.852	1.353	1.228	1.189	1.373	1.195
2018	0.986	0.910	1.416	1.254	1.184	1.329	1.205
2019	0.988	0.914	1.386	1.267	1.209	1.280	1.125
2020	1.011	0.929	1.370	1.293	1.225	1.271	1.116

Year	JEN	PCR	SAP	AND	TND	UED	AVG
2006	1.078	1.448	1.845	1.262	1.276	1.262	1.301
2007	1.086	1.498	1.796	1.206	1.233	1.277	1.307
2008	1.217	1.513	1.898	1.252	1.221	1.282	1.296
2009	1.170	1.403	1.845	1.123	1.100	1.312	1.253
2010	1.126	1.387	1.728	1.195	1.025	1.286	1.235
2011	1.128	1.444	1.627	1.164	1.104	1.172	1.215
2012	1.075	1.374	1.648	1.155	1.047	1.112	1.172
2013	1.072	1.306	1.580	1.092	1.129	1.166	1.181
2014	1.070	1.294	1.514	1.044	1.077	1.138	1.163
2015	1.071	1.314	1.552	1.018	1.180	1.180	1.157
2016	1.045	1.366	1.623	0.915	1.130	1.153	1.175
2017	1.044	1.361	1.519	1.032	1.045	1.201	1.185
2018	1.066	1.312	1.556	1.004	1.038	1.291	1.196
2019	1.030	1.320	1.508	1.001	1.084	1.292	1.185
2020	1.089	1.352	1.603	1.011	1.076	1.292	1.203

Among the DNSPs with above-average MTFP, those which increased their productivity in 2020 included SAP, PCR, END, and ENX, whilst productivity decreased for CIT and ERG, and was unchanged for UED. Among the DNSPs with below-average MTFP in 2020, those which increased their MTFP in 2020 were JEN, EVO, AGD and AND, whereas ESS's and TND's MTFP indexes decreased.

Comparing the rankings of MTFP levels in 2020 to those in 2006, ERG had the largest increase in its ranking from 10th in 2006 to 6th in 2020. Other notable increases in ranking over the same period were: UED, from 7th to 5th; ENX from 9th to 7th; and JEN from 11th to 9th. DNSPs with the largest decreases in rankings between 2006 and 2020 were: ESS, from 4th to 8th; TND from 6th to 10th; and AND, from 8th to 12th.

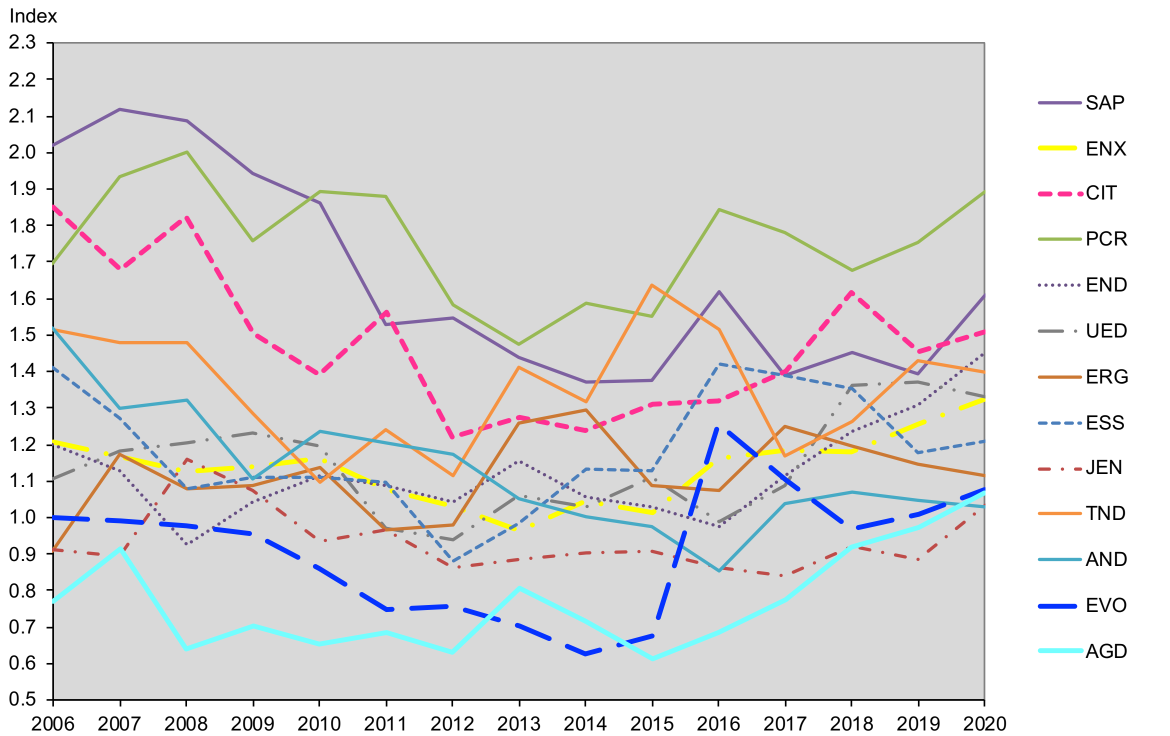
Comparing the rankings of MTFP levels in 2020 to those in 2019, END has had the largest increase in its ranking, from 6th to 4th; while JEN increased its ranking from 10th to 9th and EVO from 12th to 11th. On the other hand, the DNSPs whose ranking decreased were: UED from 4th to 5th; and ERG from 5th to 6th; TND from 9th to 10th; and AND from 11th to 12th.

3.1.2 Multilateral PFP Indexes

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

From figure 3.2 we see that Opex MPFP levels for most DNSPs decreased in the first half of the period, but this trend was mostly reversed in the period 2012 to 2014, and since that time Opex MPFP has increased.

Figure 3.2 **DNSP Multilateral Opex Partial Productivity Indexes, 2006–2020**



From figure 3.2 and Table 3.2 we see that seven DNSPs increased Opex MPFP levels in 2020 by 5 per cent or more over 2019; namely EVO (6.7 per cent), AGD (9.3 per cent), END (10.3 per cent), ENX (5.3 per cent), JEN (15.8 per cent), PCR (7.6 per cent) and SAP (14.3 per cent). Smaller increases were achieved by CIT (3.6 per cent) and ESS (2.8 per cent). The Opex MPFP levels of four DNSPs decreased in 2020, including ERG (–2.9 per cent), AND (–2.1 per cent), TND (–2.2 per cent) and UED (–2.8 per cent).[10]

Table 3.2 **DNSP Multilateral Opex Partial Productivity Indexes, 2006–2020**

Year	EVO	AGD	CIT	END	ENX	ERG	ESS
2006	1.000	0.770	1.850	1.200	1.208	0.909	1.411
2007	0.993	0.915	1.678	1.127	1.168	1.175	1.270
2008	0.976	0.641	1.824	0.925	1.128	1.078	1.077
2009	0.955	0.703	1.506	1.042	1.139	1.086	1.112
2010	0.863	0.653	1.394	1.117	1.164	1.139	1.112
2011	0.749	0.685	1.563	1.087	1.077	0.965	1.097
2012	0.759	0.630	1.221	1.045	1.032	0.978	0.882
2013	0.704	0.806	1.276	1.155	0.963	1.257	0.985
2014	0.627	0.715	1.238	1.058	1.047	1.294	1.132
2015	0.678	0.615	1.313	1.030	1.014	1.090	1.126
2016	1.255	0.685	1.319	0.976	1.164	1.073	1.421
2017	1.103	0.774	1.400	1.114	1.186	1.251	1.388
2018	0.969	0.920	1.615	1.237	1.180	1.196	1.355
2019	1.008	0.974	1.455	1.309	1.257	1.146	1.176
2020	1.078	1.069	1.508	1.451	1.326	1.113	1.210

Year	JEN	PCR	SAP	AND	TND	UED	AVG
2006	0.911	1.697	2.018	1.520	1.515	1.107	1.316
2007	0.896	1.932	2.119	1.298	1.481	1.180	1.326
2008	1.159	2.001	2.086	1.324	1.480	1.207	1.300
2009	1.074	1.758	1.945	1.107	1.285	1.231	1.226
2010	0.937	1.893	1.860	1.235	1.097	1.197	1.205
2011	0.966	1.879	1.529	1.204	1.240	0.971	1.155
2012	0.863	1.584	1.545	1.173	1.114	0.939	1.059
2013	0.887	1.475	1.441	1.052	1.411	1.063	1.113
2014	0.902	1.586	1.371	1.003	1.317	1.030	1.102
2015	0.906	1.550	1.378	0.976	1.636	1.111	1.109
2016	0.864	1.842	1.620	0.854	1.516	0.988	1.198
2017	0.839	1.782	1.390	1.038	1.171	1.089	1.194
2018	0.923	1.679	1.454	1.072	1.264	1.362	1.248
2019	0.884	1.756	1.394	1.049	1.429	1.371	1.247
2020	1.035	1.895	1.609	1.028	1.398	1.333	1.312

PCR ranked highest in terms of Opex MPFP levels in 2020 followed by SAP, CIT, and END. AND ranked lowest in terms of Opex MPFP levels in 2020, followed by JEN, AGD, EVO and

[10] As explained in Appendix A (section A1.4), growth rates are calculated using the log-difference method.

ERG. SAP and END improved their Opex MPFP ranking by two places in 2020, with SAP reaching 2nd place behind PCR. TND reduced in Opex PFP ranking by two places to become 5th ranked in 2020, whilst AND slipped by three places to become lowest ranked in 2020.

Turning to Capital MPFP, we can see from figure 3.3 and table 3.3 that there has generally been a declining trend in capital MPFP levels – a steadier trend and without the reversal seen in Opex MTFP movements. The steadier nature of the trend is to be expected given the largely sunk and long-lived nature of DNSP capital assets.

In 2020, four DNSPs improved their Capital MPFP levels, including ERG (0.6 per cent), SAP (1.3 per cent), AND (2.3 per cent) and UED (1.2 per cent). EVO's Capital MPFP in 2020 was unchanged from 2019. Out the eight DNSPs with reductions in capital MPFP levels in 2020, two of these had reductions of 3 per cent or more: CIT (–3.4 per cent) and ESS (–4.3 per cent). Others with Capital MPFP reductions included: AGD (–2.6 per cent); END (–2.5 per cent); TND (–1.6 per cent); ENX (–1.2 per cent); JEN (–1.1 per cent); and PCR (–0.9 per cent).

The highest ranked DNSPs in terms of capital productivity in 2020 were SAP followed by ERG, CIT and UED (in that order), while AGD ranked lowest followed by TND, EVO, AND and ESS. Comparing rankings in 2020 with 2006, five DNSPs increased their Capital PFP ranking by two places: EVO from 13th to 11th; CIT from 5th to 3rd; ENX from 8th to 6th; JEN from 9th to 7th; and UED from 6th to 4th. The DNSPs with substantial decreases in Capital MPFP ranking were: ESS (5 places from 4th to 9th); END (3 places from 2nd to 5th); and TND (from 10th to 12th).

Figure 3.3 **DNSP Multilateral Capital Partial Productivity Indexes, 2006–2020**

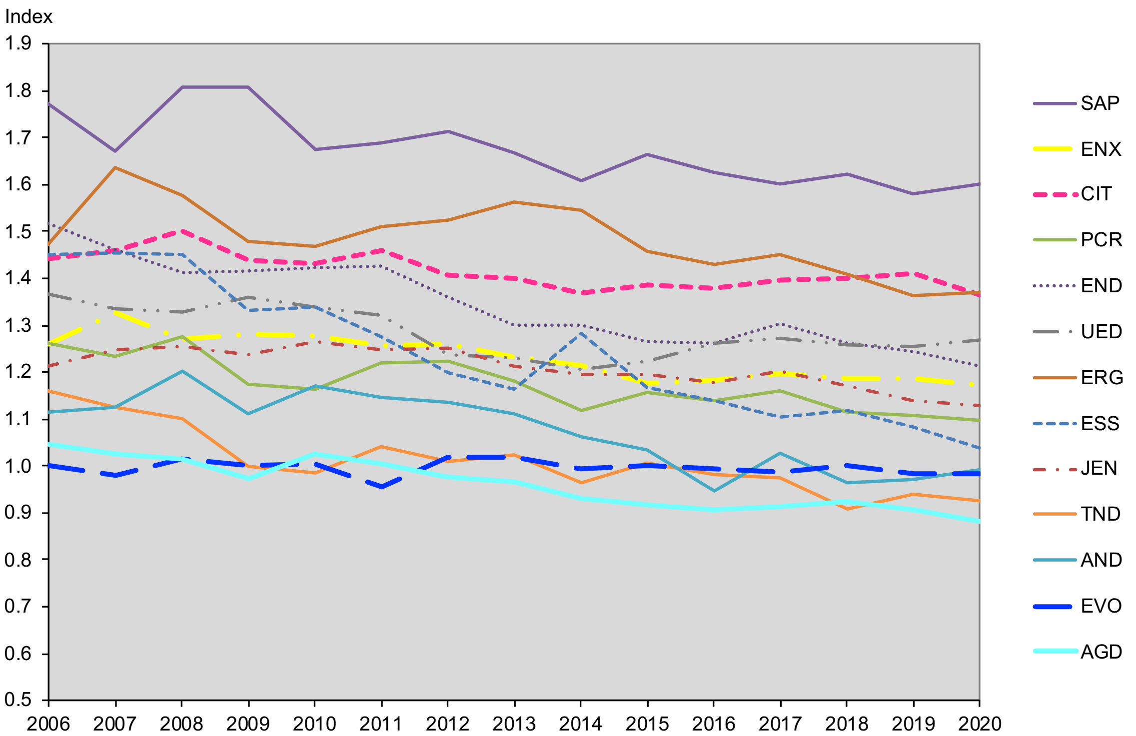


Table 3.3 **DNSP Multilateral Capital Partial Productivity Indexes, 2006–2020**

Year	EVO	AGD	CIT	END	ENX	ERG	ESS
2006	1.000	1.047	1.442	1.519	1.259	1.470	1.451
2007	0.980	1.024	1.459	1.461	1.326	1.638	1.453
2008	1.014	1.016	1.501	1.411	1.272	1.578	1.450
2009	1.001	0.973	1.439	1.416	1.282	1.479	1.332
2010	1.004	1.026	1.430	1.422	1.277	1.469	1.338
2011	0.954	1.003	1.461	1.427	1.257	1.511	1.275
2012	1.017	0.975	1.407	1.360	1.261	1.523	1.197
2013	1.019	0.966	1.398	1.302	1.233	1.562	1.162
2014	0.994	0.930	1.369	1.299	1.213	1.546	1.284
2015	1.000	0.916	1.385	1.265	1.176	1.458	1.169
2016	0.995	0.908	1.381	1.262	1.184	1.432	1.141
2017	0.987	0.914	1.397	1.304	1.197	1.450	1.106
2018	1.000	0.924	1.400	1.262	1.187	1.410	1.117
2019	0.982	0.906	1.410	1.244	1.188	1.363	1.082
2020	0.982	0.883	1.363	1.213	1.174	1.371	1.037

Year	JEN	PCR	SAP	AND	TND	UED	AVG
2006	1.211	1.262	1.773	1.114	1.159	1.365	1.313
2007	1.247	1.235	1.673	1.127	1.125	1.336	1.314
2008	1.255	1.275	1.809	1.203	1.102	1.329	1.324
2009	1.239	1.173	1.809	1.112	0.999	1.359	1.278
2010	1.266	1.165	1.673	1.172	0.985	1.340	1.274
2011	1.249	1.221	1.688	1.145	1.042	1.321	1.273
2012	1.253	1.223	1.712	1.136	1.008	1.238	1.255
2013	1.213	1.180	1.669	1.111	1.023	1.231	1.236
2014	1.194	1.117	1.607	1.063	0.963	1.207	1.214
2015	1.194	1.156	1.665	1.034	1.006	1.222	1.203
2016	1.177	1.139	1.624	0.947	0.983	1.263	1.187
2017	1.203	1.159	1.600	1.027	0.973	1.272	1.199
2018	1.170	1.114	1.621	0.964	0.909	1.257	1.180
2019	1.139	1.107	1.580	0.971	0.941	1.254	1.167
2020	1.127	1.097	1.602	0.993	0.926	1.269	1.157

3.2 Econometric opex cost function efficiency scores

While the Opex MPFP analysis presented in the preceding section 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. In this section we update the models in Economic Insights (2020a) to include data for 2019-20 (or 2020, as relevant) for the Australian and New Zealand DNSPs and 2019 data for the Ontario DNSPs.[11]

[11] Throughout this section and appendix C, when a sample is described as 2006 to 2020, it includes Ontario data

The econometric cost function models produce average opex efficiency scores for the period over which the models are estimated. Four three–output 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)[12]
- 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 monotonicity performance and the average opex efficiency scores for two periods – 2006 to 2020 and 2012 to 2020 – in this section. The corresponding regression results are presented in appendix C.

3.2.1 Monotonicity performance

Satisfying the property of monotonicity is an important requirement for estimated cost functions. This property requires that an increase in output can only be achieved with an increase in cost. Cobb-Douglas models assume constant output elasticities and if the estimated output coefficients are greater than zero then monotonicity is satisfied. For translog models, we need to check not only the sign of the estimated first–order coefficient for each output (which is the output's elasticity at the mean of the sample used for normalisation), but also the estimated output elasticity for each observation as the models assume varying output elasticities. In previous benchmarking studies (Economic Insights 2020a, 2019) the SFATLG model has produced some monotonicity violations with the full sample period, and both the SFATLG and LSETLG models produced monotonicity violations in the shorter sample period from 2012 onwards (Economic Insights 2020a:13, 34).

In this study, information on monotonicity violations for each model and for the longer and shorter sample periods is presented in appendix C. The average efficiency scores for each DNSP in table 3.4 are calculated after excluding either the SFATLG or LSETLG models (or both) if those models have violations for more than half their number of observations for that DNSP. However, as seen in Table 3.6 for the shorter period from 2012 to 2020, if a model has monotonicity violations for the great majority of DNSPs, then it will be disregarded altogether when calculating the average efficiency scores.

With the data sample from 2006 to 2020, the SFATLG model has no monotonicity violations for any of the Australian DNSPs. However, for the LSETLG model estimated over the same period, violations comprise a majority of observations for three DNSPs: CIT, JEN and UED. Hence, the results of the LSETLG model are excluded when calculating the average efficiency scores for these three DNSPs in table 3.4.

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for 2005 to 2019; and a sample described as 2012 to 2020 includes Ontario data for 2011 to 2019.

[12] The two least-squares models are estimate with panel-corrected standard errors.

For the shorter period from 2012 to 2020, the SFATLG and LSETLG models both present monotonicity violations in a majority of observations for most of the Australian DNSPs:

- For the LSETLG model these are: AGD, CIT, END, ENX, JEN, AND and UED.
- For the SFATLG model these are: AGD, CIT, END, ENX, ERG, JEN, PCR, AND and UED.

Almost all of these monotonicity violations related to the elasticity of opex with respect to customers, and both models estimate negative elasticities of opex with respect to customer numbers on average for Australian DNSPs. The monotonicity violations are so prevalent in the two TLG models in the period from 2012 that they have both been excluded for the purpose of calculating the average efficiencies for all Australian DNSPs, shown in table 3.6.

3.2.2 Summary results for the sample period 2006-2020

Opex efficiency scores for each of the 13 National Electricity Market (NEM) DNSPs across the 15-year period 2006 to 2020 for the four opex cost function models and, for comparison, opex MPFP are presented in figure 3.4 and table 3.4. Average opex efficiency scores across the five economic benchmarking methods, and average opex efficiency scores across the four econometric models only, are presented in figure 3.5. The opex efficiency scores in figures 3.4 and table 3.4 (i.e. related to the full sample period) fall into three distinct groups (using the average of five methods):

- Five DNSPs form a top performing group with average efficiency scores at or above 0.77. These are: PCR, CIT, SAP, TND and UED;
- Another six DNSPs form a middle performing group with average efficiency scores between 0.60 and 0.68. These are AND, ESS, JEN, ENX, END and ERG;
- The remaining two DNSPs – EVO and AGD – form a low performing group with average opex efficiency scores of less than 0.5.

These results are broadly similar to the corresponding results presented in Economic Insights (2020a:35–36) for the period up to 2019. If the average opex efficiency scores reported in that previous report are compared with those in Table 3.4 we can note:

- The arithmetic average of opex efficiencies for all 13 Australian DNSPs for 2006 to 2020 is 0.69, an increase of one basis point from the average of 0.68 for the previous study for the period 2006 to 2019;
- The DNSPs with changes in opex efficiency of less than one basis point include AGD, PCR, ENX, ESS and ERG;
- Those with *decreases* of opex efficiency of one basis point or more include: SAP and AND;
- Those with *increases* in opex efficiency of one basis point or more include EVO, CIT, END, JEN, TND and UED. JEN and UED had especially large increases of 5 and 4 basis points respectively.

Figure 3.4 **DNSP opex cost efficiency scores, 2006–2020**

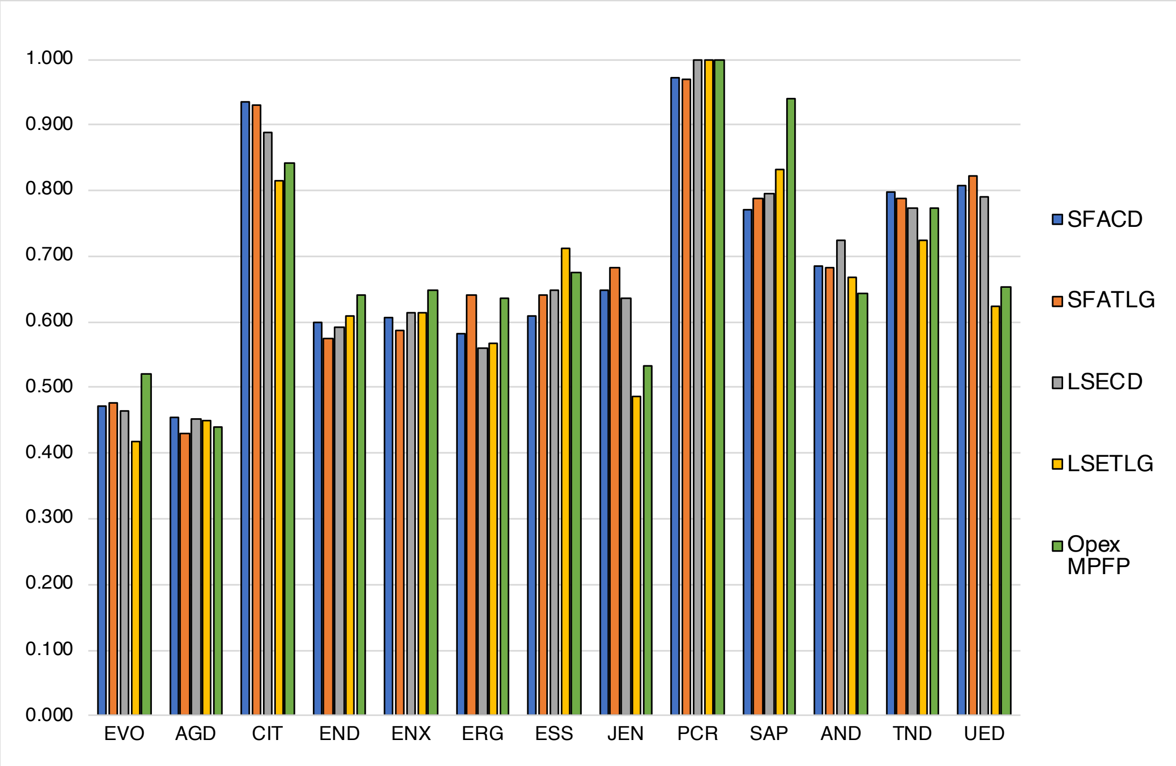


Table 3.4 **DNSP average opex cost efficiency scores, 2006–2020**

DNSP	*SFACD* (1)	*SFATLG* (2)	*LSECD* (3)	*LSETLG* (4)	*Opex MPFP* (5)	*Average of* (1)–(5)	*Average of* (1)–(4)
EVO	0.471	0.477	0.465	0.418	0.521	0.470	0.458
AGD	0.454	0.430	0.452	0.450	0.439	0.445	0.447
CIT	0.935	0.929	0.889	0.815	0.842	0.899*	0.918*
END	0.600	0.575	0.593	0.610	0.641	0.604	0.594
ENX	0.606	0.587	0.614	0.614	0.648	0.614	0.606
ERG	0.582	0.641	0.560	0.567	0.636	0.597	0.587
ESS	0.610	0.640	0.649	0.711	0.675	0.657	0.652
JEN	0.648	0.681	0.636	0.487	0.534	0.625*	0.655*
PCR	0.973	0.968	1.000	1.000	1.000	0.988	0.985
SAP	0.771	0.788	0.795	0.832	0.941	0.825	0.796
AND	0.685	0.681	0.725	0.667	0.644	0.681	0.690
TND	0.797	0.787	0.774	0.725	0.774	0.771	0.771
UED	0.808	0.823	0.791	0.623	0.653	0.769*	0.807*

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

Efficiency scores across the four econometric models are broadly similar. On average the LSETLG model produces slightly lower opex efficiencies than the other three econometric models. The Opex MPFP analysis also produces reasonably similar results to the econometric models. Figure 3.4 shows that the opex MPFP efficiency scores are generally consistent with the range of scores for the four cost function models but are somewhat higher than the opex cost function efficiency score range for EVO, END, ENX 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.

Figure 3.5 **DNSP opex cost efficiency scores, 2006–2020, average of models**

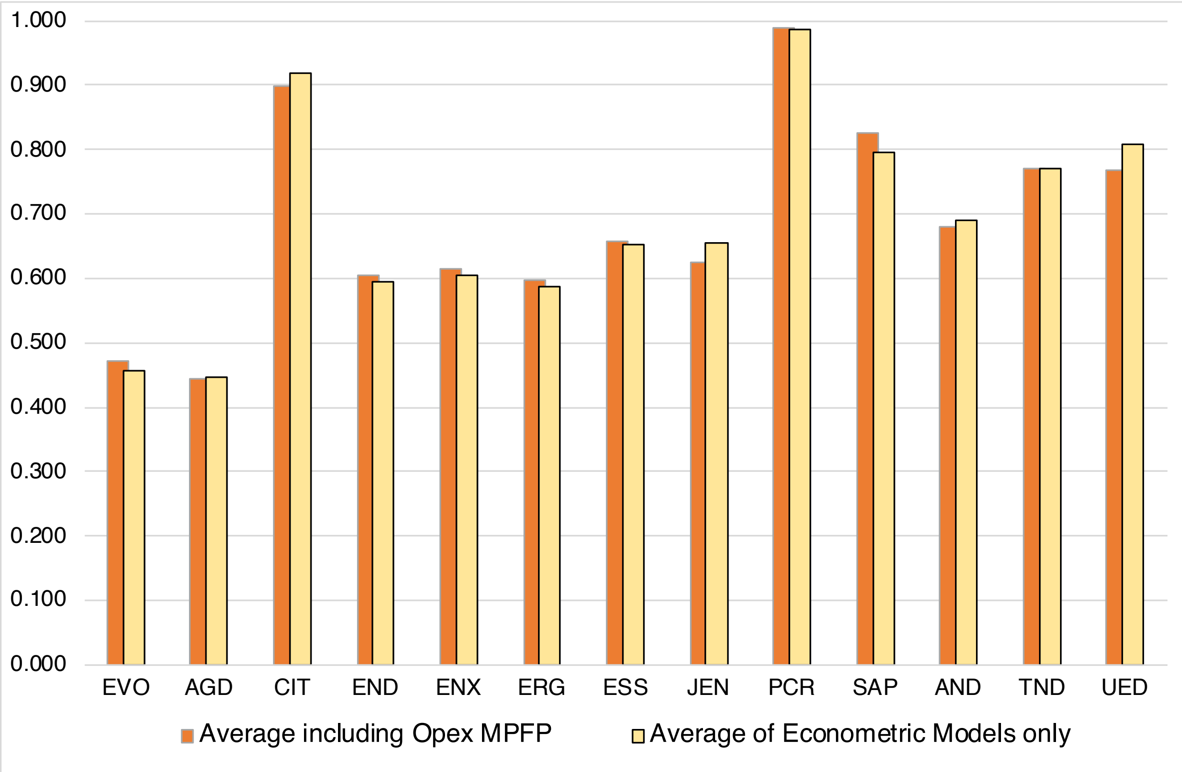


Table 3.5 presents a summary of the output elasticities estimated for the four econometric models. For the Cobb-Douglas specifications (SFACD and LSECD) the output elasticities are restricted to be the same for all observations. For the translog specifications (SFATLG and LSETLG) the output elasticities vary with different levels of the outputs and hence vary across all observations in the sample. Table 3.5 shows averages of these elasticities by country and over the full sample (i.e. including overseas DNSPs).

Table 3.5 **Average DNSP output elasticities by country and overall, 2006–2020**

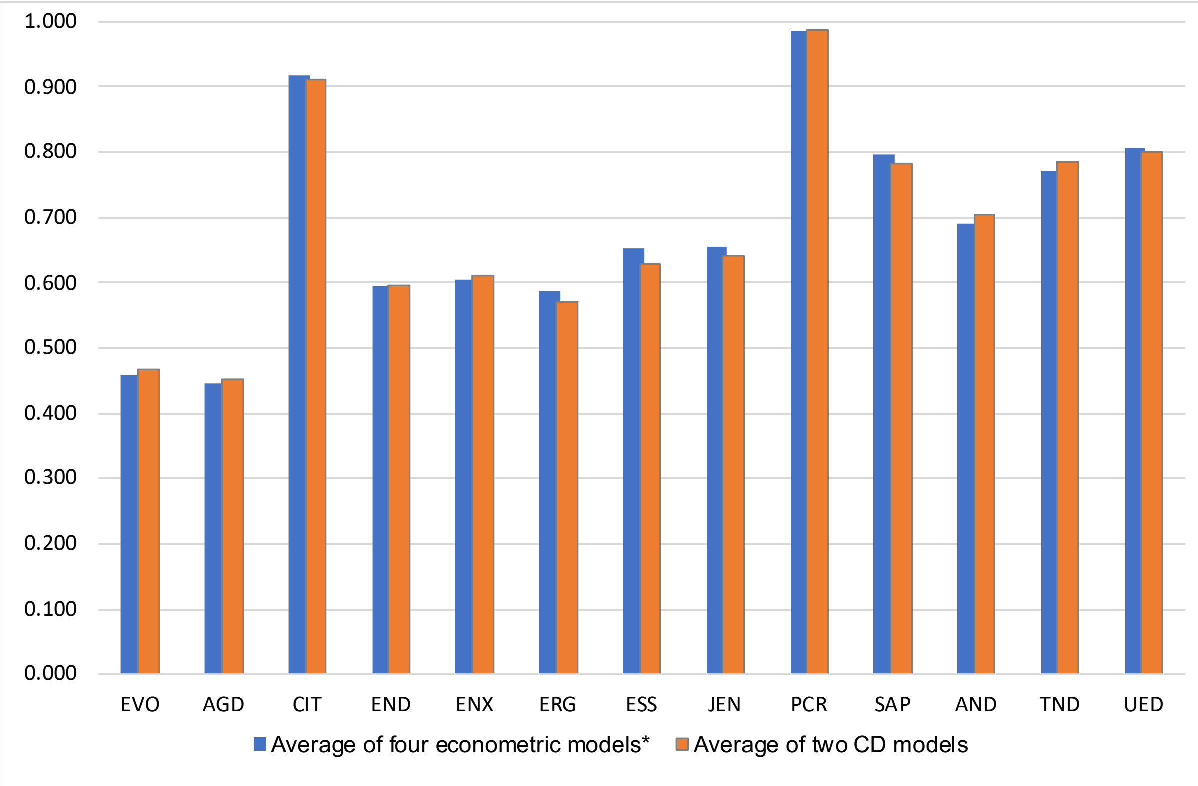
Sub-sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
	SFACD model			*LSECD model*		
All	0.440	0.118	0.411	0.569	0.154	0.254
	SFATLG model			*LSETLG model*		
Australia	0.478	0.149	0.331	0.291	0.254	0.503
New Zealand	0.414	0.118	0.475	0.593	0.214	0.119
Ontario	0.574	0.101	0.289	0.339	0.116	0.486
Full sample	0.510	0.115	0.350	0.401	0.170	0.386

For the SFATLG model, the output elasticities of the full sample and the Australian sub-sample are generally similar. The full sample's average customer numbers output elasticity is 0.51, which is slightly higher than for the Australian sub-sample (0.48). The Australian sub-sample's average circuit length output elasticity is 0.15, which is slightly higher than for the full sample at 0.12. And the Australian sub-sample's average RMD output elasticity of 0.33 is slightly smaller than for the full sample, at 0.35.

For the LSETLG model, there are some differences between the output elasticities of the full sample and those of the Australian sub-sample. The full sample average customer numbers output elasticity is 0.40, somewhat lower than that for the SFATLG model. For the Australian sub-sample, it is 0.29 which is lower than for the full sample (0.40). The Australian sub-sample average circuit length output elasticity of 0.25 is higher than for the full sample (at 0.17). And the Australian sub -sample's average RMD output elasticity of 0.50 is also higher than for the full sample (at 0.39).

The last column of Table 3.4 shows the average opex cost efficiency scores of each DNSP across four econometric models, with the exception that for CIT, JEN and UED an average of three models is used. The LSETLG is excluded for these DNSPs due to excessive monotonicity violations. Figure 3.6 compares the average efficiency scores using the four econometric models against the average efficiency scores obtained by averaging only the SFACD and LSECD models (i.e. the two Cobb-Douglas models). Table 3.6 shows that whether the average of four econometric models is used, or whether the average of only the Cobb-Douglas models is used, the resulting efficiency scores are broadly similar.

Figure 3.6 **DNSP opex cost efficiency scores, 2006–2020, average of four econometric models compared to the average of CD models**

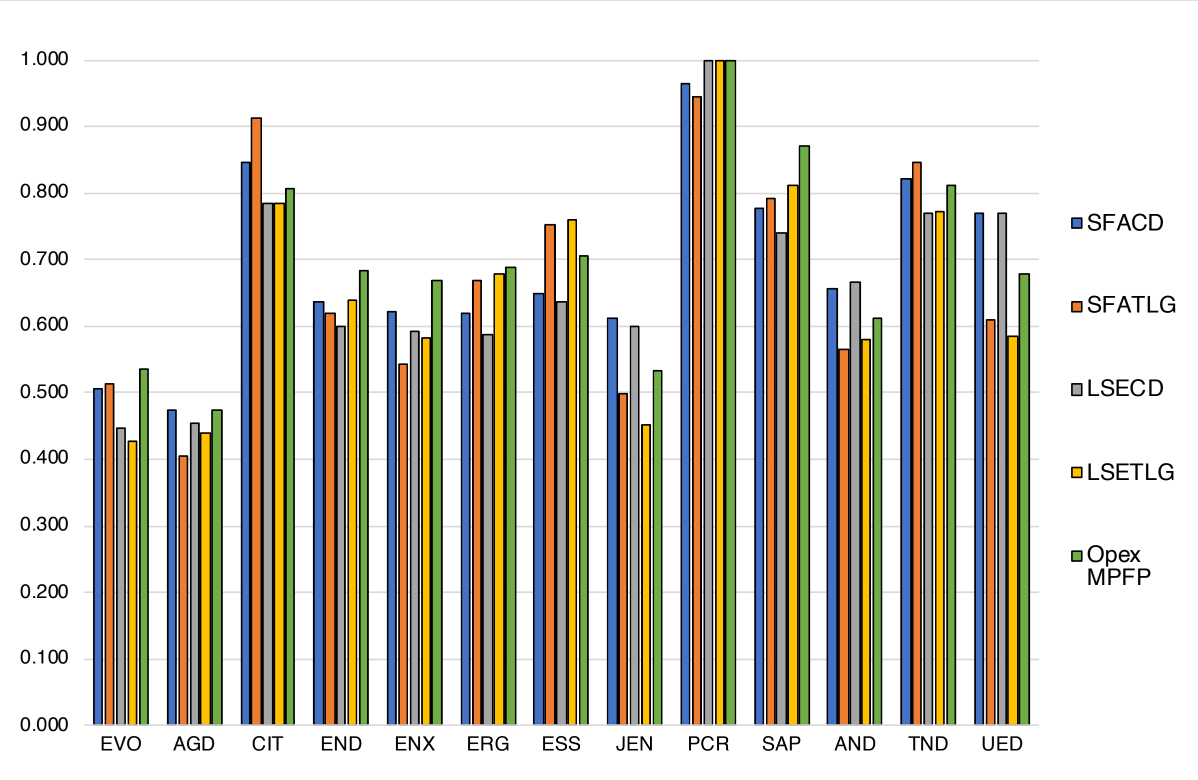


* Average of three models for CIT, JEN and UED.

3.2.3 Summary results for the sample period 2012-2020

We turn now to the opex efficiency scores from the more recent period, 2012 to 2020. Opex efficiency scores for each of the 13 NEM DNSPs across the 9-year period for the four opex cost function models and opex MPFP are presented in figure 3.7 and table 3.6. Average opex efficiency scores across the five economic benchmarking models for the 9-year period are presented in figure 3.8 and table 3.6.

Figure 3.7 **DNSP opex cost efficiency scores, 2012–2020**



From figures 3.7 and table 3.6 we see that there are still three reasonably distinct efficiency groups, and they are the same groupings of DNSPs as found for the full sample. There is also less than one basis point difference between the average efficiency score for DNSPs in the period 2012 to 2020 and that for the full period. There are, however, some notable differences in the efficiency scores for individual DNSPs.

Those with an average efficiency score in the period 2012 to 2020 which is higher than that in the full period by two basis points or more include: EVO, AGD, END, ERG and TND. Those with an average efficiency score in the shorter period which is lower than that in the full period by two basis points or more include: CIT, JEN, SAP, AND, and UED. CIT has a particularly large difference between the average efficiency score in the shorter and longer periods, being 9 basis points lower in the shorter period.

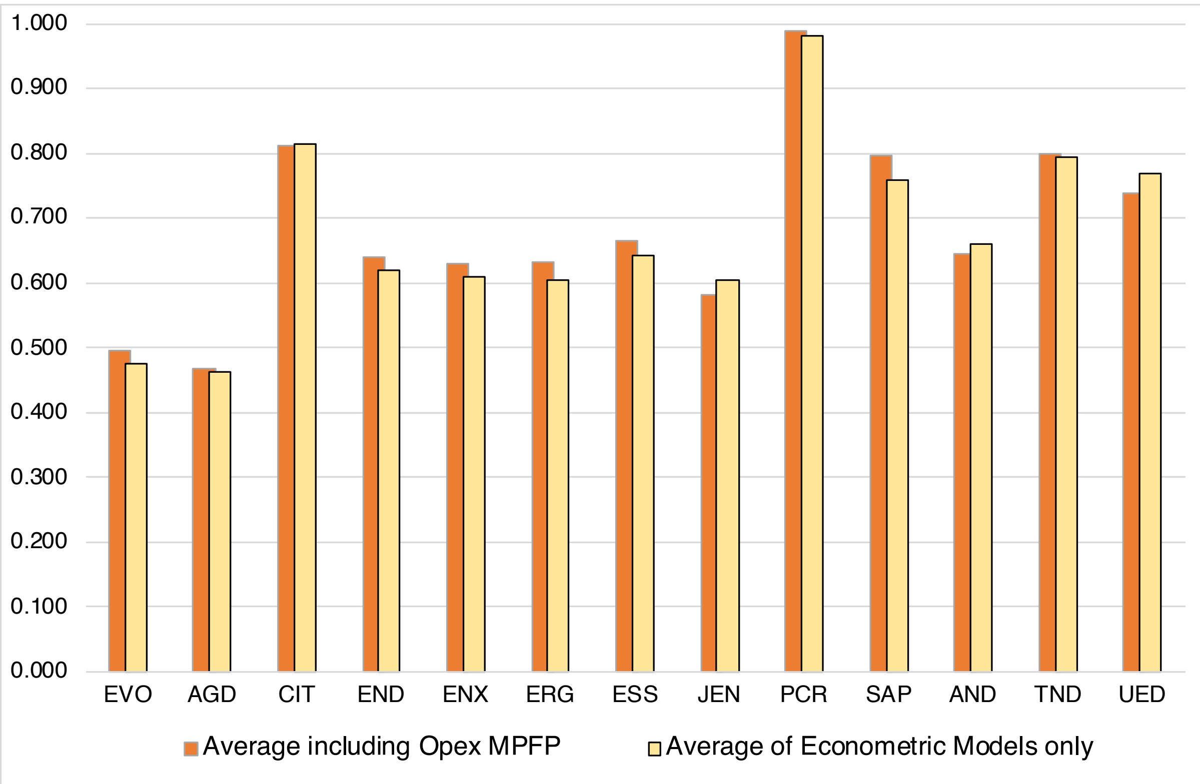
Turning to the comparison of model scores, the four opex cost function models generally produce broadly similar efficiency scores for the post-2012 period. Opex MPFP efficiency scores lie above the range of the cost function efficiency scores for EVO, END, ENX, ERG and SAP (mostly the same DNSPs as in the full sample). 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 part of the better performance of these DNSPs in terms of opex MPFP.

Table 3.6 **DNSP average opex cost efficiency scores, 2012–2020**

DNSP	*SFACD* (1)	*SFATLG* (2)	*LSECD* (3)	*LSETLG* (4)	*Opex MPFP* (5)	*Average of* (1), (3) & (5)	*Average of* (1) & (3)
EVO	0.505	0.513	0.446	0.427	0.535	0.496	0.476
AGD	0.473	0.404	0.455	0.439	0.475	0.467	0.464
CIT	0.845	0.914	0.784	0.783	0.808	0.812	0.815
END	0.638	0.620	0.600	0.639	0.684	0.641	0.619
ENX	0.623	0.543	0.593	0.583	0.670	0.629	0.608
ERG	0.620	0.669	0.587	0.678	0.688	0.632	0.604
ESS	0.649	0.752	0.637	0.759	0.706	0.664	0.643
JEN	0.611	0.499	0.600	0.452	0.534	0.582	0.605
PCR	0.963	0.944	1.000	1.000	1.000	0.988	0.982
SAP	0.776	0.791	0.740	0.811	0.872	0.796	0.758
AND	0.657	0.565	0.665	0.579	0.613	0.645	0.661
TND	0.821	0.847	0.770	0.773	0.810	0.800	0.795
UED	0.770	0.609	0.769	0.585	0.678	0.739	0.769

* Average excludes SFATLG and LSETLG as monotonicity requirement violated for a majority of DNSPs.

Figure 3.8 **DNSP opex cost efficiency scores, 2012–2020, average of models**



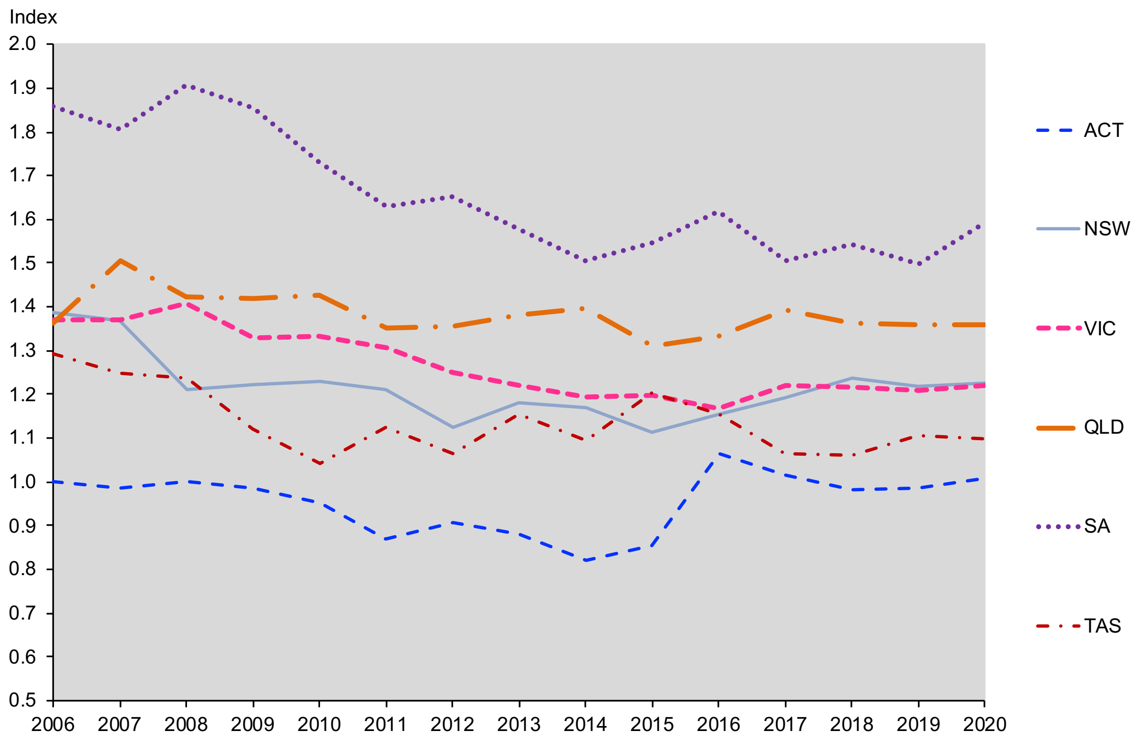
4 STATE–LEVEL DISTRIBUTION PRODUCTIVITY RESULTS

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 MTFP and opex MPFP indexes

The multifactor total factor productivity method can be used to calculate the comparative levels of TFP for electricity distribution in each state. Figure 4.1 and Table 4.1 show the MTFP of electricity distribution in each state and territory of the NEM for which RIN data is collected.

Figure 4.1 **State–level DNSP multilateral TFP indexes, 2006–2020**

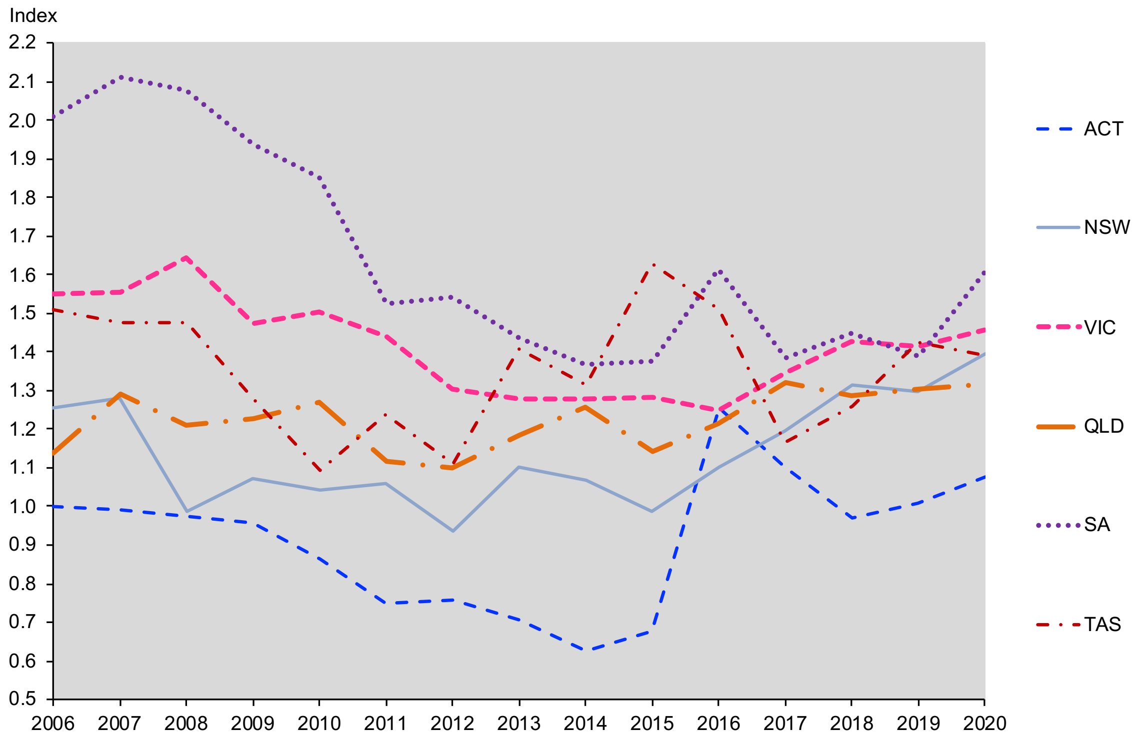


In 2020 South Australia (SA) had the highest MTFP level by a relatively wide margin followed by Queensland (QLD) being in second place. New South Wales (NSW) and Victoria (VIC) had similar levels of MTFP which were close to the average for the NEM states. Tasmania (TAS) was in fifth place in 2020, with the ACT having the lowest MTFP level. SA had the largest MTFP increase in 2020, by 6.2 per cent. The Australian Capital Territory (ACT), VIC and NSW had MTFP increases of 2.2 per cent, 1.0 per cent and 0.8 per cent in 2020. Only in TAS did MTFP decrease in 2020 by 0.7 per cent.

Table 4.1 **State–level DNSP multilateral TFP indexes, 2006–2020**

Year	ACT	NSW	VIC	QLD	SA	TAS
2006	1.000	1.388	1.371	1.362	1.859	1.295
2007	0.986	1.370	1.371	1.504	1.806	1.250
2008	1.001	1.213	1.406	1.424	1.906	1.238
2009	0.986	1.221	1.328	1.418	1.855	1.120
2010	0.951	1.228	1.332	1.428	1.731	1.044
2011	0.869	1.212	1.305	1.352	1.629	1.126
2012	0.907	1.126	1.251	1.354	1.651	1.065
2013	0.881	1.179	1.222	1.380	1.578	1.155
2014	0.820	1.170	1.193	1.397	1.507	1.096
2015	0.853	1.114	1.199	1.312	1.547	1.204
2016	1.063	1.156	1.168	1.334	1.619	1.155
2017	1.016	1.193	1.219	1.392	1.505	1.066
2018	0.984	1.236	1.215	1.364	1.545	1.061
2019	0.986	1.217	1.207	1.358	1.497	1.106
2020	1.008	1.227	1.220	1.359	1.593	1.097

Figure 4.2 **State-level DNSP multilateral Opex PFP indexes, 2006–2020**



Opex MPFP levels are shown in figure 4.2. SA's Opex MPFP grew by a large 14.4 per cent in 2020, leading to it overtake TAS and VIC in terms of the Opex MPFP level. NSW and the ACT increased Opex MPFP by 7.0 per cent and 6.7 per cent respectively in 2020. VIC and QLD increased Opex MPFP by 2.9 per cent and 1.0 per cent. TAS, which had the highest Opex MPFP in 2019, had a –2.2 per cent change in Opex MPFP in 2020, resulting in its 4th place behind SA, VIC and NSW in terms of Opex MPFP level in 2020.

Table 4.2 **State–level DNSP multilateral Opex PFP indexes, 2006–2020**

Year	ACT	NSW	VIC	QLD	SA	TAS
2006	1.000	1.254	1.549	1.138	2.011	1.510
2007	0.992	1.281	1.553	1.290	2.110	1.474
2008	0.976	0.986	1.643	1.211	2.080	1.474
2009	0.956	1.071	1.472	1.228	1.939	1.279
2010	0.863	1.043	1.506	1.271	1.853	1.093
2011	0.749	1.058	1.438	1.115	1.523	1.237
2012	0.759	0.935	1.305	1.098	1.541	1.110
2013	0.705	1.102	1.279	1.185	1.437	1.407
2014	0.627	1.069	1.277	1.258	1.366	1.312
2015	0.678	0.986	1.281	1.141	1.374	1.631
2016	1.255	1.101	1.249	1.214	1.615	1.511
2017	1.102	1.197	1.345	1.320	1.386	1.167
2018	0.969	1.315	1.428	1.289	1.450	1.260
2019	1.008	1.299	1.415	1.304	1.390	1.424
2020	1.078	1.394	1.457	1.317	1.605	1.393

4.2 Outputs, inputs and productivity change

This section presents output, input and MTFP indexes calculated for States and Territories separately (i.e. without grouping data for the purpose of calculating comparative productivity levels).

