Quantonomics

QUANTITATIVE ECONOMICS

Economic Benchmarking Results for the Australian Energy Regulator’s 2023 DNSP Annual Benchmarking Report

Report prepared for Australian Energy Regulator

3 November 2023

Michael Cunningham, Joseph Hirschberg and Alice Giovani

Quantonomics Pty Ltd
ABN: 23 165 107 844
michael@quantonomics.com.au

Contents

Acronyms & Abbreviations

DNSP names

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
kV	kilovolt
LSECD	Least squares econometrics Cobb–Douglas model
LSETLG	Least squares econometrics Translog model
MPFP	Multilateral partial factor productivity
MTFP	Multilateral total factor productivity
MVA	Megavolt ampere
MVAkms	Megavolt ampere kilometres
NEM	National Electricity Market
PFP	Partial factor productivity
RMD	Ratcheted maximum demand
SFACD	Stochastic frontier analysis Cobb–Douglas model
SFATLG	Stochastic frontier analysis Translog model
TFP	Total factor productivity
TNSP	Transmission network service provider
VCR	Value of customer reliability

1 Introduction

Quantonomics 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 2022 DNSP Benchmarking Report (AER 2022).

This annual update closely follows the methods used previously by Economic Insights (2021) and Quantonomics (2022). It includes data for the 2021-22 financial year reported by the DNSPs in their latest Economic Benchmarking Regulatory Information Notice (EBRIN) returns.

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

- The analysis of the drivers of DNSP productivity change by quantifying the contribution of each individual output and input to total factor productivity (TFP) change. This follows Economic Insights (2017) and subsequent reports.
- The opex cost function econometric results. This analysis uses a data sample of Australian, New Zealand and Ontario DNSPs for the 17-year period from 2006 to 2022, and for the 11-year period from 2012 to 2022. This follows previous analyses by Economic Insights (2014; 2015a; 2015b; 2017; 2018; 2019; 2020; 2021) and Quantonomics (2022).

1.1 Updates to Productivity Measurement Methods

The methods of analysis used in this report are the same as those used in Economic Insights (2021) and Quantonomics (2022). In addition to the methods previously used, section 3.2 and 4.2 present the results of carrying out the opex cost function analysis with opex defined on a revised basis.

The AER recently completed an investigation of options to address differences in DNSP capitalisation practices in the benchmarking framework. Differences in capitalisation practices refers to differences in accounting policies relating to capitalisation or expensing of certain cost categories, and differences in use of opex versus capital inputs. In its recently published Final Guidance Note (2023) the AER decided to:

(a) allocate a fixed proportion (100%) of capitalised corporate overheads (CCOs) expenditure to the opex series for benchmarking purposes; and

(b) move from the DNSPs' 2014 cost allocation methods (CAMs) to the 2022 CAMs as the basis for the frozen CAMs using for cost data in benchmarking.

The results using this change in definition of opex can be compared to the results using opex as previously defined which are presented in sections 3.1 and 4.1. The method used for producing the index results in section 4.2, which is documented in Appendix A section A5, is only preliminary at this stage, since the AER intends to have ongoing consultation on the most appropriate method.

1.2 Updates to data for the 2023 report

In terms of data updates between the 2022 and 2023 reports, the 2023 report incorporates the following updates to the data previously used in the 2022 report:

- EVO: revised maximum demand for the years 2015 to 2021;
- AGD and ESS: updates made to opex in 2021 relating to reversing the software as a service (SaaS) and lease accounting changes;
- AND: opex series for the years 2019 to 2021 were adjusted for reversing SaaS and lease accounting changes;
- AND: circuit length data adjustment relating to removing 22km of 66kV line that was found to be duplicated in AND's database for the years 2013 to 2021;
- ESS: Regulatory Asset Base (RAB) in 2021 relating to SaaS and leases.
- EVO: RAB in 2020-2021 relating to the use of a wrong inflation calculation in the past.
- AND: RAB in 2019-21 relating to SaaS and leases.

These updates are noted and further explained in the Data revisions tab in the DNSP consolidated file.

1.3 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 is discussed in section 1.3.4.

1.3.1 Productivity Index Numbers

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 a third observation.

The MTFP method is used for all the index-number based productivity analysis. When the MTFP method is applied to data for a single productive unit (eg, a DNSP), it provides information on the *changes over time* in productivity for that unit. When data is pooled over several units (eg, pooled across DNSPs or across states), the MTFP method also provides information on the *comparative productivity levels* of those units (in addition to information on productivity trends). Chapter 3 and Chapter 4 (section 4.1) present the comparative productivity analysis that compares productivity level of DNSPs and states respectively. The industry-, state-, and DNSP-level analyses in Chapters 2, 4 (section 4.2), and 5 respectively, examine patterns of output, input, and productivity over time. Individual output and input contributions to productivity change are also examined.

1.3.2 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,[1] equivalent to 9.8 per cent of total revenue on average[2]),

(b) Ratcheted maximum demand (RMD) in Megawatts (MW) (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 21.0 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 –11.6 per cent of gross revenue on average and equivalent to –13.6 per cent of total revenue on average).[3]

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

---

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

[2] Average across all observations (DNSPs and years). See Table A.1 of Appendix A. In the remainder of this report the output weights used are slightly different as they are based on the average across years for aggregated industry, as per the last column of Table A.2 of Appendix A.

[3] 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.

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 last carried out by Economic Insights (2020) 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).

1.3.3 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 37.8 per cent of total costs on average,[4]

(b) Overhead sub-transmission lines (quantity proxied by overhead sub-transmission MVAkms), making up 4.7 per cent of total costs on average,

(c) Overhead distribution lines (quantity proxied by overhead distribution MVAkms), making up 15.4 per cent of total costs on average,

(d) Underground sub-transmission cables (quantity proxied by underground sub-transmission MVAkms), making up 2.3 per cent of total costs on average,

(e) Underground distribution cables (quantity proxied by underground distribution MVAkms), making up 11.3 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 28.7 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 quantity 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. The AUC is computed

[4] See the last column of Table A.3 in Appendix A.

individually for each asset type in the RAB for each DNSP in each year. See Appendix A for further information.

1.3.4 Opex Cost Function Methodologies

While the productivity index number method presented above 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. When analysing opex productivity, we also include econometric modelling of operating cost functions, which allow for statistical noise and potentially allow the direct inclusion of, and hence control for, 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 is used to increase the data variations 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.[5] The parameters of these dummy

[5] 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

variables are converted to a measure 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 2022 and the sample period from 2012 to 2022. The results of this analysis are presented in chapter 3 (section 3.2) and Appendix C.

1.4 Limitations

This study uses EBRIN data, which is generally of high quality. The main limitation of the benchmarking analysis is that the DNSPs included in the sample may not be fully comparable as they operate in different operating environments which can influence the ability of an efficient DNSP to transform inputs into outputs, and these differences are not fully controlled for. Whilst the TFP and PFP index analysis presented in this report does not explicitly take account of operating environment factors (OEFs), it does to some extent indirectly account for some OEFs. Firstly, the functional output specification that includes a range of output measures allows for differences in customer density and energy density across DNSPs as part of the output specification (Economic Insights 2020, 29). Secondly, in the multilateral index method the weights applied to inputs vary between DNSPs, reflecting both their own cost shares as well as industry average cost shares and DNSP's own cost shares will vary in part due to OEFs. The econometric analysis of opex likewise accounts for differences in network density and additionally takes account of differences in the degree of undergrounding and implicitly accounts for some other OEFs (for a discussion see Quantonomics 2023).

1.5 DNSP comments on draft report

In line with previous practice, the AER made the draft version of this report available to the 13 DNSPs for comment. Six DNSPs recommended updating the MTFP and MPFP models to address capitalisation differences, as had been done for the econometric opex cost functions. This suggestion has been accepted and the pooled MTFP and MPFP index analysis has been carried out for the case where capitalised corporate overheads (CCO) are included in opex. This analysis is presented in in section 3.2 of this report. Ausgrid, AusNet, TasNetworks and Citipower/Powercor/United Energy have expressed support for the method chosen to update the MTFP and MPFP analysis at least for the present, subject to further consultation. Ausgrid suggested that the benchmark tax liability should be adjusted, along with the other adjustments

with no such dummy variable). The efficiency scores are invariant to the choice of DNSP as the base since comparative efficiency measures are subsequently scaled against the DNSP with greatest efficiency.

made for consistency. However, as Ausgrid acknowledged, the impact of this adjustment is very small and we have decided to retain the benchmark tax liability unaltered in the current report.

Some DNSPs' expressed concerns that the output weights used in index analysis should be updated more frequently, particularly in the context of significant updates to historical data. Evoenergy, Ergon, and Energex suggested that these output weights be updated annually, aligning with the updates to the econometric models. Ausgrid and Evoenergy pointed out that their analysis indicates revisions to historical data and the inclusion of additional years have a material impact on output weights, which affect efficiency rankings. The AER has indicated it plans to commission an independent review of the output weights in the upcoming 2023/24 period. In light of this upcoming review, no changes are made to outputs weights in the current report.

In relation to econometric models, Jemena, Evoenergy, Ergon, Energex, AusNet and Ausgrid have expressed concerns regarding monotonicity violations. Jemena recommends excluding the Translog models due to deteriorations in their monotonicity performance. Ergon and Energex suggest that the AER should outline a work program aimed at enhancing the statistical reliability of the econometric models. They advise exercising caution when using econometric models to determine regulatory allowances until these issues are addressed.

Quantonomics' and the AER's view is that retaining the Translog models enhances the flexibility and robustness of the analysis. Further investigation has been undertaken into the issue of monotonicity violations in Translog model, and other model performance issues, and the results are presented in a separate memorandum 'Opex Cost Function–Options to Address Performance Issues of Translog Models'. The AER intends to consult on the options presented there. In this report, the standard approaches to opex cost function modelling have been retained, even though the Translog models do not perform adequately in some instances.

It is also to be noted that the efficiency of a DNSP is determined by averaging the outcomes of only those econometric models which do not have excessive monotonicity violations. When applying the efficiency estimates, the AER compares them to an efficiency target of 0.75, which reflects a cautious approach which allows for potential limitations of the benchmark results.

Evoenergy raised concerns about the misspecification of the Cobb-Douglas opex cost function. We disagree with Evoenergy's assessment as detailed in our memo *Evoenergy – Benchmarking limitations* (Quantonomics 2023). The inclusion of higher-order terms in the TLG models, which are most often jointly significant, capture some nonlinearities that the CD models do not. On the other hand, the CD models are more parsimonious, and match the TLG models in goodness-of-fit measures that penalise the inclusion of extra variables. Consequently, we consider that both models are relevant for analysis. Averaging the efficiency scores from multiple benchmarking models can mitigate the dependence of a single model specification and promotes stability of assessments when benchmarking is annually updated.

Ausgrid and Evoenergy also raised concerns regarding the time-trend specification of the Translog models. Unlike the MTFP index analysis, the opex cost function models make no allowance efficiency improvement by the Australian DNSPs. This is an issue that may be investigated in a future review, but for the present the benchmarking roll-forward model is used to estimated changes in efficiency over time when the benchmark efficiency estimates are applied in access arrangement decisions.

Finally, certain data issues were raised. Ergon, Energex and SA Power Networks reported discrepancies in their data, however, the AER concluded that they were not sufficiently material to be remedied at the present time and instead will be addressed in the 2024 benchmarking review. Jemena requested clarification regarding the Software-as-a-Service (SaaS) adjustments, which are noted in Section 1.2.

2 Industry–level Distribution Productivity Results

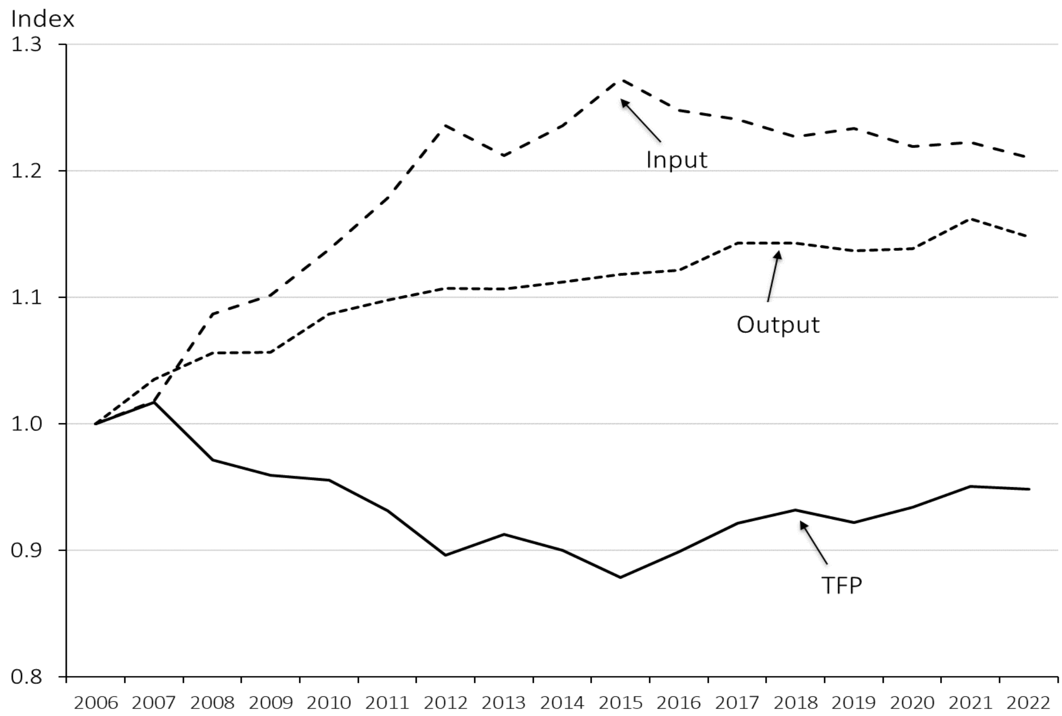
This chapter presents productivity results for the electricity distribution industry across the National Electricity Market (NEM) tates and territories in aggregate.

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 factor productivity indexes are also presented in Table 2.1.

Over the 17-year period 2006 to 2022, industry level TFP *declined* at an average annual rate of 0.3 per cent.[6] Although total output increased at an average annual rate of 0.9 per cent, total input use increased faster at a rate of 1.2 per cent. Since the average rate of change in TFP is the average rate of change in total output less the average rate of change in total inputs, this produced a negative average rate of productivity change. Although the long-run average TFP change was negative, TFP change was positive in seven years: 2007, 2013, 2016–2018 and 2020–2021. TFP growth performance was thus better in the period since 2015, than in the period from 2006 to 2015, as shown in Figure 2.1.

Figure 2.1 DNSP industry output, input and TFP indexes, 2006–2022



[6] In keeping with common practice in productivity studies, reported annual 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 shows that over the period 2006 to 2012, TFP *decreased* at an average annual rate of 1.8 per cent. From 2012 to 2022, TFP increased at an average annual rate of 0.6 per cent. Between 2021 and 2022, TFP *decreased* by 0.2 per cent.

Table 2.1 DNSP industry output, input, TFP and PFP indexes, 2006–2022

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	1.018	1.017	1.037	1.004
2008	1.056	1.087	0.971	0.924	1.003
2009	1.057	1.102	0.959	0.935	0.974
2010	1.087	1.138	0.955	0.923	0.974
2011	1.097	1.178	0.931	0.879	0.963
2012	1.107	1.236	0.896	0.812	0.950
2013	1.106	1.212	0.913	0.881	0.931
2014	1.112	1.236	0.900	0.875	0.915
2015	1.118	1.272	0.879	0.834	0.907
2016	1.121	1.247	0.899	0.903	0.896
2017	1.143	1.241	0.921	0.949	0.905
2018	1.143	1.227	0.932	0.995	0.896
2019	1.137	1.233	0.922	0.992	0.883
2020	1.139	1.219	0.934	1.043	0.874
2021	1.162	1.222	0.950	1.074	0.883
2022	1.148	1.210	0.948	1.077	0.865
Growth Rate 2006-2022	0.9%	1.2%	-0.3%	0.5%	-0.9%
Growth Rate 2006-2012	1.7%	3.5%	-1.8%	-3.5%	-0.9%
Growth Rate 2012-2022	0.4%	-0.2%	0.6%	2.9%	-0.9%
Growth Rate 2022	-1.2%	-1.0%	-0.2%	0.3%	-2.0%

2.2 Partial factor productivity trends

Partial factor productivity (PFP) is a measure of output relative to a single input. The PFP indexes for Opex and Capital in Table 2.1 and Figure 2.2 represent ratios of the total output index to indexes of these two main inputs for the distribution industry. Figure 2.2 also shows PFP indexes for each individual capital input.

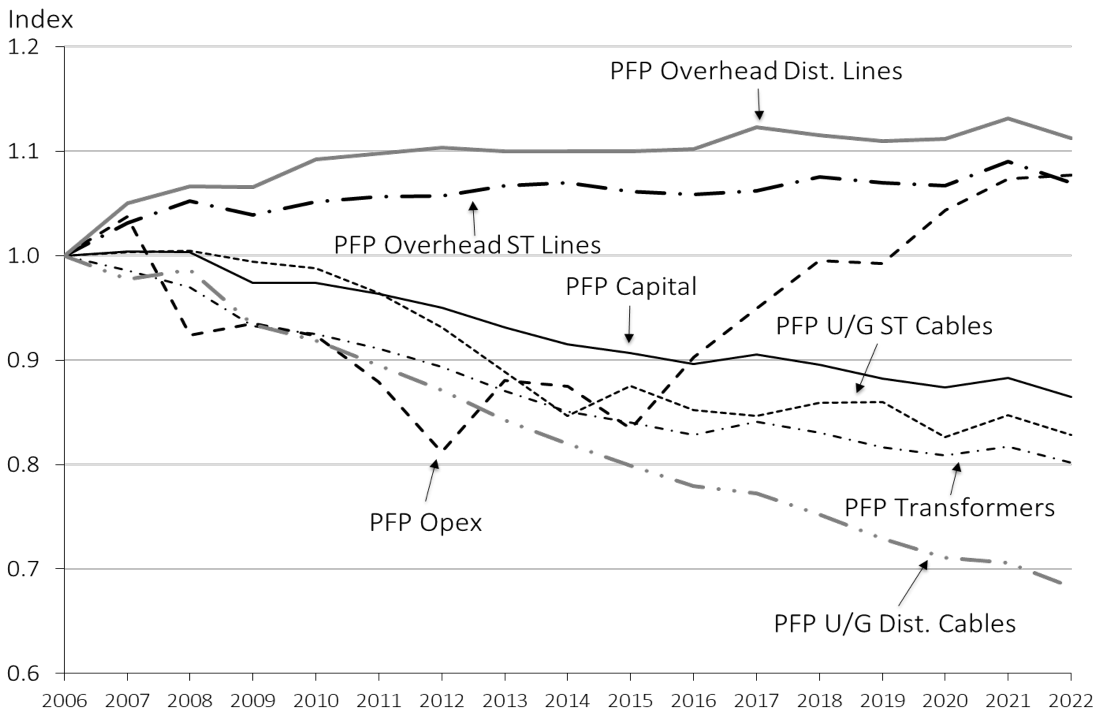
Opex PFP declined through to 2012 but has generally improved since then, as opex use has trended down. The PFP of opex inputs increased slightly overall between 2006 and 2022. In 2022, opex PFP was 7.7 per cent above its 2006 level.

Movements in the aggregate capital PFP index declined reasonably steadily over the sample period, following an essentially inverse pattern to capital input quantities (since as Figure 2.1 shows, the total output index has a reasonably stable upward trend). PFP indexes for most individual capital inputs also decreased over the same period. Among the capital inputs:

- Overhead distribution lines PFP in 2022 was 11.3 per cent higher than in 2006, and the overhead sub-transmission lines PFP was 7.0 per cent higher over the same period.
- Underground distribution cables PFP was 31.7 per cent lower in 2022 than in 2006, and underground sub-transmission PFP *declined* by 17.2 per cent over this period. As noted above, this is because underground cables have increased rapidly from a small base.
- Transformer PFP *declined* by 19.8 per cent between 2006 and 2022.

Tables showing the 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 factor productivity indexes, 2006–2022

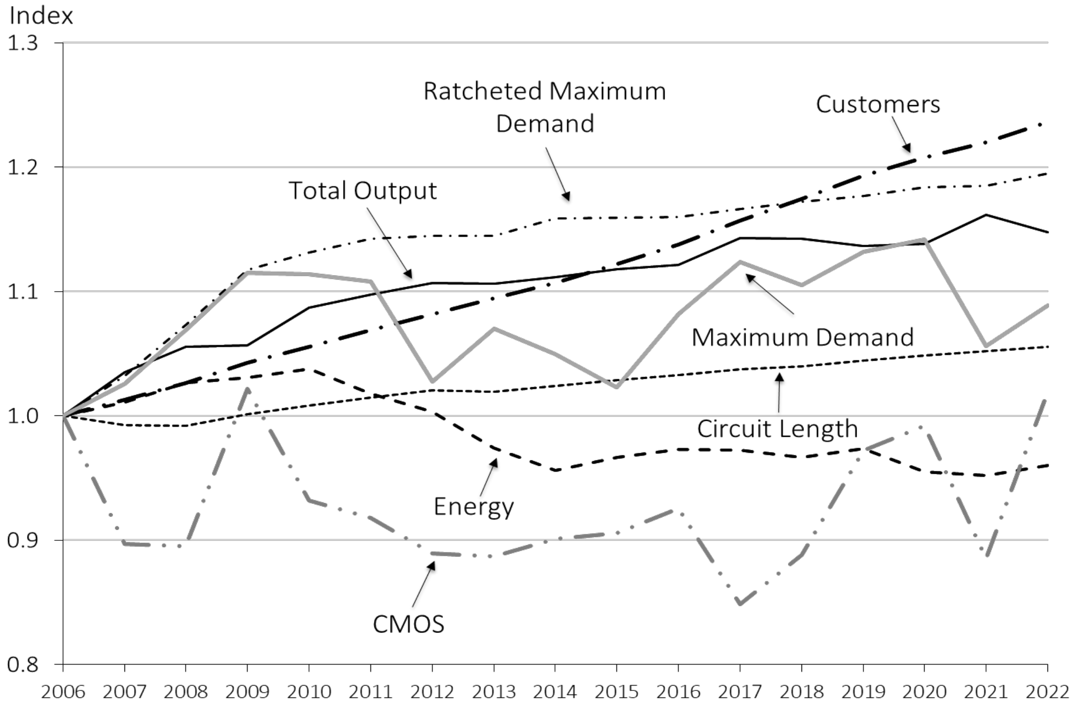


2.3 Distribution industry output and input quantity changes

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 17 years and by 2022 was only 5.6 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, 2006–2022



The customer numbers index increased steadily over the period and was 23.6 per cent higher in 2022 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. Although there was a marginal increase since then, energy throughput stayed below its 2006 level. In 2022 energy throughput was slightly less than in 2013 and 4.0 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).[7] RMD increased rapidly in the period up to 2009, and more slowly since then, even though energy throughput declined after 2010. By 2022, RMD was 19.5 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 2022, the ratio of maximum demand to energy throughput increased, but it decreased significantly in 2021. Although it increased again in 2022, it remained below the 2020 level. Over the whole period to 2022, the ratio of maximum demand to energy throughput increased by 13.4 per cent. The ratio between RMD and energy use increased more steadily and by 2022 was 24.5 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 and 2016, 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 underlying increase combined with fluctuations. By 2022, CMOS was 1.9 per cent above the 2006 level.

Since the circuit length and ratcheted maximum demand outputs together receive an average weight of 83.9 per cent of total revenue in forming the total output index,[8] 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 between 2017 and 2020 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

[7] 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.

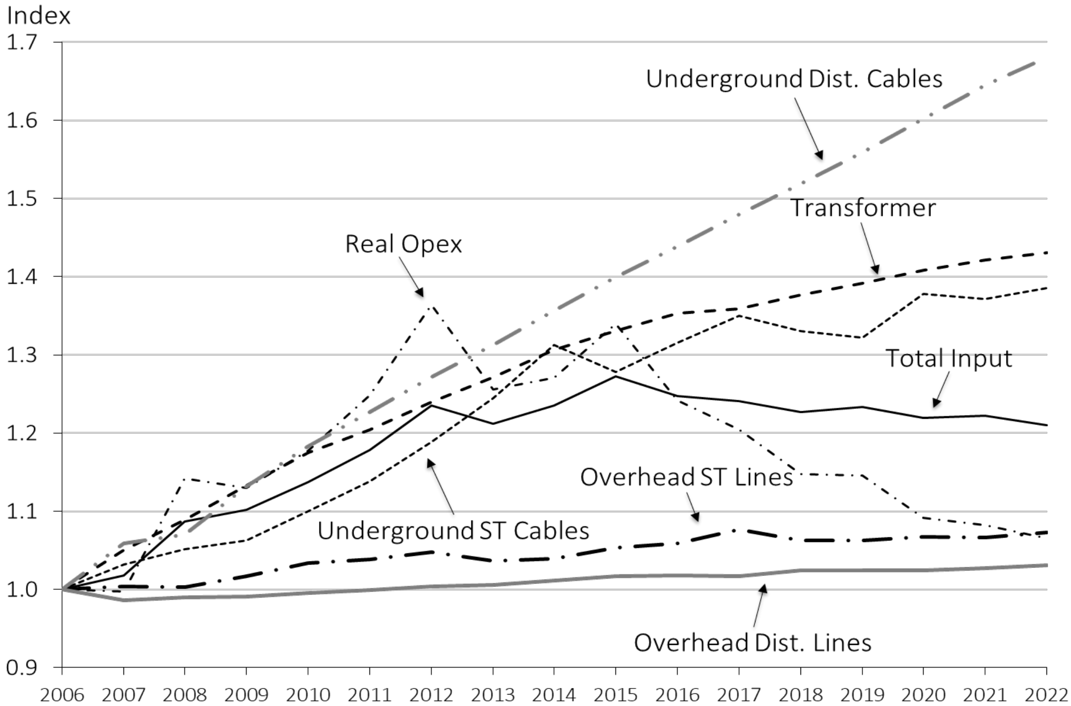
[8] The weights for outputs used in this chapter are those for the industry in Table A.3 in Appendix A which are based on the output value shares for the aggregated industry. Appendix A explains the difference between the aggregated industry value shares and those derived using a simple average over all observations as shown in Table A.1 of Appendix A.

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 37.8 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 2022 real opex was 6.5 per cent higher than in 2006.

Another input with a large weight is transformers, which accounts for 28.6 per cent of total cost for the industry. The quantity of transformers has increased steadily over the period and by 2022 was 43.1 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.

Figure 2.4 DNSP industry input quantity indexes, 2006–2022



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 2022 to be 3.1 and 7.3 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). Overhead distribution and sub-transmission lines together account for 20.0 per cent of total DNSP costs on average.

The fastest growing input quantity is that of underground distribution cables whose quantity was 68.0 per cent higher in 2022 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 38.5 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 13.6 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 66.4 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

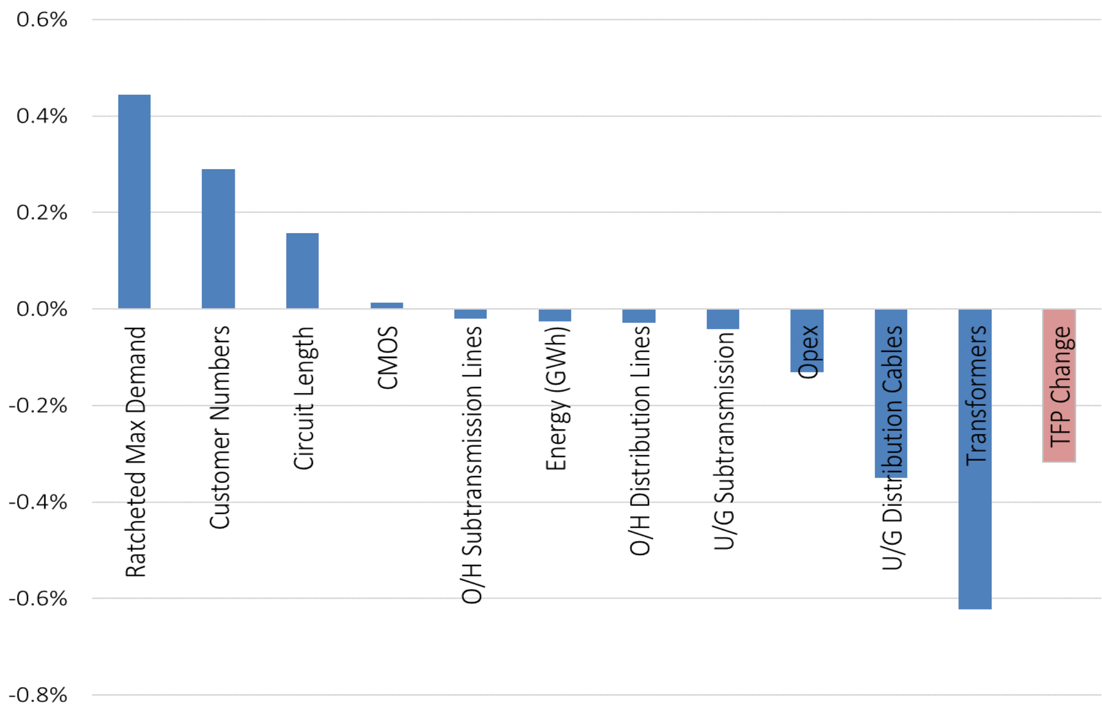
Having reviewed movements in individual output and input components in the preceding section, we now examine the contribution of each output and each input component to annual TFP change. Or, to put it another way, we want to decompose TFP change into its constituent parts. Since TFP change is the change 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 –0.3 per cent over the 17-year period 2006 to 2022. 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 red 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 red 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 17-year period comes from RMD which, despite weaker growth after 2011, had the second highest average annual output growth rate over the period of 1.1 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 0.44 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 0.3 percentage points to TFP change over the period.

Figure 2.5 Distribution industry output and input percentage point contributions to average annual TFP change, 2006–2022



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 receives a weight of –15.1 per cent on average in the total output index (ie, increases in CMOS decrease output) and, combined with an average annual change of 0.1 per cent, it made a marginal positive contribution to TFP of 0.01 percentage points. Energy throughput made a marginal negative contribution to TFP of –0.03 percentage points since this output fell over the 17-year period at an average annual rate of –0.3 per cent and it has an average weight of 9.9 per cent in total revenue.

All six inputs made negative contributions to average annual TFP change. That is, the use of all six inputs increased over the 17-year period. Overhead sub-transmission and distribution lines had average annual input growth rates of 0.4 and 0.2 per cent respectively, and due to their relatively low weights in total input (4.7 per cent and 15.4 per cent on average respectively), they made small negative contributions to TFP change: –0.02 and –0.03 percentage points respectively. Despite having a high average annual growth rate of 2.1 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 –0.04 percentage points. Underground distribution cables had the highest rate of average annual input growth over the period at 3.3 per cent and having a weight of 11.3 per cent in the total input index; they made a substantial negative contribution of –0.35 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 28.6 per cent and 37.8 per cent, respectively. Since transformer inputs have the second highest input average annual growth rate at 2.3 per cent, they make the largest negative contribution to TFP change at –0.62 percentage points. Opex has the second lowest average annual growth rate at 0.4 per cent and makes the third most negative contribution to TFP change at –0.13 percentage points.

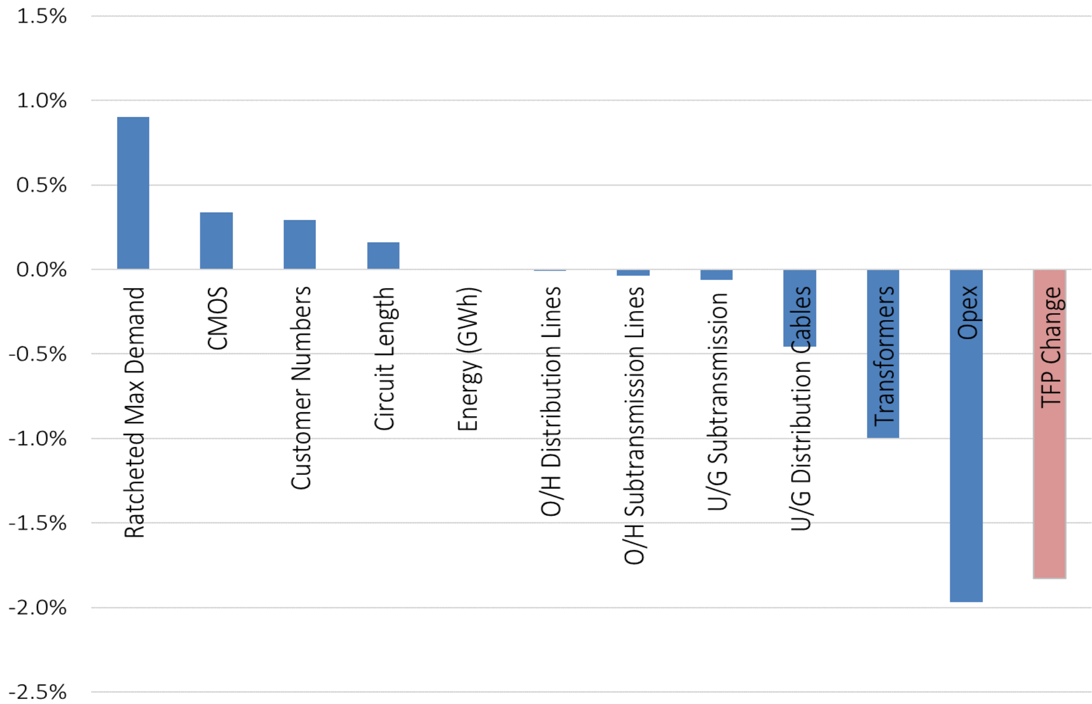
Table 2.2 Distribution industry output and input percentage point contributions to average annual TFP change: Various periods

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2022*
Energy (GWh)	-0.03%	0.00%	-0.04%	0.08%
Ratcheted Max Demand	0.44%	0.90%	0.17%	0.35%
Customer Numbers	0.29%	0.29%	0.29%	0.30%
Circuit Length	0.16%	0.16%	0.15%	0.18%
CMOS	0.01%	0.34%	-0.18%	-2.14%
Opex	-0.13%	-1.97%	0.97%	1.00%
O/H Sub-transmission Lines	-0.02%	-0.04%	-0.01%	-0.01%
O/H Distribution Lines	-0.03%	-0.01%	-0.04%	-0.04%
U/G Sub-transmission	-0.04%	-0.06%	-0.03%	0.02%
U/G Distribution Cables	-0.35%	-0.46%	-0.29%	0.05%
Transformers	-0.62%	-1.00%	-0.40%	-0.02%
TFP Change	-0.32%	-1.83%	0.59%	-0.23%

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 2022 are presented in Figure 2.7.

Average annual TFP change for the 2006 to 2012 period was more negative at –1.8 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).

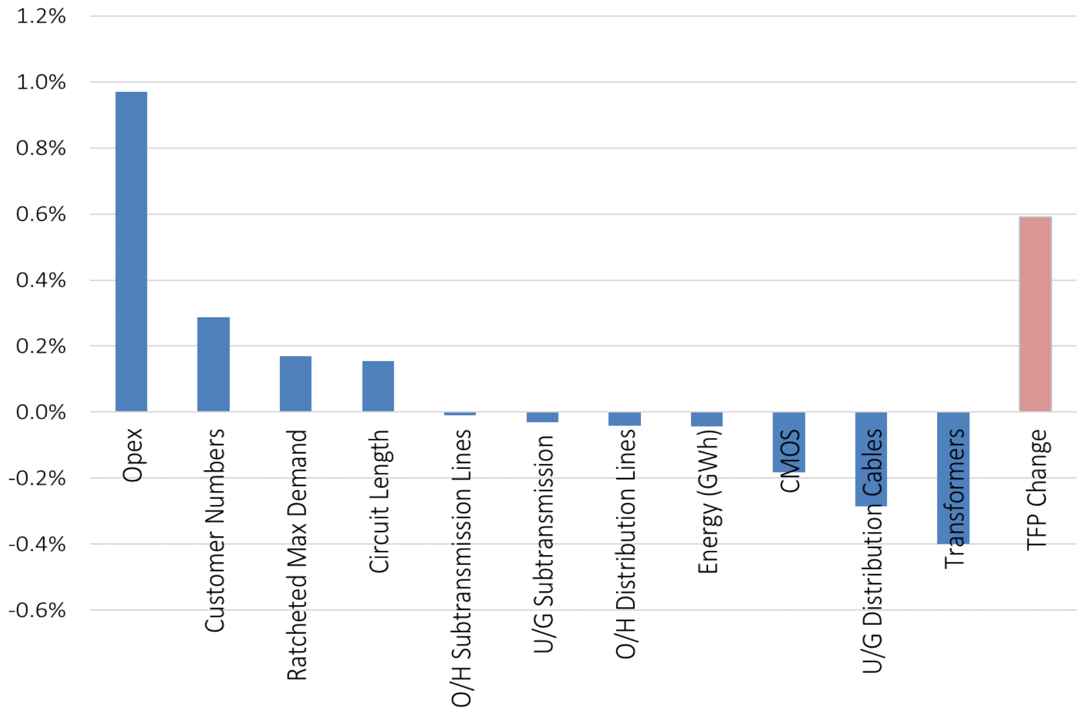
Figure 2.6 Distribution industry output and input percentage point contributions to average annual TFP change: 2006–2012



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 –1.97 percentage points to average annual TFP change over the period up to 2012.

In the period from 2012 to 2022, TFP change was positive with an annual average growth rate of 0.6 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 –2.5 per cent. This has led to opex making a positive contribution of 0.97 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.

Figure 2.7 Distribution industry output and input percentage point contributions to average annual TFP change, 2012–2022



Other contributors to improved TFP performance after 2012 are reductions in the negative contributions to TFP change from (i) transformers whose contribution fell from –1.00 percentage points (pre-2012) to –0.40 after 2012; and (ii) underground distribution cables, which decreased from –0.46 to –0.29 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 0.17 percentage points after 2012 and CMOS's contribution falling from 0.34 to –0.18 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 –0.04 after 2012).

Table 2.2 also shows the contributions of individual outputs and inputs to the TFP growth of –0.2 per cent in 2022. Similar to 2012-2022 period, opex made a significant positive contribution of 1.00 percentage points in 2022, while other inputs showed insignificant contributions. Regarding the outputs, RMD was the second largest positive contributing factor to TFP in 2022, contributing 0.35 percentage points, followed by customer numbers (0.30 percentage points), circuit length (0.18 percentage points), and energy throughput (0.08 percentage points). On the other hand, transformers had a negative contribution, albeit with a negligible value of -0.02 percentage points, while CMOS was the factor that contributed the most negatively to TFP growth, with –2.14, thus accounting for the negative TFP value in 2022.

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 2022.

Table 2.3 Distribution industry output and input annual changes (%), 2006–2022

Year	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*
Energy	1.11%	1.52%	0.42%	0.67%	-1.92%	-1.48%	-2.92%	-1.88%	1.10%	0.63%	-0.06%	-0.56%	0.69%	-1.95%	-0.34%	0.85%
RMD	3.20%	3.83%	4.08%	1.24%	0.95%	0.20%	0.00%	1.23%	0.09%	0.02%	0.58%	0.47%	0.42%	0.59%	0.10%	0.84%
Customer No.	1.30%	1.32%	1.57%	1.24%	1.23%	1.19%	1.20%	1.13%	1.34%	1.41%	1.66%	1.53%	1.55%	1.20%	1.15%	1.33%
Circuit Length	-0.76%	-0.04%	0.97%	0.69%	0.60%	0.61%	-0.12%	0.42%	0.48%	0.39%	0.43%	0.27%	0.41%	0.40%	0.38%	0.36%
CMOS	-10.86%	-0.18%	13.22%	-9.22%	-1.53%	-3.10%	-0.28%	1.57%	0.49%	2.16%	-8.69%	4.56%	9.08%	1.98%	-13.00%	14.11%
Opex	-0.23%	13.53%	-1.08%	4.11%	5.89%	8.82%	-8.23%	1.12%	5.33%	-7.58%	-3.11%	-4.78%	-0.21%	-4.86%	-0.96%	-1.56%
O/H Sub-Trans.	0.39%	-0.06%	1.34%	1.64%	0.47%	0.87%	-1.02%	0.22%	1.35%	0.57%	1.59%	-1.29%	0.03%	0.40%	-0.10%	0.63%
O/H Distrib.	-1.43%	0.41%	0.14%	0.39%	0.45%	0.40%	0.25%	0.49%	0.55%	0.10%	-0.02%	0.67%	0.02%	-0.04%	0.35%	0.40%
U/G Sub-Trans.	3.13%	1.85%	1.13%	3.47%	3.41%	4.31%	4.61%	5.33%	-2.71%	2.90%	2.58%	-1.46%	-0.61%	4.15%	-0.53%	0.97%
U/G Distrib.	5.69%	1.10%	5.55%	4.43%	3.65%	3.57%	3.23%	3.24%	3.13%	2.75%	2.86%	2.58%	2.60%	2.73%	3.05%	2.12%
Transformer	4.87%	3.66%	3.93%	3.69%	2.45%	2.87%	2.53%	2.77%	1.80%	1.69%	0.40%	1.27%	1.11%	1.20%	1.08%	0.66%

Table 2.4 Distribution industry output and input percentage point contributions to annual TFP change, 2006–2022

Year	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*
Energy	0.11%	0.15%	0.05%	0.06%	-0.19%	-0.15%	-0.28%	-0.18%	0.11%	0.06%	0.00%	-0.06%	0.07%	-0.19%	-0.03%	0.08%
RMD	1.34%	1.52%	1.61%	0.50%	0.37%	0.07%	0.00%	0.47%	0.03%	0.02%	0.22%	0.18%	0.17%	0.23%	0.03%	0.35%
Customer No.	0.31%	0.29%	0.33%	0.29%	0.27%	0.26%	0.26%	0.24%	0.28%	0.30%	0.34%	0.33%	0.34%	0.26%	0.24%	0.30%
Circuit Length	-0.34%	-0.02%	0.44%	0.33%	0.28%	0.27%	-0.05%	0.19%	0.21%	0.18%	0.19%	0.12%	0.19%	0.18%	0.17%	0.18%
CMOS	2.02%	0.02%	-2.35%	1.66%	0.24%	0.43%	0.00%	-0.21%	-0.06%	-0.28%	1.16%	-0.59%	-1.29%	-0.30%	1.90%	-2.14%
Opex	0.07%	-5.22%	0.40%	-1.56%	-2.19%	-3.30%	3.12%	-0.54%	-2.00%	2.91%	1.18%	1.74%	0.07%	1.83%	0.38%	1.00%
O/H Sub-Trans.	-0.02%	0.00%	-0.06%	-0.08%	-0.02%	-0.04%	0.05%	-0.01%	-0.06%	-0.03%	-0.08%	0.06%	0.00%	-0.02%	0.01%	-0.01%
O/H Distrib.	0.21%	-0.06%	-0.02%	-0.05%	-0.07%	-0.06%	-0.04%	-0.07%	-0.08%	-0.02%	0.00%	-0.10%	-0.01%	0.01%	-0.05%	-0.04%
U/G Sub-Trans.	-0.07%	-0.04%	-0.01%	-0.08%	-0.07%	-0.10%	-0.11%	-0.12%	0.06%	-0.07%	-0.06%	0.03%	0.02%	-0.09%	0.01%	0.02%
U/G Distrib.	-0.71%	-0.09%	-0.64%	-0.44%	-0.44%	-0.42%	-0.37%	-0.37%	-0.35%	-0.32%	-0.35%	-0.25%	-0.30%	-0.30%	-0.31%	0.05%
Transformer	-1.28%	-1.10%	-1.04%	-1.02%	-0.71%	-0.83%	-0.74%	-0.81%	-0.50%	-0.49%	-0.14%	-0.34%	-0.32%	-0.29%	-0.34%	-0.02%
TFP change	1.65%	-4.55%	-1.29%	-0.39%	-2.54%	-3.86%	1.84%	-1.41%	-2.38%	2.27%	2.45%	1.13%	-1.07%	1.31%	2.00%	-0.23%

3 DNSP multilateral total and partial factor productivity analysis

This chapter presents summary MTFP and MPFP results for each DNSP. Section 3.1 outlines the results based on standard Opex, while Section 3.2 presents the results utilising the Opex incorporating capitalised corporate overheads, with associated changes to cost share weights for all inputs.

3.1 DNSP MTFP and MPFP 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 DNSPs 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.

Figure 3.1 DNSP multilateral total factor productivity indexes, 2006–2022

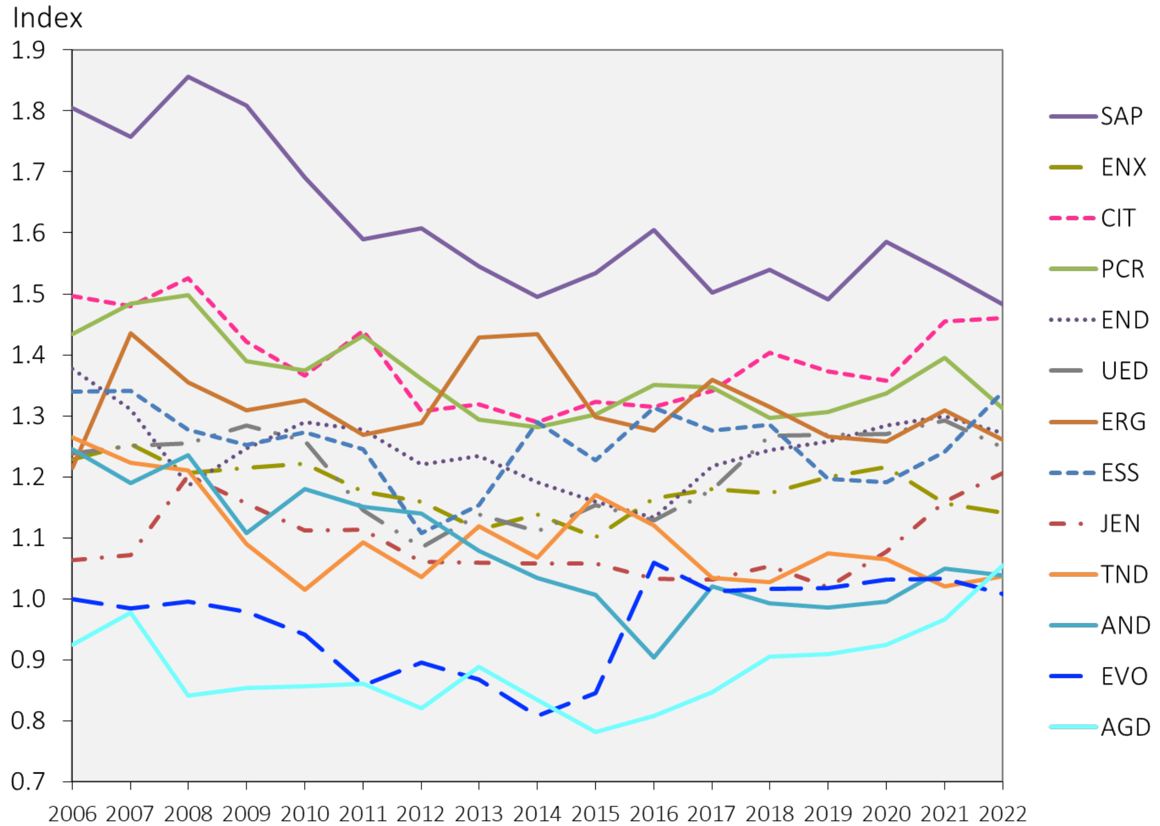


Table 3.1 DNSP multilateral total factor productivity indexes, 2006–2022

Year	EVO	AGD	CIT	END	ENX	ERG	ESS
2006	1.000	0.924	1.496	1.377	1.229	1.215	1.340
2007	0.984	0.977	1.480	1.310	1.254	1.435	1.341
2008	0.996	0.841	1.525	1.185	1.207	1.355	1.278
2009	0.978	0.853	1.421	1.246	1.215	1.308	1.251
2010	0.941	0.856	1.366	1.290	1.222	1.325	1.272
2011	0.858	0.861	1.440	1.277	1.175	1.268	1.245
2012	0.895	0.820	1.308	1.221	1.160	1.288	1.108
2013	0.868	0.889	1.319	1.233	1.113	1.429	1.154
2014	0.808	0.833	1.289	1.190	1.138	1.434	1.289
2015	0.845	0.781	1.323	1.160	1.101	1.298	1.227
2016	1.060	0.808	1.315	1.133	1.165	1.275	1.314
2017	1.012	0.846	1.341	1.218	1.179	1.359	1.276
2018	1.015	0.904	1.404	1.244	1.174	1.314	1.286
2019	1.018	0.909	1.373	1.257	1.199	1.267	1.196
2020	1.032	0.924	1.358	1.284	1.215	1.257	1.192
2021	1.033	0.966	1.455	1.299	1.156	1.309	1.242
2022	1.008	1.055	1.461	1.272	1.141	1.261	1.340

Table 3.1 (cont.)

Year	JEN	PCR	SAP	AND	TND	UED	AVG
2006	1.064	1.434	1.804	1.245	1.265	1.238	1.279
2007	1.072	1.484	1.758	1.190	1.223	1.251	1.289
2008	1.202	1.498	1.857	1.235	1.210	1.255	1.280
2009	1.156	1.390	1.809	1.108	1.090	1.284	1.239
2010	1.112	1.375	1.692	1.180	1.015	1.259	1.223
2011	1.113	1.431	1.590	1.150	1.093	1.145	1.204
2012	1.061	1.361	1.608	1.140	1.036	1.083	1.161
2013	1.059	1.294	1.545	1.078	1.119	1.138	1.172
2014	1.058	1.282	1.496	1.034	1.067	1.110	1.156
2015	1.058	1.302	1.534	1.006	1.170	1.154	1.151
2016	1.033	1.351	1.605	0.903	1.120	1.129	1.170
2017	1.031	1.346	1.502	1.020	1.034	1.178	1.180
2018	1.054	1.297	1.539	0.993	1.027	1.267	1.194
2019	1.018	1.306	1.491	0.985	1.074	1.269	1.182
2020	1.078	1.337	1.586	0.996	1.065	1.270	1.199
2021	1.159	1.395	1.535	1.049	1.021	1.292	1.224
2022	1.206	1.311	1.482	1.038	1.037	1.248	1.220

In 2006 the average MTFP index (relative to EVO in 2006) was 1.28, and it reduced to 1.22 in 2022, 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 0.88 in 2006 to 0.47 in 2022. Comparing MTFP levels in 2022:

- SAP has the highest MTFP level followed by CIT and ESS. EVO ranks lowest in terms of MTFP followed by TND and AND;
- The DNSPs with above-average MTFP indexes were SAP (with an MTFP index of 1.48), CIT (1.46), ESS (1.34), PCR (1.31), END (1.27), ERG (1.26) and UED (1.25);
- Those with below-average MTFP indexes were (from smallest to largest) EVO (1.01), TND (1.04), AND (1.04), AGD (1.06), ENX (1.14) and JEN (1.21).

Most DNSP decreased their productivity in 2022. Of the DNSPs with above-average MTFP in 2022, only two increased their productivity from 2021 to 2022, CIT and ESS. Among the DNSPs with below-average MTFP in 2022, those which increased their MTFP in 2022 were JEN, AGD, and TND. The remaining DNSPs, SAP, PRC, END, ERG, UED, ENX, AND and EVO experienced a decreased MTFP in 2022.