4.2.1 Australian Capital Territory (ACT)

The ACT is the smallest of the NEM jurisdictions and is served by one DNSP, Evoenergy. In 2020 ACT delivered 2,855 GWh to 207,237 customers over 5,610 circuit kilometres of lines and cables.

4.2.1.1 ACT productivity performance

The ACT's total output, total input and TFP indexes are presented in figure 4.3 and table 4.3. Over the 15–year period 2006 to 2020, ACT's average annual rate TFP change was zero. Between 2006 and 2012, TFP levels fell at an average annual rate of 1.9 per cent (more than 10 per cent in total). Then from 2012 to 2020, the ACT's TFP increased at an average annual rate of 1.5 per cent, restoring it to the 2006 level of TFP. In 2020, the ACT's TFP increased by 2.3 per cent.

Total output increased reasonably steadily over the period 2006 to 2020 at an average annual rate of 1.2 per cent, somewhat higher than the industry average rate of 0.9 per cent seen in chapter 3. Total input use increased at an average rate of 3.6 per cent per year up to 2012, a similar rate to the industry average in this period. Input use decreased at an average annual rate of 0.6 per cent between 2012 and 2020 (a greater decline than for the industry). The partial productivity indexes in table 5.3 show that swings in opex usage have been the main driver of the ACT's TFP changes.

Figure 4.3 **ACT output, input and TFP indexes, 2006–2020**

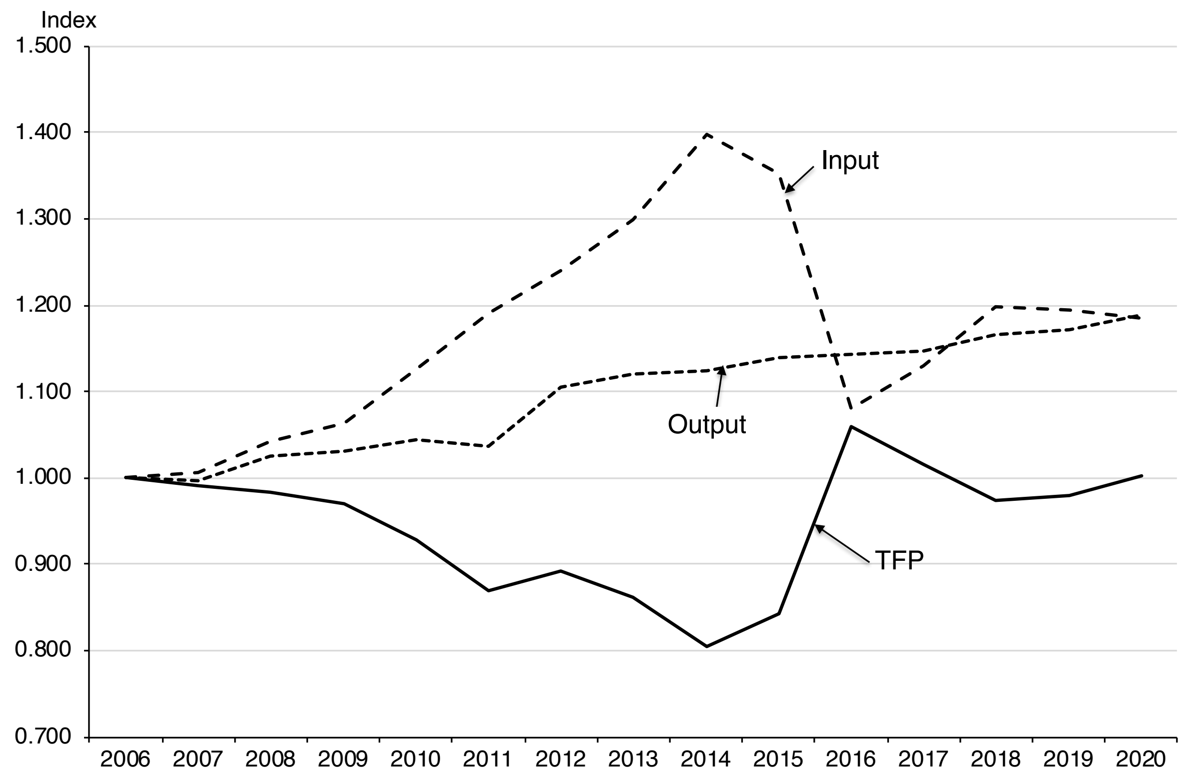


Table 4.3 **ACT output, input, TFP and PFP indexes, 2006–2020**

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	1.006	0.991	1.000	0.982
2008	1.025	1.043	0.983	0.966	0.994
2009	1.030	1.063	0.969	0.952	0.979
2010	1.045	1.126	0.929	0.856	0.977
2011	1.036	1.191	0.870	0.762	0.948
2012	1.105	1.239	0.892	0.761	0.992
2013	1.120	1.299	0.862	0.704	0.989
2014	1.125	1.398	0.804	0.625	0.974
2015	1.139	1.352	0.843	0.679	0.980
2016	1.143	1.080	1.059	1.257	0.975
2017	1.147	1.130	1.015	1.111	0.971
2018	1.166	1.198	0.973	0.969	0.977
2019	1.171	1.195	0.980	1.012	0.963
2020	1.189	1.185	1.003	1.082	0.962
Growth Rate 2006-2020	1.2%	1.2%	0.0%	0.6%	-0.3%
Growth Rate 2006-2012	1.7%	3.6%	-1.9%	-4.6%	-0.1%
Growth Rate 2012-2020	0.9%	-0.6%	1.5%	4.4%	-0.4%
Growth Rate 2020	1.5%	-0.8%	2.3%	6.7%	-0.1%

4.2.1.2 ACT output and input quantity changes

We graph the quantity indexes for the 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 customer numbers increased steadily over the period and was 34.1 per cent higher in 2020 than it was in 2006;
- Energy throughput increased slightly over the period 2006 to 2020, and in 2020 was 3.5 per cent higher than in 2006;
- the ACT's maximum demand did not exceed its 2006 level until 2012 and there was a further slight increase in ratcheted maximum demand (RMD) in 2015, so that in 2020, RMD was 14.9 per cent higher than in 2006;
- the ACT's circuit length output grew much more over the 15-year period than occurred for the industry overall and by 2020 was 20.7 per cent higher than it was in 2006 compared to an increase of 4.9 per cent for the industry.
- total customer minutes off-supply (CMOS) levels in the ACT are among the lowest of the 13 DNSPs in the NEM and for this reason CMOS receives only a negative 3.6 per cent of total revenue weight on average in ACT's total output.[13] In 2020, CMOS for the ACT was 33.4 per cent higher than in 2006.

Turning to the input side, we see from ACT's six individual inputs and total input shown in figure 4.5 that the quantity of opex increased rapidly between 2009 and 2014, being approximately 80 per cent higher in 2014 than it was in 2006. It then fell sharply in 2015 and 2016 (a combined decrease of almost 50 per cent) following the AER's price determination for ActewAGL (now Evoenergy), before increasing by a cumulative 20 per cent up to 2018 and falling by 10 per cent over 2019 and 2020. By 2020, opex was 9.9 per cent higher than in 2006. Opex has the largest average share in ACT's total costs at 39.0 per cent and so is an important driver of its total input quantity index.

Except for underground subtransmission cables, the ACT's other input component quantities increased at much more modest and steady rates over the period. Although underground subtransmission cables in 2020 were four times their level in 2020 – due to a doubling of line length and MVA capacity rating in 2014 – the total length is only 6 kilometres and this input has a negligible share in total cost. The quantity of transformer inputs, which have an average share of 26.5 per cent in ACT's total cost, increased by 29.0 per cent over the 15-year period.

[13] The weight of CMOS in the output index depends on both the value of customer reliability (VCR), which varies between DNSPs, and the quantity of CMOS, which also varies. Their product relative to total revenue determines the weight. As an indication of comparative levels of CMOS: EVO's average level of CMOS per customer is 33.7 minutes per year. Only Citipower's average CMOS per customer is lower (at 25.5 minutes per year). The average for the industry is 122.8 minutes per year.

Figure 4.4 **ACT output quantity indexes, 2006–2020**

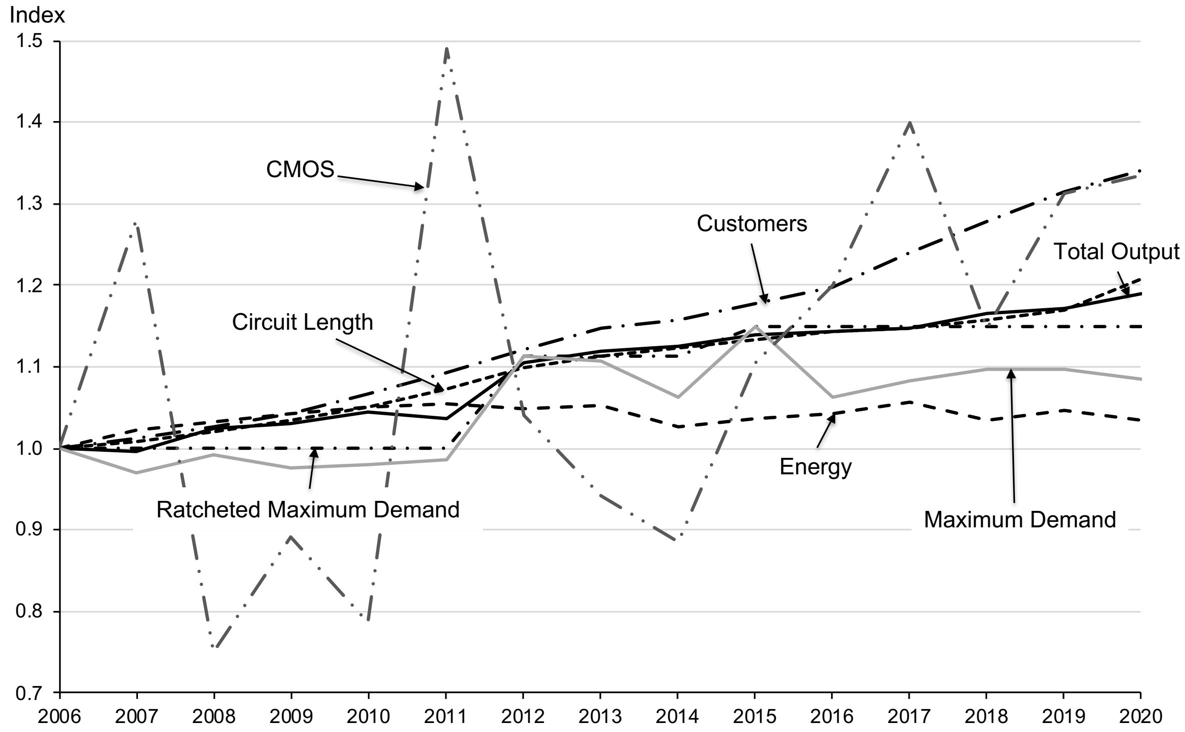
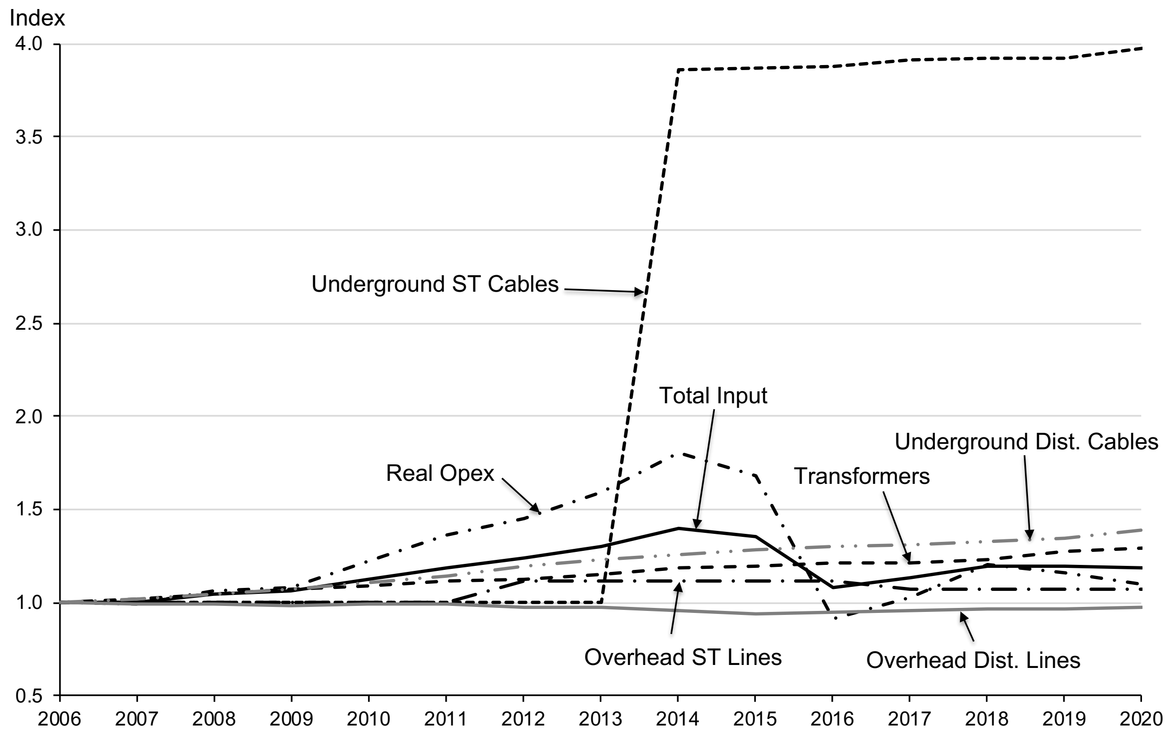


Figure 4.5 **ACT input quantity indexes, 2006–2020**



4.2.1.3 ACT output and input contributions to TFP change

Table 4.4 decomposes the ACT's TFP change into its constituent output and input contributions for the whole 15-year period and for the periods up to and after 2012. ACT's drivers of TFP change over the whole 15-year period are broadly similar to the industry as a whole. Customer numbers and circuit length and ratcheted maximum demand outputs contribute to TFP growth. For the ACT these three outputs contribute a combined 1.3 percentage points to TFP growth (which compares favourably into the industry average of 0.9 percentage points). Among the inputs to TFP growth for ACT from 2006 to 2020:

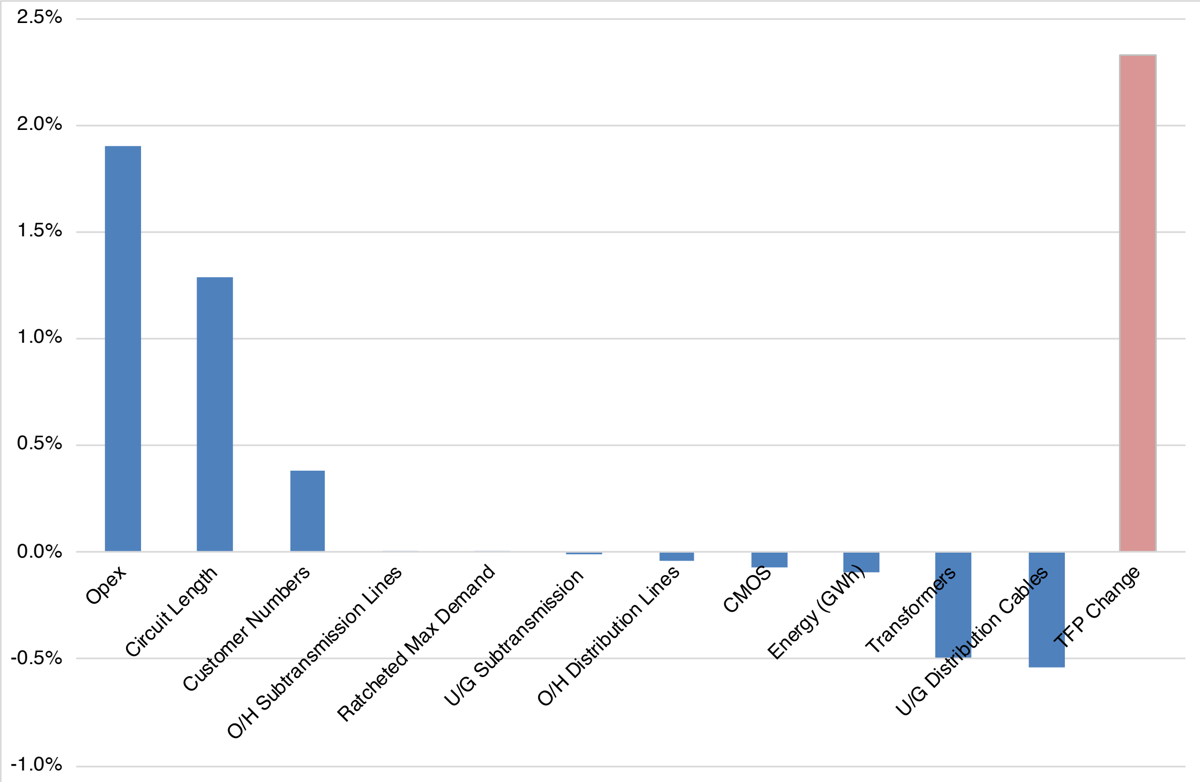
- transformer input use contributes –0.5 percentage points (compared to –0.7 for the industry);
- opex usage contributes –0.3 percentage points (similar to the industry);
- the four inputs for overhead and underground subtransmission and distribution lines together contributed –0.4 percentage points (compared to –0.6 for the industry).

Table 4.4 **ACT output and input percentage point contributions to average annual TFP change: 2006–2020, 2006–2012, 2012–2020, 2020**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2019 to 2020*
Energy (GWh)	0.02%	0.07%	-0.01%	-0.10%
Ratcheted Max Demand	0.35%	0.63%	0.14%	0.00%
Customer Numbers	0.40%	0.37%	0.43%	0.38%
Circuit Length	0.55%	0.64%	0.48%	1.29%
CMOS	-0.08%	-0.03%	-0.12%	-0.07%
Opex	-0.27%	-2.47%	1.38%	1.90%
O/H Subtransmission Lines	-0.02%	-0.06%	0.01%	0.00%
O/H Distribution Lines	0.03%	0.05%	0.01%	-0.04%
U/G Subtransmission Cables	-0.01%	0.00%	-0.01%	-0.01%
U/G Distribution Cables	-0.45%	-0.59%	-0.35%	-0.54%
Transformers	-0.49%	-0.50%	-0.48%	-0.49%
TFP Change	0.02%	-1.90%	1.47%	2.33%

Figure 4.6 shows the contributions to TFP growth from 2019 to 2020. The reduction in opex usage in 2020 contributed 1.9 percentage points to the ACT's TFP change of 2.3 per cent that year. Circuit length growth in 2020 contributed 1.3 percentage points to TFP growth while growth in transformer capacity contributed –0.5 percentage points. Underground distribution cables also contributed –0.5 percentage points.

Figure 4.6 **ACT output and input percentage point contributions to TFP change, 2020**



4.2.2 New South Wales (NSW)

NSW is the largest of the NEM jurisdictions and is served by three DNSPs: Ausgrid (AGD), Endeavour Energy (END) and Essential Energy (ESS). In 2020 the three NSW DNSPs delivered 53,896 GWh to 3.74 million customers over 273,705 circuit kilometres of lines and cables.

4.2.2.1 NSW DNSP productivity performance

NSW's total output, total input and TFP indexes are presented in figure 4.7 and table 4.5. Opex and capital partial productivity indexes are also presented in table 4.5. Over the 15-year period 2006 to 2020, the NSW DNSPs' TFP *decreased* at an average annual rate of 0.9 per cent. Although total output increased by an average annual rate of 0.5 per cent, total input use increased faster, at a rate of 1.4 per cent.

From 2006 and 2012, input use increased at an average rate of 4.4 per cent, which was followed by a moderate *reduction* of 0.9 per cent per annum in input use from 2012 to 2020. This shift in the trend of input use was the main determinant of the turnaround in the TFP trend in NSW from –3.6 per cent per annum between 2006 and 2012, to a positive TFP growth of 1.2 per cent per year from 2012 to 2020. The partial productivity indexes in table 4.5 also demonstrate that reduced opex usage was the main driver of the improved TFP performance after 2012.

Figure 4.7 **NSW DNSP output, input and TFP indexes, 2006–2020**

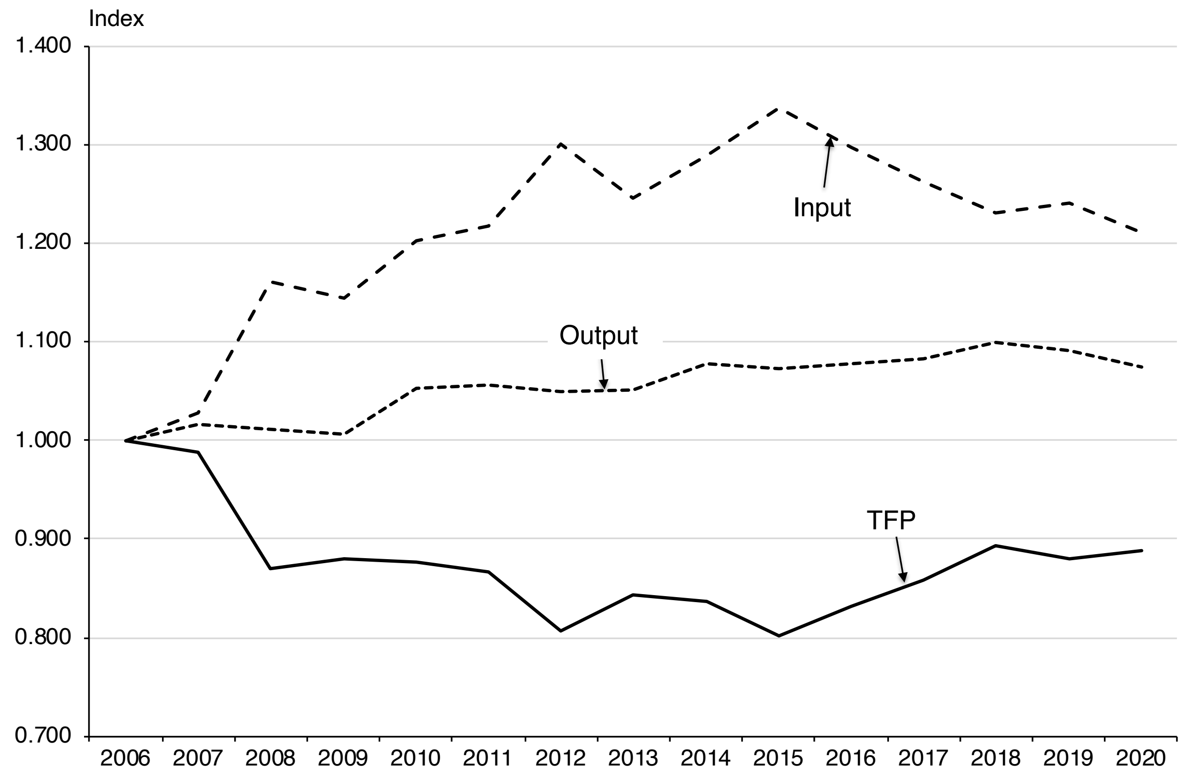


Table 4.5 **NSW DNSP output, input, TFP and PFP indexes, 2006–2020**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.017	1.028	0.989	1.020	0.968
2008	1.010	1.161	0.870	0.786	0.936
2009	1.007	1.144	0.880	0.853	0.899
2010	1.053	1.202	0.876	0.830	0.904
2011	1.055	1.217	0.867	0.842	0.881
2012	1.050	1.300	0.808	0.743	0.849
2013	1.052	1.246	0.844	0.876	0.824
2014	1.078	1.289	0.837	0.850	0.827
2015	1.072	1.336	0.802	0.784	0.813
2016	1.078	1.297	0.831	0.876	0.803
2017	1.082	1.262	0.858	0.952	0.806
2018	1.099	1.231	0.893	1.046	0.812
2019	1.091	1.241	0.879	1.034	0.798
2020	1.074	1.210	0.888	1.110	0.775
Growth Rate 2006-2020	0.5%	1.4%	-0.9%	0.7%	-1.8%
Growth Rate 2006-2012	0.8%	4.4%	-3.6%	-4.9%	-2.7%
Growth Rate 2012-2020	0.3%	-0.9%	1.2%	5.0%	-1.1%
Growth Rate 2020	-1.6%	-2.5%	0.9%	7.1%	-2.9%

4.2.2.2 NSW DNSP output and input quantity changes

Quantity indexes for the NSW DNSPs' five individual outputs are plotted in figure 4.8 and for the six individual inputs in figure 4.9. From figure 4.8 we see that NSW's output components showed a broadly similar pattern of change to the industry as a whole. From 2006 to 2020 the outputs of NSW DNSPs showed the following trends:

- customer numbers increased steadily over the period and were 17.0 per cent higher in 2020 than it was in 2006;
- energy throughput peaked in 2008 and has fallen since then. In 2020 it was 9.1 per cent below 2006;
- NSW's ratcheted maximum demand increased from 2006 until 2019 and by 2020 was 12.7 per cent higher than in 2006 (less than the increase for the industry as a whole);
- NSW's circuit length output grew by 1.1 per cent in total over the whole 15-year period (compared to an increase of 4.9 per cent for the industry);
- the total customer minutes off-supply (CMOS) performance in NSW is broadly similar to the industry as a whole, having increased by 5.1 per cent between 2006 and 2020. CMOS had an average weight of –14.3 per cent of NSW total revenue over the 15-year period.

Turning to the input side, we see from NSW's six individual inputs and total input in figure 4.9 that:

- the quantity of NSW's opex generally increased up to 2015 and decreased after that. Opex input increased at an average annual rate of 5.8 per cent from 2006 to 2012 and decreased at an average annual rate of 4.7 per cent from 2012 to 2020. In 2020, NSW opex input was 3.3 per cent below its 2006 level (compared to +9.2 per cent for the industry);
- NSW's underground distribution cables and transformers inputs also increased strongly in the sub-period to 2012, but continued to increase weakly over the period from 2012 to 2020. By 2020, these two inputs exceeded their 2006 levels by 54.1 per cent and 39.3 per cent respectively (broadly similar to 63.7 per cent and 40.8 per cent respectively for the industry);
- Overhead distribution lines and overhead subtransmission lines inputs for NSW also increased strongly over the period from 2006 to 2013, but had little or no growth after that. By 2020, these two inputs exceeded their 2006 levels by 34.6 per cent and 21.2 per cent respectively (compared to 11.7 per cent and 14.3 per cent respectively for the whole industry);
- NSW's underground subtransmission cables input in 2020 was 23.0 per cent above its 2006 level (compared to 38.3 per cent for the industry).

Figure 4.8 **NSW output quantity indexes, 2006–2020**

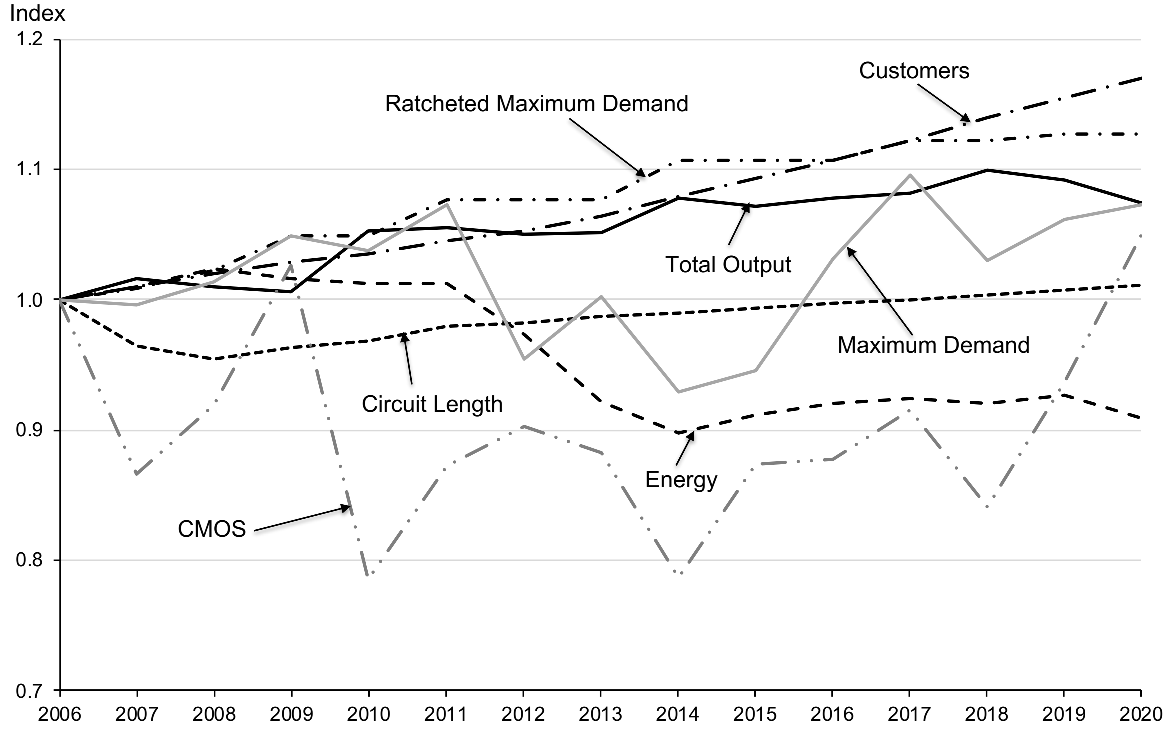
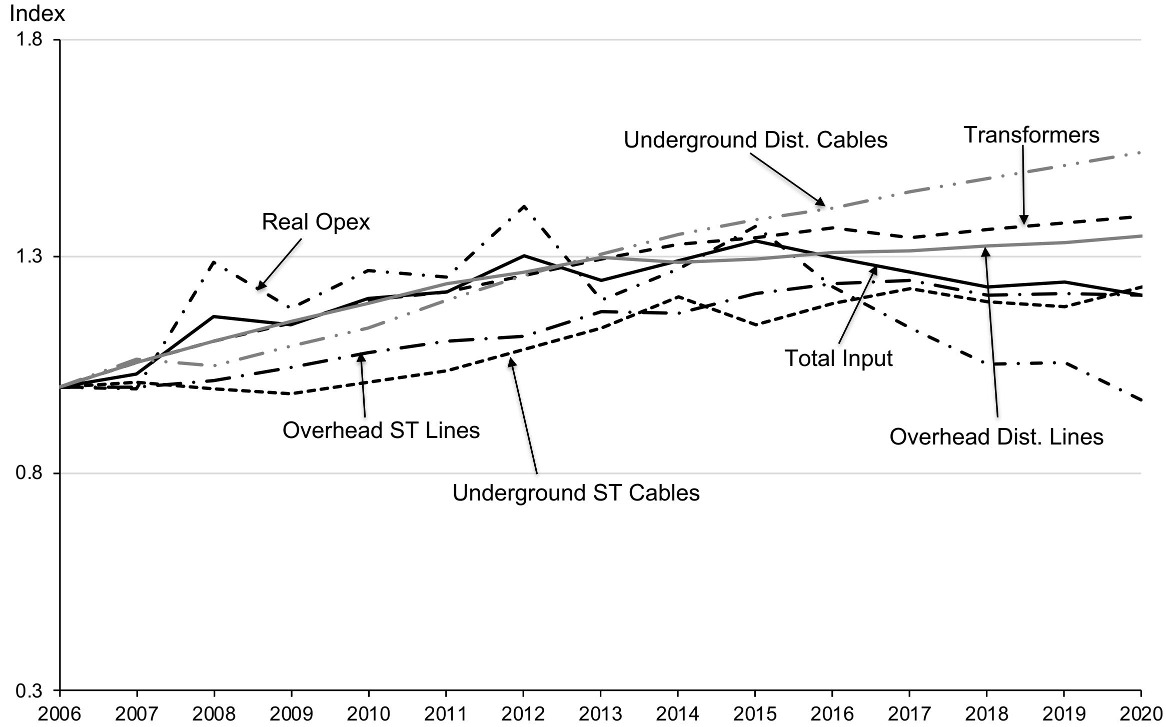


Figure 4.9 **NSW DNSP input quantity indexes, 2006–2020**



4.2.2.3 NSW output and input contributions to TFP change

Table 4.6 decomposes NSW's TFP change into its constituent output and input contributions for the whole 15-year period and for the periods up to and after 2012. NSW's drivers of TFP change for the 15-year period are broadly similar to the industry as a whole except that the major outputs (customer numbers, RMD and circuit length) contribute somewhat less due to their weaker growth in NSW, and opex makes a less negative contribution in NSW. Together, customer numbers, RMD and circuit length contribute 0.6 percentage points to TFP growth in NSW, compared to a 0.9 percentage points contribution of these three inputs to industry-wide TFP growth.

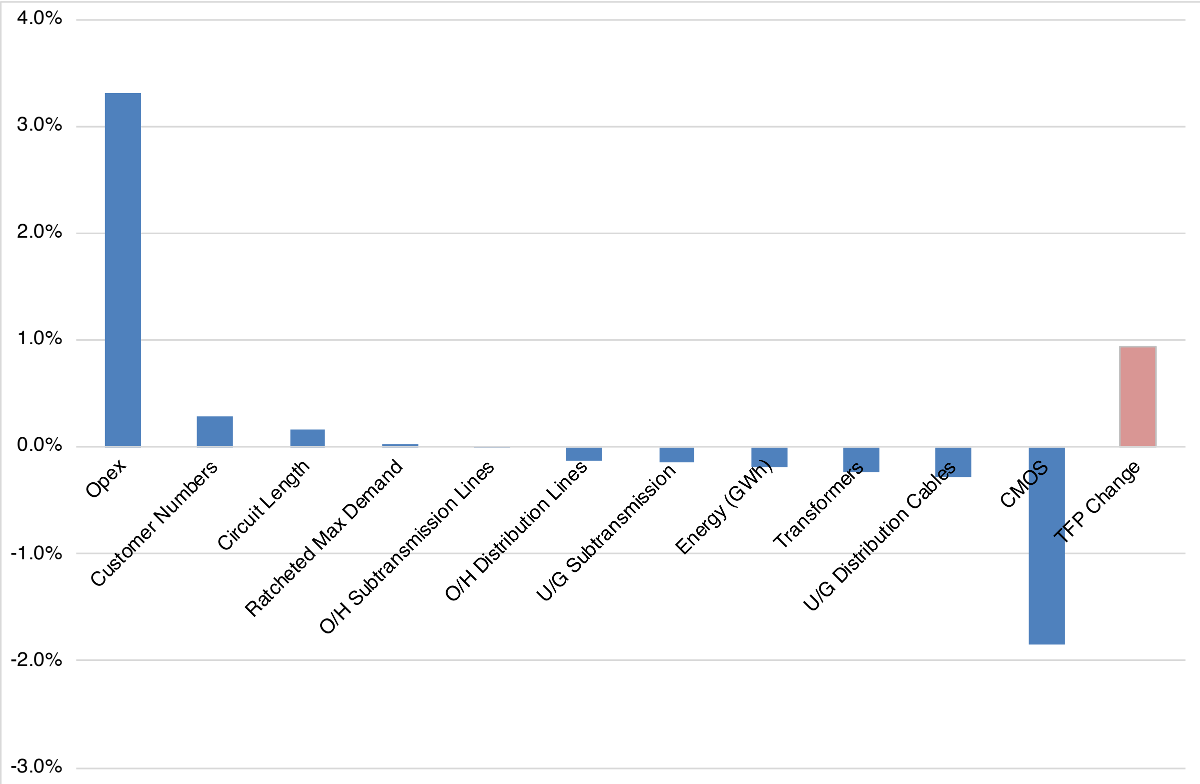
Opex has a marginal positive contribution of less than 0.1 percentage points to TFP growth in NSW over the period from 2006 to 2020 due to its decreased use as an input, whereas for the industry as a whole it contributed –0.3 percentage points to TFP growth (see Table 2.2). The other inputs, namely overhead and underground subtransmission and distribution lines, and transformers, all made similar contributions, broadly speaking, to TFP growth in NSW compared to the industry overall.

Table 4.6 **NSW output and input percentage point contributions to average annual TFP change: 2006–2020, 2006–2012, 2012–2020, 2020**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2019 to 2020*
Energy (GWh)	-0.07%	-0.05%	-0.08%	-0.19%
Ratcheted Max Demand	0.34%	0.49%	0.22%	0.02%
Customer Numbers	0.24%	0.19%	0.28%	0.29%
Circuit Length	0.03%	-0.13%	0.16%	0.16%
CMOS	-0.04%	0.31%	-0.30%	-1.86%
Opex	0.05%	-2.27%	1.79%	3.31%
O/H Subtransmission Lines	-0.07%	-0.09%	-0.05%	0.00%
O/H Distribution Lines	-0.24%	-0.41%	-0.10%	-0.14%
U/G Subtransmission Cables	-0.05%	-0.04%	-0.06%	-0.14%
U/G Distribution Cables	-0.36%	-0.43%	-0.31%	-0.28%
Transformers	-0.70%	-1.13%	-0.38%	-0.23%
TFP Change	-0.85%	-3.56%	1.18%	0.94%

Figure 4.10 shows the decomposition of TFP change from 2019 to 2020. The major positive contribution in 2020 came from a reduction in opex input; 3.3 percentage points. The major negative effect on TFP came from reduced reliability (i.e. increased CMOS); –1.9 percentage points. The contributions of all the other outputs and inputs in 2020 are individually small and on balance negative.

Figure 4.10 **NSW output and input percentage point contributions to TFP change, 2020**



4.2.3 Victoria (VIC)

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 2020 the Victorian DNSPs delivered 34,897 GWh to 3.06 million customers over 146,735 circuit kilometres of lines and cables.

4.2.3.1 Victorian DNSP productivity performance

Victoria's total output, total input and TFP indexes are presented in figure 4.11 and table 4.7. Opex and capital partial productivity indexes are also presented in table 4.7. Over the 15-year period 2006 to 2020, the Victorian DNSPs' TFP decreased at an average annual rate of 0.7 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 1.8 per cent. Victoria had slightly higher output growth and input growth, and a similar rate of TFP decline, compared to the industry as a whole. The TFP average annual change for Victorian DNSPs for the period up to 2012, at –1.5 per cent per annum, was more strongly negative than the marginal rate of decline of –0.2 per cent per annum for the period 2012 to 2020. The partial productivity indexes in table 5.7 confirm that better Opex PFP performance was the main driver of the improved TFP performance after 2012.

Figure 4.11 **VIC DNSP output, input and TFP indexes, 2006–2020**

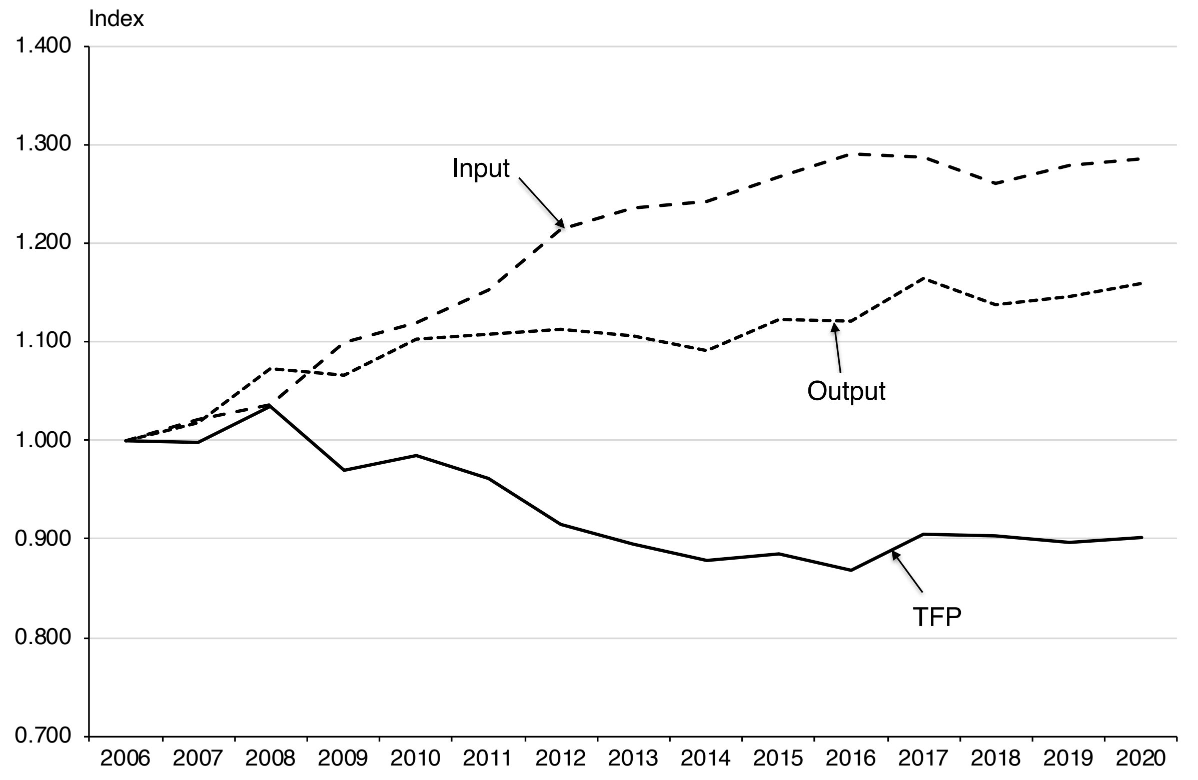


Table 4.7 **VIC DNSP output, input and TFP and PFP indexes, 2006–2020**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.019	1.021	0.998	1.003	0.994
2008	1.073	1.037	1.035	1.059	1.022
2009	1.067	1.100	0.970	0.952	0.982
2010	1.103	1.119	0.985	0.972	0.994
2011	1.107	1.152	0.961	0.928	0.982
2012	1.112	1.215	0.915	0.842	0.967
2013	1.107	1.236	0.896	0.825	0.944
2014	1.091	1.242	0.878	0.825	0.914
2015	1.122	1.268	0.885	0.825	0.926
2016	1.121	1.290	0.869	0.805	0.911
2017	1.163	1.286	0.904	0.864	0.930
2018	1.138	1.260	0.903	0.920	0.893
2019	1.146	1.279	0.896	0.912	0.888
2020	1.159	1.286	0.902	0.938	0.881
Growth Rate 2006-2020	1.1%	1.8%	-0.7%	-0.5%	-0.9%
Growth Rate 2006-2012	1.8%	3.2%	-1.5%	-2.9%	-0.6%
Growth Rate 2012-2020	0.5%	0.7%	-0.2%	1.4%	-1.2%
Growth Rate 2020	1.2%	0.5%	0.6%	2.8%	-0.8%

4.2.3.2 Victorian DNSP output and input quantity changes

The quantity indexes for the Victorian DNSPs' individual outputs (with the exception of CMOS) are plotted in figure 4.12, and the six individual inputs are plotted in figure 4.13. From figure 4.12 we see that:

- customer numbers increased steadily over the period and were 23.7 per cent higher in 2020 than it was in 2006 (similar to the industry as a whole);
- energy throughput peaked in 2010 and has fallen slowly since then. In 2020 it was 2.3 per cent below 2006 (similar to the industry as a whole);
- VIC's RMD increased up to 2009, and again from 2014 onwards. By 2020, RMD was 26.1 per cent higher than in 2006 (more than the 18.1 per cent increase for the industry as a whole);
- VIC's circuit length output grew by 8.5 per cent in total over the whole 15-year period (compared to an increase of 4.9 per cent for the industry);
- VIC's total customer minutes off-supply (CMOS) increased by 16.4 per cent in total between 2006 and 2020 (compared to a 0.8 per cent decrease for the industry over the same period). CMOS receives an average weight of –12.8 per cent of total revenue for Victoria.

In 2020, customers, circuit length and RMD all increased (RMD by 1.9 per cent) and CMOS decreased by 2.5 per cent (which contributed positively to total output growth). Only the energy output decreased in 2020, by 3.9 per cent. VIC total outputs increased in 2020 by 1.2 per cent.

Victoria's six individual inputs and total input are shown figure 4.13:

- VIC opex increased by 34.2 per cent in total up to 2013, and remained at a similar level up to 2017, after which it declined, so that in 2020 opex was 23.6 percent above its 2006 level (compared to 9.2 per cent for the industry). Opex has the largest average share in VIC total costs at 38.3 per cent and so is an important driver of its total input quantity index;
- VIC's underground distribution and subtransmission cables increased at a much higher rate that for the industry overall. By 2020, these two inputs exceeded their 2006 levels by 86.2 per cent and 81.0 per cent respectively (compared to 63.7 and 38.3 per cent for the industry).
- transformers inputs in VIC increased at a similar rate to the industry as a whole. By 2020, VIC transformer inputs exceeded their 2006 levels by 40.3 per cent;
- Overhead subtransmission and distribution lines in VIC increased much less than for the industry. By 2020, overhead subtransmission and distribution inputs exceeded their 2006 levels by 9.1 per cent and 1.5 per cent respectively (compared to 14.3 per cent and 11.7 per cent respectively for the whole industry).

Figure 4.12 **VIC output quantity indexes, 2006–2020**

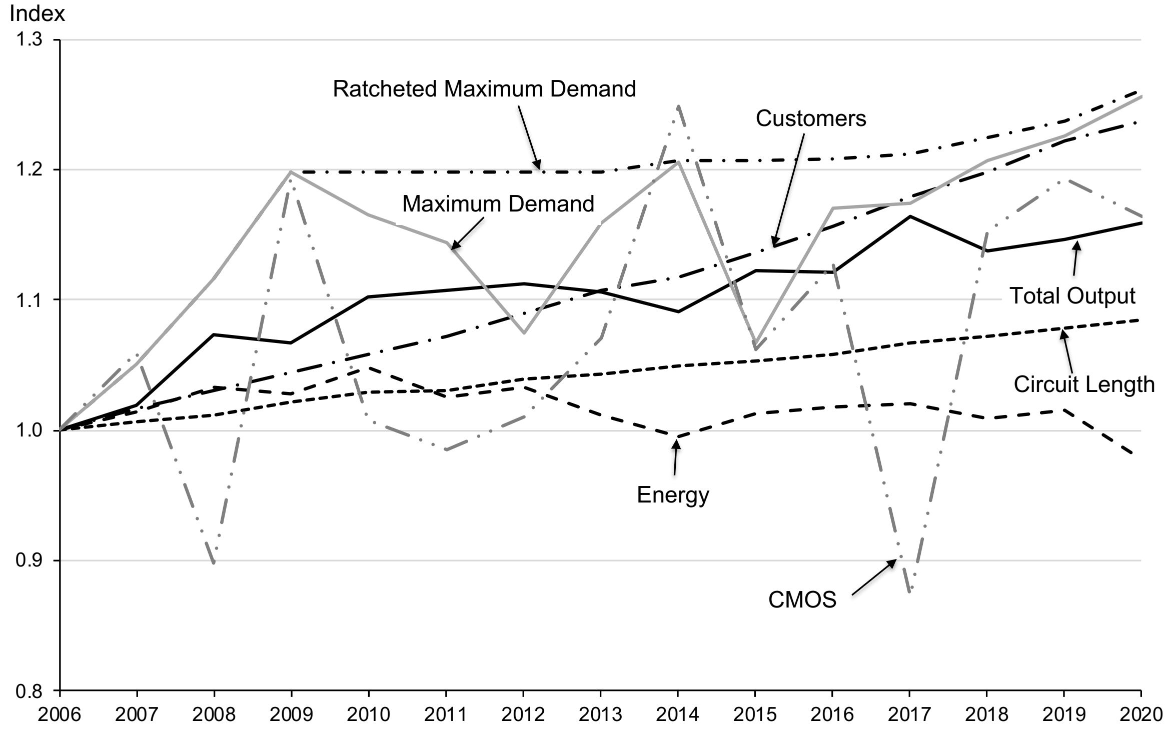
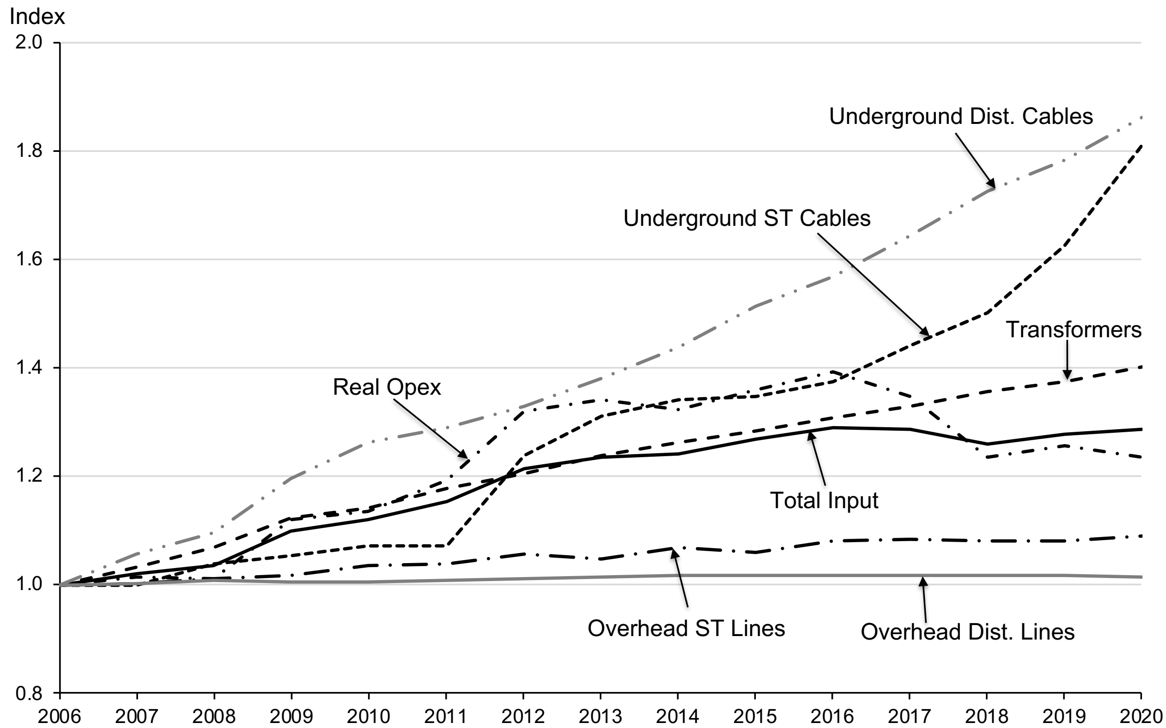


Figure 4.13 **VIC DNSP input quantity indexes, 2006–2020**



4.2.3.3 Victorian output and input contributions to TFP change

Table 4.8 decomposes VIC's TFP change into its constituent output and input contributions for the 15-year period and for the periods up to and after 2012. Victoria's drivers of TFP change for the 2006 to 2020 period are broadly similar to the industry as a whole except that CMOS makes a negative contribution to TFP growth for VIC as opposed to a marginal positive contribution for the industry. Opex also makes a more negative contribution over the 15-year period for VIC at –0.6 per cent compared to –0.3 per cent for the industry. However, transformer inputs make a less negative contribution to Victoria's TFP at –0.5 percentage points compared to –0.7 for the industry.

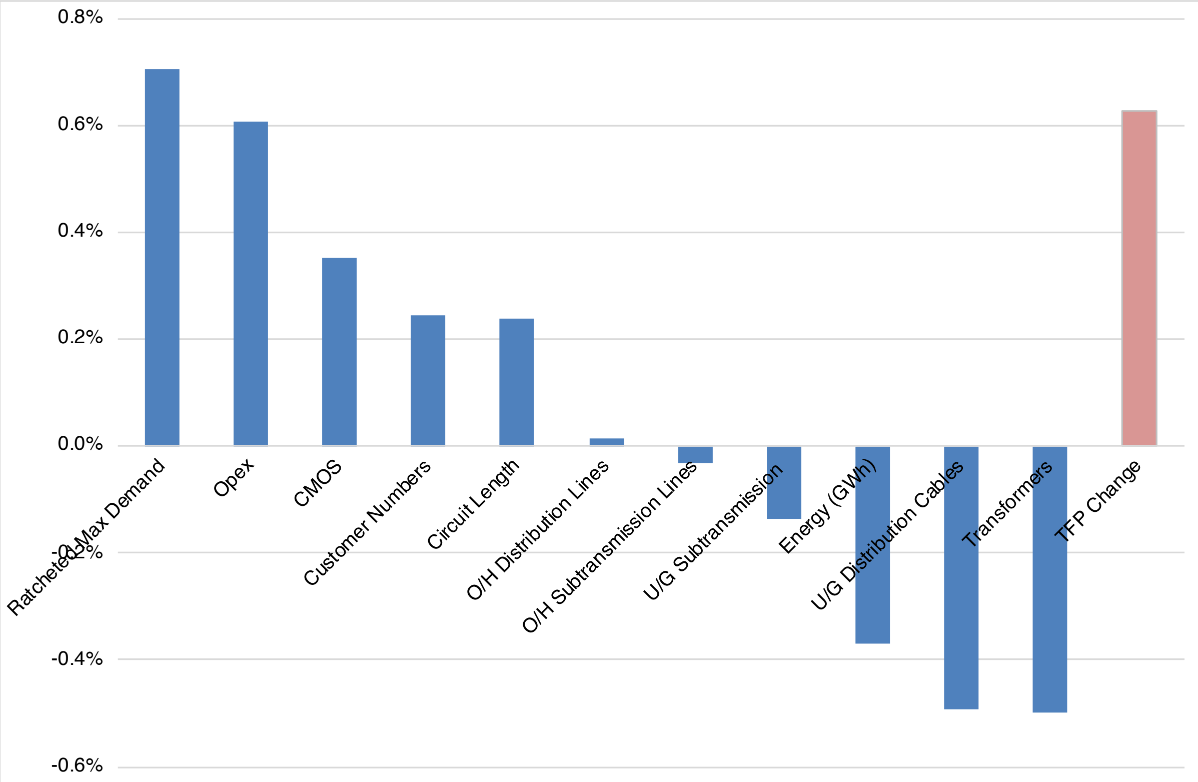
Table 4.8 **VIC output and input percentage point contributions to average annual TFP change: 2006–2020, 2006–2012, 2012–2020, 2020**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2019 to 2020*
Energy (GWh)	-0.02%	0.05%	-0.07%	-0.37%
Ratcheted Max Demand	0.63%	1.16%	0.24%	0.70%
Customer Numbers	0.32%	0.30%	0.33%	0.24%
Circuit Length	0.26%	0.28%	0.24%	0.24%
CMOS	-0.13%	-0.03%	-0.21%	0.35%
Opex	-0.59%	-1.83%	0.34%	0.61%
O/H Subtransmission Lines	-0.02%	-0.03%	-0.02%	-0.03%
O/H Distribution Lines	-0.02%	-0.04%	-0.01%	0.01%
U/G Subtransmission Cables	-0.05%	-0.05%	-0.06%	-0.14%
U/G Distribution Cables	-0.56%	-0.61%	-0.53%	-0.49%
Transformers	-0.54%	-0.69%	-0.43%	-0.50%
TFP Change	-0.74%	-1.47%	-0.19%	0.63%

Consistent with the industry as a whole, the biggest source of change in TFP between the sub-periods 2006 to 2012 and 2012 to 2020 is in opex input use. Growth in use of opex inputs in the former period contributed –1.8 percentage points to TFP growth, and reduction in opex inputs in the second half contributed 0.3 percentage points to TFP growth.

In figure 4.14 we see that most of the outputs contributed to TFP growth from 2019 to 2020. RMD, customer numbers and circuit length outputs contributed 0.7, 0.2 and 0.2 percentage points respectively. Improvement in CMOS also contributed 0.4 percentage points in 2020 TFP growth. On the other hand, reductions in energy use contributed –0.4 percentage points to the 2020 TFP growth of VIC DNSPs. On the input side, Opex savings was a major contributor to TFP growth, contributing 0.6 percentage points. This was more than offset by the negative contributions of other inputs such as transformer and underground distribution cables inputs which each contributed –0.5 percentage points. Victorian TFP growth in 2020 was 0.6 per cent compared to industry TFP growth of 1.2 per cent in the same year.

Figure 4.14 **VIC output and input percentage point contributions to TFP change, 2020**



4.2.4 Queensland (QLD)

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 2020 the two Queensland DNSPs delivered 34,708 GWh to 2.28 million customers over 208,086 circuit kilometres of lines and cables.

4.2.4.1 Queensland DNSP productivity performance

QLD's total output, total input and TFP indexes are presented in figure 4.15 and table 4.9. Opex and capital partial productivity indexes are also presented in table 4.9. Over the 15-year period 2006 to 2020, the average annual rate of TFP change of QLD DNSPs was zero per cent. QLD's total output increased by an average annual rate of 1.6 per cent over the same period, which is considerably higher than the output growth rates in NSW and VIC (and higher than for the industry as a whole). QLD's total input use also increased at an average annual rate of 1.6 per cent (mid-way between the rate of growth in NSW and VIC, and the same as that for the industry). QLD's static TFP between 2006 and 2020 compares favourably to the industry average TFP *decline* (–0.6 per cent per year).

Figure 4.15 **Qld DNSP output, input and TFP indexes, 2006–2020**

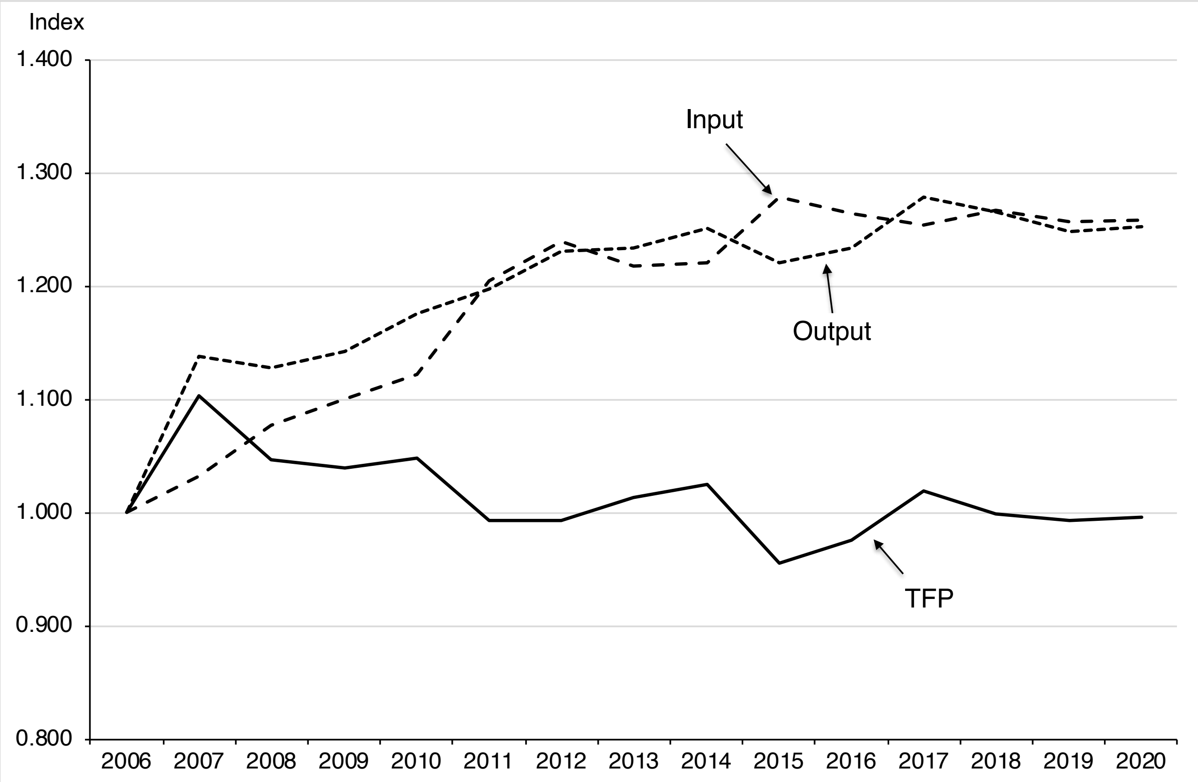


Table 4.9 **Qld DNSP output, input, TFP and PFP indexes, 2006–2020**

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	1.138	1.032	1.102	1.132	1.085
2008	1.128	1.077	1.047	1.062	1.040
2009	1.143	1.100	1.039	1.076	1.017
2010	1.176	1.122	1.049	1.113	1.013
2011	1.197	1.205	0.994	0.973	1.004
2012	1.231	1.239	0.993	0.958	1.008
2013	1.234	1.218	1.013	1.032	1.000
2014	1.251	1.220	1.025	1.095	0.985
2015	1.221	1.278	0.955	0.989	0.935
2016	1.233	1.263	0.976	1.056	0.932
2017	1.278	1.254	1.019	1.150	0.951
2018	1.266	1.267	0.999	1.123	0.933
2019	1.248	1.256	0.993	1.136	0.920
2020	1.253	1.258	0.996	1.147	0.916
Growth Rate 2006-2020	1.6%	1.6%	0.0%	1.0%	-0.6%
Growth Rate 2006-2012	3.5%	3.6%	-0.1%	-0.7%	0.1%
Growth Rate 2012-2020	0.2%	0.2%	0.0%	2.3%	-1.2%
Growth Rate 2020	0.3%	0.1%	0.2%	1.0%	-0.4%

Comparing the period before 2012 to that after 2012, it can be seen that TFP change of QLD DNSPs averaged –0.1 per cent per annum from 2006 to 2012, and was zero after 2012. The partial productivity indexes in table 4.9 show that deterioration in Opex PFP were the main influence on weakness of TFP growth before 2012, and improvement in Opex PFP after 2012 primarily explains the slightly improved TFP performance. The effect of improved Opex PFP was largely offset by deterioration of Capital PFP after 2012.

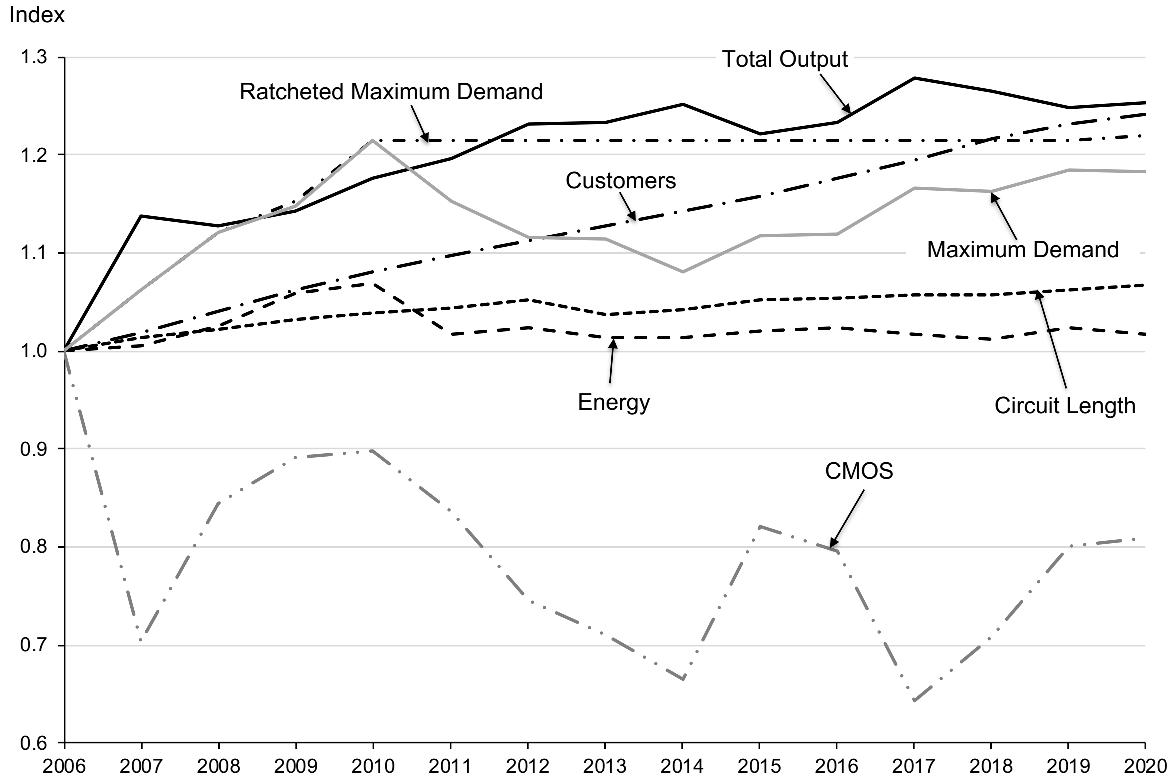
4.2.4.2 Queensland DNSP output and input quantity changes

Quantity indexes for the Queensland DNSPs' individual outputs are plotted in figure 4.16, and their six individual inputs are plotted in figure 4.17. From figure 4.16 we see that QLD'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.

- energy throughput showed less of a downturn after 2010 than for some other states and the industry overall, likely reflecting the effects of the mining boom. In 2020 it was 1.8 per cent above 2006;
- customer numbers increased steadily over the period and were 24.1 per cent higher in 2020 than it was in 2006;
- QLD's RMD increased mainly in the period up to 2010, thereafter having only an incremental increase in 2020. By 2020 was 22.0 per cent higher than in 2006 (slightly higher than the 18.1 per cent for the industry as a whole);
- QLD's circuit length output grew by 6.7 per cent in total over the whole 15-year period (slightly above the increase of 4.9 per cent for the industry);
- total customer minutes off-supply (CMOS) has generally followed a similar pattern to that of the industry although, despite a marked increase in 2015, it has declined more overall. In total it *decreased* by 19.2 per cent between 2006 and 2020 (compared to a 0.8 per cent decrease for the industry over the same period).

The circuit length and RMD outputs receive an average weight of 86.5 per cent of total revenue in forming the total output index for QLD, but in figure 4.16 the total output index often lies above these two output indexes and also above the customer numbers output index. This is due to the CMOS index which would generally lie above the other output indexes when it enters the formation of total output as a negative output (i.e. the reduction in CMOS over the period makes a positive contribution to total output). In Queensland CMOS receives an average weight of –18.6 per cent of total revenue in forming the total output index.

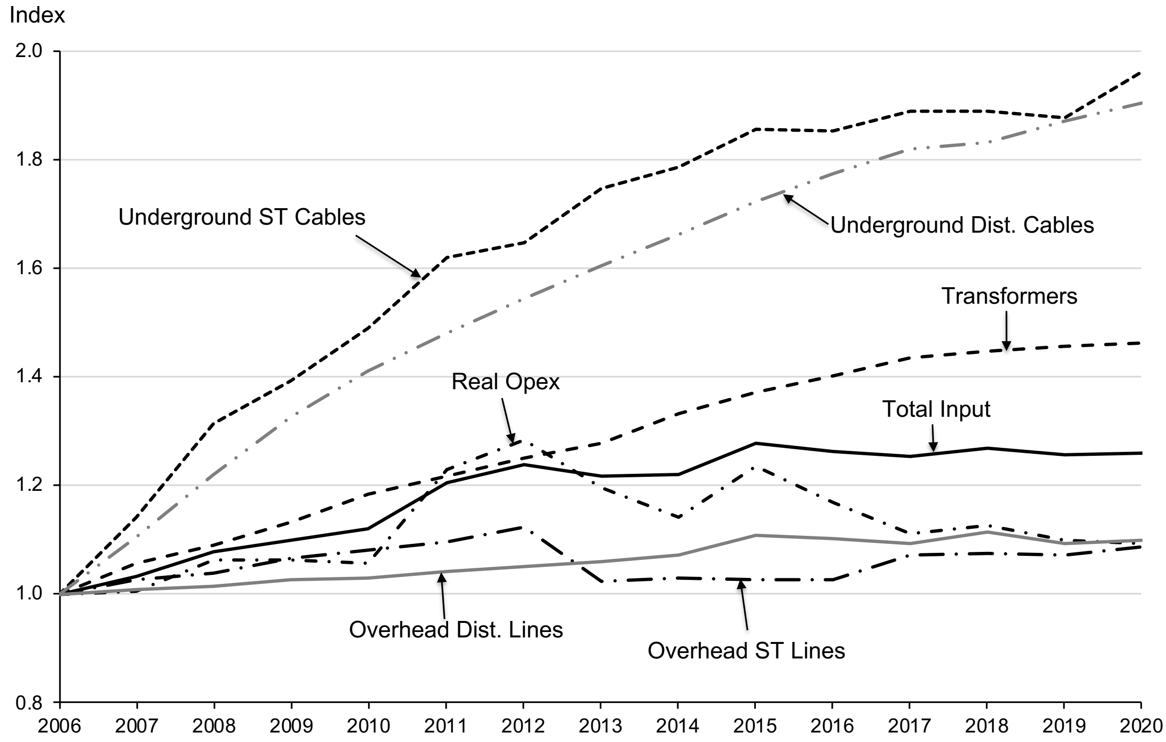
Figure 4.16 **Qld output quantity indexes, 2006–2020**



From figure 4.17, showing QLD's six individual inputs and total input, it can be seen when comparing to figure 2.3 that the quantity of Queensland's underground distribution and subtransmission cables and transformers inputs have increased more than for the industry as a whole (see figure 2.4), while its opex increased at the same rate as the industry, and overhead lines increased somewhat less than for the industry. The increase in underground cables starts from a small base and reflects Queensland's higher rate of customer numbers growth:

- QLD opex increased by 28.5 per cent in total up to 2012 (which was less than the corresponding increases for the industry of 36.4 per cent and for NSW of 41.3 per cent). It declined after 2013, so that in 2020 opex was 9.2 percent above its 2006 level (the same as for the industry). Opex has the largest average share in QLD's total costs at 36.0 per cent and so is an important driver of its total input quantity index;
- transformers inputs in QLD increased by 46.3 per cent between 2006 and 2020 (compared to 40.8 per cent for the industry over the same period);
- Overhead subtransmission and distribution lines in QLD increased by 8.8 per cent and 9.9 per cent in total, respectively, between 2006 and 2020 (compared to 14.3 per cent and 11.7 per cent respectively for the whole industry).

Figure 4.17 **Qld DNSP input quantity indexes, 2006–2020**



4.2.4.3 Queensland output and input contributions to TFP change

Table 4.10 decomposes QLD's TFP change into the contributions of individual outputs and inputs for the whole 15-year period and for the periods up to and after 2012. QLD's drivers of TFP change for the period 2006 to 2020 are broadly similar to the industry as a whole except that CMOS makes a larger positive contribution of 0.4 percentage points (compared to less than 0.1 for the industry). With regard to the contributions of other outputs and inputs:

- Customers, RMD and circuit length outputs together contributed 1.2 percentage points to QLD's average TFP growth for the period 2006 to 2020 (compared to 0.9 for the whole industry);
- Opex input contributed –0.2 percentage points to QLD's TFP rate of growth, which is similar to the industry as a whole;
- Overhead and underground sub-transmission and distribution lines together contributed –0.6 percentage points to QLD TFP growth (similar to the industry);
- transformers input contributed –0.8 percentage points to QLD's TFP rate of growth (compared to –0.7 for the industry).

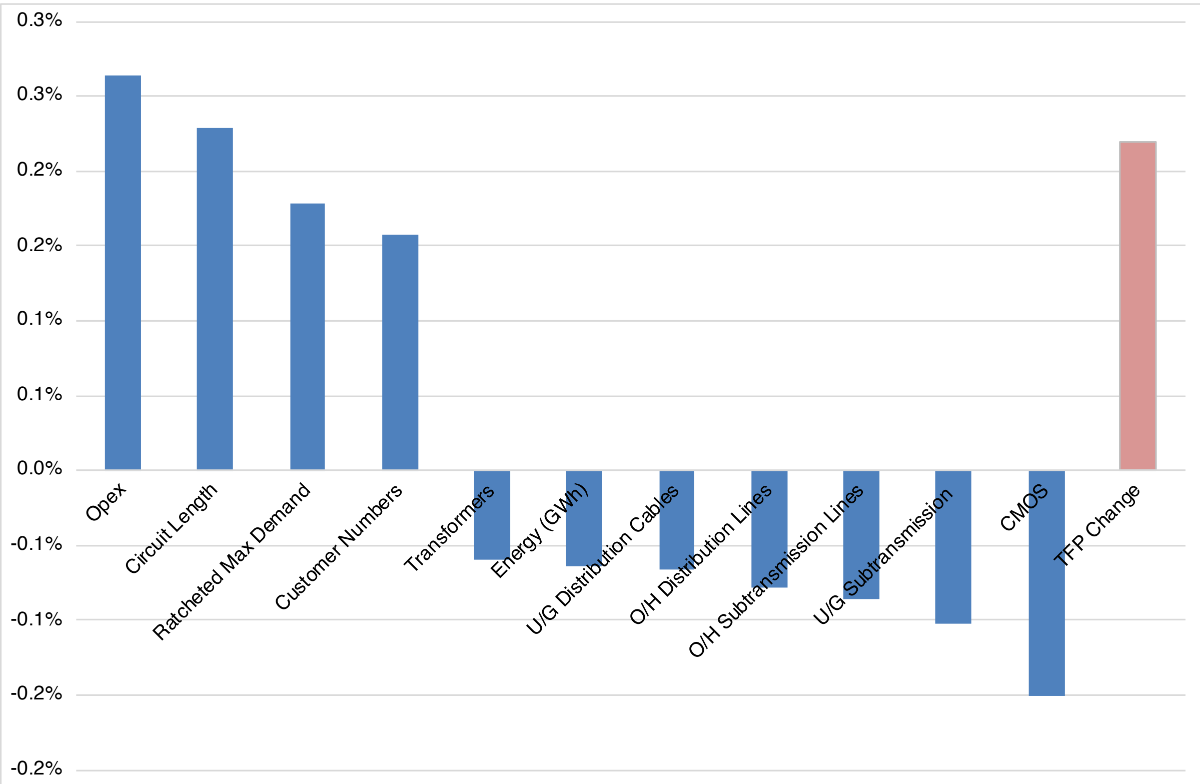
Figure 4.18 shows the contributions of individual outputs and inputs to QLD's TFP growth from 2019 to 2020 of 0.2 per cent. Among outputs, positive contributions were made by RMD, customer numbers and circuit length and negative contributions were made by energy and

CMOS. Among inputs, opex made a significant positive contribution, while all other inputs made negative contributions (because they increased).

Table 4.10 **Qld output and input percentage point contributions to average annual TFP change: 2006–2020, 2006–2012, 2012–2020, 2020**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2019 to 2020*
Energy (GWh)	0.01%	0.04%	-0.01%	-0.06%
Ratcheted Max Demand	0.60%	1.37%	0.02%	0.18%
Customer Numbers	0.35%	0.42%	0.30%	0.16%
Circuit Length	0.22%	0.41%	0.08%	0.23%
CMOS	0.42%	1.22%	-0.18%	-0.15%
Opex	-0.23%	-1.48%	0.70%	0.26%
O/H Subtransmission Lines	-0.04%	-0.13%	0.03%	-0.09%
O/H Distribution Lines	-0.12%	-0.14%	-0.10%	-0.08%
U/G Subtransmission Cables	-0.12%	-0.20%	-0.05%	-0.10%
U/G Distribution Cables	-0.33%	-0.53%	-0.19%	-0.07%
Transformers	-0.80%	-1.10%	-0.58%	-0.06%
TFP Change	-0.03%	-0.11%	0.03%	0.22%

Figure 4.18 **Qld output and input percentage point contributions to TFP change, 2020**



4.2.5 South Australia (SA)

SA is the fourth largest NEM jurisdiction (by customer numbers) and is served by one DNSP, SA Power Networks (SAP). In 2020 it delivered 9,850 GWh to 914,603 customers over 89,416 circuit kilometres of lines and cables.

4.2.5.1 SA DNSP productivity performance

SA's total output, total input and TFP indexes are presented in figure 4.19 and table 4.11. Opex and capital partial productivity indexes are also presented in table 4.11. Over the 15-year period 2006 to 2020, the SA DNSP's TFP *decreased* at an average annual rate of 1.2 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 2.1 per cent. SA thus had similar output growth and higher input growth compared to the industry as whole, and hence a larger rate of decrease in TFP.

Input use increased at a faster rate in the period 2006 to 2012 at an annual rate of 3.9 per cent, and increased more slowly from 2012 to 2020 at an annual average rate of 0.7 per cent. This pattern is typical of the industry as a whole. Although the rate of output growth was also lower after 2012 (0.2 per cent per year compared to an average rate of 1.8 per cent before 2012), the flattening of the input index led to a slower decline in TFP after 2012. Whereas SA's average annual TFP growth rate before 2012 was –2.1 per cent, from 2012 to 2020 it averaged –0.5 per cent.

Figure 4.19 **SA DNSP output, input and total factor productivity indexes, 2006–2020**

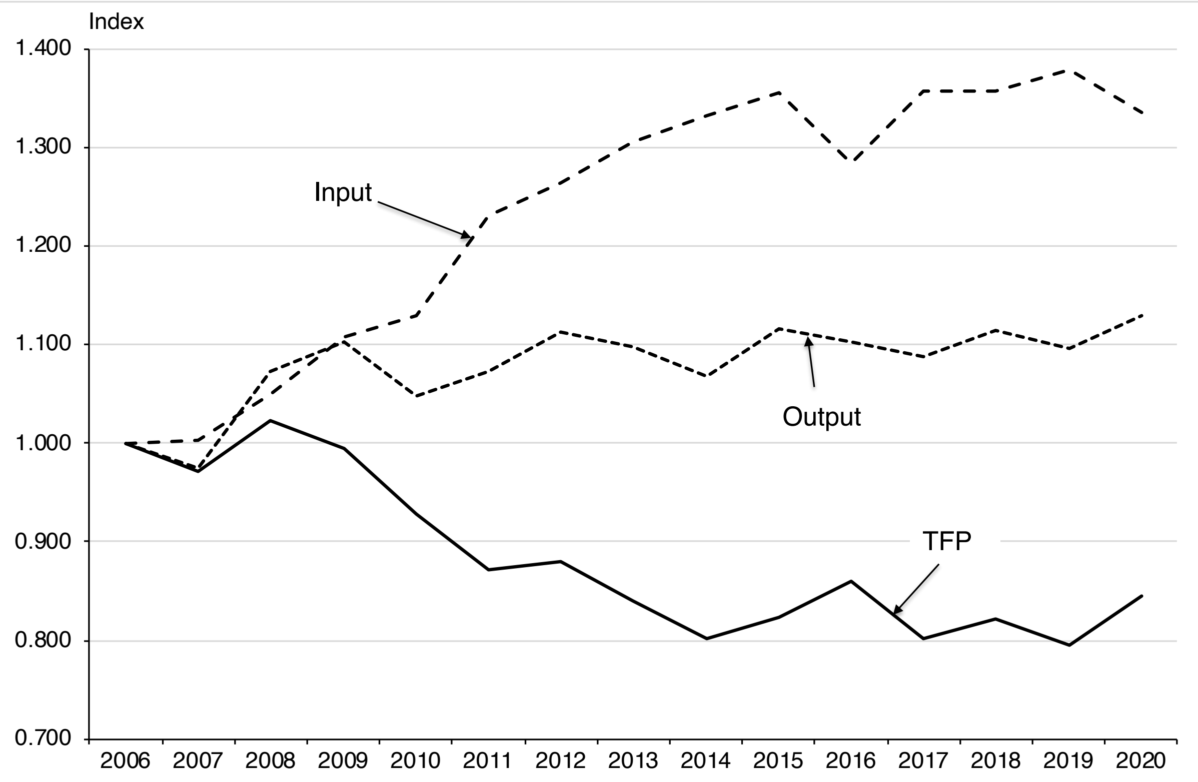


Table 4.11 **SA DNSP output, input, TFP and PFP indexes, 2006–2020**

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	1.003	0.971	1.051	0.940
2008	1.073	1.050	1.023	1.034	1.013
2009	1.102	1.107	0.995	0.964	1.011
2010	1.048	1.129	0.928	0.922	0.931
2011	1.072	1.231	0.871	0.756	0.935
2012	1.113	1.263	0.881	0.762	0.944
2013	1.098	1.306	0.841	0.710	0.917
2014	1.068	1.332	0.802	0.675	0.879
2015	1.116	1.356	0.823	0.678	0.908
2016	1.103	1.283	0.860	0.800	0.887
2017	1.088	1.357	0.802	0.685	0.868
2018	1.115	1.357	0.822	0.716	0.880
2019	1.097	1.379	0.795	0.687	0.857
2020	1.128	1.335	0.845	0.793	0.869
Growth Rate 2006-2020	0.9%	2.1%	-1.2%	-1.7%	-1.0%
Growth Rate 2006-2012	1.8%	3.9%	-2.1%	-4.5%	-1.0%
Growth Rate 2012-2020	0.2%	0.7%	-0.5%	0.5%	-1.0%
Growth Rate 2020	2.9%	-3.2%	6.1%	14.4%	1.4%

4.2.5.2 SA DNSP output and input quantity changes

Quantity indexes for SA's individual outputs are graphed in figure 4.20 and for its six individual inputs in figure 4.21. From figure 4.20 we see that:

- SA customer numbers increased steadily over the period and were 17.4 per cent higher in 2020 than in 2006 (compared to 20.8 per cent for the industry as a whole);
- like several other jurisdictions, energy throughput in SA peaked in 2010 and has fallen slowly since then. In 2020 it was 10.1 per cent below 2006; a much larger decrease than that for the industry as a whole over the same period (–4.5 per cent);
- SA's maximum demand peaked in 2009, and has not exceeded that level since. RMD had therefore been constant since 2009 at 15.5 per cent above the 2006 level. This is comparable to the increase in RMD of 18.1 per cent for the industry between 2006 and 2020;
- SA's circuit length output grew by 5.4 per cent in total over the 15-year period (a similar rate as that for the industry);
- SA's CMOS decreased by 10.0 per cent in total between 2006 and 2020, thus making a larger contribution to output growth than for the industry (where CMOS decreased in total by less than 1 per cent over the same period). CMOS receives an average weight of –17.0 per cent of total revenue for SA.

Figure 4.20 **SA output quantity indexes, 2006–2020**

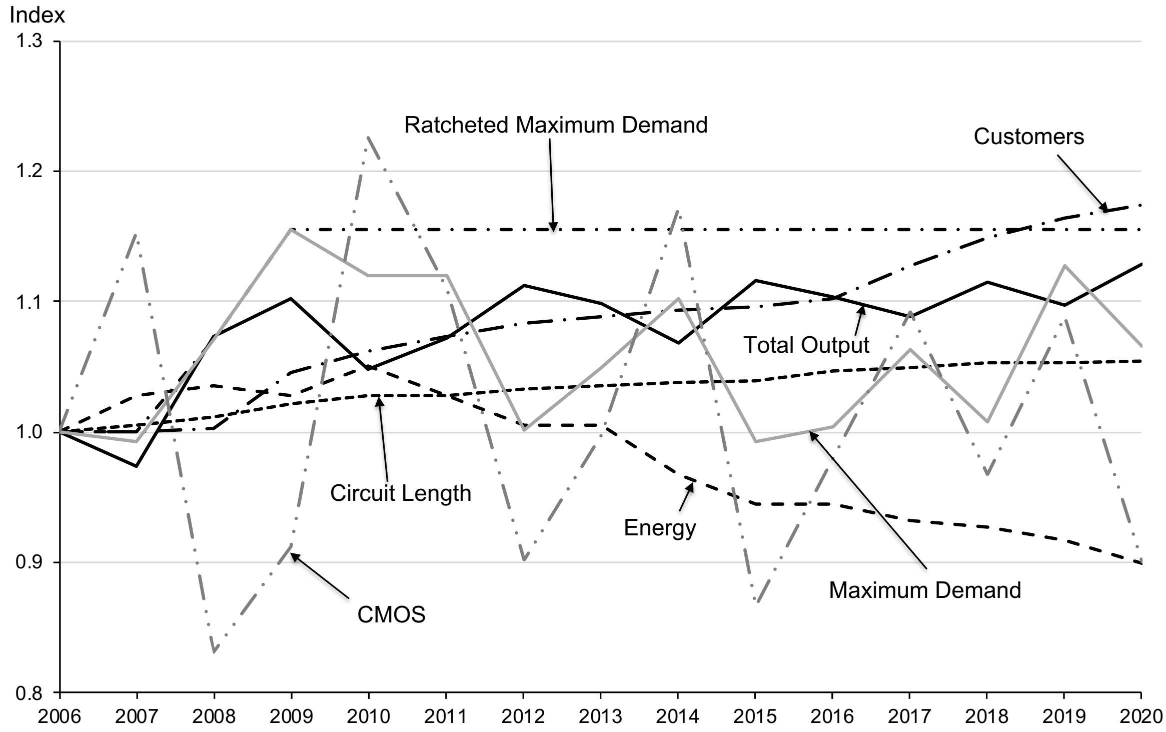
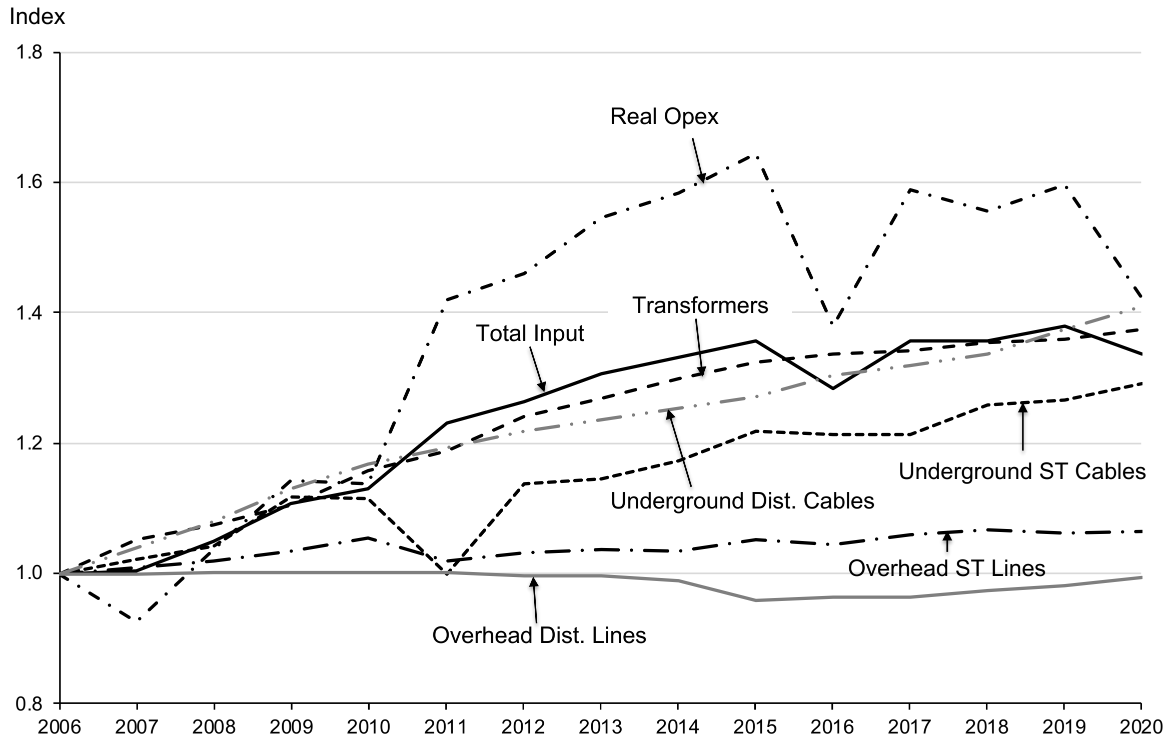


Figure 4.21 **SA DNSP input quantity indexes, 2006–2020**



Since the circuit length and ratcheted maximum demand outputs receive a combined average weight of around 85.3 per cent of total revenue in forming the total output index for SA, in figure 4.20 we see that the total output index lies between these output indexes in most years. The total output index for SA increased by 12.8 per cent between 2006 and 2020 (similar to the increase for the industry of 13.8 per cent over the same period).

Turning to figure 4.21, which shows the SA DNSP input indexes, it can be seen that SA's total input index increased by 33.5 per cent in total between 2006 and 2020, which is higher than the corresponding increase of 24.5 per cent for industry. In regard to the six individual input indexes for SA shown figure 4.21:

- SA's opex input increased by 42.3 per cent over the 15-year period, which is much greater than for the industry (an increase of 9.2 per cent over the same period). This outcome was driven by an especially strong increase in SA's opex input between 2006 and 2012 of 46.0 per cent. After 2012 there was really no significant decrease from this level until 2020. Opex has the largest average share in SA's total costs at 34.5 per cent and so is an important driver of its total input quantity index;
- underground distribution and subtransmission cables in SA increased by 41.1 per cent and 29.1 per cent respectively over the 15-year period to 2020 (compared to 63.7 and 38.3 per cent for the industry);
- transformers inputs in SA increased at a similar rate to the industry as a whole, exceeding their 2006 levels by 37.5 per cent by 2020 (compared to 40.8 per cent for the industry);
- SA's overhead subtransmission increased between 2006 and 2020 by 6.5 per cent and its overhead distribution lines *decreased* by 0.6 per cent (compared to increases of 14.3 per cent and 11.7 per cent respectively for the whole industry).

4.2.5.3 SA output and input contributions to TFP change

In table 4.12, SA's TFP change is decomposed into the contributions of the individual outputs and inputs for the whole 15-year period and for the periods up to and after 2012. SA's drivers of TFP change for the 15-year period to 2020 are broadly similar to the industry with the main exception of opex input, which has a much larger negative contribution than the industry. For SA, opex input contributed –0.8 percentage points to the average TFP growth rate of –1.2 per cent from 2006 to 2020 (compared to a negative contribution of opex –0.3 to the industry average TFP growth for the same period). Other contributions to SA's average TFP growth rate over the 15 years to 2020 include:

- Customers, RMD and circuit length outputs together contributed 0.8 percentage points (compared to 0.9 for the industry);
- Overhead and underground sub-transmission and distribution lines together contributed –0.5 percentage points (compared to –0.6 for the industry);

- transformers input contributed –0.8 percentage points (compared to –0.7 for the industry); and
- CMOS contributed 0.1 percentage points (close to zero for the industry).

Table 4.12 **SA output and input percentage point contributions to average annual TFP change: 2006–2020, 2006–2012, 2012–2020, 2020**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2019 to 2020*
Energy (GWh)	-0.08%	0.01%	-0.14%	-0.19%
Ratcheted Max Demand	0.41%	0.96%	0.00%	-0.01%
Customer Numbers	0.25%	0.30%	0.21%	0.17%
Circuit Length	0.17%	0.25%	0.11%	0.05%
CMOS	0.10%	0.26%	-0.01%	2.85%
Opex	-0.83%	-2.05%	0.09%	4.20%
O/H Subtransmission Lines	-0.01%	-0.01%	-0.01%	-0.01%
O/H Distribution Lines	0.01%	0.01%	0.01%	-0.13%
U/G Subtransmission Cables	-0.01%	-0.01%	0.00%	0.00%
U/G Distribution Cables	-0.47%	-0.69%	-0.30%	-0.43%
Transformers	-0.76%	-1.15%	-0.47%	-0.43%
TFP Change	-1.20%	-2.12%	-0.51%	6.06%

Figure 4.22 **SA output and input percentage point contributions to TFP change, 2020**

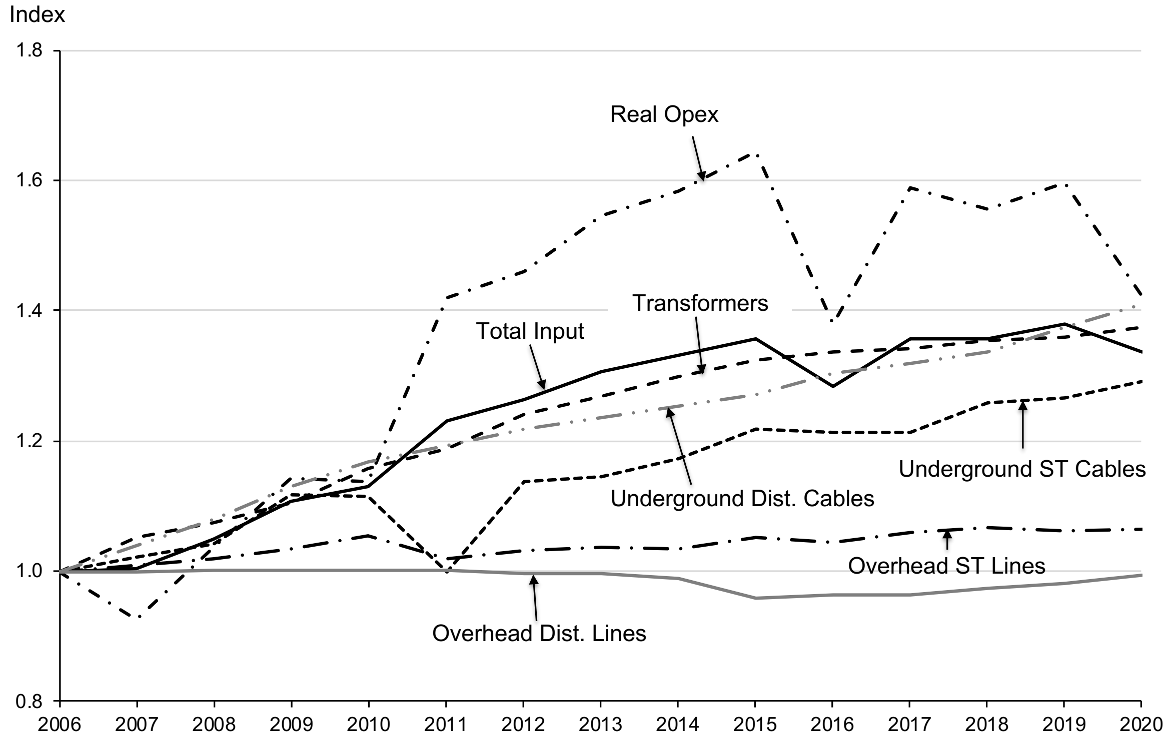


Figure 4.22 shows the percentage point contributions of individual outputs and inputs to SA's TFP growth from 2019 to 2020. SA's strong TFP increase of 6.1 per cent in 2020 was driven by a large reduction in opex inputs, which contributed 4.2 percentage points to TFP growth, and an improvement in reliability (i.e. reduction in CMOS) which contributed 2.8 percentage points. The other outputs and inputs had a combined effect of –0.9 percentage points. The biggest contributors to this component were underground distribution cables and transformers.

4.2.6 Tasmania (TAS)

TAS is the second smallest of the NEM jurisdictions (by customer numbers) and is served by one DNSP, TasNetworks Distribution (TND). In 2020 it delivered 4,401 GWh to 293,949 customers over 22,912 circuit kilometres of lines and cables.[14]

4.2.6.1 Tasmanian DNSP productivity performance

Tasmania's total output, total input and TFP indexes are presented in figure 4.23 and table 4.13. Opex and capital partial productivity indexes are also presented in table 4.13. Over the 15-year period 2006 to 2020, the Tasmanian DNSP's TFP *decreased* at an average annual rate of 1.0 per cent. Total output has increased at only 0.3 per cent per annum on average. Total input use, on the other hand, has increased at an average annual rate of 1.3 per cent. Input use increased at a faster rate of 3.4 per cent between 2006 and 2012, and changed at a rate of –0.3 per cent per year from 2012 to 2020. Output increased at an average annual rate of 0.3 per cent from 2006 to 2012, and on average increased by 0.4 per cent per annum thereafter. The net effect of these trends was that TFP *decreased* at an average rate of 3.1 per cent up to 2012 and *increased* at an average rate of 0.6 per cent from 2012 to 2020.

4.2.6.2 Tasmanian DNSP output and input quantity changes

Quantity indexes for the Tasmanian DNSP's individual outputs are shown in figure 4.24 and its six individual inputs in figure 4.25. TAS outputs had the following trends:

- customer numbers were 17.3 per cent higher in 2020 than in 2006 (compared to 20.8 per cent for the industry as a whole);
- energy throughput peaked in 2009 and decreased each year through to 2014 before recovering somewhat in later years. It was 1.1 per cent lower in 2020 than in 2006 (compared to 4.5 per cent lower for industry as a whole);

[14] As previously indicated in Economic Insights (2015b:4), TND is something of an outlier in terms of system structure in that it has by far the most 'downstream' boundary with transmission. It consequently has far less subtransmission capacity than other Australian DNSPs. While this gives it an advantage in terms of a lower quantity of subtransmission inputs (and hence it should have a high MPFP of these lines), these inputs also receive a very low weight in forming the total input quantity (and hence it receives little benefit for its higher productivity in this area when forming the MTFP measure). For example, TND has an overhead subtransmission lines MPFP several times higher than that of any other DNSP but, whereas subtransmission lines account for around 25 per cent of the total AUC of overhead lines for the industry as a whole, they account for only 1.5 per cent of TND's overhead lines AUC.

Figure 4.23 **TAS DNSP output, input and TFP indexes, 2006–2020**

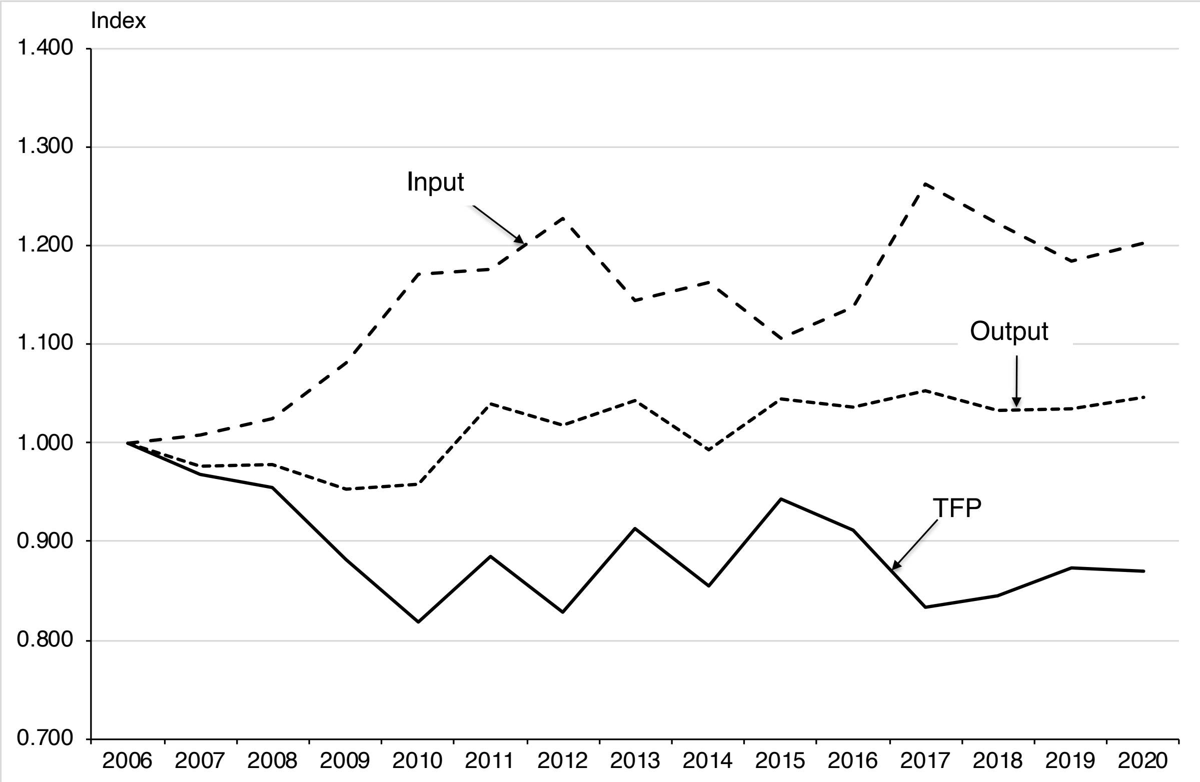


Table 4.13 **TAS DNSP output, input, TFP and PFP indexes, 2006–2020**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	0.977	1.009	0.969	0.979	0.964
2008	0.979	1.025	0.955	0.971	0.946
2009	0.953	1.080	0.882	0.846	0.903
2010	0.959	1.171	0.819	0.719	0.880
2011	1.040	1.176	0.884	0.810	0.927
2012	1.017	1.228	0.828	0.726	0.892
2013	1.043	1.144	0.912	0.918	0.910
2014	0.993	1.162	0.854	0.857	0.853
2015	1.044	1.106	0.943	1.064	0.889
2016	1.037	1.138	0.911	0.985	0.877
2017	1.052	1.261	0.834	0.761	0.879
2018	1.032	1.222	0.845	0.827	0.855
2019	1.034	1.184	0.874	0.935	0.844
2020	1.046	1.203	0.870	0.915	0.846
Growth Rate 2006-2020	0.3%	1.3%	-1.0%	-0.6%	-1.2%
Growth Rate 2006-2012	0.3%	3.4%	-3.1%	-5.3%	-1.9%
Growth Rate 2012-2020	0.4%	-0.3%	0.6%	2.9%	-0.7%
Growth Rate 2020	1.2%	1.6%	-0.4%	-2.2%	0.3%

- TAS's maximum demand increased up to 2008 and has not reached that level since, so that RMD has been constant from 2008 to 2020. RMD in 2020 was 8.6 per cent higher than in 2006 (compared to the 18.1 per cent increase for the industry as a whole);TAS's circuit length output grew by 8.0 per cent in total over the 15-year period to 2020 (compared to an increase of 4.9 per cent for the industry);

- CMOS increased by 34.5 per cent in total between 2006 and 2020 (compared to a 0.8 per cent decrease for the industry over the same period). This represents a deterioration in reliability performance. CMOS receives an average weight of –18.2 per cent of total revenue for Tasmania.

TAS's output index increased by 4.6 per cent from 2006 to 2020, compared to 13.8 per cent for the industry as a whole. CMOS had an important influence on this because it enters the total output index as a negative output (i.e. the large increase in CMOS over the period makes a substantial negative contribution to total output).