Comparing the rankings of MTFP levels in 2022 to those in 2021, ESS had the largest increases in its ranking, from 7th to 3rd, followed by AGD, which increased from 13th to 10th. On the other hand, the DNSPs whose ranking decreased were ERG from 4th to 6th , EVO from 11th to 13th, PCR from 3rd to 4th , AND from 10th to 11th and UED from 6th to 7th. SAP, CIT, END, JEN, ENX and TND did not experience changes in their ranking positions from 2021 to 2022

Comparing the rankings of MTFP levels in 2022 to those in 2006, ERG had the largest increase in its ranking from 10th in 2006 to 6th in 2022. JEN and AGD had the second largest increases from 11th to 8th, and 13th to 10th respectively. Other increases in ranking included ESS, from 5th to 3rd and UED from 8th to 7th. DNSPs with the largest decreases in rankings between 2006 and 2022 were TND, from 6th to 12th and AND from 7th to 11th. The ranking of PCR decreased from 3rd to 4th, END decreased from 4th to 5th and EVO decreased from 12th to 13th. SAP, CIT, and ENX did not experience changes in their ranking positions from 2006 to 2022

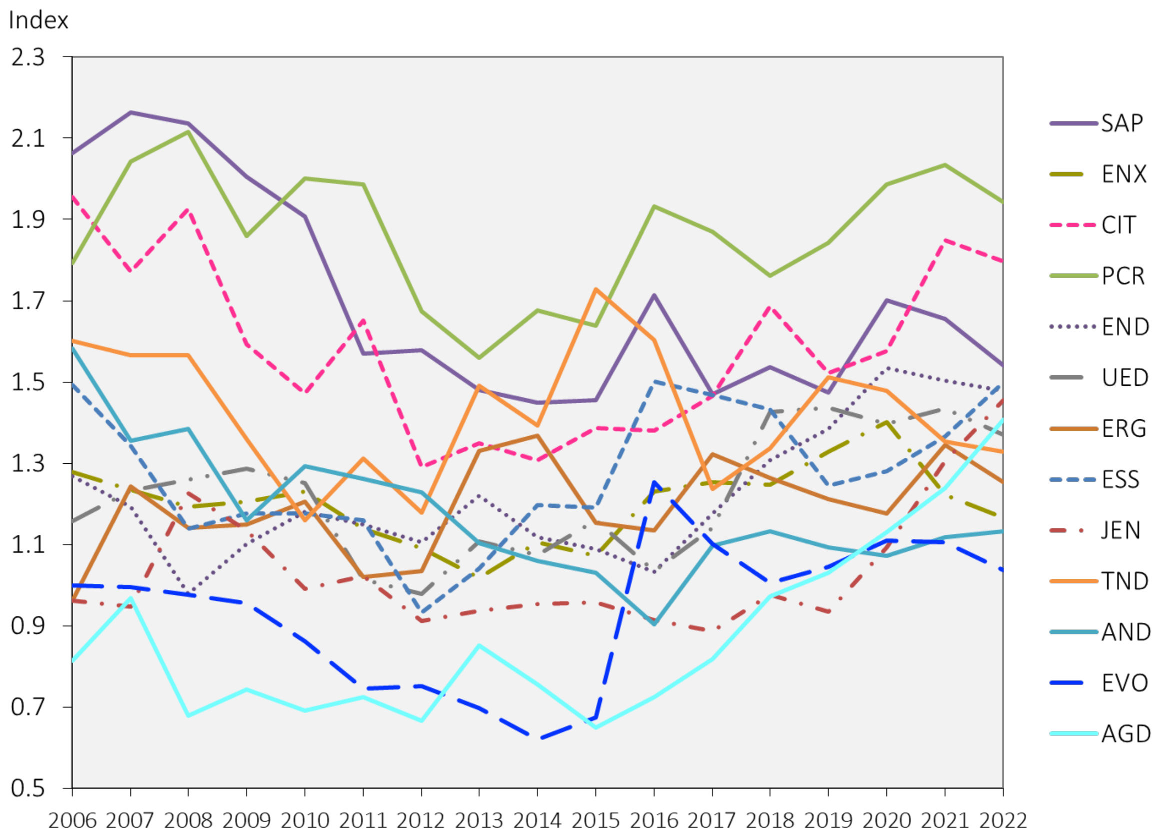
3.1.2 Multilateral PFP Indexes

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 period from 2006 to 2012, but this trend was mostly reversed in the period 2012 to 2014, and since that time Opex MPFP has increased. From Figure 3.2 and Table 3.2 we see that four DNSPs increased Opex MPFP levels in 2022, namely ADG (12.7 per cent), JEN (10.8 per cent), ESS (9.3 per cent), and AND (1.3 per cent). The Opex MPFP levels of nine DNSPs decreased in 2022, including SAP (–7.3 per cent), ERG (–7.0 per cent), EVO (–6.4 per cent), ENX, UED and PCR (all at –4.6 per cent), CIT (–2.9 per cent), TND (–1.9 per cent) and END (–1.6 per cent).[9]

PCR ranked highest in terms of Opex MPFP levels in 2022 followed by CIT and SAP. EVO ranked lowest in terms of Opex MPFP levels in 2022, followed by AND, ENX and ERG. Compared to 2021, JEN and AGD improved their Opex MPFP ranking by three places in 2022 (from 9th to 6th, and 10th to 7th respectively). whilst ESS improved from 6th to 4th place. The DNSPs that decreased their Opex MPFP ranking in 2022 compared to 2021 were END, from 4th to 5th place, ERG, from 8th to 10th, TND, from 7th to 9th place and UED that had the most substantial reduction in its Opex PFP ranking, which decreased by three places to become 8th ranked in 2022.

Figure 3.2 DNSP multilateral opex partial factor productivity indexes, 2006–2022



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

Table 3.2 DNSP multilateral opex partial factor productivity indexes, 2006–2022

Year	EVO	AGD	CIT	END	ENX	ERG	ESS
2006	1.000	0.814	1.955	1.268	1.277	0.961	1.492
2007	0.994	0.967	1.773	1.192	1.235	1.243	1.343
2008	0.977	0.678	1.927	0.978	1.192	1.141	1.139
2009	0.955	0.743	1.592	1.102	1.204	1.148	1.176
2010	0.861	0.690	1.473	1.181	1.230	1.205	1.176
2011	0.744	0.724	1.652	1.149	1.138	1.021	1.160
2012	0.750	0.666	1.290	1.104	1.091	1.034	0.932
2013	0.697	0.851	1.348	1.221	1.017	1.329	1.041
2014	0.621	0.756	1.308	1.119	1.106	1.368	1.197
2015	0.675	0.650	1.387	1.089	1.071	1.152	1.190
2016	1.252	0.724	1.381	1.032	1.230	1.134	1.502
2017	1.101	0.818	1.465	1.177	1.253	1.322	1.467
2018	1.005	0.972	1.687	1.308	1.248	1.264	1.433
2019	1.045	1.030	1.522	1.384	1.329	1.212	1.244
2020	1.109	1.130	1.575	1.534	1.402	1.177	1.280
2021	1.105	1.239	1.849	1.502	1.221	1.344	1.366
2022	1.036	1.406	1.797	1.478	1.166	1.254	1.499

Table 3.2 (cont.)

Year	JEN	PCR	SAP	AND	TND	UED	AVG
2006	0.963	1.794	2.064	1.583	1.602	1.158	1.379
2007	0.948	2.043	2.163	1.355	1.566	1.233	1.389
2008	1.226	2.115	2.137	1.384	1.565	1.260	1.363
2009	1.135	1.859	2.006	1.159	1.359	1.286	1.286
2010	0.990	2.002	1.906	1.292	1.160	1.251	1.263
2011	1.021	1.986	1.569	1.261	1.311	1.014	1.212
2012	0.912	1.675	1.578	1.228	1.178	0.977	1.109
2013	0.937	1.559	1.481	1.103	1.491	1.108	1.168
2014	0.954	1.677	1.449	1.060	1.393	1.073	1.160
2015	0.958	1.639	1.456	1.031	1.729	1.160	1.168
2016	0.913	1.932	1.713	0.903	1.602	1.033	1.258
2017	0.887	1.869	1.470	1.097	1.238	1.141	1.254
2018	0.976	1.762	1.537	1.133	1.337	1.426	1.314
2019	0.934	1.842	1.474	1.093	1.511	1.435	1.312
2020	1.094	1.986	1.701	1.072	1.478	1.397	1.379
2021	1.305	2.034	1.656	1.119	1.354	1.434	1.425
2022	1.455	1.944	1.540	1.133	1.328	1.370	1.416

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 2022, only three DNSPs improved their Capital MPFP levels, including ESS (3.5 per cent), CIT (2.2 per cent) and JEN (0.5 per cent). The remaining DNSPs with reductions in capital MPFP levels in 2022 were: END (–6.8 per cent), PCR (– 5.5 per cent), TND (–3.5 per cent), ERG (–3.0 per cent), UED (–2.4 per cent), SAP (–1.8 per cent), ENX (–1.7 per cent), EVO (–1.1 per cent), AND (–0.9 per cent) and AGD (–0.1 per cent)

The highest ranked DNSPs in terms of capital productivity in 2022 were SAP followed by CIT, ERG, and ESS (in that order), while TND ranked lowest followed by AGD, EVO, and AND. Comparing rankings in 2022 with 2006, five DNSPs increased their Capital PFP ranking: CIT from 4th to 2nd, ESS from 6th to 4th, EVO from 13th to 11th, JEN from 9th to 8th and AND from 11th to 10th. The DNSPs with substantial decreases in Capital MPFP ranking were END (4 places from 2nd to 6th) and TND (3 places from 10th to 13th).

Figure 3.3 DNSP multilateral capital partial factor productivity indexes, 2006–2022

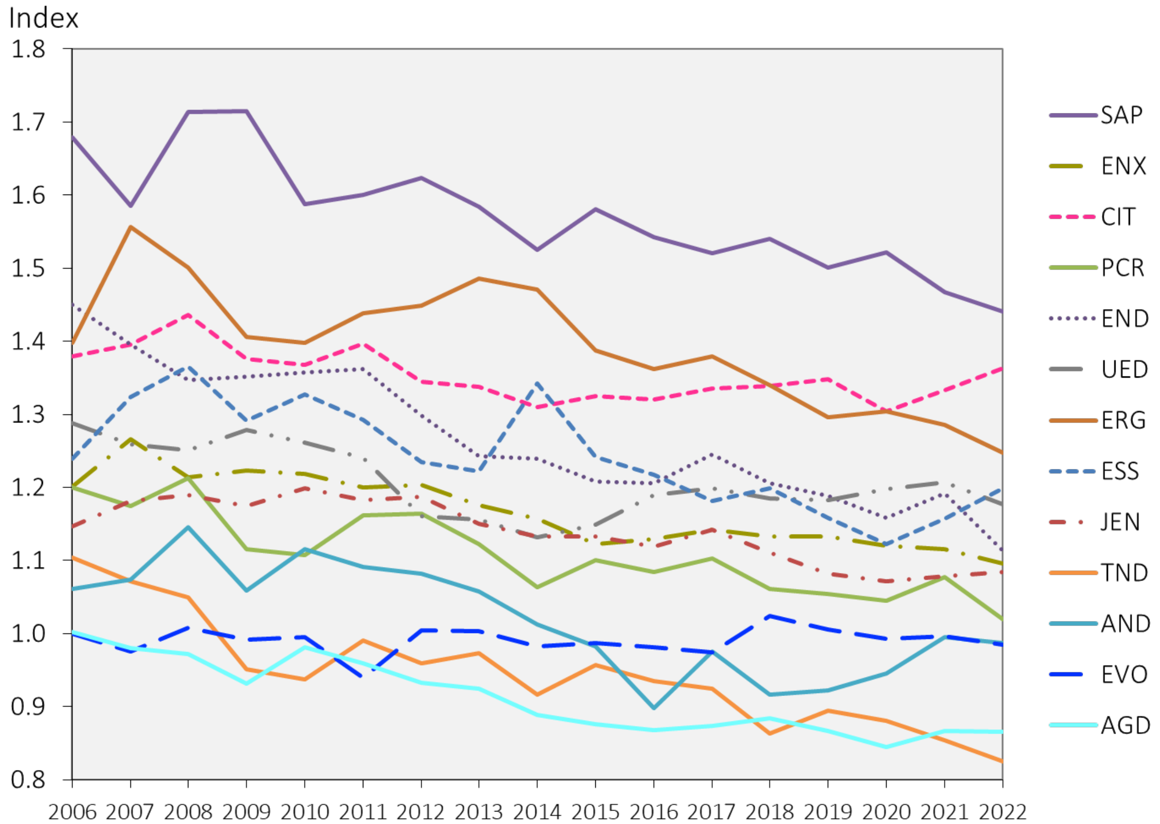


Table 3.3 DNSP multilateral capital partial factor productivity indexes, 2006–2022

Year	EVO	AGD	CIT	END	ENX	ERG	ESS
2006	1.000	1.002	1.379	1.450	1.202	1.398	1.239
2007	0.976	0.980	1.396	1.395	1.265	1.557	1.323
2008	1.008	0.972	1.435	1.347	1.213	1.501	1.366
2009	0.992	0.931	1.376	1.351	1.223	1.406	1.291
2010	0.995	0.981	1.368	1.357	1.219	1.397	1.327
2011	0.939	0.959	1.397	1.362	1.200	1.438	1.292
2012	1.005	0.933	1.345	1.298	1.203	1.449	1.234
2013	1.003	0.924	1.337	1.243	1.176	1.486	1.222
2014	0.982	0.889	1.310	1.239	1.157	1.471	1.342
2015	0.987	0.876	1.324	1.208	1.122	1.387	1.241
2016	0.982	0.868	1.320	1.205	1.130	1.362	1.217
2017	0.974	0.874	1.335	1.245	1.142	1.379	1.181
2018	1.024	0.883	1.339	1.205	1.133	1.340	1.199
2019	1.006	0.866	1.348	1.188	1.133	1.296	1.158
2020	0.992	0.844	1.304	1.158	1.119	1.304	1.123
2021	0.996	0.866	1.333	1.192	1.115	1.286	1.157
2022	0.985	0.865	1.363	1.113	1.096	1.248	1.198

Table 3.3 (cont.)

Year	JEN	PCR	SAP	AND	TND	UED	AVG
2006	1.147	1.200	1.679	1.061	1.103	1.288	1.242
2007	1.182	1.174	1.585	1.073	1.071	1.258	1.249
2008	1.189	1.212	1.714	1.145	1.049	1.250	1.262
2009	1.174	1.116	1.715	1.059	0.951	1.279	1.220
2010	1.199	1.108	1.587	1.116	0.937	1.261	1.219
2011	1.183	1.162	1.601	1.091	0.991	1.240	1.220
2012	1.187	1.164	1.624	1.082	0.959	1.160	1.203
2013	1.151	1.123	1.584	1.058	0.973	1.156	1.187
2014	1.133	1.063	1.525	1.012	0.916	1.131	1.167
2015	1.133	1.100	1.580	0.982	0.957	1.149	1.157
2016	1.119	1.084	1.542	0.898	0.935	1.189	1.142
2017	1.142	1.102	1.521	0.976	0.925	1.199	1.153
2018	1.111	1.061	1.540	0.916	0.863	1.185	1.138
2019	1.082	1.054	1.501	0.923	0.895	1.182	1.126
2020	1.071	1.045	1.522	0.945	0.880	1.198	1.116
2021	1.078	1.077	1.468	0.996	0.854	1.206	1.125
2022	1.084	1.020	1.441	0.986	0.824	1.177	1.108

3.2 DNSP MTFP and MPFP indexes with Opex including CCOs

This section presents the results of carrying out the pooled MTFP and MPFP indexes analysis with opex defined based on 2022 CAMs and including CCOs. Also, the reallocated CCOs have been excluded from the annual cost of the capital inputs for the purpose of calculating input index weights. The methodology is explained in Appendix A, section A5. The results in this section can be compared with those presented in section 3.1 to show the effect of adopting these changes.

The method used here to remove capitalised corporate overheads (CCOs) from the capital input cost share weights is preliminary. The AER intends to consult with DNSPs on approaches to removing CCOs after this year's report benchmarking is published.

3.2.1 Multilateral TFP Indexes

Updated DNSP MTFP indexes are presented in Table 3.4 and Figure 3.4. 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.

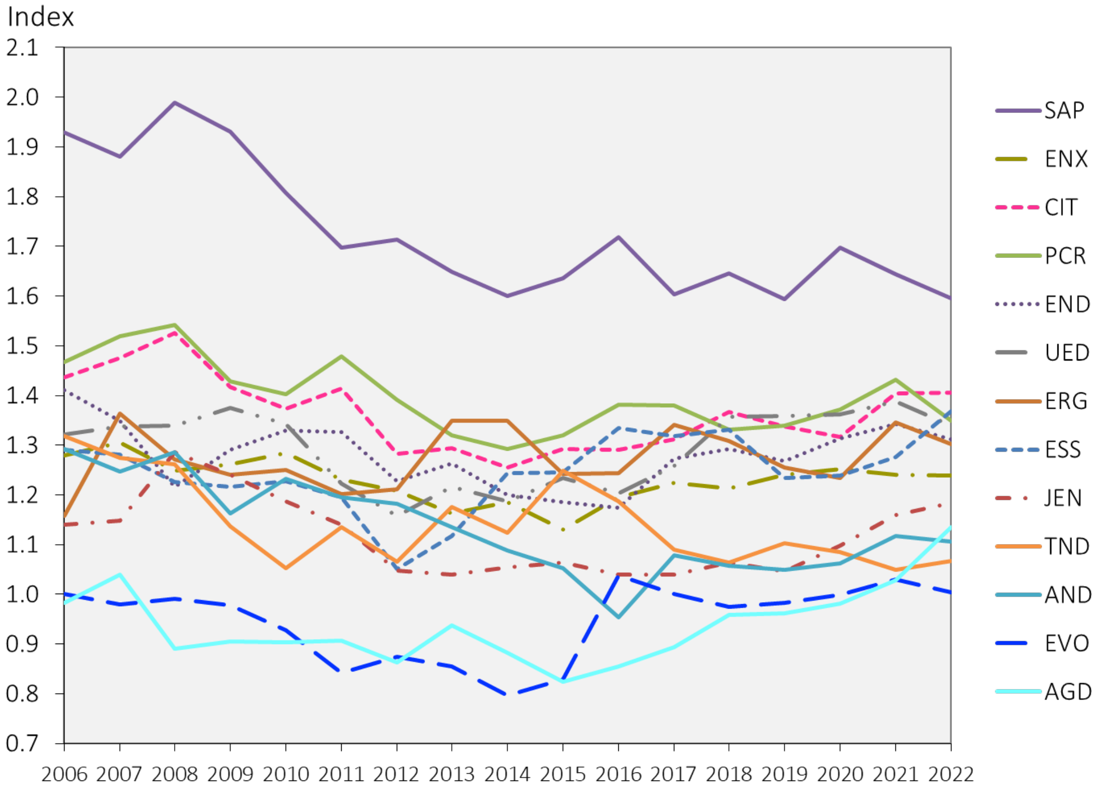
Table 3.4 DNSP multilateral total factor productivity indexes, 2006–2022

Year	EVO	AGD	CIT	END	ENX	ERG	ESS
2006	1.000	0.982	1.437	1.410	1.279	1.158	1.291
2007	0.980	1.040	1.475	1.348	1.306	1.363	1.281
2008	0.990	0.891	1.526	1.217	1.249	1.271	1.226
2009	0.977	0.905	1.416	1.291	1.261	1.241	1.216
2010	0.927	0.903	1.373	1.330	1.284	1.250	1.228
2011	0.842	0.907	1.415	1.326	1.231	1.201	1.195
2012	0.873	0.864	1.282	1.228	1.208	1.211	1.051
2013	0.854	0.937	1.294	1.262	1.163	1.349	1.117
2014	0.797	0.882	1.255	1.200	1.185	1.349	1.243
2015	0.829	0.824	1.292	1.185	1.130	1.242	1.245
2016	1.039	0.855	1.290	1.174	1.195	1.244	1.335
2017	1.000	0.894	1.312	1.273	1.224	1.341	1.318
2018	0.975	0.958	1.367	1.292	1.212	1.309	1.332
2019	0.984	0.962	1.337	1.269	1.241	1.255	1.234
2020	0.999	0.982	1.317	1.314	1.253	1.234	1.238
2021	1.029	1.028	1.404	1.342	1.241	1.346	1.276
2022	1.004	1.134	1.406	1.312	1.239	1.302	1.369

Table 3.4 (cont.)

Year	JEN	PCR	SAP	AND	TND	UED	AVG
2006	1.139	1.467	1.928	1.292	1.319	1.322	1.310
2007	1.149	1.520	1.880	1.248	1.274	1.338	1.323
2008	1.286	1.541	1.988	1.285	1.262	1.339	1.313
2009	1.241	1.428	1.931	1.163	1.137	1.375	1.276
2010	1.186	1.403	1.808	1.233	1.053	1.343	1.255
2011	1.140	1.478	1.698	1.195	1.134	1.223	1.230
2012	1.048	1.391	1.714	1.181	1.066	1.158	1.175
2013	1.039	1.320	1.649	1.135	1.175	1.217	1.193
2014	1.054	1.292	1.600	1.087	1.124	1.186	1.173
2015	1.064	1.320	1.635	1.053	1.248	1.234	1.177
2016	1.039	1.382	1.718	0.953	1.187	1.204	1.201
2017	1.039	1.380	1.603	1.079	1.090	1.258	1.216
2018	1.063	1.330	1.645	1.058	1.063	1.357	1.228
2019	1.047	1.340	1.593	1.049	1.103	1.359	1.213
2020	1.098	1.372	1.697	1.063	1.086	1.362	1.232
2021	1.159	1.432	1.644	1.118	1.049	1.388	1.266
2022	1.183	1.350	1.595	1.106	1.067	1.340	1.262

Figure 3.4 DNSP multilateral total factor productivity indexes, 2006–2022



In 2006 the average MTFP index (relative to EVO in 2006) was 1.31, and it reduced to 1.26 in 2022, 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 0.95 in 2006 to 0.59 in 2022. Comparing MTFP levels in 2022:

- SAP has the highest MTFP level followed by CIT and ESS. EVO ranks lowest in terms of MTFP followed by TND and AND;
- The DNSPs with above-average MTFP indexes were SAP (with an MTFP index of 1.59), CIT (1.41), ESS (1.37), PCR (1.35), UED (1.34), END (1.31) and ERG (1.30);
- Those with below-average MTFP indexes were (from smallest to largest) EVO (1.00), TND (1.07), AND (1.11), AGD (1.13), JEN (1.18), and ENX (1.24)

Most DNSPs decreased their productivity in 2022. Of the DNSPs with above-average MTFP in 2022, only two increased their productivity from 2021 to 2022, CIT and ESS. Among the DNSPs with below-average MTFP in 2022, those which increased their MTFP in 2022 were JEN, AGD, and TND. The remaining DNSPs, SAP, PCR, UED, END, ERG, ENX, AND and EVO experienced decreased MTFP in 2022.

Comparing the rankings of MTFP levels in 2022 to those in 2021, ESS had the largest increase in its ranking, from 7th to 3rd, followed by AGD, which increased from 13th to 10th. Another increase in ranking included CIT, from 3rd to 2nd. On the other hand, the DNSPs whose ranking decreased were PCR from 2nd to 4th, ERG from 5th to 7th, UED from 4th to 5th, AND from 10th to 11th, TND from 11th to 12th and EVO from 12th to 13th. END, SAP, ENX and JEN and did not experience changes in their ranking positions from 2021 to 2022.

Comparing the rankings of MTFP levels in 2022 to those in 2006, ESS had the largest increase in ranking from 8th to 3rd. AGD and ERG had the second largest increases from 13th to 10th and from 10th to 7th respectively. Other increases in ranking included JEN, from 11th to 9th, ENX from 9th to 8th, and CIT from 3rd to 2nd. DNSPs with the largest decreases in rankings between 2006 and 2022 were TND, from 6th to 12th and AND from 7th to 11th. The ranking of PCR decreased from 2nd to 4th, END from 4th to 6th and EVO decreased from 12th to 13th. SAP and UED did not experience a change in their first and fifth ranked positions respectively in both 2006 and 2022.

3.2.2 Multilateral PFP Indexes

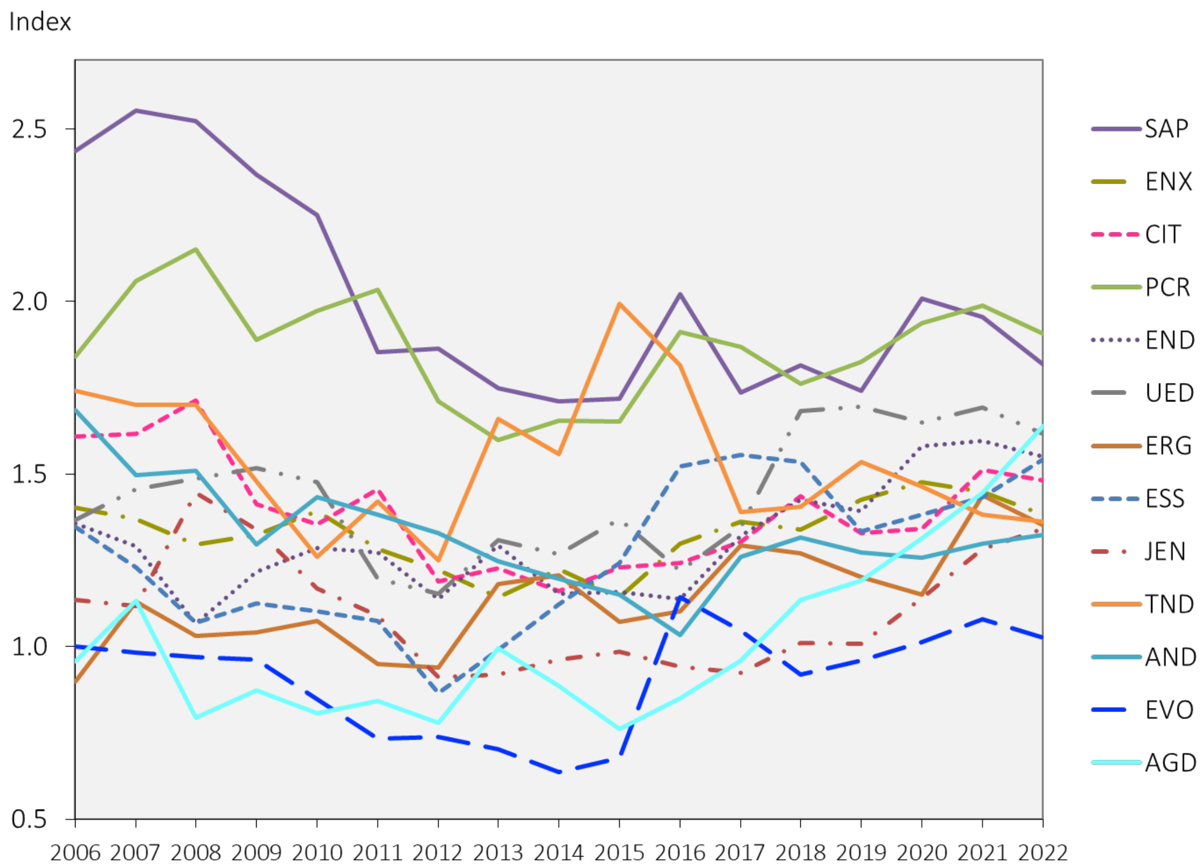
Updated Opex MPFP indexes are presented in Figure 3.5 and Table 3.5 while updated Capital MPFP indexes are presented in Figure 3.6 and Table 3.6.

From Figure 3.5 we see that Opex MPFP levels for most DNSPs decreased in the period from 2006 to 2012, but this trend was mostly reversed in the period 2012 to 2014, and since that time Opex MPFP has increased. From Figure 3.5 and Table 3.5 we see that four DNSPs increased Opex MPFP levels in 2022, namely AGD (12.5 per cent), ESS (7.4 per cent), JEN

(4.4 per cent), and AND (1.9 per cent). The Opex MPFP levels of nine DNSPs decreased in 2022, including SAP (–7.3 per cent), ERG (–6.2 per cent), EVO (–5.2 per cent), ENX and UED (both at –4.6 per cent), and PCR (–4.2 per cent), END (–2.8 per cent), CIT (–2.0 per cent) and TND (–1.6 per cent).[10]

PCR ranked highest in terms of Opex MPFP levels in 2022 followed by SAP and AGD. EVO ranked lowest in terms of Opex MPFP levels in 2022, followed by AND, JEN and ERG. Compared to 2021, AGD improved its Opex MPFP ranking by four places in 2022 (from 7th to 3rd whilst ESS improved from 9th to 6th place. JEN and TND improved their Opex MPFP ranking by one place in 2022 (from 12th to 11th, and 10th to 9th respectively). The DNSPs that decreased their Opex MPFP ranking in 2022 compared to 2021 were ERG, from 8th to 10th place, ENX, from 6th to 8th, CIT from 5th to 7th, AND, from 11th to 12th, UED, from 3rd to 4h and END, from 4th to 5th.

Figure 3.5 DNSP multilateral opex partial factor productivity indexes, 2006–2022



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

Table 3.5 DNSP multilateral opex partial factor productivity indexes, 2006–2022

Year	EVO	AGD	CIT	END	ENX	ERG	ESS
2006	1.000	0.956	1.608	1.356	1.404	0.898	1.348
2007	0.984	1.133	1.616	1.291	1.368	1.130	1.231
2008	0.969	0.795	1.713	1.065	1.296	1.031	1.070
2009	0.962	0.872	1.414	1.216	1.324	1.040	1.125
2010	0.847	0.807	1.354	1.286	1.392	1.073	1.103
2011	0.734	0.843	1.456	1.273	1.284	0.948	1.073
2012	0.737	0.778	1.188	1.137	1.221	0.938	0.866
2013	0.702	0.995	1.228	1.293	1.144	1.180	0.989
2014	0.637	0.886	1.160	1.152	1.224	1.206	1.123
2015	0.677	0.761	1.231	1.159	1.144	1.073	1.242
2016	1.142	0.851	1.241	1.137	1.299	1.103	1.523
2017	1.047	0.960	1.302	1.320	1.362	1.294	1.556
2018	0.919	1.136	1.436	1.427	1.339	1.269	1.534
2019	0.960	1.192	1.328	1.394	1.426	1.201	1.334
2020	1.012	1.314	1.343	1.580	1.477	1.149	1.383
2021	1.080	1.447	1.512	1.595	1.448	1.439	1.432
2022	1.025	1.640	1.482	1.551	1.382	1.353	1.543

Table 3.5 (cont.)

Year	JEN	PCR	SAP	AND	TND	UED	AVG
2006	1.136	1.842	2.437	1.685	1.740	1.367	1.444
2007	1.119	2.058	2.554	1.497	1.701	1.456	1.472
2008	1.447	2.152	2.523	1.510	1.700	1.488	1.443
2009	1.340	1.888	2.368	1.295	1.480	1.518	1.372
2010	1.169	1.974	2.251	1.433	1.261	1.477	1.341
2011	1.090	2.033	1.853	1.382	1.420	1.197	1.276
2012	0.911	1.711	1.863	1.328	1.250	1.154	1.160
2013	0.919	1.599	1.749	1.248	1.660	1.308	1.232
2014	0.962	1.656	1.711	1.196	1.558	1.267	1.211
2015	0.986	1.652	1.719	1.150	1.994	1.369	1.243
2016	0.943	1.911	2.022	1.034	1.814	1.220	1.326
2017	0.925	1.867	1.735	1.259	1.390	1.347	1.336
2018	1.010	1.761	1.814	1.316	1.405	1.684	1.388
2019	1.008	1.825	1.740	1.274	1.535	1.695	1.378
2020	1.141	1.937	2.008	1.256	1.464	1.650	1.440
2021	1.283	1.988	1.955	1.299	1.382	1.693	1.504
2022	1.341	1.907	1.818	1.324	1.361	1.617	1.488

Turning to Capital MPFP, we can see from Figure 3.6 and Table 3.6 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 2022, only three DNSPs improved their Capital MPFP levels, including ESS (3.6 per cent), CIT (2.1 per cent) and JEN (0.5 per cent). The remaining DNSPs with reductions in capital MPFP levels in 2022 were: END (–6.9 per cent), PCR (– 5.3 per cent), TND (–3.6 per cent), ERG (–3.0 per cent), UED (–2.4 per cent), SAP (–1.8 per cent), ENX (–1.7 per cent), EVO (–1.1 per cent), AND (–0.7 per cent) and AGD (–0.2 per cent)

The highest ranked DNSPs in terms of capital productivity in 2022 were SAP followed by CIT, ERG, and ESS (in that order), while TND ranked lowest followed by AGD, AND and EVO. Comparing rankings in 2022 with 2006, four DNSPs increased their Capital PFP ranking: EVO from 13th to 10th, CIT from 4th to 2nd, ESS from 6th to 4th and JEN from 9th to 8th. The DNSPs with decreases in Capital MPFP ranking were END (4 places from 2nd to 6th), TND (3 places from 10th to 13th) and PCR (1 place from 8th to 9th).

Figure 3.6 DNSP multilateral capital partial factor productivity indexes, 2006–2022

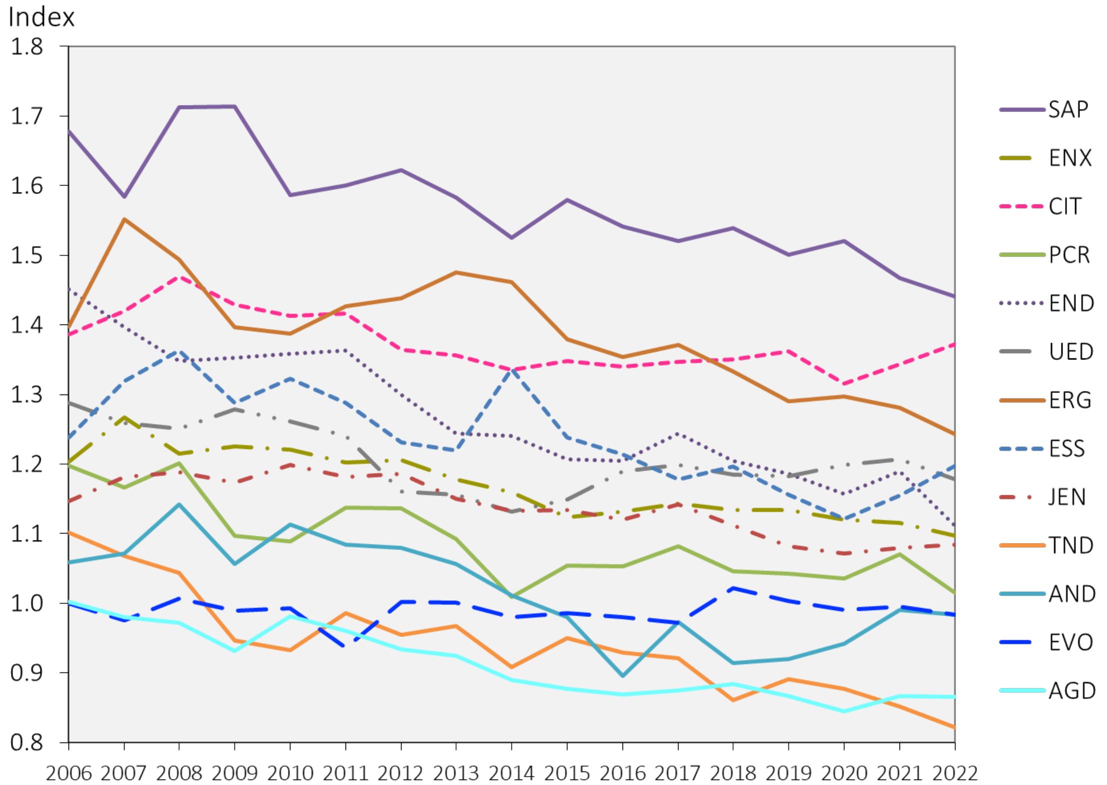


Table 3.6 DNSP multilateral capital partial factor productivity indexes, 2006–2022

Year	EVO	AGD	CIT	END	ENX	ERG	ESS
2006	1.000	1.002	1.386	1.451	1.203	1.398	1.238
2007	0.975	0.980	1.419	1.396	1.267	1.552	1.319
2008	1.006	0.972	1.470	1.348	1.215	1.493	1.363
2009	0.989	0.931	1.429	1.353	1.225	1.397	1.288
2010	0.992	0.981	1.413	1.358	1.221	1.387	1.323
2011	0.937	0.960	1.417	1.363	1.202	1.427	1.288
2012	1.002	0.933	1.364	1.299	1.205	1.438	1.231
2013	1.001	0.925	1.356	1.243	1.178	1.475	1.220
2014	0.980	0.890	1.336	1.240	1.159	1.461	1.337
2015	0.986	0.877	1.348	1.207	1.124	1.379	1.238
2016	0.979	0.869	1.340	1.205	1.132	1.354	1.213
2017	0.972	0.875	1.347	1.244	1.144	1.371	1.178
2018	1.022	0.884	1.350	1.204	1.134	1.333	1.196
2019	1.003	0.867	1.362	1.186	1.134	1.290	1.156
2020	0.991	0.845	1.316	1.157	1.120	1.297	1.121
2021	0.995	0.867	1.343	1.190	1.116	1.281	1.155
2022	0.984	0.865	1.373	1.111	1.097	1.243	1.197

Table 3.6 (cont.)

Year	JEN	PCR	SAP	AND	TND	UED	AVG
2006	1.146	1.198	1.678	1.059	1.101	1.288	1.242
2007	1.181	1.167	1.584	1.071	1.068	1.259	1.249
2008	1.188	1.201	1.713	1.142	1.044	1.251	1.262
2009	1.173	1.097	1.714	1.056	0.947	1.279	1.221
2010	1.199	1.088	1.586	1.113	0.933	1.261	1.220
2011	1.181	1.137	1.600	1.084	0.986	1.241	1.217
2012	1.186	1.136	1.623	1.080	0.955	1.160	1.201
2013	1.150	1.092	1.583	1.056	0.967	1.156	1.185
2014	1.133	1.009	1.525	1.011	0.908	1.132	1.163
2015	1.134	1.054	1.580	0.980	0.950	1.149	1.154
2016	1.120	1.053	1.542	0.896	0.929	1.190	1.140
2017	1.142	1.082	1.520	0.973	0.921	1.199	1.151
2018	1.112	1.046	1.540	0.915	0.860	1.185	1.137
2019	1.082	1.042	1.501	0.919	0.891	1.183	1.124
2020	1.072	1.036	1.521	0.941	0.877	1.198	1.115
2021	1.079	1.070	1.467	0.991	0.851	1.207	1.124
2022	1.084	1.014	1.440	0.983	0.821	1.178	1.107

4 Econometric opex cost function analysis

This chapter presents the update of the econometric opex cost function models. Section 4.1 outlines the results based on standard Opex, while Section 4.2 presents the results utilising the Opex incorporating capitalised corporate overheads.

4.1 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 potentially allows the direct inclusion of adjustment for operating environment factors. In this section we update the models in Economic Insights (2020, 2021) and Quantonomics (2022) to include data for 2021-22 for the Australian and New Zealand DNSPs and 2021 data for the Ontario DNSPs.[11]

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 2022 and 2012 to 2022 – in this section. The corresponding regression results are presented in Appendix C.

4.1.1 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, holding other things constant. 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

[11] Throughout this section and appendix C, when a sample is described as 2006 to 2022, it includes Ontario data for 2005 to 2021; and a sample described as 2012 to 2022 includes Ontario data for 2011 to 2021.

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

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 the SFATLG and LSETLG models have produced some monotonicity violations (Economic Insights 2019; 2020; 2021; Quantonomics 2022). The practice has been to calculate average efficiency scores for each DNSP after excluding either the SFATLG or LSETLG models (or both) if those models have an excessive number of monotonicity violations, representing more than half their number of observations for that DNSP. Further, if a model has monotonicity violations for the great majority of Australian DNSPs, then it will be disregarded altogether when calculating the average efficiency scores.

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 4.1 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.

For the models applied to the full data sample from 2006 to 2022 (see Tables C.7 and C.8 of Appendix C) the LSETLG model has monotonicity violations in 19.5 per cent of the observations on Australian DNSPs. These violations specifically relate to the variable Customer Numbers. Monotonicity violations occurred in more than half of the observations for three Australian DNSPs (CIT, JEN and UED) and for these three DNSPs, the LSETLG model is not included in the average efficiency scores for the 2006 to 2022.

The SFATLG model has monotonicity violations 29.4 per cent of the observations on Australian DNSPs. In 28.1 per cent of the observations, there is a negative elasticity for Customer Numbers and 1.4 per cent of observations have a negative elasticity for Ratcheted Maximum Demand. Three Australian DNSPs (ERG, ESS and SAP) had monotonicity violations in more than half of the observations, and as a result, the SFATLG model is not included in the average of efficiency scores for these three DNSPs for the 2006 to 2022 period.

These results represent a significant deterioration in the monotonicity performance of the Translog models in the long sample period when compared to the results reported in 2022 and 2021. In the 2022 results, neither the LSETLG nor the SFATLG model had any monotonicity violations for Australian DNSPs when estimated using the full sample period. In the 2021 study, the SFATLG model has no monotonicity violations for any of the Australian DNSPs, but the LSETLG model had excessive monotonicity violations for three Australian DNSPs.

For the models applied to the shorter sample period from 2012 to 2022 (see Tables C.15 and C.16 of Appendix C), the LSETLG model has monotonicity violations in 46.9 per cent of Australian DNSP observations, with all violations relating to the Customer Number variable. Six Australian DNSPs (AGD, CIT, ENX, JEN, AND and UED) had monotonicity violations for more than half of the observations. For these six DNSPs, the LSETLG model is not included in the average efficiency scores for the 2012 to 2022.

The SFATLG model has monotonicity violations in 72.7 per cent of the observations on Australian DNSPs, all related to the Customer number variable. In this shorter period, the SFATLG model has monotonicity violations for more than half of the observations for ten of the 13 Australian DNSPs (EVO, AGD, CIT, END, ENX, JEN, PCR, SAP, AND and UED), shown in Table 3.6, and hence this model is not included in the average efficiency scores for any DNSPs for the 2012 to 2022 period.

The monotonicity results obtained using the shorter period from 2012 to 2022 also represent a deterioration compared to the results obtained for the shorter sample period in the previous reports (Quantonomics 2022; Economic Insights 2021). In the 2022 analysis, the short-term LSETLG model had excessive monotonicity violations for five Australian DNSPs, and the SFATLG model had excessive monotonicity violations for nine Australian DNSPs. In the 2021 study, using the shorter sample period, the LSETLG model had excessive monotonicity violations for seven Australian DNSPs and the SFATLG model had excessive monotonicity violations for nine Australian DNSPs.

4.1.2 Summary results for the sample period 2006-2022

Opex efficiency scores for each of the 13 NEM DNSPs across the 17-year period 2006 to 2022 for the four opex cost function models and, for comparison, opex MPFP are presented in Table 4.1 and in Figure 4.1 (the latter excluding the omitted SFATLG model and LSETLG model as necessary). The last two columns of Table 4.1 show averages of efficiency scores:

(a) across all models including opex PFP (but excluding the SFATLG model for three DNSPs, and excluding the LSETLG model for three DNSPs, as a result of the monotonicity violations); and

(b) across only the econometric model estimates (with the same exclusions).

The same average opex efficiency scores across for all models, and for the econometric models only, are presented in Figure 4.2. The opex efficiency scores averaged over all methods indicate:

- PCR and CIT have the highest average efficiency scores (0.99 and 0.91 respectively);
- SAP and TND also had an efficiency score above the average (0.82 and 0.80 respectively);
- The sample average opex efficiency score is 0.69, and DNSPs with opex efficiency close to average are UED (0.74), ESS (0.68), and AND (0.67);
- Several DNSPs are below average but not the lowest in terms of opex efficiency. These include JEN (0.66); ERG (0.60), END (0.60) and ENX (0.58).

- The two DNSPs with lowest opex efficiency are EVO (0.50) and AGD (0.44).

These rankings are similar to those in Quantonomics (2022).

Figure 4.1 DNSP opex cost efficiency scores, 2006–2022

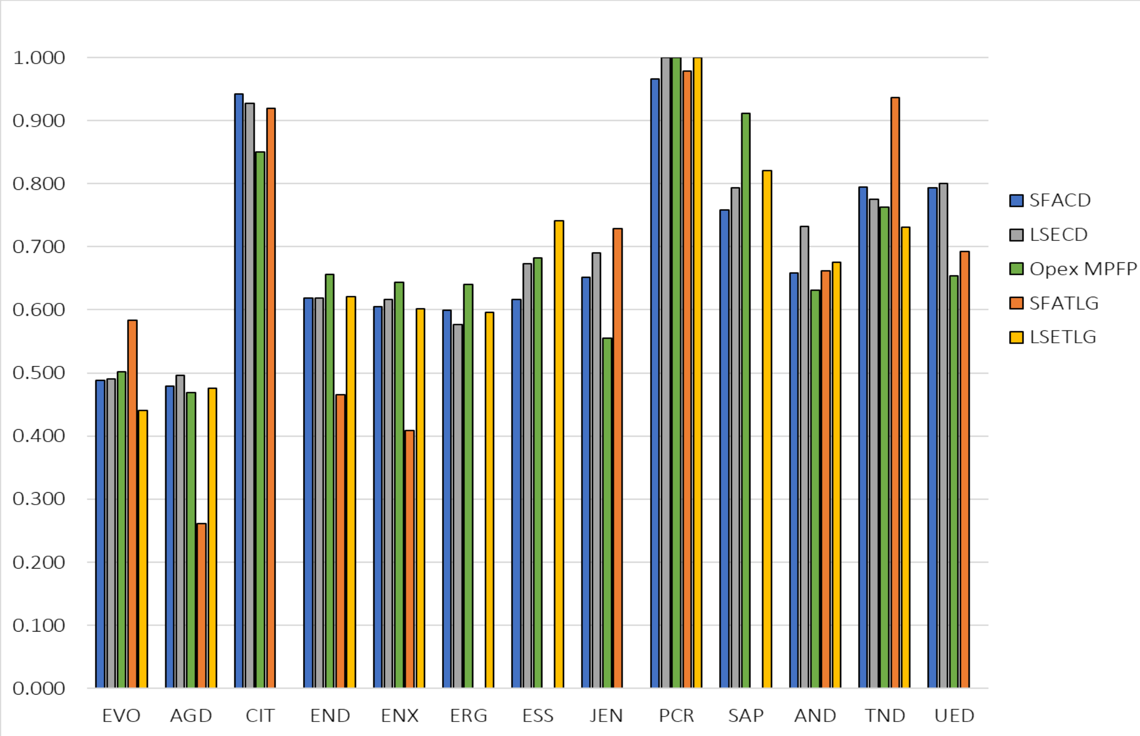


Table 4.1 DNSP average opex cost efficiency scores, 2006–2022

DNSP	*SFACD* (1)	*SFATLG* (2)	*LSECD* (3)	*LSETLG* (4)	*Opex MPFP* (5)	*Average all Methods*	*Average econometric Models*
EVO	0.488	0.584	0.490	0.440	0.502	0.501	0.500
AGD	0.479	0.261	0.496	0.476	0.468	0.436	0.428
CIT	0.942	0.919	0.928	0.845	0.851	0.910*	0.930*
END	0.619	0.465	0.618	0.621	0.656	0.596	0.581
ENX	0.606	0.409	0.617	0.602	0.644	0.575	0.558
ERG	0.599	0.771	0.577	0.596	0.640	0.603**	0.591**
ESS	0.616	0.747	0.673	0.741	0.682	0.678**	0.677**
JEN	0.651	0.728	0.690	0.536	0.555	0.656*	0.690*
PCR	0.965	0.979	1.000	1.000	1.000	0.989	0.986
SAP	0.758	0.776	0.793	0.820	0.911	0.821**	0.790**
AND	0.659	0.662	0.732	0.676	0.631	0.672	0.682
TND	0.795	0.936	0.776	0.731	0.763	0.800	0.809
UED	0.794	0.692	0.800	0.635	0.654	0.735*	0.762*

Note: * Excludes LSETLG; ** Excludes SFATLG.

The overall average efficiency scores are also similar between models. The average efficiency score of the SFACD and SFATLG models are 0.69 and 0.66 respectively, and the average efficiency scores of the LSECD and LSETLG models are 0.71 and 0.67, respectively. Table 4.1 also compares the average of the econometric efficiency score estimates with an estimate obtained from the relative Opex PFP measures from the index analysis (taking the highest Opex PFP as equal to 1). The average relative Opex PFP is 0.69, which is similar to the econometric analysis.

Compared to the results in the 2022 report, JEN, TND and EVO average efficiency scores have improved by more than two per cent. The DNSPs that deteriorated their average efficiency score in 2022 compared to 2021 were ENX (–2.7 per cent), AGD (–1.3 per cent), END (–1.0 per cent), UED (–0.8 per cent) and ERG (–0.5 per cent).

Figure 4.2 shows the average efficiency scores of all models (including opex PFP), and for the econometric models only. The results are broadly similar whichever of these two averaging approaches is used.

Table 4.2 presents a summary of the cost-output elasticities estimated for the four econometric models. For the Cobb-Douglas specifications (SFACD and LSECD) the cost-output elasticities are restricted to be the same for all observations. For the Translog specifications (SFATLG and LSETLG) the cost-output elasticities vary with different levels of the outputs and hence vary across all observations in the sample.

Figure 4.2 DNSP opex cost efficiency scores, 2006–2022, average of models

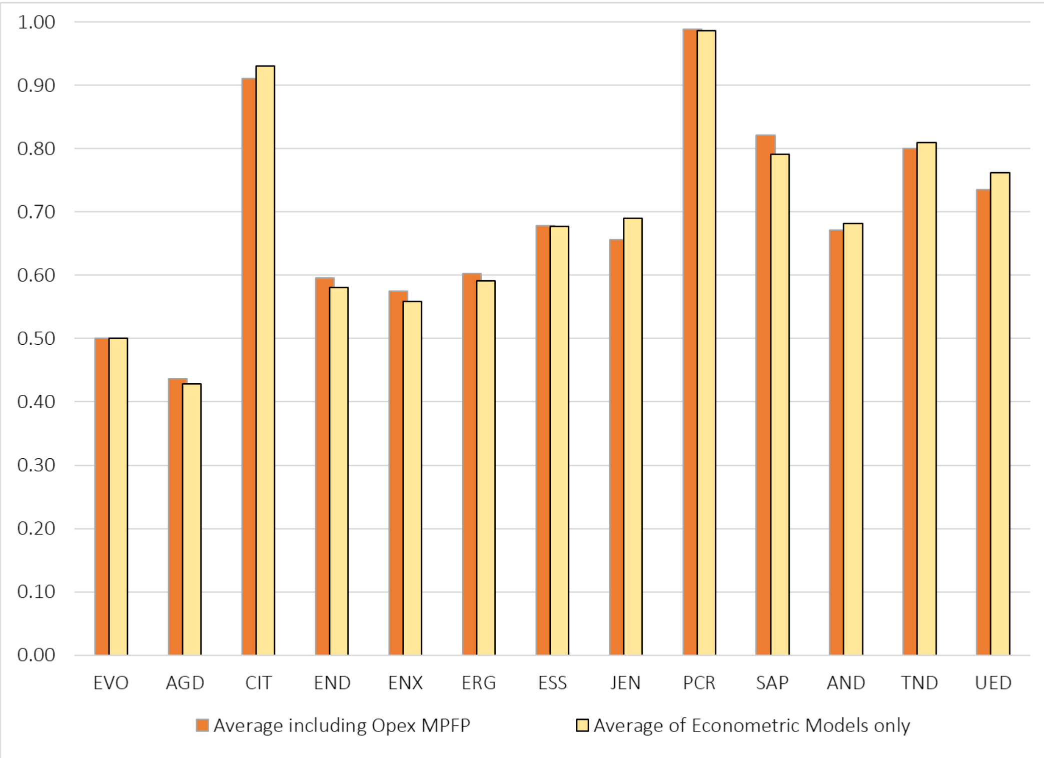


Table 4.2 Average DNSP output elasticities by country and overall, 2006–2022

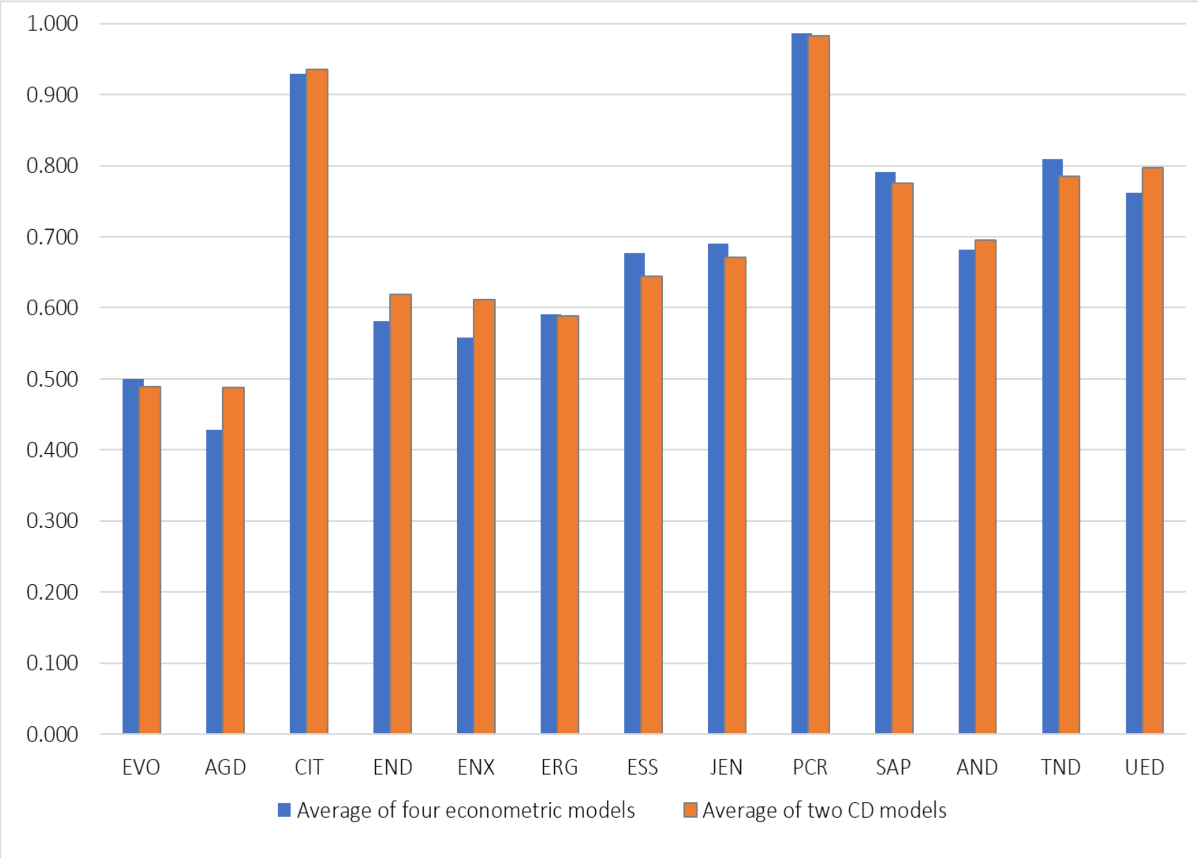
Sub-sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
		SFACD model			*LSECD model*	
All	0.364	0.132	0.475	0.565	0.170	0.238
		SFATLG model			*LSETLG model*	
Australia	0.113	0.303	0.273	0.293	0.267	0.470
New Zealand	0.443	0.016	0.659	0.642	0.216	0.075
Ontario	0.424	0.055	0.392	0.311	0.131	0.499
Full sample	0.369	0.092	0.445	0.401	0.182	0.373

Table 4.2 shows averages of these elasticities by country and over the full sample (ie, including overseas DNSPs). The average cost-output elasticities for the Translog model, when taken over the whole sample, are broadly similar to those estimated using the Cobb-Douglas specification. The cost-output elasticities for the Australian sub-sample, in the Translog models, tend to be smaller for the customer numbers output and larger for circuit length, compared to the average for the full sample. For example:

- in the SFATLG model, the customer numbers elasticity is 0.113 for Australian DNSPs, and 0.369 for the whole sample; and in the LSETLG model, the customer numbers elasticity is 0.293 for Australian DNSPs, and 0.401 for the whole sample;
- the circuit length elasticity for Australian DNSPs in the SFATLG model is 0.303, compared to 0.092 for the whole sample; and in the LSETLG model, the circuit length elasticity is 0.267 for Australian DNSPs compared to 0.182 for the whole sample.