Figure 4.24 **TAS output quantity indexes, 2006–2019**

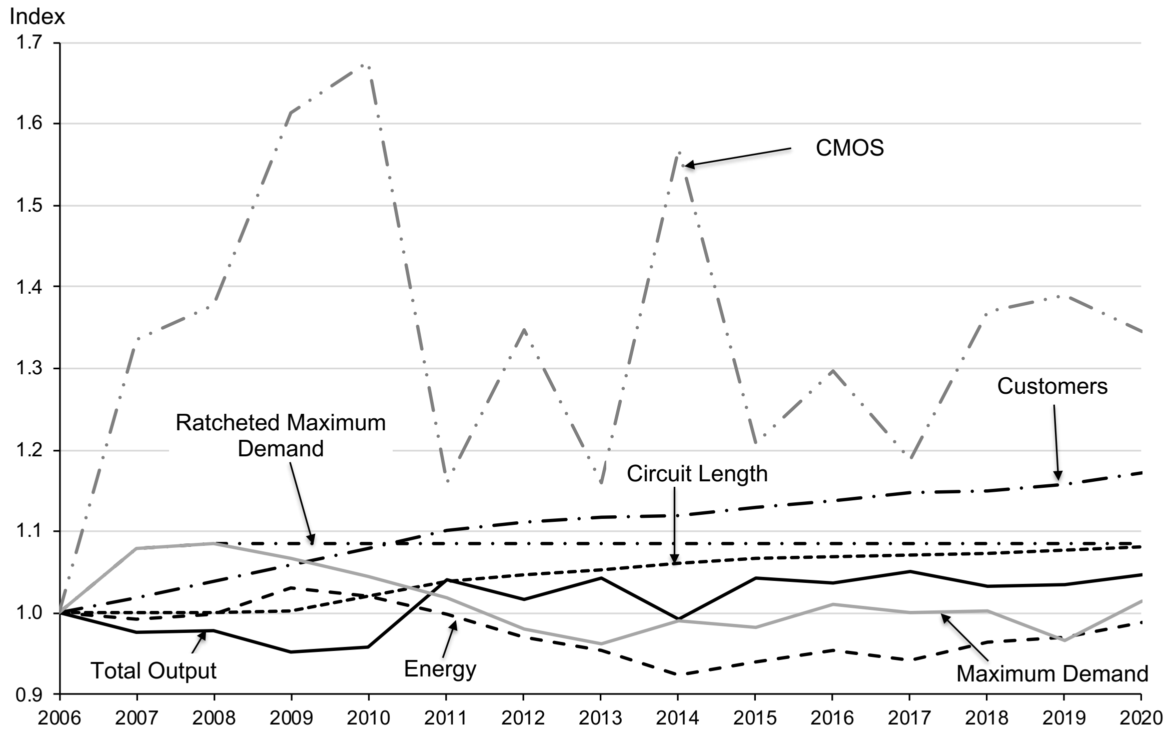


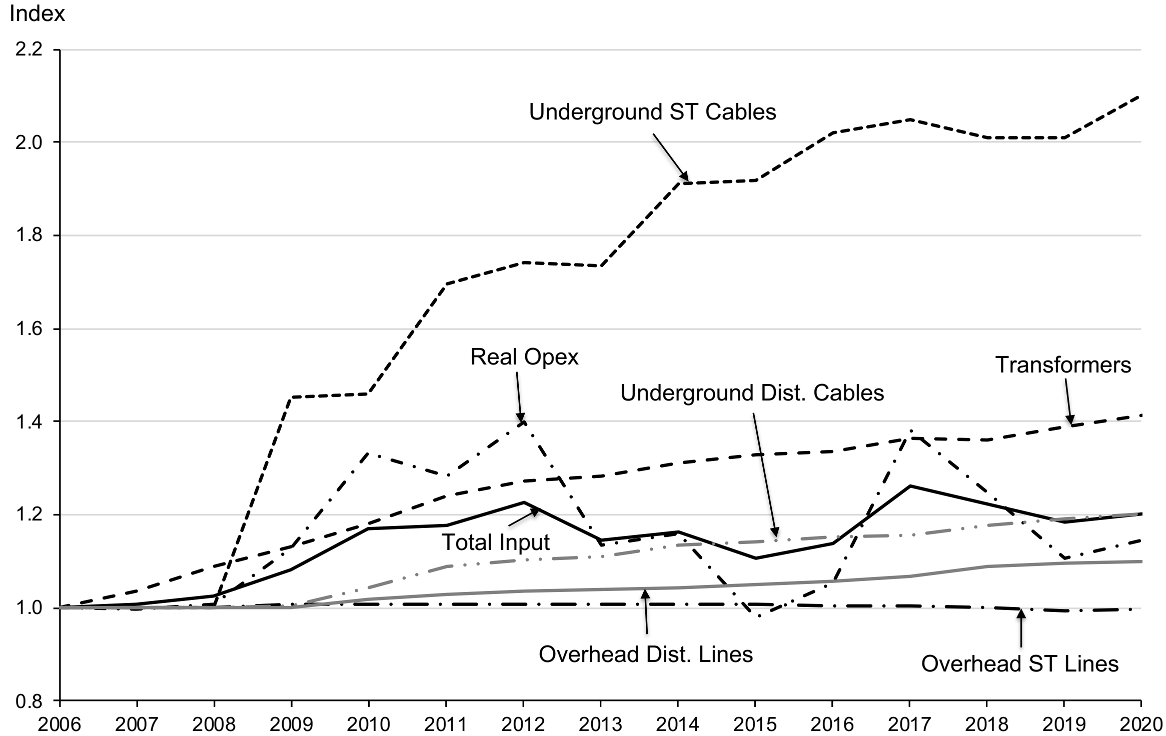
Figure 4.25 plots TAS's six individual inputs and the total input index:

- opex input increased by 14.4 per cent from 2006 to 2020. A substantial increase occurred in the period up to 2012 (at an average annual rate of 5.6 per cent, or 40.0 per cent in total), with a net decrease in the period from 2012 to 2020. The increase of opex over the whole 15-year period is higher than that for the industry. As noted in Economic Insights (2018), part of this increase was to address bushfire and other risks. Opex has the largest average share in Tasmania's total costs at 35.1 per cent and so is an important driver of total input quantity;

- transformers inputs in TAS increased at a similar rate to the industry as a whole; by 2020 exceeding the 2006 level by 41.4 per cent (compared to 40.8 per cent for the industry);
- TAS's underground distribution cables inputs increased by 20.1 per cent in total over the 15 years to 2020 (compared to 63.7 per cent for the industry). TAS's underground subtransmission cables more than doubled over the 15-year period, off a low base;
- Overhead subtransmission and distribution lines in TAS were in 2020, –0.4 per cent and +9.9 per cent of the 2006 respectively (compared to +14.3 per cent and +11.7 per cent respectively for the whole industry).

From figure 4.25 we see the TAS total input quantity index has generally been below the quantity indexes for opex and transformers and above the quantity index for overhead distribution and subtransmission lines. Total input quantity increased by 20.3 per cent over the 15 years to 2020, compared to 24.5 per cent for the industry overall.

Figure 4.25 **TAS DNSP input quantity indexes, 2006–2020**



4.2.6.3 Tasmanian output and input contributions to TFP change

Table 4.14 presents the decomposition of TAS's TFP change into its constituent outputs and inputs for the whole 15-year period and for the periods up to and after 2012. Tasmania's drivers of TFP change for the whole 15-year period are, in most case, broadly similar to the industry as a whole except that CMOS makes a much larger negative contribution to TFP growth for Tasmania whereas it is slightly positive for the industry.

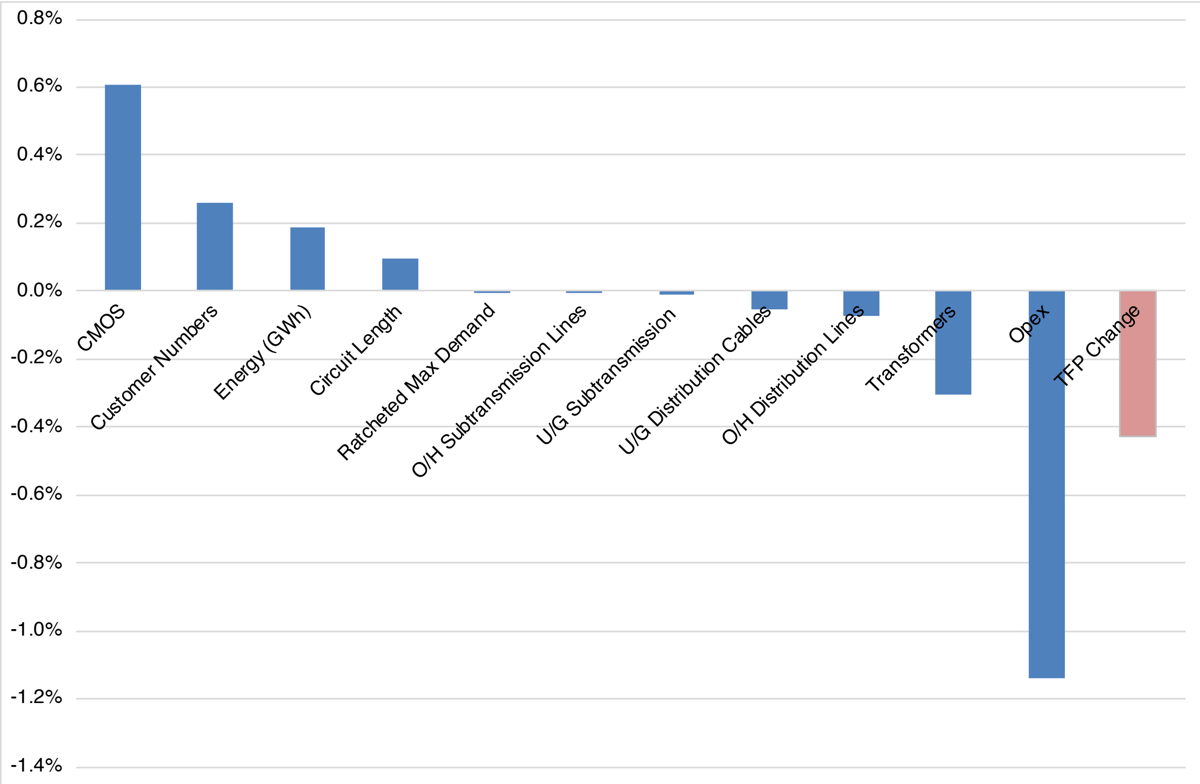
Among the outputs, RMD, customer numbers and circuit length together contributed 0.7 percentage points to TAS's average TFP change of –1.0 per cent over the period 2006 to 2020 (compared to a 0.9 percentage points contribution of these outputs to the industry TFP change). The biggest difference between TAS and the industry as a whole is with CMOS, which contributed –0.4 to TAS TFP compared to a negligible effect for the industry. The contributions of inputs were similar to those for the industry. Opex contributed –0.3 percentage points for TAS, the same as for the industry. Overhead and underground distribution and subtransmission lines together contributed –0.4 percentage points to TAS TFP change (compared to –0.6 percentage points for the industry). Transformers contributed –0.6 percentage points to TAS's TFP growth rate (compared to –0.7 percentage points for the industry).

Table 4.14 **TAS output and input percentage point contributions to average annual TFP change: 2006–2020, 2006–2012, 2012–2020, 2020**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2019 to 2020*
Energy (GWh)	-0.01%	-0.05%	0.02%	0.19%
Ratcheted Max Demand	0.24%	0.55%	0.00%	0.00%
Customer Numbers	0.25%	0.39%	0.15%	0.26%
Circuit Length	0.26%	0.36%	0.18%	0.10%
CMOS	-0.41%	-0.97%	0.00%	0.61%
Opex	-0.34%	-2.01%	0.91%	-1.14%
O/H Subtransmission Lines	0.00%	0.00%	0.00%	0.00%
O/H Distribution Lines	-0.19%	-0.15%	-0.21%	-0.07%
U/G Subtransmission Cables	-0.02%	-0.03%	-0.01%	-0.01%
U/G Distribution Cables	-0.15%	-0.19%	-0.12%	-0.05%
Transformers	-0.62%	-1.04%	-0.31%	-0.30%
TFP Change	-1.00%	-3.14%	0.61%	-0.43%

Figure 4.26 shows the contributions of individual inputs and outputs to TAS's TFP growth from 2019 to 2020 of –0.4 per cent. Improvement in CMOS contributed +0.6 percentage points to TFP growth and an increase in opex contributed –1.1 percentage points.

Figure 4.26 **TAS output and input percentage point contributions to TFP change, 2020**



5 DNSP OUTPUTS, INPUTS AND PRODUCTIVITY CHANGE

This chapter presents indexes for outputs, inputs and productivity 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.

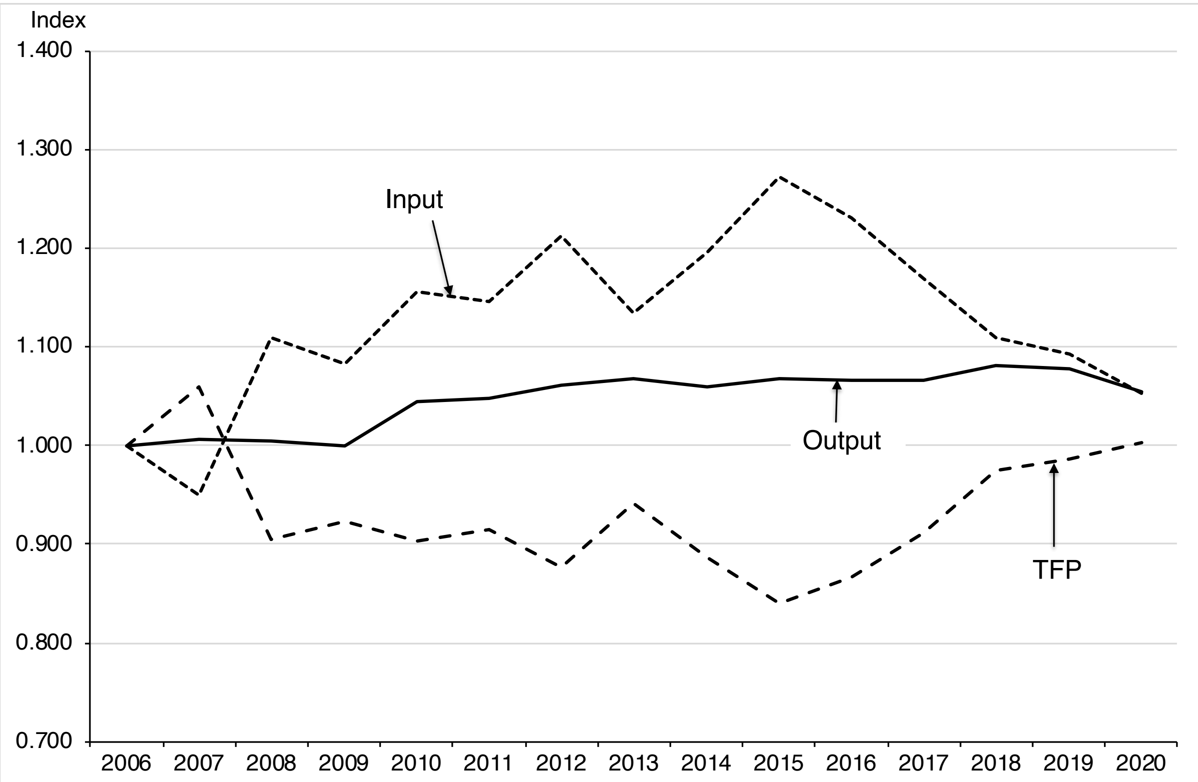
5.1 Ausgrid (AGD)

In 2020, AGD delivered 24,934 GWh to 1.76 million customers over 42,295 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.

5.1.1 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, 2006–2020**



Over the 15-year period 2006 to 2020, AGD's TFP averaged an annual rate of change of zero. This can be compared to the industry's average annual change of –0.6 per cent over the same period. AGD's total output increased over the same period at an average annual rate of 0.4 per cent. This is lower than the industry average rate of growth in output of 0.9 per cent per annum. AGD's average annual rate of increase in input use of 0.4 per cent was much lower higher than the rate of increase in total input use for the industry (1.6 per cent per year).

Table 5.1 **AGD output, input, TFP and PFP indexes, 2006–2020**

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	0.949	1.060	1.188	0.982
2008	1.004	1.109	0.905	0.834	0.956
2009	0.999	1.082	0.924	0.917	0.926
2010	1.044	1.155	0.904	0.845	0.938
2011	1.048	1.146	0.914	0.888	0.924
2012	1.061	1.212	0.876	0.814	0.908
2013	1.068	1.134	0.942	1.037	0.889
2014	1.059	1.196	0.886	0.923	0.860
2015	1.068	1.272	0.839	0.793	0.863
2016	1.066	1.231	0.866	0.886	0.849
2017	1.066	1.168	0.912	1.002	0.862
2018	1.081	1.109	0.974	1.188	0.872
2019	1.077	1.092	0.986	1.259	0.864
2020	1.054	1.052	1.002	1.389	0.841
Growth Rate 2006-2020	0.4%	0.4%	0.0%	2.3%	-1.2%
Growth Rate 2006-2012	1.0%	3.2%	-2.2%	-3.4%	-1.6%
Growth Rate 2012-2020	-0.1%	-1.8%	1.7%	6.7%	-1.0%
Growth Rate 2020	-2.1%	-3.7%	1.6%	9.8%	-2.8%

Over the period from 2006 to 2012, TFP increased in three years and decreased in three years, but overall TFP decreased at an average rate of –2.2 per cent per year. From 2012 to 2020, TFP increased in six out of eight years, and on average TFP increased at an annual rate of 1.7 per cent. The TFP increase in 2020 of 1.6 per cent is consistent with the trend in the period since 2012.

During the first part of the sample period, up to 2012, AGD's output increased comparatively strongly at 1.0 per cent per annum, whereas in the later period after 2012, the rate of change of the output index was slightly negative at –0.1 per cent. The effect of changing output trends on TFP was swamped by the much larger movements in input index growth. From 2006 to 2012, the input index increased at an average annual rate of 3.2 per cent, whereas in the period after 2012 the input index fell at an average annual rate of –1.8 per cent. The high rate of input growth in the period up to 2012 resulted in a strong rate of decrease in TFP, and the reductions of the input index after 2012 resulted in positive TFP growth.

The partial productivity indexes in table 5.1 show that the turnaround from negative to positive average annual rates of change of TFP after 2012 was associated with a reduced rate of decrease in Capital PFP, and a substantial turn-around in Opex PFP. The latter's large falls in the period up to 2012, were replaced by strong increases in the period after 2012.

5.1.2 AGD's output and input quantity changes

Figure 5.2 plots the quantity indexes for AGD's individual outputs and figure 5.3 plots indexes for the six individual inputs. Regarding outputs:

- AGD's circuit length (the output component that receives the largest weight in forming the output index) has increased steadily at an average rate of 0.6 per cent per annum from 2006 to 2020, and by 2020 was 9.2 per cent above the 2006 level (which is higher than the increase of 4.9 per cent, for the industry over the 15-year period).
- AGD's energy throughput has decreased at a greater rate than for the industry as a whole, decreasing at an average rate of –1.3 per cent per annum between 2006 and 2020, while industry energy throughput decreased at an annual average rate of –0.3 per cent over the same period. In 2020, AGD's energy throughput was 17.2 per cent below its 2006 level compared to the industry's throughput then being 4.5 per cent less than it was in 2006.
- RMD increased though to 2011, in total by 7.3 per cent, and remained constant thereafter. Maximum demand reduced considerably after 2011 and up to 2015 in line with reduced energy demand, but increased after 2015 despite flat energy demand. The increase in RMD over the 15-year period is less than that of the industry (18.1 per cent in total).
- AGD's customers increased at an average rate of 0.9 per cent per annum from 2006 to 2020, or 14.0 per cent in total, which is less than the average rate of customer growth for the industry over the same period of 1.3 per cent per annum, or 20.8 per cent in total.
- CMOS increased in 2020 by 22.0 per cent over the preceding year, and 20.8 per cent higher than in 2006. CMOS in 2020 exceeded all previous years of the sample except 2009.

Turning to inputs shown in figure 5.3, we see:

- The quantity of opex increased at an average annual rate of 4.4 per cent over the period from 2006 to 2012, and although it later reached a peak in 2015, there was a subsequent decline, so that over the period from 2012 to 2020, the average annual rate of change of opex was –6.8 per cent. Over the 15-year period to 2020, opex input decreased in total by 24.1 per cent. This compares favourably to the total increase of 9.2 per cent for the industry over the same period.
- Overhead sub-transmission and distribution lines in 2020, compared to 2006, were 3.4 per cent lower and 3.9 per cent higher respectively. These outcomes compare with 14.3 per cent and 11.7 per cent increases, respectively, for the industry over the same period.
- Underground sub-transmission and distribution cables were, in 2020, 8.1 and 32.7 per cent higher than in 2006 respectively. This can be compared to increases of 38.3 per cent and 63.7 per cent respectively for the industry over the same period.
- AGD's quantity of transformers increased steadily over most of the 15-year period, before levelling off from about 2016. By 2020, transformer inputs were 35.4 per cent above the 2006 level, which is a smaller increase than the industry's 40.8 per cent.

Figure 5.2 **AGD output quantity indexes, 2006–2020**

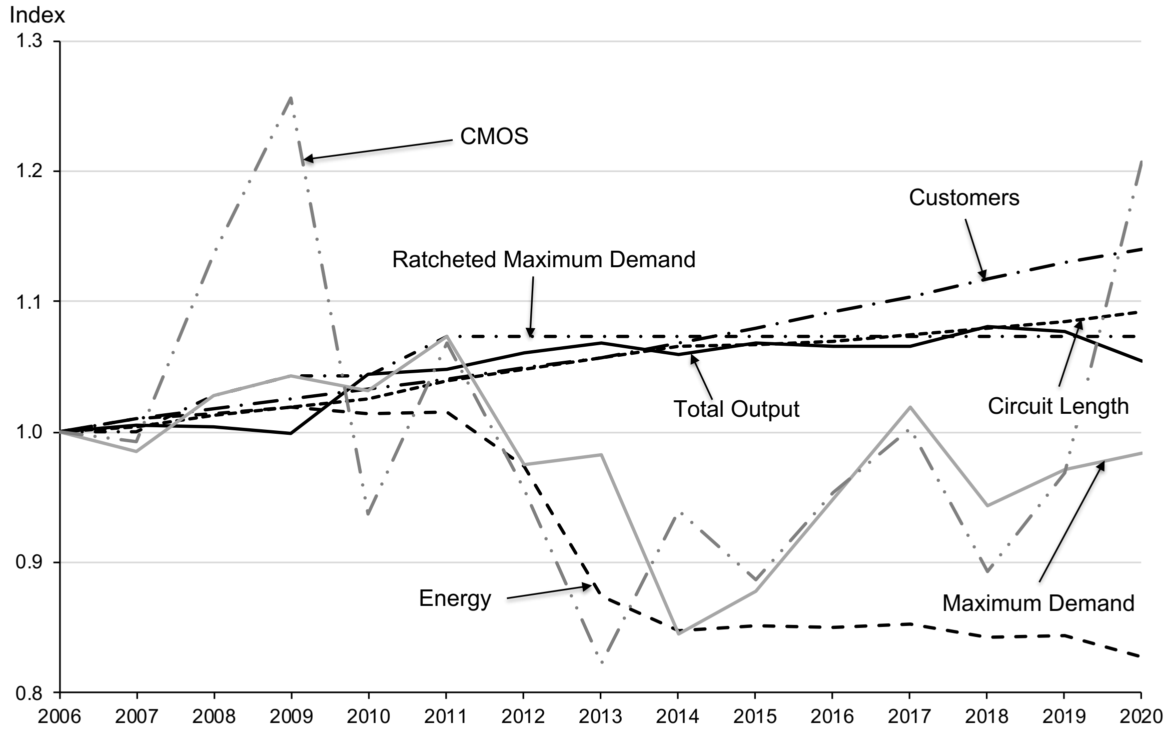
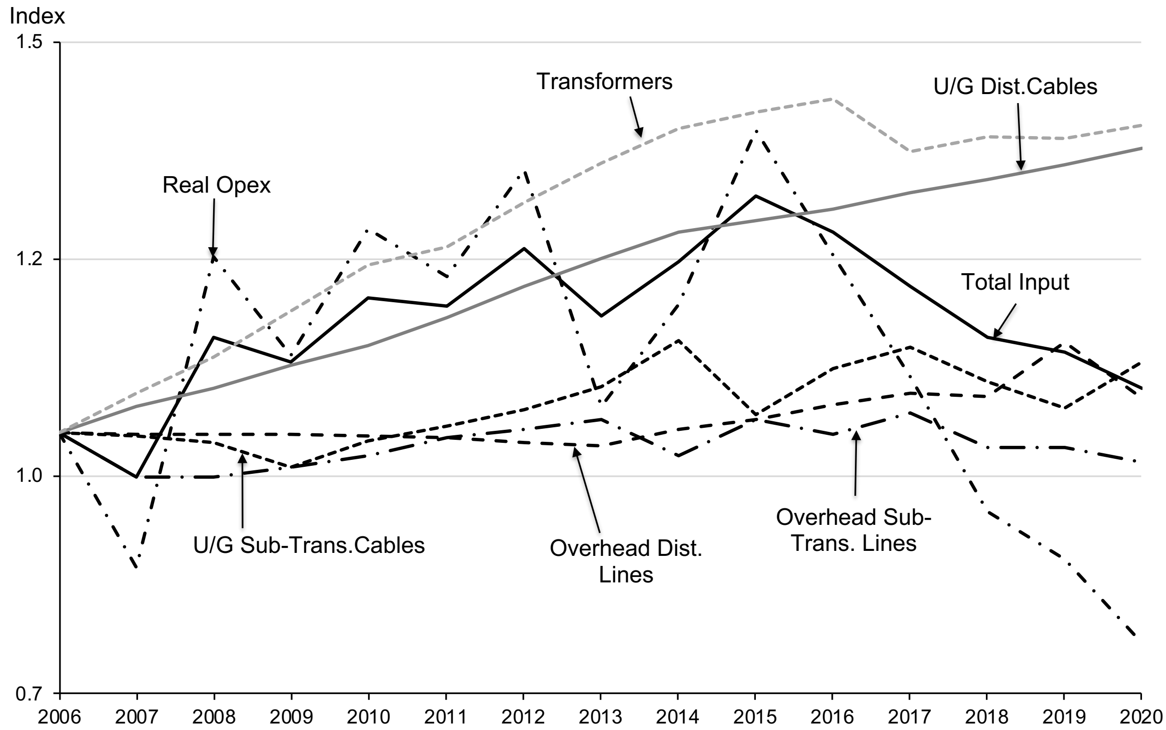


Figure 5.3 **AGD input quantity indexes, 2006–2020**



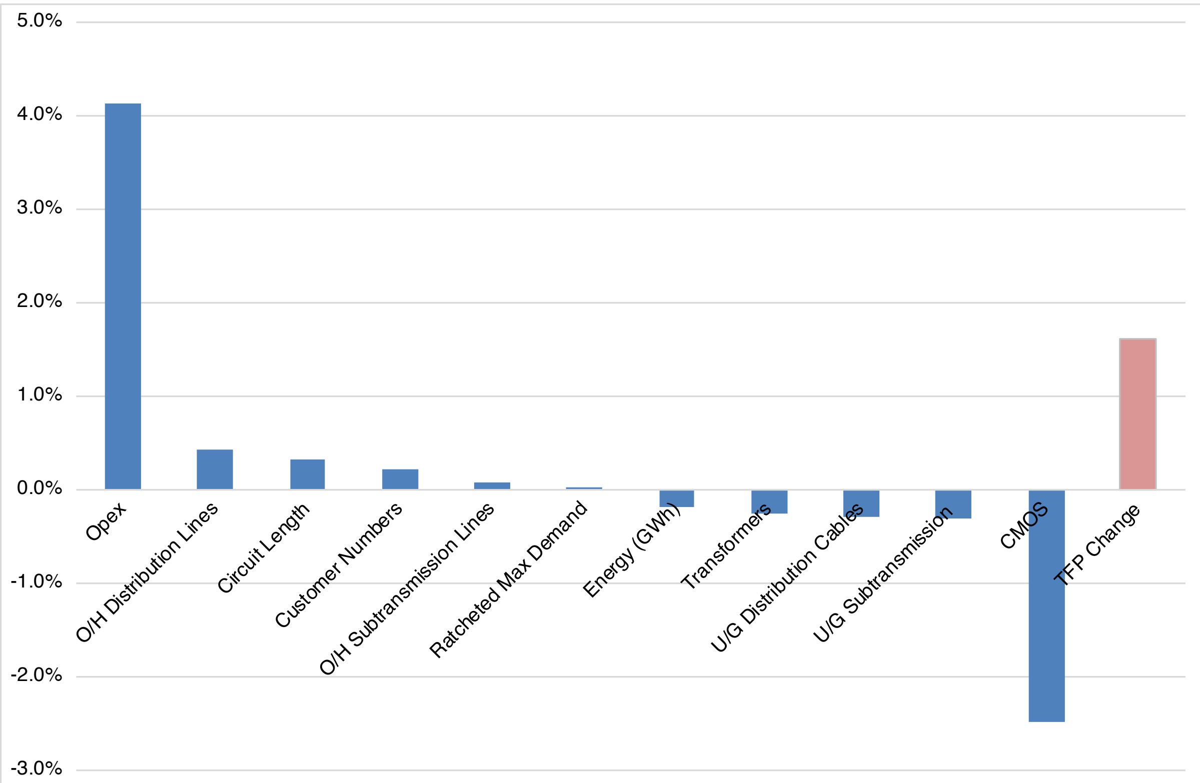
5.1.3 AGD's output and input contributions to TFP change

Table 5.2 shows the decomposition of AGD's rate of TFP change into the contributions of the individual outputs and inputs for the whole 15-year period and for the periods up to and after 2012. Figure 5.4 shows the contributions of outputs and inputs to AGD's rate of TFP change between 2019 and 2020.

Table 5.2 **AGD output and input percentage point contributions to average annual TFP change: 2006–2020, 2006–2012, 2012–2020, 2020**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2019 to 2020*
Energy (GWh)	-0.13%	-0.05%	-0.19%	-0.20%
Ratcheted Max Demand	0.19%	0.44%	0.00%	0.01%
Customer Numbers	0.19%	0.17%	0.21%	0.21%
Circuit Length	0.28%	0.35%	0.22%	0.32%
CMOS	-0.15%	0.07%	-0.33%	-2.48%
Opex	0.63%	-1.65%	2.35%	4.13%
O/H Subtransmission Lines	0.01%	0.00%	0.02%	0.07%
O/H Distribution Lines	-0.02%	0.01%	-0.04%	0.43%
U/G Subtransmission Cables	-0.03%	-0.02%	-0.04%	-0.32%
U/G Distribution Cables	-0.29%	-0.35%	-0.25%	-0.29%
Transformers	-0.66%	-1.19%	-0.27%	-0.27%
TFP Change	0.01%	-2.21%	1.68%	1.60%

Figure 5.4 **AGD output and input percentage point contributions to TFP change in 2020**



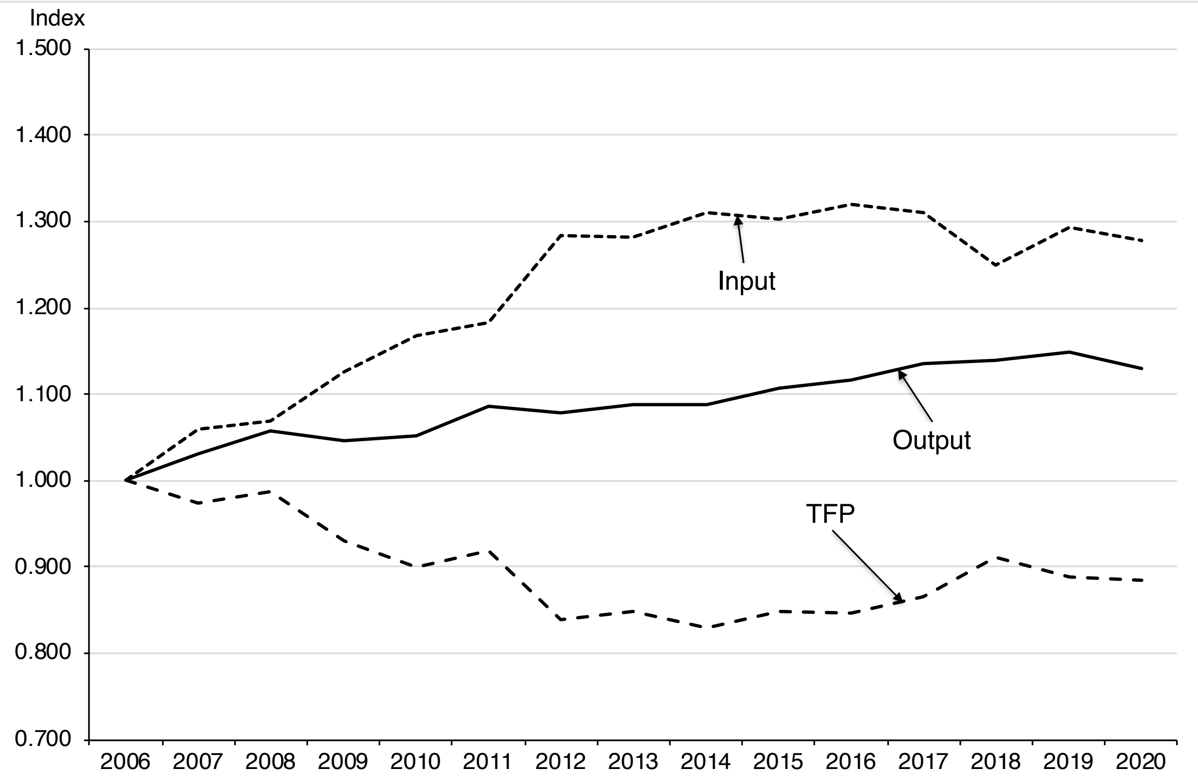
5.2 CitiPower (CIT)

In 2020, CIT delivered 5,179 GWh to 346,468 customers over 4,569 circuit kilometres of lines and cables. CIT is the smallest of the Victorian DNSPs (in terms of customer numbers) and covers central Melbourne, including the Melbourne CBD.

5.2.1 CIT's productivity performance

CIT'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 **CIT's output, input and TFP indexes, 2006–2020**



Over the 15-year period 2006 to 2020, CIT's TFP decreased at an average annual rate of change of –0.9 per cent, which is slightly larger decline than the industry's average annual TFP change of –0.6 per cent over the same period. CIT's total output increased over the 15-year period at an average annual rate of 0.9 per cent. This is the same rate as for the industry. CIT's average annual rate of increase in input use of 1.8 per cent was slightly higher than the rate of increase in total input use for the industry (1.6 per cent per year).

The decrease in TFP mostly occurred in the first half of the period, and was associated with a large increase in input use – averaging a 4.2 per cent increase per year. From 2006 to 2012, TFP *decreased* at average annual rate of 2.9 per cent. Input use stabilised in the period after 2012, and average TFP growth was 0.6 per cent per annum.

Table 5.3 **CIT's output, input, TFP and PFP indexes, 2006–2020**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.032	1.059	0.974	0.903	0.997
2008	1.057	1.070	0.988	0.972	0.994
2009	1.047	1.126	0.930	0.816	0.970
2010	1.053	1.169	0.901	0.756	0.954
2011	1.087	1.182	0.919	0.840	0.947
2012	1.078	1.283	0.840	0.661	0.916
2013	1.087	1.282	0.848	0.691	0.911
2014	1.087	1.310	0.830	0.675	0.893
2015	1.106	1.303	0.849	0.713	0.901
2016	1.116	1.319	0.847	0.715	0.897
2017	1.136	1.311	0.866	0.754	0.907
2018	1.138	1.250	0.911	0.876	0.921
2019	1.148	1.293	0.888	0.786	0.924
2020	1.130	1.279	0.884	0.823	0.903
Growth Rate 2006-2020	0.9%	1.8%	-0.9%	-1.4%	-0.7%
Growth Rate 2006-2012	1.2%	4.2%	-2.9%	-6.9%	-1.5%
Growth Rate 2012-2020	0.6%	0.0%	0.6%	2.7%	-0.2%
Growth Rate 2020	-1.6%	-1.1%	-0.4%	4.5%	-2.3%

The partial productivity indexes in table 5.3 show that:

- The partial productivity of capital inputs has declined consistently, at an average rate of –0.7 per cent per year. The rate of decline was strongest in the period up to 2012, and was only marginal in the period after 2012.
- The partial productivity of opex input declined particularly strongly in the period up to 2012 (average annual rate of –6.9 per cent), whereas it increased moderately since 2012 (at a rate of 2.7 per cent per annum).

5.2.2 CIT's output and input quantity changes

Figure 5.6 graphs the quantity indexes for CIT's individual outputs. Figure 5.7 graphs quantity indexes for its six individual inputs. Regarding outputs:

- CIT's circuit length has increased steadily at an average rate of 1.0 per cent per annum from 2006 to 2020, and by 2020 was 15.6 per cent above the 2006 level (which is higher than the increase of 4.9 per cent, for the industry over the 15-year period). Circuit length is the output with the largest weight in the output index.
- CIT's energy throughput decreased over the 15-year period at a faster rate than for the industry as a whole, decreasing at an average rate of –1.0 per cent per annum between 2006 and 2020 (compared to –0.3 per cent for the industry over the same period). In

2020, CIT's energy throughput was 13.3 per cent below its 2006 level compared to the industry's energy throughput then being 4.5 per cent less than it was in 2006.

- RMD increased from 2006 though to 2009 by 10.4 per cent in total and remained at that level until further increasing from 2017 to 2020. Maximum demand appears to have declined in the period from 2009 to 2015 similar to energy throughput, but has increased since 2015 despite further declines in energy demand. The increase in RMD in the latter years of the sample period meant that by 2020 RMD was 17.5 per cent above its 2006 level which is similar to the industry as a whole (an 18.1 per cent increase over the same period).
- CIT's customers increased at an average rate of 1.1 per cent per annum from 2006 to 2020, or 17.5 per cent in total, which is similar to the average rate of customer growth for the industry over the same period (1.3 per cent per annum, or 20.8 per cent in total).
- CMOS increased in 2020 by 25.8 per cent, and was in 2020 32.4 per cent higher than in 2006. CMOS in 2020 exceeded all previous years of the sample except 2014.

Turning to inputs shown in figure 5.7, we see:

- The quantity of CIT's opex increased at an average annual rate of 8.1 per cent (or 63.0 per cent in total) over the period from 2006 to 2012. Opex input subsequently declined slowly over the period from 2012 to 2020, averaging –2.1 per cent per annum. By 2020, opex was 37.4 per cent above its 2006 level. This compares unfavourably to the total increase of 9.2 per cent for the industry over the same period.
- Overhead sub-transmission and distribution lines in 2020 were 2.0 per cent higher and 9.3 per cent *lower* respectively, than in 2006. These outcomes compare with increases of 14.3 per cent and 11.7 per cent respectively for the industry over the same period.
- Underground sub-transmission and distribution cables were, in 2020, 85.9 and 23.9 per cent higher than in 2006 respectively. This can be compared to increases of 38.3 per cent and 63.7 per cent respectively for the industry over the same period.
- CIT's quantity of transformers increased steadily over most of the 15-year period and by 2020, transformer inputs were 25.1 per cent above the 2006 level, which is a smaller increase than the industry's 40.8 per cent.

5.2.3 CIT's output and input contributions to TFP change

Table 5.4 shows the decomposition of CIT's rate of TFP change into the contributions of the individual outputs and inputs for the whole 15-year period and for the periods up to and after 2012. Figure 5.8 shows the contributions of outputs and inputs to CIT's rate of TFP change between 2019 and 2020.

Figure 5.6 **CIT's output quantity indexes, 2006–2020**

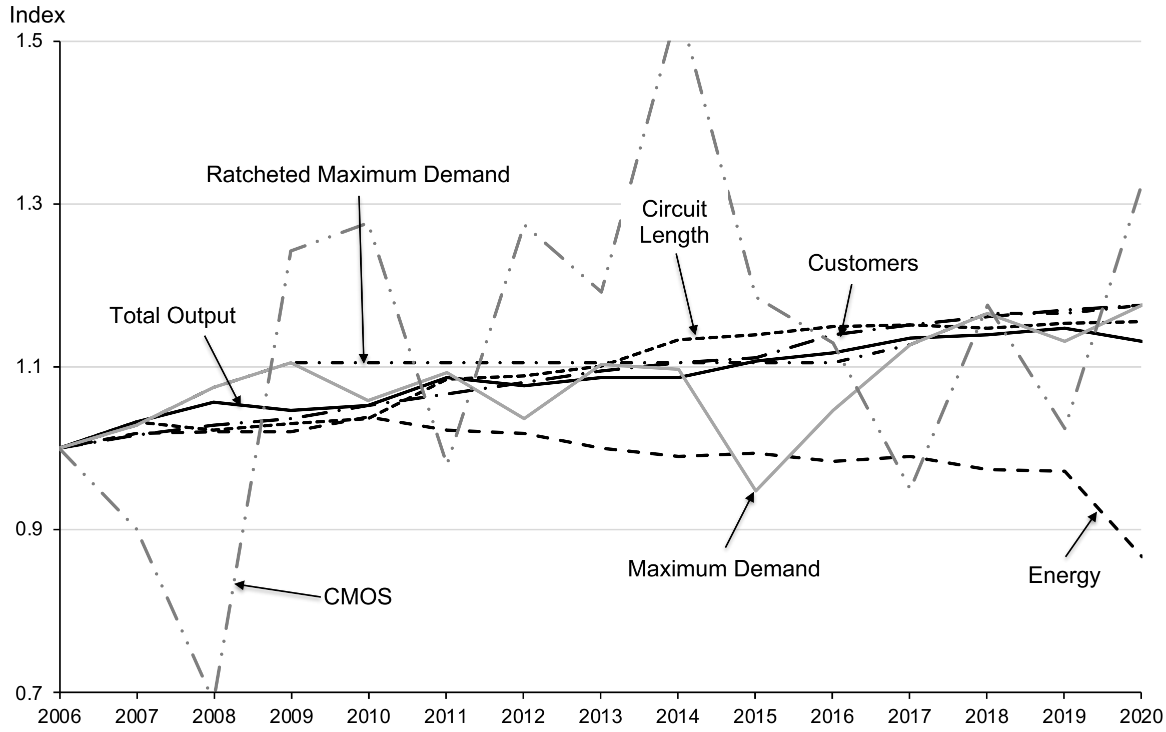


Figure 5.7 **CIT's input quantity indexes, 2006–2020**

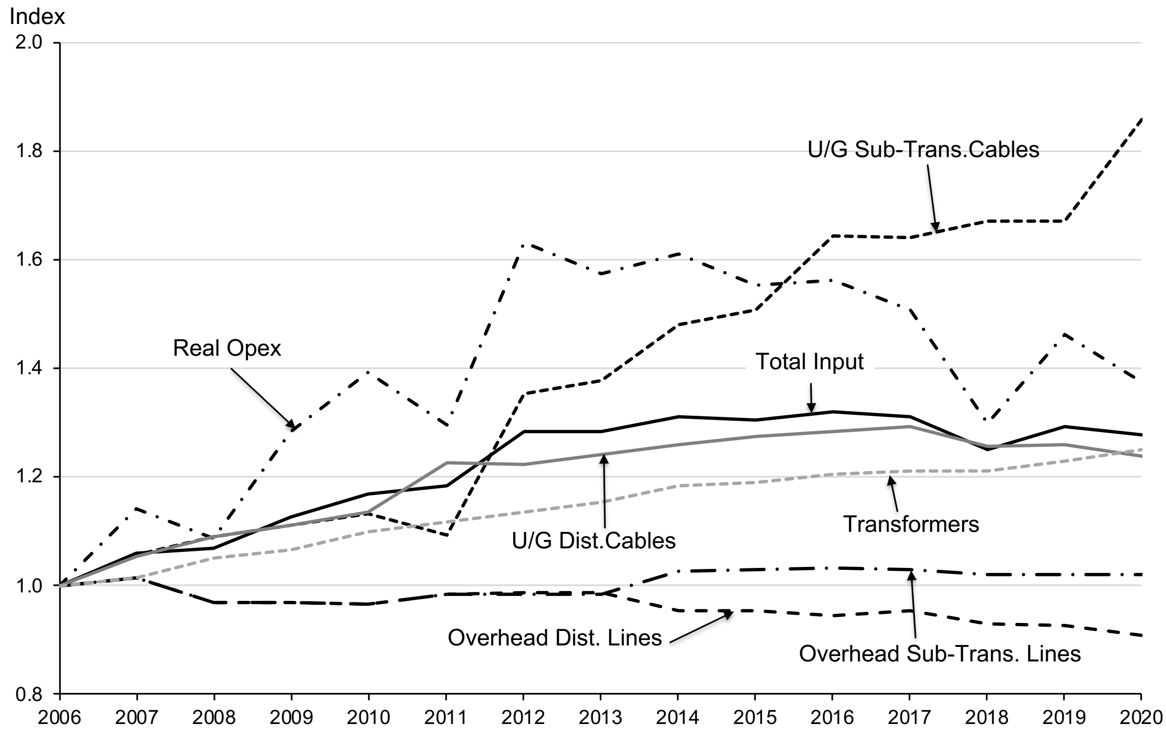
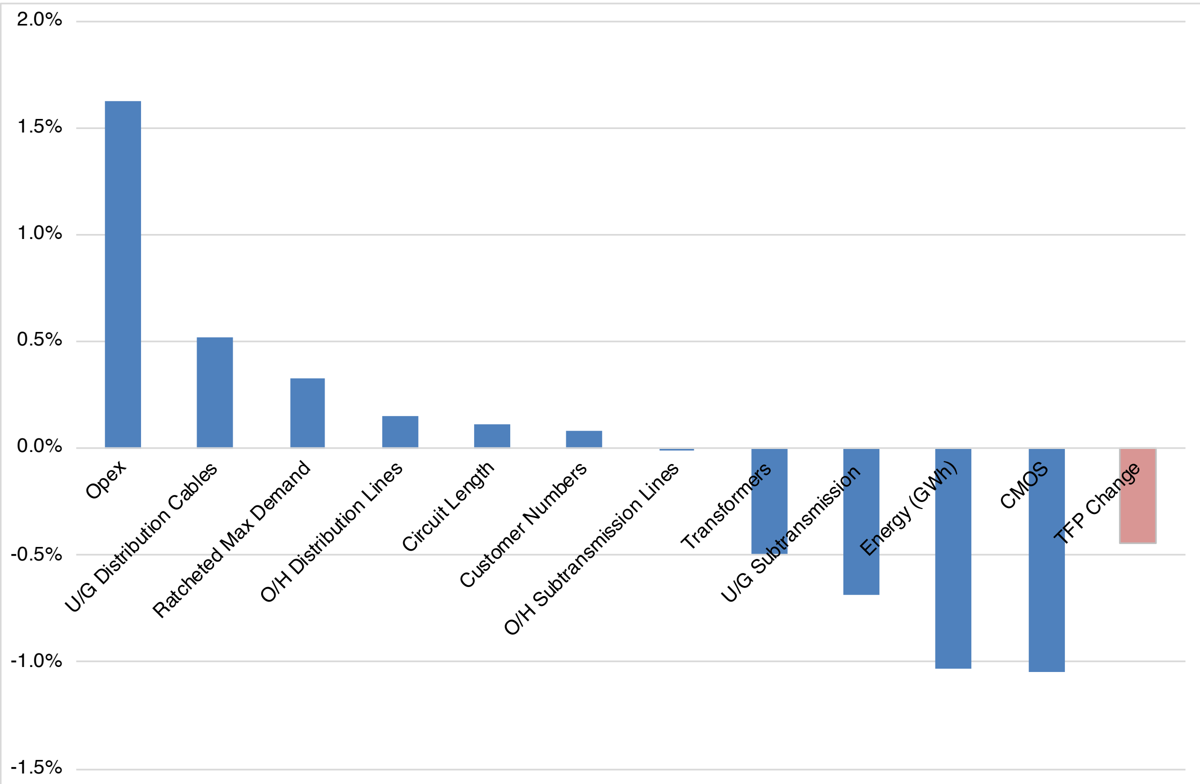


Table 5.4 **CIT's output and input percentage point contributions to average annual TFP change: 2006–2020, 2006–2012, 2012–2020 and 2020**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2019 to 2020*
Energy (GWh)	-0.09%	0.03%	-0.18%	-1.03%
Ratcheted Max Demand	0.41%	0.58%	0.27%	0.33%
Customer Numbers	0.22%	0.25%	0.20%	0.08%
Circuit Length	0.42%	0.58%	0.31%	0.11%
CMOS	-0.08%	-0.19%	0.00%	-1.05%
Opex	-0.56%	-2.12%	0.61%	1.62%
O/H Subtransmission Lines	0.00%	0.00%	0.00%	0.00%
O/H Distribution Lines	0.05%	0.01%	0.07%	0.15%
U/G Subtransmission Cables	-0.29%	-0.33%	-0.26%	-0.69%
U/G Distribution Cables	-0.52%	-1.13%	-0.05%	0.52%
Transformers	-0.43%	-0.59%	-0.32%	-0.49%
TFP Change	-0.88%	-2.91%	0.64%	-0.44%

Figure 5.8 **CIT's output and input percentage point contributions to TFP change, 2020**



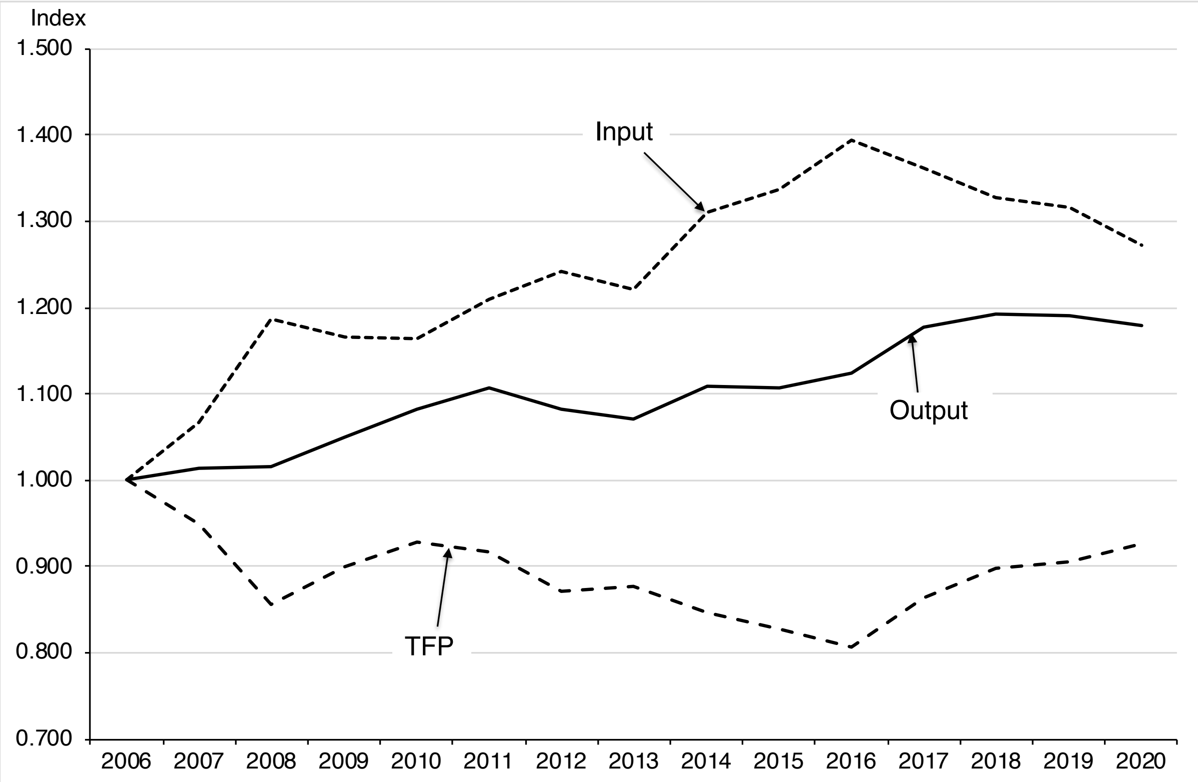
5.3 Endeavour Energy (END)

In 2020, END delivered 16,511 GWh to 1.05 million customers over 38,725 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.

5.3.1 END's productivity performance

END'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 **END's output, input and TFP indexes, 2006–2020**



Over the 15-year period 2006 to 2020, END's TFP decreased at an average annual rate of change of –0.5 per cent, which is similar to the industry's average annual change of –0.6 per cent over the same period. END's total output increased over the same period at an average annual rate of 1.2 per cent, which is similar to the industry average rate of growth in output of 0.9 per cent per annum. END's average annual rate of increase in input use of 1.7 per cent, which is similar to the industry's rate of increase in total input use of 1.6 per cent per year.

END's TFP had an overall declining trend up to 2016, but has since increased steadily. Over the period from 2006 to 2012, the average annual rate of TFP change was –2.3 per cent, and over the period from 2012 to 2020 the average annual rate of TFP change was 0.8 per cent. Again, these trends are broadly similar to those for the industry as a whole.

The rate of output growth in the periods before and after 2012 were similar, whereas the rate of growth of input usage was much higher in the period 2006 to 2012 (averaging 3.6 per cent per year) than in the period 2012 to 2020 (averaging 0.3 per cent per year). The large change in input growth explains the turn-around in the TFP trend.

The partial productivity indexes in table 5.5 show the following trends:

- Capital PFP has declined consistently, at an average rate of –1.7 per cent per year. Although the rate of decline was slightly stronger in the period up to 2012, the decline continued through the period after 2012.
- Opex PFP declined in the period up to 2012, averaging an annual rate of –2.3 per cent, whereas it has increased at a rate of 4.1 per cent per annum after 2012.

Table 5.5 **END's output, input, TFP and PFP indexes, 2006–2020**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.014	1.068	0.950	0.940	0.959
2008	1.015	1.187	0.856	0.771	0.922
2009	1.049	1.166	0.900	0.869	0.923
2010	1.082	1.165	0.929	0.932	0.923
2011	1.107	1.209	0.916	0.908	0.920
2012	1.082	1.242	0.871	0.872	0.869
2013	1.071	1.222	0.876	0.964	0.826
2014	1.109	1.310	0.847	0.884	0.823
2015	1.107	1.337	0.828	0.860	0.808
2016	1.125	1.393	0.808	0.815	0.804
2017	1.177	1.362	0.864	0.930	0.824
2018	1.192	1.328	0.898	1.033	0.819
2019	1.191	1.316	0.905	1.093	0.802
2020	1.179	1.272	0.927	1.211	0.785
Growth Rate 2006-2020	1.2%	1.7%	-0.5%	1.4%	-1.7%
Growth Rate 2006-2012	1.3%	3.6%	-2.3%	-2.3%	-2.3%
Growth Rate 2012-2020	1.1%	0.3%	0.8%	4.1%	-1.3%
Growth Rate 2020	-1.0%	-3.4%	2.4%	10.3%	-2.2%

5.3.2 END's output and input quantity changes

Figure 5.10 graphs the quantity indexes for END's individual outputs. Figure 5.11 graphs quantity indexes for its six individual inputs. Regarding outputs:

- END's circuit length (which is the output with the largest weight in the output index) has increased steadily at an average rate of 1.3 per cent per annum from 2006 to 2020, and by 2020 was 19.4 per cent above the 2006 level (which is higher than the total increase of 4.9 per cent for the industry over the same period).

- END's energy throughput decreased marginally over the 15-year period, at an average annual rate of –0.3 per cent per year, which is the same rate decline as for the industry over the same period. In 2020, END's energy throughput was 4.0 per cent below its level in 2006.
- RMD increased from 2006 though to 2011 by 10.1 per cent in total and then increased further in 2017, so that by 2020, RMD was 15.0 per cent above its 2006 level. This pattern is similar to the industry as a whole, reflecting an increase in the ratio of maximum demand to energy throughput in recent years. On average END's RMD increased at an annual rate of 1.0 per cent between 2006 and 2020.
- END's customers increased at an average rate of 1.5 per cent per annum from 2006 to 2020, or 23.5 per cent in total, which is similar to the average rate of customer growth for the industry over the same period (1.3 per cent per annum, or 20.8 per cent in total).
- CMOS increased in 2020 by 13.4 per cent, and was in 2020 8.7 per cent higher than in 2006. On average over the period from 2006 to 2020, CMOS changed at an annual rate of 0.6 per cent, which exceeded the industry's average rate of –0.1 per cent. Recall that an increase in CMOS reduces output.

Turning to inputs shown in figure 5.11, we see:

- The quantity of END's opex *decreased* at an average annual rate of 0.2 per cent over the period from 2006 to 2020. By 2020, opex input was 2.7 per cent below its 2006 level. This compares favourably to the industry, for which opex input increased by 9.2 per cent in total over the same period. END's opex decrease was the net effect of an increase in the period 2006 to 2012, averaging 3.6 per cent per annum, and a decrease after 2012, at an average rate of –3.0 per cent per annum.
- Overhead subtransmission and distribution lines in 2020 were 2.4 per cent higher and 3.6 per cent *lower* respectively, than in 2006. These inputs did not change substantially, unlike the industry increases of 14.3 per cent and 11.7 per cent respectively over the same period.
- END's underground subtransmission and distribution cables were, in 2020, 127.4 and 114.3 per cent higher than in 2006 respectively. These increases are much higher than those for the industry as a whole, namely 38.3 per cent and 63.7 per cent respectively for these two inputs.
- END's quantity of transformers increased steadily over the 15-year period at an average annual rate of 2.7 per cent, and by 2020, transformer inputs were 46.8 per cent above the 2006 level, which is a larger increase than the industry's 40.8 per cent.

5.3.3 END's output and input contributions to TFP change

Table 5.6 shows the decomposition of END's rate of TFP change into the contributions of the individual outputs and inputs for the whole 15-year period and for the periods up to and after 2012. Figure 5.12 shows the contributions of outputs and inputs to END's rate of TFP change between 2019 and 2020.

Figure 5.10 **END's output quantity indexes, 2006–2020**

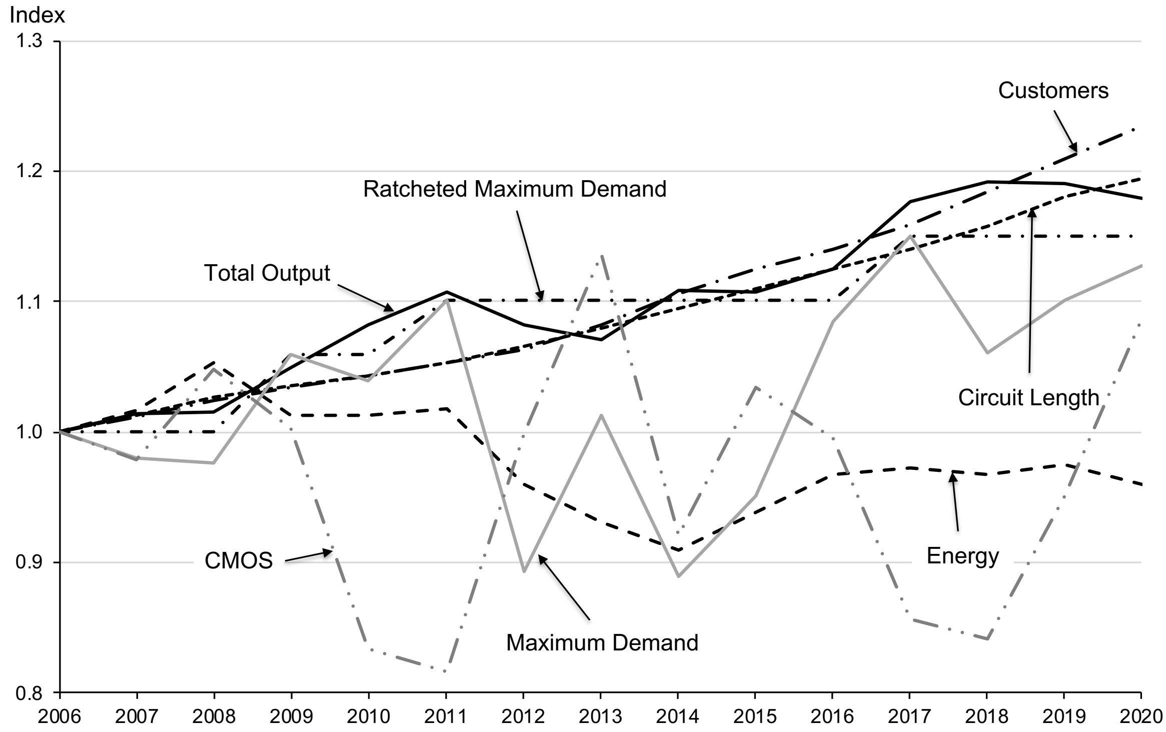


Figure 5.11 **END's input quantity indexes, 2006–2020**

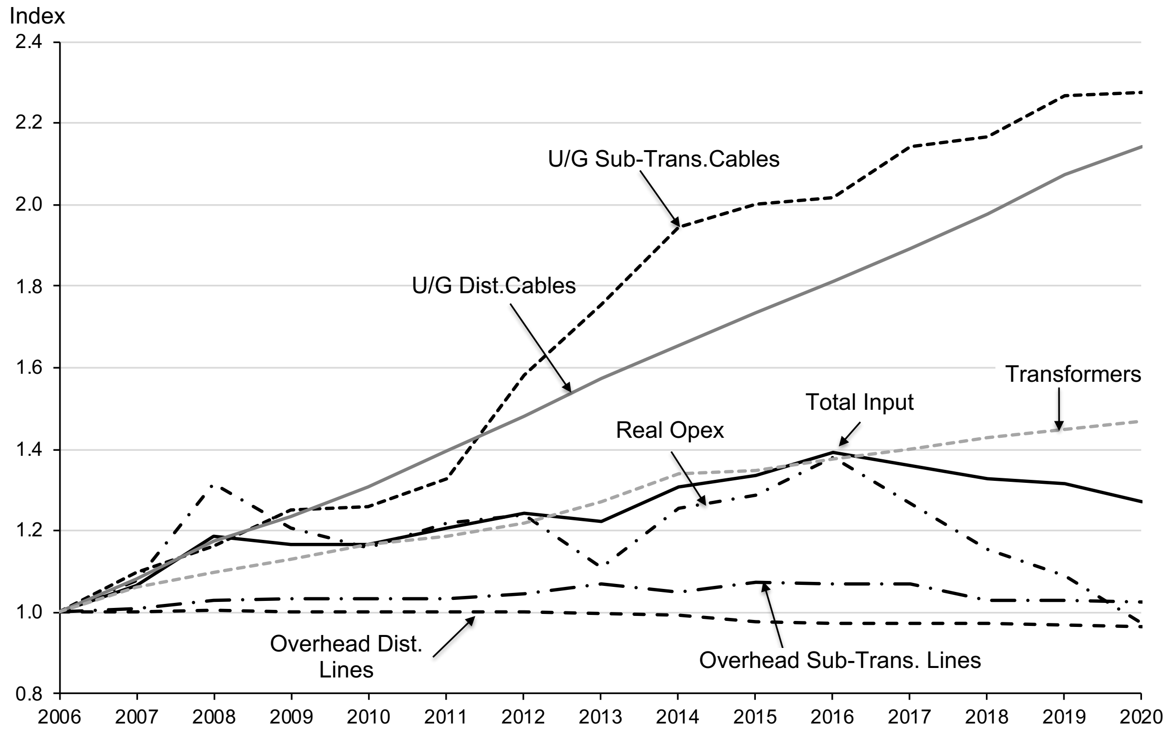
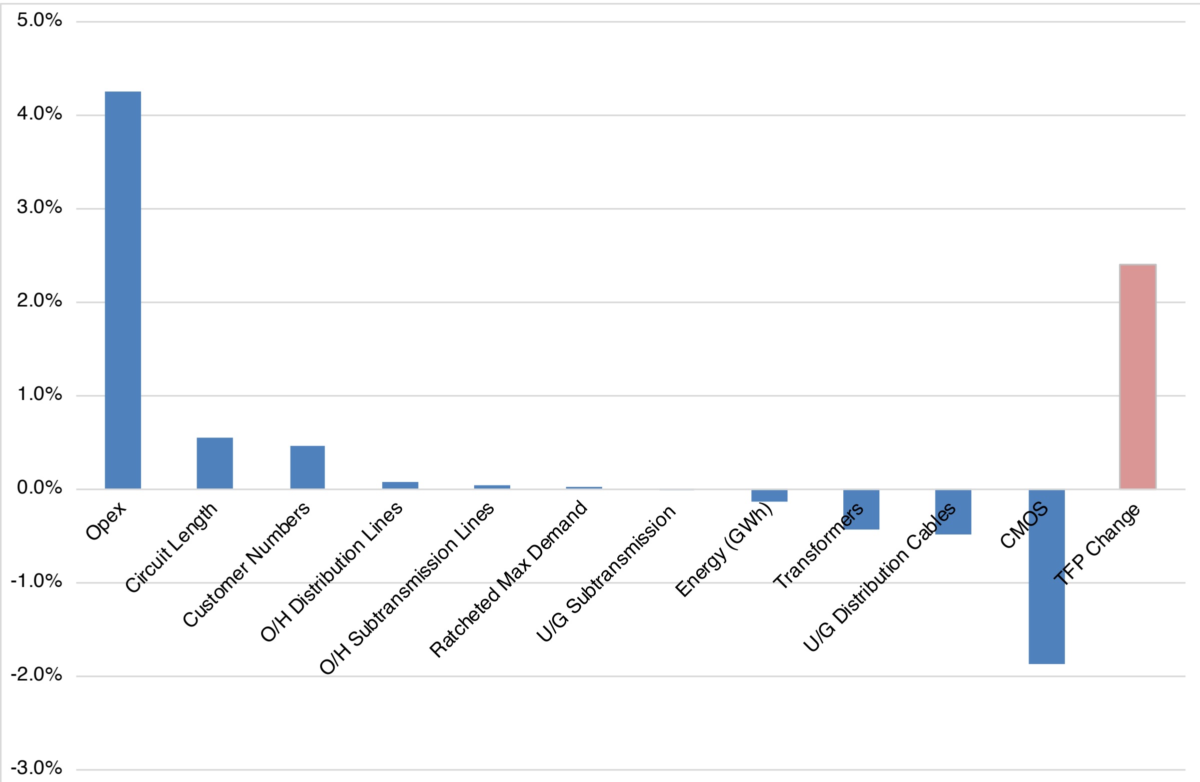


Table 5.6 **END's output and input percentage point contributions to average annual TFP change: 2006–2020, 2006–2012, 2012–2020, and 2020**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2019 to 2020*
Energy (GWh)	-0.03%	-0.07%	0.00%	-0.15%
Ratcheted Max Demand	0.39%	0.63%	0.21%	0.02%
Customer Numbers	0.32%	0.23%	0.39%	0.46%
Circuit Length	0.57%	0.49%	0.63%	0.55%
CMOS	-0.08%	0.03%	-0.16%	-1.88%
Opex	0.05%	-1.42%	1.16%	4.24%
O/H Subtransmission Lines	0.00%	-0.03%	0.01%	0.04%
O/H Distribution Lines	0.03%	0.00%	0.05%	0.07%
U/G Subtransmission Cables	-0.11%	-0.13%	-0.09%	-0.02%
U/G Distribution Cables	-0.90%	-1.09%	-0.75%	-0.49%
Transformers	-0.79%	-0.95%	-0.67%	-0.44%
TFP Change	-0.54%	-2.31%	0.78%	2.40%

Figure 5.12 **END's output and input percentage point contributions to TFP change, 2020**



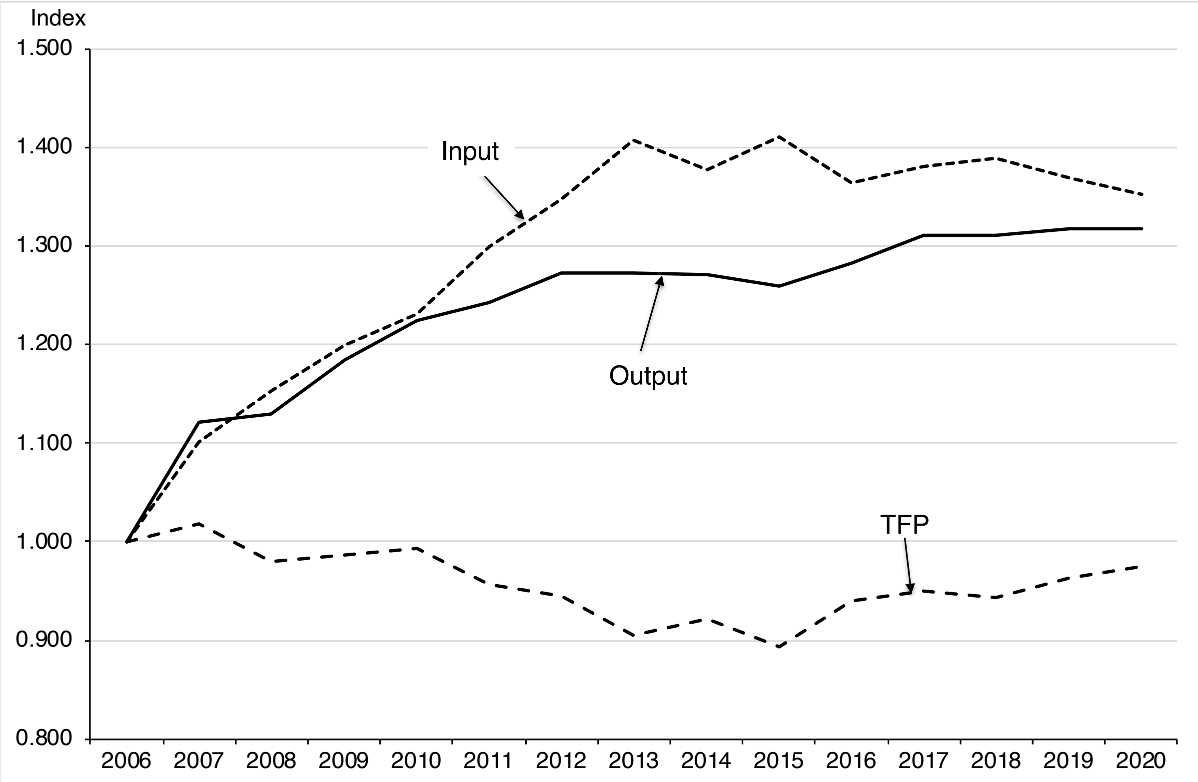
5.4 Energex (ENX)

In 2020, ENX delivered 21,141 GWh to 1.52 million customers over 55,190 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.

5.4.1 ENX's productivity performance

ENX'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 **ENX's output, input and TFP indexes, 2006–2020**



Over the whole period from 2006 to 2020, ENX's TFP decreased only slightly, at an average annual rate of change of –0.2 per cent. This can be compared to the industry's average annual change of –0.6 per cent over the same period. As figure 5.13 shows, ENX's TFP decreased significantly in the first half of the period and increased in the second half. In the period 2006 to 2012, ENX's TFP changed annually on average at –0.9 per cent. From 2012 to 2020, ENX's TFP increased at an average rate of 0.4 per cent per year.

While for many DNSPs, shifts in trends on the input side were the major influence on shifts in TFP trends, for ENX there were important changes in both output and input trends before and after 2012. ENX's total output increased at an average rate of 4.0 per cent per annum up to 2012, and by just 0.4 per cent per annum after 2012 – and averaging 2.0 per cent per annum over the whole 15-year period, which is higher than that for the industry of 0.9 per cent per annum. ENX's inputs increased at an average rate of 5.0 per cent per annum over the period from 2006 to 2012, and by zero from 2012 to 2020 – and increasing on average by 2.2 per cent per annum over the whole 15-year period, which is higher than the industry's average input increase of 1.6 per cent per annum. These trends resulted in ENX's TFP decreasing in the first half of the period (an average rate of change of –0.9 per cent per year) and increasing in the second half (an average rate of change of 0.4 per cent per year).

The partial productivity indexes in table 5.7 show the following trends:

- Capital PFP declined on average rate of –0.7 per cent per year from 2006 to 2020, although this decline has been concentrated in the period after 2012.
- Opex PFP declined in the period up to 2012, averaging an annual rate of –2.7 per cent, whereas it has increased at a rate of 3.2 per cent per annum after 2012. On average over the full period, opex PFP increased at an average annual rate of 0.6 per cent, which partially offset the effect of declining Capital PFP on TFP.

Table 5.7 **ENX's output, input, TFP and PFP indexes, 2006–2020**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.121	1.101	1.018	0.964	1.049
2008	1.129	1.152	0.980	0.932	1.010
2009	1.184	1.200	0.987	0.941	1.013
2010	1.224	1.231	0.994	0.961	1.013
2011	1.243	1.299	0.957	0.889	0.998
2012	1.273	1.347	0.945	0.850	0.998
2013	1.272	1.406	0.905	0.794	0.976
2014	1.271	1.378	0.922	0.864	0.959
2015	1.259	1.410	0.893	0.839	0.924
2016	1.283	1.363	0.941	0.961	0.929
2017	1.311	1.381	0.950	0.978	0.935
2018	1.311	1.388	0.944	0.974	0.927
2019	1.317	1.368	0.963	1.037	0.924
2020	1.317	1.352	0.974	1.095	0.912
Growth Rate 2006-2020	2.0%	2.2%	-0.2%	0.6%	-0.7%
Growth Rate 2006-2012	4.0%	5.0%	-0.9%	-2.7%	0.0%
Growth Rate 2012-2020	0.4%	0.0%	0.4%	3.2%	-1.1%
Growth Rate 2020	0.0%	-1.2%	1.2%	5.4%	-1.3%

5.4.2 ENX's output and input quantity changes

Figure 5.14 graphs the quantity indexes for ENX's individual outputs. Figure 5.15 graphs quantity indexes for its six individual inputs. Regarding outputs:

- ENX's circuit length increased steadily at an average rate of 1.2 per cent per annum from 2006 to 2020, and by 2020 was 18.3 per cent above the 2006 level (which is higher than the total increase of 4.9 per cent for the industry over the same period). Circuit length is the output with the largest weight in the output index.

- ENX's energy throughput increased marginally over the 15-year period, at an average annual rate of 0.2 per cent per year (compared to a marginal decline for the industry over the same period). In 2020, ENX's energy throughput was 2.5 per cent above its 2006 level.
- On average ENX's RMD increased at an annual rate of 1.7 per cent between 2006 and 2020. RMD increased strongly from 2006 through to 2010, by 25.4 per cent in total, and the only subsequent increase was in 2020, taking RMD to 26.3 per cent above its level in 2006. This pattern is similar to the industry as a whole, where there has been a general increase in the ratio of maximum demand to energy delivered since about 2014.
- ENX's customers increased at an average rate of 1.6 per cent per annum from 2006 to 2020, or 25.1 per cent in total, which is similar to the average rate of customer growth for the industry over the same period (1.3 per cent per annum, or 20.8 per cent in total).
- CMOS decreased over the 15-year period, averaging a rate of change of –2.4 per cent annually. The average rate of change in CMOS over the period to 2012 was –9.8 per cent, and the average rate of change after 2012 was 3.2 per cent. By 2020, ENX's CMOS was 28.5 per cent *below* its 2006 level. This decrease contributed to the increase of output.

Turning to inputs shown in figure 5.15, we see:

- The quantity of ENX's opex increased at an average annual rate of 1.3 per cent over the period from 2006 to 2020. By 2020, opex input was 20.3 per cent above its 2006 level. This compares unfavourably to the industry, for which opex input increased by 9.2 per cent in total over the same period. ENX's opex increased strongly in the period 2006 to 2012, at an average rate of 6.7 per cent per annum, and it decreased after 2012 at an average rate of –2.7 per cent per annum.
- Overhead sub-transmission and distribution lines in 2020 were 21.3 per cent and 2.6 per cent *higher* respectively, than in 2006. These changes compare to the industry increases of 14.3 per cent and 11.7 per cent respectively over the same period.
- ENX's underground sub-transmission and distribution cables were, in 2020, 97.7 and 83.0 per cent higher than in 2006 respectively. These increases are much higher than those for the industry as a whole, namely 38.3 per cent and 63.7 per cent respectively over the same period.
- ENX's quantity of transformer inputs increased steadily over the 15-year period at an average annual rate of 2.8 per cent, and by 2020, transformer inputs were 47.8 per cent above the 2006 level, which is a larger increase than the industry's 40.8 per cent.

5.4.3 ENX's output and input contributions to TFP change

Table 5.8 shows the decomposition of ENX's rate of TFP change into the contributions of the individual outputs and inputs for the whole 15-year period and for the periods up to and after 2012. Figure 5.16 shows the contributions of outputs and inputs to ENX's rate of TFP change between 2019 and 2020.

Figure 5.14 **ENX's output quantity indexes, 2006–2020**

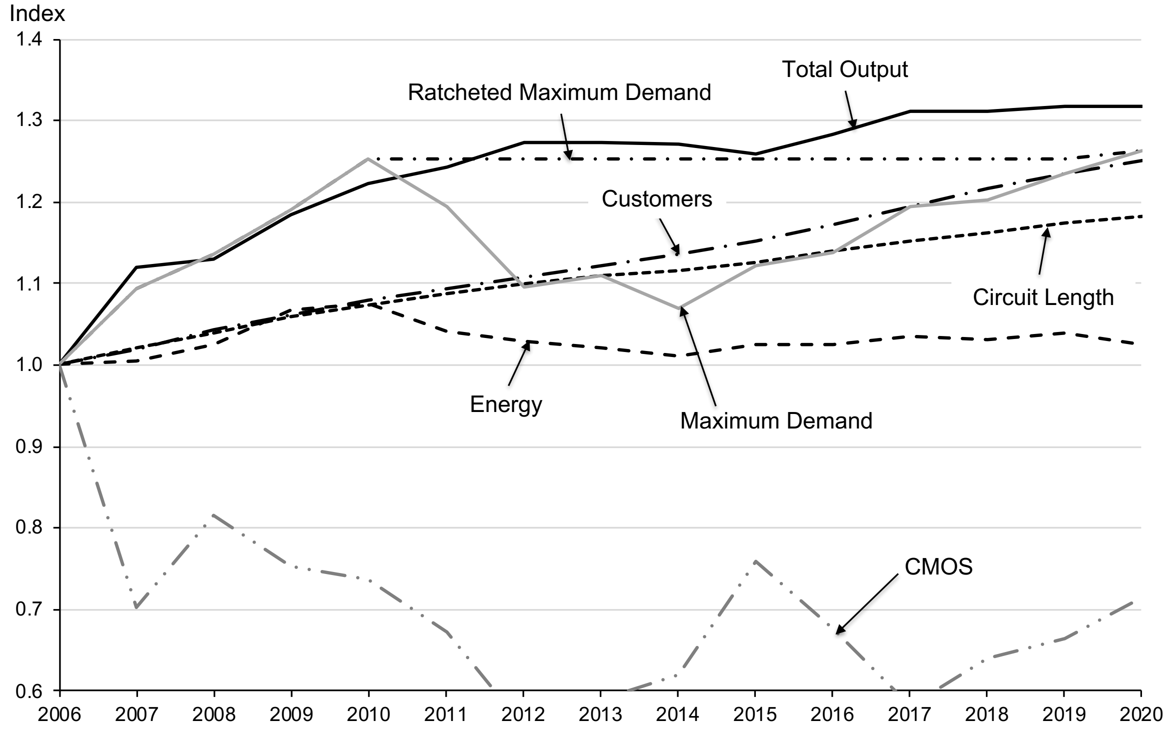


Figure 5.15 **ENX's input quantity indexes, 2006–2020**

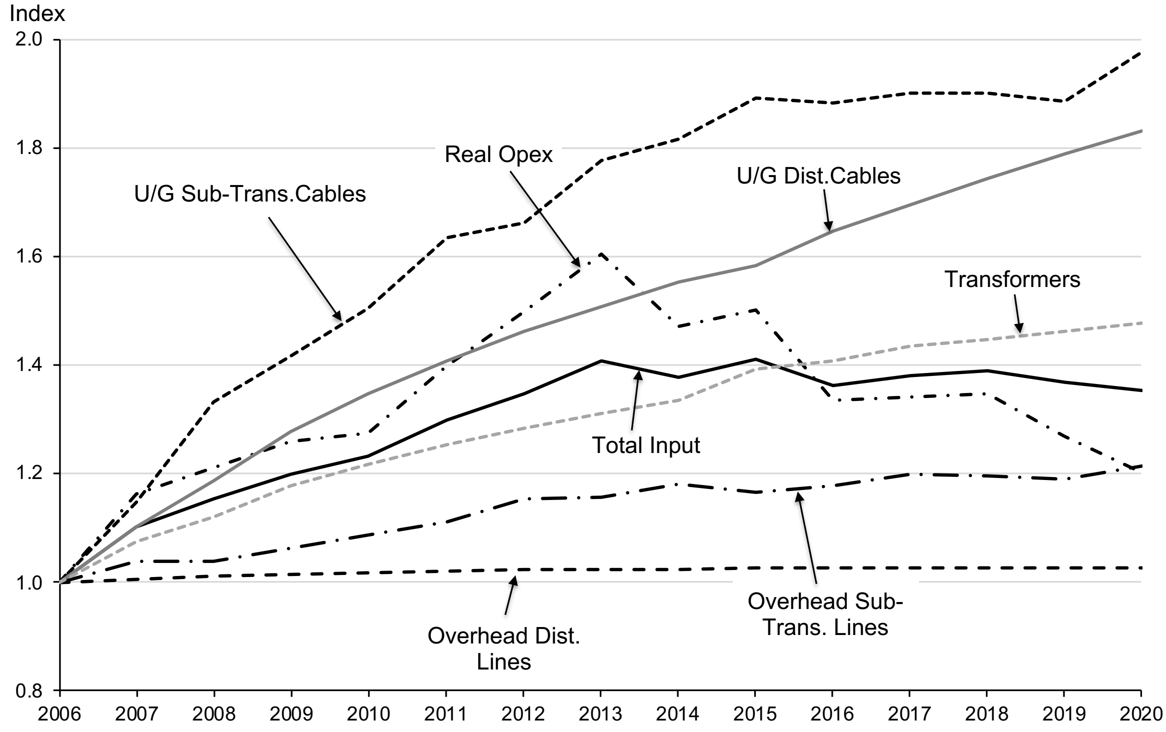
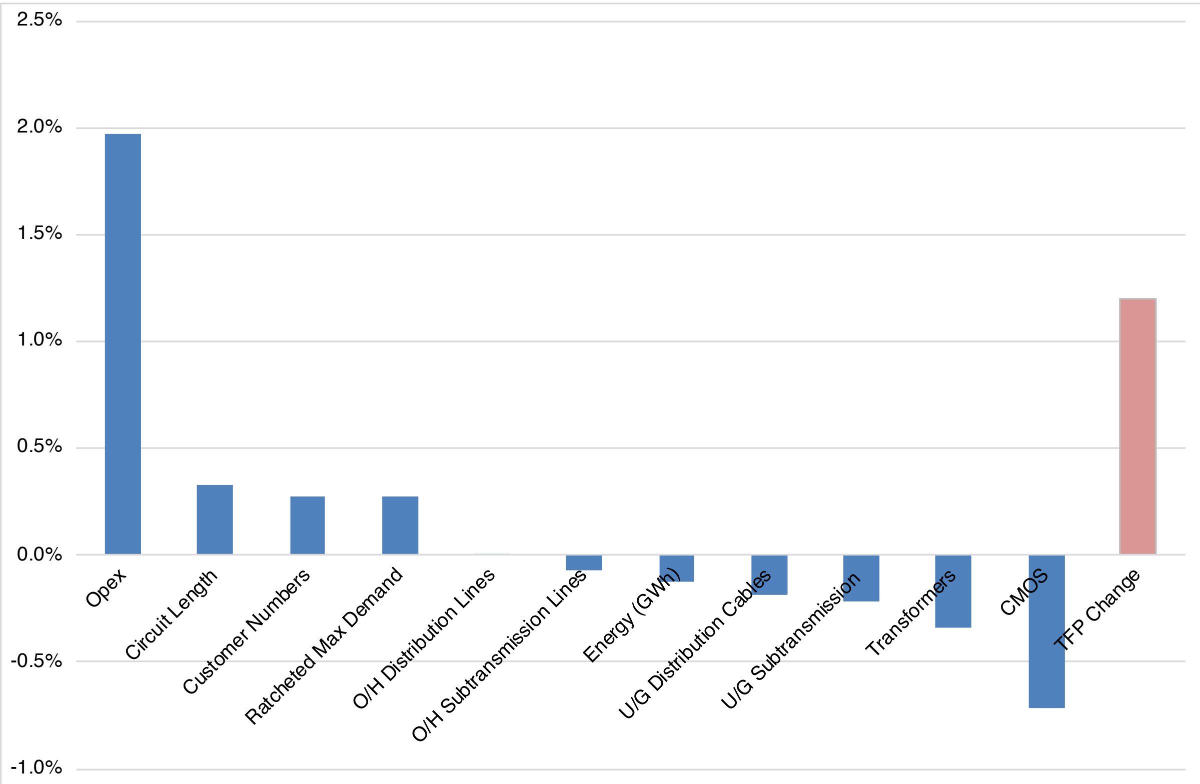


Table 5.8 **ENX's output and input percentage point contributions to average annual TFP change: 2006–2020, 2006–2012, 2012–2020, 2020**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2019 to 2020*
Energy (GWh)	0.02%	0.05%	0.00%	-0.13%
Ratcheted Max Demand	0.65%	1.48%	0.03%	0.27%
Customer Numbers	0.34%	0.38%	0.31%	0.27%
Circuit Length	0.54%	0.73%	0.39%	0.33%
CMOS	0.43%	1.39%	-0.30%	-0.71%
Opex	-0.47%	-2.38%	0.95%	1.97%
O/H Subtransmission Lines	-0.05%	-0.08%	-0.02%	-0.07%
O/H Distribution Lines	-0.02%	-0.05%	-0.01%	0.00%
U/G Subtransmission Cables	-0.22%	-0.38%	-0.10%	-0.21%
U/G Distribution Cables	-0.51%	-0.75%	-0.33%	-0.19%
Transformers	-0.88%	-1.33%	-0.54%	-0.34%
TFP Change	-0.19%	-0.94%	0.38%	1.20%

Figure 5.16 **ENX's output and input percentage point contributions to TFP change in 2020**



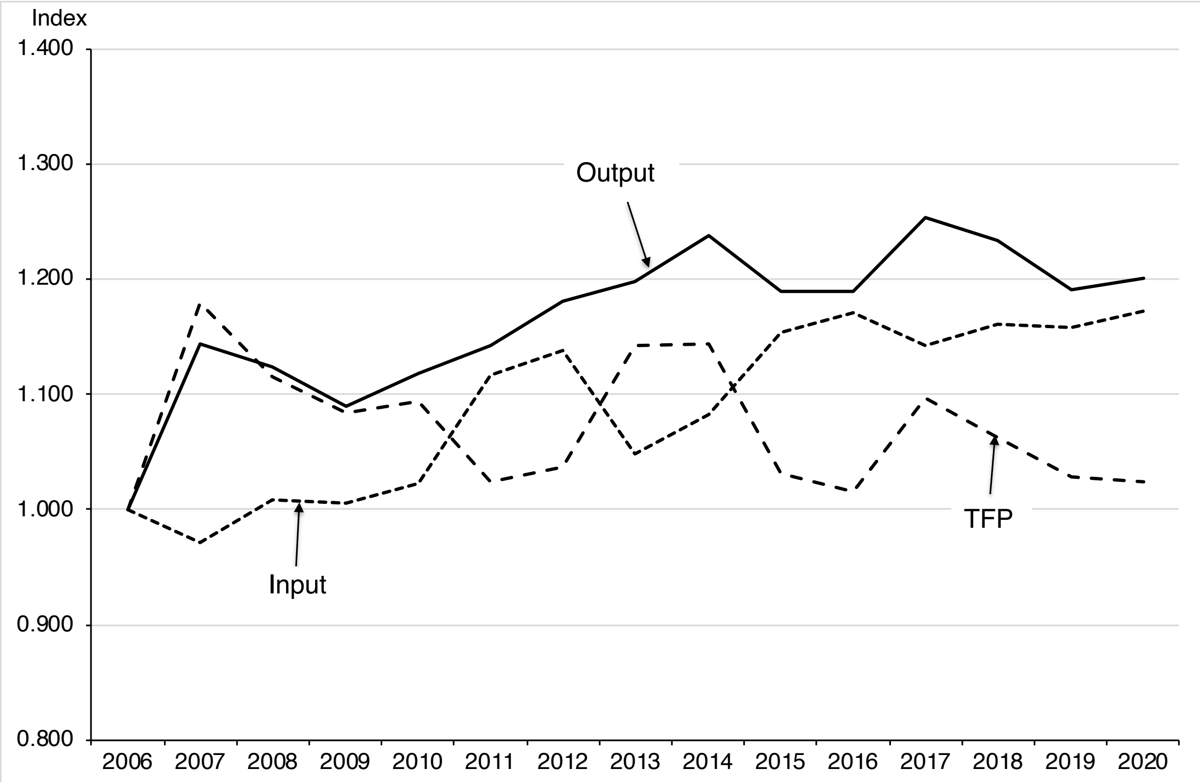
5.5 Ergon Energy (ERG)

In 2020, ERG delivered 13,567 GWh to 762,303 customers over 152,896 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.

5.5.1 ERG's productivity performance

ERG'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 **ERG's output, input and total factor productivity indexes, 2006–2020**



Over the 15-year period 2006 to 2020, ERG's TFP increased marginally, at an average annual rate of change of 0.2 per cent. This compares favourably to the industry's average annual TFP change of –0.6 per cent over the same period. In some years there have been large increases in ERG's TFP, such as 2007, 2013 and 2017. Some other years have seen substantial decreases, including 2008, 2011 and 2015.

ERG's total output increased over the 15-year period at an average annual rate of 1.3 per cent. This is higher than the industry average rate of growth in output of 0.9 per cent per annum. ERG's average annual rate of increase in input use of 1.1 per cent over the 15-year period was slightly lower than the rate of increase in total input use for the industry (1.6 per cent per year). The higher output growth and lower input growth compared to the industry resulted in the more favourable TFP outcome.

The rates of growth of output and input usage were both much higher in the period 2006 to 2012 (averaging 2.8 and 2.2 per cent per year respectively) than in the period 2012 to 2020 (where they averaged 0.2 and 0.4 per cent per year respectively). The average rate of TFP change from 2006 to 2012 was 0.6 per cent per year, while after 2012 the rate of decline was at –0.2 per cent per annum.

The partial productivity indexes in table 5.9 show that Opex PFP has improved at an average annual rate of 1.2 per cent over the 15-year period. Capital PFP improved in the period from 2006 to 2012, and an average annual rate of 0.4 per cent, but deteriorated after 2012; with an average rate of change of –1.1 per cent per annum.

Table 5.9 **ERG's output, input, TFP and PFP indexes, 2006–2020**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.144	0.971	1.179	1.285	1.116
2008	1.124	1.008	1.115	1.179	1.079
2009	1.090	1.006	1.083	1.185	1.023
2010	1.118	1.022	1.094	1.242	1.013
2011	1.143	1.116	1.024	1.032	1.014
2012	1.180	1.138	1.037	1.044	1.022
2013	1.197	1.049	1.142	1.333	1.043
2014	1.238	1.082	1.144	1.372	1.027
2015	1.189	1.153	1.031	1.144	0.967
2016	1.190	1.171	1.016	1.137	0.948
2017	1.253	1.143	1.096	1.329	0.980
2018	1.233	1.160	1.063	1.274	0.954
2019	1.191	1.158	1.028	1.222	0.927
2020	1.200	1.172	1.024	1.188	0.934
Growth Rate 2006-2020	1.3%	1.1%	0.2%	1.2%	-0.5%
Growth Rate 2006-2012	2.8%	2.2%	0.6%	0.7%	0.4%
Growth Rate 2012-2020	0.2%	0.4%	-0.2%	1.6%	-1.1%
Growth Rate 2020	0.8%	1.2%	-0.4%	-2.9%	0.8%

5.5.2 ERG's output and input quantity changes

Figure 5.18 graphs the quantity indexes for ERG's individual outputs. Figure 5.19 graphs quantity indexes for its six individual inputs. Regarding outputs:

- ERG's circuit length increased marginally, at an average annual rate of 0.2 per cent from 2006 to 2020, and by 2020 was 3.1 per cent above the 2006 level (compared to a total increase of 4.9 per cent for the industry over the same period). Circuit length is the output with the largest weight in the output index.
- ERG's energy throughput did not increase over the 15-year period, with an average annual increase of zero per cent (compared to a marginal decline for the industry over the same period). In 2020, ERG's energy throughput was 0.1 per cent above its 2006 level.
- On average ERG's RMD increased at an annual rate of 1.0 per cent between 2006 and 2020. RMD increased from 2006 through to 2010 by 15.5 per cent in total, and did not increase further in the remainder of the period. Maximum demand did not again reach its 2010 level.

- ERG's customers increased at an average rate of 1.4 per cent per annum from 2006 to 2020, or 22.1 per cent in total, which is similar to the average rate of customer growth for the industry over the same period (1.3 per cent per annum, or 20.8 per cent in total).
- CMOS decreased over the 15-year period, averaging a rate of change of –1.0 per cent annually. The average rate of change in CMOS over the period to 2012 was –2.3 per cent, and the average rate of change after 2012 was zero. By 2020, ENX's CMOS was 13.0 per cent *below* its 2006 level. This decrease contributed to the increase of output.

Turning to inputs shown in figure 5.19, we see:

- The quantity of ERG's opex increased at an average annual rate of 0.1 per cent over the period from 2006 to 2020. By 2020, opex input was 1.0 per cent above its 2006 level. This compares favourably to the industry, for which opex input increased by 9.2 per cent in total over the same period. ERG's opex increased in the period 2006 to 2012, at an average rate of 2.0 per cent per annum, and it decreased after 2012 at an average rate of –1.4 per cent per annum.
- Overhead sub-transmission and distribution lines in 2020 were 2.2 per cent and 13.8 per cent higher respectively, than in 2006. These changes compare to the industry increases of 14.3 per cent and 11.7 per cent respectively over the same period.
- ERG's underground sub-transmission and distribution cables were, in 2020, 75.4 and 104.7 per cent higher than in 2006 respectively. These increases are higher than those for the industry as a whole, namely 38.3 per cent and 63.7 per cent respectively over the same period.
- ERG's quantity of transformer inputs increased steadily over most of the 15-year period, plateauing in the period from 2017 to 2020. The average annual rate of change over the 15-year period was 2.6 per cent, and by 2020, transformer inputs were 43.7 per cent above the 2006 level, which is similar to the industry's 40.8 per cent. Transformers is the input with the largest weight in the capital input index.

5.5.3 ERG's output and input contributions to TFP change

Table 5.10 shows the decomposition of ERG's rate of TFP change into the contributions of the individual outputs and inputs for the whole 15-year period and for the periods up to and after 2012. Figure 5.20 shows the contributions of outputs and inputs to ERG's rate of TFP change between 2019 and 2020.

Figure 5.18 **ERG's output quantity indexes, 2006–2020**

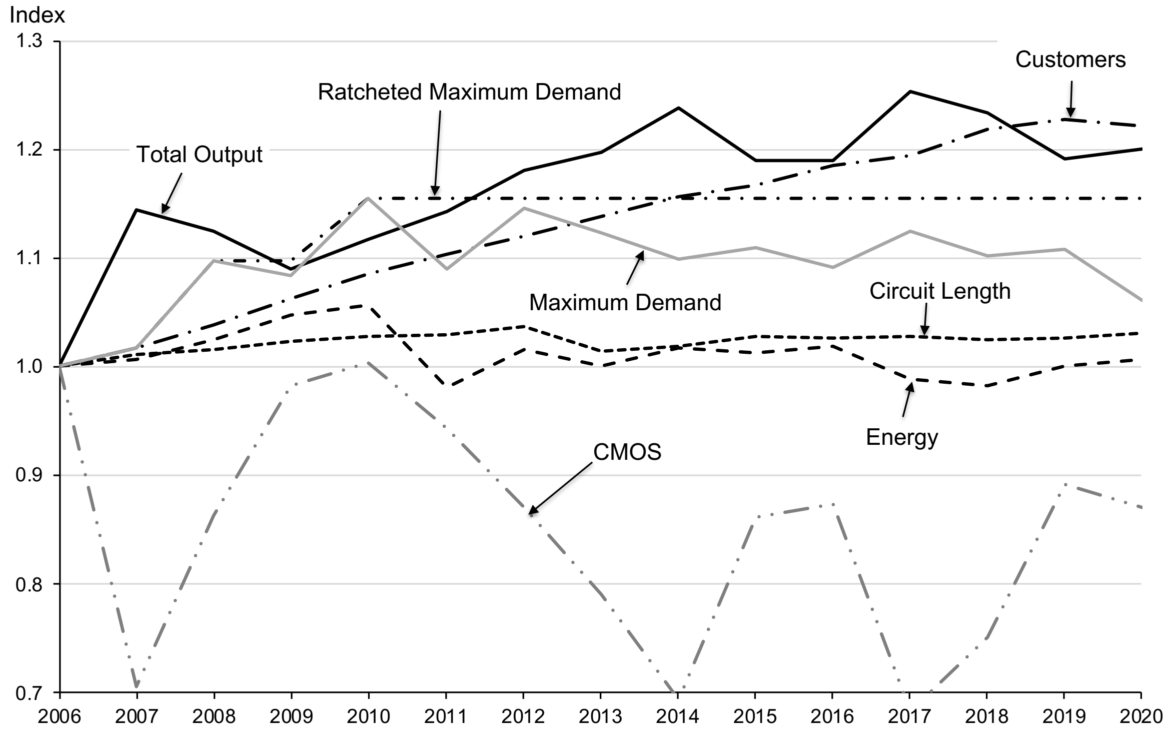


Figure 5.19 **ERG's input quantity indexes, 2006–2020**

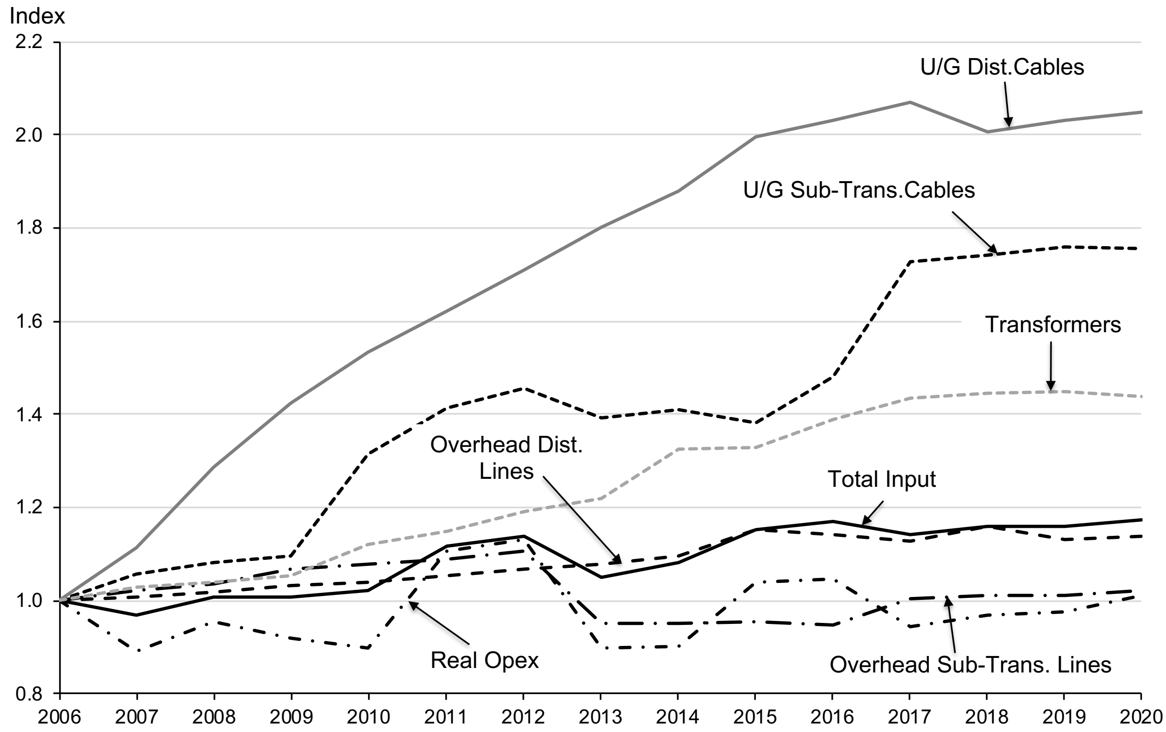
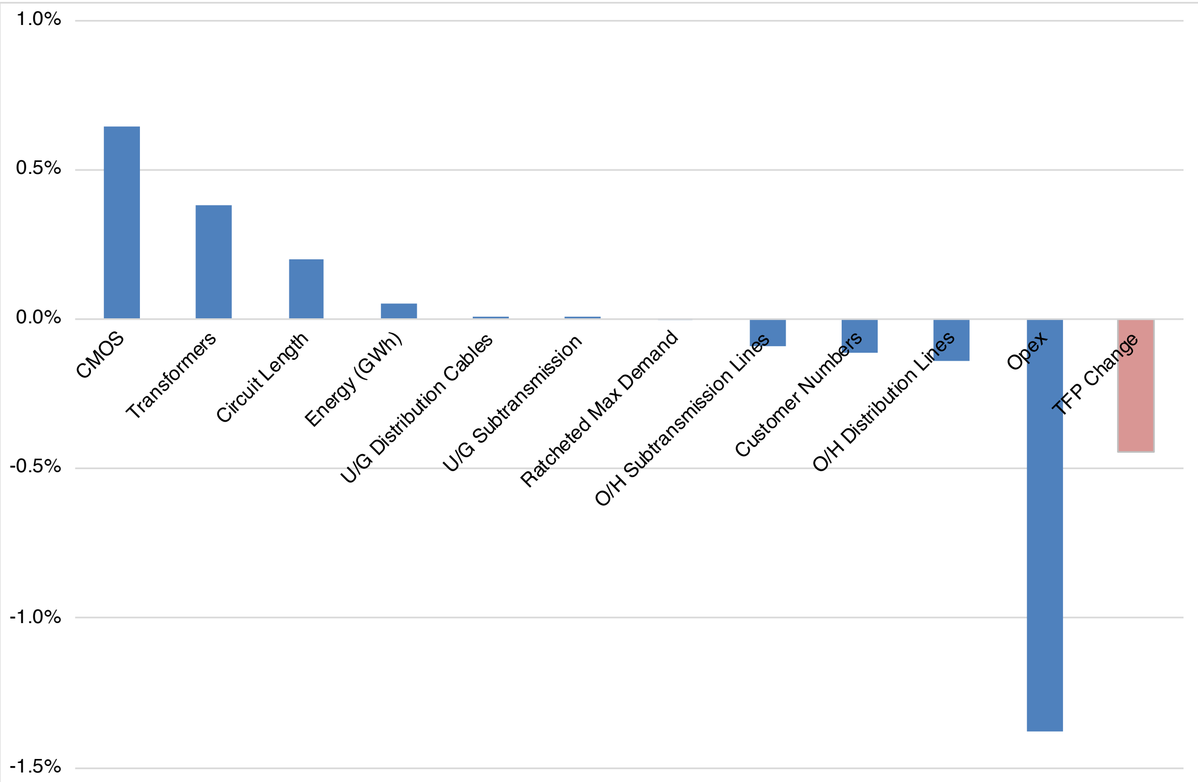


Table 5.10 **ERG's output and input percentage point contributions to average annual TFP change: 2006–2020, 2006–2012, 2012–2020, 2020**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2019 to 2020*
Energy (GWh)	0.01%	0.03%	-0.01%	0.05%
Ratcheted Max Demand	0.46%	1.08%	0.00%	0.00%
Customer Numbers	0.35%	0.48%	0.25%	-0.11%
Circuit Length	0.11%	0.31%	-0.03%	0.20%
CMOS	0.37%	0.87%	0.00%	0.64%
Opex	-0.03%	-0.67%	0.46%	-1.38%
O/H Subtransmission Lines	-0.01%	-0.17%	0.10%	-0.09%
O/H Distribution Lines	-0.20%	-0.22%	-0.17%	-0.14%
U/G Subtransmission Cables	-0.02%	-0.02%	-0.01%	0.00%
U/G Distribution Cables	-0.16%	-0.28%	-0.07%	0.01%
Transformers	-0.72%	-0.79%	-0.67%	0.38%
TFP Change	0.17%	0.60%	-0.16%	-0.44%

Figure 5.20 **ERG's output and input percentage point contributions to TFP change, 2020**



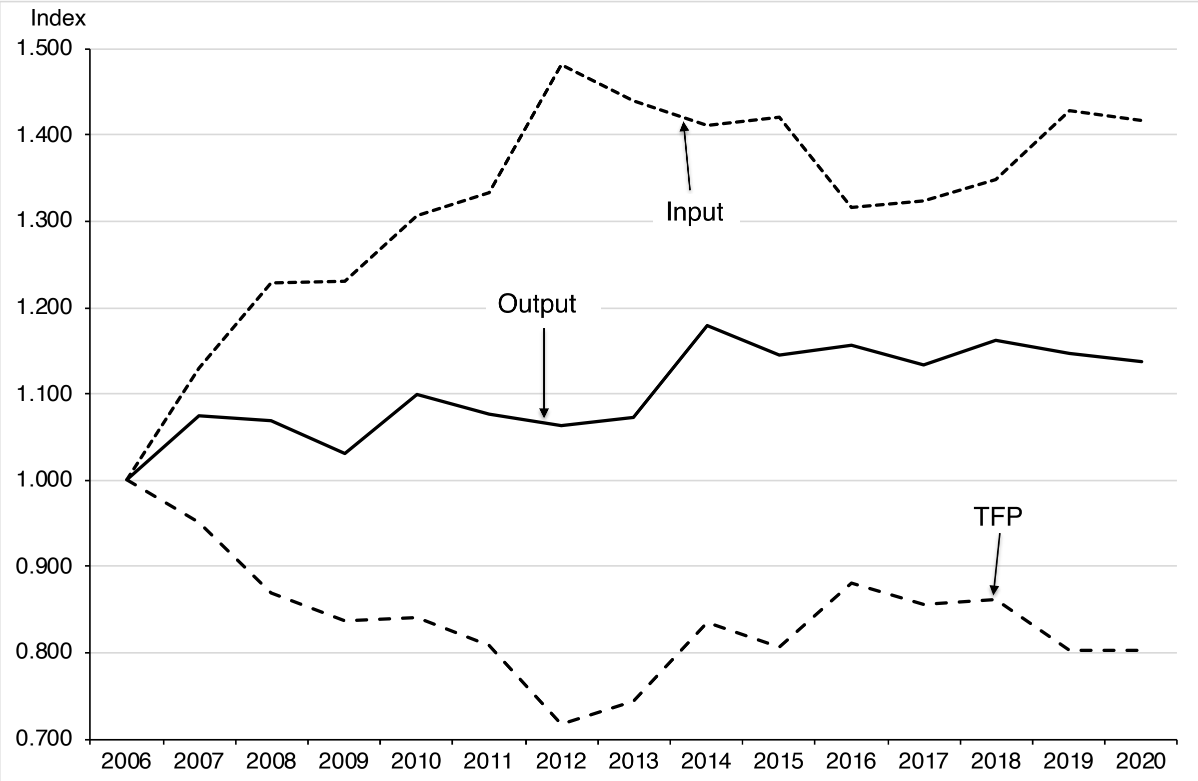
5.6 Essential Energy (ESS)

In 2020, ESS delivered 12,450 GWh to 925,966 customers over 192,685 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 fourth largest NEM DNSP in terms of customer numbers but by far the largest in terms of network length.