Figure 4.3 compares the average efficiency scores using all the valid econometric models (excluding the SFATLG model or the LSETLG model when necessary) against the average efficiency scores obtained by averaging only the two Cobb-Douglas models, SFACD and LSECD. This shows that whether the average of all valid econometric models is used, or whether the average of only the Cobb-Douglas models is used, the resulting efficiency scores are broadly similar.

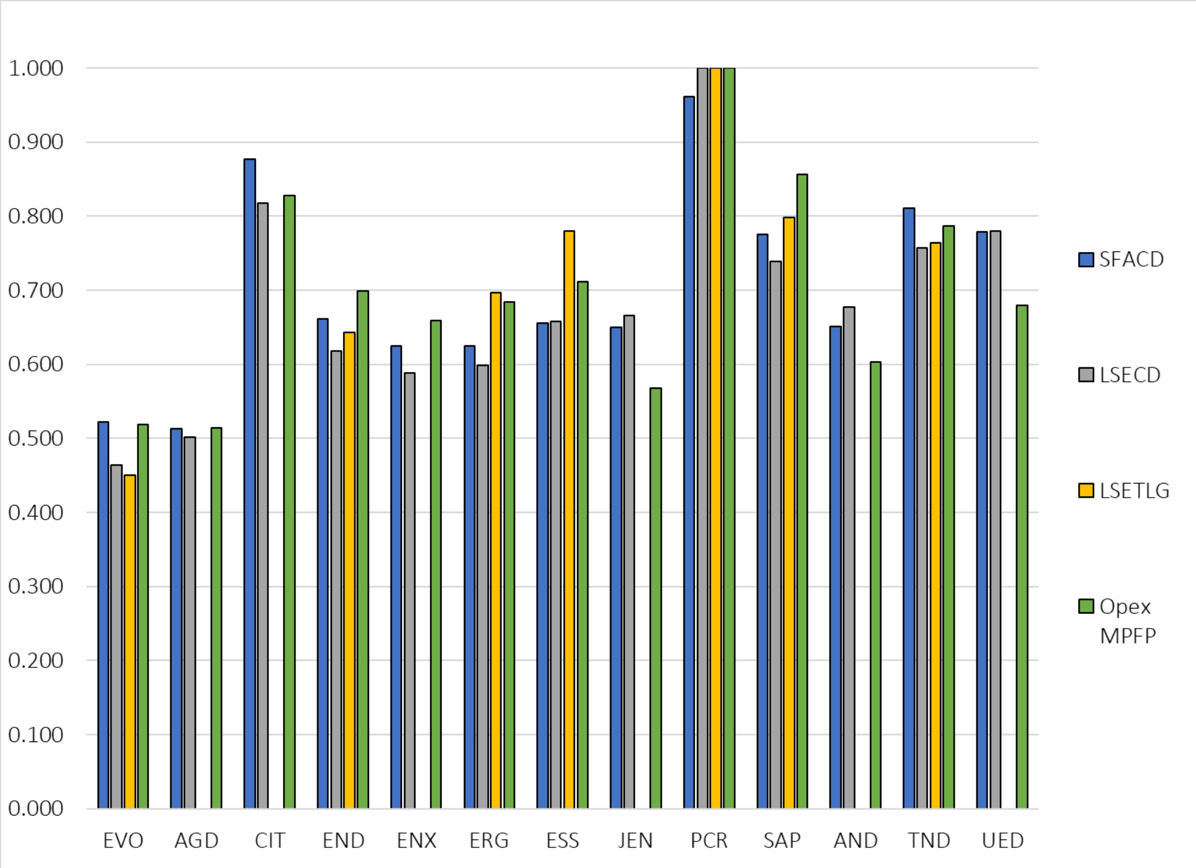
Figure 4.3 DNSP opex cost efficiency scores, 2006–2022, average of four econometric models compared to the average of CD models



4.1.3 Summary results for the sample period 2012-2022

We turn now to the opex efficiency scores based on the more recent period, 2012 to 2022. Opex efficiency scores are presented in Figure 4.4 and Table 4.3 for each of the 13 NEM DNSPs. Table 4.3 shows the results from the four opex cost function models and opex MPFP. For each DNSP, opex efficiency scores averaged across econometric benchmarking models where feasible (with the SFATLG model excluded in all cases, and the LSETLG model also excluded for six of the 13 DNSPs), and also averaged over all methods (ie, the same econometric models plus opex PFP). Figure 4.4 shows the efficiency score result for each DNSP using each of the included methods. Figure 4.5compares the efficiency scores averaged over all methods (including opex PFP) compared to the average over the included econometric models.

Figure 4.4 DNSP opex cost efficiency scores, 2012–2022



From Figure 4.4 and Table 4.3 we see that the rankings are reasonably similar to the full sample period. PCR and CIT have the highest opex efficiency measures, 0.99 and 0.84 respectively. The next highest ranked in terms of opex efficiency are SAP, TND and UED. The two lowest ranked DNSPs in terms of opex efficiency are EVO and AGD, the same as for the full sample. The average efficiency score for the Australian DNSPs (using the averages shown in the second last column of Table 4.3) for the period from 2012 to 2022 is 0.70, which similar to the average for the full period.

Turning to the comparison between the models in terms of average scores for the post-2012 period, the SFACD model has an average efficiency score of 0.70 and; the LSECD and LSETLG models have average efficiency scores of 0.68 and 0.73 respectively.

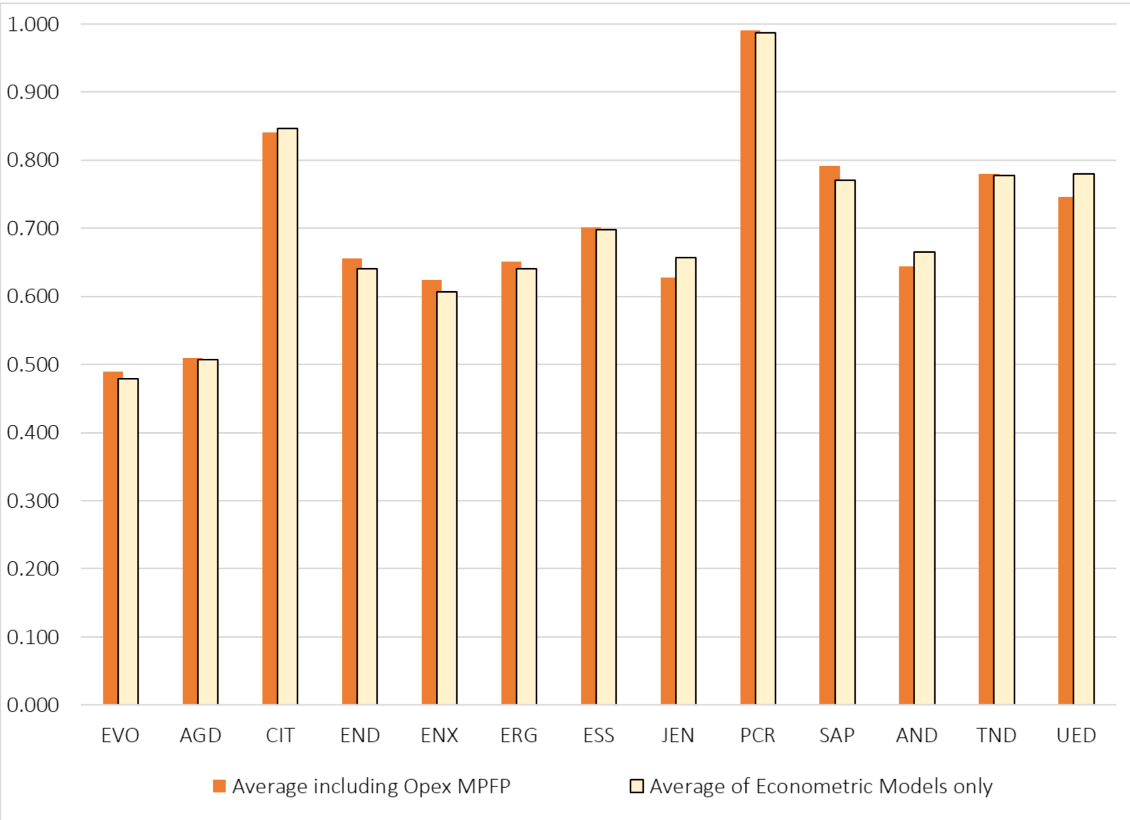
Figure 4.5 shows, for the shorter sample period, the average efficiency scores when the average is calculated for the two CD and the LSETLG econometric models plus the opex PFP-based score, and when the average is calculated only for the same econometric models. Again, the results are broadly similar whichever of these two averaging approaches is used.

Table 4.3 DNSP average opex cost efficiency scores, 2012–2022

DNSP	*SFACD* (1)	*SFATLG* (2)[13]	*LSECD* (3)	*LSETLG* (4)	*Opex MPFP* (5)	*Average all methods***	*Average econometric Models***
EVO	0.523	0.536	0.464	0.451	0.519	0.489	0.479
AGD	0.513	0.360	0.501	0.472	0.514	0.510*	0.507*
CIT	0.877	0.867	0.817	0.820	0.827	0.840*	0.847*
END	0.661	0.591	0.618	0.643	0.699	0.656	0.641
ENX	0.625	0.482	0.589	0.569	0.659	0.624*	0.607*
ERG	0.625	0.700	0.598	0.697	0.684	0.651	0.640
ESS	0.655	0.754	0.658	0.780	0.712	0.701	0.698
JEN	0.649	0.536	0.666	0.520	0.568	0.628*	0.658*
PCR	0.961	0.948	1.000	1.000	1.000	0.990	0.987
SAP	0.775	0.781	0.739	0.798	0.857	0.792	0.771
AND	0.651	0.580	0.678	0.602	0.604	0.644*	0.665*
TND	0.810	0.873	0.757	0.764	0.786	0.779	0.777
UED	0.779	0.582	0.780	0.611	0.680	0.746*	0.779*

Note: * Excludes LSETLG; ** Excludes SFATLG.

Figure 4.5 DNSP opex cost efficiency scores, 2012–2022, average of models



[13] SFATLG model has monotonicity violations for 72.7 per cent of the observations on Australian DNSPs and monotonicity violations for more than half of the observations for ten Australian DNSPs in this shorter period, and while reported here these results are not included in the average efficiency scores for the 2012 to 2022 period.

4.2 Econometric opex cost function efficiency scores with Opex including CCOs

This section presents the results of carrying out the opex cost function analysis with opex defined on the revised basis which includes CCOs. The results in this section can be compared with those presented in section 4.1 to show the effect of adopting these changes on the estimates of DNSPs' opex efficiency.

4.2.1 Monotonicity performance

The average efficiency scores for each DNSP in Tables 4.4 and 4.6 (the long and short periods respectively) are calculated after excluding either the SFATLG or LSETLG models if those models have monotonicity violations for more than half their number of observations for that DNSP.

For the models applied to the full data sample from 2006 to 2022 (see Tables C.23 and C.24 of Appendix C) the LSETLG model has monotonicity violations in 10.0 per cent of the observations on Australian DNSPs. These violations specifically relate to the variable Customer Numbers. Monotonicity violations occurred in more than half of the observations for one Australian DNSP (UED) and for it, the LSETLG model is not included in the average efficiency scores for the 2006 to 2022.

The SFATLG model has a negative elasticity and therefore monotonicity violations in 23.5 per cent of the Australian DNSP observations for Customer Numbers and 18.6 per cent of observations for Ratcheted Maximum Demand. Five Australian DNSPs (AGD, ERG, ESS, SAP and UED) had monotonicity violations in more than half of the observations, and as a result, the SFATLG model is not included in the average of efficiency scores for these five DNSPs for the 2006 to 2022 period.

For the models applied to the shorter sample period from 2012 to 2022 (see Tables C.31 and C.32 of Appendix C), the LSETLG model has monotonicity violations in 49.7 per cent of Australian DNSP observations, with all violations relating to the Customer Number variable. Seven of the 13 Australian DNSPs (AGD, CIT, END, ENX, JEN, AND and UED) had monotonicity violations for more than half of the observations, and hence this model is not included in any of the average efficiency scores for any DNSPs for the 2012 to 2022 period.

The SFATLG model has monotonicity violations in 74.1 per cent of the observations on Australian DNSPs, all related to the Customer number variable. In this shorter period, the SFATLG model has monotonicity violations for more than half of the observations for ten of the 13 Australian DNSPs (EVO, AGD, CIT, END, ENX, JEN, PCR, SAP, AND and UED), shown in Table 4.6, and hence this model is not included in any of the average efficiency scores for any DNSPs for the 2012 to 2022 period.

The monotonicity results obtained when opex is defined to include capitalised corporate overheads represent a deterioration compared to the results when the standard opex definition is used, both for the long period (2006 to 2022) and the shorter period (2012 to 2022).

4.2.2 Summary results for the sample period 2006-2022

Opex efficiency scores for each of the 13 NEM DNSPs across the 17-year period 2006 to 2022 for the four opex cost function models for comparison, opex MPFP, are set out in Table 4.4 and in Figure 4.6. The last two columns of Table 4.4 show averages of efficiency scores across all models including opex PFP (but excluding the SFATLG model for five DNSPs, and excluding the LSETLG model for UED, as a result of the monotonicity violations) and across only the econometric model estimates (with the same exclusions). The opex efficiency scores averaged over all methods indicate:

- PCR, SAP and UED have the highest average efficiency scores (0.97, 0.95 and 0.87 respectively);
- TND and CIT have efficiency scores significantly above the average (0.84 and 0.77 respectively);
- The sample average opex efficiency score is 0.71, and DNSPs with opex efficiency close to average are AND (0.74) and JEN (0.66);
- Several DNSPs are below average but not the lowest in terms of opex efficiency. These include ESS (0.66), ENX (0.63), END (0.62), ERG (0.57) and AGD (0.55);
- The DNSP with lowest opex efficiency is EVO (0.48).

The overall average efficiency scores are also similar between models. The average efficiency score of the SFACD and SFATLG models are 0.72 and 0.71 respectively, and the average efficiency scores of the LSECD and LSETLG models are 0.75 and 0.70, respectively. Table 4.4 also compares the average of the econometric efficiency score estimates with an estimate obtained from the relative Opex PFP measures from the index analysis (taking the highest Opex PFP as equal to 1). The average relative Opex PFP is 0.68, which is similar to the econometric analysis.

Figure 4.7 shows the average efficiency scores of all models (including opex PFP), and for the econometric models only. The results are broadly similar whichever of these two averaging approaches is used. Table 4.5 presents a summary of the cost-output elasticities estimated for the four econometric models. In the Cobb-Douglas specifications (SFACD and LSECD) the cost-output elasticities are restricted to be the same for all observations. In the Translog specifications (SFATLG and LSETLG) the cost-output elasticities vary with different levels of the outputs and hence vary across all observations in the sample.

Figure 4.6 DNSP opex cost efficiency scores, 2006–2022

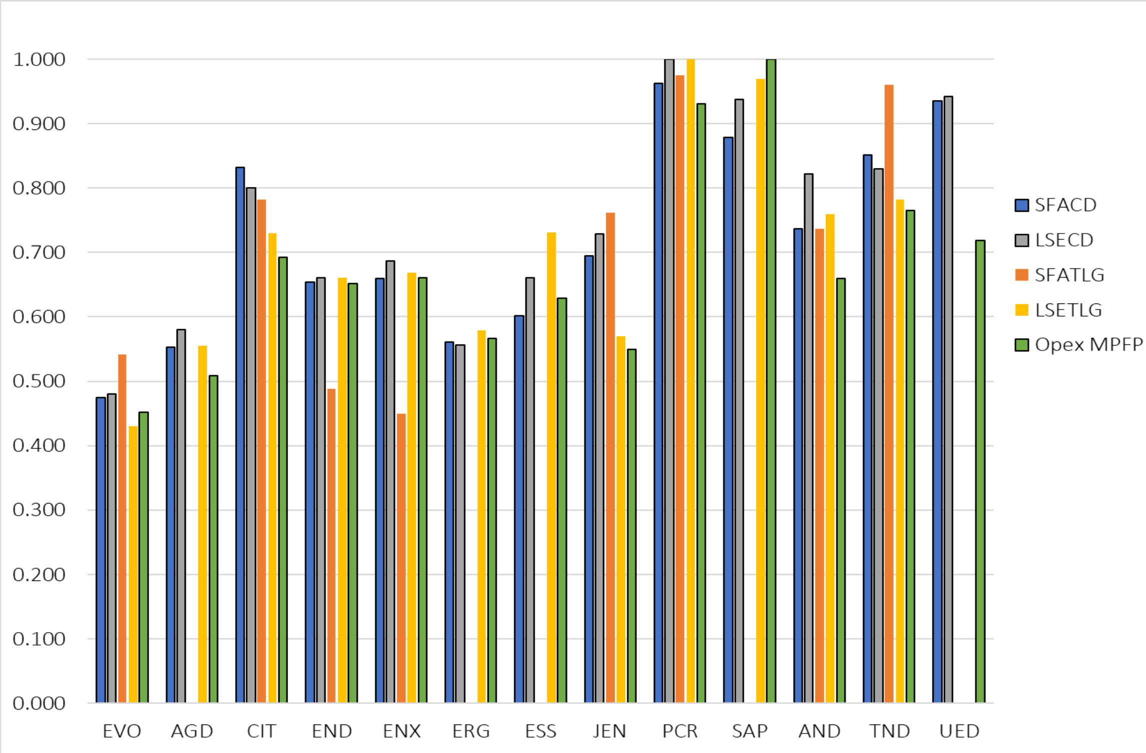


Table 4.4 DNSP average opex cost efficiency scores, 2006–2022

DNSP	*SFACD* (1)	*SFATLG* (2)	*LSECD* (3)	*LSETLG* (4)	*Opex MPFP* (5)	*Average all Methods*	*Average econometric Models*
EVO	0.475	0.542	0.480	0.431	0.452	0.476	0.482
AGD	0.553	0.307	0.580	0.555	0.509	0.549**	0.563**
CIT	0.833	0.783	0.800	0.730	0.692	0.767	0.786
END	0.653	0.488	0.660	0.660	0.652	0.623	0.616
ENX	0.660	0.450	0.687	0.668	0.660	0.625	0.616
ERG	0.561	0.744	0.556	0.579	0.566	0.566**	0.565**
ESS	0.601	0.751	0.660	0.731	0.629	0.656**	0.664**
JEN	0.695	0.761	0.728	0.570	0.549	0.661	0.689
PCR	0.963	0.975	1.000	1.000	0.931	0.974	0.984
SAP	0.879	0.910	0.937	0.969	1.000	0.946**	0.928**
AND	0.737	0.737	0.822	0.760	0.659	0.743	0.764
TND	0.851	0.961	0.830	0.782	0.765	0.838	0.856
UED	0.935	0.812	0.943	0.751	0.718	0.865***	0.939***

Note: * Excludes LSETLG; ** Excludes SFATLG; *** Excludes both LSETLG and SFATLG.

Figure 4.7 DNSP opex cost efficiency scores, 2006–2022, average of models

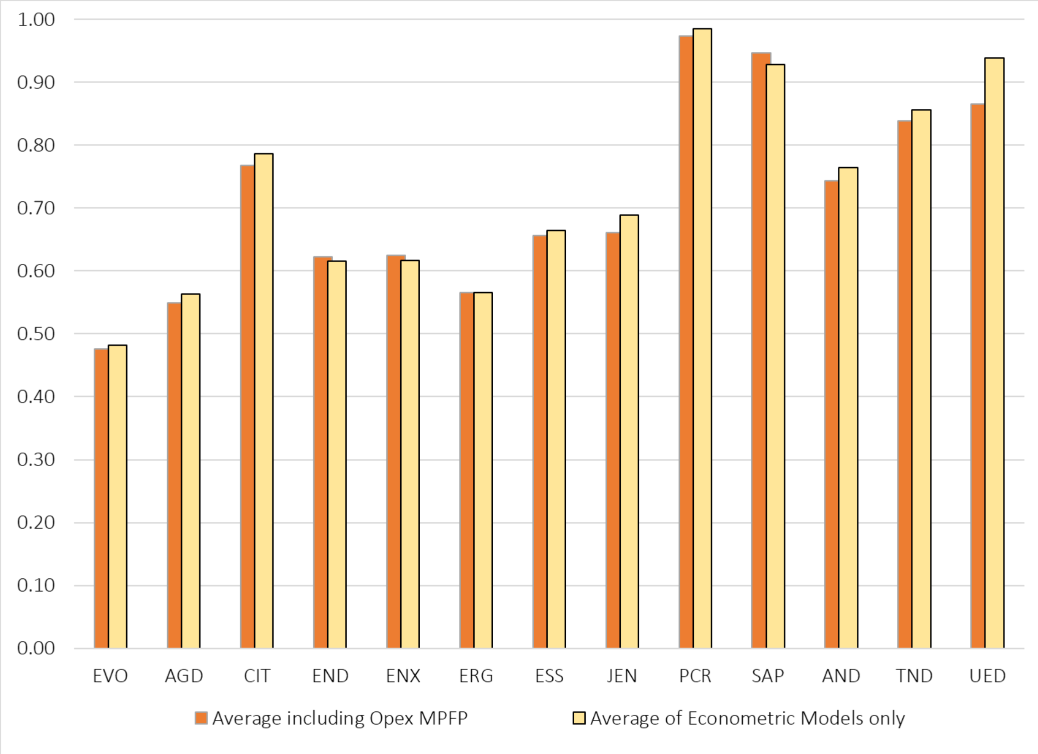


Table 4.5 shows averages of the Translog model elasticities by country and over the full sample (ie, including overseas DNSPs). The average cost-output elasticities for the SFA Translog model, when taken over the whole sample, are broadly similar to the SFA estimated using the Cobb-Douglas specification.

Table 4.5 Average DNSP output elasticities by country and overall, 2006–2022

Sub-sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
		SFACD model			*LSECD model*	
All	0.376	0.123	0.467	0.561	0.172	0.240
		SFATLG model			*LSETLG model*	
Australia	0.166	0.307	0.241	0.296	0.270	0.463
New Zealand	0.456	0.031	0.638	0.639	0.220	0.075
Ontario	0.448	0.043	0.385	0.315	0.130	0.496
Full sample	0.395	0.091	0.429	0.403	0.183	0.370

Table 4.5 also shows the cost-output elasticities for the Australian sub-sample in the Translog models tend to be smaller for the customer numbers output and larger for circuit length, compared to the average for the full sample. For example:

- in the SFATLG model, the customer numbers elasticity is 0.17 for Australian DNSPs, and 0.40 for the whole sample; and in the LSETLG model, the customer numbers elasticity is 0.30 for Australian DNSPs, and 0.40 for the whole sample;
- the circuit length elasticity for Australian DNSPs in the SFATLG model is 0.31, compared to 0.09 for the whole sample; and in the LSETLG model, the circuit length elasticity is 0.27 for Australian DNSPs compared to 0.18 for the whole sample.

4.2.3 Summary results for the sample period 2012-2022

We turn now to the opex efficiency scores based on the more recent period, 2012 to 2022. Opex efficiency scores are presented in Figure 4.8 and Table 4.6 for each of the 13 NEM DNSPs. Table 4.6 shows the results from the four opex cost function models and opex MPFP. For each DNSP, opex efficiency scores averaged across econometric benchmarking models where feasible (with both Translog models excluded in all cases). Figure 4.8 shows the efficiency score result for each DNSP using each of the included methods.

From Figure 4.8 and Table 4.6 we see that the rankings are reasonably similar to the full sample period. PCR and SAP have the highest opex efficiency measures, 0.98 and 0.92 respectively. The next highest ranked in terms of opex efficiency are UED, TND and CIT. The two lowest ranked DNSPs in terms of opex efficiency are AGD and EVO, the same as for the full sample. The average efficiency score for the Australian DNSPs (using the averages shown in the second last column of Table 4.6) for the period from 2012 to 2022 is 0.73, which similar to the average for the full period.

Turning to the comparison between the models in terms of average scores for the post-2012 period, the SFACD model has average efficiency scores of 0.73 and the LSECD model has average efficiency scores of 0.72.

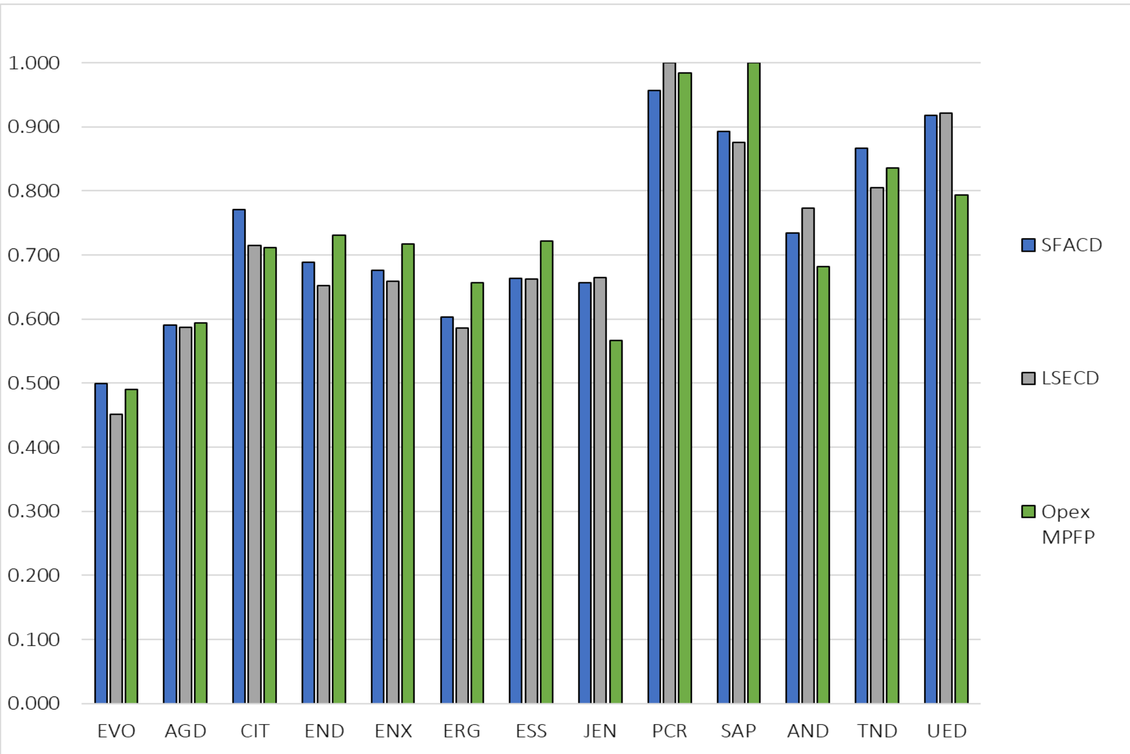
Figure 4.9 shows, for the shorter sample period, the average efficiency scores when the average is calculated for the two CD econometric models plus the opex PFP-based score, and when the average is calculated only for the same econometric models. Again, the results are broadly similar whichever of these two averaging approaches is used.

Table 4.6 DNSP average opex cost efficiency scores, 2012–2022

DNSP	*SFACD* (1)	*SFATLG* (2)[14]	*LSECD* (3)	*LSETLG* (4)	*Opex MPFP* (5)	*Average all methods****	*Average econometric Models****
EVO	0.499	0.518	0.452	0.439	0.490	0.480	0.475
AGD	0.591	0.379	0.587	0.552	0.594	0.591	0.589
CIT	0.770	0.767	0.715	0.719	0.712	0.732	0.742
END	0.689	0.587	0.652	0.679	0.731	0.691	0.671
ENX	0.677	0.486	0.659	0.634	0.717	0.684	0.668
ERG	0.603	0.720	0.586	0.691	0.657	0.615	0.594
ESS	0.664	0.809	0.663	0.793	0.722	0.683	0.664
JEN	0.657	0.548	0.664	0.522	0.567	0.629	0.661
PCR	0.957	0.934	1.000	1.000	0.984	0.980	0.979
SAP	0.892	0.902	0.875	0.947	1.000	0.923	0.884
AND	0.734	0.644	0.773	0.685	0.682	0.730	0.753
TND	0.867	0.943	0.805	0.816	0.836	0.836	0.836
UED	0.918	0.668	0.921	0.722	0.793	0.878	0.920

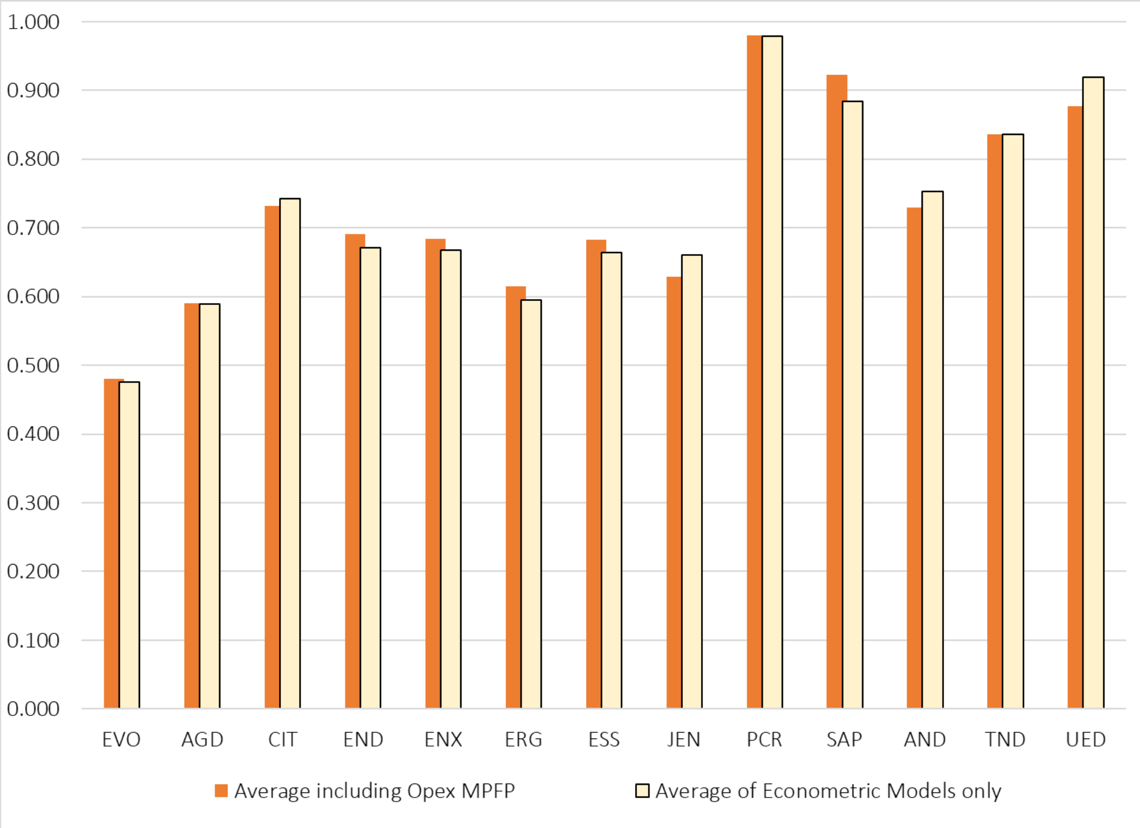
Note: *** Excludes LSETLG and SFATLG.

Figure 4.8 DNSP opex cost efficiency scores, 2012–2022



[14] SFATLG model has monotonicity violations for 72.7 per cent of the observations on Australian DNSPs and monotonicity violations for more than half of the observations for ten Australian DNSPs in this shorter period, and while reported here these results are not included in the average efficiency scores for the 2012 to 2022 period.

Figure 4.9 DNSP opex cost efficiency scores, 2012–2022, average of models



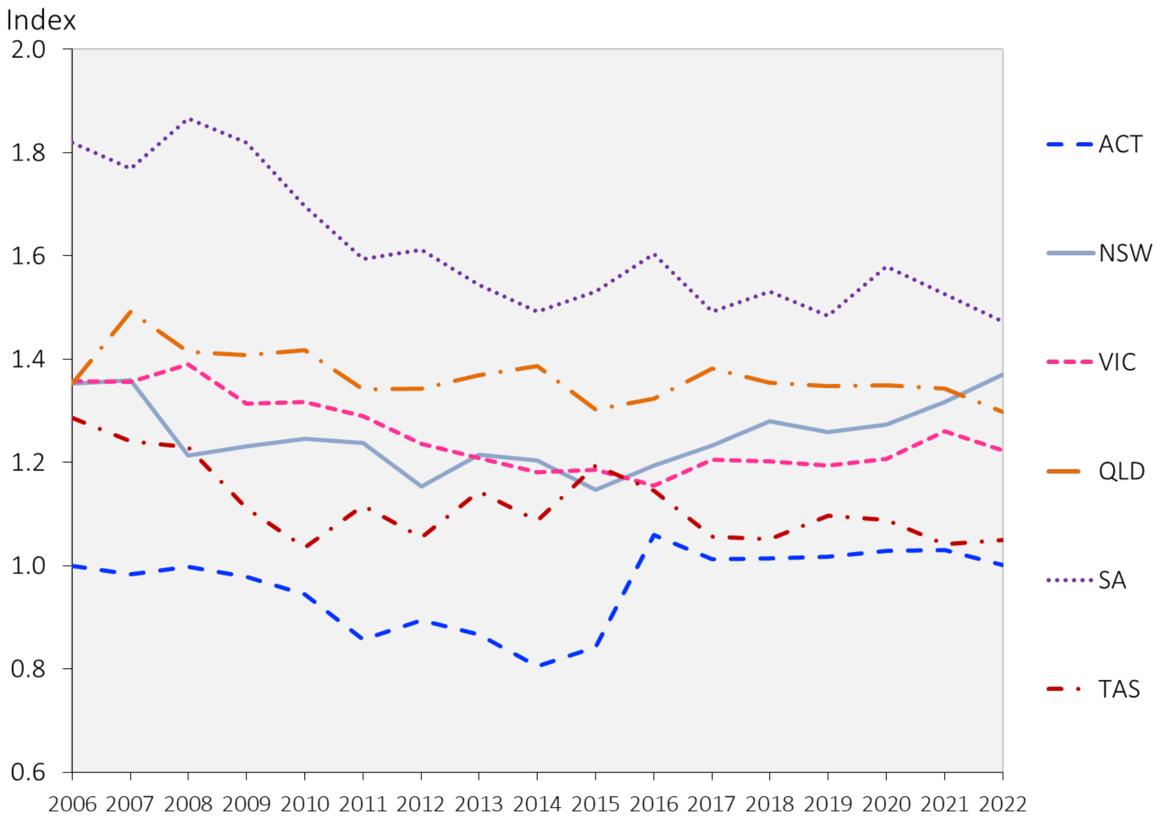
5 State–level Distribution Productivity Results

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.

5.1 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 5.1 and Table 5.1 show the MTFP of electricity distribution in each state and territory of the NEM for which RIN data is collected.

Figure 5.1 State–level DNSP multilateral TFP indexes, 2006–2022



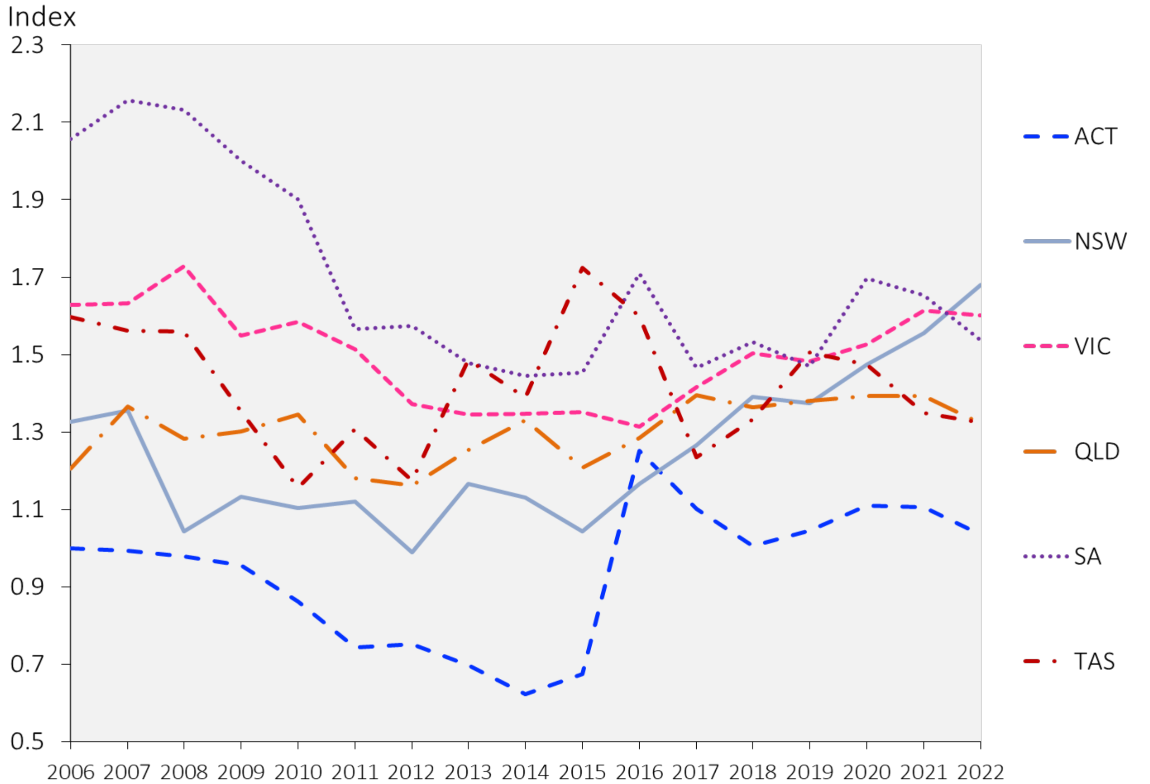
In 2022, South Australia (SA) had the highest MTFP level followed by New South Wales (NSW) being in second place. Queensland (QLD) and Victoria (VIC) placed third and fourth position which were close to the average for the NEM states. Tasmania (TAS) was in fifth place in 2022, with the Australian Capital Territory (ACT) having the lowest MTFP level.

NSW had the largest MTFP increase in 2022, by 4.0 per cent, whilst TAS had an MTFP increase of 0.7 per cent in 2022. The remaining states all had reduced MTFP in 2022 compared to 2021. For SA, QLD, VIC and ACT the MTFP changes in 2022 were –3.6 per cent, –3.5 per cent, –3.1 per cent and – 2.9 per cent respectively.

Table 5.1 State–level DNSP multilateral TFP indexes, 2006–2022

Year	ACT	NSW	VIC	QLD	SA	TAS
2006	1.000	1.353	1.357	1.353	1.819	1.285
2007	0.983	1.360	1.356	1.493	1.769	1.242
2008	0.998	1.214	1.390	1.414	1.866	1.229
2009	0.979	1.231	1.314	1.407	1.820	1.111
2010	0.945	1.246	1.317	1.418	1.696	1.034
2011	0.857	1.238	1.290	1.342	1.594	1.116
2012	0.894	1.153	1.236	1.343	1.613	1.055
2013	0.867	1.216	1.208	1.369	1.544	1.144
2014	0.806	1.203	1.181	1.387	1.492	1.087
2015	0.842	1.147	1.186	1.302	1.531	1.194
2016	1.060	1.193	1.155	1.324	1.603	1.145
2017	1.012	1.233	1.206	1.381	1.492	1.056
2018	1.014	1.279	1.203	1.354	1.531	1.051
2019	1.016	1.258	1.193	1.348	1.483	1.097
2020	1.029	1.274	1.207	1.350	1.579	1.088
2021	1.030	1.317	1.260	1.343	1.526	1.042
2022	1.001	1.370	1.222	1.297	1.473	1.050

Figure 5.2 State-level DNSP multilateral Opex PFP indexes, 2006–2022



Opex MPFP levels by State are shown in Figure 5.2 and Table 5.2. In 2022, NSW had the highest Opex MTFP level, slightly ahead of VIC. The states with average Opex MTFP levels were SA, TAS and QLD, whereas the ACT had much lower level of Opex MTFP in 2022 than the other states.

In 2022 NSW's Opex MPFP grew by 7.7 per cent compared to 2021. All the other DNSPs' Opex MPFP decreased. SA, which had the highest Opex MTFP level in 2021, also decreased by the largest amount in 2022 (–7.3 per cent), followed by the ACT (–6.5 per cent) and QLD (–5.3 per cent). Other Opex MTFP decreases in 2022 included the TAS (–1.9 per cent) and VIC (–0.8 per cent).

Table 5.2 State–level DNSP multilateral Opex PFP indexes, 2006–2022

Year	ACT	NSW	VIC	QLD	SA	TAS
2006	1.000	1.327	1.629	1.205	2.058	1.598
2007	0.993	1.355	1.633	1.365	2.156	1.561
2008	0.977	1.043	1.728	1.282	2.132	1.560
2009	0.955	1.133	1.549	1.300	2.001	1.354
2010	0.861	1.103	1.584	1.346	1.900	1.156
2011	0.744	1.119	1.513	1.180	1.565	1.308
2012	0.751	0.988	1.373	1.161	1.575	1.174
2013	0.697	1.165	1.346	1.254	1.477	1.487
2014	0.621	1.130	1.347	1.330	1.445	1.388
2015	0.675	1.043	1.351	1.207	1.453	1.724
2016	1.252	1.165	1.314	1.284	1.708	1.598
2017	1.100	1.266	1.416	1.396	1.466	1.234
2018	1.005	1.390	1.503	1.363	1.533	1.333
2019	1.044	1.374	1.482	1.380	1.470	1.506
2020	1.109	1.475	1.526	1.393	1.697	1.473
2021	1.104	1.555	1.614	1.393	1.652	1.349
2022	1.03	1.68	1.60	1.32	1.54	1.32

5.2 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).

5.2.1 Australian Capital Territory (ACT)

The ACT is the smallest of the NEM jurisdictions in terms of customer numbers and is served by one DNSP, Evoenergy. In 2022 ACT delivered 2,898 GWh to 216,948 customers over 4,828 circuit kilometres of lines and cables.

ACT productivity performance

The ACT's total output, total input and TFP indexes are presented in Figure 5.3 and Table 5.3. Over the 17-year period 2006 to 2022, ACT's average annual rate of TFP change was 0.1

per cent. Between 2006 and 2012, TFP fell at an average annual rate of 2.0 per cent (more than 10 per cent in total). Then, from 2012 to 2022, the ACT's TFP increased at an average annual rate of 1.3 per cent, fully restoring the 2006 level of TFP. In 2022, the ACT's TFP *decreased* by 2.3 per cent.

Total output increased reasonably steadily over the period 2006 to 2022 at an average annual rate of 1.4 per cent, similar to the industry average rate of 0.9 per cent seen in chapter 3. Total input use increased at an average rate of 3.5 per cent per year up to 2012, the same rate as the industry average rate in this period. The average annual growth rate of input use was zero between 2012 and 2022, again similar to the industry (which *decreased* by 0.2 per cent over the same period). The indexes in Table 5.3 show that swings in opex usage, and hence opex PFP, have been the main driver of the changes in the ACT's TFP trends.

Figure 5.3 ACT output, input and TFP indexes, 2006–2022

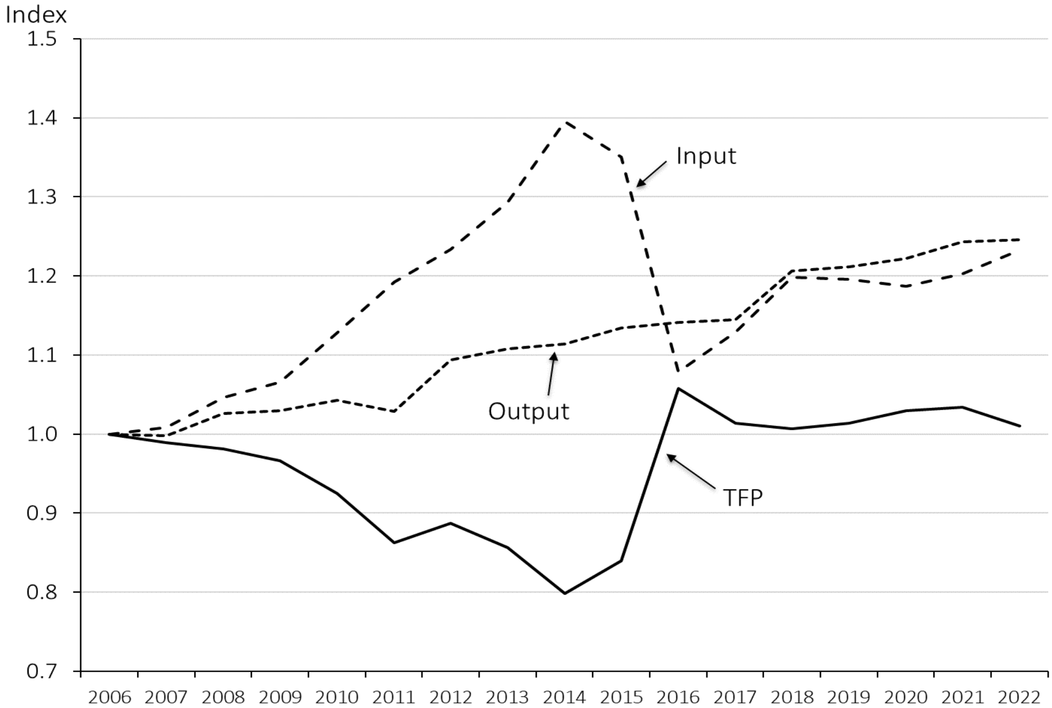


Table 5.3 ACT output, input, TFP and PFP indexes, 2006–2022

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	0.998	1.008	0.989	1.002	0.980
2008	1.026	1.046	0.981	0.967	0.990
2009	1.029	1.066	0.966	0.951	0.974
2010	1.043	1.128	0.925	0.854	0.972
2011	1.029	1.193	0.863	0.757	0.940
2012	1.093	1.233	0.887	0.752	0.991
2013	1.107	1.293	0.857	0.696	0.987
2014	1.114	1.395	0.799	0.619	0.971
2015	1.134	1.350	0.840	0.676	0.980
2016	1.141	1.079	1.057	1.254	0.972
2017	1.145	1.129	1.014	1.109	0.969
2018	1.207	1.198	1.007	1.003	1.010
2019	1.211	1.195	1.013	1.047	0.995
2020	1.222	1.187	1.029	1.112	0.984
2021	1.243	1.202	1.034	1.112	0.991
2022	1.245	1.233	1.010	1.046	0.980
Growth Rate 2006-2022	1.4%	1.3%	0.1%	0.3%	-0.1%
Growth Rate 2006-2012	1.5%	3.5%	-2.0%	-4.7%	-0.2%
Growth Rate 2012-2022	1.3%	0.0%	1.3%	3.3%	-0.1%
Growth Rate 2022	0.2%	2.5%	-2.3%	-6.1%	-1.1%

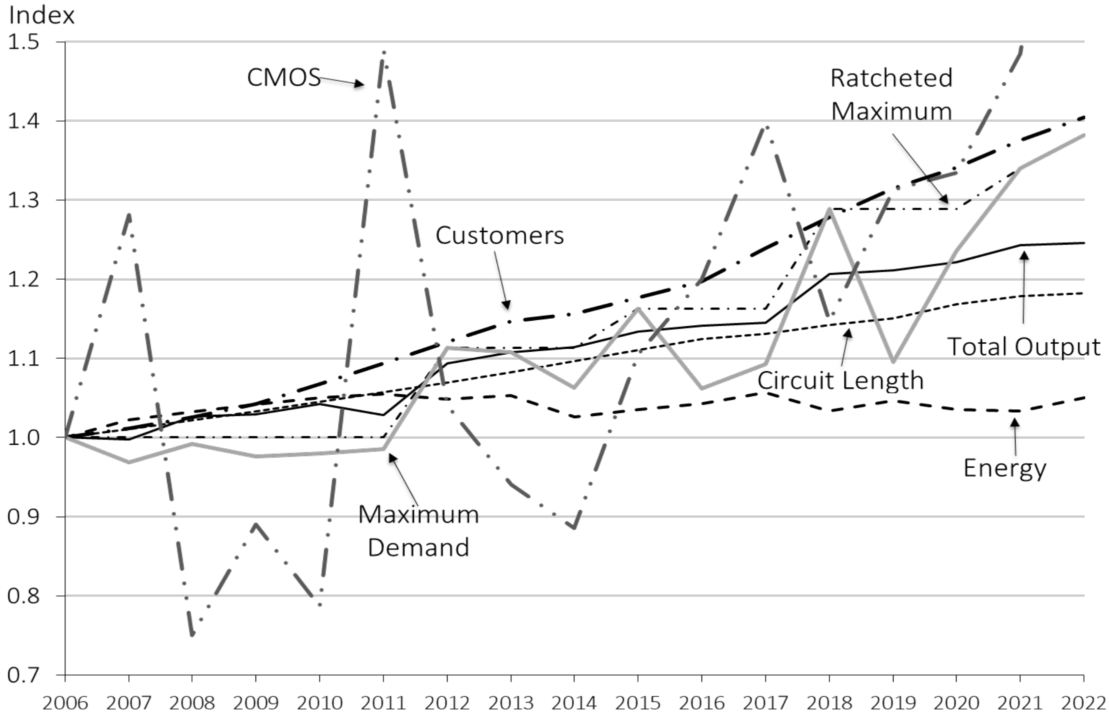
ACT output and input quantity changes

We graph the quantity indexes for the ACT's five individual outputs in Figure 5.4 and for its six individual inputs in Figure 5.5, respectively. From Figure 5.4 we see that:

- The customer numbers output increased steadily over the period and was 40.4 per cent higher in 2022 than it was in 2006;
- Energy throughput increased slightly over the period 2006 to 2022, and in 2022 was 5.1 per cent higher than in 2006;
- The ACT's maximum demand did not exceed its 2006 level until 2012 and there was a further increase in ratcheted maximum demand (RMD) in 2015 and the following years, so that in 2022, RMD was 38.2 per cent higher than in 2006;
- The ACT's circuit length output grew much more over the 17-year period than occurred for the industry overall and by 2022 was 18.2 per cent higher than it was in 2006 compared to an increase of 5.6 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 3.9 per

cent of total revenue weight on average in ACT's total output.[15] In 2022, CMOS for the ACT was 93.8 per cent higher than in 2006, after a 26.6 per cent increase in 2022.

Figure 5.4 ACT output quantity indexes, 2006–2022



Turning to the input side, we see from ACT's six individual inputs and total input shown in Figure 5.5 that the quantity of opex increased rapidly between 2008 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 over 30 per cent up to 2018 and falling again up to 2020. By 2022, opex was 19.1 per cent higher than in 2006.

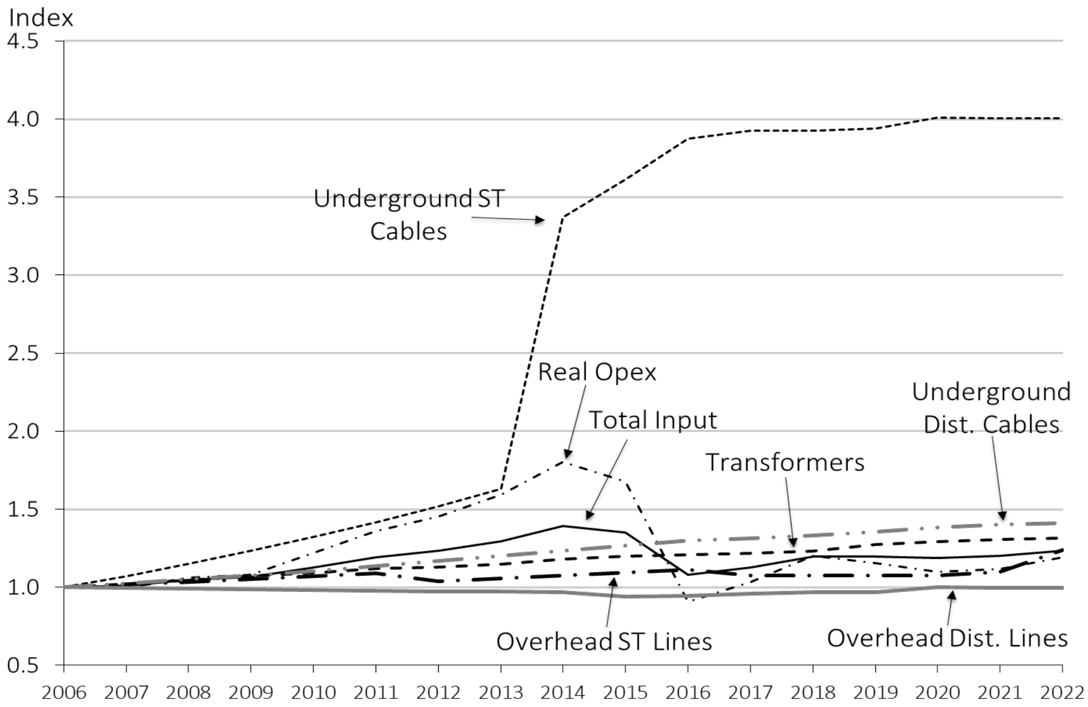
Opex has the largest average share in ACT's total costs at 39.3 per cent and so is an important driver of its total input quantity index.

Except for underground sub-transmission cables, the ACT's other input component quantities increased at more modest and steady rates over the period. Although underground sub-transmission cables in 2022 were four times their level in 2006 – due to an almost doubling of the MVA capacity rating in 2014 – the total length in 2022 is only 5 kilometres, and this input

[15] On average over the 2006 to 2022 period, EVO's CMOS is lowest whereas its CMOS per customer is second lowest after CIT. EVO's CMOS per customer is 79 per cent below the sample average. 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. EVO's average weight attributed to CMOS of –3.9 per cent is the lowest in the sample, being slightly lower than that of CIT.

has a negligible share in total cost. The quantity of transformer inputs, which have an average share of 27.0 per cent in ACT's total cost, increased by 31.7 per cent over the 17-year period.