5.6.1 ESS's productivity performance

ESS'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 **ESS's output, input and TFP indexes, 2006–2020**



Over the 15-year period 2006 to 2020, ESS's TFP decreased at an average annual rate of change of –1.6 per cent. This can be compared to the industry's average annual change of –0.6 per cent over the same period. Most of the decline in ESS's TFP occurred in the period up to 2012, where the average rate of TFP change was –5.5 per cent per year. The only years in which there were significant increases in ESS's TFP were 2013, 2014 and 2016. These increases were sufficient to raise the average rate of TFP change in the period 2012 to 2020 to 1.4 per cent per year.

ESS's total output increased over the 15-year period at an average annual rate of 0.9 per cent. This is the same as the industry average rate of growth in output over the same period. ESS's average annual rate of increase in input use was 2.5 per cent, which is considerably higher than the industry's rate of increase in total input use (1.6 per cent per year). Whereas output growth was at a reasonably steady rate, input use increased especially strongly in the period up to 2012 (at an average annual rate of 6.5 per cent) and decreased moderately thereafter (at an average annual rate of change of –0.6 per cent per year).

The partial productivity indexes in table 5.11 show the following trends:

- Capital PFP declined on average rate of –1.9 per cent per year from 2006 to 2020. The strongest decline was in the period up to 2012, averaging–3.6 per cent per annum, with a continued but lesser decline averaging –0.6 per cent per annum after 2012.
- Opex PFP declined rapidly in the period up to 2012, averaging –8.3 per cent per annum, whereas it has increased at a rate of 4.2 per cent per annum after 2012. On average over the full period, Opex PFP declined, averaging –1.2 per cent per annum.

Table 5.11 **ESS's output, input, TFP and PFP indexes, 2006–2020**

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	1.074	1.130	0.951	0.894	0.995
2008	1.069	1.229	0.869	0.757	0.961
2009	1.031	1.231	0.838	0.781	0.881
2010	1.099	1.306	0.841	0.776	0.887
2011	1.077	1.333	0.808	0.763	0.839
2012	1.064	1.481	0.718	0.609	0.808
2013	1.073	1.440	0.745	0.679	0.792
2014	1.178	1.410	0.835	0.786	0.870
2015	1.145	1.420	0.806	0.780	0.825
2016	1.157	1.315	0.880	0.999	0.818
2017	1.134	1.324	0.856	0.973	0.798
2018	1.162	1.349	0.862	0.950	0.811
2019	1.147	1.427	0.804	0.826	0.789
2020	1.137	1.417	0.802	0.849	0.770
Growth Rate 2006-2020	0.9%	2.5%	-1.6%	-1.2%	-1.9%
Growth Rate 2006-2012	1.0%	6.5%	-5.5%	-8.3%	-3.6%
Growth Rate 2012-2020	0.8%	-0.6%	1.4%	4.2%	-0.6%
Growth Rate 2020	-0.9%	-0.8%	-0.1%	2.8%	-2.5%

5.6.2 ESS's output and input quantity changes

Figure 5.22 graphs the quantity indexes for ESS's individual outputs. Figure 5.23 graphs quantity indexes for its six individual inputs. Regarding outputs:

- Circuit length is the output with the largest weight in the output index. ESS's circuit length *decreased* by 3.4 per cent in total between 2006 and 2020. This represents an average rate of change of –0.3 per cent per annum over the same period. This compares to a total increase of 4.9 per cent for the industry over the same period.

- ESS's energy throughput increased at an average annual rate of 0.3 per cent per year over the 15-year period, or 4.1 per cent in total from 2006 to 2020 (compared to a marginal decline for the industry over the same period).
- On average ESS's RMD increased at an annual rate of 1.5 per cent between 2006 and 2020, taking RMD in 2020 to 22.5 per cent above its 2006 level. Maximum demand has grown more strongly than energy throughput in the period from 2012 to 2020. Maximum demand grew at an average annual rate of 2.4 per cent over this period, whereas energy throughput increased at an average annual rate of 0.6 per cent.
- ESS's customers increased at an average rate of 1.1 per cent per annum 2006 and 2020, or 15.9 per cent in total, which is similar to the average rate of customer growth for the industry over the same period (1.3 per cent per annum, or 20.8 per cent in total).
- CMOS decreased over the 15-year period, averaging a rate of change of –0.4 per cent annually. The average rate of change in CMOS over the period to 2012 was –2.9 per cent, and the average rate of change after 2012 was 1.5 per cent. By 2020, ESS's CMOS was 5.1 per cent below its 2006 level, thereby contributing to the increase of output.

Turning to inputs shown in figure 5.23, we see:

- The quantity of ESS's opex increased at an average annual rate of 2.1 per cent over the period from 2006 to 2020. By 2020, opex input was 33.8 per cent above its 2006 level. This compares unfavourably to the industry, for which opex input increased by 9.2 per cent in total over the same period. ESS's opex increased strongly in the period 2006 to 2012, at an average rate of 9.3 per cent per annum, and it decreased after 2012 at an average rate of –3.3 per cent per annum.
- Overhead sub-transmission and distribution lines in 2020 were 64.2 per cent and 49.6 per cent higher, respectively, than in 2006. These changes are greater than the industry increases of 14.3 per cent and 11.7 per cent respectively over the same period.
- ESS's underground sub-transmission and distribution cables were, in 2020, 82.9 and 77.7 per cent higher than in 2006 respectively. These increases are higher than those for the industry as a whole, namely 38.3 per cent and 63.7 per cent respectively over the same period.
- ESS's quantity of transformer inputs increased steadily over the 15-year period at an average annual rate of 2.3 per cent, and by 2020, transformer inputs were 38.9 per cent above the 2006 level, which is similar to the industry's 40.8 per cent.

5.6.3 ESS's output and input contributions to TFP change

Table 5.12 shows the decomposition of ESS's rate of TFP change into the contributions of the individual outputs and inputs for the whole 15-year period and for the periods up to and after 2012. Figure 5.24 shows the contributions of outputs and inputs to ESS's rate of TFP change between 2019 and 2020.

Figure 5.22 **ESS's output quantity indexes, 2006–2020**

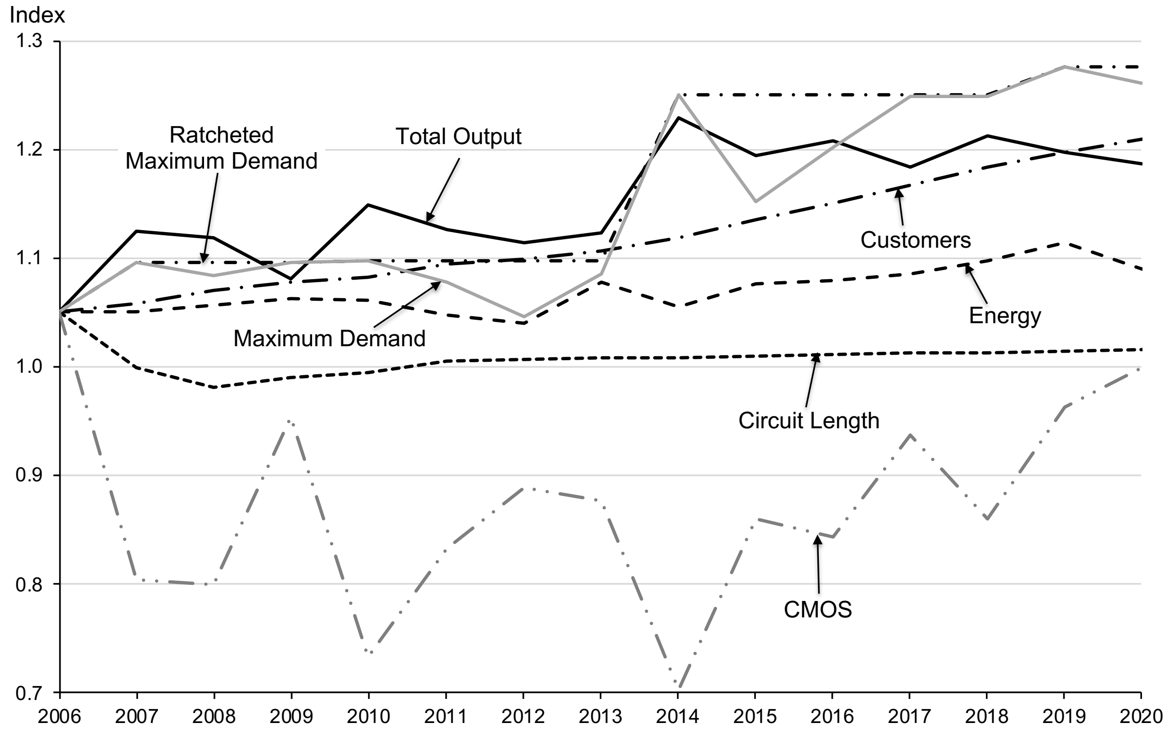


Figure 5.23 **ESS's input quantity indexes, 2006–2020**

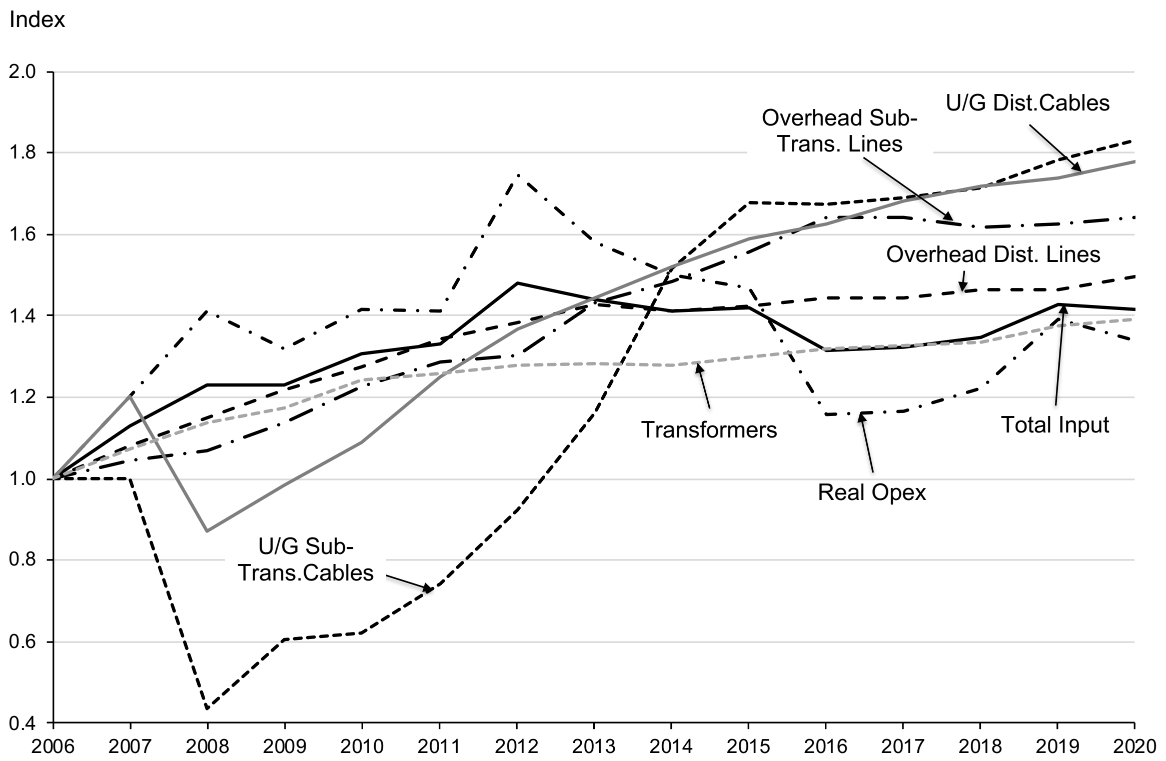
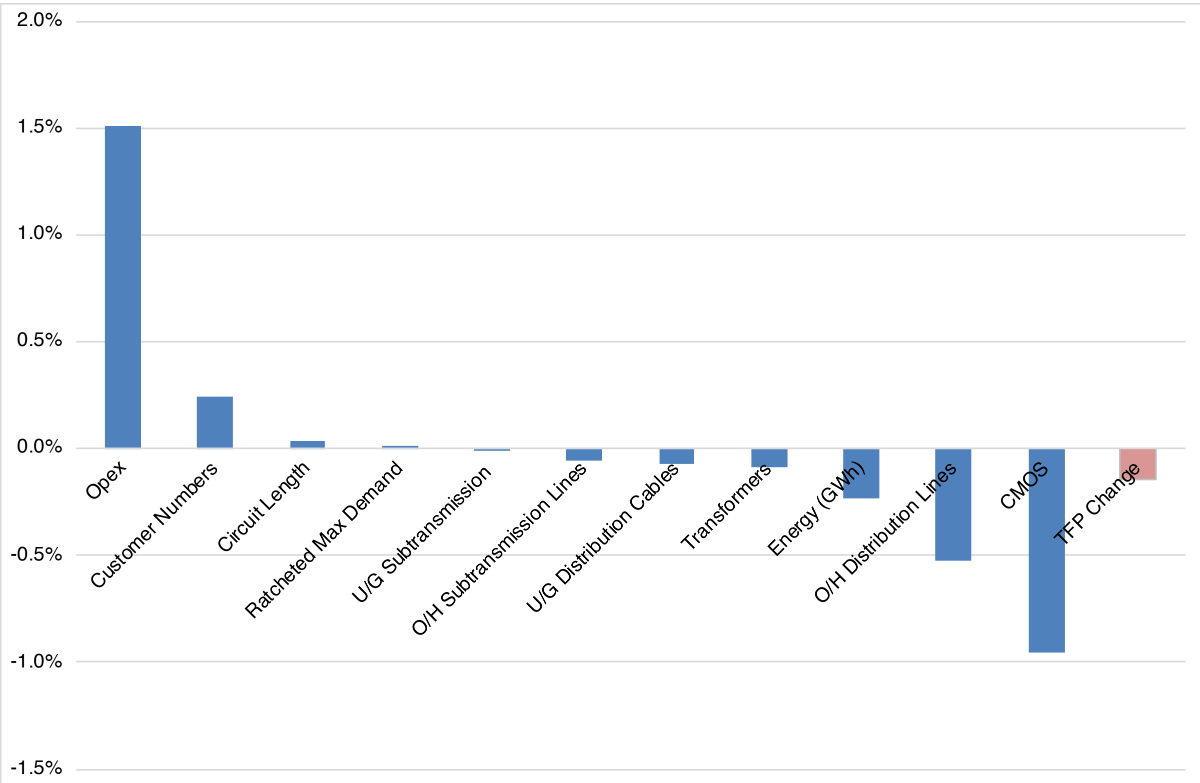


Table 5.12 **ESS's output and input percentage point contributions to average annual TFP change: 2006–2020, 2006–2012, 2012–2020, and 2020**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2019 to 2020*
Energy (GWh)	0.03%	-0.01%	0.06%	-0.23%
Ratcheted Max Demand	0.62%	0.36%	0.81%	0.01%
Customer Numbers	0.24%	0.20%	0.28%	0.24%
Circuit Length	-0.13%	-0.37%	0.06%	0.04%
CMOS	0.15%	0.85%	-0.38%	-0.96%
Opex	-0.85%	-3.83%	1.39%	1.51%
O/H Subtransmission Lines	-0.26%	-0.34%	-0.20%	-0.06%
O/H Distribution Lines	-0.55%	-0.98%	-0.24%	-0.52%
U/G Subtransmission Cables	-0.01%	0.00%	-0.02%	-0.01%
U/G Distribution Cables	-0.16%	-0.20%	-0.12%	-0.08%
Transformers	-0.66%	-1.21%	-0.25%	-0.09%
TFP Change	-1.57%	-5.52%	1.39%	-0.14%

Figure 5.24 **ESS's output and input percentage point contributions to TFP change, 2020**



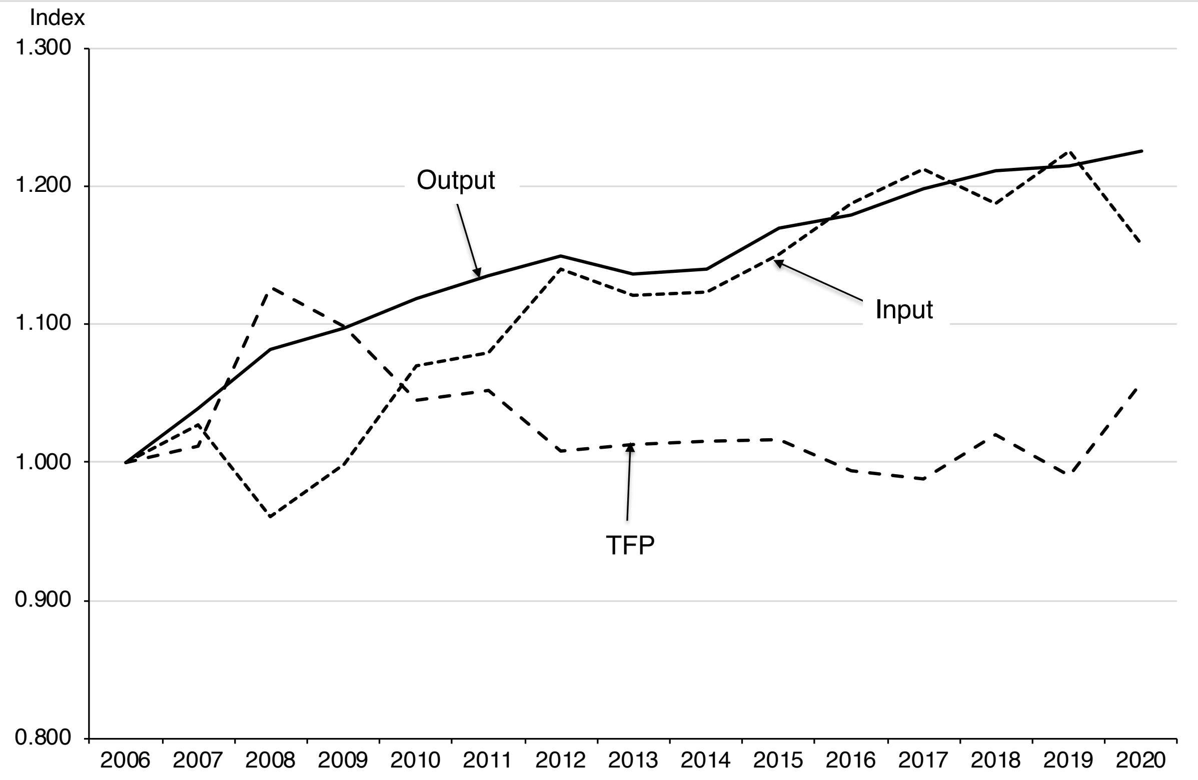
5.7 Jemena Electricity Networks (JEN)

In 2020, JEN delivered 4,107 GWh to 366,841 customers over 6,699 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.

5.7.1 JEN's productivity performance

JEN'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 **JEN's output, input, and TFP indexes, 2006–2020**



Over the 15-year period 2006 to 2020, JEN's TFP increased at an average annual rate of change of 0.4 per cent per annum. This compares favourably to the industry's average annual change of –0.6 per cent over the same period. Over the period from 2006 to 2012, the rate of increase in TFP was 0.1 per cent per annum, and in the period from 2012 to 2020, the rate of increase was 0.6 per cent per annum.

JEN's total output increased over 15-year period at an average annual rate of 1.5 per cent. This is higher than the industry average rate of growth in output of 0.9 per cent per annum. JEN's average annual rate of increase in input use of 1.0 per cent over the same period was lower than the rate of increase in total input use for the industry (1.6 per cent per year). The rate of output growth was higher in the period up to 2012 (at 2.3 per cent per annum) than in the period after

2012 (at 0.8 per cent per annum). The rate of input growth was also higher in the period up to 2012 (at 2.2 per cent per annum) than in the period after 2012 (at 0.2 per cent per annum).

The partial productivity indexes in table 5.13 show the following trends:

- Capital PFP increased marginally, at an average rate of 0.1 per cent per year, from 2006 to 2020. In the period up to 2012, Capital PFP increased at a rate of 1.1 per cent per annum, whilst in the period after 2012, the rate of change in Capital PFP averaged –0.6 per cent per annum.
- Opex PFP increased on average at a rate of 0.9 per cent per annum from 2006 to 2020. In the period up to 2012, Opex PFP decreased by 1.0 per cent per annum, on average, whereas it has increased at a rate of 2.3 per cent per annum after 2012.

Table 5.13 **JEN's output, input, TFP and PFP indexes, 2006–2020**

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	1.039	1.027	1.011	0.984	1.034
2008	1.082	0.961	1.126	1.269	1.043
2009	1.097	0.999	1.098	1.179	1.039
2010	1.118	1.070	1.045	1.025	1.061
2011	1.135	1.079	1.052	1.054	1.051
2012	1.149	1.140	1.008	0.940	1.065
2013	1.136	1.121	1.013	0.971	1.046
2014	1.140	1.123	1.015	0.988	1.036
2015	1.170	1.151	1.016	0.988	1.039
2016	1.179	1.187	0.993	0.941	1.033
2017	1.198	1.212	0.988	0.913	1.048
2018	1.211	1.188	1.020	1.005	1.032
2019	1.214	1.226	0.990	0.964	1.011
2020	1.225	1.158	1.058	1.131	1.014
Growth Rate 2006-2020	1.5%	1.0%	0.4%	0.9%	0.1%
Growth Rate 2006-2012	2.3%	2.2%	0.1%	-1.0%	1.1%
Growth Rate 2012-2020	0.8%	0.2%	0.6%	2.3%	-0.6%
Growth Rate 2020	0.9%	-5.7%	6.6%	15.9%	0.3%

5.7.2 JEN's output and input quantity changes

Figure 5.26 graphs the quantity indexes for JEN's individual outputs. Figure 5.27 graphs quantity indexes for its six individual inputs. Regarding outputs:

- The output component that receives the largest weight in forming the output index is circuit length. JEN's circuit length has increased steadily at an average rate of 1.1 per cent per annum from 2006 to 2020; and by 2020 was 17.1 per cent above the 2006 level (which is higher than the increase of 4.9 per cent for the industry over the 15-year period).

- JEN's energy throughput decreased at an average rate of –0.3 per cent per annum between 2006 and 2020; the same rate as that for the industry. In 2020, JEN's energy throughput was 4.0 per cent below its 2006 level.
- RMD increased up to 2009, in total by 21.8 per cent, and remained at around that level in 2019, with a further increase in 2020. The total increase in RMD over the 15-year period was 25.5 per cent, which is greater than that of the industry (18.1 per cent in total).
- JEN's customers increased at an average rate of 1.6 per cent per annum between 2006 and 2020, or 25.1 per cent in total, which higher than the average rate of customer growth for the industry over the same period of 1.3 per cent per annum, or 20.8 per cent in total.
- CMOS decreased significantly over the period from 2006 to 2012, at an average annual rate of –4.2 per cent per year. This contributed significantly to output growth over this period. However, from 2012 to 2020, CMOS increased at an average annual rate of 1.9 per cent per annum. By 2020, CMOS was 9.9 per cent lower than the level in 2006.

Turning to inputs shown in figure 5.27, we see:

- The quantity of opex increased at an average annual rate of 0.6 per cent from 2006 to 2020, and by 2020, opex was 8.4 per cent above its level in 2006 – similar to the total increase of 9.2 per cent for the industry over the same period. In the periods before and after 2012, there are two distinct trends in JEN's opex input. From 2006 to 2012 opex increased at a rate of 3.3 per cent per annum, whereas from 2012 to 2020, JEN's opex *decreased* at a rate of 1.5 per cent per annum.
- Overhead sub-transmission and distribution lines in 2020 were 16.6 and 1.0 per cent higher, respectively, than their 2006 level. These outcomes compare with 14.3 per cent and 11.7 per cent increases, respectively, for the industry over the same period.
- Underground sub-transmission and distribution cables in 2020 were 50.0 and 96.7 per cent higher than in 2006 respectively. This can be compared to increases of 38.3 per cent and 63.7 per cent respectively for the industry over the same period.
- JEN's quantity of transformers increased steadily over the 15-year period, at an average rate of 2.8 per cent per annum. By 2020, transformer inputs were 48.1 per cent above the 2006 level, which is a larger increase than the industry's 40.8 per cent.

5.7.3 JEN's output and input contributions to TFP change

Table 5.14 shows the decomposition of JEN's rate of TFP change into the contributions of the individual outputs and inputs for the whole 15-year period and for the periods up to and after 2012. Figure 5.28 shows the contributions of outputs and inputs to JEN's rate of TFP change between 2019 and 2020.

Figure 5.26 **JEN's output quantity indexes, 2006–2020**

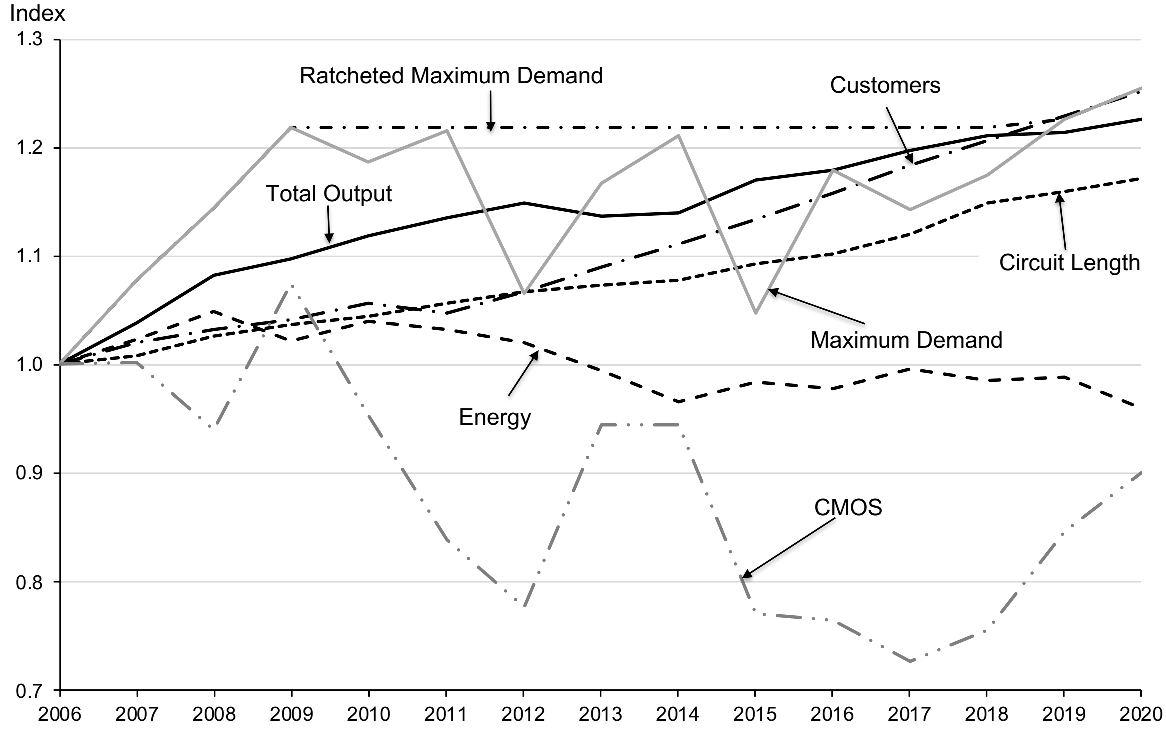


Figure 5.27 **JEN's DNSP input quantity indexes, 2006–2020**

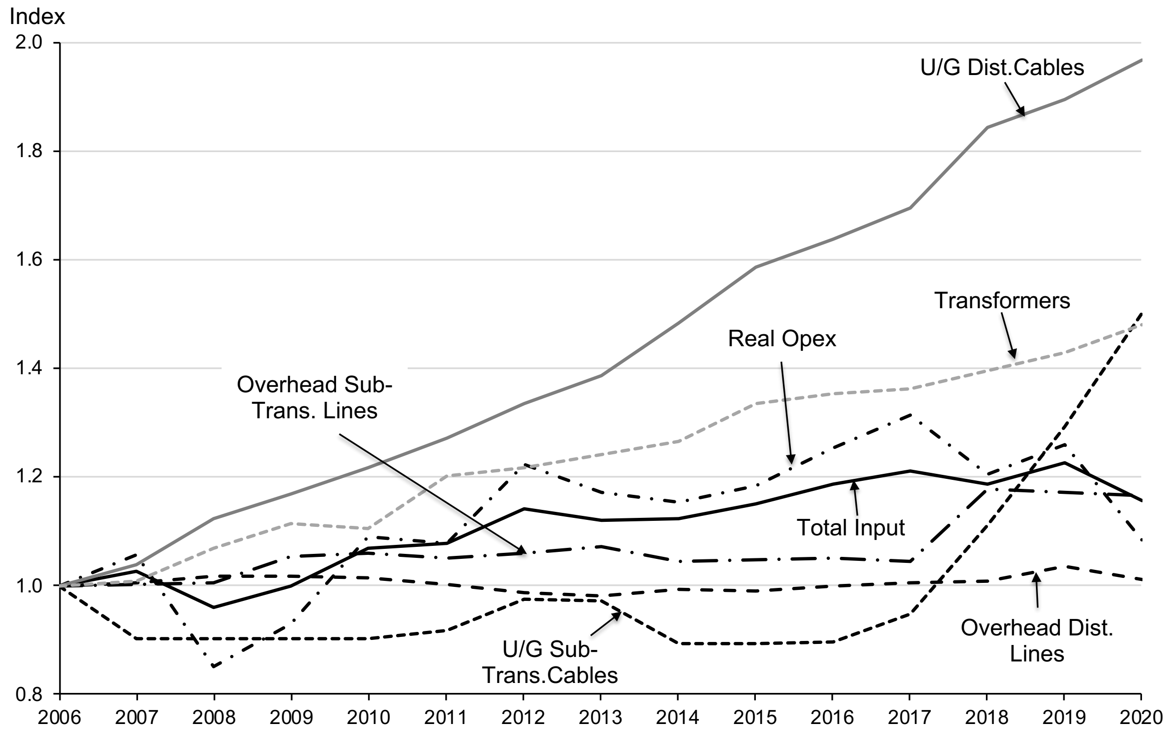
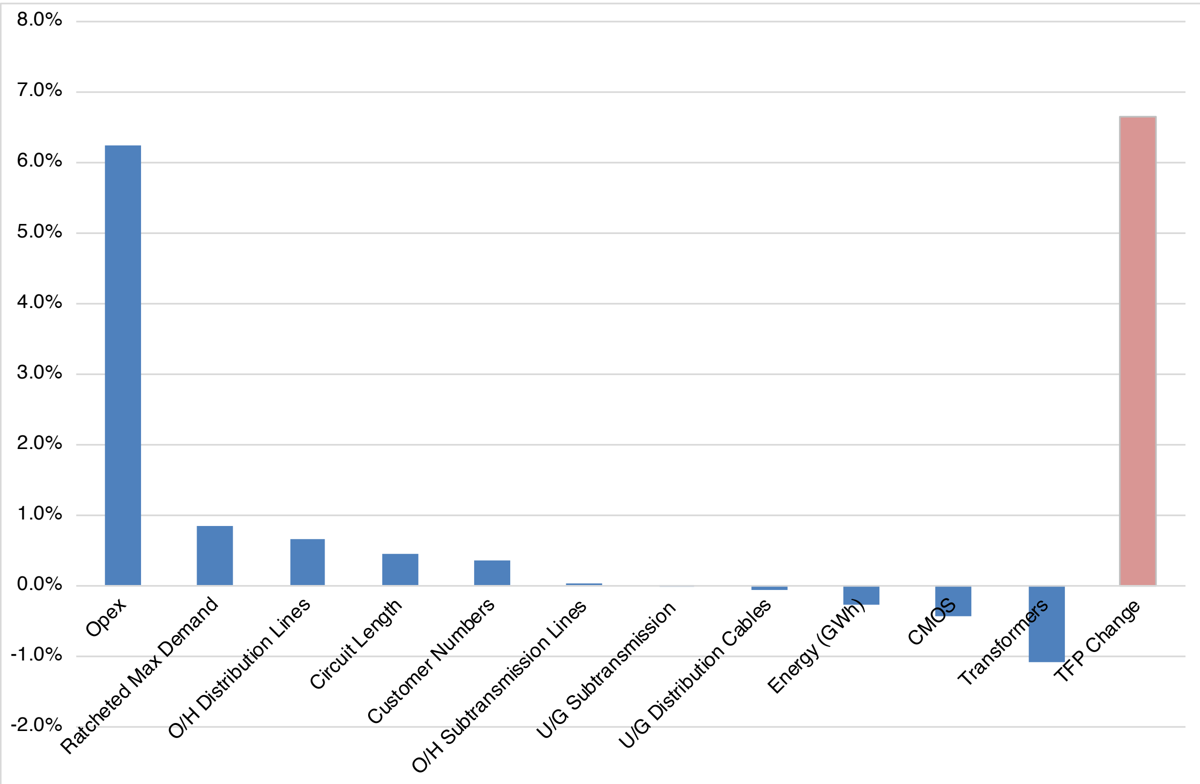


Table 5.14 **JEN's output and input percentage point contributions to average annual TFP change: 2006–2020, 2006–2012, 2012–2020 and 2020**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2019 to 2020*
Energy (GWh)	-0.03%	0.03%	-0.07%	-0.27%
Ratcheted Max Demand	0.60%	1.22%	0.13%	0.85%
Customer Numbers	0.32%	0.22%	0.39%	0.34%
Circuit Length	0.48%	0.47%	0.49%	0.44%
CMOS	0.08%	0.38%	-0.14%	-0.43%
Opex	-0.26%	-1.48%	0.65%	6.22%
O/H Subtransmission Lines	-0.05%	-0.04%	-0.06%	0.03%
O/H Distribution Lines	-0.02%	0.05%	-0.08%	0.67%
U/G Subtransmission Cables	-0.01%	0.00%	-0.01%	-0.03%
U/G Distribution Cables	-0.10%	-0.11%	-0.10%	-0.07%
Transformers	-0.60%	-0.61%	-0.60%	-1.09%
TFP Change	0.41%	0.13%	0.61%	6.64%

Figure 5.28 **JEN's output and input percentage point contributions to TFP change, 2020**



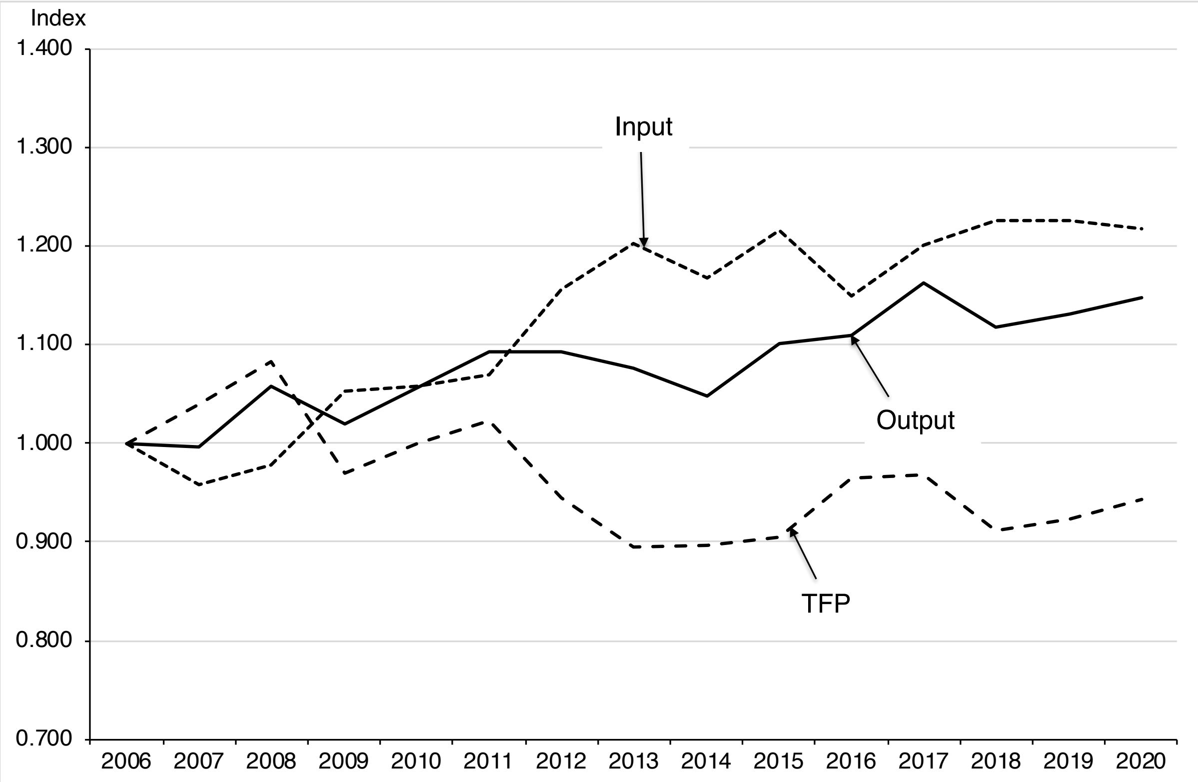
5.8 Powercor (PCR)

In 2020, PCR delivered 10,648 GWh to 863,408 customers over 76,306 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.

5.8.1 PCR's productivity performance

PCR'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 **PCR's output, input and TFP indexes, 2006–2020**



Over the 15-year period 2006 to 2020, PCR's TFP decreased at an average annual rate of change of –0.4 per cent. This is similar to the industry's average annual change of –0.6 per cent over the same period. The period from 2006 to 2012 saw a decline in PCR's TFP, at an average rate of –0.9 per cent per year, and in the period from 2012 to 2020, the rate of TFP change was zero.

PCR's total output increased over the 15-year period at an average annual rate of 1.0 per cent. This is similar to the industry average rate of growth in output of 0.9 per cent per annum. PCR's average annual rate of increase in input use of 1.4 per cent was similar to the rate of increase in total input use for the industry (1.6 per cent per year). The average rate of growth of output in the period up to 2012 was 1.5 per cent per year, and in the period after 2012 it was 0.6 per cent per year. Input usage increased at an average rate of 2.4 per cent per year from 2006 to 2012, and by 0.6 per cent per year after 2012.

The partial productivity indexes in table 5.15 show the following trends:

- Capital PFP decreased reasonably consistently, averaging an annual rate of –1.2 per cent per annum.
- Opex PFP increased on average at a rate of 0.7 per cent per annum from 2006 to 2020. In the period up to 2012, Opex PFP *decreased* by 1.2 per cent per annum, on average, whereas it has *increased* at a rate of 2.2 per cent per annum after 2012.

Table 5.15 **PCR's output, input, TFP and PFP indexes, 2006–2020**

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	0.958	1.040	1.137	0.975
2008	1.058	0.978	1.082	1.181	1.017
2009	1.020	1.053	0.969	1.032	0.925
2010	1.057	1.058	0.999	1.114	0.928
2011	1.093	1.069	1.022	1.108	0.965
2012	1.092	1.155	0.945	0.933	0.953
2013	1.077	1.202	0.896	0.866	0.917
2014	1.047	1.168	0.897	0.927	0.874
2015	1.100	1.216	0.905	0.909	0.900
2016	1.110	1.150	0.965	1.081	0.892
2017	1.162	1.201	0.968	1.050	0.913
2018	1.117	1.226	0.911	0.984	0.862
2019	1.131	1.226	0.923	1.029	0.855
2020	1.147	1.217	0.943	1.109	0.844
Growth Rate 2006-2020	1.0%	1.4%	-0.4%	0.7%	-1.2%
Growth Rate 2006-2012	1.5%	2.4%	-0.9%	-1.2%	-0.8%
Growth Rate 2012-2020	0.6%	0.6%	0.0%	2.2%	-1.5%
Growth Rate 2020	1.4%	-0.8%	2.1%	7.5%	-1.3%

5.8.2 PCR's output and input quantity changes

Figure 5.30 graphs the quantity indexes for PCR's individual outputs. Figure 5.31 graphs quantity indexes for its six individual inputs. Regarding outputs:

- PCR's circuit length increased steadily at an average rate of 0.4 per cent per annum from 2006 to 2020; and by 2020 was 6.5 per cent above the 2006 level (which is only slightly higher than the increase of 4.9 per cent for the industry over the same period). Circuit length has the largest weight in the output index.

- PCR's energy throughput increased at an average rate of 0.3 per cent per annum between 2006 and 2020 (compared to –0.3 per cent per annum for the industry). PCR's energy throughput in 2020 was 4.9 per cent above its 2006 level.
- RMD increased at an average annual rate of 1.8 per cent per annum on average over the 15-year period to 2020, and maximum demand increased at the same rate. In 2020, RMD was 29.4 per cent higher than it was in 2006.
- PCR's customers increased at an average rate of 1.9 per cent per annum between 2006 and 2020, or 30.0 per cent in total, which is higher than the average rate of customer growth for the industry over the same period of 1.3 per cent per annum, or 20.8 per cent in total.
- Although CMOS was volatile, there was a consistent upward trend, and over the period from 2006 to 2020, the increase averaged 2.2 per cent per year. This detracted from output growth and hence TFP growth. By 2020, CMOS was 36.4 per cent higher than its level in 2006.

Turning to inputs shown in figure 5.31, we see:

- The quantity of opex increased at an average annual rate of 0.2 per cent from 2006 to 2020, and by 2020, opex was 3.4 per cent above its level in 2006, which compares favourably to the total increase of 9.2 per cent for the industry over the same period. In the period up to 2012, opex input increased at an average rate of 2.6 per cent per annum. After 2012, opex input decreased, averaging –1.6 per cent per annum.
- Overhead sub-transmission and distribution lines in 2020 were 1.2 and 1.8 per cent higher, respectively, than their 2006 level. These increases were lower than the 14.3 per cent and 11.7 per cent increases, respectively, for the industry over the same period.
- Underground sub-transmission and distribution cables in 2020 were 297.3 per cent and 127.0 per cent higher than in 2006 respectively. This can be compared to increases of 38.3 per cent and 63.7 per cent respectively for the industry over the same period.
- PCR's quantity of transformers increased steadily over the 15-year period, at an average rate of 2.7 per cent per annum. By 2020, transformer inputs were 46.4 per cent above the 2006 level, being comparable to the industry increase of 40.8 per cent over the same period.

5.8.3 PCR's output and input contributions to TFP change

Table 5.16 shows the decomposition of PCR's rate of TFP change into the contributions of the individual outputs and inputs for the whole 15-year period and for the periods up to and after 2012. Figure 5.32 shows the contributions of outputs and inputs to PCR's rate of TFP change between 2019 and 2020.

Figure 5.30 **PCR's output quantity indexes, 2006–2020**

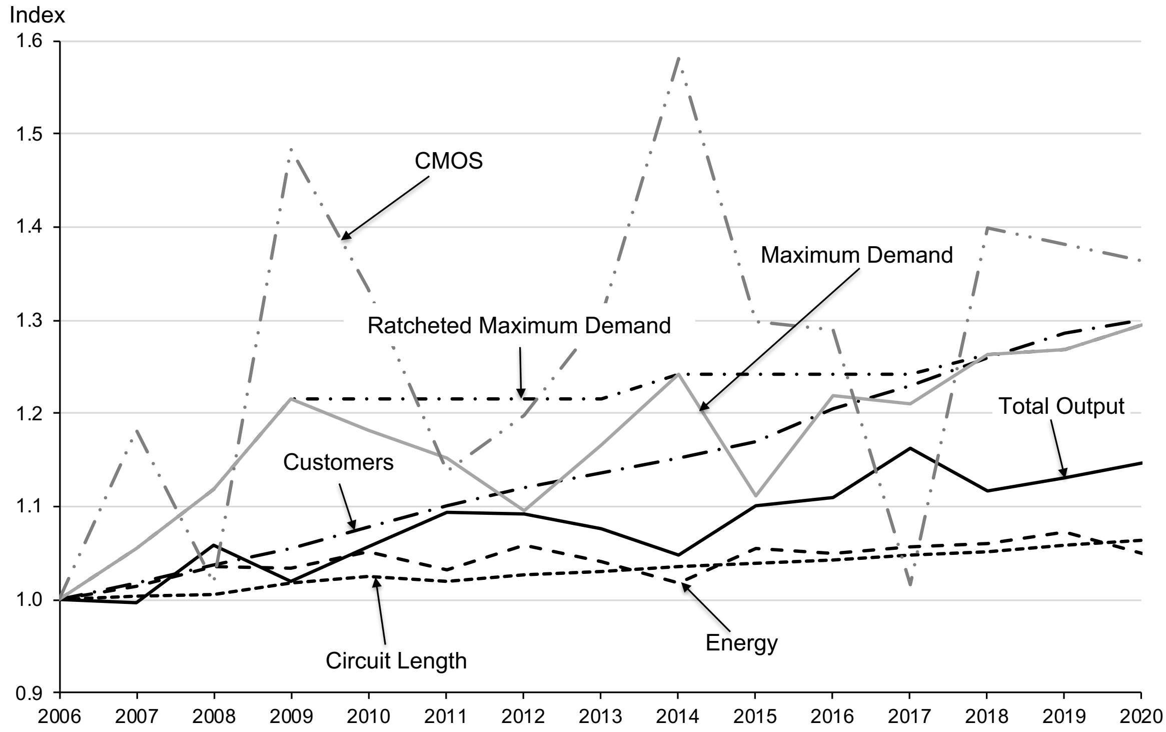


Figure 5.31 **PCR's DNSP input quantity indexes, 2006–2020**

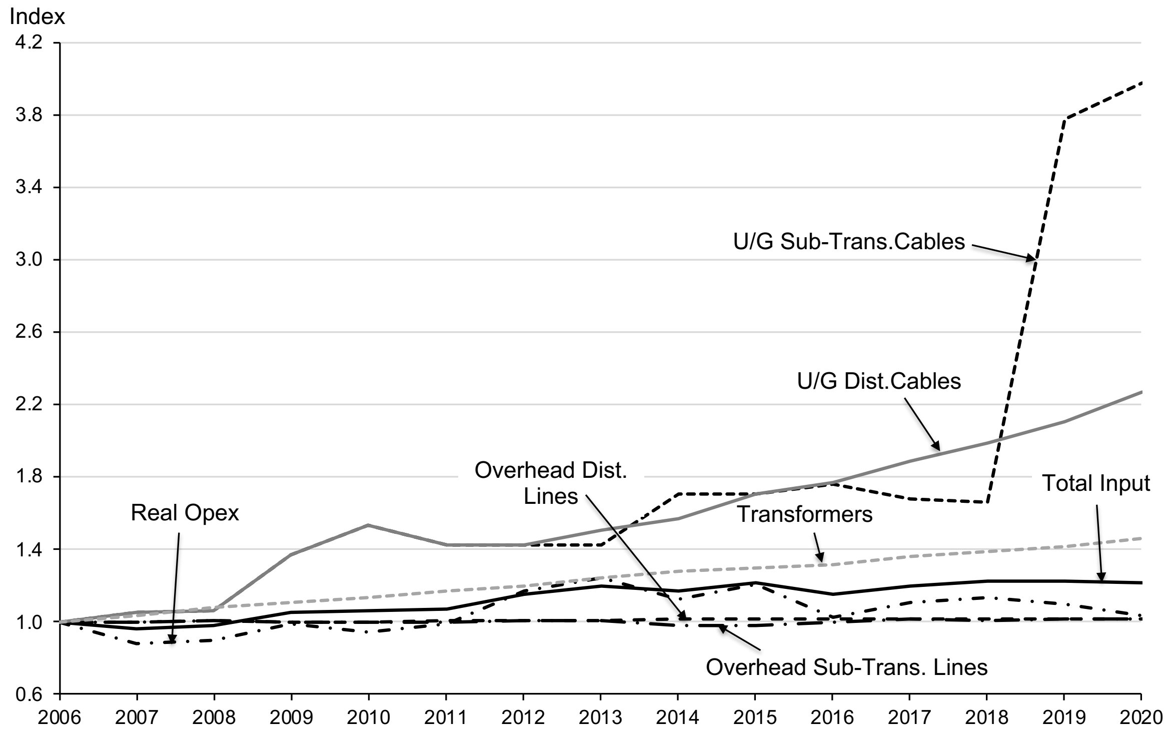
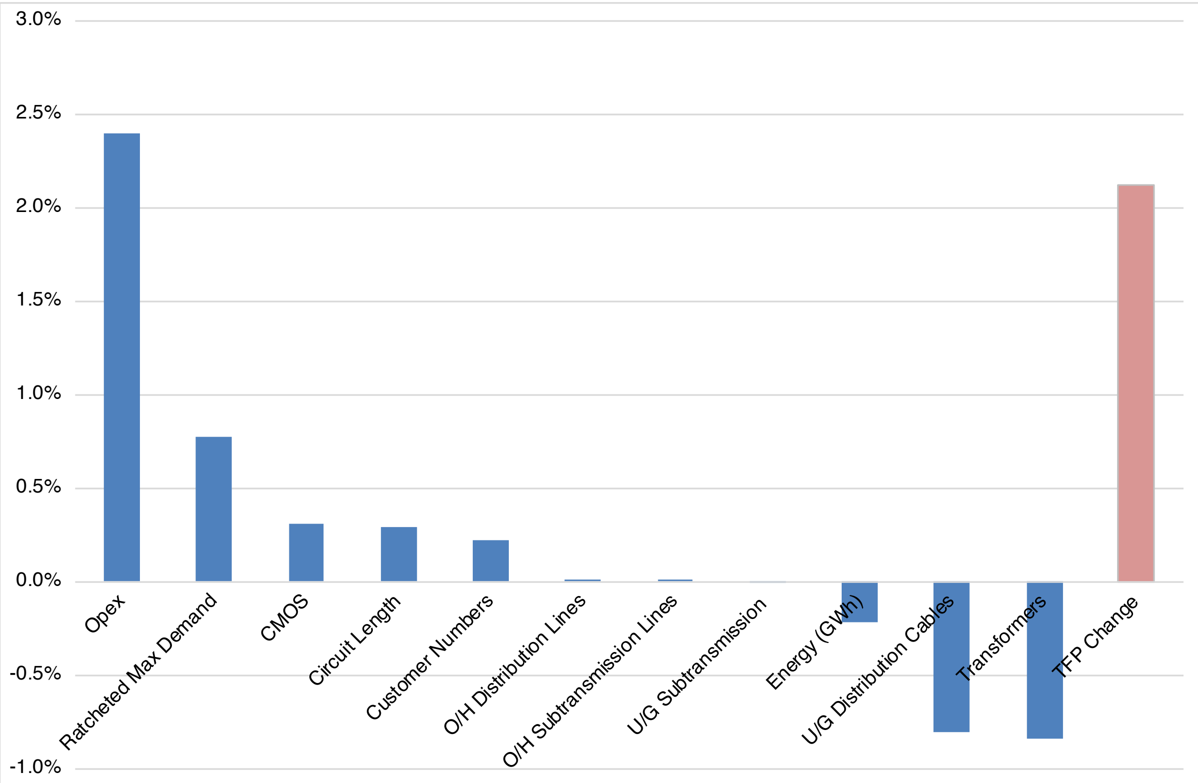


Table 5.16 **PCR's output and input percentage point contributions to average annual TFP change: 2006–2020, 2006–2012, 2012–2020 and 2020**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2019 to 2020*
Energy (GWh)	0.04%	0.10%	-0.01%	-0.22%
Ratcheted Max Demand	0.74%	1.31%	0.31%	0.77%
Customer Numbers	0.41%	0.42%	0.41%	0.22%
Circuit Length	0.21%	0.21%	0.21%	0.29%
CMOS	-0.41%	-0.56%	-0.30%	0.31%
Opex	-0.11%	-1.10%	0.64%	2.40%
O/H Subtransmission Lines	0.00%	0.00%	0.00%	0.00%
O/H Distribution Lines	-0.03%	-0.02%	-0.03%	0.00%
U/G Subtransmission Cables	-0.01%	-0.01%	-0.01%	0.00%
U/G Distribution Cables	-0.66%	-0.68%	-0.64%	-0.80%
Transformers	-0.60%	-0.60%	-0.60%	-0.84%
TFP Change	-0.42%	-0.94%	-0.03%	2.12%

Figure 5.32 **PCR's output and input percentage point contributions to TFP change, 2020**



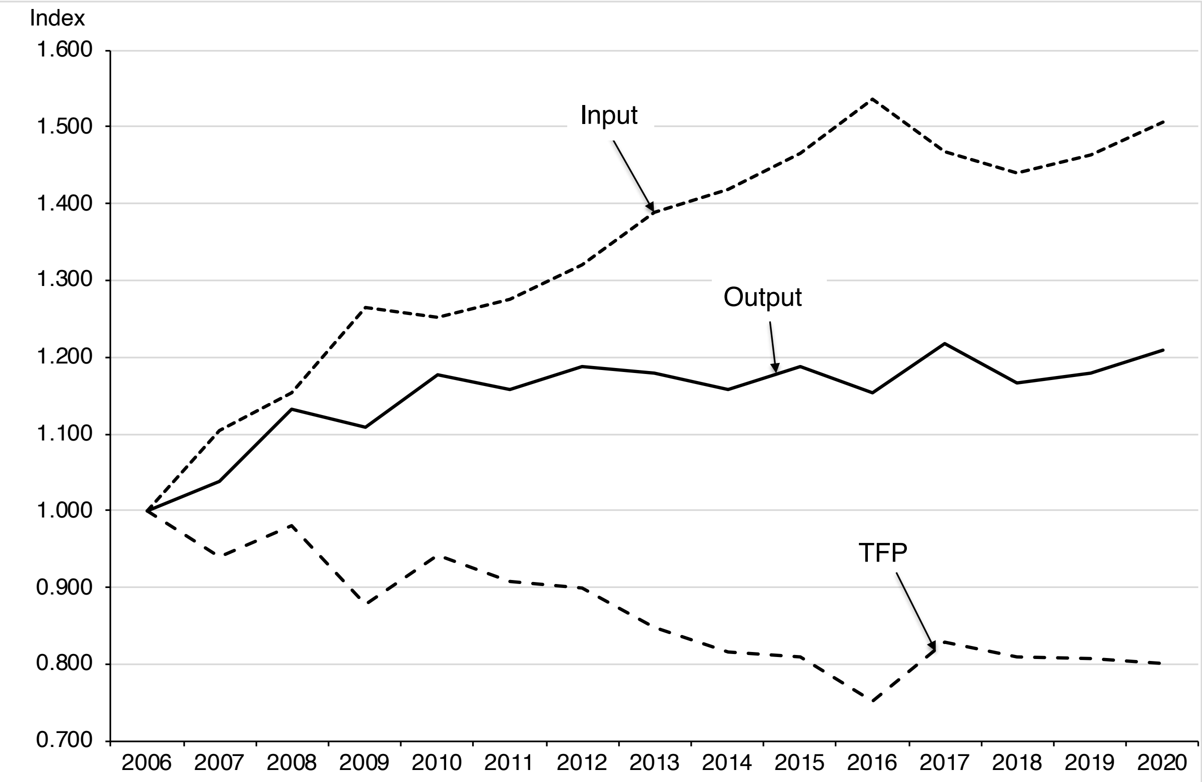
5.9 AusNet Services Distribution (AND)

In 2020, AND delivered 7,460 GWh to 776,854 customers over 45,734 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.