Figure 5.5 ACT input quantity indexes, 2006–2022



ACT output and input contributions to TFP change

Table 5.4 decomposes the ACT's TFP change into its constituent output and input contributions for the whole 17-year period, for the periods up to and after 2012, and for 2022. ACT's drivers of TFP change over the whole 17-year period show the following patterns. Customer numbers, circuit length and RMD outputs contributed the most to TFP growth – a combined contribution of 1.6 percentage points per year (which compares favourably into the industry average of 0.9 percentage points). CMOS was a small negative contributor to TFP growth for the ACT (–0.2 percentage points) rather than a small positive contributor for the industry (0.01 percentage points).

Among the inputs' contributions to TFP growth for ACT from 2006 to 2022:

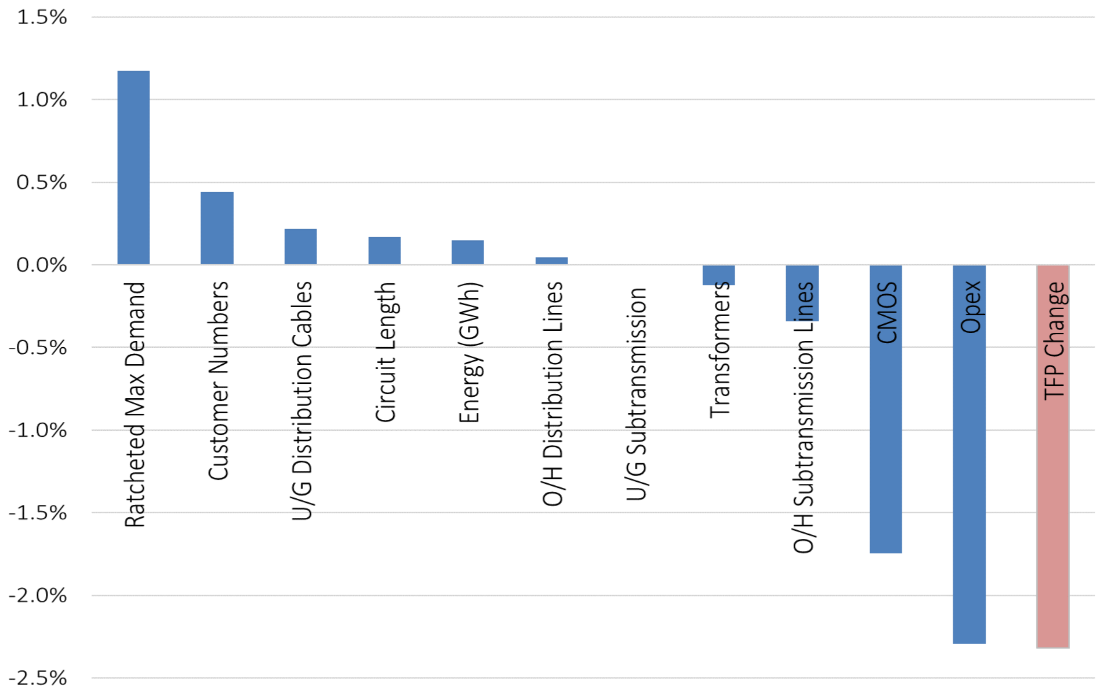
- Transformer input use contributes –0.5 percentage points (compared to –0.6 for the industry);
- Opex usage contributes –0.4 percentage points (compared to –0.1 for the industry);
- The four inputs for overhead and underground sub-transmission and distribution lines together contributed –0.4 percentage points (similar for the industry).

Table 5.4 ACT output and input percentage point contributions to average annual TFP change: various periods

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2021 to 2022*
Energy (GWh)	0.03%	0.07%	0.00%	0.15%
Ratcheted Max Demand	0.72%	0.63%	0.77%	1.17%
Customer Numbers	0.41%	0.37%	0.44%	0.44%
Circuit Length	0.43%	0.46%	0.41%	0.17%
CMOS	-0.21%	-0.04%	-0.32%	-1.75%
Opex	-0.42%	-2.48%	0.81%	-2.29%
O/H Sub-transmission Lines	-0.04%	-0.02%	-0.05%	-0.34%
O/H Distribution Lines	0.00%	0.05%	-0.02%	0.05%
U/G Sub-transmission Cables	-0.01%	-0.01%	-0.01%	0.00%
U/G Distribution Cables	-0.38%	-0.52%	-0.30%	0.22%
Transformers	-0.46%	-0.51%	-0.43%	-0.12%
TFP Change	0.06%	-2.00%	1.30%	-2.32%

Figure 5.6 shows the contributions to TFP growth in 2022. An increase in opex usage in 2022 contributed –2.3 percentage points, and an increase in CMOS also contributed –1.8 percentage points, to the ACT's TFP change of –2.3 per cent that year. Growth of circuit length, energy throughput and customer numbers in 2022 together contributed 0.8 percentage points to TFP growth while growth in transformer capacity and overhead sub-transmission cables together contributed –0.5 percentage points. RMD was the factor that contributed most to TFP, by 1.2 percentage points.

Figure 5.6 ACT output and input percentage point contributions to TFP change, 2022



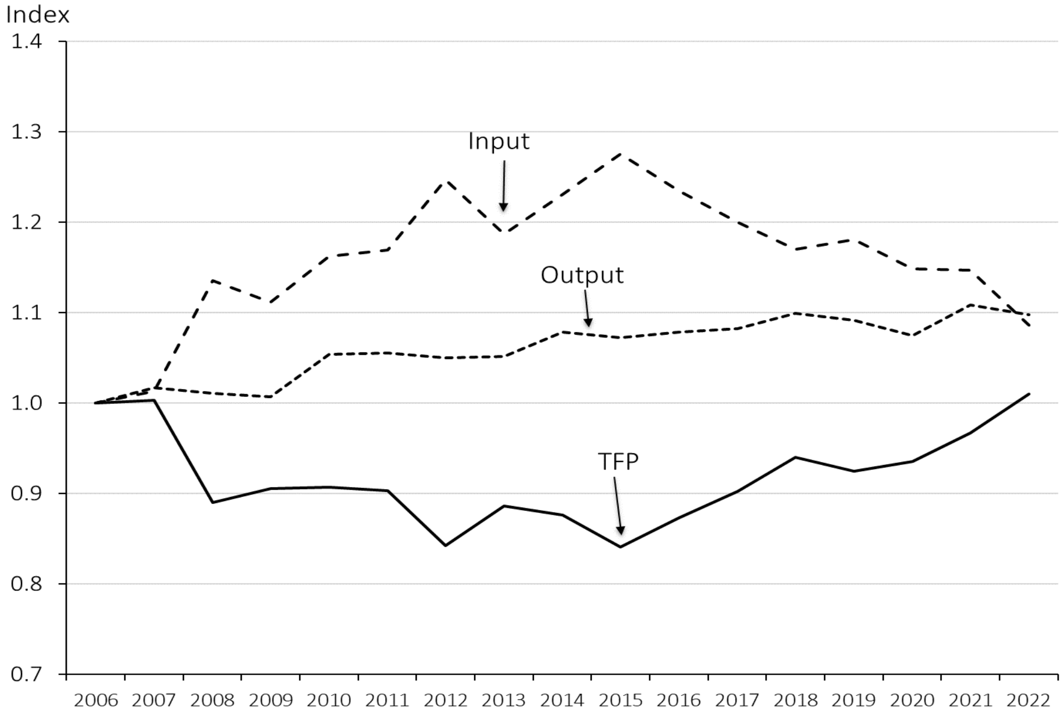
5.2.2 New South Wales (NSW)

NSW is the largest of the NEM jurisdictions in terms of customer numbers and is served by three DNSPs: Ausgrid (AGD), Endeavour Energy (END) and Essential Energy (ESS). In 2022, the three NSW DNSPs delivered 53,397 GWh to 3.81 million customers over 275,460 circuit kilometres of lines and cables.

NSW DNSP productivity performance

NSW's total output, total input and TFP indexes are presented in Figure 5.7 and Table 5.5. Opex and capital PFP indexes are also presented in Table 5.5. Over the 17-year period 2006 to 2022, the NSW DNSPs' TFP increased at an average annual rate of 0.1 per cent. This growth is attributed to a 0.6 per cent increase in the annual growth rate of total output and a 0.5 per cent increase in the annual growth rate of total input. Notably, in 2022, the output index value surpassed the input index value for the first time since 2007.

Figure 5.7 NSW DNSP output, input and TFP indexes, 2006–2022



From 2006 and 2012, input use increased at an average annual rate of 3.7 per cent, which was followed by a *reduction* of 1.4 per cent per annum in input use from 2012 to 2022. This shift in the trend of input use was the main determinant of the turnaround in the TFP trend in NSW from –2.9 per cent per annum between 2006 and 2012, to a positive TFP growth of 1.8 per cent per year from 2012 to 2022. The PFP indexes in Table 5.5 also demonstrate that reduced opex usage was the main driver of the improved TFP performance after 2012.

Table 5.5 NSW DNSP output, input, TFP and PFP indexes, 2006–2022

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	1.013	1.003	1.021	0.991
2008	1.010	1.136	0.890	0.786	0.972
2009	1.007	1.112	0.905	0.853	0.943
2010	1.053	1.162	0.907	0.830	0.956
2011	1.056	1.169	0.903	0.842	0.940
2012	1.050	1.246	0.843	0.743	0.911
2013	1.052	1.187	0.886	0.876	0.890
2014	1.079	1.231	0.876	0.850	0.892
2015	1.072	1.275	0.841	0.784	0.878
2016	1.078	1.235	0.873	0.877	0.870
2017	1.082	1.200	0.902	0.952	0.873
2018	1.099	1.170	0.940	1.046	0.881
2019	1.091	1.181	0.924	1.034	0.864
2020	1.074	1.148	0.935	1.110	0.843
2021	1.109	1.147	0.967	1.170	0.862
2022	1.097	1.086	1.010	1.264	0.850
Growth Rate 2006-2022	0.6%	0.5%	0.1%	1.5%	-1.0%
Growth Rate 2006-2012	0.8%	3.7%	-2.9%	-4.9%	-1.6%
Growth Rate 2012-2022	0.4%	-1.4%	1.8%	5.3%	-0.7%
Growth Rate 2022	-1.0%	-5.4%	4.4%	7.7%	-1.5%

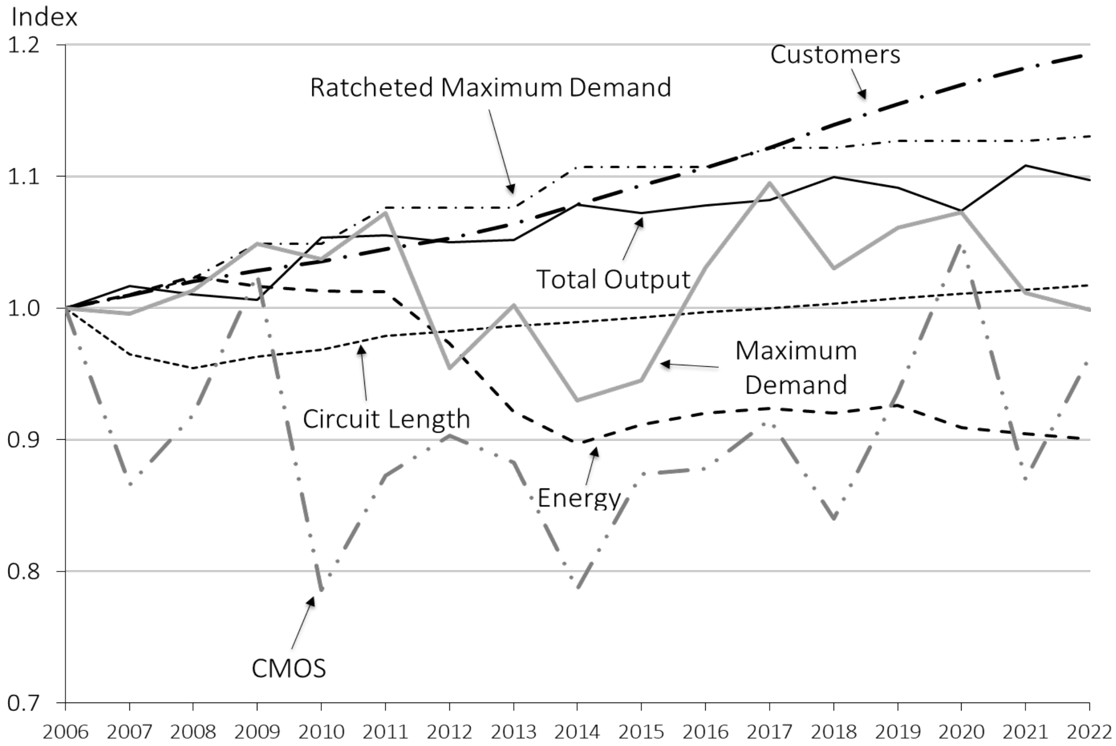
NSW DNSP output and input quantity changes

Quantity indexes for the NSW DNSPs' five individual outputs are plotted in Figure 5.8 and for the six individual inputs in Figure 5.9. From Figure 5.8 we see that NSW's output components showed a broadly similar pattern of change to the industry as a whole. From 2006 to 2022 the outputs of NSW DNSPs showed the following trends:

- Customer numbers increased steadily over the period and were 19.3 per cent higher in 2022 than it was in 2006;
- Energy throughput peaked in 2008 and has fallen since then. In 2022 it was 9.9 per cent below 2006;
- RMD increased from 2006 until 2019 and has since been relatively flat. In 2022 it was 13.1 per cent higher than in 2006 (less than the increase for the industry as a whole);
- Circuit length output grew by 1.7 per cent in total over the whole 17-year period (compared to an increase of 5.6 per cent for the industry);
- Customer minutes off-supply (CMOS) experienced a *decrease* of 3.7 percent, which contrasts with the industry as a whole, where it increased by 1.9 percent. Over the 17-

year period, CMOS accounted for an average weight of –14.4 per cent of the total revenue in NSW.

Figure 5.8 NSW output quantity indexes, 2006–2022

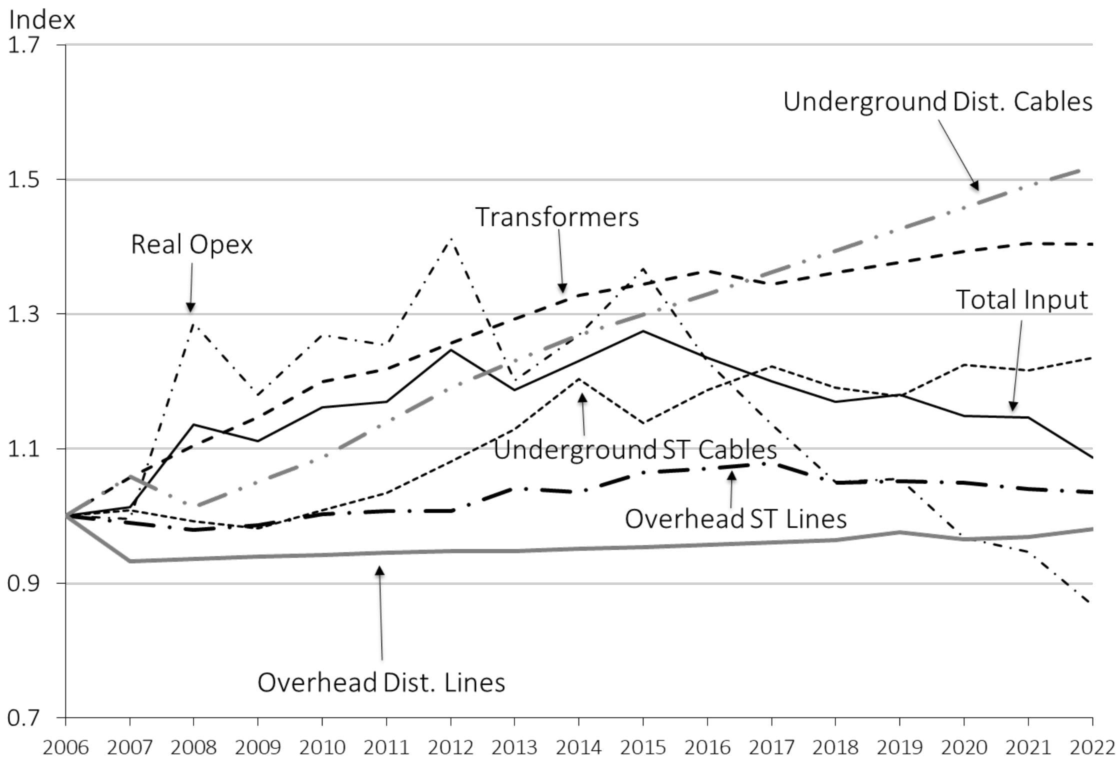


Among the inputs, we see from NSW's six individual inputs and total input in Figure 5.9 that:

- 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 4.9 per cent from 2012 to 2022. In 2022, NSW opex input was 13.2 per cent below its 2006 level (compared to 6.5 per cent above 2006 level for the industry);
- NSW's underground distribution cables and transformers inputs also increased strongly in the sub-period to 2012 and continued to increase but at a lower rate over the period from 2012 to 2022. By 2022, these two inputs exceeded their 2006 levels by 51.9 per cent and 40.4 per cent respectively (broadly similar to 68.0 per cent and 43.1 per cent respectively for the industry);
- Overhead distribution lines and overhead sub-transmission lines inputs for NSW remained relatively stable from 2006 to 2022. By 2022, these two inputs had *decreased* to 1.9 per cent and increased to 3.5 per cent, respectively (compared to 3.1 per cent and 7.3 per cent respectively for the whole industry);

- NSW's underground sub-transmission cables input in 2022 was 23.5 per cent above its 2006 level (compared to 38.5 per cent for the industry).

Figure 5.9 NSW DNSP input quantity indexes, 2006–2022



NSW output and input contributions to TFP change

Table 5.6 decomposes NSW's TFP change into its constituent output and input contributions for the whole 17-year period, for the periods up to and after 2012, and for 2022. NSW's drivers of TFP change for the 17-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 positive 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.

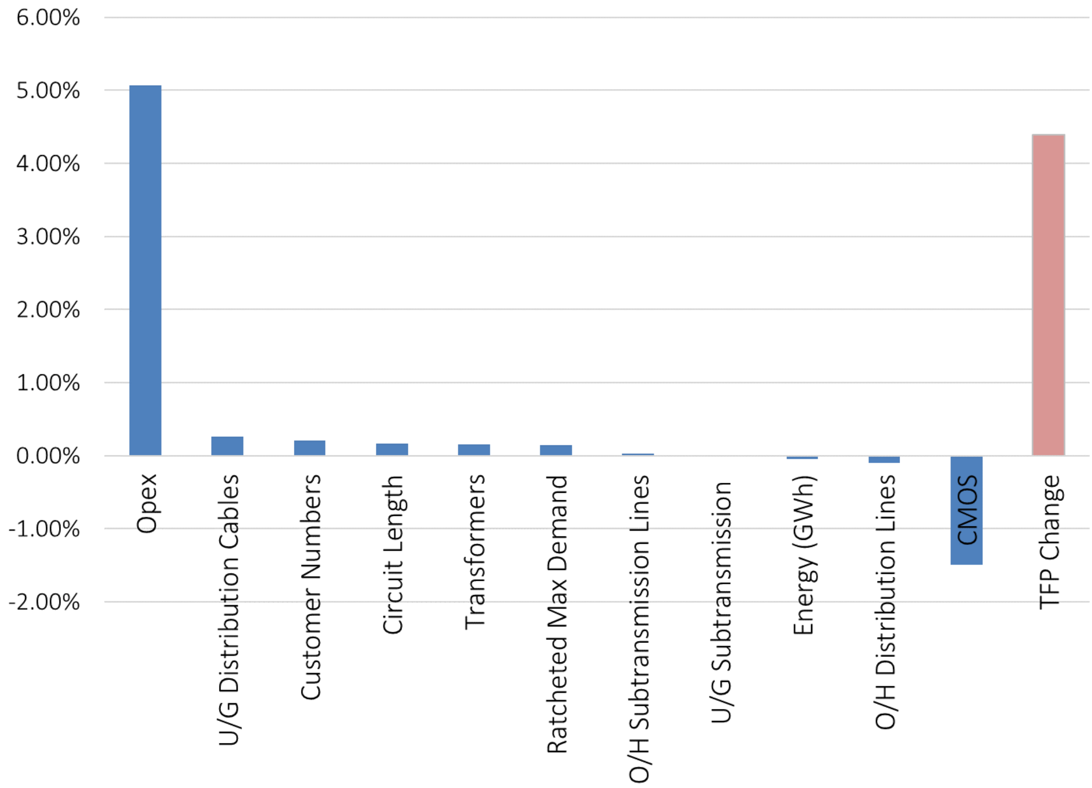
Opex has a positive contribution of 0.4 percentage points to TFP growth in NSW over the period from 2006 to 2022 due to its decreased use as an input, whereas for the industry as a whole it contributed –0.1 percentage point to TFP growth (see Table 2.2). The other inputs, namely overhead and underground sub-transmission and distribution lines, and transformers, all made broadly similar contributions to TFP growth in NSW compared to the industry overall.

Table 5.6 NSW output and input percentage point contributions to average annual TFP change: various periods

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2021 to 2022*
Energy (GWh)	-0.07%	-0.05%	-0.08%	-0.04%
Ratcheted Max Demand	0.30%	0.49%	0.19%	0.15%
Customer Numbers	0.24%	0.19%	0.26%	0.21%
Circuit Length	0.05%	-0.13%	0.16%	0.16%
CMOS	0.06%	0.31%	-0.10%	-1.49%
Opex	0.41%	-2.27%	2.02%	5.06%
O/H Sub-transmission Lines	-0.01%	-0.01%	-0.01%	0.03%
O/H Distribution Lines	0.01%	0.10%	-0.04%	-0.10%
U/G Sub-transmission Cables	-0.04%	-0.04%	-0.04%	-0.01%
U/G Distribution Cables	-0.27%	-0.32%	-0.24%	0.27%
Transformers	-0.62%	-1.12%	-0.32%	0.15%
TFP Change	0.06%	-2.86%	1.81%	4.39%

Figure 5.10 shows the decomposition of TFP change of 4.4 per cent in 2022. The major positive contribution in 2022 came from reduction in Opex, which contributed 5.1 percentage points. The major negative effects on TFP came from decreases in reliability (ie, increases in CMOS), which contributed –1.5 percentage points. The contributions of all the other outputs and inputs in 2022 are individually small, and on balance positive, contributing together 0.82 percentage points.

Figure 5.10 NSW output and input percentage point contributions to TFP change, 2022



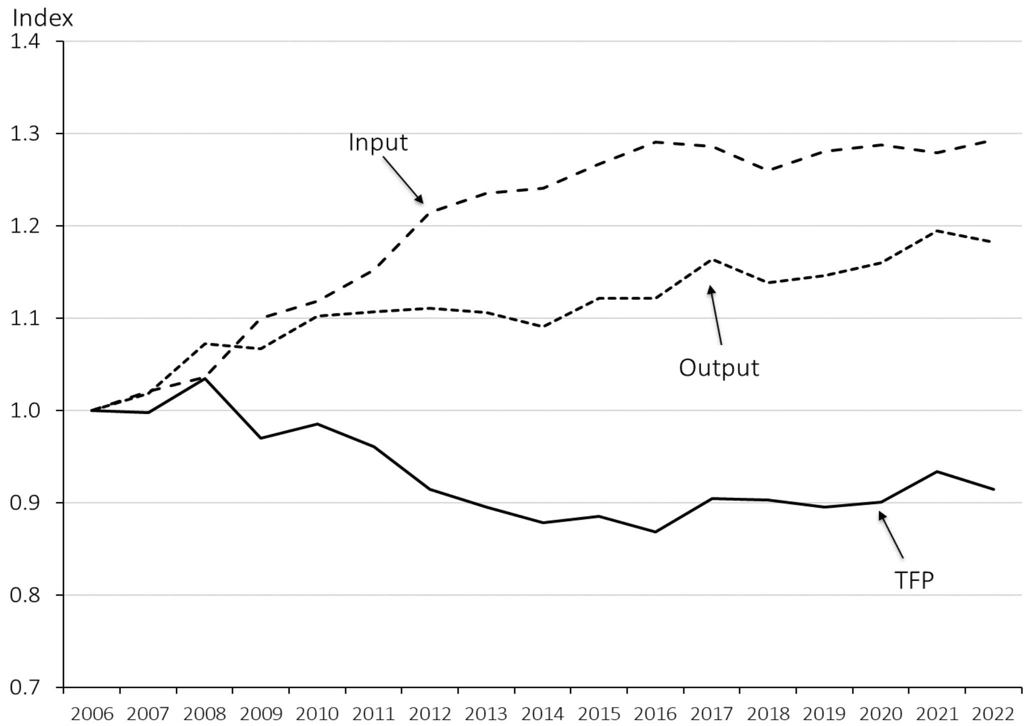
5.2.3 Victoria (VIC)

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 2022 the Victorian DNSPs delivered 35,651 GWh to 3.13 million customers over 147,912 circuit kilometres of lines and cables.

Victorian DNSP productivity performance

Victoria's total output, total input and TFP indexes are presented in Figure 5.11 and Table 4.7. Opex and capital PFP indexes are also presented in Table 5.7. Over the 17-year period 2006 to 2022, the Victorian DNSPs' TFP *decreased* at an average annual rate of 0.6 per cent. Although total output increased by an average annual rate of 1.1 per cent, total input use increased faster, at a rate of 1.7 per cent.

Figure 5.11 VIC DNSP output, input and TFP indexes, 2006–2022



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, compares to a zero rate of growth per annum for the period 2012 to 2022. The PFP indexes in Table 5.7 confirm that better Opex PFP performance was the main driver of the improved TFP performance after 2012.

Table 5.7 VIC DNSP output, input and TFP and PFP indexes, 2006–2022

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	1.018	1.021	0.998	1.003	0.994
2008	1.072	1.036	1.035	1.059	1.022
2009	1.067	1.100	0.970	0.953	0.981
2010	1.102	1.119	0.985	0.972	0.994
2011	1.107	1.152	0.961	0.928	0.982
2012	1.111	1.215	0.915	0.842	0.966
2013	1.106	1.235	0.895	0.825	0.943
2014	1.090	1.241	0.879	0.827	0.913
2015	1.121	1.267	0.885	0.828	0.925
2016	1.121	1.290	0.869	0.806	0.910
2017	1.163	1.286	0.905	0.865	0.930
2018	1.138	1.260	0.903	0.921	0.893
2019	1.146	1.281	0.895	0.908	0.888
2020	1.160	1.288	0.901	0.935	0.881
2021	1.195	1.279	0.934	0.986	0.901
2022	1.182	1.293	0.914	0.980	0.878
Growth Rate 2006-2022	1.1%	1.7%	-0.6%	-0.1%	-0.8%
Growth Rate 2006-2012	1.8%	3.2%	-1.5%	-2.9%	-0.6%
Growth Rate 2012-2022	0.7%	0.7%	0.0%	1.6%	-1.0%
Growth Rate 2022	-1.1%	1.1%	-2.1%	-0.6%	-2.6%

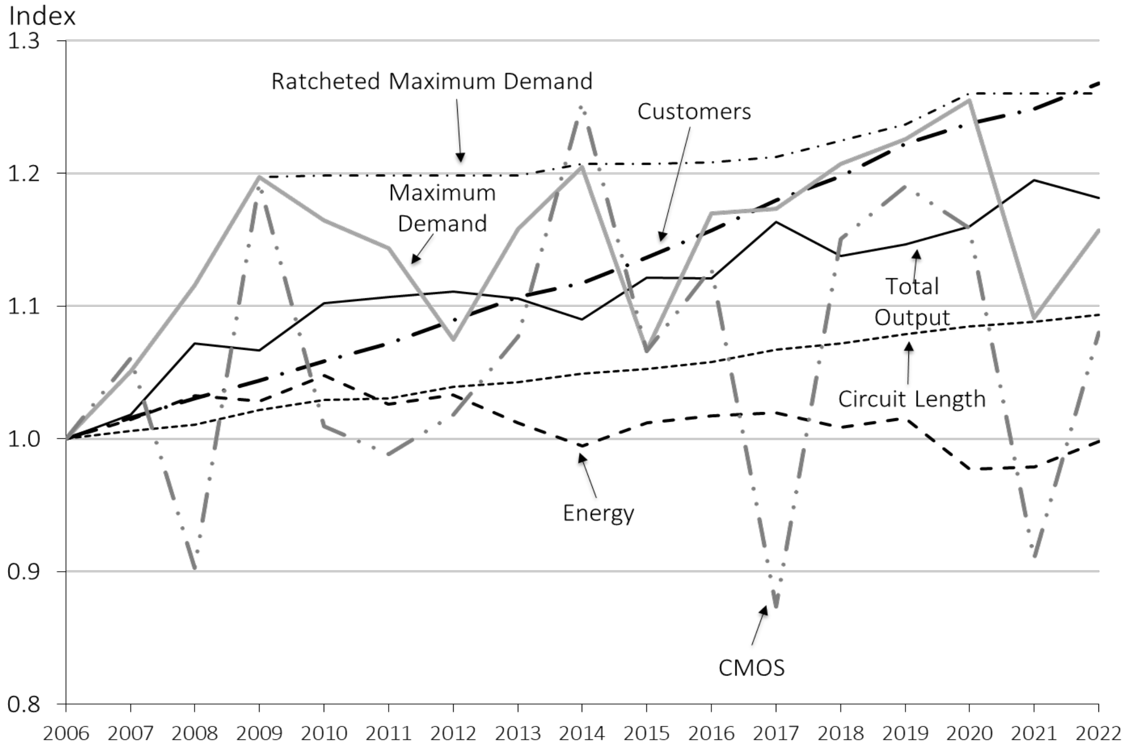
Victorian DNSP output and input quantity changes

The quantity indexes for the Victorian DNSPs' individual outputs are plotted in Figure 5.12, and the six individual inputs are plotted in Figure 5.13. From Figure 5.12 we see that:

- Customer numbers increased steadily over the period and were 26.8 per cent higher in 2022 than in 2006 (similar to the industry as a whole);
- Energy throughput peaked in 2010 and has fallen slowly since then. In 2022 it was 0.2 per cent below 2006 (a smaller decline than for the industry as a whole);
- VIC's RMD increased up to 2009, and again from 2014 onwards. By 2022, RMD was 26.1 per cent higher than in 2006 (more than the 19.5 per cent increase for the industry as a whole);
- VIC's circuit length output grew by 9.4 per cent in total over the whole 17-year period (compared to an increase of 5.6 per cent for the industry);
- VIC's total customer minutes off-supply (CMOS) increased by 8.0 per cent in total between 2006 and 2022 (compared to a 1.9 per cent increase for the industry over the same period). CMOS receives an average weight of –12.6 per cent of total revenue for Victoria.

In 2022, customers and circuit length increased by 1.5 per cent and 0.5 per cent respectively. CMOS increased by 17.2 per cent, which contributed negatively to total output growth. Energy output also increased in 2022, by 2.0 per cent, whilst RMD remained unchanged. VIC total *outputs decreased* in 2022 by 1.1 per cent.

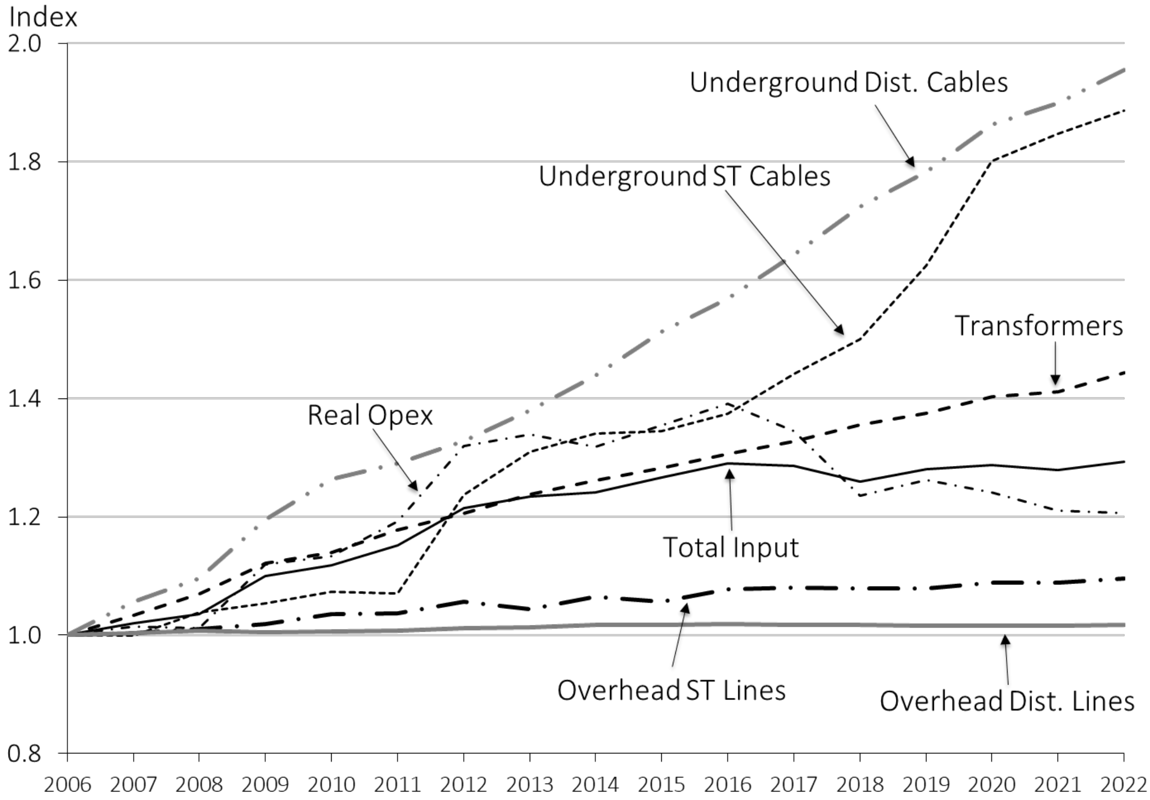
Figure 5.12 VIC output quantity indexes, 2006–2022



Victoria's six individual inputs and total input are shown Figure 5.13:

- VIC opex increased by 34.0 per cent in total up to 2013, and remained at a similar level up to 2017, after which it declined, so that in 2022 opex was 20.6 per cent above its 2006 level (compared to 6.5 per cent for the industry). Opex has the largest average share in VIC total costs at 37.4 per cent and so is an important driver of its total input quantity index;
- VIC's underground distribution and sub-transmission cables increased at a much higher rate that for the industry overall. By 2022, these two inputs exceeded their 2006 levels by 95.5 per cent and 88.7 per cent respectively (compared to 68.0 and 38.5 per cent for the industry).
- Transformers inputs in VIC increased at a similar rate to the industry as a whole. By 2022, VIC transformer inputs exceeded their 2006 levels by 44.3 per cent;
- By 2022, overhead sub-transmission and distribution inputs exceeded their 2006 levels by 9.6 per cent and 1.7 per cent respectively (compared to 7.3 per cent and 3.1 per cent respectively for the whole industry).

Figure 5.13 VIC DNSP input quantity indexes, 2006–2022



Victorian output and input contributions to TFP change

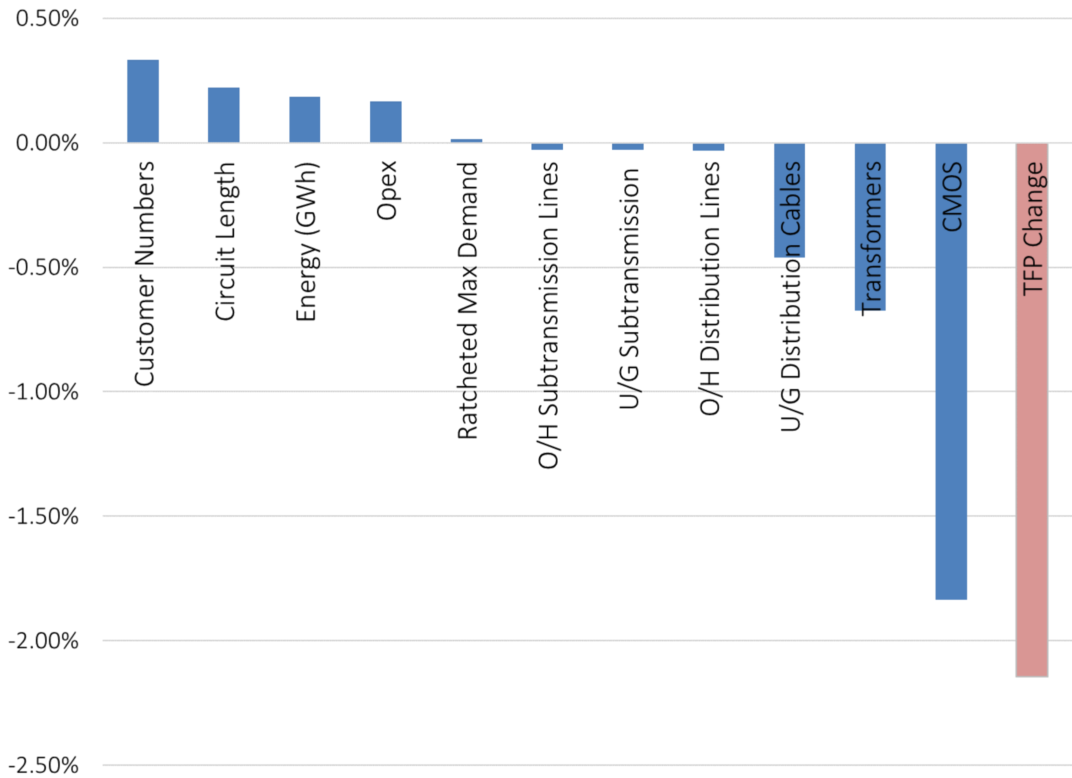
Table 5.8 decomposes VIC's TFP change into its constituent output and input contributions for the 17-year period, for the periods up to and after 2012, and for 2022. Victoria's drivers of TFP change for the 2006 to 2022 period are broadly similar to the industry as a whole. Transformer inputs made a smaller negative contribution to Victoria's TFP at –0.5 percentage points compared to –0.6 for the industry and underground distribution cables contributed negatively to Victoria's TFP at –0.5 compared to –0.4 for the industry.

Consistent with the industry as a whole, the biggest source of change in TFP between the sub-periods 2006 to 2012 and 2012 to 2022 is in the opex input use. Growth in use of opex inputs in the former period contributed –1.8 percentage points to VIC TFP growth, and reductions in opex inputs in the latter period contributed 0.5 percentage points to VIC TFP growth.

Table 5.8 VIC output and input percentage point contributions to average annual TFP change: various periods

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2021 to 2022*
Energy (GWh)	0.00%	0.05%	-0.03%	0.18%
Ratcheted Max Demand	0.55%	1.16%	0.19%	0.01%
Customer Numbers	0.32%	0.30%	0.33%	0.33%
Circuit Length	0.25%	0.28%	0.24%	0.22%
CMOS	0.10%	-0.04%	0.19%	-1.83%
Opex	-0.40%	-1.82%	0.45%	0.17%
O/H Sub-transmission Lines	-0.02%	-0.03%	-0.01%	-0.03%
O/H Distribution Lines	-0.02%	-0.04%	-0.01%	-0.03%
U/G Sub-transmission Cables	-0.05%	-0.04%	-0.06%	-0.03%
U/G Distribution Cables	-0.54%	-0.60%	-0.50%	-0.46%
Transformers	-0.52%	-0.70%	-0.42%	-0.68%
TFP Change	-0.33%	-1.49%	0.36%	-2.14%

Figure 5.14 VIC output and input percentage point contributions to TFP change, 2022



In Figure 5.14 we see that the largest single contribution to VIC TFP *decrease* of 2.1 per cent in 2022 was decline in reliability (i.e., increase in CMOS), which contributed –1.8 percentage points. Among the outputs, the other contributors were customer numbers, circuit length and energy throughput outputs, which combined contributed 0.7 percentage points. On the input side, Opex savings was the only positive contributor to TFP growth, contributing 0.2 percentage points. Transformers negatively contributed –0.7 percentage points and the remainder together contributed –0.6 percentage points.

5.2.4 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 2022 the two Queensland DNSPs delivered 35,076 GWh to 2.35 million customers over 210,063 circuit kilometres of lines and cables.

Queensland DNSP productivity performance

QLD's total output, total input and TFP indexes are presented in Figure 5.15 and Table 5.9. Opex and capital PFP indexes are also presented in Table 5.9. Over the 17-year period 2006 to 2022, the average annual rate of TFP change of QLD DNSPs was –0.2 per cent. QLD's total output increased by an average annual rate of 1.3 per cent over the same period, which is higher than the output growth rates in NSW and VIC (and higher than for the industry as a whole, which was 0.9 per cent over the same period). QLD's total input use increased at an average annual rate of 1.5 per cent (which is less than for VIC, higher than for NSW and similar to the average for the industry). QLD's *decline* TFP growth between 2006 and 2022 is consistent to the industry average TFP *decline* during the same period.

Figure 5.15 Qld DNSP output, input and TFP indexes, 2006–2022

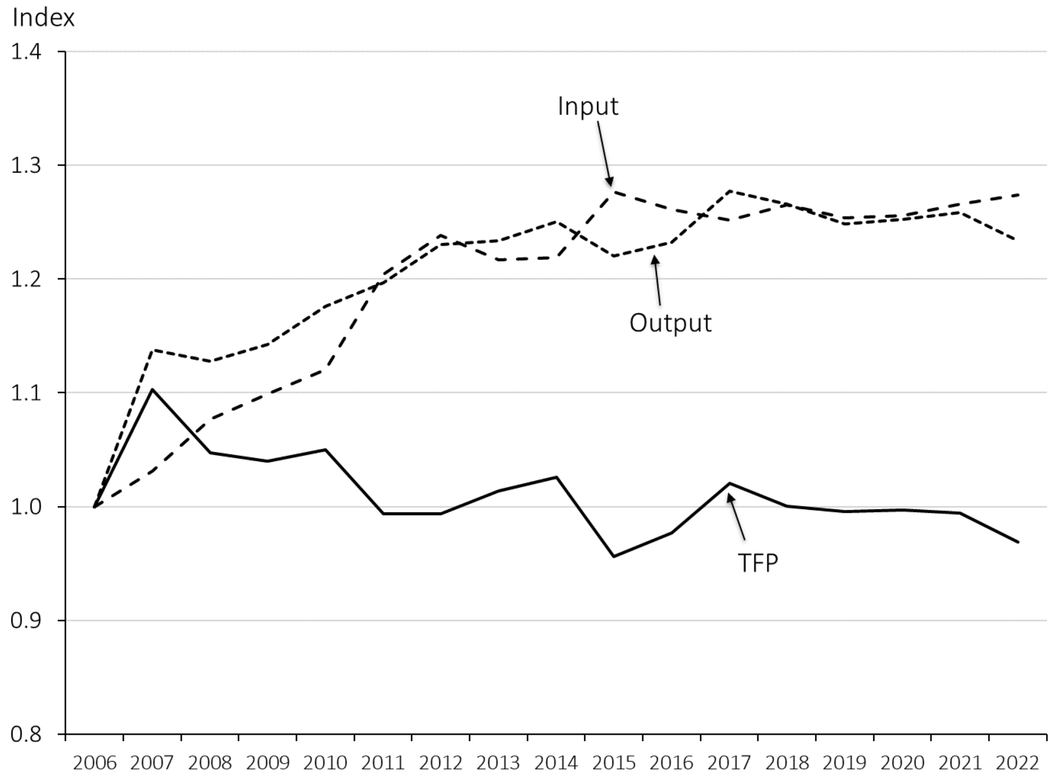


Table 5.9 Qld DNSP output, input, TFP and PFP indexes, 2006–2022

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.138	1.031	1.103	1.132	1.085
2008	1.128	1.077	1.047	1.062	1.040
2009	1.143	1.099	1.040	1.076	1.017
2010	1.176	1.120	1.050	1.113	1.013
2011	1.197	1.204	0.994	0.973	1.004
2012	1.231	1.238	0.994	0.958	1.008
2013	1.233	1.217	1.014	1.032	1.001
2014	1.250	1.219	1.026	1.095	0.986
2015	1.220	1.276	0.956	0.989	0.936
2016	1.232	1.261	0.977	1.055	0.933
2017	1.278	1.252	1.020	1.150	0.951
2018	1.266	1.265	1.001	1.123	0.934
2019	1.249	1.254	0.996	1.136	0.921
2020	1.252	1.256	0.997	1.147	0.916
2021	1.259	1.266	0.994	1.150	0.911
2022	1.234	1.274	0.969	1.090	0.889
Growth Rate 2006-2022	1.3%	1.5%	-0.2%	0.5%	-0.7%
Growth Rate 2006-2012	3.5%	3.6%	-0.1%	-0.7%	0.1%
Growth Rate 2012-2022	0.0%	0.3%	-0.3%	1.3%	-1.3%
Growth Rate 2022	-2.0%	0.6%	-2.6%	-5.4%	-2.5%

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 –0.3 after 2012. The PFP indexes in Table 5.9 show that deterioration in Opex PFP was a major influence on TFP growth before 2012, and improvement in Opex PFP together with deterioration of capital PFP, influenced TFP growth after 2012.

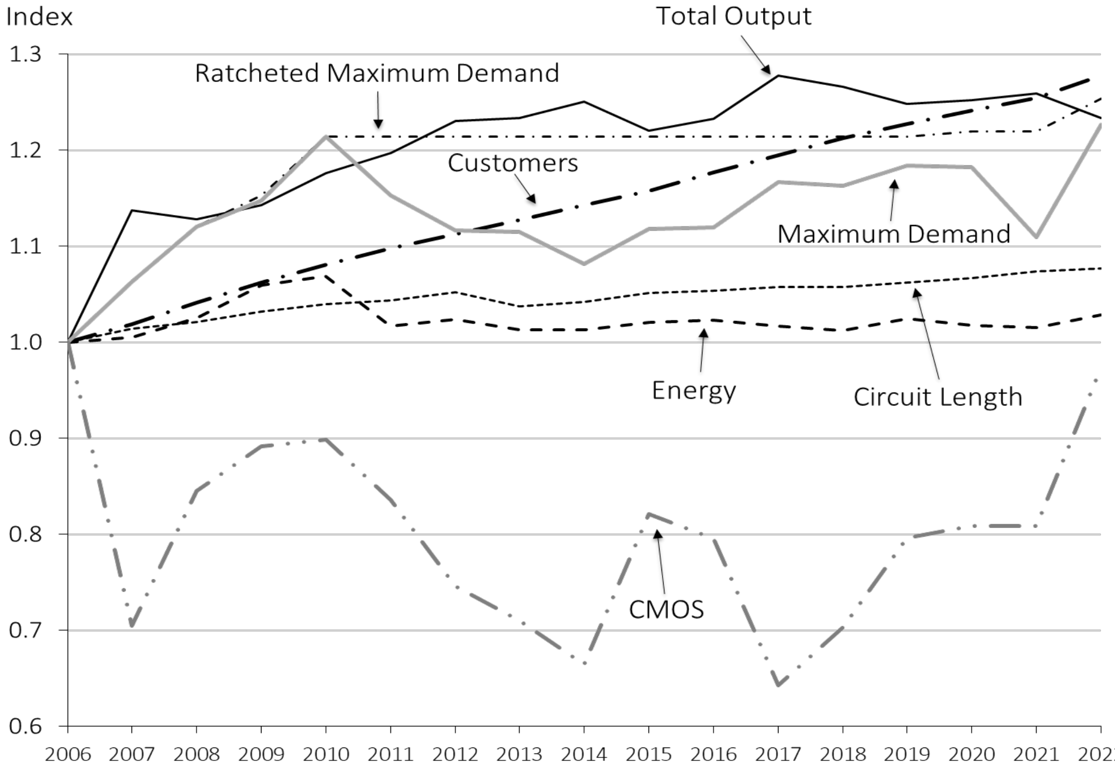
Queensland DNSP output and input quantity changes

Quantity indexes for the Queensland DNSPs' individual outputs are plotted in Figure 5.16, and their six individual inputs are plotted in Figure 5.17. From Figure 5.16 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 2022 it was 2.8 per cent above 2006 (compared to 4.0 per cent *below* 2006 for the industry as a whole);
- Customer numbers increased steadily over the period and were 27.8 per cent higher in 2022 than it was in 2006;

- QLD's RMD increased mainly in the period up to 2010, thereafter having only an incremental increase in 2020 and 2022. By 2022, it reached its peak and was 25.4 per cent higher compared to the levels in 2006 (slightly higher than the 19.5 per cent for the industry as a whole);
- QLD's circuit length output grew by 7.7 per cent in total over the whole 17-year period (slightly above the increase of 5.6 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 overall. In total, it *decreased* by 2.6 per cent between 2006 and 2022 (compared to a 1.9 per cent increase for the industry over the same period).

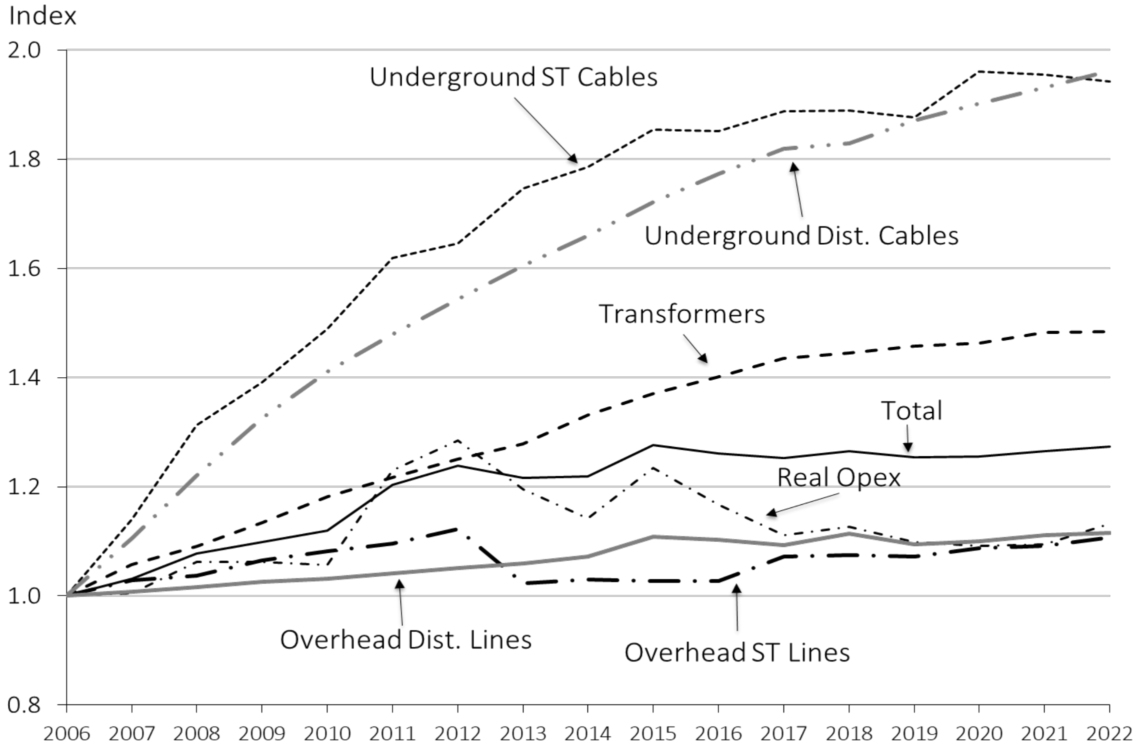
Figure 5.16 Qld output quantity indexes, 2006–2022



The circuit length and RMD outputs together receive an average weight of 86.7 per cent of total revenue in forming the total output index for QLD, but in Figure 5.16 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 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 –18.9 per cent of total revenue in forming the total output index.

From Figure 5.17, showing QLD's six individual inputs and total input, it can be seen when comparing to Figure 2.4 that the quantity of Queensland's underground distribution and sub-transmission cables and transformers inputs have increased more than for the industry as a whole. The increase in underground cables starts from a small base and reflects Queensland's higher rate of customer numbers growth.

Figure 5.17 Qld DNSP input quantity indexes, 2006–2022



Opex in QLD increased at a similar rate to the industry average, and overhead lines increased somewhat less than for the industry. QLD opex increased by 28.5 per cent in total up to 2012 (which was less than the corresponding increase for the industry of 36.4 per cent). It declined afterward, so that in 2022 opex was 13.2 per cent above its 2006 level (higher than the industry average of 6.5). Opex has the largest average share in QLD's total costs at 37.3 per cent and so is an important driver of its total input quantity index. Among the other inputs:

- Transformers inputs in QLD increased by 48.4 per cent between 2006 and 2022 (compared to 43.1 per cent for the industry over the same period);
- Overhead sub-transmission and distribution lines in QLD increased by 10.7 per cent and 11.6 per cent, respectively, in total between 2006 and 2022 (compared to 7.3 per cent and 3.1 per cent respectively for the whole industry).