5.9.1 AND's productivity performance

AND'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 **AND's output, input and TFP indexes, 2006–2020**



Over the 15-year period 2006 to 2020, AND's TFP decreased at an average annual rate of change of –1.6 per cent. This compares unfavourably to the industry's average annual change of –0.6 per cent over the same period. The decline in AND's TFP was at a fairly consistent rate throughout the 15-year period.

AND's total output increased over the 15-year period at an average annual rate of 1.4 per cent. This is higher than the industry average rate of growth in output of 0.9 per cent per annum. Output increased more strongly in the period up to 2012 (averaging 2.9 per year) than in the period after 2012 (averaging 0.2 per cent per year).

AND's average annual rate of increase in input use of 2.9 per cent from 2006 to 2020 was higher than the rate of increase in total input use for the industry (1.6 per cent per year). Input usage increased most strongly in the period up to 2012 (averaging 4.6 per year) and continued to increase, but less strongly, after 2012 (averaging 1.7 per cent per year). By 2020, the input index was 50.7 per cent higher than in 2006 (compared to 24.5 per cent higher for the industry).

The partial productivity indexes in table 5.17 show the following trends:

- After a marginal increase in the period from 2006 to 2012, Capital PFP decreased in the period after 2012. On average over the full 15-year period, the average rate of change in Capital PFP was –0.6 per cent per annum.
- Opex PFP declined over the 15-year period, the average rate of change being –3.0 per cent per annum.

Table 5.17 **AND's output, input, TFP and PFP indexes, 2006–2020**

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	1.105	0.940	0.849	0.999
2008	1.131	1.153	0.981	0.859	1.073
2009	1.110	1.264	0.878	0.727	0.997
2010	1.178	1.251	0.942	0.798	1.052
2011	1.157	1.276	0.907	0.778	1.007
2012	1.188	1.319	0.900	0.753	1.014
2013	1.179	1.390	0.848	0.674	0.988
2014	1.157	1.419	0.816	0.642	0.957
2015	1.187	1.465	0.810	0.622	0.969
2016	1.154	1.537	0.751	0.549	0.925
2017	1.217	1.468	0.829	0.661	0.961
2018	1.166	1.440	0.810	0.688	0.903
2019	1.179	1.462	0.806	0.673	0.909
2020	1.208	1.507	0.802	0.657	0.915
Growth Rate 2006-2020	1.4%	2.9%	-1.6%	-3.0%	-0.6%
Growth Rate 2006-2012	2.9%	4.6%	-1.8%	-4.7%	0.2%
Growth Rate 2012-2020	0.2%	1.7%	-1.4%	-1.7%	-1.3%
Growth Rate 2020	2.4%	3.0%	-0.6%	-2.4%	0.7%

5.9.2 AND's output and input quantity changes

Figure 5.34 graphs the quantity indexes for AND's individual outputs. Figure 5.35 graphs quantity indexes for its six individual inputs. Regarding outputs:

- Circuit length has the largest weight in the output index. AND's circuit length increased at an average rate of 0.7 per cent per annum from 2006 to 2020; and by 2020 was 10.2 per cent above the 2006 level (which is higher than the increase of 4.9 per cent for the industry over the same period).

- AND's energy throughput increased marginally, at an average rate of 0.1 per cent per annum between 2006 and 2020 (compared to –0.3 per cent per annum for the industry). AND's energy throughput in 2020 was 0.8 per cent above its 2006 level.
- RMD increased between 2006 and 2020, in total by 30.8 per cent, representing an average annual growth rate of 1.9 per cent. This was a larger increase of RMD than for the industry.
- AND's customers increased at an average rate of 1.8 per cent per annum between 2006 and 2020, or 28.3 per cent in total, which is higher than the average rate of customer growth for the industry over the same period of 1.3 per cent per annum, or 20.8 per cent in total.
- Although CMOS was below the 2006 level for most of the 15-year period, increases in recent years resulted in CMOS in 2020, being 17.0 per cent higher than its level in 2006.

Turning to inputs shown in figure 5.35, we see:

- The quantity of AND's opex increased at an average annual rate of 4.3 per cent from 2006 to 2020, and by 2020, opex was 83.8 per cent above its level in 2006, which compares unfavourably to the total increase of 9.2 per cent for the industry over the same period. In the period up to 2012, opex input increased at an average rate of 7.6 per cent per annum. After 2012, opex input increased, averaging 1.9 per cent per annum.
- Overhead sub-transmission and distribution lines in 2020 were 12.5 and 0.4 per cent higher, respectively, than their 2006 level. These increases compare to the 14.3 per cent and 11.7 per cent increases, respectively, for the industry over the same period.
- Underground sub-transmission and distribution cables in 2020 were 248.4 per cent and 104.9 per cent higher than in 2006 respectively. This can be compared to increases of 38.3 per cent and 63.7 per cent respectively for the industry over the same period.
- Transformers have the largest weight in the input index. AND's quantity of transformers increased over the 15-year period at an average rate of 2.5 per cent per annum. By 2020, transformer inputs were 42.9 per cent above the 2006 level, similar to the industry increase of 40.8 per cent over the same period.

5.9.3 AND's output and input contributions to TFP change

Table 5.18 shows the decomposition of AND's rate of TFP change into the contributions of the individual outputs and inputs for the whole 15-year period and for the periods up to and after 2012. Figure 5.36 shows the contributions of outputs and inputs to AND's rate of TFP change between 2019 and 2020.

Figure 5.34 **AND's output quantity indexes, 2006–2020**

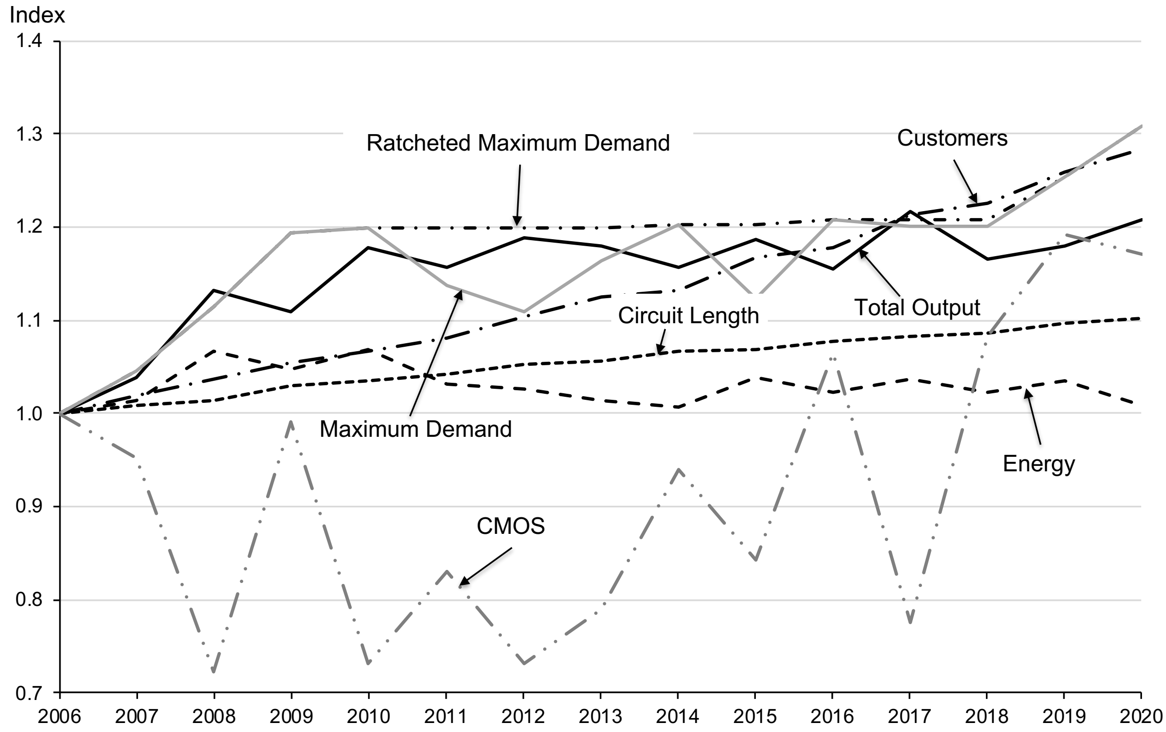


Figure 5.35 **AND's input quantity indexes, 2006–2020**

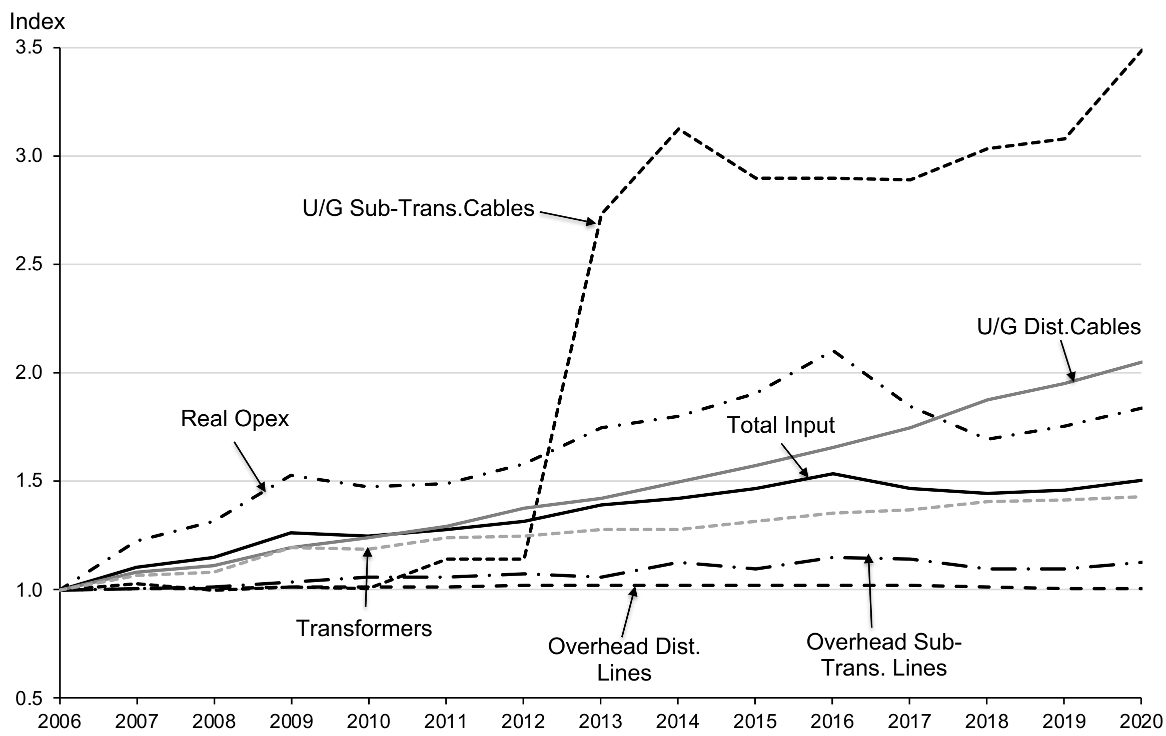
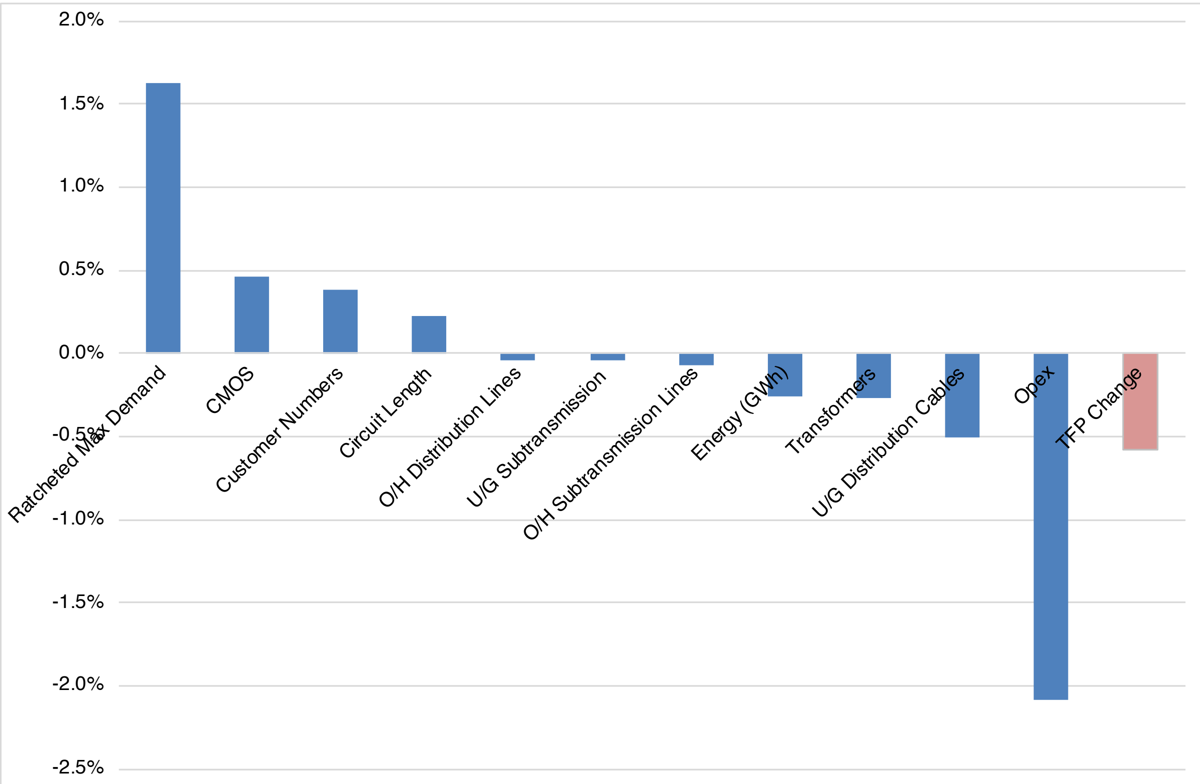


Table 5.18 **AND's output and input percentage point contributions to average annual TFP change: 2006–2020, 2006–2012, 2012–2020, 2020**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2019 to 2020*
Energy (GWh)	0.01%	0.05%	-0.02%	-0.26%
Ratcheted Max Demand	0.76%	1.22%	0.42%	1.62%
Customer Numbers	0.39%	0.37%	0.40%	0.38%
Circuit Length	0.32%	0.40%	0.25%	0.22%
CMOS	-0.12%	0.83%	-0.83%	0.46%
Opex	-1.74%	-3.04%	-0.77%	-2.08%
O/H Subtransmission Lines	-0.02%	-0.03%	-0.02%	-0.07%
O/H Distribution Lines	-0.01%	-0.08%	0.05%	-0.04%
U/G Subtransmission Cables	-0.02%	-0.01%	-0.03%	-0.04%
U/G Distribution Cables	-0.62%	-0.68%	-0.57%	-0.51%
Transformers	-0.52%	-0.78%	-0.33%	-0.27%
TFP Change	-1.58%	-1.75%	-1.45%	-0.58%

Figure 5.36 **AND's output and input percentage point contributions to TFP change, 2020**



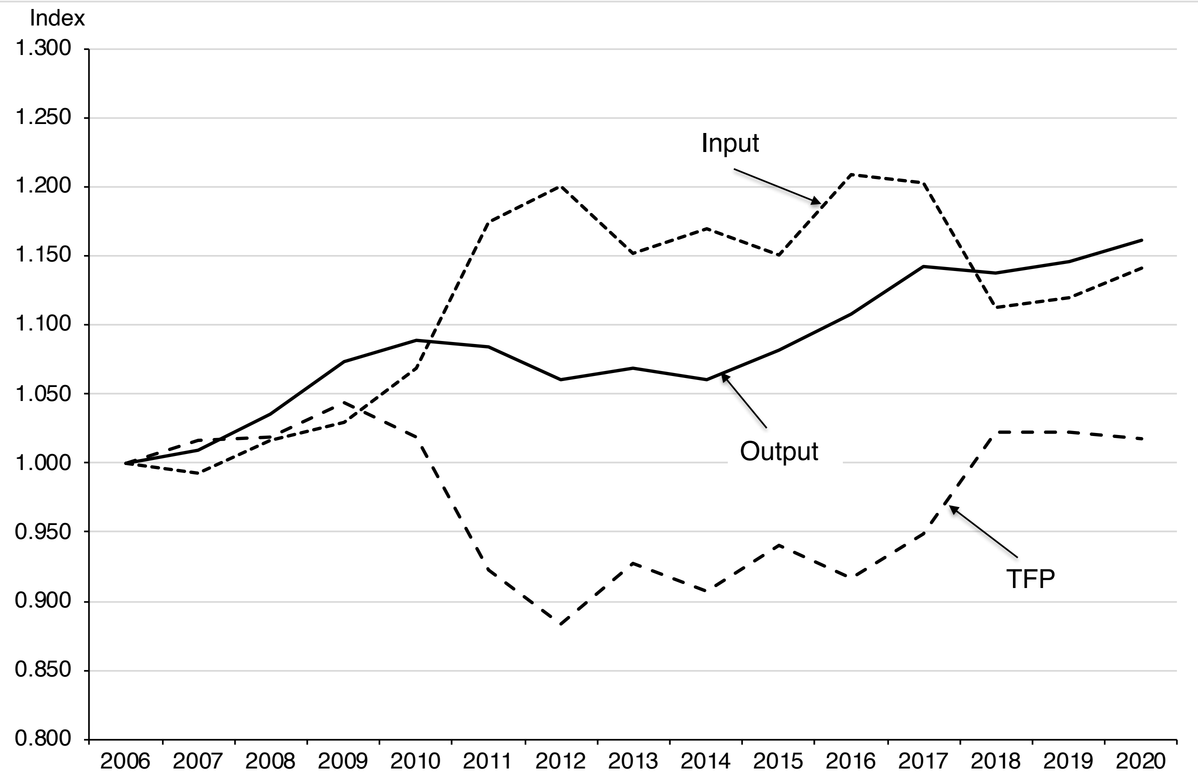
5.10 United Energy (UED)

In 2020, UED delivered 7,502 GWh to 703,119 customers over 13,426 circuit kilometres of lines and cables. UED distributes electricity across east and south–east Melbourne and the Mornington Peninsula.

5.10.1 UED's productivity performance

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

Figure 5.37 **UED's output, input and TFP indexes, 2006–2020**



Over the 15-year period 2006 to 2020, UED's TFP increased marginally, at an average annual rate of 0.1 per cent per annum. This can be compared to the industry's average annual change of –0.6 per cent over the same period. UED's TFP decreased by 2.1 per cent per year, on average, from 2006 to 2012. It increased by an average of 1.8 per cent per year from 2012 to 2020.

UED's total output increased over the period from 2006 to 2020 at an average annual rate of 1.1 per cent. This is similar to the industry average rate of growth in output of 0.9 per cent per annum for the same period. UED's average annual rate of increase in input use of 0.9 per cent was lower than the rate of increase in total input use for the industry (1.6 per cent per year). The rate of growth of input usage was much higher in the period 2006 to 2012 (averaging 3.0 per cent per year) and decreased in the period 2012 to 2020 (averaging –0.6 per cent per year).

The partial productivity indexes in table 5.19 show the following trends:

- Capital PFP declines on average over the period, although this decline was concentrated in the period up to 2012. In the period from 2006 to 2012, the rate of change in Capital PFP averaged –1.7 per cent per annum, and after 2012 its average rate of change was 0.2 per cent per annum. On average over the full 15-year period, the average rate of change in Capital PFP was –0.6 per cent per annum.

- Opex PFP increased over the 15-year period, the average rate of change being 1.3 per cent per annum. Over the period to 2012, the average rate of change of Opex PFP was –2.6 per cent per annum. In the period after 2012, the average rate of change of Opex PFP was 4.2 per cent per annum.

Table 5.19 **UED's output, input, TFP and PFP indexes, 2006–2020**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.009	0.993	1.016	1.070	0.983
2008	1.036	1.016	1.019	1.095	0.974
2009	1.074	1.029	1.043	1.115	0.999
2010	1.089	1.069	1.018	1.083	0.979
2011	1.084	1.175	0.923	0.880	0.956
2012	1.060	1.200	0.883	0.855	0.905
2013	1.068	1.151	0.928	0.968	0.903
2014	1.060	1.169	0.907	0.939	0.887
2015	1.082	1.151	0.940	1.010	0.898
2016	1.107	1.208	0.916	0.894	0.928
2017	1.142	1.203	0.949	0.980	0.928
2018	1.137	1.112	1.022	1.228	0.917
2019	1.145	1.120	1.023	1.235	0.915
2020	1.161	1.141	1.017	1.193	0.921
Growth Rate 2006-2020	1.1%	0.9%	0.1%	1.3%	-0.6%
Growth Rate 2006-2012	1.0%	3.0%	-2.1%	-2.6%	-1.7%
Growth Rate 2012-2020	1.1%	-0.6%	1.8%	4.2%	0.2%
Growth Rate 2020	1.3%	1.9%	-0.5%	-3.4%	0.7%

5.10.2 UED's output and input quantity changes

Figure 5.38 graphs the quantity indexes for UED's individual outputs. Figure 5.39 graphs quantity indexes for its six individual inputs. Regarding outputs:

- UED's circuit length increased at an average rate of 0.6 per cent per annum from 2006 to 2020; and by 2020 was 8.4 per cent above the 2006 level (which is higher than the increase of 4.9 per cent for the industry over the same period).

- UED's energy throughput decreased between 2006 and 2020, averaging an annual rate of –0.4 per cent per annum (similar to –0.3 per cent per annum for the industry). UED's energy throughput in 2020 was 5.2 per cent below its 2006 level.
- RMD increased from 2006 to 2009 by 23.9 per cent in total. RMD remained essentially constant after that, except for a small further increase in 2014. The average annual rate of increase in RMD from 2006 to 2020 was 1.6 per cent. In 2020, UED's RMD was 24.3 per cent higher than it was in 2006.
- UED's customers increased at an average rate of 1.0 per cent per annum between 2006 and 2020, or 14.8 per cent in total, which is less than the average rate of customer growth for the industry over the same period of 1.3 per cent per annum, or 20.8 per cent in total.
- CMOS increased considerably in the period up to 2012, at an average annual rate of 8.3 per cent. It remained high until 2014, after which UED's CMOS declined. The average rate of change between 2012 and 2020 was –9.7 per cent per year. By 2020, CMOS was 24.4 per cent below the level in 2006.

Turning to inputs shown in figure 5.39, we see:

- The quantity of opex *decreased* at an average annual rate of 0.2 per cent from 2006 to 2020, and by 2020 opex was 2.7 per cent below its level in 2006, which compares favourably to the total increase of 9.2 per cent for the industry over the same period. In the period up to 2012, opex input increased at an average rate of 3.6 per cent per annum. After 2012, opex input decreased, averaging –3.0 per cent per annum.
- Overhead sub-transmission and distribution lines in 2020 were 24.2 and 3.9 per cent higher, respectively, than their 2006 level. These increases can be compared to the 14.3 per cent and 11.7 per cent increases, respectively, for the industry over the same period.
- Underground sub-transmission and distribution cables in 2020 were 21.6 per cent and 51.5 per cent higher than in 2006 respectively. This can be compared to increases of 38.3 per cent and 63.7 per cent respectively for the industry over the same period.
- UED's quantity of transformers increased, at an average rate of 2.4 per cent per annum over the 15-year period. By 2020, transformer inputs were 40.0 per cent above the 2006 level, which is close to the industry increase of 40.8 per cent over the same period.

5.10.3 UED's output and input contributions to TFP change

Table 5.20 shows the decomposition of UED's rate of TFP change into the contributions of the individual outputs and inputs for the whole 15-year period and for the periods up to and after 2012. Figure 6.40 shows the contributions of outputs and inputs to UED's rate of TFP change between 2019 and 2020.

Figure 5.38 **UED's output quantity indexes, 2006–2020**

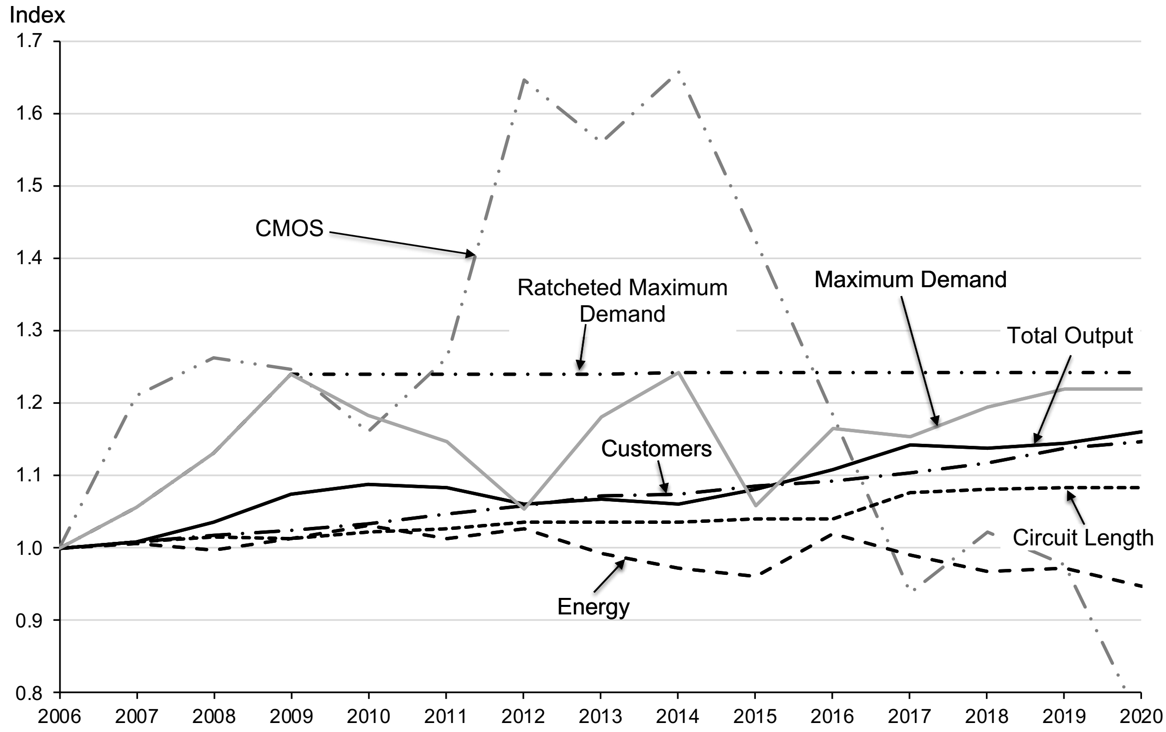


Figure 5.39 **UED's input quantity indexes, 2006–2020**

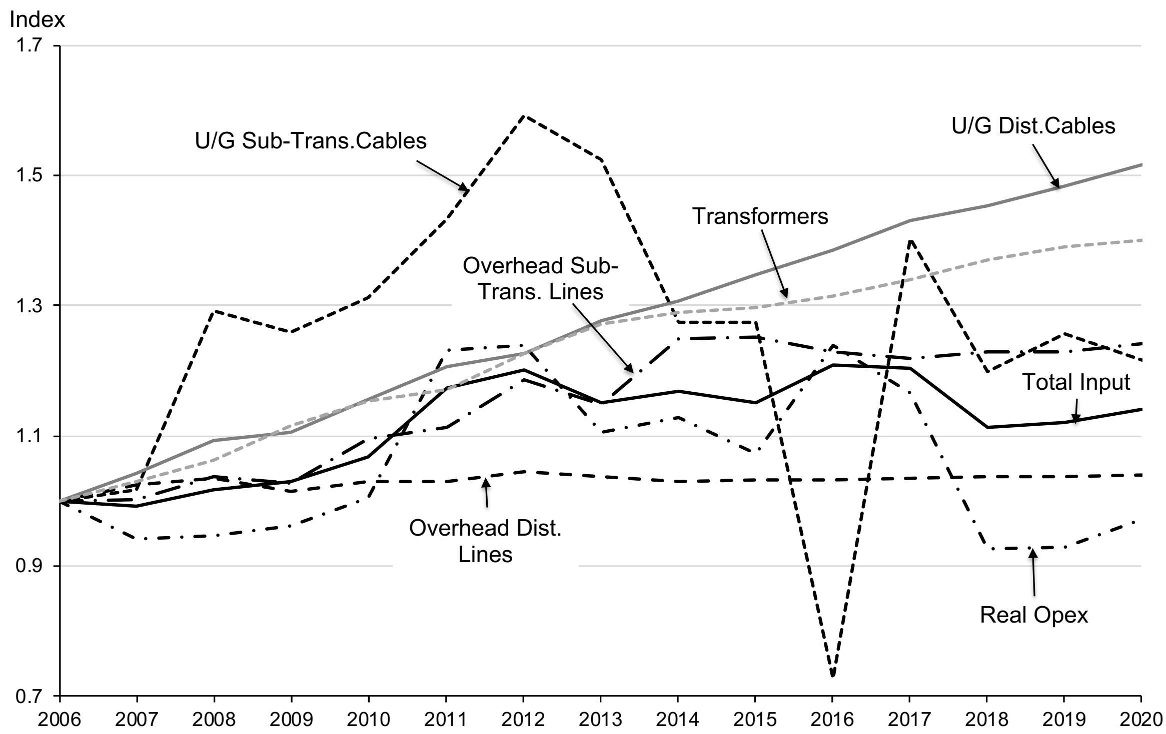
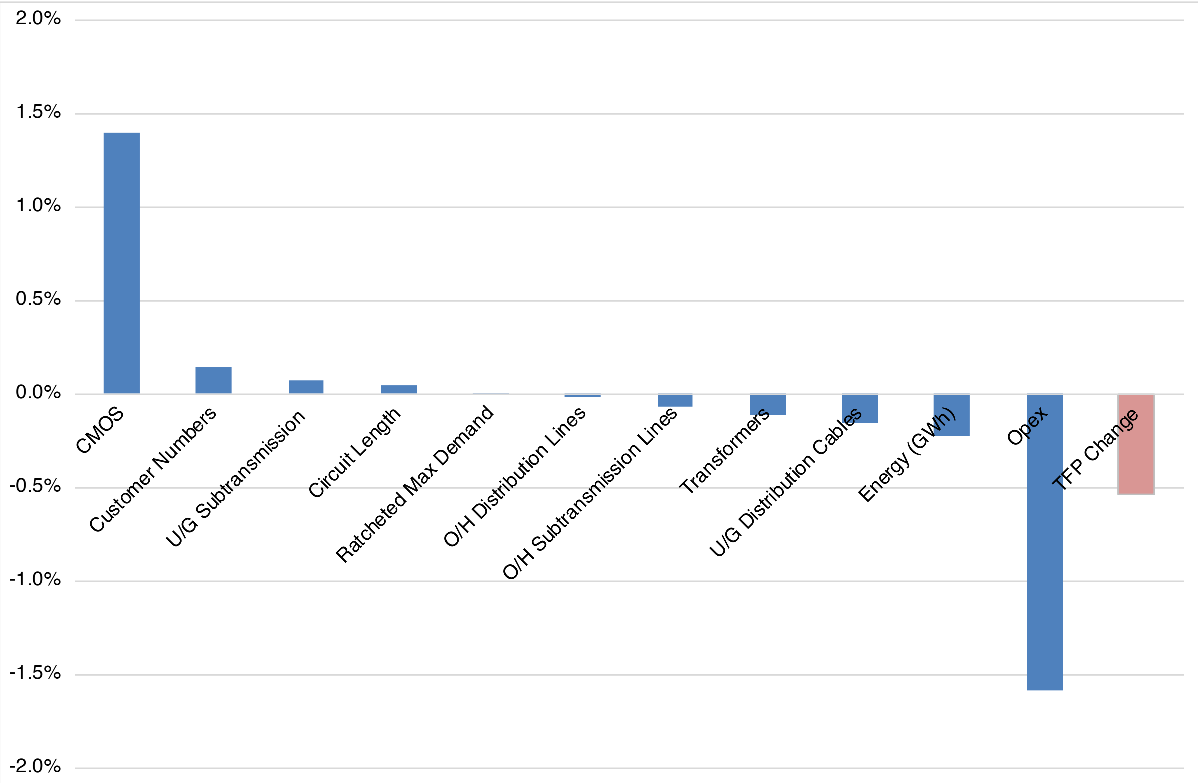


Table 5.20 **UED's output and input percentage point contributions to average annual TFP change: 2006–2020, 2006–2013, 2013–2020 and 2020**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2019 to 2020*
Energy (GWh)	-0.03%	0.04%	-0.09%	-0.23%
Ratcheted Max Demand	0.57%	1.31%	0.01%	-0.01%
Customer Numbers	0.19%	0.19%	0.20%	0.14%
Circuit Length	0.24%	0.24%	0.24%	0.04%
CMOS	0.10%	-0.81%	0.78%	1.40%
Opex	0.07%	-1.45%	1.21%	-1.59%
O/H Subtransmission Lines	-0.10%	-0.18%	-0.05%	-0.07%
O/H Distribution Lines	-0.06%	-0.15%	0.01%	-0.02%
U/G Subtransmission Cables	-0.02%	-0.14%	0.07%	0.07%
U/G Distribution Cables	-0.27%	-0.30%	-0.25%	-0.16%
Transformers	-0.56%	-0.83%	-0.36%	-0.12%
TFP Change	0.12%	-2.07%	1.77%	-0.54%

Figure 5.40 **UED's output and input percentage point contributions to TFP change, 2020**



APPENDIX A: METHODOLOGY

A1 Indexing Methods

Productivity refers to the quantitative relationship between the outputs produced (by a firm, industry or economy) and the inputs used to produce those outputs. This report concerns the outputs produced and inputs used by electricity distribution businesses, and the relationship of outputs to inputs is measured using an index of outputs produced and an index of inputs used. 'Total factor productivity' (TFP) refers to the ratio of an index of all outputs produced by a business to an index of all inputs consumed in producing those outputs. 'Partial factor productivity' (PFP) refers to a ratio of a measure of all or some outputs to a measure of a single input. This report measures TFP using the multilateral Törnqvist TFP (MTFP) index method developed by Caves, Christensen and Diewert (1982).

A1.1 Multilateral Törnqvist TFP index

The method for calculating time series TFP rates of change for individual DNSPs is the same method as that used for calculating the comparative levels of TFP between DNSPs, namely the multilateral Törnqvist TFP index (MTFP) of Caves, Christensen and Diewert (1982) shown in equation (1). For the productivity growth and contributions analyses the multilateral Törnqvist index is applied to the annual time-series observations for each of the 13 DNSP individually or to the aggregated time-series for the industry as a whole. For productivity comparative analysis, for comparing between DNSPs, the data is pooled as panel data and the index is applied across the full sample of 195 observations. For productivity comparative analysis of States (and Territories), the data is first aggregated by State and data for the six States is pooled as panel data and the index is applied across the resulting sample of 90 observations.

$$
\begin{aligned}
\ln (TFP_m/TFP_n) \quad = \quad & \Sigma_i (R_{im}+R_i^*) (\ln Y_{im} - \ln Y_i^*)/2 - \\
& \Sigma_i (R_{in}+R_i^*) (\ln Y_{in} - \ln Y_i^*)/2 - \\
& \Sigma_j (S_{jm}+S_j^*) (\ln X_{jm} - \ln X_j^*)/2 + \\
& \Sigma_j (S_{jn}+S_j^*) (\ln X_{jn} - \ln X_j^*)/2
\end{aligned}
\qquad (1)
$$

where m and n are two adjacent observations;[15] i denotes individual outputs; j denotes individual inputs; and

- R_{im} is the revenue share of the ith output at observation m;
- S_{jm} is the cost share of the jth input at observation m;

[15] A sequence of observations will be ordered by firm and by time-period. When the sample includes more than one firm, *m* might represent the period after *n* for the same firm, or *n* might represent the last observation for one firm and *m* would then represent the first observation of the next firm. If there is only one firm in the sample, the *m* is the period after *n*.

- R_i^* is the revenue share of the ith output averaged over the whole sample;[16]
- S_j^* is the cost share of the jth input averaged over the whole sample;
- Y_{im} is the quantity of the ith output at observation m;
- X_{jm} is the quantity of the jth input at observation m;
- Y_i^* is the average quantity of the ith output over the whole sample;
- X_j^* is the average quantity of the jth input over the whole sample.

To derive the TFP index, an arbitrarily chosen observation is set equal to 1.0. Here the first observation in the sample is used, and the rates of change for every subsequent observation in the sample, calculated using (A.1), are applied sequentially from this base.

The MTFP allows 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. Transitivity 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. 'Characteristicity' says that when comparing two observations, the index should use sufficient information relating to those two observations.[17] The multilateral Törnqvist index satisfies these properties for the whole sample by making comparisons through the sample mean.

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

A1.2 Output and Input Indexes

The rate of change in TFP is equal to the rate of change in the output index minus the rate of change in the input index. Equation (1) can be separated into these two components. The rate of change in the output index is given by:

$$\ln (Y_m/Y_n) = \Sigma_i (R_{im}+R_i^*) (\ln Y_{im} - \ln Y_i^*)/2 - \Sigma_i (R_{in}+R_i^*) (\ln Y_{in} - \ln Y_i^*)/2 \qquad (2)$$

[16] If there is more than one firm in the sample, it is the average over all firms and all periods. If there is only one firm in the sample, it is the average over all periods.

[17] Caves, Christensen and Diewert (1982:74) state that 'characteristicity' refers to the "degree to which weights are specific to the comparison at hand". The OECD (2007:236) (in relation to purchasing power parities) suggests that 'characteristicity' is a property whereby multilateral comparisons differ as little as possible from binary comparisons, subject to satisfying transitivity.

Similarly, the rate of change in the input index is given by:

$$\ln(X_m/X_n) = \Sigma_j (S_{jm}+S_j^*) (\ln X_{jm} - \ln X_j^*)/2 - \Sigma_j (S_{jn}+S_j^*) (\ln X_{jn} - \ln X_j^*)/2 \quad (3)$$

Again. these are converted into output and input indexes by setting the value for the index at the first observation of the sample as equal to 1.0 and applying the rates of change specified by (2) or (3), as appropriate, sequentially for every subsequent observation in the sample.

A1.3 Partial Factor Productivity Indexes

Analysis of partial factor productivity (PFP) trends, where total output is expressed relative to individual inputs, assists to interpret the sources of TFP trends. A partial factor productivity measure is obtained by dividing the index of all outputs over an index of one input, or over an index of a sub-group of inputs. Also note that for the construction of partial productivity indexes, we may need inputs indexes for individual inputs, or for sub-groups of inputs. For a sub-group of inputs, equation (3) applies, but the summation is only over the inputs in the sub-group, and the cost shares need to be re-scaled to sum to 1 for the sub-group. For an individual input k, the growth rate is given simply by: $\ln(X_{km}/X_{kn})$. Again, the index is obtained by setting the first observation in the data set to 1.0.

A1.4 Growth Rates of Indexes

Growth rates in productivity indexes have generally been reported in earlier Economic Insights reports as logarithmic measures, and this report uses the same method of calculation for growth rates presented in tables. That is, the growth rate of a variable Y between period t – 1 and period t is calculated as: $g_t^Y = \ln Y_t - \ln Y_{t-1}$.[18] The log-difference growth rate can be related to the more common growth rate measure based on the first period as follows: $(Y_t - Y_{t-1})/Y_{t-1} = \exp(g_t^Y) - 1$. That is, the relative index values are: $Y_t/Y_{t-1} = \exp(g_t^Y)$.

Although reported annual growth rates are measured as log-differences, the discussion in this report also refers to total percentage changes over the whole period from 2006 to 2020, and these comparisons are not expressed in terms of log growth rates. Economic Insights (2020a Appendix C) also included, as supplementary information, trend measures of growth rates based on linear regression.[19] This report also presents regression-based trend estimates for TFP indexes in Appendix B.

[18] It follows that some decreases in positively-valued variables can be larger (in absolute terms) than –100 per cent. For example, if $Y_{t-1} = 150$ and $Y_t = 50$, then the rate of change using the log measure is –109.9 per cent. This is because the basis for the rate of change measure is not period t – 1, but at a mid-point between periods t – 1 and t.

[19] For the linear regression model: $\ln Y_t = a + b.t + \varepsilon_t$, the estimated coefficient $\hat{b}$ is a measure of the average growth rate of Y over the sample period.

A2 Output and input contributions to TFP change

Analysis of contributions to TFP change of the individual outputs and inputs, which involves decomposing TFP change into its constituent parts. Since TFP change is the change in total output quantity less the change in total input quantity, the contribution of an individual output (input) will depend on the change in the output's (input's) quantity and the weight it receives in forming the total output (total input) quantity index. However, this calculation has to be done in a way that is consistent with the index methodology to provide a decomposition that is consistent and robust. The multilateral Törnqvist index methodology allows us to readily decompose productivity change into the contributions of changes in each output and each input.

The analysis of contributions to TFP change is carried out only for individual firm and industry TFP trends. In this case subscripts *n* and *m* in equation (1) refer only to successive periods. To emphasise this, *m* is denoted *t* and *n* is denoted *t*–1. The *percentage point contribution* of output *i* to productivity change between years *t* and *t–1* ($Cont^Y_{i,t}$) is given by the following equation:

$$Cont^Y_{i,t} = (R_{i,t}+R_i^*)\,(\ln Y_{i,t} - \ln Y_i^*)/2 - (R_{i,t-1}+R_i^*)\,(\ln Y_{i,t-1} - \ln Y_i^*)/2 \qquad (4)$$

And, the *percentage point contribution* of input *j* to productivity change between years *t* and *t*–1 ($Cont^X_{j,t}$) is given by the following equation:

$$Cont^X_{j,t} = -(S_{j,t}+S_j^*)\,(\ln X_{j,t} - \ln X_j^*)/2 + (S_{j,t-1}+S_j^*)\,(\ln X_{j,t-1} - \ln X_j^*)/2 \qquad (5)$$

where all variables in equations (4) and (5) have the same definition as those in equation (1). Using these consistent equations ensures the sum of the percentage point contributions of all outputs and all inputs equals the rate of TFP change obtained in equation (1).

A3 Index Weights

This section explains the method by which index weights are calculated based on value shares of outputs and cost shares of inputs. The value shares applied to outputs are shadow prices based on estimates of the marginal cost of producing each output. For four of the outputs, an econometric cost analysis was used to derive the marginal cost estimates for each output used as the basis for value-share weights. Economic Insights (2020a Appendix B) estimated the costs attributable to each output using the data and method described below. Those estimates are intended to apply for several years and are used in this study.

A3.1 Leontief Cost Function Estimation

The study used 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:

$$C(y^k, w^k, t) = \sum_{i=1}^{M} w_i^k \,[\sum_{j=1}^{N} (a_{ij})^2\, y_j^k\, (1+b_i t)] \qquad (6)$$

where there are M inputs and N outputs, w_i is an input price, y_j is an output, t is a time trend representing technological change and there are k observations. The input/output coefficients a_{ij} are squared to ensure the non–negativity requirement is satisfied; i.e. 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:

$$x_i^k = \sum\nolimits_{j=1}^{N} (a_{ij})^2 y_j^k (1+b_i t) \tag{7}$$

where the i's represent the M inputs, the j's the N outputs and t is a time trend representing the 13 years, 2006 to 2018. The input demand equations were estimated separately for each of the 13 DNSPs using the non–linear regression facility in Shazam (Northwest Econometrics 2007) and data for the years 2006 to 2018. Given the absence of cross equation restrictions, each input demand equation is estimated separately. We then derive the estimated output cost shares, s_j^k, for each output j and each observation k from the 13 firm–specific cost functions as follows:

$$s_j^k = \{\sum\nolimits_{i=1}^{M} w_i^k [(a_{ij}^f)^2 y_j^k (1+b_i^f t)]\} / \{\sum\nolimits_{i=1}^{M} w_i^k [\sum\nolimits_{j=1}^{N} (a_{ij}^f)^2 y_j^k (1+b_i^f t)]\} \tag{8}$$

where f=1,..,5.

Then a weighted average of the estimated output cost shares was calculated across all observations to form an overall estimated output cost share ($\bar{s}_j$) where the weight in the weighted average, g^k, for each observation k, is given by that observation's estimated total cost divided by the overall sum of estimated total costs across all observations:

$$g^k = C_f(b, y^k, w^k, t) / \sum\nolimits_k C_f(b, y^k, w^k, t) \tag{9}$$

A3.2 Weight of CMOS & Re-calibration of Output Weights

The fifth output is Customer Minutes Off-supply (CMOS), the negative of which is a measure supply reliability. The formal way in which reliability is incorporated into the analysis is to treat CMOS as an undesirable output. The method of incorporating undesirable outputs into the multilateral productivity index originates with Pittman (1983), and the method used here is consistent with that approach.

The weight applied to the reliability output is based on the estimated (negative) value of CMOS (i.e. the cost imposed on consumers) as measured by the Values of Customer Reliability (VCR) published by the AER (2019a, 2019b). Since direct data are not readily available on the cost of improving DNSP reliability, economic benchmarking has relied on the VCR, which is a measure of how consumers value supply interruptions. The VCR, expressed on a per minute basis, is multiplied by the quantity of CMOS. That is, the cost of CMOS is based on: $CMOS \times VCR$.

Weights are then re-calibrated as shares of 'gross revenue', which is defined as the sum of total revenue plus the value of energy not supplied. Since reliability carries a negative weight in the output index, this ensures that all of the weights sum to unity. This is shown in Table A.1, using sample average values; weights as shares of total revenue vary across observations in the sample because both revenue and the value of CMOS vary.

Table A.1 **Output cost-based weights (industry average*)**

Output	*Shares of gross revenue (%)*	*Shares of revenue (%)*
Energy throughput	8.58[(a)]	9.75
Ratcheted max. demand	33.76[(a)]	38.37
Customer numbers	18.52[(a)]	21.05
Circuit length	39.14[(a)]	44.49
CMOS	-11.97	-13.67
Total		100.00

Note: Percentages shown may not sum to 100.00 due to rounding.
* Average across all observations (DNSPs and years); (a) Derived from Leontief cost function analysis.

The average output weights for each DNSP and for the aggregated industry are shown in Table A.2.

Table A.2 **Output cost share weights by DNSP (%, average 2006 to 2020)**

Input	*EVO*	*AGD*	*CIT*	*END*	*ENX*	*ERG*	*ESS*
Energy throughput	8.89	9.49	8.96	9.75	9.50	10.86	10.41
Ratcheted max. demand	34.98	37.33	35.25	38.38	37.38	42.72	40.95
Customer numbers	19.19	20.48	19.34	21.05	20.51	23.43	22.47
Circuit length	40.55	43.28	40.86	44.49	43.34	49.53	47.48
CMOS	–3.61	–10.57	–4.40	–13.68	–10.73	–26.54	–21.31
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Input	*JEN*	*PCR*	*SAP*	*AND*	*TND*	*UED*	*Industry**
Energy throughput	9.27	10.24	10.04	9.91	10.14	9.32	9.88
Ratcheted max. demand	36.49	40.30	39.51	39.00	39.91	36.66	38.86
Customer numbers	20.02	22.11	21.68	21.40	21.89	20.11	21.32
Circuit length	42.31	46.72	45.81	45.22	46.27	42.50	45.06
CMOS	–8.10	–19.38	–17.05	–15.52	–18.21	–8.58	–15.11
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Note: Percentages shown may not sum to 100.00 due to rounding; * Average across years for aggregated industry.

A3.4 Input weights & Asset Unit Costs

The input weights are the estimated cost shares of each input. The cost of the opex input is nominal opex. The cost of the capital inputs, in aggregate, is calculated by the AER from the other components of the building block calculation, namely: (a) the return on capital – i.e. the weighted average cost of capital (WACC) applied to the opening regulatory asset base (RAB);

(b) the return of capital – the straight-line depreciation of the RAB less the inflation indexation of the RAB; and (c) benchmark tax liability. This aggregate cost of capital inputs is decomposed by the AER into the separate capital inputs using estimated shares of each capital asset type in the RAB for each DNSP in each year. The decomposed capital-related costs are referred to as the annual user cost (AUC) for each capital input. Table A.3 shows the average cost shares of each input for each DNSP.

Table A.3 **Input cost share weights by DNSP (%, average 2006 to 2020)**

Input	*EVO*	*AGD*	*CIT*	*END*	*ENX*	*ERG*	*ESS*
Real opex	39.03	36.45	26.48	39.40	36.09	35.92	40.04
O/H Subtrans. lines	3.41	4.01	0.56	3.79	3.61	9.52	6.98
O/H Distribution lines	12.36	6.68	6.85	9.76	12.07	21.48	19.85
U/G Subtrans. cables	0.06	5.86	6.80	1.63	4.86	0.47	0.20
U/G Distribution cables	18.63	14.05	34.61	16.52	12.04	3.42	3.86
Transformers	26.51	32.95	24.70	28.90	31.33	29.19	29.07
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Input	*JEN*	*PCR*	*SAP*	*AND*	*TND*	*UED*	*Industry**
Real opex	42.23	40.15	34.49	39.86	35.09	38.32	37.19
O/H Subtrans. lines	4.84	3.85	2.05	2.62	0.44	7.29	4.73
O/H Distribution lines	29.14	22.54	10.73	25.14	27.50	21.41	15.40
U/G Subtrans. cables	0.19	0.10	0.34	0.21	0.36	1.94	2.31
U/G Distribution cables	2.10	11.48	18.27	12.00	11.97	9.61	11.50
Transformers	21.51	21.87	34.14	20.17	24.64	21.42	28.87
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Note: Percentages shown may not sum to 100.00 due to rounding. * Average across years for aggregated industry.

A4 Opex Cost Function Methodologies

This section documents the methods used to estimate the econometric cost functions, the results of which are discussed in section 3.2 and presented in detail in appendix C. To outline our methods we begin by defining the following notation:

C = nominal opex;

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

$K = (K_1, K_2, ..., K_H)$ = an $H \times 1$ vector of capital quantities;[20]

$Z = (Z_1, Z_2, ..., Z_R)$ = an $R \times 1$ vector of operating environment factors;[21] and

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

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

[20] Note that this is the general functional form for the opex econometric models. In the specific specification used in this report, we have not included capital quantity as an explanatory variable.

[21] In the specific specification used in this report, we have incorporated one operating environment factor into the model, namely the percentage of lines underground.

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, $x_1 = \log(X_1)$.

A4.1 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:

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

while the translog cost frontier may be specified as:

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

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; Kumbhakar and Lovell 2000). These dummy variables are defined as:

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

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

$$c_{it} = \beta_0 + \sum_{m=1}^{M} \beta_m x_{mit} + \sum_{n=2}^{N} \delta_n D_{nit} + \lambda_1 t + v_{it} \tag{12}$$

and

$$c_{it} = \beta_0 + \sum_{m=1}^{M} \beta_m x_{mit} + 0.5 \sum_{m=1}^{M} \sum_{l=1}^{M} \beta_{ml} x_{mit} x_{lit} + \sum_{n=2}^{N} \delta_n D_{nit} + \lambda_1 t + v_{it}, \tag{13}$$

respectively.

In this study, the models in equations (12) and (13) 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 (2012 ch.11), and have been calculated using the *xtpcse* command in *Stata Release 16* (StataCorp 2020).

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

$$CE_n = \exp[\min(\hat{\delta}_n) - \hat{\delta}_n], \quad (n = 1, 2, ..., N) \tag{14}$$

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.

A4.2 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 (10) and (11) to obtain a Cobb–Douglas stochastic cost frontier:

$$c_{it} = \beta_0 + \sum_{m=1}^{M} \beta_m x_{mit} + \lambda_1 t + v_{it} + u_i \tag{15}$$

and a translog stochastic cost frontier:

$$c_{it} = \beta_0 + \sum_{m=1}^{M} \beta_m x_{mit} + 0.5 \sum_{m=1}^{M} \sum_{l=1}^{M} \beta_{ml} x_{mit} x_{lit} + \lambda_1 t + v_{it} + u_i, \tag{16}$$

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 $|N(\mu, \sigma_u^2)|$.

Given these distributional assumptions, the unknown parameters in models (15) and (16) can be estimated using Maximum Likelihood Estimation (MLE) methods. In this study we do this using the *xtfrontier* command in *Stata Release 16*.

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

$$CE_n = \exp[u_n], \quad (n = 1, 2, ..., N) \tag{17}$$

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:

$$CE_n = E[\exp(u_n) \mid (v_n + u_n)], \quad (n = 1, 2, ..., N) \tag{18}$$

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: REGRESSION–BASED TREND GROWTH RATES

Table B1 **Distribution output, input, total factor productivity and partial productivity index trend annual growth rates, 2006–2020**

DNSP	*Output*	*Input*	*TFP*	*PFP Index*	
Period	*Index*	*Index*	*Index*	*Opex*	*Capital*
Industry					
Growth Rate 2006–20	0.8%	1.6%	-0.8%	0.1%	-1.3%
Growth Rate 2006–12	1.6%	3.7%	-2.1%	-3.4%	-1.4%
Growth Rate 2012–20	0.4%	0.0%	0.5%	2.9%	-1.0%
EVO					
Growth Rate 2006–20	1.3%	1.2%	0.1%	0.7%	-0.2%
Growth Rate 2006–12	1.4%	3.8%	-2.4%	-5.3%	-0.4%
Growth Rate 2012–20	0.8%	-1.5%	2.4%	6.5%	-0.3%
AGD					
Growth Rate 2006–20	0.5%	0.7%	-0.1%	1.7%	-1.1%
Growth Rate 2006–12	1.1%	3.5%	-2.5%	-4.2%	-1.5%
Growth Rate 2012–20	0.1%	-1.5%	1.6%	5.8%	-0.6%
CIT					
Growth Rate 2006–20	0.9%	1.7%	-0.9%	-1.3%	-0.8%
Growth Rate 2006–12	1.2%	3.8%	-2.6%	-5.9%	-1.5%
Growth Rate 2012–20	0.8%	-0.1%	0.9%	3.1%	0.1%
END					
Growth Rate 2006–20	1.3%	1.8%	-0.5%	1.2%	-1.6%
Growth Rate 2006–12	1.7%	3.1%	-1.4%	-1.0%	-1.8%
Growth Rate 2012–20	1.5%	0.6%	0.8%	3.5%	-0.8%
ENX					
Growth Rate 2006–20	1.5%	1.9%	-0.4%	0.5%	-0.9%
Growth Rate 2006–12	3.6%	4.6%	-1.0%	-2.2%	-0.4%
Growth Rate 2012–20	0.6%	-0.1%	0.7%	3.7%	-1.0%
ERG					
Growth Rate 2006–20	1.0%	1.4%	-0.3%	0.7%	-1.0%
Growth Rate 2006–12	1.7%	2.4%	-0.7%	-0.9%	-0.7%
Growth Rate 2012–20	0.2%	0.9%	-0.8%	0.4%	-1.4%
ESS					
Growth Rate 2006–20	0.9%	1.7%	-0.8%	0.5%	-1.7%
Growth Rate 2006–12	0.8%	5.6%	-4.8%	-6.4%	-3.8%
Growth Rate 2012–20	0.7%	-0.6%	1.3%	4.2%	-0.6%

Table B1 **(cont.)**

DNSP *Period*	*Output* *Index*	*Input* *Index*	*TFP* *Index*	*PFP Index* *Opex*	*PFP Index* *Capital*
JEN					
Growth Rate 2006–20	1.2%	1.6%	-0.3%	-0.6%	-0.1%
Growth Rate 2006–12	2.2%	2.1%	0.1%	-0.9%	0.9%
Growth Rate 2012–20	1.0%	0.8%	0.2%	1.1%	-0.5%
PCR					
Growth Rate 2006–20	0.9%	1.8%	-0.9%	-0.4%	-1.1%
Growth Rate 2006–12	1.6%	2.6%	-1.0%	-1.1%	-0.9%
Growth Rate 2012–20	0.9%	0.6%	0.3%	2.5%	-1.2%
SAP					
Growth Rate 2006–20	0.7%	2.4%	-1.7%	-2.9%	-1.1%
Growth Rate 2006–12	1.7%	4.2%	-2.5%	-5.7%	-1.0%
Growth Rate 2012–20	0.2%	0.7%	-0.5%	0.3%	-1.0%
AND					
Growth Rate 2006–20	0.9%	2.6%	-1.7%	-2.7%	-1.0%
Growth Rate 2006–12	2.8%	4.3%	-1.5%	-3.9%	0.1%
Growth Rate 2012–20	0.2%	1.2%	-1.0%	-0.6%	-1.3%
TND					
Growth Rate 2006–20	0.5%	1.2%	-0.7%	-0.2%	-1.0%
Growth Rate 2006–12	0.6%	3.8%	-3.2%	-5.8%	-1.8%
Growth Rate 2012–20	0.3%	0.4%	-0.1%	0.9%	-0.7%
UED					
Growth Rate 2006–20	0.9%	1.1%	-0.2%	0.7%	-0.7%
Growth Rate 2006–12	1.3%	3.3%	-2.0%	-3.1%	-1.2%
Growth Rate 2012–20	1.3%	-0.6%	1.8%	4.3%	0.4%

APPENDIX C: OPEX COST FUNCTION REGRESSION RESULTS

C1 Full sample results

The models in this section all have 1,010 observations. The LSE models use panel-corrected standard errors.

Table C.1 **SFA Cobb–Douglas cost frontier estimates using 2006–2020 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.440	0.076	5.777
ln(CircLen)	0.118	0.044	2.659
ln(RMDemand)	0.411	0.064	6.382
ln(ShareUGC)	-0.178	0.032	-5.600
Year	0.015	0.001	15.183
Country dummy variables:			
New Zealand	0.186	0.093	2.012
Ontario	0.231	0.079	2.909
Constant	-20.492	1.986	-10.316
Variance parameters:			
Mu	0.331	0.064	5.17
SigmaU squared	0.043	0.012	3.609
SigmaV squared	0.013	0.001	21.689
LLF			638.983

Table C.2 **SFA translog cost function estimates using 2006–2020 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.510	0.084	6.103
ln(CircLen)=x2	0.115	0.053	2.151
ln(RMDemand)=x3	0.350	0.074	4.756
x1*x1/2	0.478	0.460	1.040
x1*x2	-0.209	0.117	-1.780
x1*x3	-0.279	0.372	-0.749
x2*x2/2	0.070	0.063	1.096
x2*x3	0.160	0.100	1.597
x3*x3/2	0.095	0.304	0.313
ln(ShareUGC)	-0.153	0.039	-3.942
Year	0.014	0.001	11.904
Country dummy variables:			
New Zealand	0.205	0.128	1.600
Ontario	0.246	0.091	2.696
Constant	-18.262	2.343	-7.794
Variance parameters:			
Mu	0.333	0.087	3.806
SigmaU squared	0.052	0.019	2.779
SigmaV squared	0.013	0.001	21.390
LLF			641.37

Table C.3 **LSE Cobb–Douglas cost function estimates using 2006–2020 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.569	0.066	8.620
ln(CircLen)	0.154	0.029	5.297
ln(RMDemand)	0.254	0.061	4.186
ln(ShareUGC)	-0.161	0.022	-7.183
Year	0.014	0.002	8.182
Country dummy variables:			
New Zealand	-0.238	0.135	-1.765
Ontario	-0.077	0.134	-0.576
DNSP dummy variables:			
AGD	0.028	0.180	0.155
CIT	-0.648	0.152	-4.251
END	-0.243	0.153	-1.589
ENX	-0.278	0.144	-1.927
ERG	-0.186	0.157	-1.183
ESS	-0.333	0.167	-1.993
JEN	-0.314	0.151	-2.073
PCR	-0.766	0.152	-5.039
SAP	-0.536	0.151	-3.542
AND	-0.445	0.150	-2.973
TND	-0.510	0.160	-3.195
UED	-0.532	0.155	-3.428
Constant	-18.357	3.485	-5.268
R–Square			0.992

Translog versus Cobb-Douglas Specifications

In considering the adequacy of the Cobb-Douglas and translog specifications, the primary consideration used in this report is the extent to which there are serious monotonicity violations. Monotonicity refers to the requirement that an output cannot be increased without an increase in cost, so that the elasticity of cost with respect to each output should not be negative. This is an economic criterion, rather than a statistical criterion. A focus on the monotonicity criterion is consistent with the approach taken in the 2020 report.

It can also be informative to have regard to statistical criteria, and so we test whether the additional variables in the translog model, which don't appear in the Cobb-Douglas, are jointly significantly different from zero. In the SFA models, the Wald test for the null hypothesis that coefficients on the higher-order terms in C.2, which don't appear in C.1, are jointly equal to zero yields a p-value of 0.6063. This means that the null hypothesis cannot be rejected at a significance level of 0.05 (or at a less stringent significance level). In the LSE models, the Wald test for the null hypothesis that coefficients on the higher-order terms in C.4, which don't appear in C.3, are jointly equal to zero yields a p-value of 0.0000. This means that the null hypothesis can be rejected at a significance level of 0.05 (or at more stringent significance level). This means there are two very different conclusions on the importance of the higher-order terms included in the translog specification but not included in the Cobb-Douglas specification, depending on whether LSE or SFA estimation is used.

Table C.4 **LSE translog cost function estimates using 2006–2020 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.401	0.070	5.702
ln(CircLen)=x2	0.170	0.030	5.684
ln(RMDemand)=x3	0.386	0.059	6.572
x1*x1/2	-0.971	0.480	-2.024
x1*x2	0.357	0.116	3.082
x1*x3	0.547	0.368	1.488
x2*x2/2	-0.031	0.041	-0.757
x2*x3	-0.300	0.093	-3.217
x3*x3/2	-0.156	0.284	-0.550
ln(ShareUGC)	-0.140	0.026	-5.351
Year	0.015	0.002	8.856
Country dummy variables:			
New Zealand	-0.322	0.131	-2.464
Ontario	-0.194	0.130	-1.501
DNSP dummy variables:			
AGD	-0.073	0.184	-0.396
CIT	-0.668	0.149	-4.497
END	-0.377	0.152	-2.486
ENX	-0.385	0.146	-2.628
ERG	-0.304	0.171	-1.776
ESS	-0.531	0.180	-2.948
JEN	-0.152	0.158	-0.962
PCR	-0.872	0.151	-5.770
SAP	-0.688	0.153	-4.501
AND	-0.467	0.150	-3.103
TND	-0.551	0.155	-3.546
UED	-0.398	0.164	-2.419
Constant	-20.509	3.471	-5.909
R–Square			0.992

Elasticities & Monotonicity Violations in TLG models

Tables C.5 and C.6 provide information on the average elasticities of real opex with respect to each of the outputs in the translog models. Tables C.7 and C.8 show the proportions of observations for which there are monotonicity violations.

Table C.5 **Average DNSP output elasticities by country 2006–2020**

	SFATLG model			*LSETLG model*		
Sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
Australia	0.478	0.149	0.331	0.291	0.254	0.503
New Zealand	0.414	0.118	0.475	0.593	0.214	0.119
Ontario	0.574	0.101	0.289	0.339	0.116	0.486
Full sample	0.510	0.115	0.350	0.401	0.170	0.386

Table C.6 **Average DNSP output elasticities by Aust. DNSP, 2006–2020**

	SFATLG model			*LSETLG model*		
Sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
EVO	0.593	0.092	0.278	0.201	0.224	0.548
AGD	0.599	0.130	0.200	0.008	0.282	0.795
CIT	0.704	0.076	0.155	-0.027	0.217	0.809
END	0.482	0.167	0.293	0.262	0.219	0.597
ENX	0.524	0.149	0.269	0.149	0.277	0.657
ERG	0.117	0.285	0.580	0.913	0.152	0.046
ESS	0.199	0.239	0.550	0.733	0.256	0.104
JEN	0.738	0.039	0.175	-0.112	0.321	0.764
PCR	0.369	0.181	0.422	0.453	0.273	0.340
SAP	0.322	0.207	0.440	0.533	0.238	0.313
AND	0.502	0.124	0.342	0.222	0.331	0.482
TND	0.354	0.184	0.437	0.578	0.181	0.271
UED	0.715	0.061	0.166	-0.129	0.329	0.813
Total (Aust.)	0.478	0.149	0.331	0.291	0.254	0.503

Table C.7 **Frequency of monotonicity violations by country 2006–2020**

	SFATLG model			*LSETLG model*		
Sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
Australia	0.0%	0.0%	0.0%	25.1%	0.0%	0.0%
New Zealand	0.0%	0.0%	0.0%	0.0%	0.0%	34.4%
Ontario	0.0%	0.0%	0.0%	0.0%	1.1%	0.0%
Full sample	0.0%	0.0%	0.0%	4.9%	0.6%	9.7%

Table C.8 **Frequency of monotonicity violations by DNSP (Aust.) 2006-2020**

	SFATLG model			*LSETLG model*		
Sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
EVO	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGD	0.0%	0.0%	0.0%	33.3%	0.0%	0.0%
CIT	0.0%	0.0%	0.0%	93.3%	0.0%	0.0%
END	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENX	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ERG	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ESS	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
JEN	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%
PCR	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SAP	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AND	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TND	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
UED	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%
Total (Aust.)	0.0%	0.0%	0.0%	25.1%	0.0%	0.0%

C2 Sample from 2012 to 2020

The models in this section all have 602 observations.

Table C.9 **SFA Cobb–Douglas cost frontier estimates using 2012–2020 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.410	0.098	4.181
ln(CircLen)	0.229	0.049	4.657
ln(RMDemand)	0.323	0.092	3.523
ln(ShareUGC)	-0.090	0.042	-2.152
Year	0.008	0.002	4.446
Country dummy variables:			
New Zealand	0.071	0.096	0.741
Ontario	0.255	0.092	2.778
Constant	-6.302	3.586	-1.757
Variance parameters:			
Mu	0.360	0.064	5.585
SigmaU squared	0.035	0.008	4.175
SigmaV squared	0.010	0.001	16.314
LLF			425.673

Table C.10 **SFA translog cost function estimates using 2012–2020 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.374	0.115	3.240
ln(CircLen)=x2	0.229	0.054	4.278
ln(RMDemand)=x3	0.362	0.102	3.550
x1*x1/2	-1.993	0.642	-3.103
x1*x2	0.369	0.168	2.188
x1*x3	1.417	0.495	2.861
x2*x2/2	0.073	0.078	0.938
x2*x3	-0.423	0.131	-3.232
x3*x3/2	-0.842	0.391	-2.153
ln(ShareUGC)	-0.065	0.051	-1.275
Year	0.009	0.002	4.575
Country dummy variables:			
New Zealand	-0.087	0.113	-0.769
Ontario	0.123	0.095	1.305
Constant	-8.074	3.888	-2.077
Variance parameters:			
Mu	0.426	0.083	5.128
SigmaU squared	0.034	0.009	3.899
SigmaV squared	0.009	0.001	15.732
LLF			438.649

Translog versus Cobb-Douglas Specifications

As previously noted, in considering the adequacy of the Cobb-Douglas and translog specifications, the primary consideration used in this report is the extent to which there are serious monotonicity violations. This is consistent with the approach taken in the 2020 report. That said, it can also be informative to test whether the additional variables in the translog model, which don’t appear in the Cobb-Douglas, are jointly significantly different from zero.

Using the shorter sample period, in the SFA models, the Wald test for the null hypothesis that coefficients on the higher-order terms in C.10, which don’t appear in C.9, are jointly equal to zero yields a p-value of 0.0005. This means that the null hypothesis can be rejected at a significance level of 0.05. In the LSE models, the Wald test for the null hypothesis that coefficients on the higher-order terms in C.12, which don’t appear in C.11, are jointly equal to zero yields a p-value of 0.0000. This means that the null hypothesis can be rejected at a significance level of 0.05. This means that in both models the additional terms in the translog model are jointly statistically significant.

Table C.11 **LSE Cobb–Douglas cost function estimates using 2012–2020 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.555	0.074	7.475
ln(CircLen)	0.184	0.031	5.930
ln(RMDemand)	0.244	0.071	3.415
ln(ShareUGC)	-0.162	0.026	-6.313
Year	0.009	0.003	2.972
Country dummy variables:			
New Zealand	-0.245	0.170	-1.436
Ontario	-0.067	0.170	-0.393
DNSP dummy variables:			
AGD	-0.019	0.210	-0.090
CIT	-0.564	0.182	-3.109
END	-0.297	0.186	-1.595
ENX	-0.285	0.181	-1.579
ERG	-0.275	0.188	-1.460
ESS	-0.356	0.197	-1.807
JEN	-0.296	0.179	-1.655
PCR	-0.807	0.183	-4.409
SAP	-0.506	0.181	-2.801
AND	-0.399	0.178	-2.237
TND	-0.545	0.197	-2.762
UED	-0.544	0.190	-2.864
Constant	-6.994	5.786	-1.209
R–Square			0.995

Table C.12 **LSE translog cost function estimates using 2012–2020 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.333	0.077	4.314
ln(CircLen)=x2	0.219	0.029	7.443
ln(RMDemand)=x3	0.408	0.065	6.241
x1*x1/2	-1.483	0.575	-2.580
x1*x2	0.373	0.130	2.865
x1*x3	0.943	0.438	2.155
x2*x2/2	0.023	0.042	0.539
x2*x3	-0.365	0.103	-3.538
x3*x3/2	-0.408	0.336	-1.213
ln(ShareUGC)	-0.119	0.025	-4.718
Year	0.011	0.003	3.911
Country dummy variables:			
New Zealand	-0.367	0.154	-2.383
Ontario	-0.192	0.153	-1.250
DNSP dummy variables:			
AGD	-0.026	0.199	-0.130
CIT	-0.606	0.166	-3.657
END	-0.402	0.171	-2.353
ENX	-0.311	0.170	-1.832
ERG	-0.461	0.190	-2.433
ESS	-0.574	0.201	-2.856
JEN	-0.055	0.173	-0.316
PCR	-0.850	0.172	-4.943
SAP	-0.640	0.171	-3.745
AND	-0.304	0.173	-1.756
TND	-0.592	0.180	-3.293
UED	-0.314	0.184	-1.701
Constant	-11.069	5.461	-2.027
R–Square			0.995

Elasticities & Monotonicity Violations in TLG models

Tables E.13 and E.14 provide information on the average elasticities of real opex with respect to each of the outputs in the translog models. Tables E.15 and E.16 show the proportions of observations for which there are monotonicity violations.

Table C.13 **Average DNSP output elasticities by country 2012–2020**

	SFATLG model			*LSETLG model*		
Sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
Australia	-0.130	0.342	0.669	-0.027	0.335	0.701
New Zealand	0.446	0.389	0.127	0.507	0.315	0.101
Ontario	0.523	0.100	0.376	0.372	0.124	0.465
Full sample	0.374	0.229	0.362	0.333	0.219	0.408

Table C.14 **Average DNSP output elasticities by Aust. DNSP, 2012–2020**

	SFATLG model			*LSETLG model*		
Sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
EVO	-0.015	0.259	0.677	0.014	0.267	0.675
AGD	-0.494	0.281	1.057	-0.387	0.325	1.094
CIT	-0.193	0.151	0.952	-0.215	0.213	0.982
END	-0.056	0.252	0.693	-0.025	0.275	0.796
ENX	-0.364	0.327	0.889	-0.242	0.345	0.929
ERG	0.639	0.369	-0.075	0.663	0.303	0.124
ESS	0.210	0.499	0.173	0.379	0.415	0.254
JEN	-0.619	0.339	1.138	-0.458	0.361	1.021
PCR	-0.108	0.443	0.532	0.062	0.400	0.553
SAP	0.084	0.397	0.404	0.198	0.358	0.486
AND	-0.465	0.480	0.824	-0.224	0.446	0.749
TND	0.364	0.316	0.254	0.386	0.282	0.345
UED	-0.672	0.332	1.182	-0.508	0.364	1.103
Total (Aust.)	-0.130	0.342	0.669	-0.027	0.335	0.701

Table C.15 **Frequency of monotonicity violations by country 2012–2020**

	SFATLG model			*LSETLG model*		
Sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
Australia	64.1%	0.0%	7.7%	57.3%	0.0%	0.0%
New Zealand	25.1%	0.0%	36.8%	5.8%	0.0%	44.4%
Ontario	3.2%	8.0%	2.9%	3.8%	4.1%	2.9%
Full sample	21.3%	4.2%	13.5%	14.8%	2.2%	14.1%

Table C.16 **Frequency of monotonicity violations by DNSP (Aust.) 2012-2020**

	SFATLG model			*LSETLG model*		
Sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
EVO	44.4%	0.0%	0.0%	44.4%	0.0%	0.0%
AGD	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%
CIT	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%
END	77.8%	0.0%	0.0%	77.8%	0.0%	0.0%
ENX	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%
ERG	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%
ESS	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
JEN	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%
PCR	100.0%	0.0%	0.0%	22.2%	0.0%	0.0%
SAP	11.1%	0.0%	0.0%	0.0%	0.0%	0.0%
AND	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%
TND	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
UED	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%
Total (Aust.)	64.1%	0.0%	7.7%	57.3%	0.0%	0.0%

C3 Examination of Alternative Specifications

An examination of alternative specifications for the opex cost function has been carried out to determine whether there is scope to improve on the Translog (TLG) specification with regard to satisfying the monotonicity requirement from economic theory. Last year Economic Insights (2020a) examined a two-output opex cost function model, and found it to be adequate in regards to monotonicity. While the results with the two-output model specifications indicate that these models address monotonicity violations, we recognise some downsides of this approach. In particular, the two-output models may suffer from the omitted variable problem in econometric modelling. Given the currently understood importance of all three outputs, these models also introduce a difficulty when applying them in the context of resets, without additional OEF assessment. Thus, the scope and direction taken in examining alternative specifications this year is different. The specification search kept the same outputs and other variables as used in the models described above because the Cobb-Douglas (CD) three-output specification is considered satisfactory, and is assumed to be a basic or minimum specification. For this reason, the two-output model tested in 2020 was not examined in this exercise.

The main variations to the models described in section C1 and C2 were to test specifications intermediate between the TLG and CD specifications (called 'hybrid' models)—i.e. the TLG model with some parameters constrained to zero. The rationale for testing hybrid models is as follows. The monotonicity violations are most likely the result of the greater flexibility in the TLG functional form in which the edges of the isoquants can 'bend backwards' in places because the data is thinner in those extreme regions and hence the shape of the production surface could be more influenced by a handful of atypical observations. By imposing selected constraints on the TLG model (by setting the coefficients on some squared terms to be zero), thereby making it somewhat less flexible, this may make its curvature more 'well behaved' in the face of atypical or outlying observations.

The key finding from the testing of 'hybrid' models are as follows. A specification in which the squared terms applying to the two highly correlated outputs (customer numbers and RMD) are excluded, but the squared term on circuit length and the three interaction terms are retained, reduces the frequency of the monotonicity violations for Australian DNSPs in various different sample periods tested. The remaining 2nd-order terms are jointly significant in at least one of the SFA and LSE models, and often in both.

Whether this hybrid specification can consistently and adequately reduce the monotonicity violation issues (compared to TLG) in future samples remains uncertain. The performance of this hybrid specification should be tested again with additional data in 2022, to see if it performs adequately. If so, then in circumstances where the TLG model is inadequate due to excessive monotonicity violations, and if the hybrid specification does not have excessive violations for the same DNSPs, then it might possibly be used as a substitute for the TLG model for the purpose of calculating an average efficiency score over four models.

We also consider this could address Jemena's concern, outlined in section 1.4, in relation to year-to-year inclusion/exclusion of translog models introducing volatility into the efficiency assessment. If a hybrid model (between CD and TLG) can adequately address the monotonicity violation problem, then it can potentially be used instead of the more flexible TLG model for at least those DNSPs with monotonicity violations with the base TLG models.

APPENDIX D: INDIVIDUAL OUTPUTS & INPUTS: GROWTH RATES & PFP

Table D.1 **Distribution industry individual output, input and PFP growth rates**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2020*
Outputs:				
Energy (GWh)	-0.3%	0.1%	-0.6%	-2.0%
Ratcheted Max Demand (MVA)	1.2%	2.3%	0.4%	0.6%
Customer Numbers	1.3%	1.3%	1.4%	1.1%
Circuit Length (km)	0.3%	0.3%	0.3%	0.4%
CMOS	-0.1%	-2.0%	1.4%	1.9%
Inputs:				
Real Opex ($'000 2006)	0.6%	5.2%	-2.8%	-4.9%
O/H Sub-tran. Lines (MVA-kms)	1.0%	1.6%	0.4%	0.4%
O/H Distr. Lines (MVA-kms)	0.8%	1.3%	0.4%	0.5%
U/G Sub-tran. Lines (MVA-kms)	2.3%	2.9%	1.9%	4.2%
U/G Sub-tran. Lines (MVA-kms)	3.5%	4.4%	2.9%	2.7%
Transformers (MVA)	2.4%	3.6%	1.6%	1.2%
All Capital inputs	2.1%	3.0%	1.5%	1.3%
Partial productivity:				
Output / Real Opex	0.3%	-3.5%	3.1%	5.1%
Output / OH Sub-tran. Lines	0.0%	0.1%	-0.1%	-0.3%
Output / OH Distr. Lines	0.1%	0.4%	-0.1%	-0.3%
Output / UG Sub-tran. Lines	-1.4%	-1.2%	-1.5%	-4.0%
Output / UG Distr. Lines	-2.6%	-2.7%	-2.6%	-2.5%
Output / Transformers	-1.5%	-1.9%	-1.3%	-1.0%
Output / Capital	-1.2%	-1.3%	-1.1%	-1.1%

Table D.2 **EVO's individual output, input and PFP growth rates**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2020*
Outputs:				
Energy (GWh)	0.2%	0.8%	-0.2%	-1.1%
Ratcheted Max Demand (MVA)	1.0%	1.8%	0.4%	0.0%
Customer Numbers	2.1%	1.9%	2.2%	2.0%
Circuit Length (km)	1.3%	1.6%	1.2%	3.2%
CMOS	2.1%	0.7%	3.1%	1.6%
Inputs:				
Real Opex ($'000 2006)	0.7%	6.2%	-3.5%	-5.2%
O/H Sub-tran. Lines (MVA-kms)	0.5%	1.8%	-0.4%	0.0%
O/H Distr. Lines (MVA-kms)	-0.2%	-0.4%	-0.1%	0.3%
U/G Sub-tran. Lines (MVA-kms)	9.9%	0.0%	17.2%	1.3%
U/G Sub-tran. Lines (MVA-kms)	2.4%	2.9%	1.9%	3.1%
Transformers (MVA)	1.8%	2.0%	1.7%	1.4%
All Capital inputs	1.5%	1.8%	1.3%	1.7%

Table D.2 **(cont.)**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2020*
Partial productivity:				
Output / Real Opex	0.6%	-4.6%	4.4%	6.7%
Output / OH Sub-tran. Lines	0.7%	-0.1%	1.3%	1.5%
Output / OH Distr. Lines	1.4%	2.1%	1.0%	1.2%
Output / UG Sub-tran. Lines	-8.6%	1.7%	-16.3%	0.2%
Output / UG Distr. Lines	-1.1%	-1.2%	-1.0%	-1.5%
Output / Transformers	-0.6%	-0.3%	-0.8%	0.1%
Output / Capital	-0.3%	-0.1%	-0.4%	-0.1%

Table D.3 **AGD's individual output, input and PFP growth rates**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2020*
Outputs:				
Energy (GWh)	-1.3%	-0.4%	-2.0%	-1.9%
Ratcheted Max Demand (MVA)	0.5%	1.2%	0.0%	0.0%
Customer Numbers	0.9%	0.8%	1.0%	0.9%
Circuit Length (km)	0.6%	0.8%	0.5%	0.7%
CMOS	1.3%	-0.8%	2.9%	22.0%
Inputs:				
Real Opex ($'000 2006)	-2.0%	4.4%	-6.8%	-11.9%
O/H Sub-tran. Lines (MVA-kms)	-0.2%	0.1%	-0.5%	-1.7%
O/H Distr. Lines (MVA-kms)	0.3%	-0.2%	0.6%	-6.0%
U/G Sub-tran. Lines (MVA-kms)	0.6%	0.4%	0.7%	4.9%
U/G Sub-tran. Lines (MVA-kms)	2.0%	2.6%	1.6%	1.5%
Transformers (MVA)	2.2%	3.9%	0.8%	1.1%
All Capital inputs	1.6%	2.6%	0.9%	0.6%
Partial productivity:				
Output / Real Opex	2.3%	-3.4%	6.7%	9.8%
Output / OH Sub-tran. Lines	0.6%	0.9%	0.4%	-0.4%
Output / OH Distr. Lines	0.1%	1.2%	-0.7%	3.9%
Output / UG Sub-tran. Lines	-0.2%	0.6%	-0.7%	-7.0%
Output / UG Distr. Lines	-1.6%	-1.6%	-1.7%	-3.6%
Output / Transformers	-1.8%	-2.9%	-0.9%	-3.3%
Output / Capital	-1.2%	-1.6%	-1.0%	-2.8%

Table D.4 **CIT's individual output, input and PFP growth rates**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2020*
Outputs:				
Energy (GWh)	-1.0%	0.3%	-2.0%	-11.5%
Ratcheted Max Demand (MVA)	1.2%	1.7%	0.8%	0.9%
Customer Numbers	1.1%	1.3%	1.0%	0.4%
Circuit Length (km)	1.0%	1.4%	0.8%	0.3%
CMOS	2.0%	4.0%	0.5%	25.8%
Inputs:				
Real Opex ($'000 2006)	2.3%	8.1%	-2.1%	-6.1%
O/H Sub-tran. Lines (MVA-kms)	0.1%	-0.3%	0.4%	0.1%
O/H Distr. Lines (MVA-kms)	-0.7%	-0.2%	-1.1%	-2.3%
U/G Sub-tran. Lines (MVA-kms)	4.4%	5.0%	4.0%	10.7%
U/G Sub-tran. Lines (MVA-kms)	1.5%	3.3%	0.2%	-1.5%
Transformers (MVA)	1.6%	2.1%	1.2%	1.8%
All Capital inputs	1.6%	2.7%	0.8%	0.7%
Partial productivity:				
Output / Real Opex	-1.4%	-6.9%	2.7%	4.5%
Output / OH Sub-tran. Lines	0.7%	1.5%	0.2%	-1.7%
Output / OH Distr. Lines	1.6%	1.5%	1.6%	0.7%
Output / UG Sub-tran. Lines	-3.6%	-3.8%	-3.4%	-12.3%
Output / UG Distr. Lines	-0.7%	-2.1%	0.4%	-0.1%
Output / Transformers	-0.7%	-0.9%	-0.6%	-3.3%
Output / Capital	-0.7%	-1.5%	-0.2%	-2.3%

Table D.5 **END's individual output, input and PFP growth rates**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2020*
Outputs:				
Energy (GWh)	-0.3%	-0.7%	0.0%	-1.5%
Ratcheted Max Demand (MVA)	1.0%	1.6%	0.5%	0.0%
Customer Numbers	1.5%	1.0%	1.9%	2.1%
Circuit Length (km)	1.3%	1.1%	1.4%	1.1%
CMOS	0.6%	0.0%	1.0%	13.4%
Inputs:				
Real Opex ($'000 2006)	-0.2%	3.6%	-3.0%	-11.3%
O/H Sub-tran. Lines (MVA-kms)	0.2%	0.8%	-0.3%	-0.7%
O/H Distr. Lines (MVA-kms)	-0.3%	0.0%	-0.5%	-0.6%
U/G Sub-tran. Lines (MVA-kms)	5.9%	7.6%	4.5%	0.4%
U/G Sub-tran. Lines (MVA-kms)	5.4%	6.6%	4.6%	3.3%
Transformers (MVA)	2.7%	3.3%	2.3%	1.5%
All Capital inputs	2.9%	3.7%	2.3%	1.2%

Table D.5 **(cont.)**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2020*
Partial productivity:				
Output / Real Opex	1.4%	-2.3%	4.1%	10.3%
Output / OH Sub-tran. Lines	1.0%	0.5%	1.4%	-0.3%
Output / OH Distr. Lines	1.4%	1.3%	1.6%	-0.4%
Output / UG Sub-tran. Lines	-4.7%	-6.3%	-3.5%	-1.4%
Output / UG Distr. Lines	-4.3%	-5.2%	-3.5%	-4.3%
Output / Transformers	-1.6%	-2.0%	-1.2%	-2.5%
Output / Capital	-1.7%	-2.3%	-1.3%	-2.2%

Table D.6 **ENX's individual output, input and PFP growth rates**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2020*
Outputs:				
Energy (GWh)	0.2%	0.5%	0.0%	-1.3%
Ratcheted Max Demand (MVA)	1.7%	3.8%	0.1%	0.7%
Customer Numbers	1.6%	1.7%	1.5%	1.3%
Circuit Length (km)	1.2%	1.6%	0.9%	0.8%
CMOS	-2.4%	-9.8%	3.2%	7.3%
Inputs:				
Real Opex ($'000 2006)	1.3%	6.7%	-2.7%	-5.4%
O/H Sub-tran. Lines (MVA-kms)	1.4%	2.4%	0.6%	2.0%
O/H Distr. Lines (MVA-kms)	0.2%	0.4%	0.0%	0.0%
U/G Sub-tran. Lines (MVA-kms)	4.9%	8.5%	2.2%	4.7%
U/G Sub-tran. Lines (MVA-kms)	4.3%	6.3%	2.8%	2.2%
Transformers (MVA)	2.8%	4.2%	1.8%	1.2%
All Capital inputs	2.6%	4.0%	1.6%	1.3%
Partial productivity:				
Output / Real Opex	0.6%	-2.7%	3.2%	5.4%
Output / OH Sub-tran. Lines	0.6%	1.6%	-0.2%	-2.0%
Output / OH Distr. Lines	1.8%	3.7%	0.4%	0.1%
Output / UG Sub-tran. Lines	-2.9%	-4.4%	-1.7%	-4.7%
Output / UG Distr. Lines	-2.3%	-2.3%	-2.4%	-2.2%
Output / Transformers	-0.8%	-0.1%	-1.3%	-1.1%
Output / Capital	-0.7%	0.0%	-1.1%	-1.3%

Table D.7 **ERG's individual output, input and PFP growth rates**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2020*
Outputs:				
Energy (GWh)	0.0%	0.3%	-0.1%	0.5%
Ratcheted Max Demand (MVA)	1.0%	2.4%	0.0%	0.0%
Customer Numbers	1.4%	1.9%	1.1%	-0.5%
Circuit Length (km)	0.2%	0.6%	-0.1%	0.4%
CMOS	-1.0%	-2.3%	0.0%	-2.5%
Inputs:				
Real Opex ($'000 2006)	0.1%	2.0%	-1.4%	3.6%
O/H Sub-tran. Lines (MVA-kms)	0.2%	1.7%	-1.0%	1.1%
O/H Distr. Lines (MVA-kms)	0.9%	1.1%	0.8%	0.7%
U/G Sub-tran. Lines (MVA-kms)	4.0%	6.3%	2.3%	-0.3%
U/G Sub-tran. Lines (MVA-kms)	5.1%	8.9%	2.2%	0.7%
Transformers (MVA)	2.6%	2.9%	2.4%	-0.9%
All Capital inputs	1.8%	2.4%	1.3%	0.0%
Partial productivity:				
Output / Real Opex	1.2%	0.7%	1.6%	-2.9%
Output / OH Sub-tran. Lines	1.1%	1.1%	1.2%	-0.3%
Output / OH Distr. Lines	0.4%	1.7%	-0.6%	0.1%
Output / UG Sub-tran. Lines	-2.7%	-3.5%	-2.1%	1.0%
Output / UG Distr. Lines	-3.8%	-6.2%	-2.0%	0.0%
Output / Transformers	-1.3%	-0.1%	-2.2%	1.7%
Output / Capital	-0.5%	0.4%	-1.1%	0.8%

Table D.8 **ESS's individual output, input and PFP growth rates**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2020*
Outputs:				
Energy (GWh)	0.3%	-0.2%	0.6%	-2.2%
Ratcheted Max Demand (MVA)	1.5%	0.8%	2.0%	0.0%
Customer Numbers	1.1%	0.8%	1.2%	1.0%
Circuit Length (km)	-0.3%	-0.7%	0.1%	0.1%
CMOS	-0.4%	-2.9%	1.5%	3.8%
Inputs:				
Real Opex ($'000 2006)	2.1%	9.3%	-3.3%	-3.7%
O/H Sub-tran. Lines (MVA-kms)	3.5%	4.4%	2.9%	1.0%
O/H Distr. Lines (MVA-kms)	2.9%	5.4%	1.0%	2.3%
U/G Sub-tran. Lines (MVA-kms)	4.3%	-1.3%	8.5%	2.7%
U/G Sub-tran. Lines (MVA-kms)	4.1%	5.2%	3.3%	2.3%
Transformers (MVA)	2.3%	4.1%	1.0%	1.0%
All Capital inputs	2.8%	4.6%	1.4%	1.6%

Table D.8 **(cont.)**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2020*
Partial productivity:				
Output / Real Opex	-1.2%	-8.3%	4.2%	2.8%
Output / OH Sub-tran. Lines	-2.6%	-3.4%	-2.1%	-1.9%
Output / OH Distr. Lines	-2.0%	-4.4%	-0.2%	-3.2%
Output / UG Sub-tran. Lines	-3.4%	2.3%	-7.7%	-3.6%
Output / UG Distr. Lines	-3.2%	-4.2%	-2.4%	-3.2%
Output / Transformers	-1.4%	-3.1%	-0.2%	-1.9%
Output / Capital	-1.9%	-3.6%	-0.6%	-2.5%

Table D.9 **JEN's individual output, input and PFP growth rates**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2020*
Outputs:				
Energy (GWh)	-0.3%	0.3%	-0.8%	-2.9%
Ratcheted Max Demand (MVA)	1.6%	3.3%	0.4%	2.3%
Customer Numbers	1.6%	1.1%	2.0%	1.8%
Circuit Length (km)	1.1%	1.1%	1.2%	1.1%
CMOS	-0.7%	-4.2%	1.9%	6.2%
Inputs:				
Real Opex ($'000 2006)	0.6%	3.3%	-1.5%	-15.0%
O/H Sub-tran. Lines (MVA-kms)	1.1%	1.0%	1.2%	-0.5%
O/H Distr. Lines (MVA-kms)	0.1%	-0.2%	0.3%	-2.4%
U/G Sub-tran. Lines (MVA-kms)	2.9%	-0.4%	5.4%	14.8%
U/G Sub-tran. Lines (MVA-kms)	4.8%	4.8%	4.8%	3.9%
Transformers (MVA)	2.8%	3.3%	2.4%	3.6%
All Capital inputs	1.4%	1.3%	1.4%	0.6%
Partial productivity:				
Output / Real Opex	0.9%	-1.0%	2.3%	15.9%
Output / OH Sub-tran. Lines	0.4%	1.4%	-0.4%	1.4%
Output / OH Distr. Lines	1.4%	2.5%	0.5%	3.3%
Output / UG Sub-tran. Lines	-1.4%	2.7%	-4.6%	-13.9%
Output / UG Distr. Lines	-3.4%	-2.5%	-4.0%	-2.9%
Output / Transformers	-1.4%	-1.0%	-1.6%	-2.7%
Output / Capital	0.1%	1.1%	-0.6%	0.3%

Table D.10 **PCR's individual output, input and PFP growth rates**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2020*
Outputs:				
Energy (GWh)	0.3%	1.0%	-0.1%	-2.2%
Ratcheted Max Demand (MVA)	1.8%	3.3%	0.8%	2.0%
Customer Numbers	1.9%	1.9%	1.9%	1.1%
Circuit Length (km)	0.4%	0.4%	0.5%	0.6%
CMOS	2.2%	3.0%	1.6%	-1.3%
Inputs:				
Real Opex ($'000 2006)	0.2%	2.6%	-1.6%	-6.2%
O/H Sub-tran. Lines (MVA-kms)	0.1%	0.1%	0.1%	0.0%
O/H Distr. Lines (MVA-kms)	0.1%	0.1%	0.2%	0.0%
U/G Sub-tran. Lines (MVA-kms)	9.9%	5.9%	12.8%	5.0%
U/G Sub-tran. Lines (MVA-kms)	5.9%	5.9%	5.8%	7.6%
Transformers (MVA)	2.7%	3.0%	2.5%	3.3%
All Capital inputs	2.2%	2.3%	2.1%	2.7%
Partial productivity:				
Output / Real Opex	0.7%	-1.2%	2.2%	7.5%
Output / OH Sub-tran. Lines	0.9%	1.3%	0.6%	1.4%
Output / OH Distr. Lines	0.9%	1.4%	0.5%	1.4%
Output / UG Sub-tran. Lines	-8.9%	-4.4%	-12.2%	-3.7%
Output / UG Distr. Lines	-4.9%	-4.5%	-5.2%	-6.2%
Output / Transformers	-1.7%	-1.6%	-1.9%	-1.9%
Output / Capital	-1.2%	-0.8%	-1.5%	-1.3%

Table D.11 **SAP's individual output, input and PFP growth rates**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2020*
Outputs:				
Energy (GWh)	-0.8%	0.1%	-1.4%	-2.0%
Ratcheted Max Demand (MVA)	1.0%	2.4%	0.0%	0.0%
Customer Numbers	1.1%	1.3%	1.0%	0.9%
Circuit Length (km)	0.4%	0.5%	0.2%	0.1%
CMOS	-0.8%	-1.7%	0.0%	-19.0%
Inputs:				
Real Opex ($'000 2006)	2.5%	6.3%	-0.3%	-11.5%
O/H Sub-tran. Lines (MVA-kms)	0.5%	0.5%	0.4%	0.4%
O/H Distr. Lines (MVA-kms)	0.0%	0.0%	0.0%	1.3%
U/G Sub-tran. Lines (MVA-kms)	1.8%	2.1%	1.6%	2.1%
U/G Sub-tran. Lines (MVA-kms)	2.5%	3.3%	1.8%	2.5%
Transformers (MVA)	2.3%	3.6%	1.3%	1.1%
All Capital inputs	1.9%	2.7%	1.2%	1.4%

Table D.11 **(cont.)**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2020*
Partial productivity:				
Output / Real Opex	-1.7%	-4.5%	0.5%	14.4%
Output / OH Sub-tran. Lines	0.4%	1.2%	-0.2%	2.5%
Output / OH Distr. Lines	0.9%	1.8%	0.2%	1.5%
Output / UG Sub-tran. Lines	-1.0%	-0.4%	-1.4%	0.8%
Output / UG Distr. Lines	-1.6%	-1.5%	-1.7%	0.3%
Output / Transformers	-1.4%	-1.8%	-1.1%	1.8%
Output / Capital	-1.0%	-1.0%	-1.0%	1.4%

Table D.12 **AND's individual output, input and PFP growth rates**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2020*
Outputs:				
Energy (GWh)	0.1%	0.4%	-0.2%	-2.6%
Ratcheted Max Demand (MVA)	1.9%	3.0%	1.1%	4.2%
Customer Numbers	1.8%	1.7%	1.9%	1.9%
Circuit Length (km)	0.7%	0.9%	0.6%	0.5%
CMOS	1.1%	-5.2%	5.9%	-1.8%
Inputs:				
Real Opex ($'000 2006)	4.3%	7.6%	1.9%	4.9%
O/H Sub-tran. Lines (MVA-kms)	0.8%	1.2%	0.6%	2.8%
O/H Distr. Lines (MVA-kms)	0.0%	0.4%	-0.2%	0.1%
U/G Sub-tran. Lines (MVA-kms)	8.9%	2.3%	13.9%	12.5%
U/G Sub-tran. Lines (MVA-kms)	5.1%	5.3%	5.0%	5.0%
Transformers (MVA)	2.5%	3.7%	1.7%	1.0%
All Capital inputs	2.0%	2.6%	1.5%	1.8%
Partial productivity:				
Output / Real Opex	-3.0%	-4.7%	-1.7%	-2.4%
Output / OH Sub-tran. Lines	0.5%	1.7%	-0.3%	-0.3%
Output / OH Distr. Lines	1.3%	2.5%	0.4%	2.3%
Output / UG Sub-tran. Lines	-7.6%	0.6%	-13.7%	-10.0%
Output / UG Distr. Lines	-3.8%	-2.4%	-4.8%	-2.6%
Output / Transformers	-1.2%	-0.9%	-1.5%	1.4%
Output / Capital	-0.6%	0.2%	-1.3%	0.7%

Table D.13 **TND's individual output, input and PFP growth rates**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2020*
Outputs:				
Energy (GWh)	-0.1%	-0.5%	0.2%	1.8%
Ratcheted Max Demand (MVA)	0.6%	1.4%	0.0%	0.0%
Customer Numbers	1.1%	1.8%	0.7%	1.2%
Circuit Length (km)	0.6%	0.8%	0.4%	0.2%
CMOS	2.1%	5.0%	0.0%	-3.3%
Inputs:				
Real Opex ($'000 2006)	1.0%	5.6%	-2.5%	3.3%
O/H Sub-tran. Lines (MVA-kms)	0.0%	0.1%	-0.1%	0.2%
O/H Distr. Lines (MVA-kms)	0.7%	0.6%	0.7%	0.2%
U/G Sub-tran. Lines (MVA-kms)	5.3%	9.2%	2.4%	4.4%
U/G Sub-tran. Lines (MVA-kms)	1.3%	1.6%	1.1%	0.8%
Transformers (MVA)	2.5%	4.0%	1.3%	1.8%
All Capital inputs	1.5%	2.2%	1.0%	0.9%
Partial productivity:				
Output / Real Opex	-0.6%	-5.3%	2.9%	-2.2%
Output / OH Sub-tran. Lines	0.4%	0.2%	0.5%	1.0%
Output / OH Distr. Lines	-0.4%	-0.3%	-0.4%	0.9%
Output / UG Sub-tran. Lines	-5.0%	-9.0%	-2.0%	-3.3%
Output / UG Distr. Lines	-1.0%	-1.3%	-0.7%	0.4%
Output / Transformers	-2.2%	-3.7%	-1.0%	-0.6%
Output / Capital	-1.2%	-1.9%	-0.7%	0.3%

Table D.14 **UED's individual output, input and PFP growth rates**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2020*
Outputs:				
Energy (GWh)	-0.4%	0.4%	-1.0%	-2.5%
Ratcheted Max Demand (MVA)	1.6%	3.6%	0.0%	0.0%
Customer Numbers	1.0%	0.9%	1.0%	0.8%
Circuit Length (km)	0.6%	0.6%	0.6%	0.1%
CMOS	-2.0%	8.3%	-9.7%	-25.6%
Inputs:				
Real Opex ($'000 2006)	-0.2%	3.6%	-3.0%	4.7%
O/H Sub-tran. Lines (MVA-kms)	1.6%	2.8%	0.6%	1.1%
O/H Distr. Lines (MVA-kms)	0.3%	0.7%	-0.1%	0.1%
U/G Sub-tran. Lines (MVA-kms)	1.4%	7.7%	-3.4%	-3.4%
U/G Sub-tran. Lines (MVA-kms)	3.0%	3.4%	2.6%	2.1%
Transformers (MVA)	2.4%	3.4%	1.6%	0.8%
All Capital inputs	1.7%	2.6%	0.9%	0.7%

Table D.14 **(cont.)**

Year	*2006 to 2020*	*2006 to 2012*	*2012 to 2020*	*2020*
Partial productivity:				
Output / Real Opex	1.3%	-2.6%	4.2%	-3.4%
Output / OH Sub-tran. Lines	-0.5%	-1.9%	0.5%	0.2%
Output / OH Distr. Lines	0.8%	0.2%	1.2%	1.2%
Output / UG Sub-tran. Lines	-0.3%	-6.8%	4.5%	4.7%
Output / UG Distr. Lines	-1.9%	-2.4%	-1.5%	-0.8%
Output / Transformers	-1.3%	-2.4%	-0.5%	0.6%
Output / Capital	-0.6%	-1.7%	0.2%	0.7%

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