Queensland output and input contributions to TFP change

Table 5.10 decomposes QLD's TFP change into the contributions of individual outputs and inputs for the whole 17-year period, for the periods up to and after 2012, and for 2021. QLD's drivers of TFP change for the period 2006 to 2022 are broadly similar to the industry as a whole, except that RMD make slightly larger positive contribution of 0.6 percentage points (compared to 0.4 for the industry) and Opex make a make slightly larger negative contribution of – 0.3 percentage points (compared to –0.1 for the industry). With regard to the contributions of other outputs and inputs:

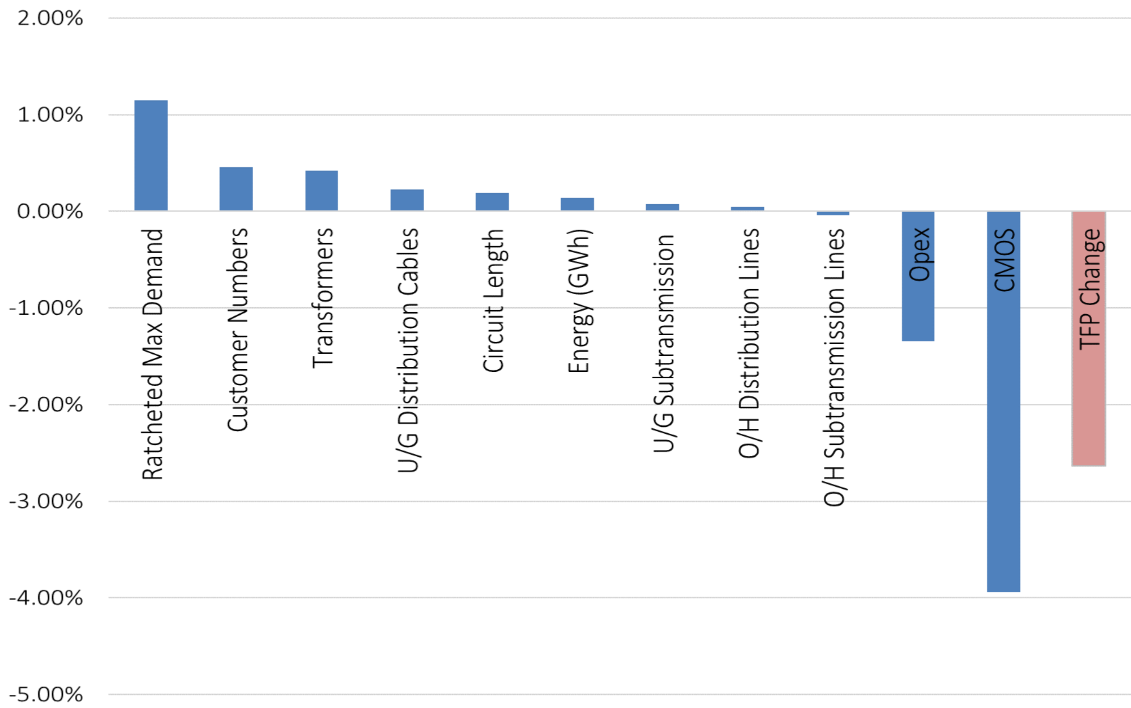
- Customers and circuit length outputs together contributed 0.6 percentage points to QLD's average TFP growth for the period 2006 to 2022 (compared to 0.4 for the whole industry);
- CMOS output contributed 0.1 percentage points to QLD's TFP rate of growth, compared to zero for the industry;
- Overhead and underground sub-transmission and distribution lines together contributed –0.5 percentage points to QLD TFP growth (–0.4 for the industry);
- Transformers input contributed –0.7 percentage points to QLD's TFP rate of growth (compared to –0.6 for the industry).

Table 5.10 Qld output and input percentage point contributions to average annual TFP change: various periods

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2021 to 2022*
Energy (GWh)	0.02%	0.04%	0.01%	0.14%
Ratcheted Max Demand	0.60%	1.37%	0.13%	1.15%
Customer Numbers	0.35%	0.42%	0.31%	0.46%
Circuit Length	0.23%	0.41%	0.11%	0.19%
CMOS	0.12%	1.21%	-0.54%	-3.94%
Opex	-0.30%	-1.50%	0.43%	-1.35%
O/H Sub-transmission Lines	-0.04%	-0.13%	0.02%	-0.04%
O/H Distribution Lines	-0.11%	-0.14%	-0.09%	0.05%
U/G Sub-transmission Cables	-0.09%	-0.19%	-0.03%	0.07%
U/G Distribution Cables	-0.28%	-0.51%	-0.14%	0.22%
Transformers	-0.70%	-1.08%	-0.46%	0.42%
TFP Change	-0.20%	-0.10%	-0.26%	-2.63%

Figure 5.18 shows the contributions of individual outputs and inputs to QLD's TFP growth in 2022 of –2.6 per cent. Among outputs, positive contributions were made by RMD, customer numbers and circuit length. Among inputs, opex made a negative contribution, and CMOS made the largest negative contribution to the decline in TFP growth.

Figure 5.18 Qld output and input percentage point contributions to TFP change, 2022



5.2.5 South Australia (SA)

SA is the fourth largest NEM jurisdiction (by customer numbers) and is served by one DNSP, SA Power Networks (SAP). In 2022 it delivered 9,774 GWh to 928,729 customers over 90,006 circuit kilometres of lines and cables.

SA DNSP productivity performance

SA's total output, total input and TFP indexes are presented in Figure 5.19 and Table 5.11. Opex and capital PFP indexes are also presented in Table 5.11. Over the 17-year period 2006 to 2022, the SA DNSP's TFP *decreased* at an average annual rate of 1.5 per cent. Although total output increased by an average annual rate of 0.7 per cent, total input use increased faster, at a rate of 2.1 per cent. SA thus had slightly lower 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 4.0 per cent and increased more slowly from 2012 to 2022 at an annual average rate of 1.0 per cent. This pattern is similar to that for the industry as a whole, except the growth of inputs after 2012 differs from the decrease in the level of inputs for the industry. Although the rate of output growth was also lower after 2012 (zero 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 –2.2 per cent, from 2012 to 2022 it averaged –1.0 per cent.

Figure 5.19 SA DNSP output, input and total factor productivity indexes, 2006–2022

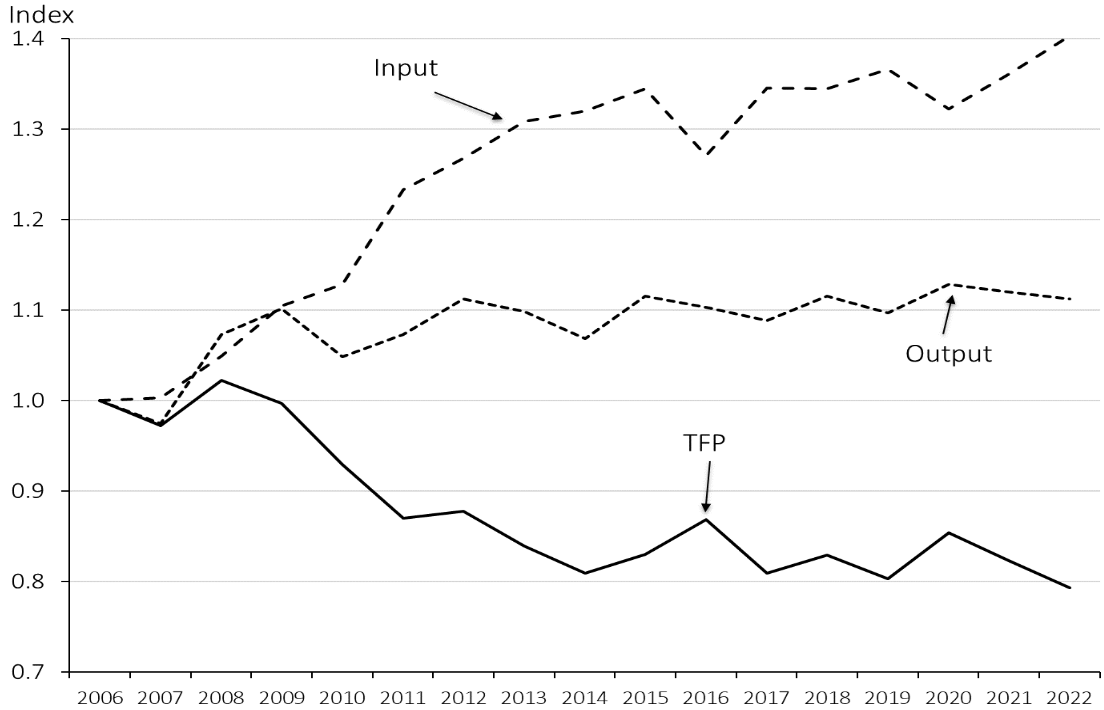


Table 5.11 SA DNSP output, input, TFP and PFP indexes, 2006–2022

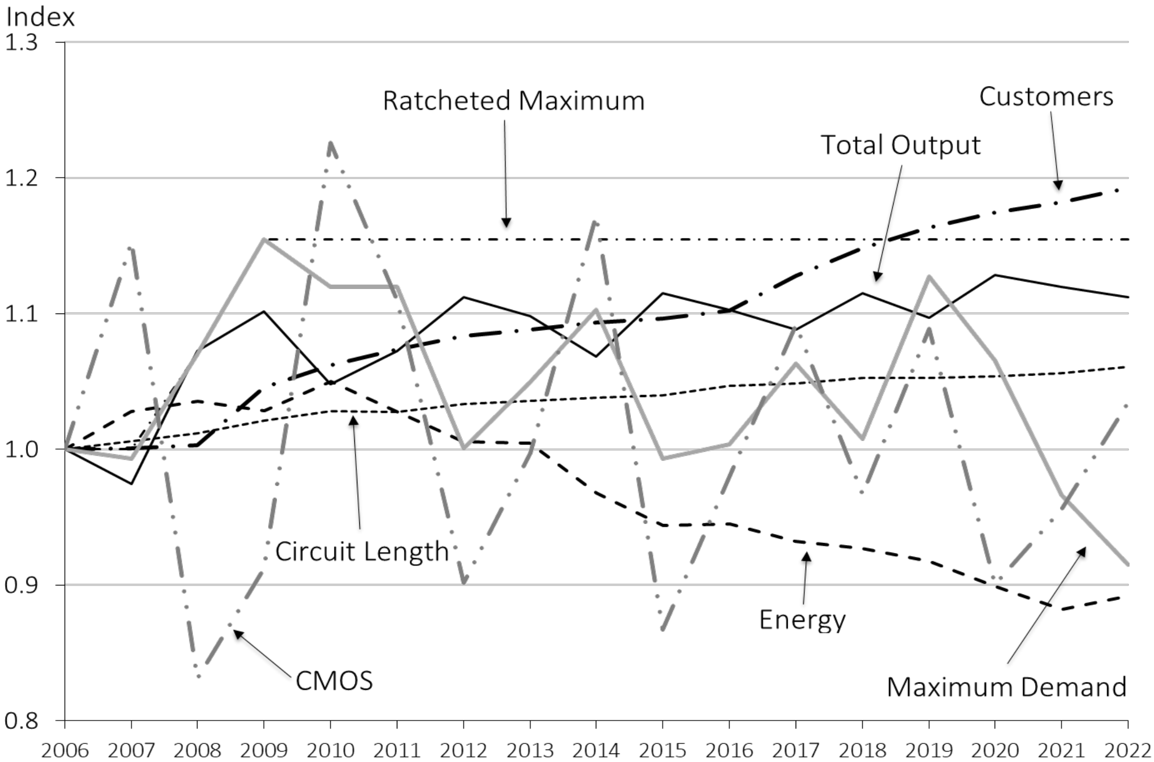
Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	0.974	1.003	0.972	1.049	0.940
2008	1.073	1.049	1.022	1.036	1.013
2009	1.102	1.105	0.997	0.972	1.011
2010	1.048	1.129	0.929	0.924	0.931
2011	1.073	1.233	0.870	0.759	0.935
2012	1.112	1.268	0.878	0.761	0.943
2013	1.098	1.308	0.839	0.714	0.916
2014	1.068	1.320	0.809	0.698	0.878
2015	1.115	1.344	0.830	0.701	0.907
2016	1.103	1.270	0.868	0.827	0.887
2017	1.089	1.345	0.809	0.708	0.867
2018	1.115	1.344	0.829	0.741	0.879
2019	1.097	1.366	0.803	0.710	0.856
2020	1.128	1.322	0.853	0.820	0.869
2021	1.120	1.361	0.823	0.798	0.833
2022	1.112	1.403	0.793	0.742	0.818
Growth Rate 2006-2022	0.7%	2.1%	-1.5%	-1.9%	-1.3%
Growth Rate 2006-2012	1.8%	4.0%	-2.2%	-4.5%	-1.0%
Growth Rate 2012-2022	0.0%	1.0%	-1.0%	-0.3%	-1.4%
Growth Rate 2022	-0.7%	3.1%	-3.7%	-7.2%	-1.8%

SA DNSP output and input quantity changes

Quantity indexes for SA's individual outputs are graphed in Figure 5.20 and for its six individual inputs in Figure 5.21. From Figure 5.20 we see that:

- SA customer numbers increased steadily over the period and were 19.2 per cent higher in 2022 than in 2006 (compared to 23.6 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 2022 it was 10.8 per cent below 2006; a much larger decrease than that for the industry as a whole over the same period (–4.0 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 19.5 per cent for the industry between 2006 and 2022;
- SA's circuit length output grew by 6.1 per cent in total over the 17-year period (compared to 5.6 per cent for the industry);
- SA's CMOS increased by 3.5 per cent in total between 2006 and 2022, thus making a greater contribution to output growth than for the industry (where CMOS increased by 1.9 per cent over the same period). CMOS receives an average weight of –16.6 per cent of total revenue for SA.

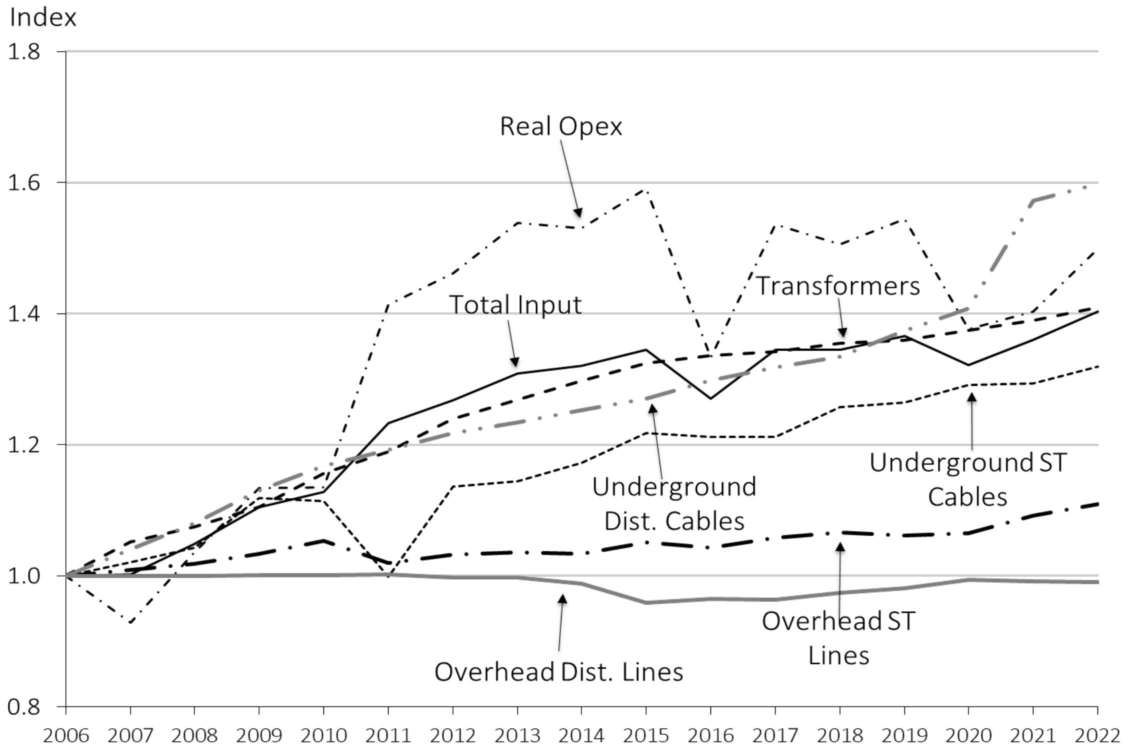
Figure 5.20 SA output quantity indexes, 2006–2022



Since the circuit length and RMD outputs receive a combined average weight of around 85.0 per cent of total revenue in forming the total output index for SA, we see in Figure 5.20 that the total output index lies between these output indexes in most years. The total output index for SA increased by 11.2 per cent between 2006 and 2022 (less than the increase for the industry of 14.8 per cent over the same period).

Turning to Figure 5.21, which shows the SA DNSP input indexes, it can be seen that SA's total input index increased by 40.3 per cent in total between 2006 and 2022, which is higher than the corresponding increase of 21.0 per cent for industry.

Figure 5.21 SA DNSP input quantity indexes, 2006–2022



In regard to the six individual input indexes for SA shown Figure 5.21:

- SA's opex input increased by 49.9 per cent over the 17-year period, which is much greater than for the industry (an increase of 6.5 per cent over the same period). This outcome was driven by an especially strong increase in SA's opex input between 2006 and 2015 of 59.1 per cent. After 2015 there was a small underlying decrease up to 2022. Opex has the largest average share in SA's total costs at 35.7 per cent and so is an important driver of its total input quantity index;
- Underground distribution and sub-transmission cables in SA increased by 59.8 per cent and 32.0 per cent respectively over the 17-year period to 2022 (compared to 68.0 and 38.5 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 41.0 per cent by 2022 (compared to 43.1 per cent for the industry);
- SA's overhead sub-transmission increased between 2006 and 2021 by 10.9 per cent and its overhead distribution lines *decreased* by 1.0 per cent (compared to increases of 7.3 per cent and 3.1 per cent respectively for the whole industry).

SA output and input contributions to TFP change

In Table 5.12, SA's TFP change is decomposed into the contributions of the individual outputs and inputs for the whole 17-year period, for the periods up to and after 2012, and for 2022. SA's drivers of TFP change for the 17-year period to 2022 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 –0.9 percentage points to the average TFP growth rate of –1.5 per cent from 2006 to 2022 (compared to a negative contribution of opex of –0.1 percentage points to the industry average TFP growth rate of –0.3 per cent for the same period). Other contributions to SA's average TFP growth rate over the 17 years to 2022 include:

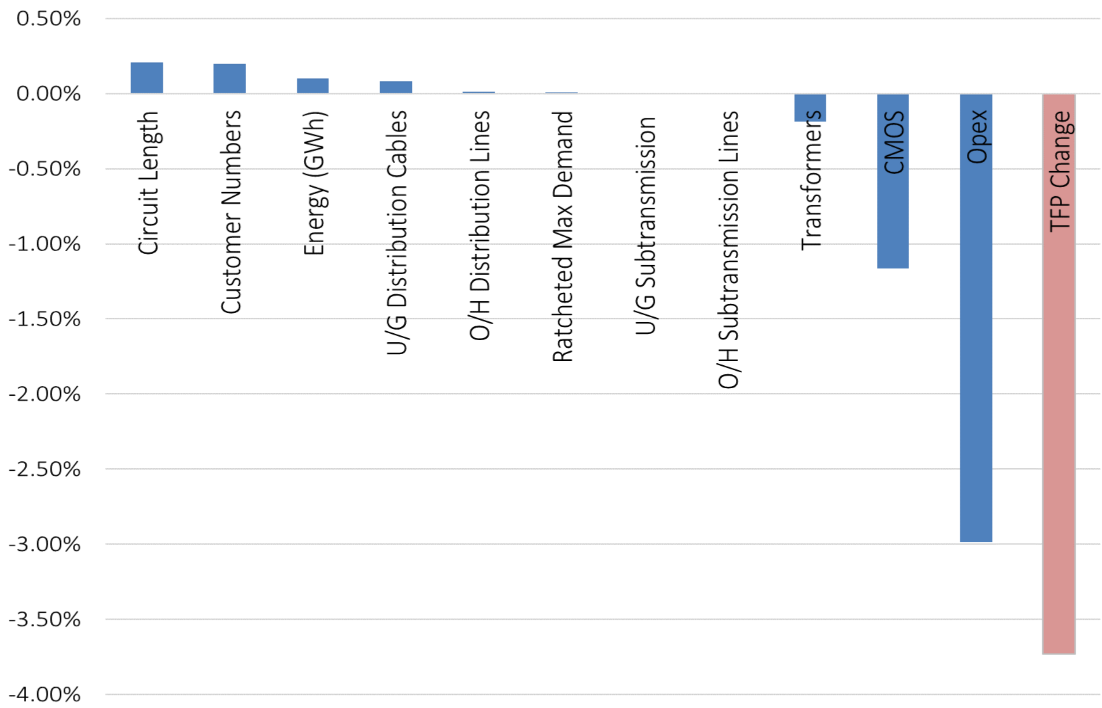
- Customers, RMD and circuit length outputs together contributed 0.8 percentage points (compared to 0.9 for the industry);
- Overhead and underground sub-transmission and distribution lines together contributed –0.5 percentage points (compared to –0.4 for the industry);
- Transformers input contributed –0.7 percentage points (–0.6 the industry); and
- CMOS contributed close to zero percentage points (the same as for the industry).

Table 5.12 SA output and input percentage point contributions to average annual TFP change: various periods

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2021 to 2022*
Energy (GWh)	-0.07%	0.01%	-0.12%	0.10%
Ratcheted Max Demand	0.36%	0.96%	0.00%	0.01%
Customer Numbers	0.24%	0.30%	0.20%	0.20%
Circuit Length	0.17%	0.26%	0.12%	0.21%
CMOS	-0.03%	0.25%	-0.21%	-1.17%
Opex	-0.90%	-2.12%	-0.17%	-2.99%
O/H Sub-transmission Lines	-0.01%	-0.01%	-0.01%	0.00%
O/H Distribution Lines	0.01%	0.01%	0.01%	0.01%
U/G Sub-transmission Cables	0.00%	-0.01%	0.00%	0.00%
U/G Distribution Cables	-0.51%	-0.68%	-0.41%	0.08%
Transformers	-0.70%	-1.14%	-0.44%	-0.19%
TFP Change	-1.45%	-2.18%	-1.02%	-3.73%

Figure 5.22 shows the percentage point contributions of individual outputs and inputs to SA's TFP growth in 2022. SA's large TFP *decrease* of 3.7 per cent in 2022 was driven mainly by a significant increase in opex and decrease in reliability (i.e., increase in CMOS). The increase in opex contributed –3.0 percentage points, and the increase in CMOS contributed –1.2 percentage points to TFP growth in 2022. Circuit length, customer numbers and energy throughput together positively contributed to 0.3 to TFP growth, transformer contributed –0.2 percentage points. The overhead and underground inputs had a marginal collaboration of 0.1 percentage points to TFP growth in 2022

Figure 5.22 SA output and input percentage point contributions to TFP change, 2022



5.2.6 Tasmania (TAS)

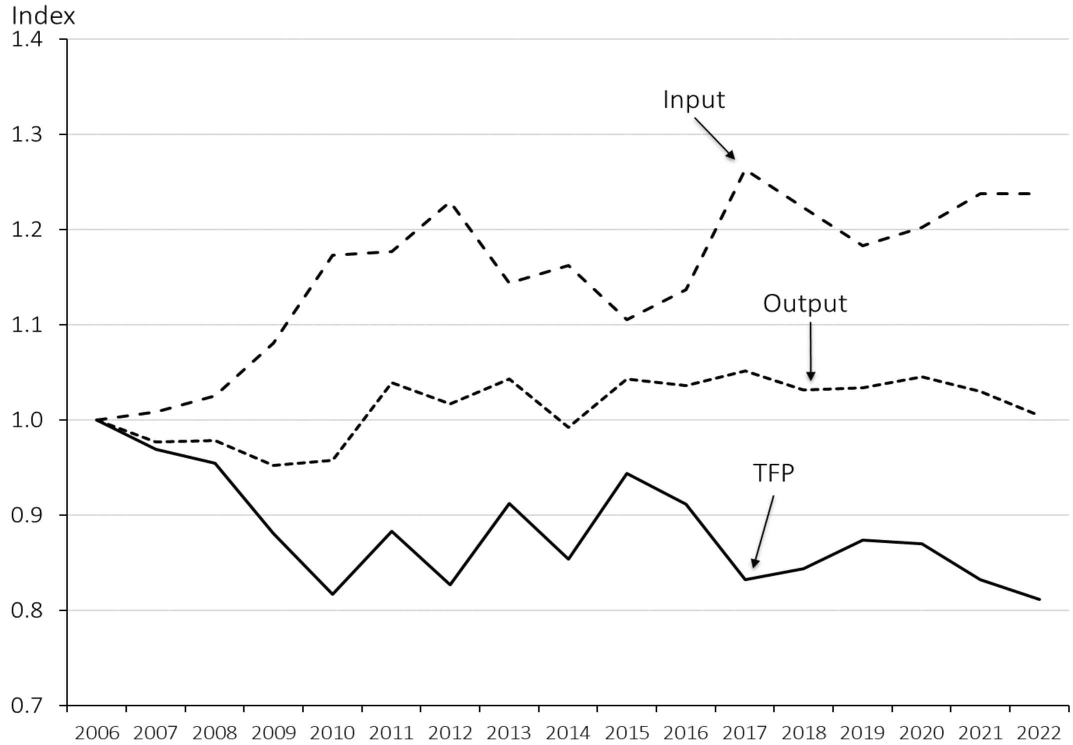
TAS is the second smallest of the NEM jurisdictions (by customer numbers) and is served by one DNSP, TasNetworks Distribution (TND). In 2022 it delivered 4,581 GWh to 301,064 customers over 22, 545 circuit kilometres of lines and cables.[16]

[16] 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 sub-transmission capacity than other Australian DNSPs. While this gives it an advantage in terms of a lower quantity of sub-transmission 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 sub-transmission lines MPFP several times higher than that of any other DNSP but, whereas sub-transmission 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.

Tasmanian DNSP productivity performance

Tasmania's total output, total input and TFP indexes are presented in Figure 5.23 and Table 5.13. Opex and capital PFP indexes are also presented in Table 5.13. Over the 17-year period 2006 to 2022, the Tasmanian DNSP's TFP *decreased* at an average annual rate of 1.3 per cent. Total output has increased zero per cent per annum on average. Total input use, on the other hand, increased at an average annual rate of 1.3 per cent over the 17-yeasr period. Input use increased at a faster rate of 3.4 per cent between 2006 and 2012, and at a rate of 0.1 per cent per year from 2012 to 2022. Output increased at an average annual rate of 0.3 per cent from 2006 to 2012, and on average *decreased* by 0.1 per cent per annum thereafter. The net effect of these trends was that TFP *decreased* at an average rate of 3.2 per cent up to 2012 and *decreased* at an average rate of 0.2 per cent from 2012 to 2022.

Figure 5.23 TAS DNSP output, input and TFP indexes, 2006–2022



Tasmanian DNSP output and input quantity changes

Quantity indexes for the Tasmanian DNSP's individual outputs are shown in Figure 5.24 and its six individual inputs in Figure 5.25. TAS outputs had the following trends:

- Customer numbers were 20.1 per cent higher in 2022 than in 2006 (compared to 23.6 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 3.0 per cent higher in 2022 than in 2006 (compared to 4.0 per cent lower for industry as a whole);
- TAS's maximum demand increased up to 2008 and has not reached that level since, so that RMD has been constant from 2008 to 2022 at 8.6 per cent higher than in 2006 (compared to the 19.5 per cent increase for the industry as a whole).
- TAS's circuit length output grew by 6.3 per cent in total over the 17-year period to 2022 (compared to an increase of 5.6 per cent for the industry);
- CMOS increased by 65.0 per cent in total between 2006 and 2022 (compared to an increase of 1.9 per cent for the industry over the same period). This represents a significant deterioration in reliability performance compared to 2006. CMOS receives an average weight of –18.6 per cent of total revenue for Tasmania.

Table 5.13 TAS DNSP output, input, TFP and PFP indexes, 2006–2022

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	1.008	0.969	0.979	0.964
2008	0.978	1.025	0.954	0.971	0.946
2009	0.952	1.081	0.881	0.846	0.902
2010	0.958	1.173	0.817	0.718	0.880
2011	1.039	1.177	0.883	0.810	0.926
2012	1.016	1.229	0.827	0.726	0.892
2013	1.043	1.143	0.912	0.918	0.910
2014	0.992	1.162	0.853	0.856	0.852
2015	1.043	1.105	0.944	1.063	0.888
2016	1.036	1.137	0.911	0.984	0.877
2017	1.051	1.263	0.832	0.760	0.878
2018	1.032	1.223	0.844	0.826	0.854
2019	1.034	1.183	0.874	0.934	0.843
2020	1.046	1.202	0.870	0.914	0.846
2021	1.030	1.238	0.832	0.838	0.829
2022	1.005	1.238	0.812	0.823	0.802
Growth Rate 2006-2022	0.0%	1.3%	-1.3%	-1.2%	-1.4%
Growth Rate 2006-2012	0.3%	3.4%	-3.2%	-5.3%	-1.9%
Growth Rate 2012-2022	-0.1%	0.1%	-0.2%	1.3%	-1.1%
Growth Rate 2022	-2.5%	0.0%	-2.5%	-1.8%	-3.3%

TAS's output index increased only by 0.5 per cent from 2006 to 2022, compared to 14.8 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 5.24 TAS output quantity indexes, 2006–2022

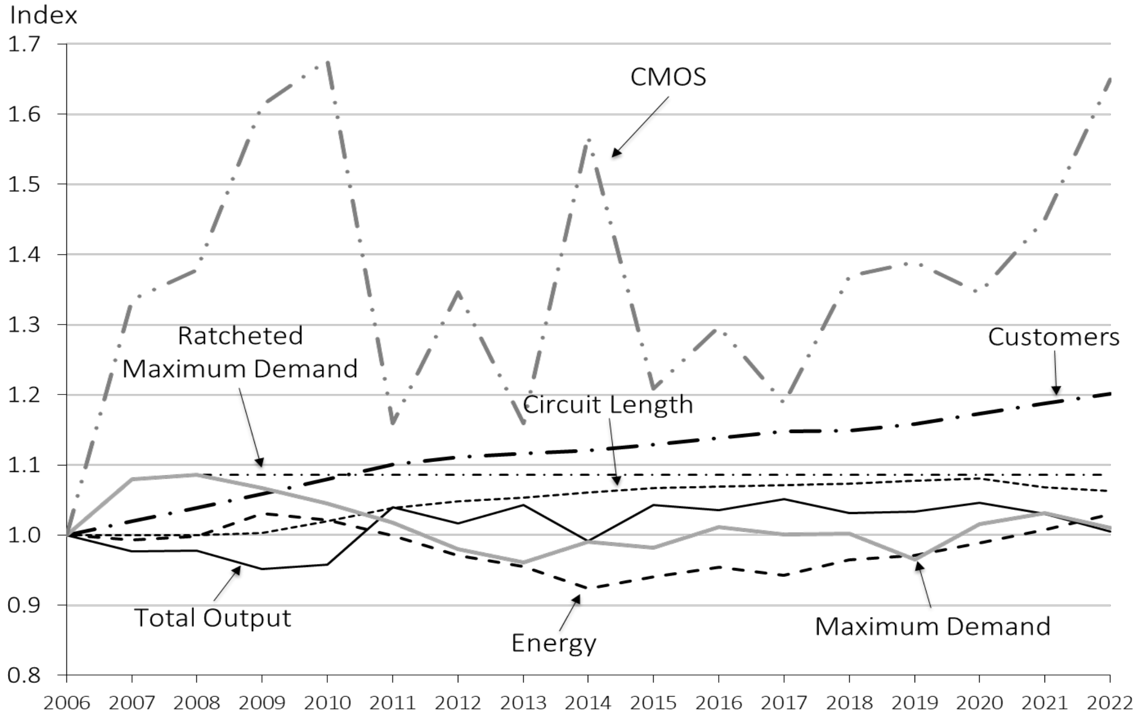
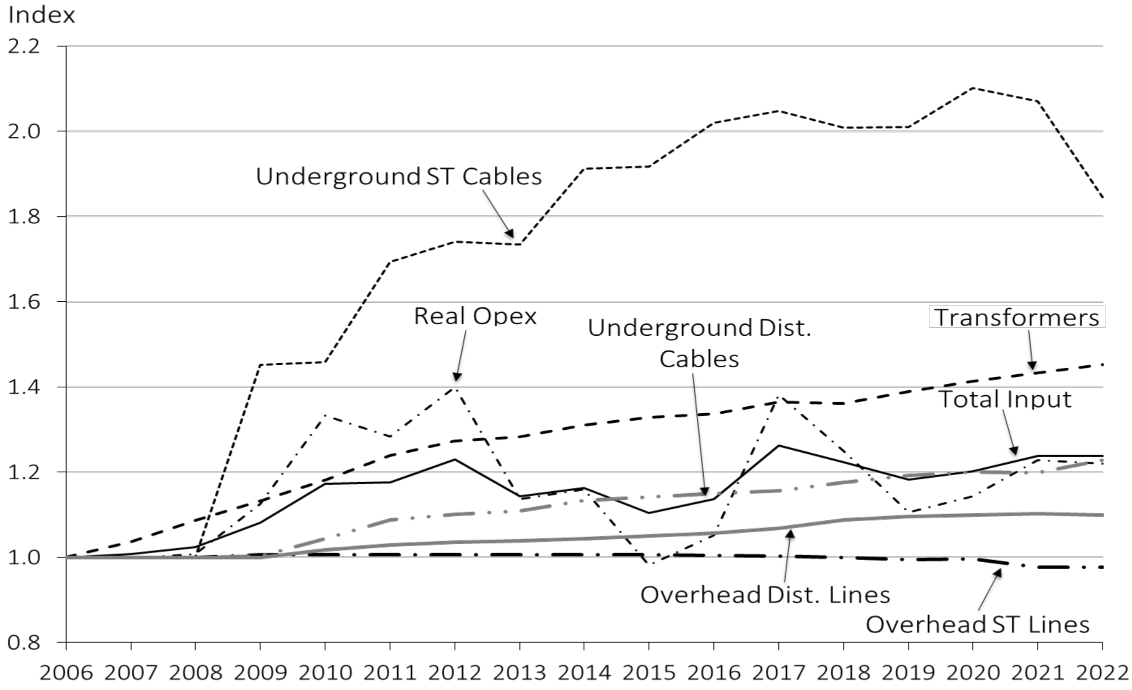


Figure 5.25 plots TAS's six individual inputs and the total input index:

- Opex input increased by 22.1 per cent from 2006 to 2022. 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 2022. The increase of opex over the whole 17-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 36.3 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 2022 exceeding the 2006 level by 45.3 per cent (compared to 43.1 per cent for the industry);
- TAS's underground distribution cables inputs increased by 22.9 per cent in total over the 17 years to 2023 (compared to 68.0 per cent for the industry). TAS's underground sub-transmission cables more increased 84.5 per cent in the 17-year period, off a low base;
- Overhead sub-transmission and distribution lines in TAS were in 2022, –2.3 per cent and 10.0 per cent from 2006, respectively (compared to 7.3 per cent and 3.1 per cent respectively for the whole industry).

From Figure 5.25 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 sub-transmission lines. Total input quantity increased by 23.8 per cent over the 17 years to 2022, compared to 21.1 per cent for the industry overall.

Figure 5.25 TAS DNSP input quantity indexes, 2006–2022



Tasmanian output and input contributions to TFP change

Table 5.14 presents the decomposition of TAS's TFP change into its constituent outputs and inputs for the whole 17-year period, for the periods up to and after 2012, and for 2022. Tasmania's drivers of TFP change for the whole 17-year period show several differences to those for the industry as a whole. Among the outputs:

- RMD, customer numbers and circuit length together contributed 0.6 percentage points to TAS's average TFP change of –1.3 per cent from 2006 to 2022, compared to a 0.9 percentage points contribution of these outputs to the industry TFP change; and
- CMOS contributed –0.6 percentage points to average TAS TFP growth from 2006 to 2022, compared to zero contribution for the industry.

Among the inputs:

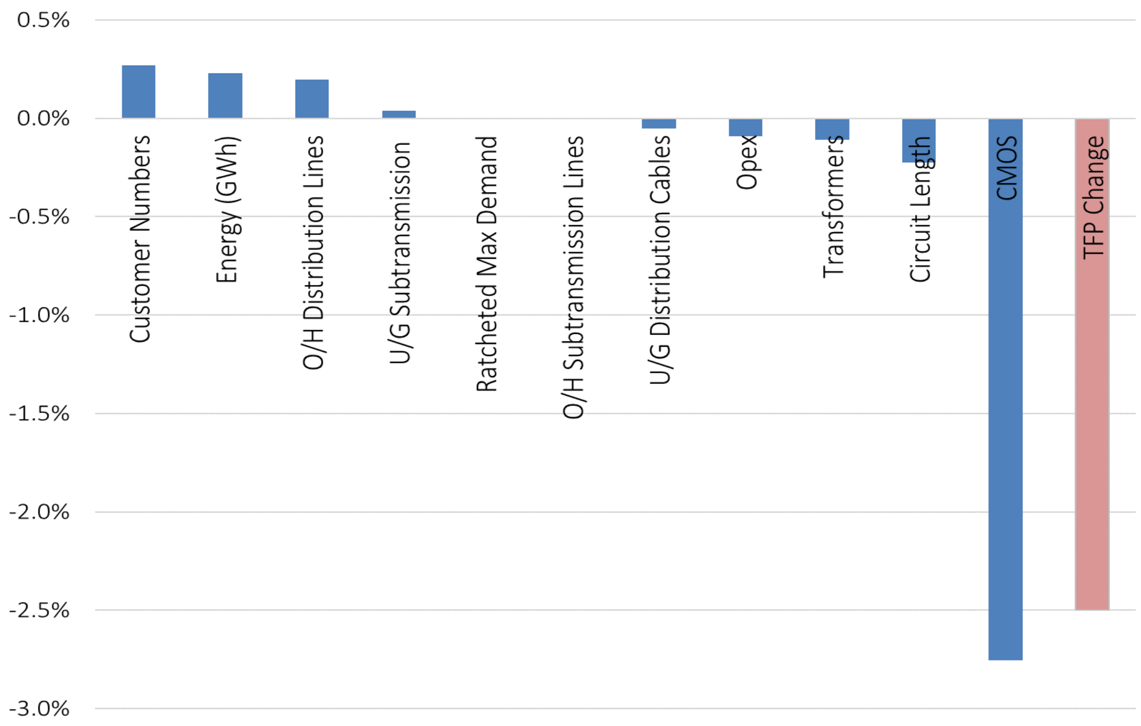
- Opex growth contributed –0.5 percentage points to TAS average TFP growth, compared to –0.1 percentage points for the industry.
- Overhead and underground distribution and sub-transmission lines, taken together contributed –0.3 percentage points to TAS TFP change, compared to –0.4 percentage points for the industry. Transformers contributed –0.6 percentage points to TAS's TFP growth rate the same as the industry.

Figure 5.26 shows the contributions of individual inputs and outputs to TAS's TFP growth from 2021 to 2022 of –2.5 per cent. Deterioration in reliability was the main driver of this and contributed –2.75 percentage points to lower TFP growth.

Table 5.14 TAS output and input percentage point contributions to average annual TFP change: various periods

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2021 to 2022*
Energy (GWh)	0.02%	-0.05%	0.06%	0.23%
Ratcheted Max Demand	0.21%	0.55%	0.00%	0.00%
Customer Numbers	0.25%	0.39%	0.17%	0.27%
Circuit Length	0.18%	0.36%	0.07%	-0.22%
CMOS	-0.63%	-0.98%	-0.42%	-2.75%
Opex	-0.48%	-2.04%	0.47%	-0.09%
O/H Sub-transmission Lines	0.00%	0.00%	0.00%	0.00%
O/H Distribution Lines	-0.15%	-0.15%	-0.15%	0.20%
U/G Sub-transmission Cables	-0.01%	-0.03%	0.00%	0.04%
U/G Distribution Cables	-0.13%	-0.19%	-0.10%	-0.05%
Transformers	-0.56%	-1.03%	-0.28%	-0.11%
TFP Change	-1.30%	-3.17%	-0.18%	-2.50%

Figure 5.26 TAS output and input percentage point contributions to TFP change, 2022



6 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.

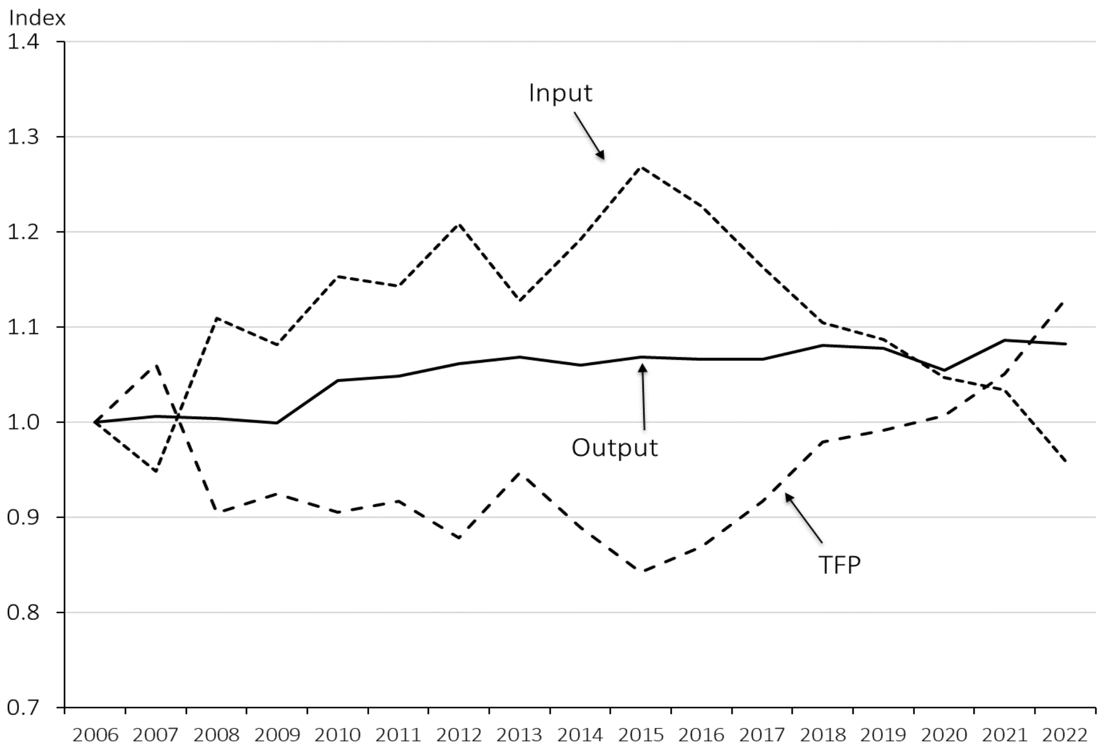
6.1 Ausgrid (AGD)

In 2022, AGD delivered 24,235 GWh to 1.78 million customers over 42,714 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.

6.1.1 AGD's productivity performance

AGD's total output, total input and TFP indexes are presented in Figure 6.1 and Table 6.1. Opex and capital PFP indexes are also presented in Table 6.1.

Figure 6.1 AGD output, input and total factor productivity indexes, 2006–2022



Over the 17-year period 2006 to 2022, AGD's TFP averaged an annual rate of change of 0.8 per cent. This can be compared to the industry's average annual change of –0.3 per cent over the same period. AGD's total output increased over the same period at an average annual rate of 0.5 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 *decrease* in input use of 0.3 per cent was much lower than the rate of increase in total input use for the industry (1.2 per cent per year).

Table 6.1 AGD output, input, TFP and PFP indexes, 2006–2022

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.006	0.948	1.061	1.188	0.981
2008	1.004	1.109	0.905	0.834	0.956
2009	0.999	1.081	0.924	0.917	0.926
2010	1.044	1.153	0.906	0.845	0.938
2011	1.048	1.143	0.917	0.888	0.925
2012	1.061	1.208	0.879	0.814	0.908
2013	1.068	1.128	0.947	1.037	0.890
2014	1.060	1.192	0.889	0.923	0.861
2015	1.068	1.269	0.842	0.793	0.863
2016	1.066	1.226	0.869	0.886	0.850
2017	1.066	1.163	0.917	1.002	0.862
2018	1.081	1.104	0.979	1.188	0.873
2019	1.077	1.087	0.991	1.260	0.865
2020	1.054	1.047	1.007	1.389	0.841
2021	1.086	1.034	1.051	1.515	0.862
2022	1.082	0.959	1.129	1.722	0.853
Growth Rate 2006-2022	0.5%	-0.3%	0.8%	3.4%	-1.0%
Growth Rate 2006-2012	1.0%	3.1%	-2.2%	-3.4%	-1.6%
Growth Rate 2012-2022	0.2%	-2.3%	2.5%	7.5%	-0.6%
Growth Rate 2022	-0.4%	-7.5%	7.1%	12.8%	-1.1%

Over the period from 2006 to 2012, AGD's TFP increased in some years but overall, it *decreased* at an average rate of 2.2 per cent per year. From 2012 to 2022, TFP increased in most years, and on average TFP increased at an annual rate of 2.5 per cent. The TFP increase in 2022 of 7.1 per cent is one of AGN's largest single year increases. 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 0.2 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 3.1 per cent, whereas in the period after 2012 the input index fell, averaging an annual rate of –2.3 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 PFP indexes in Table 6.1 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 trends. The latter's large reductions in the period up to 2012, were replaced by strong increases in the period after 2012.

6.1.2 AGD's output and input quantity changes

Figure 6.2 plots the quantity indexes for AGD's individual outputs and Figure 6.3 plots indexes for the six individual inputs. Regarding outputs, in Figure 6.2, we see:

- AGD's circuit length (the output component that receives the largest weight in forming the output index, 43.2 per cent) has increased steadily and by 2022 was 10.3 per cent above the 2006 level (which is higher than the increase of 5.6 per cent, for the industry over the 17-year period).
- AGD's energy throughput decreased at a greater rate than for the industry. In 2022, AGD's energy throughput was 19.5 per cent below its 2006 level compared to the industry's throughput then being 4.0 per cent less than it was in 2006.
- RMD increased though to 2011, in total by 7.3 per cent, and remained constant thereafter. Although maximum demand reduced considerably after 2011, it increased after 2015 despite flat energy demand, but did not reach its 2011 level.
- AGD's customers increased by 15.3 per cent in total between 2006 and 2022, which is less than the increase in customers for the industry over the same period (23.6 per cent in total, or 1.3 per cent per year).
- CMOS in 2022 was 0.7 per cent lower than in 2006, which is lower than the increase of 1.9 per cent for the industry over the same period.

With regard to input movements, in Figure 6.3:

- Over the 17-year period to 2022, opex input *decreased* in total by 37.1 per cent. This compares favourably to the total increase of 6.5 per cent for the industry over the same period.
- Overhead sub-transmission and distribution lines in 2022, compared to 2006, were 4.8 per cent *lower* and 11.9 per cent higher respectively (compared to 7.3 per cent and 3.1 per cent increases, respectively, for the industry over the same period).
- Underground sub-transmission and distribution cables were, in 2022, 7.3 and 35.1 per cent higher than in 2006 respectively (compared to increases of 38.5 per cent and 68.0 per cent respectively for the industry over the same period).
- AGD's quantity of transformers increased strongly over the period from 2006 to 2012, and more slowly in the period from 2012 to 2022. By 2022, transformer inputs were

36.1 per cent above the 2006 level, which is a smaller increase than the industry's 43.1 per cent.

Figure 6.2 AGD output quantity indexes, 2006–2022

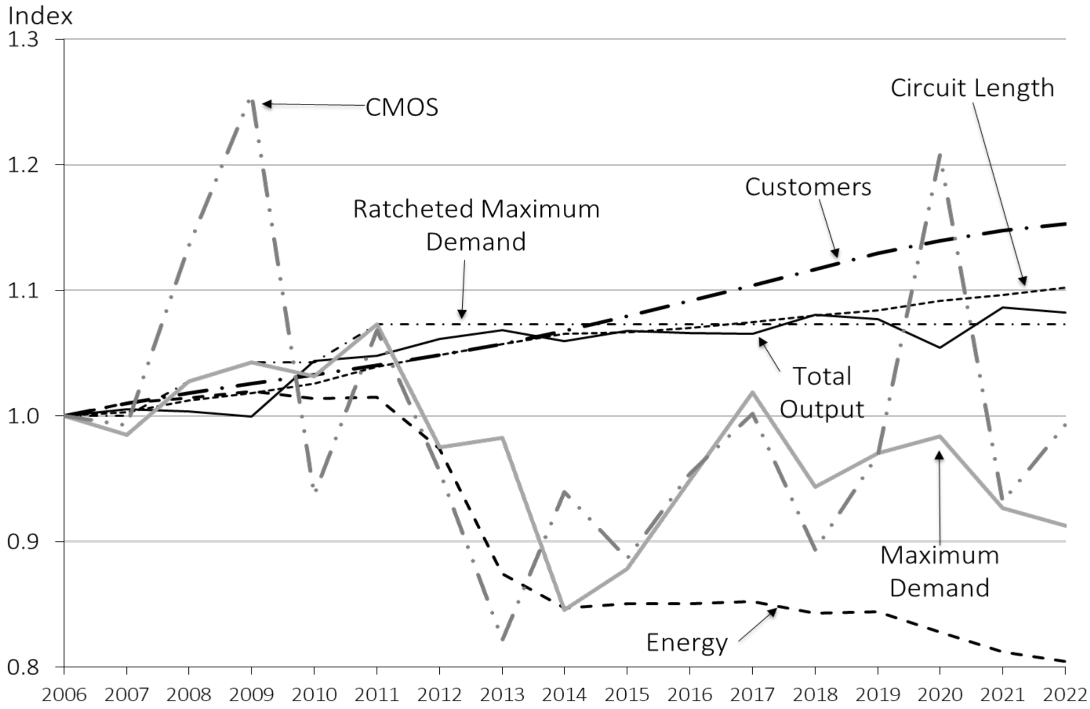
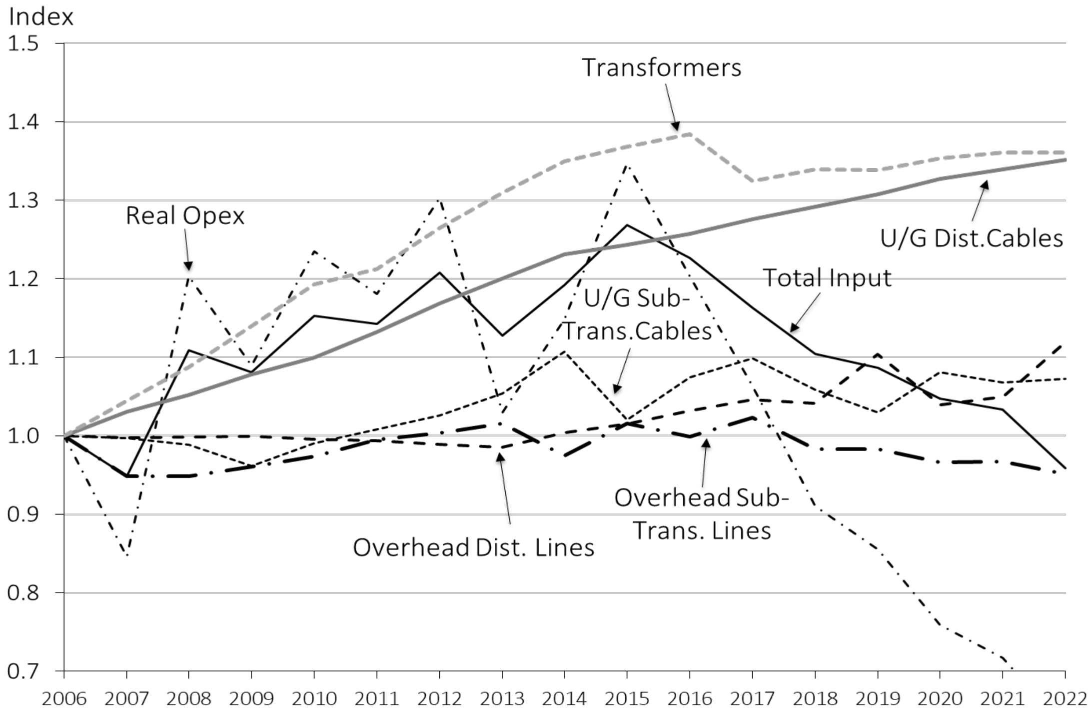


Figure 6.3 AGD input quantity indexes, 2006–2022



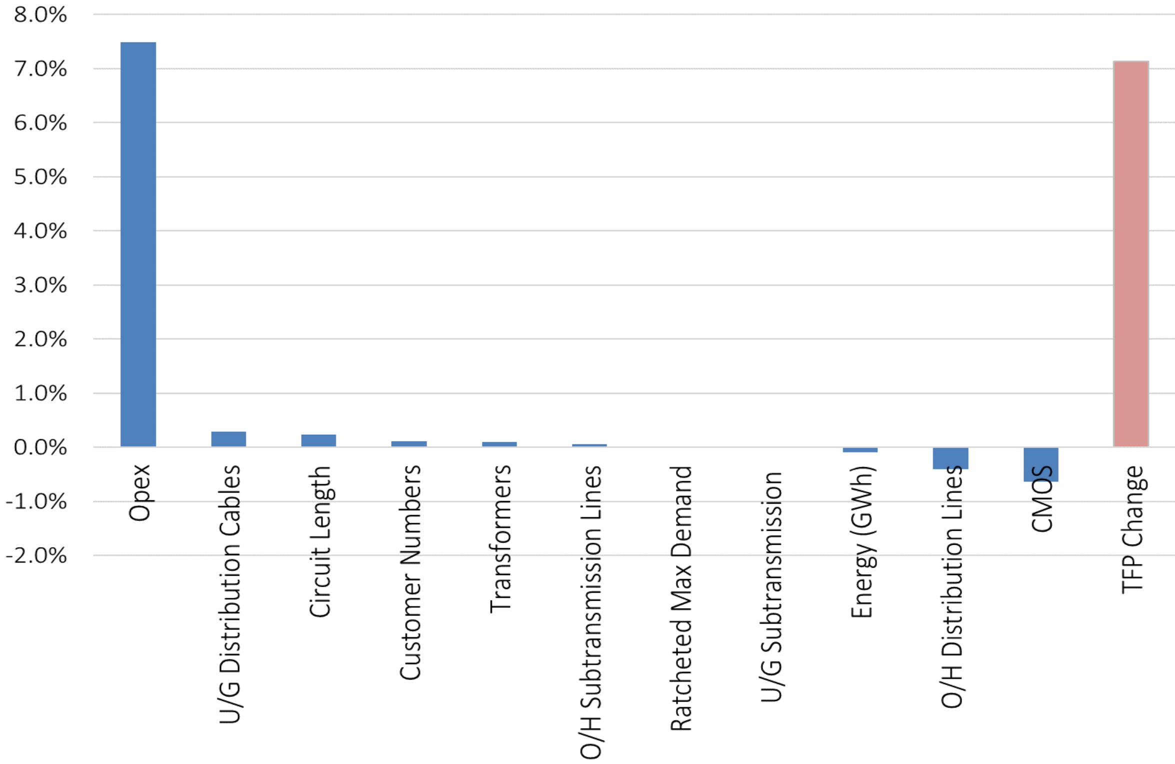
6.1.3 AGD's output and input contributions to TFP change

Table 6.2 shows the decomposition of AGD's rate of TFP change into the contributions of the individual outputs and inputs for the whole 17-year period, for the periods up to and after 2012, and for 2022. Figure 6.4 shows the contributions of outputs and inputs to AGD's rate of TFP change of 7.1 per cent in 2022.

Table 6.2 AGD output and input percentage point contributions to average annual TFP change: various periods

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2021 to 2022*
Energy (GWh)	-0.13%	-0.05%	-0.18%	-0.09%
Ratcheted Max Demand	0.17%	0.44%	0.00%	0.00%
Customer Numbers	0.18%	0.17%	0.19%	0.10%
Circuit Length	0.27%	0.35%	0.22%	0.24%
CMOS	0.01%	0.08%	-0.04%	-0.63%
Opex	1.15%	-1.61%	2.81%	7.49%
O/H Sub-transmission Lines	0.01%	0.00%	0.02%	0.05%
O/H Distribution Lines	-0.05%	0.01%	-0.08%	-0.40%
U/G Sub-transmission Cables	-0.02%	-0.02%	-0.03%	0.00%
U/G Distribution Cables	-0.24%	-0.35%	-0.18%	0.29%
Transformers	-0.59%	-1.18%	-0.23%	0.09%
TFP Change	0.76%	-2.15%	2.50%	7.14%

Figure 6.4 AGD output and input percentage point contributions to TFP change, 2022



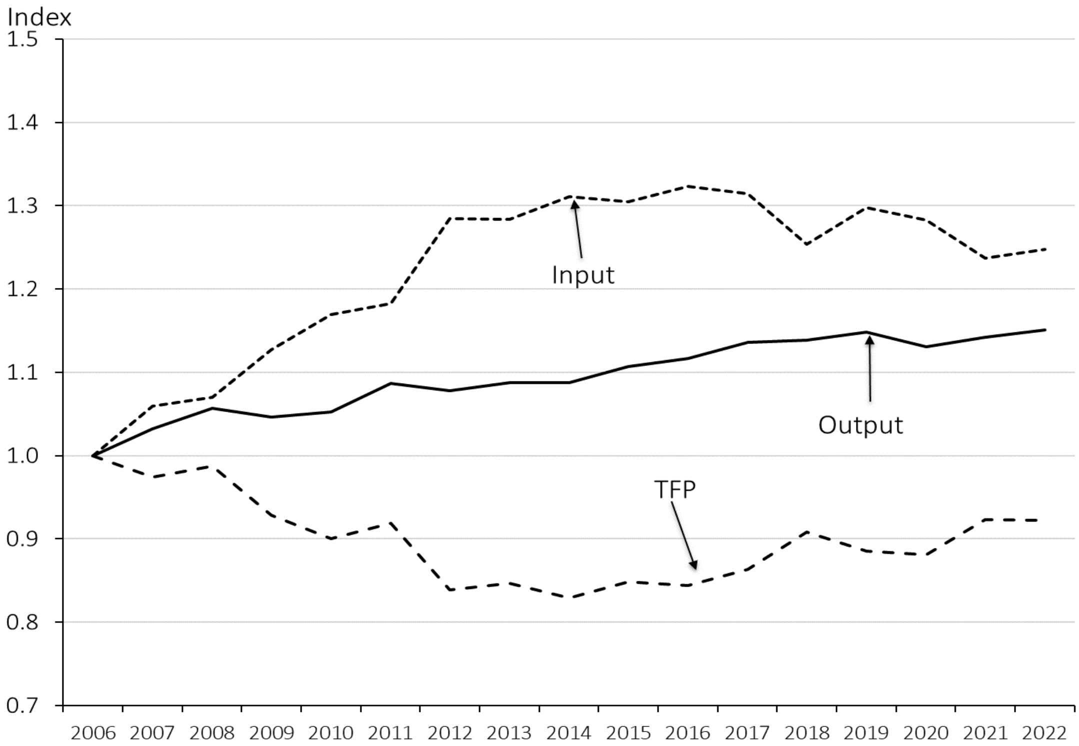
6.2 CitiPower (CIT)

In 2022, CIT delivered 5,252 GWh to 348,303 customers over 4,578 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.

6.2.1 CIT's productivity performance

CIT's total output, total input and TFP indexes are presented in Figure 6.5 and Table 6.3. Opex and capital PFP indexes are also presented in Table 6.3.

Figure 6.5 CIT's output, input and TFP indexes, 2006–2022



Over the 17-year period 2006 to 2022, CIT's TFP *decreased* at an average annual rate of 0.5 per cent, which is similar to the industry's average annual TFP change of –0.3 per cent over the same period. CIT's total output increased over the 17-year period at an average annual rate of 0.9 per cent, which is the same as for the industry (0.9 per cent per year). CIT's average annual rate of increase in input use of 1.4 per cent was similar to the for the industry as a whole (1.2 per cent).

The decrease in TFP mostly occurred in the period from 2006 to 2012 and was associated with a large increase in input use, averaging a 4.2 per cent increase per year over this period. TFP *decreased* at average annual rate of 2.9 per cent over this period. Input use stabilised in the period 2012 to 2022, with an average annual rate of change of –0.3 per cent, and average TFP growth in this period was 1.0 per cent per annum.

Table 6.3 CIT's output, input, TFP and PFP indexes, 2006–2022

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	1.032	1.060	0.974	0.903	0.997
2008	1.056	1.070	0.988	0.972	0.994
2009	1.047	1.127	0.929	0.816	0.970
2010	1.053	1.169	0.901	0.756	0.954
2011	1.087	1.183	0.919	0.840	0.946
2012	1.078	1.285	0.839	0.661	0.916
2013	1.087	1.283	0.847	0.691	0.911
2014	1.087	1.311	0.829	0.675	0.893
2015	1.107	1.305	0.848	0.713	0.901
2016	1.117	1.323	0.844	0.708	0.897
2017	1.136	1.315	0.864	0.747	0.907
2018	1.138	1.254	0.908	0.866	0.921
2019	1.148	1.297	0.885	0.778	0.924
2020	1.131	1.283	0.881	0.813	0.904
2021	1.142	1.237	0.923	0.946	0.909
2022	1.151	1.247	0.923	0.916	0.921
Growth Rate 2006-2022	0.9%	1.4%	-0.5%	-0.6%	-0.5%
Growth Rate 2006-2012	1.2%	4.2%	-2.9%	-6.9%	-1.5%
Growth Rate 2012-2022	0.7%	-0.3%	1.0%	3.4%	0.1%
Growth Rate 2022	0.8%	0.8%	0.0%	-3.3%	1.3%

The PFP indexes in Table 6.3 show that:

- The PFP of capital inputs has *declined* at an average rate of 0.5 per cent per year from 2006 to 2022. The rate of decline was strongest in the period up to 2012 and was only marginal in the period after 2012.
- The PFP of opex input declined particularly strongly in the period up to 2012, at average annual rate of –6.9 per cent, whereas it increased at an average rate of 3.4 per cent per annum from 2012 to 2022.

6.2.2 CIT's output and input quantity changes

Figure 6.6 graphs the quantity indexes for CIT's individual outputs. Figure 6.7 graphs quantity indexes for its six individual inputs.

Regarding outputs in Figure 6.6:

- CIT's circuit length has increased steadily and by 2022 was 15.9 per cent above the 2006 level (higher than the increase of 5.6 per cent for the industry over the same period).
- CIT's energy throughput decreased over the 17-year period at a faster rate than for the industry, and in 2022, CIT's energy throughput was 12.1 per cent below its 2006 level (compared to a 4.0 per cent reduction for the industry).
- RMD increased from 2006 through to 2009 by 10.4 per cent in total and further increased from 2017 to 2020, despite the strong decline in energy throughput. By 2022 RMD was 17.5 per cent above its 2006 level which is similar to the industry as a whole (a 19.5 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 2022, or 18.1 per cent in total, which is slightly lower than the rate of customer growth for the industry over the same period.
- CMOS in 2022 was 10.3 per cent lower than in 2006. The compares unfavourably to the industry total change of 1.9 per cent over the same period.

Turning to inputs shown in Figure 6.7, 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 over the period from 2012 to 2022, averaging –2.7 per cent per annum. In 2022, opex was 25.6 per cent above its 2006 level. This compares to the total increase of 6.5 per cent for the industry over the same period.
- Overhead sub-transmission and distribution lines in 2022 were 2.0 per cent higher and 8.6 per cent *lower* respectively, than in 2006 (compared with increases of 7.3 per cent and 3.1 per cent respectively for the industry over the same period).
- Underground sub-transmission and distribution cables in 2022, were 87.5 and 23.3 per cent higher than in 2006 respectively (compared to increases of 38.5 per cent and 68.0 per cent respectively for the industry over the same period).
- CIT's quantity of transformers increased steadily over most of the 17-year period and by 2022, transformer inputs were 25.0 per cent above the 2006 level, a smaller increase than the industry's 43.1 per cent.

Figure 6.6 CIT's output quantity indexes, 2006–2022

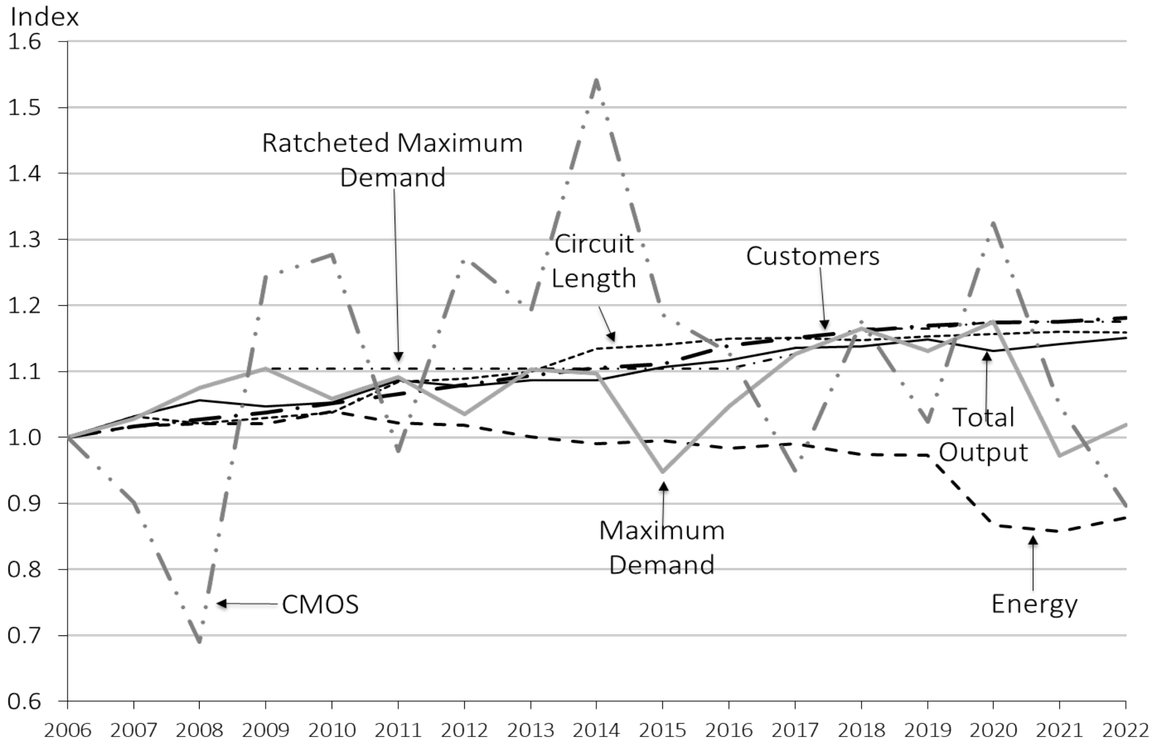
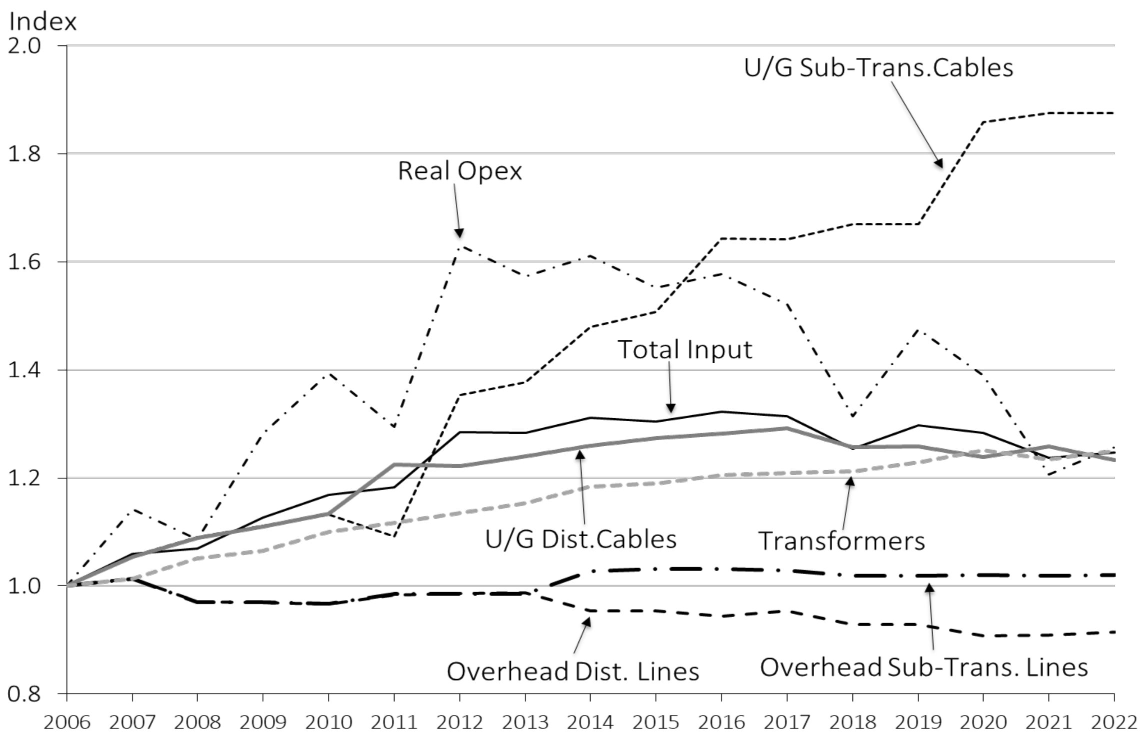


Figure 6.7 CIT's input quantity indexes, 2006–2022



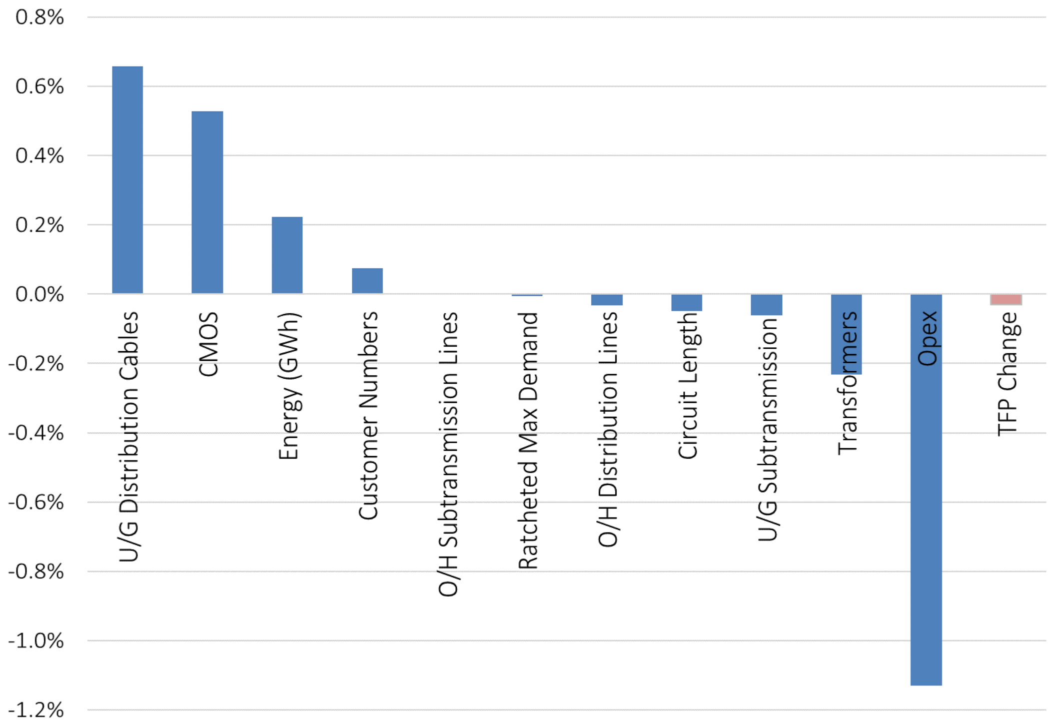
6.2.3 CIT's output and input contributions to TFP change

Table 6.4 shows the decomposition of CIT's rate of TFP change into the contributions of the individual outputs and inputs for the whole 17-year period, for the periods up to and after 2012, and for 2022. Figure 6.8 shows the contributions of outputs and inputs to CIT's rate of TFP change of –0.03 per cent in 2022.

Table 6.4 CIT's output and input percentage point contributions to average annual TFP change: various periods

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2021 to 2022*
Energy (GWh)	-0.08%	0.03%	-0.14%	0.22%
Ratcheted Max Demand	0.35%	0.58%	0.22%	-0.01%
Customer Numbers	0.20%	0.25%	0.17%	0.08%
Circuit Length	0.38%	0.58%	0.26%	-0.05%
CMOS	0.08%	-0.19%	0.24%	0.53%
Opex	-0.10%	-2.14%	1.12%	-1.13%
O/H Sub-transmission Lines	0.00%	0.00%	0.00%	0.00%
O/H Distribution Lines	0.04%	0.01%	0.05%	-0.03%
U/G Sub-transmission Cables	-0.27%	-0.33%	-0.23%	-0.06%
U/G Distribution Cables	-0.48%	-1.13%	-0.09%	0.66%
Transformers	-0.34%	-0.60%	-0.19%	-0.23%
TFP Change	-0.22%	-2.93%	1.41%	-0.03%

Figure 6.8 CIT's output and input percentage point contributions to TFP change, 2022



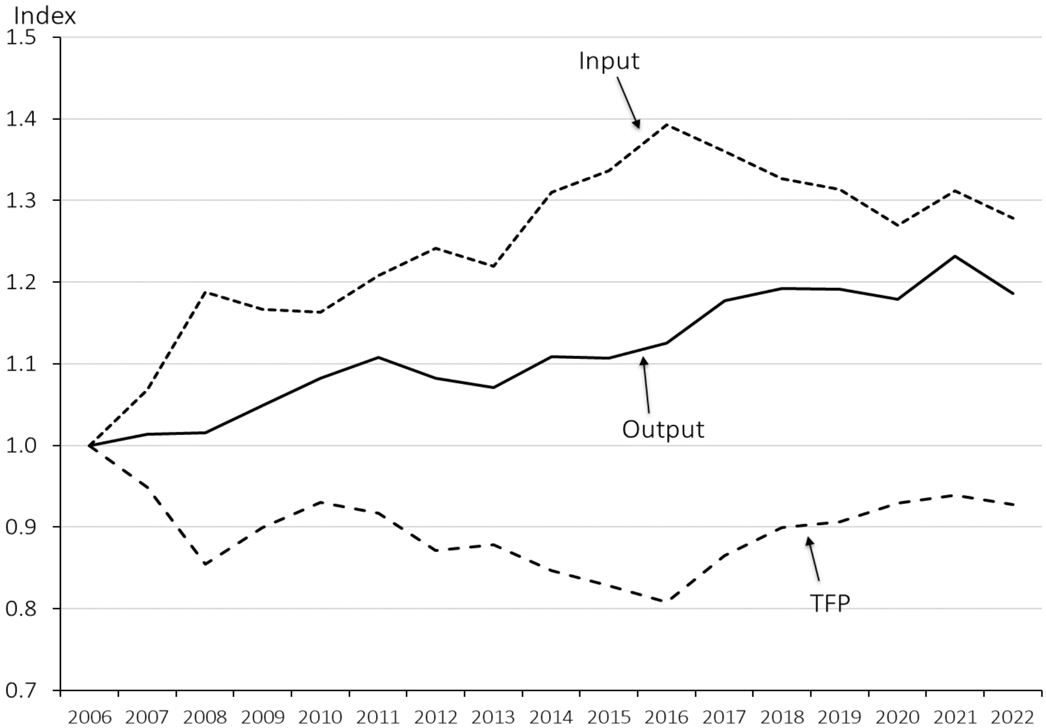
6.3 Endeavour Energy (END)

In 2022, END delivered 16,711 GWh to 1.08 million customers over 39,622 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.

6.3.1 END's productivity performance

END's total output, total input and TFP indexes are presented in Figure 6.9 and Table 6.5. Opex and capital PFP indexes are also presented in Table 6.5.

Figure 6.9 END's output, input and TFP indexes, 2006–2022



Over the 17-year period 2006 to 2022, END's TFP *decreased* at an average annual rate of 0.5 per cent, which is similar to the industry's average annual change of –0.3 per cent over the same period. END's total output increased over the same period at an average annual rate of 1.1 per cent, which higher than the industry average rate of output growth of 0.9 per cent per annum. END's average annual rate of increase in input use of 1.5 per cent is also higher than the industry's rate of increase in total input use of 1.2 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 2022 the average annual rate of TFP change was 0.6 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 2022 (averaging 0.3 per cent per year). The large change in input growth explains the turn-around in the TFP trend.

The PFP indexes in Table 6.5 show the following trends:

- Capital PFP *declined* at an average rate of 1.6 per cent per year over the 17-year period. The rate of decline was greater in the period up to 2012 (–2.3 per cent), but decline continued in the period after 2012 (–1.2 per cent).
- Opex PFP increased on average over the 17-year period (averaging 1.0 per cent per year), but this covers very different trends in the period up to 2012 (with an average annual rate of –2.3 per cent) and after 2012 (with an average increase of 2.9 per cent per annum).

Table 6.5 END's output, input, TFP and PFP indexes, 2006–2022

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	0.949	0.940	0.959
2008	1.015	1.188	0.855	0.771	0.922
2009	1.049	1.167	0.899	0.869	0.923
2010	1.082	1.164	0.930	0.933	0.923
2011	1.108	1.208	0.917	0.908	0.920
2012	1.082	1.241	0.872	0.873	0.869
2013	1.071	1.220	0.878	0.964	0.826
2014	1.109	1.310	0.847	0.884	0.823
2015	1.107	1.336	0.829	0.860	0.808
2016	1.125	1.393	0.808	0.815	0.804
2017	1.177	1.360	0.865	0.930	0.824
2018	1.193	1.326	0.899	1.034	0.819
2019	1.191	1.314	0.907	1.093	0.803
2020	1.179	1.269	0.929	1.211	0.785
2021	1.232	1.312	0.939	1.187	0.807
2022	1.186	1.278	0.928	1.166	0.774
Growth Rate 2006-2022	1.1%	1.5%	-0.5%	1.0%	-1.6%
Growth Rate 2006-2012	1.3%	3.6%	-2.3%	-2.3%	-2.3%
Growth Rate 2012-2022	0.9%	0.3%	0.6%	2.9%	-1.2%
Growth Rate 2022	-3.8%	-2.6%	-1.2%	-1.8%	-4.2%

6.3.2 END's output and input quantity changes

Figure 6.10 graphs the quantity indexes for END's individual outputs. Figure 6.11 graphs quantity indexes for its six individual inputs.

Regarding outputs in Figure 6.10:

- END's circuit length has increased steadily and by 2022 was 22.2 per cent above the 2006 level (compared to a 5.6 per cent increase for the industry over the same period).
- END's energy throughput decreased marginally over the 17-year period, following a similar pattern to the industry. In 2022, END's energy throughput was 2.8 per cent below its level in 2006 (compared to a total *decrease* of 4.0 per cent for the industry over the same period).
- RMD increased from 2006 through to 2011 by 10.1 per cent in total and then increased further in 2017, so that by 2022, RMD was 15.0 per cent above its 2006 level. This pattern is similar to the industry as a whole (an increase of 19.5 per cent in RMD over the same period), reflecting an increase in the ratio of maximum demand to energy throughput in recent years.
- END's customers increased at an average rate of 1.5 per cent per annum from 2006 to 2022, or 27.5 per cent in total, which is similar to the rate of customer growth for the industry (23.6 per cent in total over the same period).
- CMOS's annual growth rate in 2022 was 34.5 per cent, and in that year, CMOS was 17.7 per cent lower than in 2006. This increase between 2006 to 2022 was greater than that for the industry (1.9 per cent total change) over the same period, although CMOS for individual DNSPs is usually volatile (noting that a reduction in CMOS increases output).

Turning to inputs shown in Figure 6.11, we see:

- The quantity of END's opex input increased at an average annual rate of 0.1 per cent over the period from 2006 to 2022, or 1.7 per cent in total over that period. This compares favourably to the industry, for which opex input increased by 6.5 per cent in total over the same period. END's opex increased in the period 2006 to 2012 (averaging 3.6 per cent per annum), substantially offset by a decrease after 2012 (at an average rate of –2.0 per cent per annum).
- Overhead sub-transmission and distribution lines were 1.2 and 3.6 per cent *lower* respectively in 2022 compared to 2006. This contrasts with the industry total increases in these two inputs of 7.3 per cent and 3.1 per cent respectively over the same period. END's underground sub-transmission and distribution cables inputs in 2022 were 143.1 and 132.2 per cent higher than in 2006 respectively. These increases are much higher than those for the industry as a whole for these two inputs (38.5 per cent and 68.0 per cent respectively).
- END's quantity of transformers increased steadily over the 17-year period at an average annual rate of 2.4 per cent, and by 2022 transformer inputs were 47.1 per cent above the 2006 level, which is a larger increase than the industry's 43.1 per cent.

Figure 6.10 END's output quantity indexes, 2006–2022

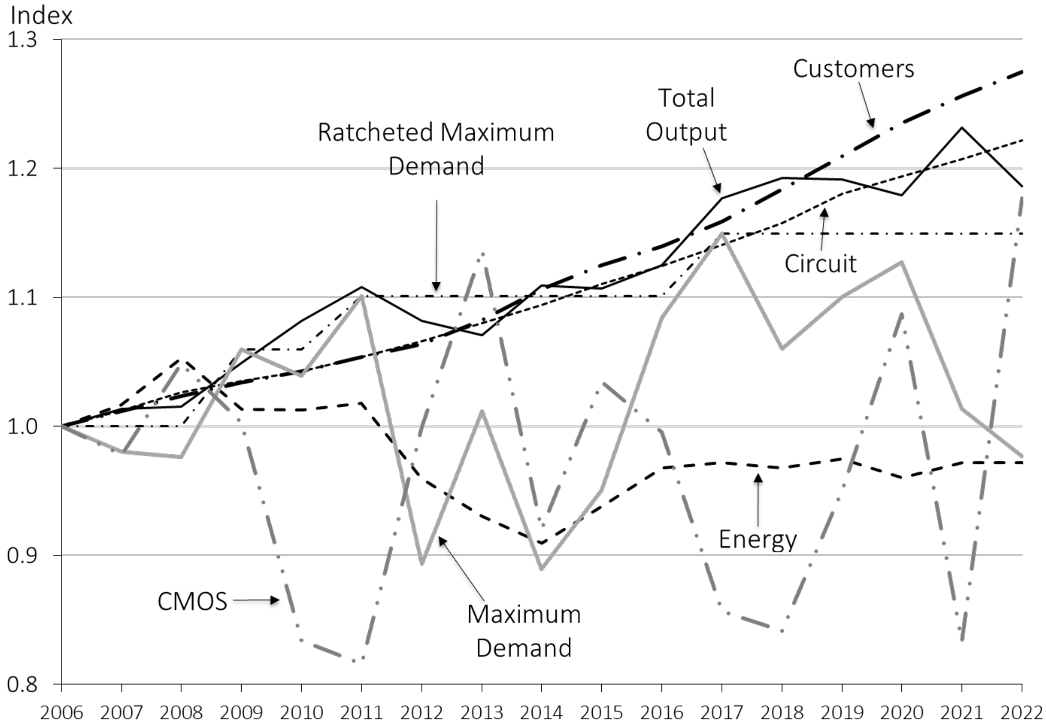
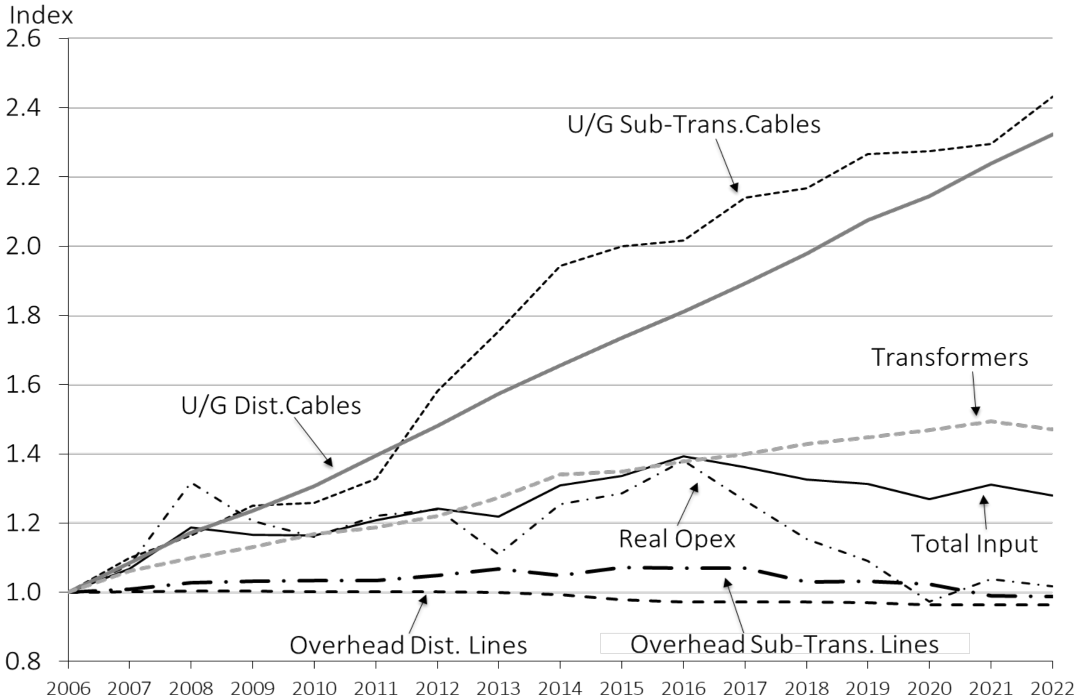


Figure 6.11 END's input quantity indexes, 2006–2022



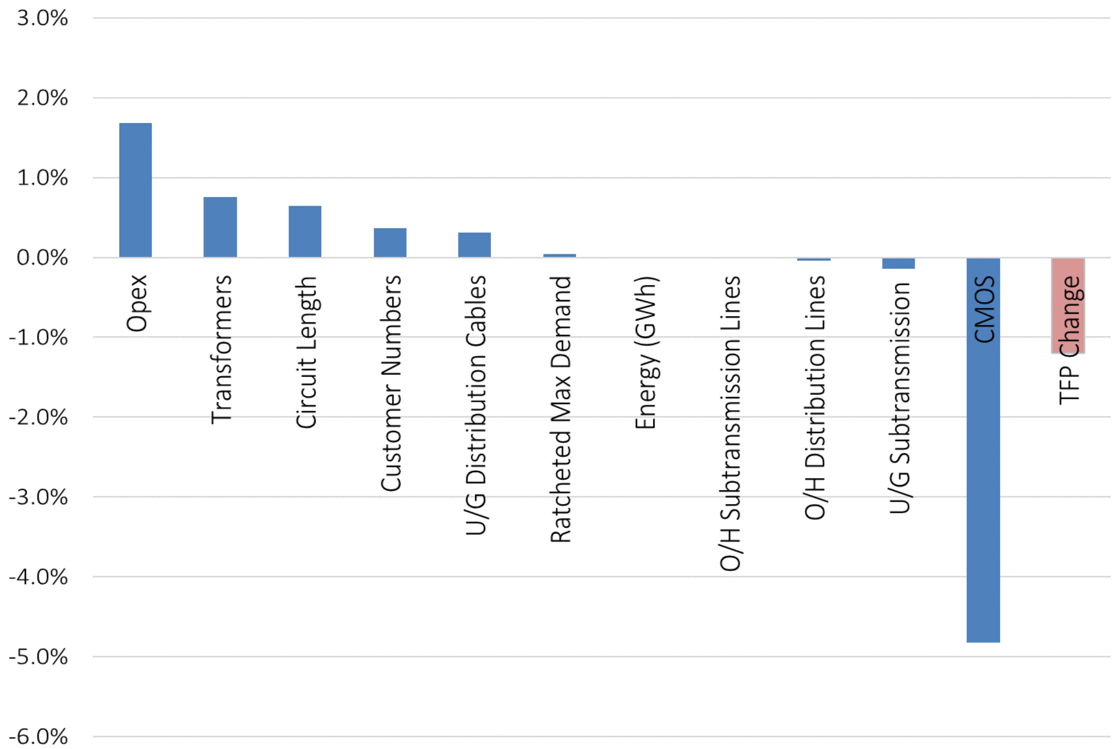
6.3.3 END's output and input contributions to TFP change

Table 6.6 shows the decomposition of END's rate of TFP change into the contributions of the individual outputs and inputs for the whole 17-year period, for the periods up to and after 2012, and for 2022. Figure 6.12 shows the contributions of outputs and inputs to END's rate of TFP change of -1.2 per cent in 2022.

Table 6.6 END's output and input percentage point contributions to average annual TFP change: various periods

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2021 to 2022*
Energy (GWh)	-0.02%	-0.07%	0.01%	0.00%
Ratcheted Max Demand	0.34%	0.63%	0.17%	0.05%
Customer Numbers	0.33%	0.23%	0.38%	0.37%
Circuit Length	0.57%	0.49%	0.61%	0.64%
CMOS	-0.15%	0.03%	-0.26%	-4.82%
Opex	0.01%	-1.43%	0.86%	1.68%
O/H Sub-transmission Lines	0.01%	-0.03%	0.03%	-0.01%
O/H Distribution Lines	0.02%	0.00%	0.03%	-0.04%
U/G Sub-transmission Cables	-0.11%	-0.14%	-0.09%	-0.14%
U/G Distribution Cables	-0.80%	-1.07%	-0.63%	0.31%
Transformers	-0.66%	-0.94%	-0.50%	0.76%
TFP Change	-0.47%	-2.29%	0.62%	-1.20%

Figure 6.12 END's output and input percentage point contributions to TFP change, 2022



6.4 Energex (ENX)

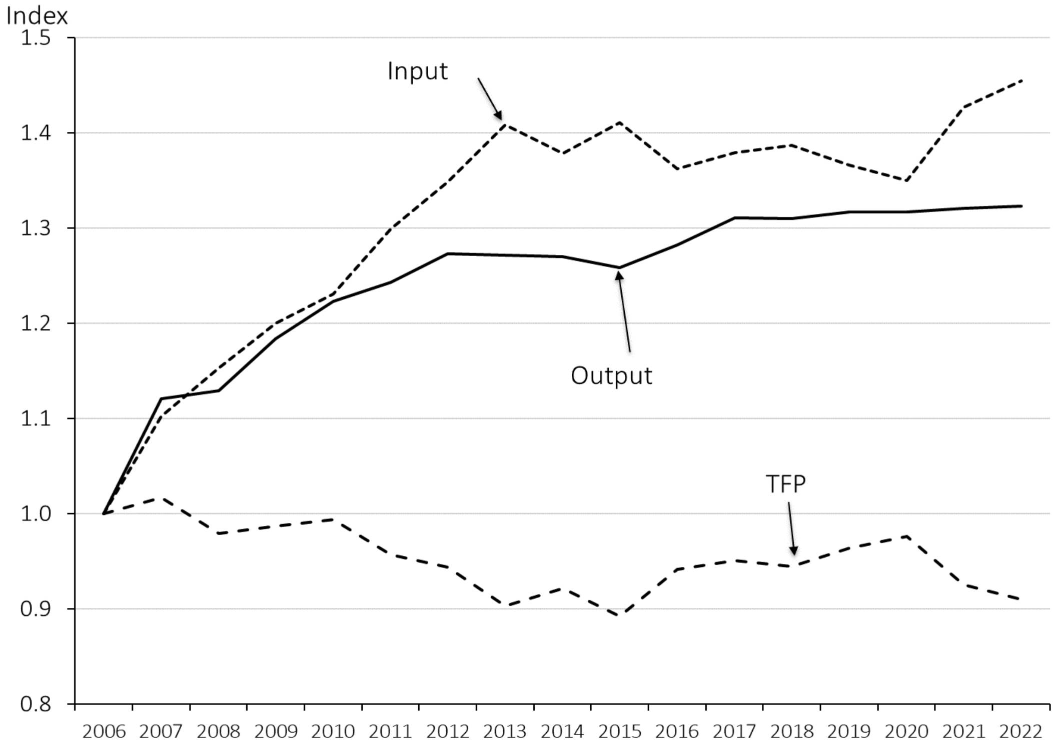
In 2022, ENX delivered 21,295 GWh to 1.57 million customers over 55,887 circuit kilometres of lines and cables. ENX distributes electricity in Southeast Queensland including the major urban areas of Brisbane, Gold Coast, Sunshine Coast, Logan, Ipswich, Redlands and Moreton Bay. ENX's electricity distribution 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.

6.4.1 ENX's productivity performance

ENX's total output, total input and TFP indexes are presented in Figure 6.13 and Table 6.7. Opex and capital PFP indexes are also presented in Table 6.7.

Over the whole period from 2006 to 2022, ENX's TFP *decreased* at an annual rate of 0.6 per cent similar to the industry's average annual change of –0.3 over the same period. As Figure 5.13 shows, ENX's TFP decreased significantly in the period from 2006 to 2012, on average at –1.0 per cent per year, and decreased more slowly in the period from 2012 to 2022, an average growth rate of –0.4 per cent per year. This differs from the industry average TFP trends, which deteriorated at a higher rate in the period up to 2012 and saw TFP growth in the period after 2012.

Figure 6.13 ENX's output, input and TFP indexes, 2006–2022



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, reducing to 0.4 per cent per annum after 2012. The average output growth of 1.7 per cent per annum over the whole 17-year period is considerably 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 0.8 per cent per annum from 2012 to 2022. The average rate of increase in inputs of 2.3 per cent per annum over the 17-year period is also much higher than the industry's average input increase of 1.2 per cent per annum. These output and input trends resulted in ENX's TFP trends previously discussed.

The PFP indexes in Table 6.7 show the following trends:

- Capital PFP declined on average by 0.6 per cent per year from 2006 to 2022, 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 increased at a rate of 0.7 per cent per annum after 2012. On average over the full period, opex PFP averaged an annual rate of change of –0.6 per cent.

Table 6.7 ENX's output, input, TFP and PFP indexes, 2006–2022

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.120	1.102	1.017	0.964	1.050
2008	1.129	1.153	0.979	0.932	1.010
2009	1.184	1.200	0.987	0.941	1.014
2010	1.223	1.231	0.994	0.961	1.013
2011	1.243	1.299	0.956	0.888	0.998
2012	1.273	1.348	0.944	0.850	0.999
2013	1.272	1.408	0.903	0.793	0.977
2014	1.270	1.379	0.921	0.863	0.959
2015	1.258	1.410	0.892	0.838	0.924
2016	1.282	1.362	0.941	0.961	0.930
2017	1.311	1.379	0.950	0.977	0.936
2018	1.310	1.387	0.944	0.973	0.927
2019	1.316	1.366	0.964	1.037	0.924
2020	1.317	1.350	0.976	1.094	0.912
2021	1.320	1.427	0.926	0.954	0.907
2022	1.323	1.454	0.910	0.912	0.903
Growth Rate 2006-2022	1.7%	2.3%	-0.6%	-0.6%	-0.6%
Growth Rate 2006-2012	4.0%	5.0%	-1.0%	-2.7%	0.0%
Growth Rate 2012-2022	0.4%	0.8%	-0.4%	0.7%	-1.0%
Growth Rate 2022	0.2%	1.9%	-1.7%	-4.5%	-0.5%

6.4.2 ENX's output and input quantity changes

Figure 6.14 graphs the quantity indexes for ENX's individual outputs. Figure 6.15 graphs quantity indexes for its six individual inputs.

Regarding outputs in Figure 6.14:

- ENX's circuit length output increased in total by 19.8 per cent between 2006 to 2022 (which is higher than the industry increase of 5.6 per cent over the same period).
- ENX's energy throughput increased marginally over the 17-year period, by 3.3 per cent in total from 2006 to 2022 (compared to a *decline* of 4.0 per cent for the industry over the same period).
- On average ENX's RMD increased considerably up to 2010 but remained constant for most subsequent years except for a small further increase in 2020 and 2022. In 2022 it was 32.0 per cent above its level in 2006. This is a larger increase than for the industry as a whole (19.5 per cent over the same period).
- ENX's customers output increased by 29.5 per cent in total from 2006 to 2022, or 1.6 per cent per year, which is slightly higher than industry customer growth (23.6 per cent in total, or 1.3 per cent per annum).
- CMOS *decreased* over the 17-year period 2006 to 2022 by 10.8 per cent in total. This compares to the industry average increase in CMOS of 1.9 per cent over the same period, and thus represents an above average improvement in reliability by ENX.

Turning to inputs shown in Figure 6.15, we see:

- The quantity of ENX's opex increased at an average annual rate of 2.3 per cent from 2006 to 2022. In 2022 opex input was 45.1 per cent above its 2006 level. This compares unfavourably to the industry, for which opex input increased by 6.5 per cent in total over the same period.
- Overhead sub-transmission and distribution lines in 2022 were 25.7 per cent and 2.7 per cent higher respectively, than in 2006 (compared to the industry increases of 7.3 per cent and 3.1 per cent respectively over the same period).
- ENX's underground sub-transmission and distribution cables in 2022 were 95.8 and 89.2 per cent higher than in 2006 respectively (compared to increases of 38.5 per cent and 68.0 per cent respectively for the industry as a whole over the same period).
- ENX's quantity of transformer inputs increased strongly over the 17-year period at an average annual rate of 2.6 per cent, and by 2022 transformer inputs were 50.8 per cent above the 2006 level; a larger increase than the industry's 43.1 per cent over the same period.

Figure 6.14 ENX's output quantity indexes, 2006–2022

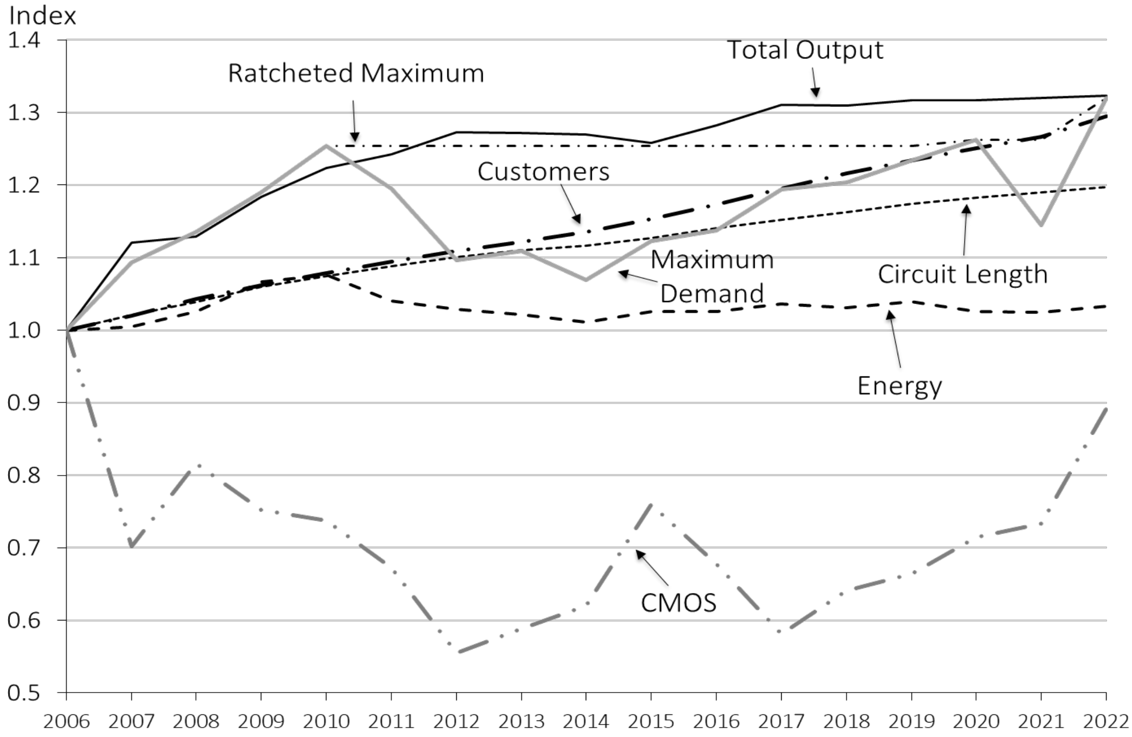
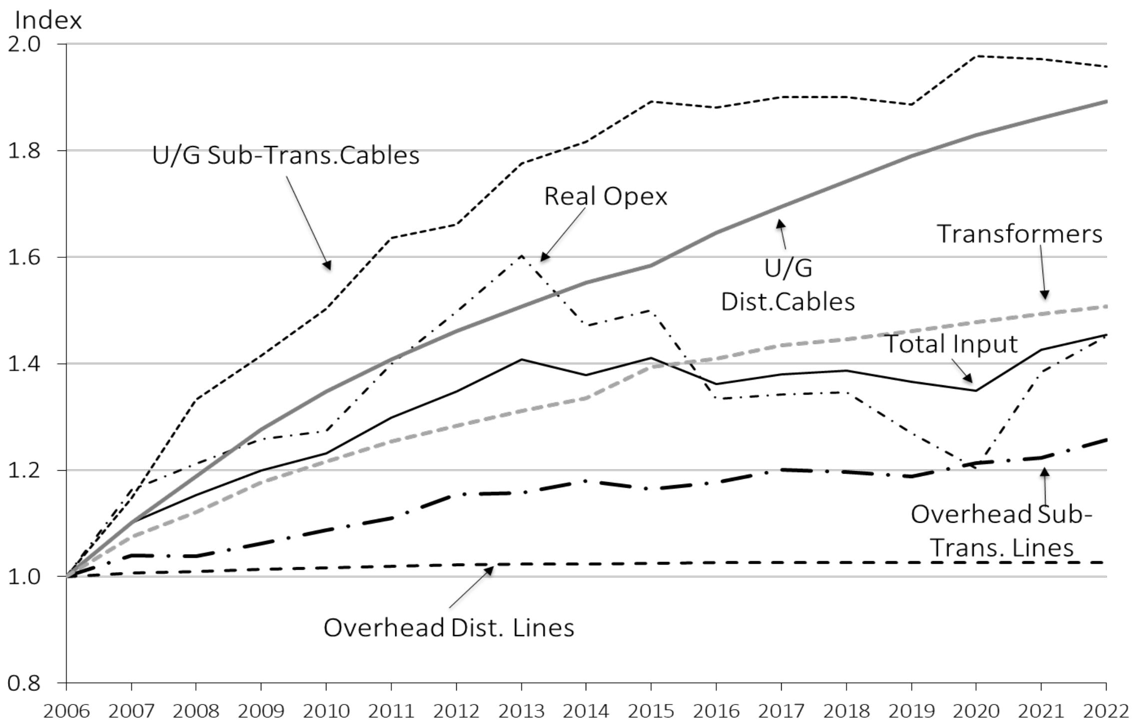


Figure 6.15 ENX's input quantity indexes, 2006–2022



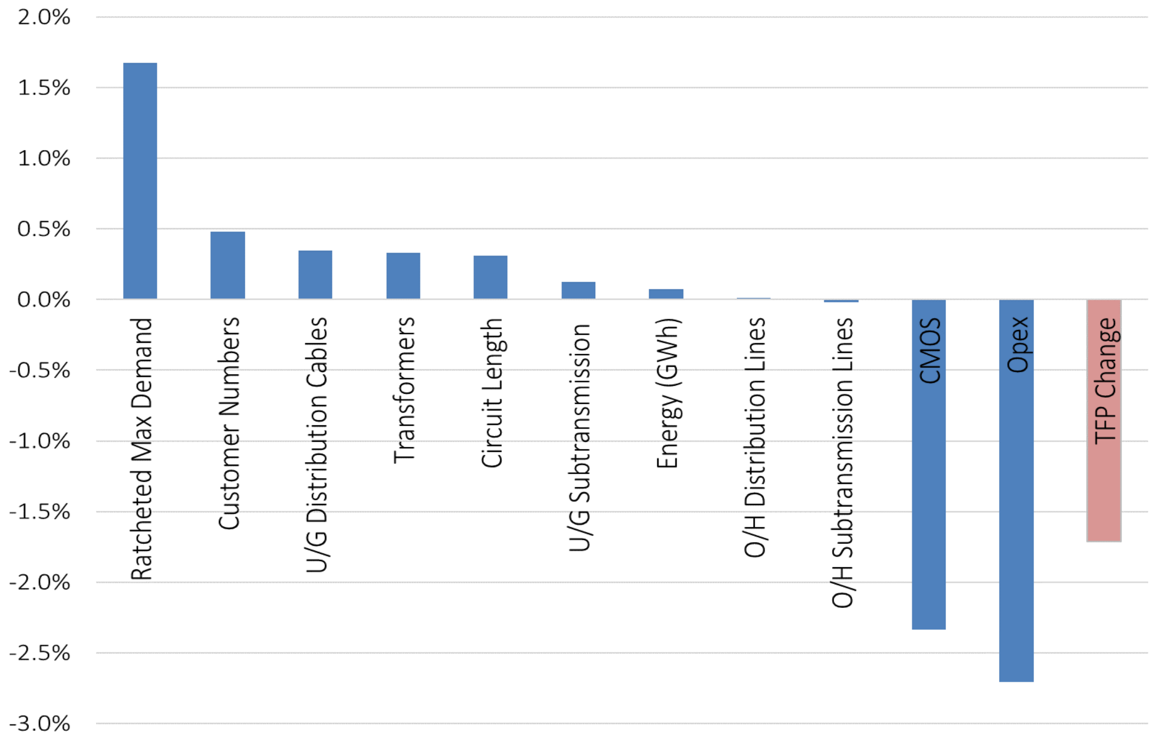
6.4.3 ENX's output and input contributions to TFP change

Table 6.8 shows the decomposition of ENX's rate of TFP change into the contributions of the individual outputs and inputs for the whole 17-year period, for the periods up to and after 2012, and for 2022. Figure 6.16 shows the contributions of outputs and inputs to ENX's rate of TFP change of –1.7 per cent between 2021 and 2022.

Table 6.8 ENX's output and input percentage point contributions to average annual TFP change: various periods

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2021 to 2022*
Energy (GWh)	0.02%	0.05%	0.00%	0.07%
Ratcheted Max Demand	0.68%	1.48%	0.20%	1.67%
Customer Numbers	0.34%	0.38%	0.32%	0.48%
Circuit Length	0.51%	0.74%	0.37%	0.31%
CMOS	0.20%	1.37%	-0.50%	-2.34%
Opex	-0.92%	-2.43%	-0.02%	-2.71%
O/H Sub-transmission Lines	-0.04%	-0.08%	-0.02%	-0.02%
O/H Distribution Lines	-0.02%	-0.05%	0.00%	0.01%
U/G Sub-transmission Cables	-0.18%	-0.38%	-0.06%	0.13%
U/G Distribution Cables	-0.42%	-0.73%	-0.23%	0.34%
Transformers	-0.75%	-1.31%	-0.42%	0.33%
TFP Change	-0.59%	-0.96%	-0.37%	-1.71%

Figure 6.16 ENX's output and input percentage point contributions to TFP change in 2022



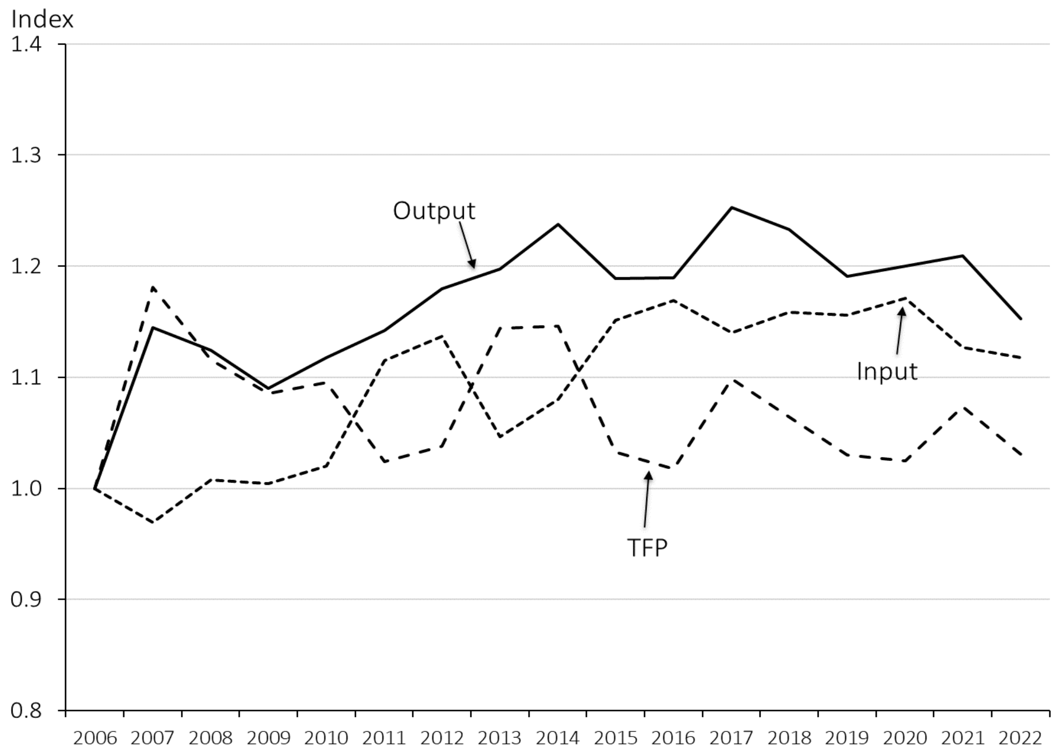
6.5 Ergon Energy (ERG)

In 2022, ERG delivered 13,780 GWh to 776,533 customers over 154,176 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.

6.5.1 ERG's productivity performance

ERG's total output, total input and TFP indexes are presented in Figure 6.17 and Table 6.9. Opex and capital PFP indexes are also presented in Table 6.9.

Figure 6.17 ERG's output, input and total factor productivity indexes, 2006–2022



Over the 17-year period 2006 to 2022, ERG's TFP increased at an average annual rate of change of 0.2 per cent. This compares favourably to the industry's average annual TFP change of –0.3 per cent over the same period. In some years there have been large increases in ERG's TFP, such as 2007, 2013 and 2017, and other years have seen substantial decreases, including 2008, 2011 and 2015.

ERG's total output increased over the 17-year period at an average annual rate 0.9 per cent, which is the same the industry average output growth rate per annum. ERG's average annual rate of increase in input use of 0.7 per cent over the 17-year period is lower than the average rate of increase in industry total input use of 1.2 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 2.1 per cent per year respectively) than in the period 2012 to 2022 (where they averaged both –0.2 per cent per year). The average rate of TFP change from 2006 to 2012 was 0.6 per cent per year, while from 2012 to 2022 it averaged an increase of –0.1 per cent per annum.

The PFP indexes in Table 6.9 show that Opex PFP has improved at an average annual rate of 1.5 per cent over the 17-year period. Capital PFP improved slightly in the period from 2006 to 2012 (at an average annual rate of 0.4 per cent) but deteriorated after 2012; with an average rate of change of –1.4 per cent per annum. The average trend growth rate in capital MPFP over the 17-year period was –0.8 per cent per annum.

Table 6.9 ERG's output, input, TFP and PFP indexes, 2006–2022

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.145	0.970	1.181	1.286	1.117
2008	1.124	1.007	1.116	1.179	1.079
2009	1.090	1.004	1.085	1.185	1.023
2010	1.118	1.020	1.096	1.242	1.013
2011	1.142	1.115	1.024	1.032	1.014
2012	1.180	1.137	1.038	1.044	1.022
2013	1.197	1.046	1.144	1.333	1.043
2014	1.238	1.080	1.146	1.372	1.028
2015	1.189	1.152	1.032	1.144	0.967
2016	1.189	1.169	1.017	1.136	0.948
2017	1.253	1.140	1.099	1.329	0.980
2018	1.233	1.158	1.065	1.273	0.953
2019	1.191	1.156	1.030	1.222	0.927
2020	1.200	1.171	1.025	1.187	0.934
2021	1.209	1.127	1.073	1.369	0.928
2022	1.152	1.118	1.031	1.281	0.886
Growth Rate 2006-2022	0.9%	0.7%	0.2%	1.5%	-0.8%
Growth Rate 2006-2012	2.8%	2.1%	0.6%	0.7%	0.4%
Growth Rate 2012-2022	-0.2%	-0.2%	-0.1%	2.0%	-1.4%
Growth Rate 2022	-4.8%	-0.8%	-4.0%	-6.6%	-4.6%

6.5.2 ERG's output and input quantity changes

Figure 6.18 graphs the quantity indexes for ERG's individual outputs. Figure 6.19 graphs quantity indexes for its six individual inputs.

Regarding outputs in Figure 6.18:

- ERG's circuit length output increased by 3.9 per cent in total between 2006 and 2022 (compared to a total increase of 5.6 per cent for the industry over the same period).
- ERG's energy throughput in 2022 was 2.2 per cent higher than in 2006. This compares to the industry's total reduction in energy throughput of 4.0 per cent over the same period.
- The increase of ERG's RMD output from 2006 to 2022 was 15.5 per cent. All of this increase occurred in the period up to 2010. The timing and size of this RMD increase is broadly similar to that for the industry (a 19.5 per cent increase over the period 2006 to 2022, concentrated in the period before 2012).
- ERG's customers increased at an average annual rate of 1.4 per cent from 2006 to 2022, or 24.4 per cent in total, which is similar to customer growth for the industry over the same period (1.3 per cent per annum, or 23.6 per cent in total).
- CMOS increased for ERG over the 17-year period to 2022 by 2.8 per cent in total, which is comparable to the industry CMOS increase of 1.9 per cent over the same period.

Turning to inputs shown in Figure 6.19, we see:

- The quantity of ERG's opex input *decreased* by 10.0 per cent in total between 2006 and 2022, which represents an average annual rate of change of –0.7 per cent. This compares favourably to the industry, for which opex input increased by 6.5 per cent in total over the 17-year 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 2.3 per cent per annum.
- Overhead sub-transmission and distribution lines in 2022 were 2.8 per cent and 16.3 per cent higher respectively, than in 2006. These changes compare to the industry increases of 7.3 per cent and 3.1 per cent respectively over the same period.
- ERG's underground sub-transmission and distribution cables in 2022 were 75.4 and 110.4 per cent higher than in 2006 respectively. These increases are higher than those for the industry as a whole, namely 38.5 per cent and 68.0 per cent respectively over the same period.
- ERG's quantity of transformer inputs increased steadily over most of the 17-year period, plateauing from 2017. The average annual rate of change from 2006 to 2022 was 2.3 per cent, an increase of 44.0 per cent in total (compared to the industry's 43.1 per cent increase over the same period). Transformers is the input with the largest weight in the capital input index.

Figure 6.18 ERG's output quantity indexes, 2006–2022

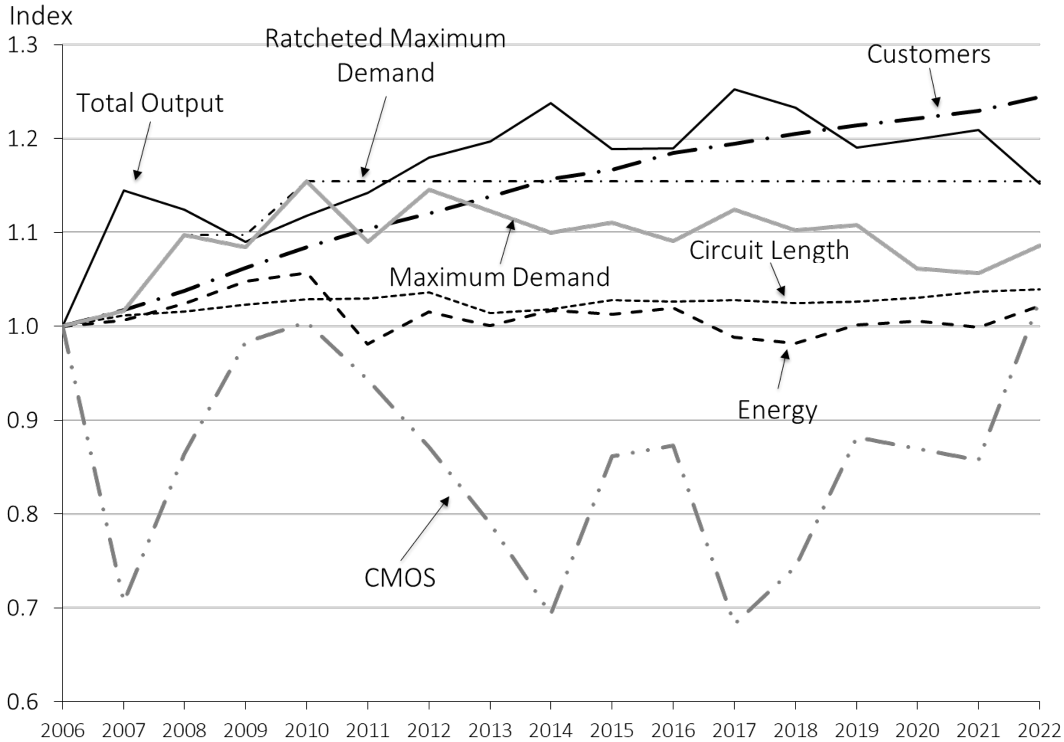
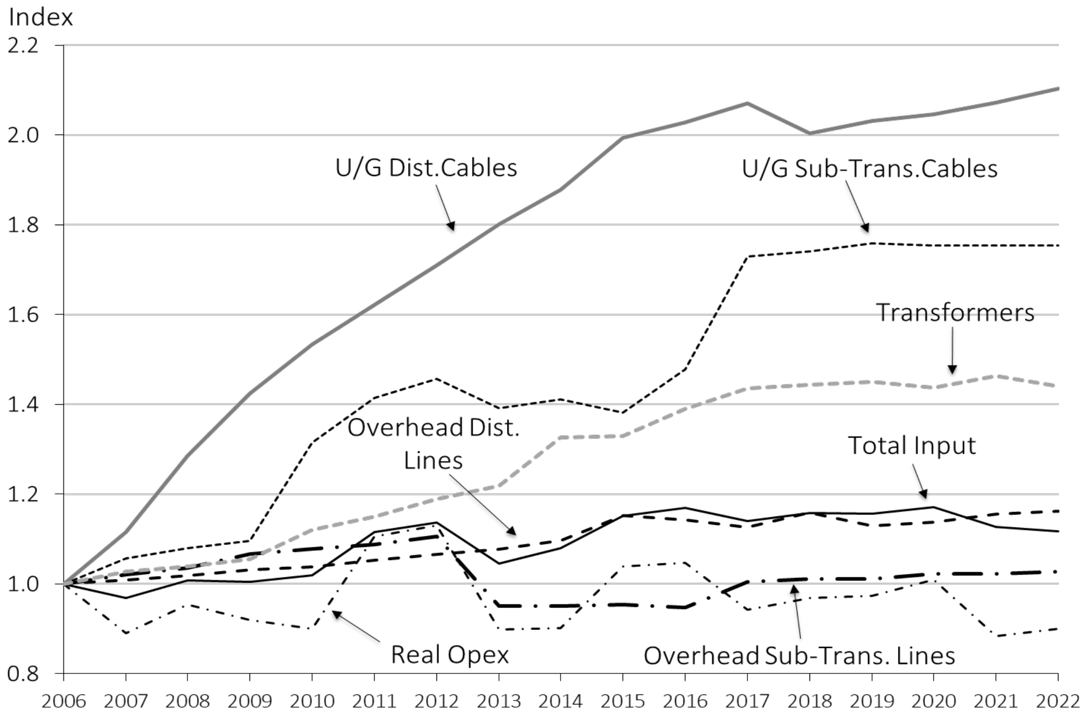


Figure 6.19 ERG's input quantity indexes, 2006–2022



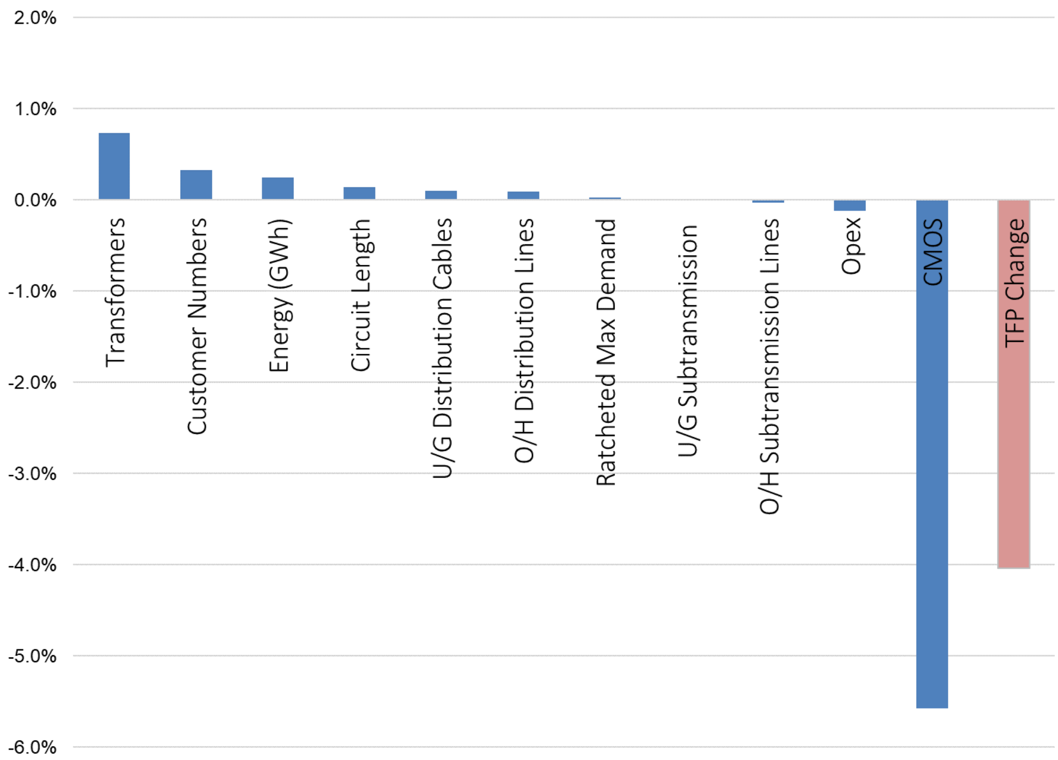
6.5.3 ERG's output and input contributions to TFP change

Table 6.10 shows the decomposition of ERG's rate of TFP change into the contributions of the individual outputs and inputs for the whole 17-year period, for the periods up to and after 2012, and for 2022. Figure 6.20 shows the contributions of outputs and inputs to ERG's rate of TFP change of –4.0 per cent in 2022.

Table 6.10 ERG's output and input percentage point contributions to average annual TFP change: various sources

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2021 to 2022*
Energy (GWh)	0.02%	0.03%	0.01%	0.25%
Ratcheted Max Demand	0.41%	1.09%	0.00%	0.02%
Customer Numbers	0.34%	0.48%	0.25%	0.33%
Circuit Length	0.13%	0.31%	0.02%	0.14%
CMOS	0.00%	0.85%	-0.52%	-5.57%
Opex	0.28%	-0.68%	0.85%	-0.12%
O/H Sub-transmission Lines	-0.01%	-0.17%	0.08%	-0.03%
O/H Distribution Lines	-0.19%	-0.22%	-0.17%	0.09%
U/G Sub-transmission Cables	-0.01%	-0.02%	-0.01%	0.01%
U/G Distribution Cables	-0.13%	-0.27%	-0.05%	0.10%
Transformers	-0.63%	-0.78%	-0.54%	0.73%
TFP Change	0.19%	0.62%	-0.07%	-4.04%

Figure 6.20 ERG's output and input percentage point contributions to TFP change, 2022



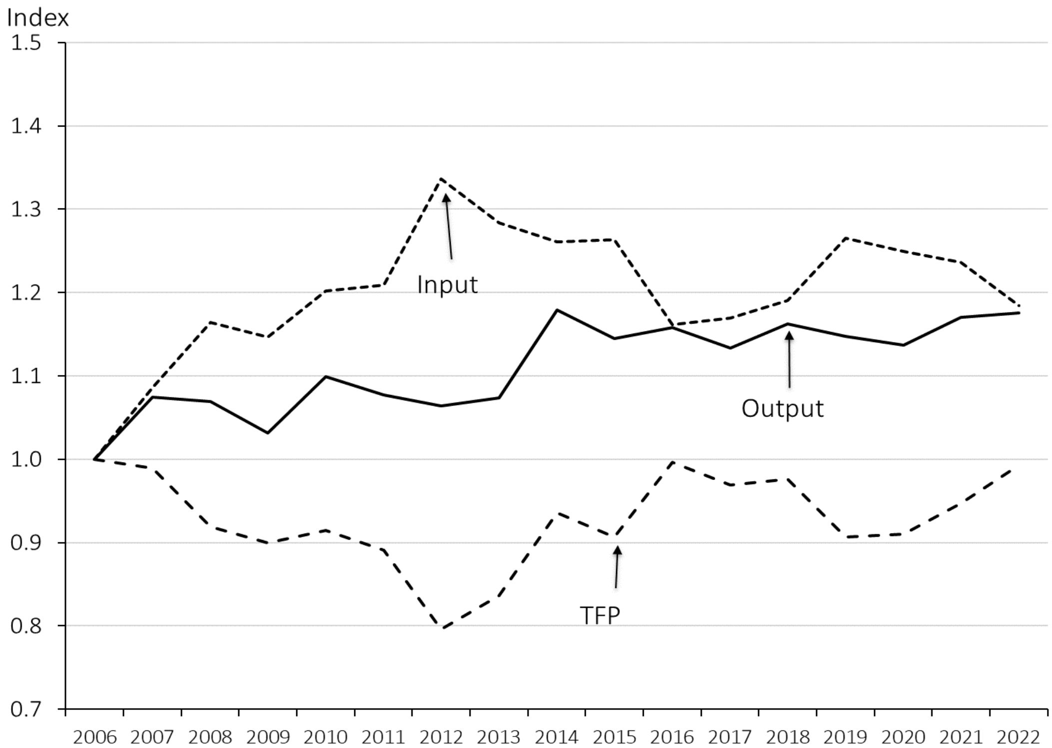
6.6 Essential Energy (ESS)

In 2022, ESS delivered 12,451 GWh to 945,393 customers over 193,124 circuit kilometres of lines and cables. ESS distributes electricity throughout 95 per cent of New South Wales's 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.

6.6.1 ESS's productivity performance

ESS's total output, total input and TFP indexes are presented in Figure 6.21 and Table 6.11. Opex and capital PFP indexes are also presented in Table 6.11.

Figure 6.21 ESS's output, input and TFP indexes, 2006–2022



Over the 17-year period 2006 to 2022, ESS's TFP average annual rate of change was zero per cent. This compares favourably to the industry's average annual change of –0.3 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 –3.8 per cent per year. However, in the period 2012 to 2022, ESS's TFP increased at an average rate of 2.2 per cent per year. Its TFP increase in 2022 was 4.7 per cent.

ESS's total output increased over the 17-year period at an average annual rate of 1.0 per cent (similar to the 0.9 per cent of industry average over the same period). ESS's average annual rate of increase in input use was 1.1 per cent in the period 2006 to 2022, which is similar to the industry's rate of increase in total input use (1.2 per cent per year). Whereas output growth was at a reasonably steady rate, input use increased mostly in the period up to 2012 (at an average annual rate of 4.8 per cent) and had then a decrease, with the average rate of change being –1.2 from 2012 to 2022.

The PFP indexes in Table 6.11 show the following trends:

- Capital PFP *declined* on average rate of 0.2 per cent per year from 2006 to 2022. The decline was greater in the period up to 2012, averaging –0.6 per cent per annum. After 2012, Capital PFP averaged zero per cent per annum
- 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 4.9 per cent per annum after 2012. Over the full period, Opex PFP averaged zero per cent per annum.

Table 6.11 ESS's output, input, TFP and PFP indexes, 2006–2022

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.075	1.086	0.990	0.895	1.062
2008	1.069	1.164	0.919	0.757	1.056
2009	1.031	1.146	0.900	0.781	0.995
2010	1.099	1.202	0.915	0.777	1.022
2011	1.077	1.209	0.891	0.763	0.989
2012	1.064	1.336	0.796	0.609	0.965
2013	1.073	1.284	0.836	0.679	0.962
2014	1.179	1.261	0.935	0.786	1.052
2015	1.145	1.263	0.906	0.780	1.007
2016	1.158	1.161	0.997	1.000	1.005
2017	1.134	1.170	0.969	0.973	0.978
2018	1.163	1.191	0.976	0.950	0.999
2019	1.147	1.265	0.907	0.826	0.969
2020	1.137	1.250	0.910	0.850	0.954
2021	1.171	1.236	0.947	0.907	0.976
2022	1.175	1.184	0.993	0.995	0.970
Growth Rate 2006-2022	1.0%	1.1%	0.0%	0.0%	-0.2%
Growth Rate 2006-2012	1.0%	4.8%	-3.8%	-8.3%	-0.6%
Growth Rate 2012-2022	1.0%	-1.2%	2.2%	4.9%	0.0%
Growth Rate 2022	0.4%	-4.3%	4.7%	9.3%	-0.6%

6.6.2 ESS's output and input quantity changes

Figure 6.22 graphs the quantity indexes for ESS's individual outputs. Figure 6.23 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 3.2 per cent in total between 2006 and 2022. This compares to a total increase of 5.6 per cent for the industry over the same period.
- ESS's energy throughput increased at an average annual rate of 0.2 per cent per year over the 17-year period, or 4.1 per cent in total (compared to a total decline of 4.0 per cent for the industry over the same period).
- ESS's RMD increased by 24.5 per cent in total between 2006 and 2022. This shows that maximum demand has grown much more strongly than energy throughput, especially in the period from 2012 to 2022. Consequently, RMD grew at an average annual rate of 1.7 per cent from 2012 to 2022, whereas energy throughput increased at an average annual rate of 0.5 per cent over this period.
- ESS's customers output increased at an average rate of 1.1 per cent per annum over the 17-year period, or 18.3 per cent in total, which is less than the average rate of customer growth for the industry over the same period (23.6 per cent in total).
- CMOS *decreased* over the 17-year period by 13.0 per cent in total, which is less than the industry increase of 1.9 per cent in total.

Turning to inputs shown in Figure 6.23, we see:

- The quantity of ESS's opex increased at an average annual rate of 1.0 per cent over the period from 2006 to 2022, or 18.1 per cent in total. This compares unfavourably to the industry, for which opex input increased by 6.5 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 -3.9 per cent per annum.
- Overhead sub-transmission and distribution lines in 2022 were 12.4 per cent higher and 4.4 per cent lower, respectively, than in 2006. These changes are compared to the industry increases of 7.3 per cent and 3.1 per cent respectively over the same period.
- ESS's underground sub-transmission and distribution cables inputs in 2022 were 57.8 and 35.7 per cent higher than in 2006 respectively. These changes are compared to the industry as a whole, increases of 38.5 per cent and 68.0 per cent respectively over the same period.
- ESS's quantity of transformer inputs increased over the 17-year period at an average annual rate of 2.2 per cent, and by 2022, transformer inputs were 41.2 per cent above the 2006 level, similar to the industry's 43.1 per cent increase.

Figure 6.22 ESS's output quantity indexes, 2006–2022

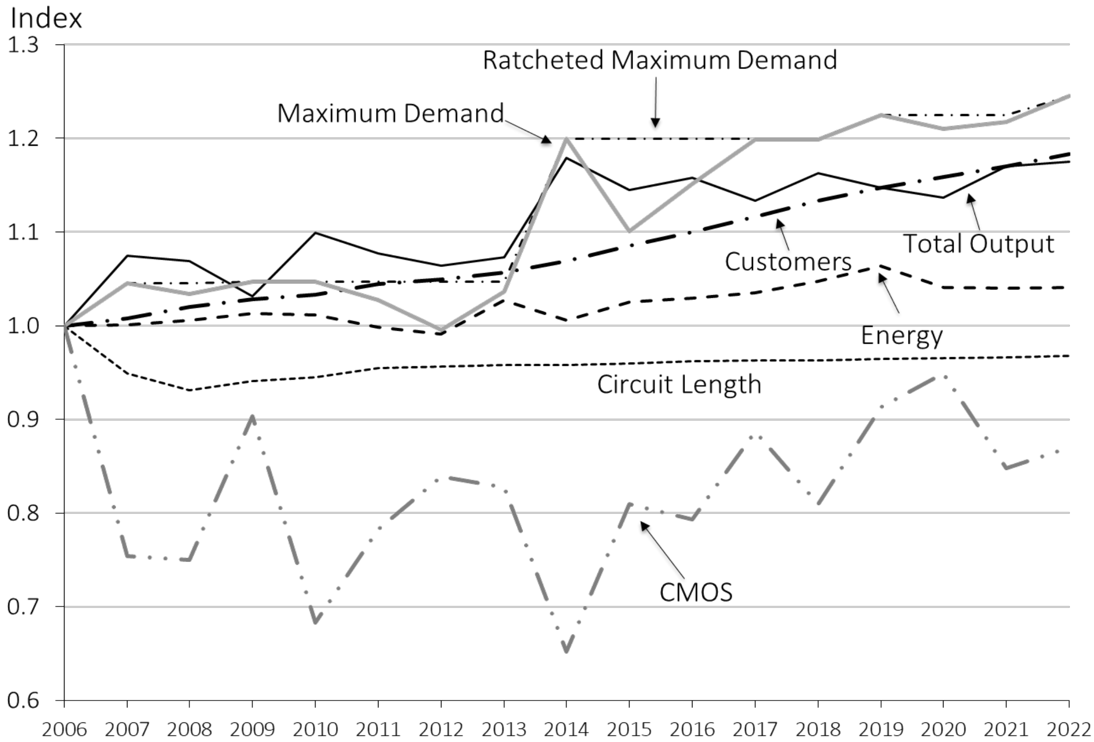
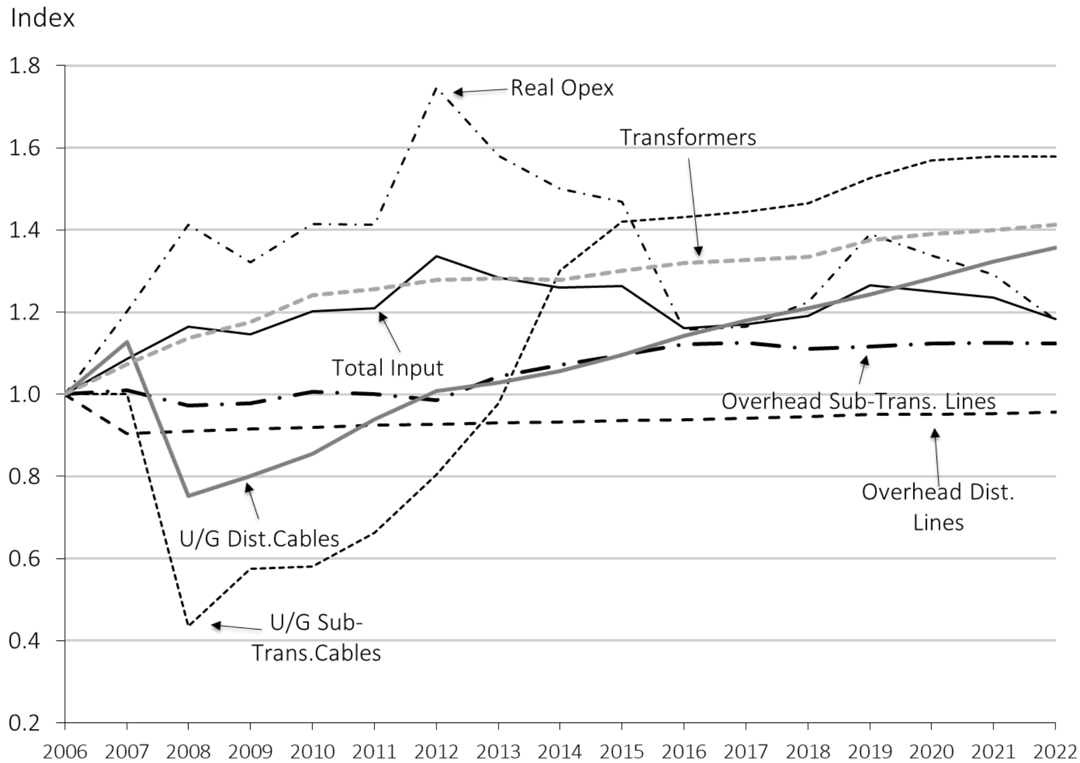


Figure 6.23 ESS's input quantity indexes, 2006–2022



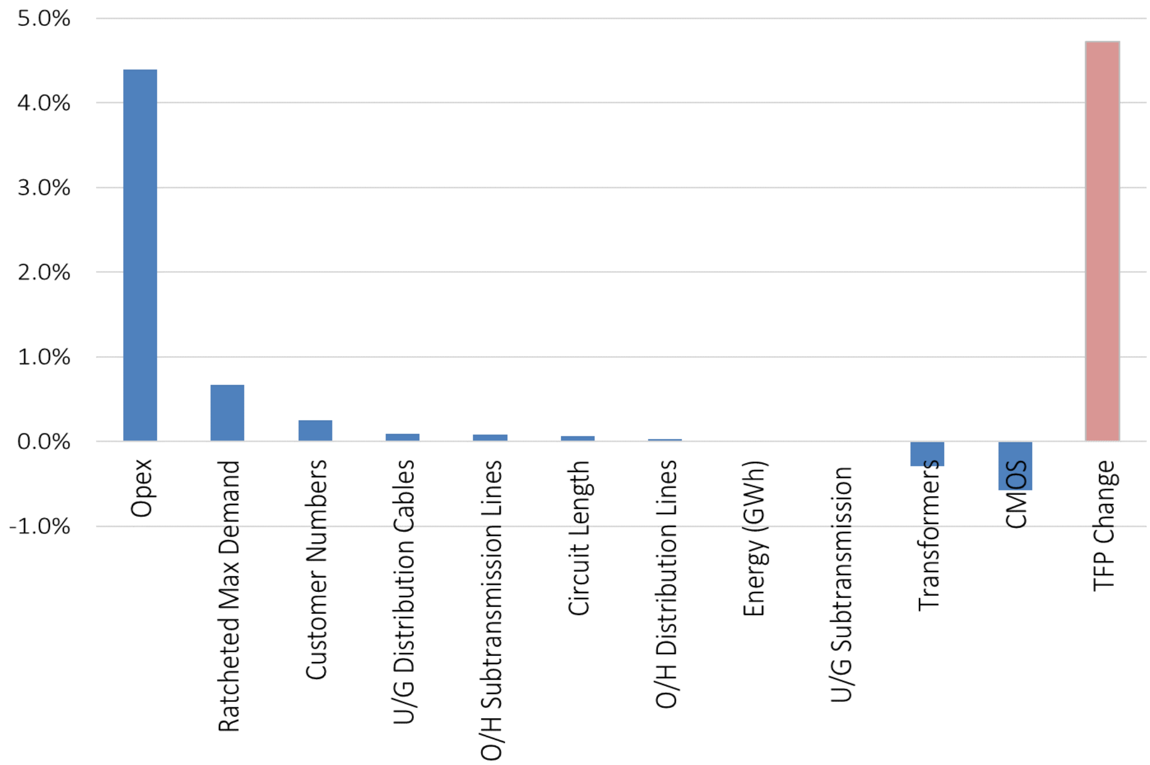
6.6.3 ESS's output and input contributions to TFP change

Table 6.12 shows the decomposition of ESS's rate of TFP change into the contributions of the individual outputs and inputs for the whole 17-year period, for the periods up to and after 2012, and for 2021. Figure 6.24 shows the contributions of outputs and inputs to ESS's rate of TFP change of 4.7 per cent in 2022.

Table 6.12 ESS's output and input percentage point contributions to average annual TFP change: various periods

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2021 to 2022*
Energy (GWh)	0.03%	-0.01%	0.05%	0.01%
Ratcheted Max Demand	0.58%	0.37%	0.71%	0.67%
Customer Numbers	0.24%	0.20%	0.27%	0.25%
Circuit Length	-0.10%	-0.37%	0.06%	0.06%
CMOS	0.26%	0.85%	-0.09%	-0.57%
Opex	-0.38%	-3.87%	1.71%	4.39%
O/H Sub-transmission Lines	-0.05%	0.01%	-0.08%	0.08%
O/H Distribution Lines	0.05%	0.23%	-0.05%	0.03%
U/G Sub-transmission Cables	-0.01%	0.01%	-0.01%	0.00%
U/G Distribution Cables	-0.06%	0.00%	-0.09%	0.09%
Transformers	-0.61%	-1.20%	-0.26%	-0.29%
TFP Change	-0.05%	-3.80%	2.20%	4.72%

Figure 6.24 ESS's output and input percentage point contributions to TFP change, 2022



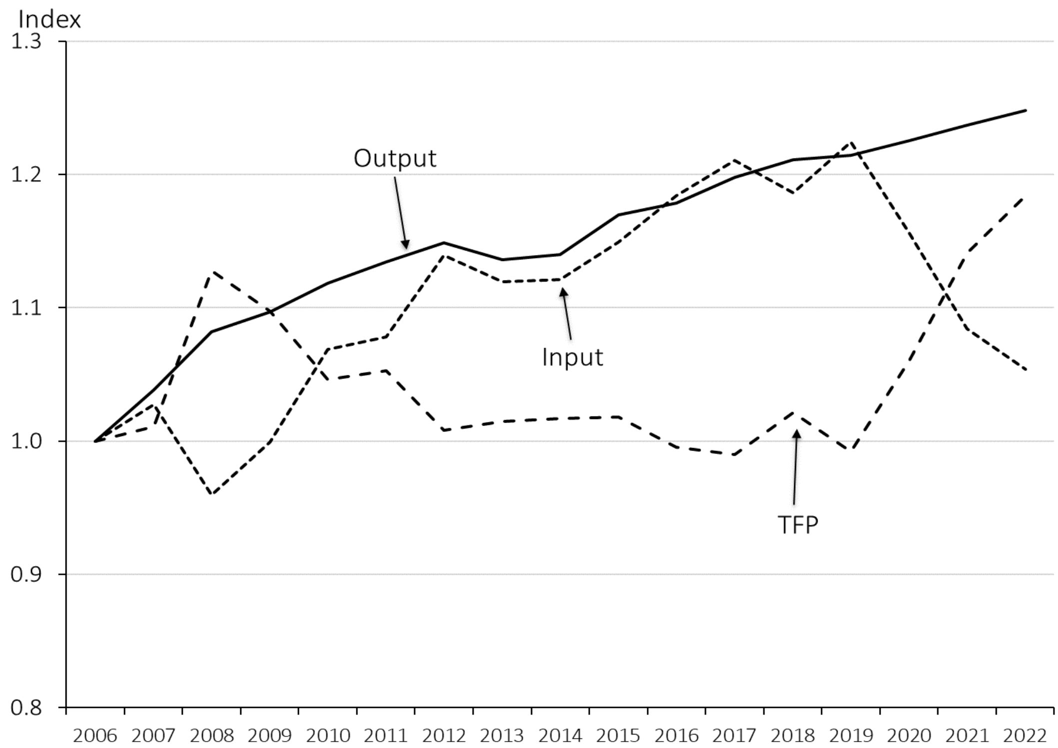
6.7 Jemena Electricity Networks (JEN)

In 2022, JEN delivered 4,256 GWh to 374,388 customers over 6,818 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.

6.7.1 JEN's productivity performance

JEN's total output, total input and TFP indexes are presented in Figure 6.25 and Table 6.13. Opex and capital PFP indexes are also presented in Table 6.13.

Figure 6.25 JEN's output, input, and TFP indexes, 2006–2022



Over the 17-year period 2006 to 2022, JEN's TFP increased at an average annual rate of change of 1.1 per cent per annum. This compares favourably to the industry's average annual change of –0.3 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 2022, the rate of increase was 1.7 per cent per annum.

JEN's total output increased over 17-year period at an average annual rate of 1.4 per cent, which 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 0.3 per cent over the same period is lower than for the industry (1.2 per cent per year). JEN's 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 0.9 per cent per annum). Its 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 –0.8 per cent per annum).

The PFP indexes in Table 6.13 show the following trends:

- Capital PFP increased marginally, at an average rate of 0.1 per cent per year, from 2006 to 2022. In the period up to 2012, Capital PFP increased at a rate of 1.0 per cent per annum, whilst in the period after 2012, the rate of change in Capital PFP averaged –0.4 per cent per annum.
- Opex PFP increased on average at a rate of 2.6 per cent per annum from 2006 to 2022. 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 4.9 per cent per annum after 2012.

Table 6.13 JEN's output, input, TFP and PFP indexes, 2006–2022

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	1.028	1.011	0.984	1.034
2008	1.082	0.959	1.128	1.269	1.043
2009	1.097	0.999	1.098	1.179	1.039
2010	1.118	1.069	1.046	1.025	1.061
2011	1.135	1.078	1.052	1.054	1.051
2012	1.149	1.140	1.008	0.940	1.065
2013	1.136	1.120	1.015	0.971	1.047
2014	1.140	1.121	1.017	0.988	1.037
2015	1.170	1.149	1.018	0.988	1.040
2016	1.179	1.184	0.995	0.941	1.034
2017	1.198	1.210	0.990	0.913	1.048
2018	1.211	1.186	1.021	1.005	1.032
2019	1.214	1.224	0.992	0.964	1.011
2020	1.225	1.156	1.060	1.131	1.014
2021	1.237	1.084	1.141	1.347	1.018
2022	1.248	1.054	1.184	1.501	1.021
Growth Rate 2006-2022	1.4%	0.3%	1.1%	2.6%	0.1%
Growth Rate 2006-2012	2.3%	2.2%	0.1%	-1.0%	1.0%
Growth Rate 2012-2022	0.9%	-0.8%	1.7%	4.9%	-0.4%
Growth Rate 2022	0.9%	-2.8%	3.7%	10.8%	0.3%

6.7.2 JEN's output and input quantity changes

Figure 6.26 graphs the quantity indexes for JEN's individual outputs. Figure 6.27 graphs quantity indexes for its six individual inputs. Regarding outputs:

- The output with largest weight in the output index, circuit length, increased steadily at an average rate of 1.1 per cent per annum from 2006 to 2022; a total increase of 19.2

per cent (which is higher than the increase of 5.6 per cent for the industry over the 17-year period).

- JEN's energy throughput had an average rate of zero per cent per annum between 2006 and 2022; compared to –0.3 per cent per annum for the industry. In 2022, JEN's energy throughput was 0.5 per cent below its 2006 level.
- RMD increased up to 2009, with further increases in 2019 and 2020. In total, RMD increased by 25.5 per cent between 2006 and 2022. This is greater than that of the industry (19.5 per cent in total).
- JEN's customers increased at an average rate of 1.6 per cent per annum between 2006 and 2022, or 27.7 per cent in total (compared to total customer growth of 23.6 per cent for the industry over the same period).
- CMOS *decreased* by 14.1 per cent in total over the period from 2006 to 2022 (compared to an increase in CMOS of 1.9 per cent for the industry over the same period).

Turning to inputs shown in Figure 6.27, we see:

- The quantity of JEN's opex input decreased between 2006 and 2022, averaging an annual rate of change of –1.2 per cent. By 2022, opex was 16.9 per cent below its level in 2006. This compares favourably to the total increase of industry opex inputs of 6.5 per cent 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 2022, JEN's opex *decreased* at a rate of 4.1 per cent per annum. This is largely attributable to substantial declines in 2022 (–10.0 per cent)
- Overhead sub-transmission and distribution lines in 2022 were 15.9 and 2.9 per cent higher, respectively, than their 2006 level. These outcomes compare with 7.3 per cent and 3.1 per cent increases, respectively, for the industry over the same period.
- Underground sub-transmission and distribution cables in 2022 were 68.0 and 108.7 per cent higher than in 2006 respectively. This can be compared to increases of 38.5 per cent and 68.0 per cent respectively for the industry over the same period.
- JEN's quantity of transformers increased reasonably steadily over the 17-year period, at an average rate of 2.6 per cent per annum. By 2022, transformer inputs were 50.4 per cent above the 2006 level, which is a larger increase than the industry's 43.1 per cent.

Figure 6.26 JEN's output quantity indexes, 2006–2022

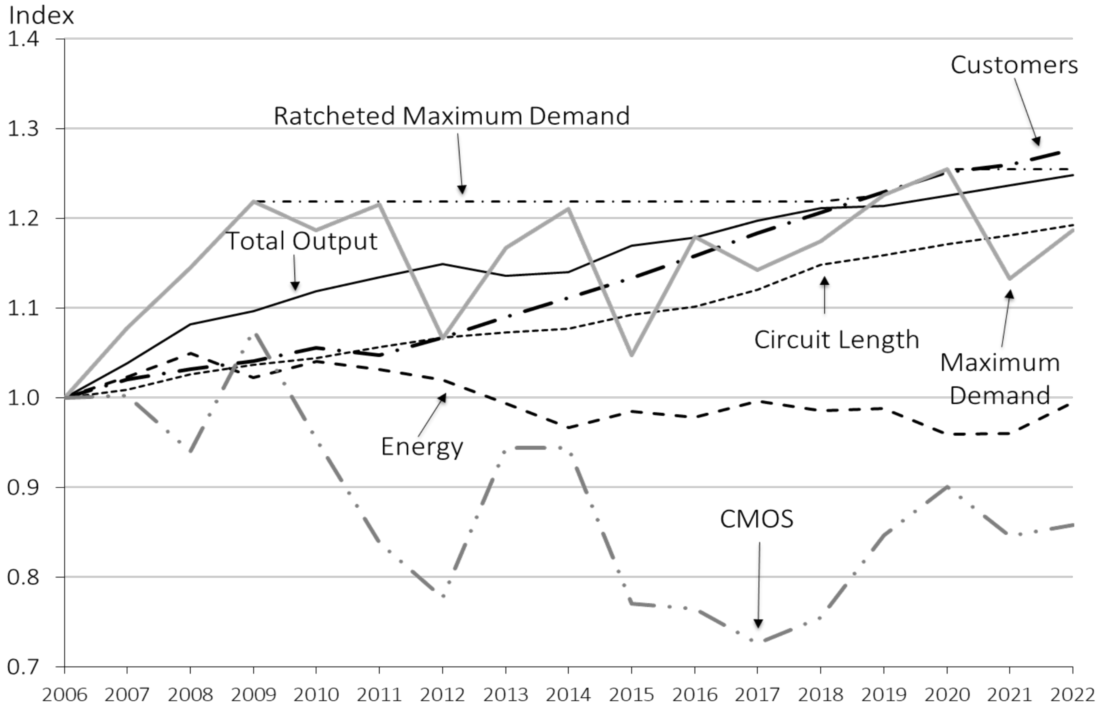
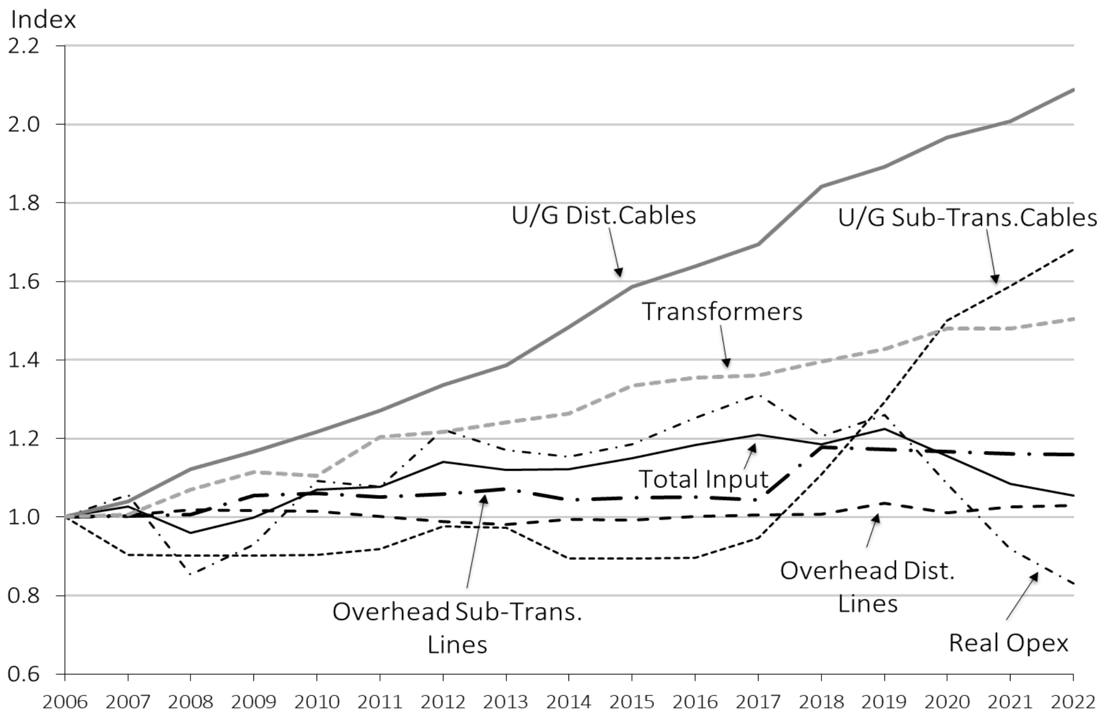


Figure 6.27 JEN's DNSP input quantity indexes, 2006–2022



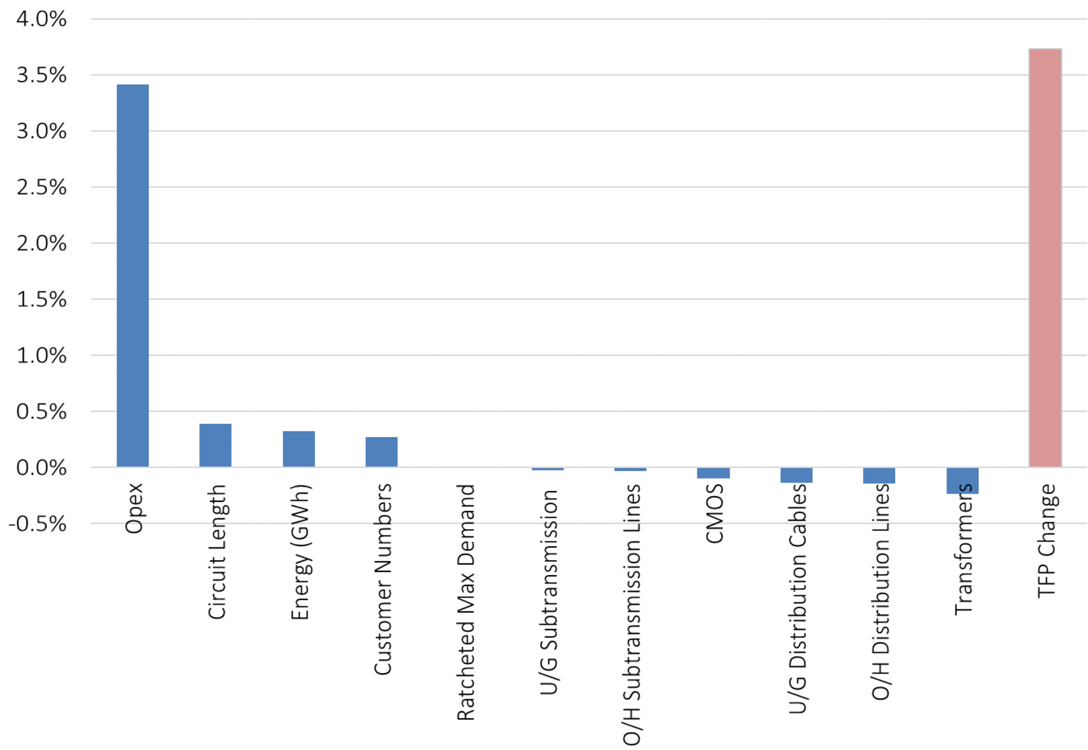
6.7.3 JEN's output and input contributions to TFP change

Table 6.14 shows the decomposition of JEN's rate of TFP change into the contributions of the individual outputs and inputs for the whole 17-year period, for the periods up to and after 2012, and for 2022. Figure 6.28 shows the contributions of outputs and inputs to JEN's rate of TFP change of 3.7 per cent between 2021 and 2022.

Table 6.14 JEN's output and input percentage point contributions to average annual TFP change: various points

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2021 to 2022*
Energy (GWh)	0.00%	0.03%	-0.02%	0.32%
Ratcheted Max Demand	0.52%	1.22%	0.11%	0.00%
Customer Numbers	0.32%	0.22%	0.37%	0.27%
Circuit Length	0.49%	0.47%	0.50%	0.39%
CMOS	0.12%	0.37%	-0.04%	-0.10%
Opex	0.83%	-1.47%	2.21%	3.42%
O/H Sub-transmission Lines	-0.05%	-0.04%	-0.05%	-0.03%
O/H Distribution Lines	-0.08%	0.05%	-0.16%	-0.14%
U/G Sub-transmission Cables	-0.01%	0.00%	-0.01%	-0.02%
U/G Distribution Cables	-0.10%	-0.11%	-0.10%	-0.14%
Transformers	-0.52%	-0.61%	-0.47%	-0.24%
TFP Change	1.51%	0.14%	2.34%	3.73%

Figure 6.28 JEN's output and input percentage point contributions to TFP change, 2022



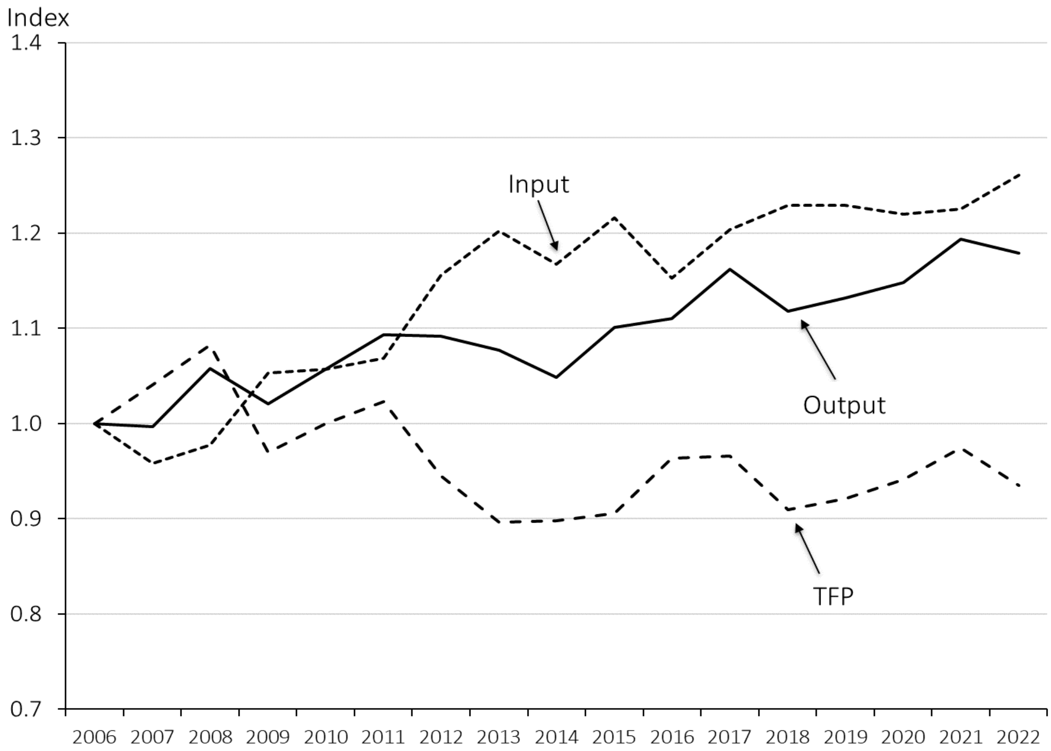
6.8 Powercor (PCR)

In 2022, PCR delivered 10, 963 GWh to 902,215 customers over 76,999 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.

6.8.1 PCR's productivity performance

PCR's total output, total input and TFP indexes are presented in Figure 6.29 and Table 6.15. Opex and capital PFP indexes are also presented in Table 6.15.

Figure 6.29 PCR's output, input and TFP indexes, 2006–2022



Over the 17-year period, PCR's TFP decreased at an average annual rate of change of 0.4 per cent. This can be compared to the industry's average annual change of 0.3 per cent over the same period. The period from 2006 to 2012 saw a higher rate of decline in PCR's TFP, at an average rate of change of –0.9 per cent per year, while in the period from 2012 to 2022, TFP *decreased* at an average annual rate of 0.1 per cent.

PCR's total output increased over the 17-year period at an average annual rate of 1.1 per cent (similar to the industry average rate of output growth of 0.9 per cent per annum). PCR's average annual rate of increase in input use of 1.5 per cent over the same period was similar to that for the industry (1.2 per cent per year). The average rate of growth of output for PCR in the period up to 2012 was 1.5 per cent per year, and in the period after 2012 it was 0.8 per cent per year. PCR's input usage increased at an average rate of 2.4 per cent per year from 2006 to 2012, and by 0.9 per cent per year after 2012.

The PFP indexes in Table 6.15 show the following trends:

- Capital PFP decreased reasonably consistently, averaging an annual rate of change of –1.1 per cent per annum.
- Opex PFP increased on average at a rate of 0.5 per cent per annum from 2006 to 2022. 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 1.5 per cent per annum from 2012 to 2022.

Table 6.15 PCR's output, input, TFP and PFP indexes, 2006–2022

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	0.997	0.958	1.041	1.137	0.975
2008	1.058	0.977	1.082	1.181	1.016
2009	1.021	1.053	0.969	1.033	0.925
2010	1.057	1.057	1.000	1.115	0.928
2011	1.093	1.069	1.023	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	1.048	1.167	0.898	0.928	0.874
2015	1.101	1.216	0.905	0.909	0.901
2016	1.110	1.153	0.963	1.073	0.893
2017	1.162	1.203	0.966	1.042	0.913
2018	1.118	1.229	0.910	0.977	0.862
2019	1.132	1.229	0.921	1.021	0.856
2020	1.148	1.220	0.941	1.101	0.845
2021	1.194	1.225	0.975	1.133	0.875
2022	1.179	1.261	0.935	1.079	0.846
Growth Rate 2006-2022	1.1%	1.5%	-0.4%	0.5%	-1.1%
Growth Rate 2006-2012	1.5%	2.4%	-0.9%	-1.2%	-0.8%
Growth Rate 2012-2022	0.8%	0.9%	-0.1%	1.5%	-1.3%
Growth Rate 2022	-1.3%	2.9%	-4.1%	-4.8%	-3.3%

6.8.2 PCR's output and input quantity changes

Figure 6.30 graphs the quantity indexes for PCR's individual outputs. Figure 6.31 graphs quantity indexes for its six individual inputs.

Regarding outputs in Figure 6.30:

- PCR's circuit length increased steadily at an average rate of 0.5 per cent per annum from 2006 to 2022; and by 2022 was 7.4 per cent above the 2006 level (slightly higher than the increase of 5.6 per cent for the industry over the same period).

- PCR's energy throughput increased at an average rate of 0.5 per cent per annum between 2006 and 2022 (compared to –0.3 per cent per annum for the industry). PCR's energy throughput in 2022 was 8.0 per cent above its 2006 level (compared to a *decrease* of 4.0 per cent for the industry).
- RMD increased at an average annual rate of 1.7 per cent per annum on average over the 17-year period to 2022. In 2022, RMD was 29.4 per cent higher than it was in 2006 (a greater increase than the industry RMD increase of 19.5 per cent in total over the same period).
- PCR's customers increased at an average rate of 2.0 per cent per annum between 2006 and 2022, or 35.9 per cent in total. This is higher than the 23.6 per cent customer increase for the industry in total over the same period.
- Although CMOS was volatile there was an upward trend, and over the period from 2006 to 2022, PCR's CMOS increased by 28.3 per cent in total (compared to 1.9 per cent for the industry). This detracted from PCR's output growth since CMOS has a negative weight.

Turning to inputs shown in Figure 6.31, we see:

- The quantity of opex input increased at an average annual rate of 0.6 per cent from 2006 to 2022, so that opex input in 2022 was 9.2 per cent above its level in 2006 (compared to 6.5 per cent for the industry over the same period). In the period up to 2012, PCR's opex input increased at an average rate of 2.6 per cent per annum. After 2012, opex input decreased, averaging 0.7 per cent per annum.
- Overhead sub-transmission and distribution lines in 2022 were 2.0 and 1.9 per cent higher, respectively, than their 2006 level. These increases were lower than the 7.3 per cent and 3.1 per cent increases, respectively, for the industry over the same period.
- Underground sub-transmission and distribution cables in 2022 were 375.2 per cent and 143.0 per cent higher than in 2006 respectively. This can be compared to increases of 38.5 per cent and 68.0 per cent respectively for the industry over the same period.
- PCR's quantity of transformers increased steadily over the 17-year period, at an average rate of 2.7 per cent per annum. By 2022, transformer inputs were 51.1 per cent above the 2006 level (comparable to the industry increase of 43.1 per cent over the same period).

Figure 6.30 PCR's output quantity indexes, 2006–2022

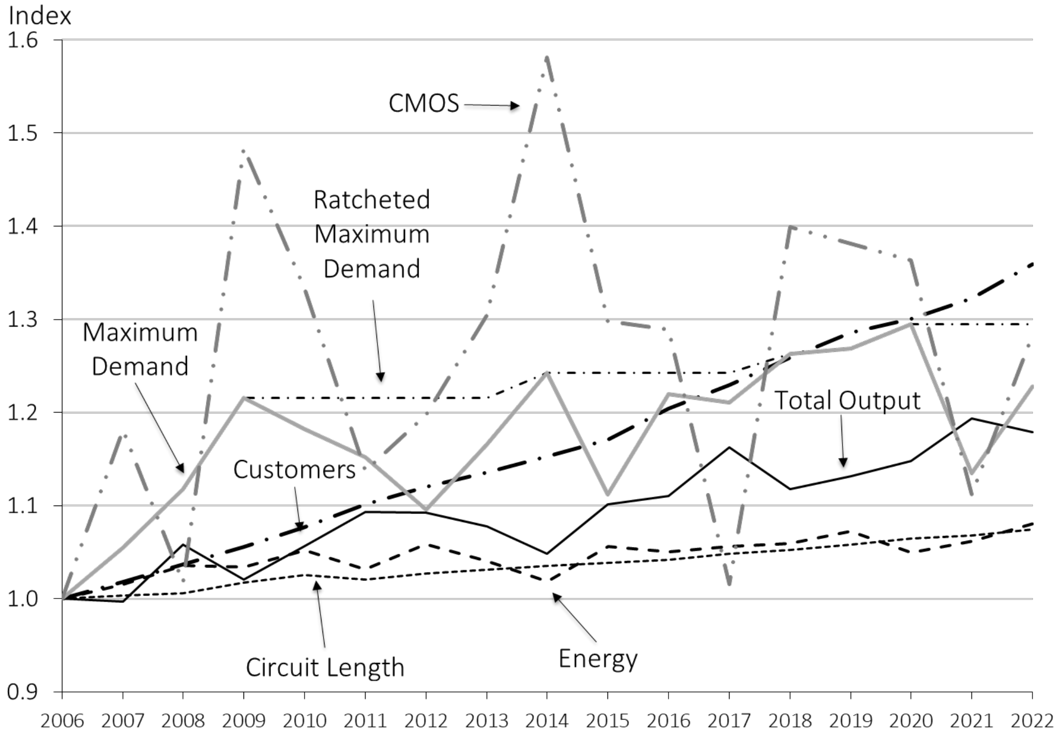
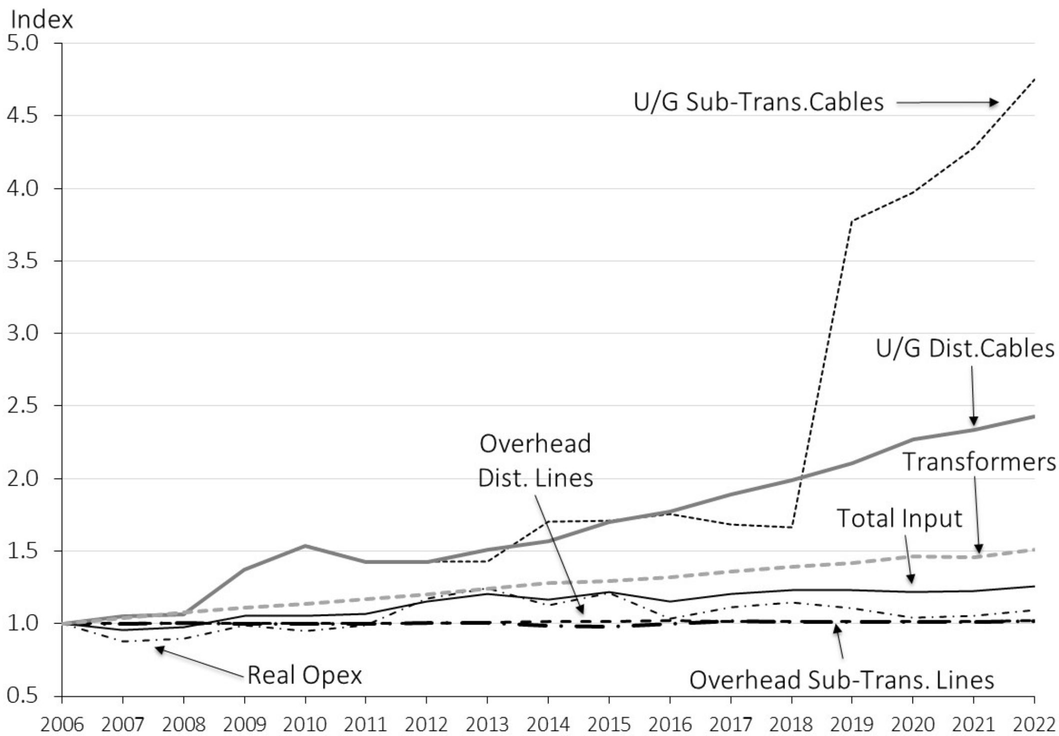


Figure 6.31 PCR's DNSP input quantity indexes, 2006–2022



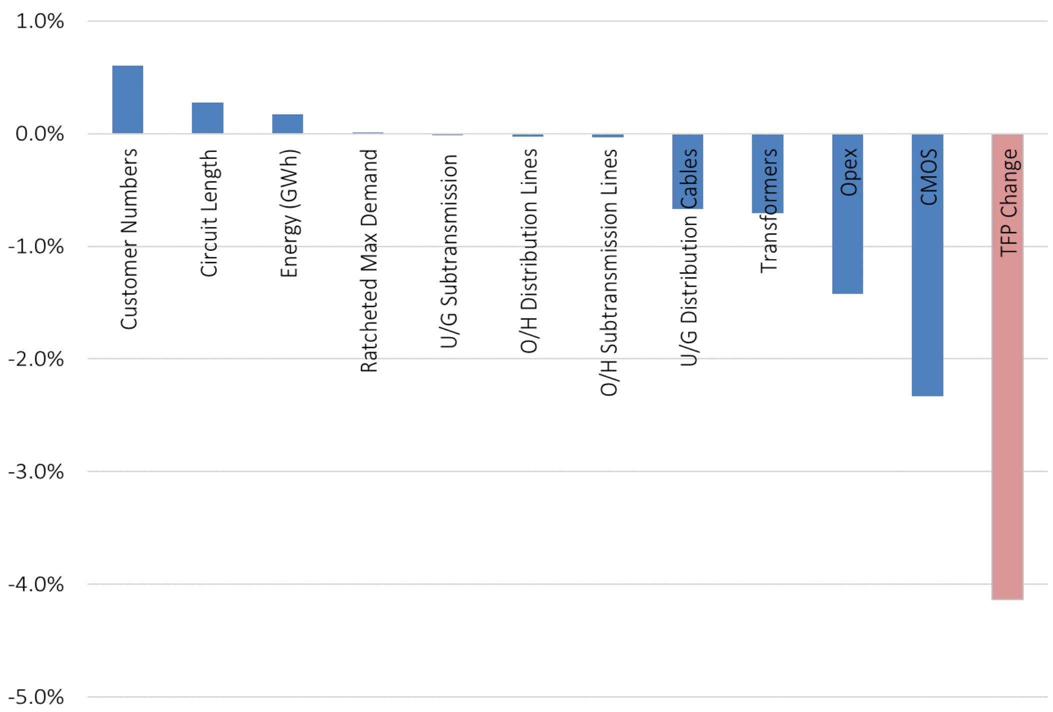
6.8.3 PCR's output and input contributions to TFP change

Table 6.16 shows the decomposition of PCR's rate of TFP change into the contributions of the individual outputs and inputs for the whole 17-year period, for the periods up to and after 2012, and for 2022. Figure 5.32 shows the contributions of outputs and inputs to PCR's rate of TFP change of –4.1 per cent in 2022.

Table 6.16 PCR's output and input percentage point contributions to average annual TFP change: various periods

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2021 to 2022*
Energy (GWh)	0.06%	0.10%	0.03%	0.17%
Ratcheted Max Demand	0.64%	1.31%	0.24%	0.01%
Customer Numbers	0.44%	0.41%	0.45%	0.60%
Circuit Length	0.21%	0.20%	0.22%	0.28%
CMOS	-0.08%	-0.56%	0.21%	-2.33%
Opex	-0.25%	-1.11%	0.26%	-1.42%
O/H Sub-transmission Lines	0.00%	0.00%	0.00%	-0.03%
O/H Distribution Lines	-0.03%	-0.02%	-0.03%	-0.03%
U/G Sub-transmission Cables	-0.01%	-0.01%	-0.01%	-0.02%
U/G Distribution Cables	-0.64%	-0.68%	-0.62%	-0.67%
Transformers	-0.54%	-0.59%	-0.50%	-0.70%
TFP Change	-0.20%	-0.94%	0.25%	-4.14%

Figure 6.32 PCR's output and input percentage point contributions to TFP change, 2022



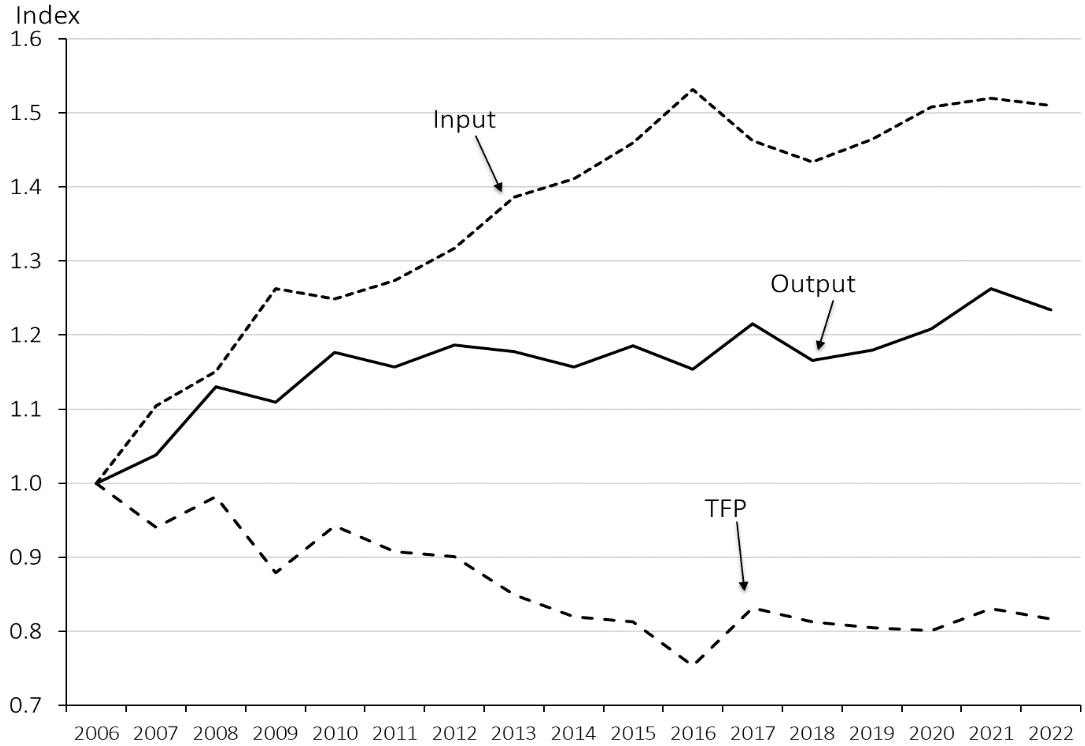
6.9 AusNet Services Distribution (AND)

In 2022, AND delivered 7,588 GWh to 796,623 customers over 46,043 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.

6.9.1 AND's productivity performance

AND's total output, total input and TFP indexes are presented in Figure 6.33 and Table 6.17. Opex and capital PFP indexes are also presented in Table 6.17.

Figure 6.33 AND's output, input and TFP indexes, 2006–2022



Over the 17-year period 2006 to 2022, AND's TFP *decreased* at an average annual rate of 1.3 per cent. This compares unfavourably to the industry's average annual change of –0.3 per cent over the same period. With a few exceptions, the decline in AND's TFP was consistent over the 17-year period.

AND's total output increased over the 17-year period at an average annual rate of 1.4 per cent, which is higher than the industry average rate of output growth of 0.9 per cent per annum over the same period. AND's output increased more strongly in the period up to 2012 (averaging 2.8 per year) than in the period from 2012 to 2022 (averaging 0.4 per cent per year).

AND's average annual rate of increase in input use of 2.7 per cent from 2006 to 2022 was higher than the rate of increase in total input use for the industry (1.2 per cent per year). AND's 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 1.4 per cent per year). By 2022, the input index was 51.0 per cent higher than in 2006 (compared to 21.0 per cent higher for the industry).

The PFP indexes in Table 6.17 show the following trends:

- After a marginal increase in the period from 2006 to 2012 (at an average rate of 0.2 per cent per year), capital PFP decreased in the period after 2012 (averaging an annual rate of change of –1.1 per cent). On average over the full 17-year period, the average rate of change in capital PFP was –0.6 per cent per annum.
- Opex PFP declined over the 17-year period, the average rate of change being –2.3 per cent per annum. This contrasts with the industry overall, for which opex PFP increased at an average rate of 0.5 per cent per year over the same period.

Table 6.17 AND's output, input, TFP and PFP indexes, 2006–2022

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	0.852	0.999
2008	1.130	1.151	0.982	0.862	1.072
2009	1.109	1.262	0.879	0.731	0.997
2010	1.177	1.249	0.942	0.802	1.051
2011	1.157	1.274	0.908	0.782	1.006
2012	1.186	1.317	0.901	0.757	1.013
2013	1.178	1.387	0.849	0.679	0.988
2014	1.157	1.412	0.820	0.652	0.956
2015	1.186	1.459	0.812	0.631	0.966
2016	1.154	1.532	0.753	0.558	0.922
2017	1.216	1.463	0.831	0.671	0.958
2018	1.166	1.434	0.813	0.699	0.901
2019	1.179	1.465	0.805	0.674	0.908
2020	1.208	1.508	0.801	0.658	0.914
2021	1.262	1.520	0.831	0.684	0.948
2022	1.234	1.510	0.817	0.697	0.910
Growth Rate 2006-2022	1.4%	2.7%	-1.3%	-2.3%	-0.6%
Growth Rate 2006-2012	2.8%	4.6%	-1.7%	-4.6%	0.2%
Growth Rate 2012-2022	0.4%	1.4%	-1.0%	-0.9%	-1.1%
Growth Rate 2022	-2.3%	-0.6%	-1.7%	1.8%	-4.1%

6.9.2 AND's output and input quantity changes

Figure 6.34 graphs the quantity indexes for AND's individual outputs. Figure 6.35 graphs quantity indexes for its six individual inputs. Regarding outputs:

- Circuit length, which has the largest weight in the output index, increased at an average rate of 0.7 per cent per annum from 2006 to 2022, and was 10.9 per cent higher than the 2006 level in 2022 (which is higher than the increase of 5.6 per cent for the industry over the same period).
- Energy throughput increased marginally, at an average rate of 0.2 per cent per annum between 2006 and 2022, and by 2022 was 2.6 per cent above its 2006 level.
- RMD increased between 2006 and 2022 in total by 30.8 per cent, representing an average annual growth rate of 1.7 per cent. This is a much larger increase than the 19.5 per cent total increase in RMD for the industry between 2006 and 2022.
- Customers increased at an average rate of 1.8 per cent per annum between 2006 and 2022, or 31.6 per cent in total. This is higher than total customer growth for the industry over the same period of 23.6 per cent.
- CMOS increased by 22.4 per cent in 2022 and was 8.3 per cent above the 2006 level, contrasting to the industry, which in 2022 was 1.9 per cent above the 2006 level.

Turning to inputs shown in Figure 6.35, we see:

- The quantity of AND’s opex input increased at an average annual rate of 3.7 per cent from 2006 to 2022, and in the latter year it was 77.1 per cent above its level in 2006, which compares unfavourably to the total increase of 6.5 per cent for the industry over the same period. In the period up to 2012, AND’s opex input increased at an average rate of 7.5 per cent per annum, and from 2012 to 2022 it increased at an average rate of 1.3 per cent per annum.
- Overhead sub-transmission and distribution lines in 2022 were 13.3 and zero per cent higher, respectively, than their 2006 level. These increases compare to the 7.3 per cent and 3.1 per cent increases respectively for the industry over the same period.
- Underground sub-transmission and distribution cables in 2022 were 223.9 per cent and 115.8 per cent higher than in 2006 respectively, compared to increases of 38.5 per cent and 68.0 per cent respectively for the industry over the same period.
- Transformer inputs, which have the largest weight in the input index, increased over the 17-year period at an average rate of 2.5 per cent per annum. By 2022, transformer inputs were 48.4 per cent above the 2006 level, similar to the industry increase of 43.1 per cent over the same period.

Figure 6.34 AND's output quantity indexes, 2006–2022

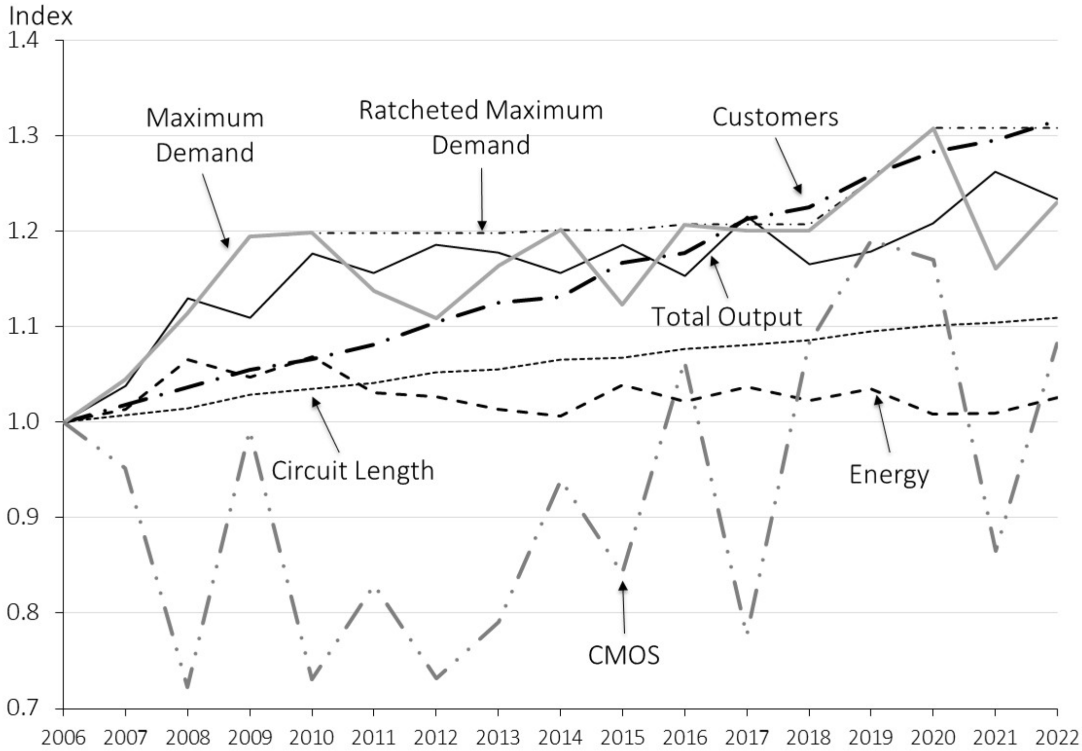
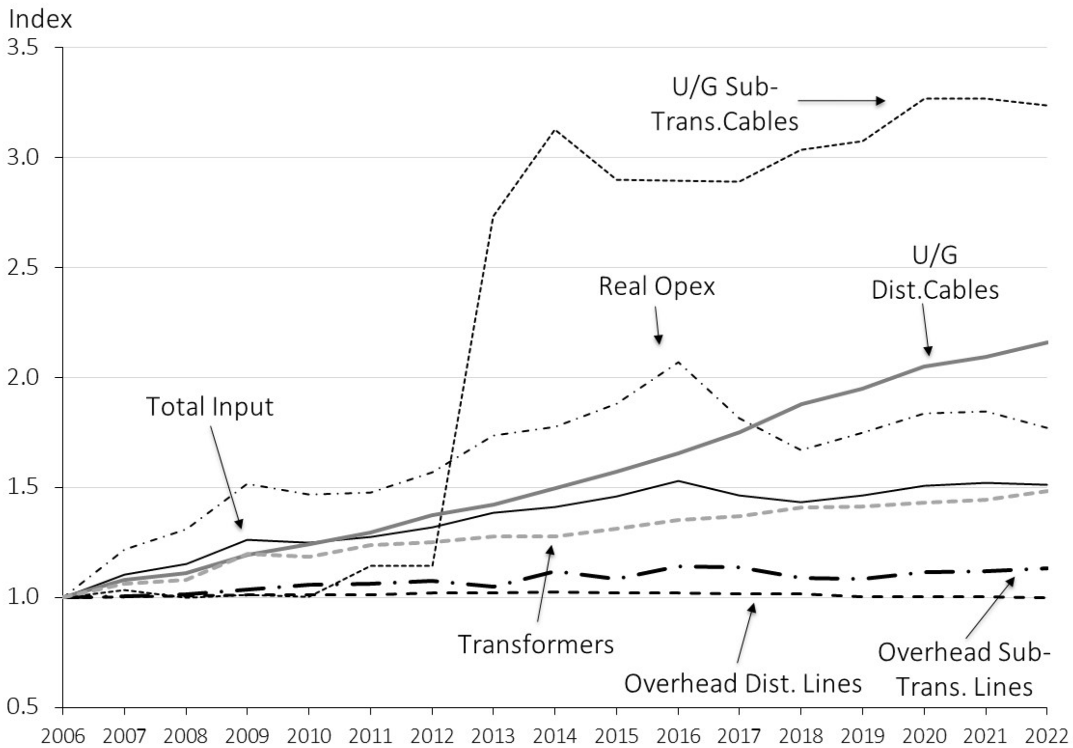


Figure 6.35 AND's input quantity indexes, 2006–2022



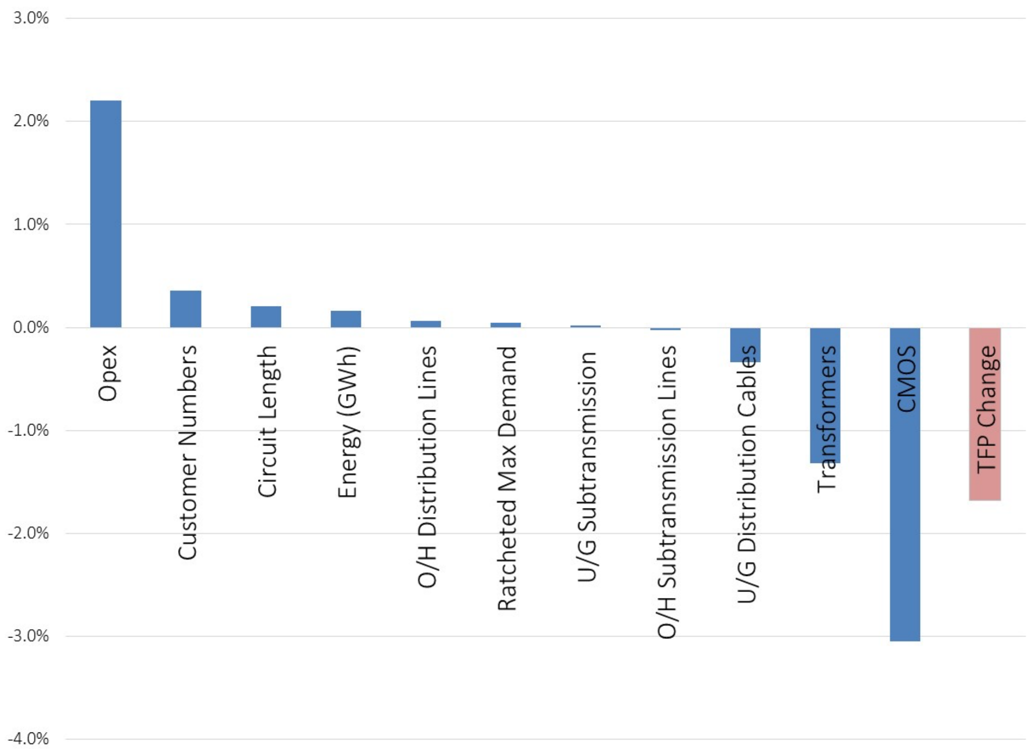
6.9.3 AND's output and input contributions to TFP change

Table 6.18 shows the decomposition of AND's rate of TFP change into the contributions of the individual outputs and inputs for the whole 17-year period, for the periods up to and after 2012, and for 2022. Figure 6.36 shows the contributions of outputs and inputs to AND's rate of TFP change of –1.7 per cent between 2021 and 2022.

Table 6.18 AND's output and input percentage point contributions to average annual TFP change: various periods

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2021 to 2022*
Energy (GWh)	0.02%	0.04%	0.00%	0.16%
Ratcheted Max Demand	0.66%	1.22%	0.33%	0.04%
Customer Numbers	0.38%	0.37%	0.39%	0.36%
Circuit Length	0.30%	0.40%	0.24%	0.20%
CMOS	0.22%	0.81%	-0.13%	-3.05%
Opex	-1.45%	-3.01%	-0.52%	2.21%
O/H Sub-transmission Lines	-0.02%	-0.03%	-0.01%	-0.03%
O/H Distribution Lines	0.00%	-0.08%	0.06%	0.06%
U/G Sub-transmission Cables	-0.02%	-0.01%	-0.02%	0.02%
U/G Distribution Cables	-0.57%	-0.67%	-0.51%	-0.34%
Transformers	-0.57%	-0.79%	-0.44%	-1.32%
TFP Change	-1.04%	-1.74%	-0.62%	-1.68%

Figure 6.36 AND's output and input percentage point contributions to TFP change, 2022



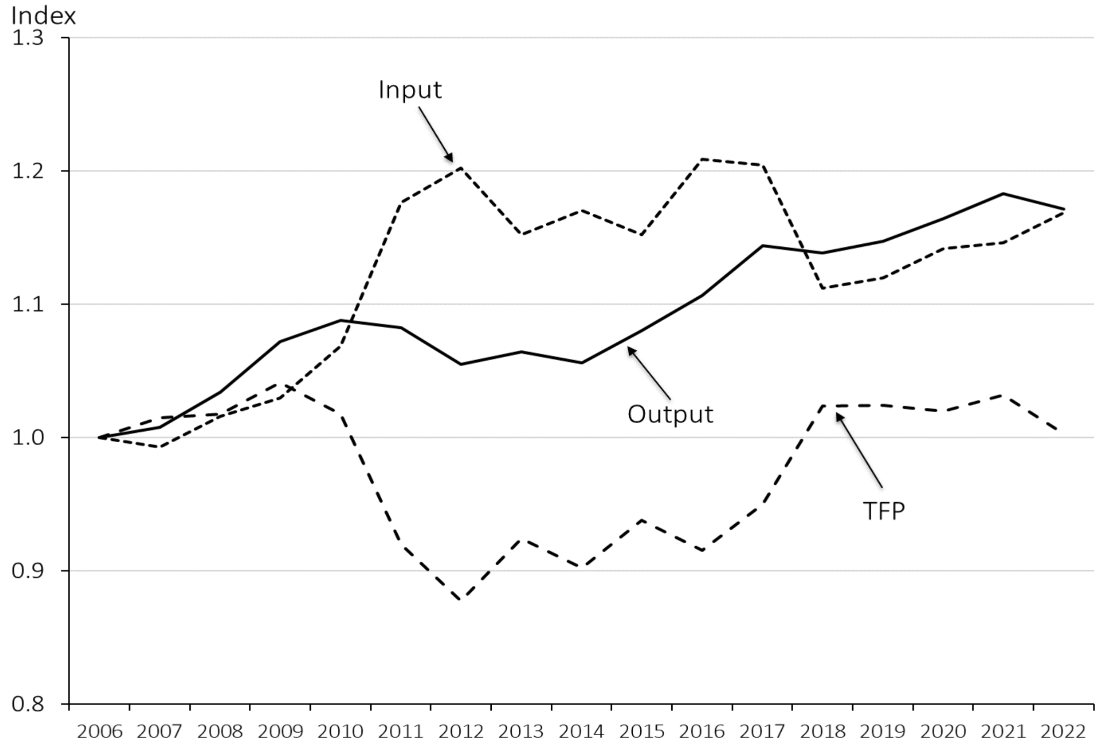
6.10 United Energy (UED)

In 2022, UED delivered 7,591 GWh to 710,296 customers over 13,475 circuit kilometres of lines and cables. UED distributes electricity across east and south–east Melbourne and the Mornington Peninsula.

6.10.1 UED's productivity performance

UED's total output, total input and TFP indexes are presented in Figure 6.37 and Table 6.19. Opex and capital PFP indexes are also presented in Table 6.19.

Figure 6.37 UED's output, input and TFP indexes, 2006–2022



Over the 17-year period 2006 to 2022, UED's TFP had an average annual rate of zero per cent per annum, which can be compared to the industry's average annual change of –0.3 per cent over the same period. UED's TFP *decreased* by 2.2 per cent per year, on average, from 2006 to 2012. It increased by an average of 1.4 per cent per year from 2012 to 2022.

UED's total output increased over the period from 2006 to 2022 at an average annual rate of 1.0 per cent, 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 1.0 per cent was lower than the rate of increase in total input use for the industry (1.2 per cent per year). The rate of growth of input usage was much higher in the period 2006 to 2012 (averaging 3.1 per cent per year) and decreased in the period 2012 to 2022 (averaging –0.3 per cent per year).

The PFP indexes in Table 6.19 show the following trends:

- Capital PFP declined on average over the 17-year period by 0.6 per cent per annum. This decline was concentrated in the period from 2006 to 2012, at an average of 1.8 per cent per annum, and after 2012 its average rate of change increased by 0.1 per cent per annum.
- Opex PFP increased over the 17-year period, by 1.0 per cent per annum. In the period from 2006 to 2012, the average rate of change of opex PFP was –2.7 per cent per annum, and in the period after 2012, it was 3.4 per cent per annum.

Table 6.19 UED's output, input, TFP and PFP indexes, 2006–2022

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.008	0.993	1.015	1.069	0.981
2008	1.034	1.016	1.018	1.093	0.972
2009	1.072	1.030	1.041	1.114	0.997
2010	1.088	1.069	1.018	1.082	0.977
2011	1.082	1.176	0.920	0.879	0.952
2012	1.055	1.202	0.878	0.851	0.899
2013	1.064	1.152	0.924	0.964	0.898
2014	1.056	1.170	0.902	0.935	0.881
2015	1.080	1.152	0.938	1.008	0.895
2016	1.107	1.209	0.916	0.894	0.927
2017	1.144	1.204	0.950	0.982	0.928
2018	1.138	1.112	1.023	1.230	0.917
2019	1.147	1.120	1.024	1.236	0.915
2020	1.164	1.142	1.020	1.197	0.922
2021	1.183	1.146	1.032	1.221	0.925
2022	1.171	1.168	1.002	1.173	0.907
Growth Rate 2006-2022	1.0%	1.0%	0.0%	1.0%	-0.6%
Growth Rate 2006-2012	0.9%	3.1%	-2.2%	-2.7%	-1.8%
Growth Rate 2012-2022	1.1%	-0.3%	1.4%	3.4%	0.1%
Growth Rate 2022	-1.0%	1.9%	-2.9%	-4.0%	-2.0%

6.10.2 UED's output and input quantity changes

Figure 6.38 graphs the quantity indexes for UED's individual outputs. Figure 6.39 graphs quantity indexes for its six individual inputs. Regarding outputs:

- UED's circuit length increased at an average rate of 0.5 per cent per annum from 2006 to 2022; with a total increase of 8.8 per cent over this period (which is higher than the increase of 5.6 per cent total increase for the industry over the same period).

- UED's energy throughput decreased between 2006 and 2022, averaging an annual rate of –0.3 per cent per annum (in line with the industry increase average –0.3 per cent per annum). UED's energy throughput in 2022 was 4.1 per cent below its 2006 level.
- RMD increased from 2006 to 2009 and has remained essentially constant thereafter, except for a small further increase in 2014. In 2022, UED's RMD was 24.3 per cent higher than it was in 2006, similar to the 19.5 per cent total increase in RMD for the industry.
- UED's customers increased at an average rate of 1.0 per cent per annum between 2006 and 2022, or 15.9 per cent in total, which is marginally less than the average rate of customer growth for the industry over the same period of 1.3 per cent per annum, or 23.6 per cent in total.
- CMOS increased considerably in the period up to 2012 but has since declined. In 2022, UED's level of CMOS was 23.5 per cent below its level in 2006. This contrasts to an increase of 1.9 per cent for the industry over the same period.

Turning to inputs shown in Figure 6.39, we see:

- The quantity of opex had an average annual rate of zero per cent from 2006 to 2022, and by 2022 opex was 0.1 per cent below its level in 2006, which compares favourably to the total increase of 6.5 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* at an average rate of 2.3 per cent per annum.
- Overhead sub-transmission and distribution lines in 2022 were 24.0 and 5.8 per cent higher, respectively, than their 2006 level. These increases can be compared to the 7.3 per cent and 3.1 per cent increases, respectively, for the industry over the same period.
- Underground sub-transmission and distribution cables in 2022 were 17.9 per cent and 57.0 per cent higher than in 2006 respectively. This can be compared to increases of 38.5 per cent and 68.0 per cent respectively for the industry over the same period.
- UED's quantity of transformers increased, at an average rate of 2.5 per cent per annum over the 17-year period. By 2022, transformer inputs were 46.5 per cent above the 2006 level, which is similar to the increase for the industry (at 43.1 per cent).

Figure 6.38 UED's output quantity indexes, 2006–2022

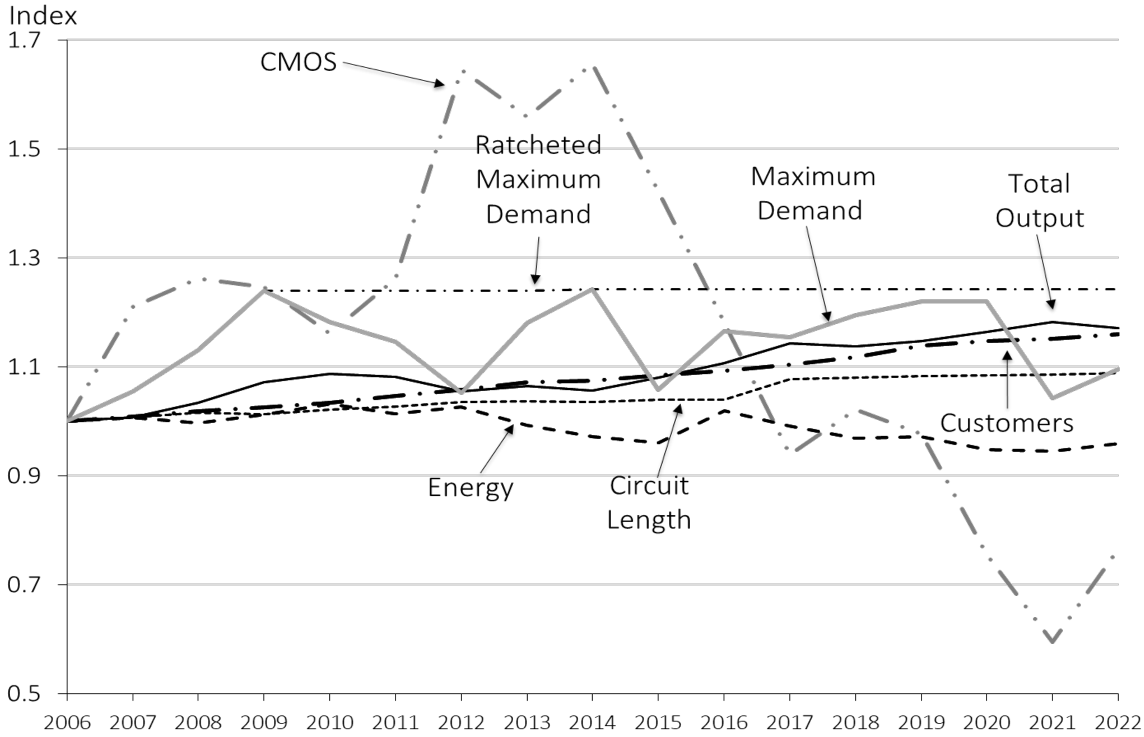
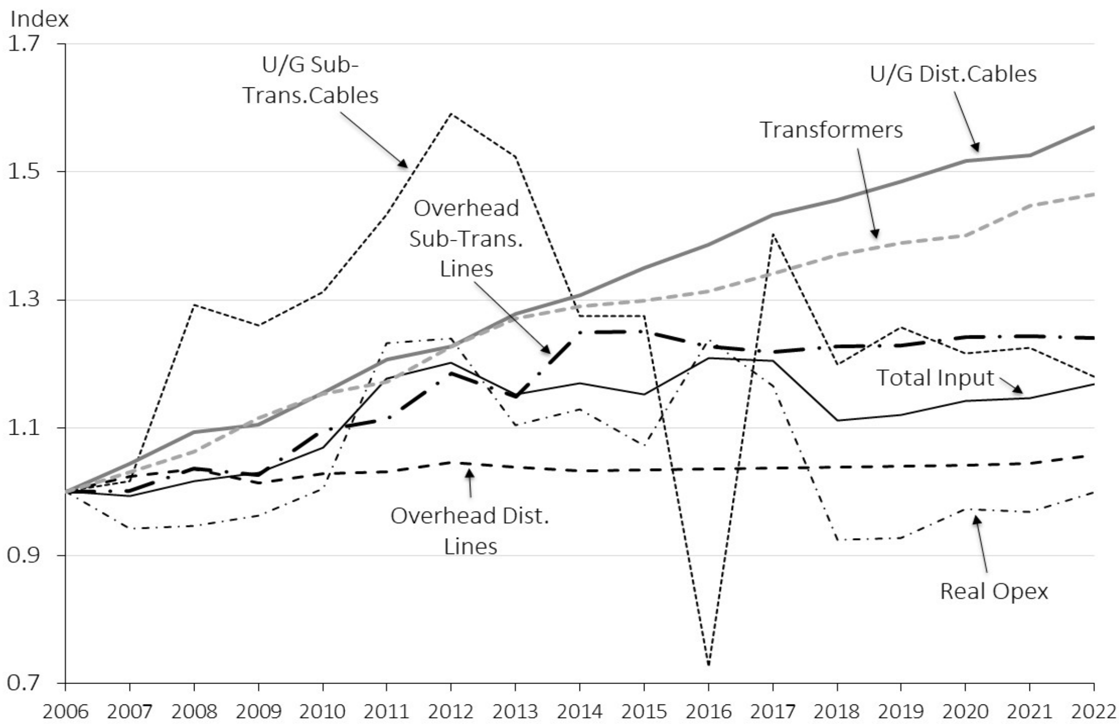


Figure 6.39 UED's input quantity indexes, 2006–2022



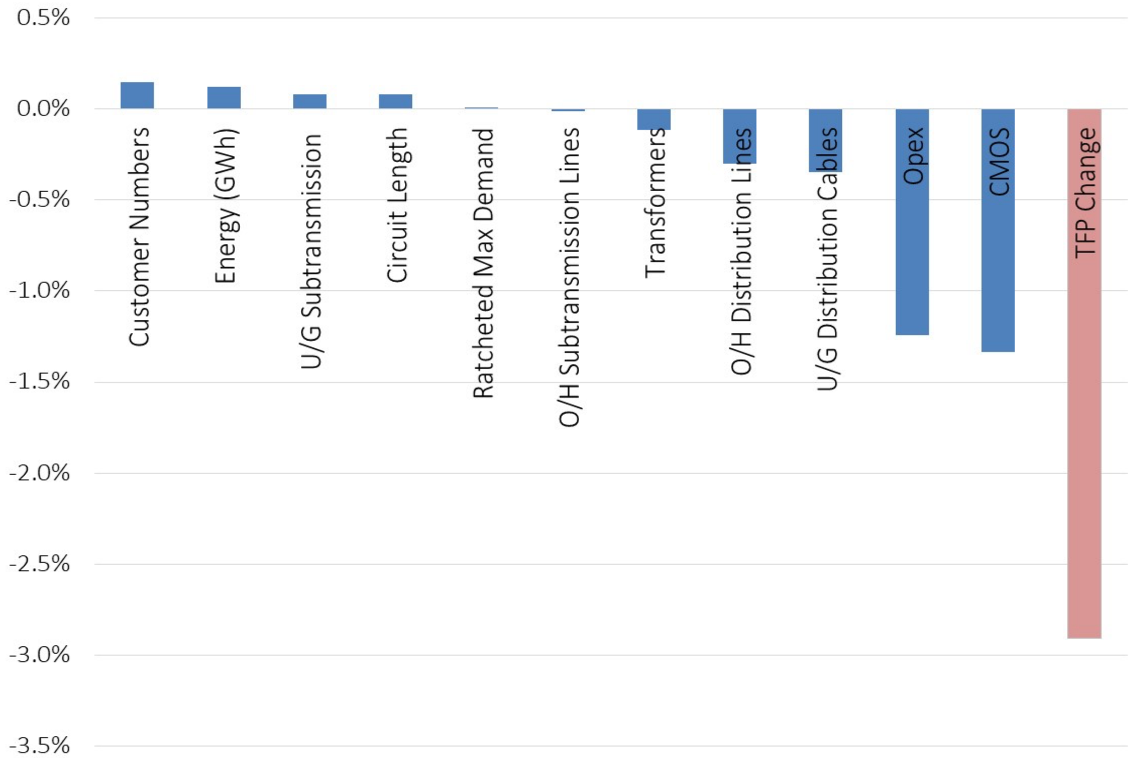
6.10.3 UED's output and input contributions to TFP change

Table 6.20 shows the decomposition of UED's rate of TFP change into the contributions of the individual outputs and inputs for the whole 17-year period, for the periods up to and after 2012, and for 2022. Figure 6.40 shows the contributions of outputs and inputs to UED's rate of TFP change of –2.9 per cent between 2021 and 2022.

Table 6.20 UED's output and input percentage point contributions to average annual TFP change: various points

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2021 to 2022*
Energy (GWh)	-0.03%	0.04%	-0.07%	0.12%
Ratcheted Max Demand	0.50%	1.32%	0.01%	0.01%
Customer Numbers	0.19%	0.19%	0.19%	0.15%
Circuit Length	0.23%	0.24%	0.22%	0.08%
CMOS	0.20%	-0.90%	0.85%	-1.34%
Opex	0.02%	-1.46%	0.90%	-1.24%
O/H Sub-transmission Lines	-0.09%	-0.18%	-0.04%	-0.01%
O/H Distribution Lines	-0.08%	-0.15%	-0.03%	-0.30%
U/G Sub-transmission Cables	-0.02%	-0.14%	0.06%	0.08%
U/G Distribution Cables	-0.26%	-0.30%	-0.24%	-0.34%
Transformers	-0.57%	-0.84%	-0.41%	-0.12%
TFP Change	0.09%	-2.18%	1.45%	-2.91%

Figure 6.40 UED's output and input percentage point contributions to TFP change, 2022



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, to each of the aggregated data at the state level, and 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 208 observations. For productivity comparative analysis of States (and Territories), the data for the six States is pooled as panel data and the index is applied across the resulting sample of 96 observations.

$$\ln\left(\frac{TFP_m}{TFP_n}\right) = \sum_i \left(\frac{R_{im} + R_i^*}{2}\right) \ln\left(\frac{Y_{im}}{Y_i^*}\right) - \sum_i \left(\frac{R_{in} + R_i^*}{2}\right) \ln\left(\frac{Y_{in}}{Y_i^*}\right) - \sum_j \left(\frac{S_{jm} + S_j^*}{2}\right) \ln\left(\frac{X_{jm}}{X_j^*}\right) + \sum_j \left(\frac{S_{jn} + S_j^*}{2}\right) \ln\left(\frac{X_{jn}}{X_j^*}\right) \quad (1)$$

where m and n are two adjacent observations;[17] i denotes individual outputs; j denotes individual inputs; and

- R_{im} is the revenue share of the ith output at observation m;

[17] 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.

- S_{jm} is the cost share of the *j*th input at observation *m*;
- R_i^* is the revenue share of the *i*th output averaged over the whole sample;[18]
- S_j^* is the cost share of the *j*th input averaged over the whole sample;
- Y_{im} is the quantity of the *i*th output at observation *m*;
- X_{jm} is the quantity of the *j*th input at observation *m*;
- Y_i^* is the average quantity of the *i*th output over the whole sample;
- X_j^* is the average quantity of the *j*th 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.[19] 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:

---

[18] 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.

[19] 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 (2012, 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.

$$\ln\left(\frac{Y_m}{Y_n}\right) = \sum_i \left(\frac{R_{im} + R_i^*}{2}\right) \ln\left(\frac{Y_{im}}{Y_i^*}\right) - \sum_i \left(\frac{R_{in} + R_i^*}{2}\right) \ln\left(\frac{Y_{in}}{Y_i^*}\right) \qquad (2)$$

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

$$\ln\left(\frac{X_m}{X_n}\right) = \sum_j \left(\frac{S_{jm} + S_j^*}{2}\right) \ln\left(\frac{X_{jm}}{X_j^*}\right) - \sum_j \left(\frac{S_{jn} + S_j^*}{2}\right) \ln\left(\frac{X_{jn}}{X_j^*}\right) \qquad (3)$$

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 PFP 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: $g_t^Y = \ln Y_t - \ln Y_{t-1}$.[20] 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 2021, and these comparisons are not expressed in terms of log growth rates. Economic Insights (2020 Appendix C) also included, as supplementary information, trend measures of annual growth

[20] 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.

rates based on linear regression.[21] This report also presents regression-based trend estimates for TFP indexes in Appendix B.

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 $t-1$ ($Cont_{i,t}^{Y}$) is given by the following equation:

$$Cont_{i,t}^{Y} = \left(\frac{R_{i,t} + R_i^*}{2}\right) \ln\left(\frac{Y_{i,t}}{Y_i^*}\right) - \left(\frac{R_{i,t-1} + R_i^*}{2}\right) \ln\left(\frac{Y_{i,t-1}}{Y_i^*}\right) \quad (4)$$

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

$$Cont_{j,t}^{X} = \left(\frac{S_{j,t} + S_j^*}{2}\right) \ln\left(\frac{X_{j,t}}{X_j^*}\right) - \left(\frac{S_{j,t-1} + S_j^*}{2}\right) \ln\left(\frac{X_{j,t-1}}{X_j^*}\right) \quad (5)$$

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

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

as the basis for value-share weights. Economic Insights (2020 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

In the index analysis in this study, the output specification is based on functional outputs, and the weights for these outputs are based on the imputed or shadow values of these outputs. These imputed values were estimated by Economic Insights (2020) using econometric analysis of the total cost function. A multi–output Leontief cost function specification was used, and output cost shares were estimated for each of the outputs used in the index analysis. The method used by Economic Insights was a similar procedure to that used in Lawrence (2003) and Lawrence and Diewert (2006). This study uses the same weights, which are shown in Table A.1.

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 (2019; 2019). 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 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. The values of the shares of revenue, as shown in Table A.1, are exclusively utilized in Section 1.3 to explain the transition from shares of gross revenue—derived from the Leontief cost function discussed in section A3.1— to shares of revenue. Industry output weights mentioned in the remaining sections are derived from the last column of Table A.2.

Table A.1 Output cost-based weights (industry average 2006 to 2022*)

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)]	44.48
CMOS	-11.61	-13.65
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 Economic Insights' Leontief cost function analysis.

A3.3 Output Weights by DNSP and for the Aggregated Industry

The average output weights for each DNSP and for the aggregated industry are shown in Table A.2. The output cost share weights for the aggregated industry shown in the last column of Table A.2 are slightly different than the output cost share weights shown in Table A.1, derived by averaging across all observations. This is because the value (or customer cost) per minute of CMOS differs substantially between DNSPs and the industry average shares shown in Table A.2 are based on the weighted average value of CMOS, rather than the simple average implied in Table A.1.

Table A.2 Output cost share weights by DNSP (%, average 2006 to 2022)

Output	*EVO*	*AGD*	*CIT*	*END*	*ENX*	*ERG*	*ESS*
Energy throughput	8.91	9.48	8.94	9.76	9.51	10.90	10.43
Ratcheted max. demand	35.06	37.29	35.19	38.39	37.41	42.88	41.03
Customer numbers	19.24	20.46	19.31	21.06	20.52	23.52	22.51
Circuit length	40.65	43.24	40.80	44.50	43.38	49.72	47.57
CMOS	-3.86	-10.47	-4.24	-13.70	-10.82	-27.02	-21.54
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Output	*JEN*	*PCR*	*SAP*	*AND*	*TND*	*UED*	*Industry**
Energy throughput	9.25	10.19	10.00	9.87	10.18	9.34	9.88
Ratcheted max. demand	36.41	40.09	39.36	38.84	40.04	36.76	38.86
Customer numbers	19.97	21.99	21.59	21.31	21.97	20.17	21.32
Circuit length	42.21	46.48	45.63	45.03	46.42	42.62	45.05
CMOS	-7.85	-18.76	-16.58	-15.04	-18.61	-8.90	-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 & annual user cost of capital

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. Using this information, the annual user cost (AUC) is calculated for each asset class. 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 2022)

Input	*EVO*	*AGD*	*CIT*	*END*	*ENX*	*ERG*	*ESS*
Real opex	39.30	36.44	26.65	40.04	37.73	36.82	40.95
O/H Sub-trans. lines	3.37	4.01	0.55	3.99	3.52	9.18	6.79
O/H Distribution lines	12.13	6.70	6.82	9.63	11.95	21.27	19.82
U/G Sub-trans. cables	0.06	5.94	6.78	1.74	4.71	0.46	0.20
U/G Distribution cables	18.16	14.05	34.48	16.11	11.54	3.30	3.74
Transformers	26.98	32.87	24.72	28.49	30.55	28.98	28.51
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	41.64	40.25	35.67	40.07	36.27	38.47	37.79
O/H Sub-trans. lines	4.97	3.82	1.91	2.57	0.42	7.40	4.65
O/H Distribution lines	29.15	22.33	10.32	24.85	27.35	21.36	15.35
U/G Sub-trans. cables	0.19	0.10	0.31	0.22	0.34	1.97	2.28
U/G Distribution cables	2.10	11.37	17.55	11.67	11.49	9.59	11.28
Transformers	21.95	22.13	34.24	20.61	24.12	21.20	28.65
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.

A3.5 Output and Input weights by State and Territory

Tables A.4 and A.5 show the complete set of output and input weights by State which are referred to in chapter 4.

Table A.4 Output cost share weights by State (%, average 2006 to 2022)

Output	*ACT*	*NSW*	*VIC*	*QLD*	*SA*	*TAS*
Energy throughput	8.91	9.81	9.66	10.20	10.00	10.18
Ratcheted max. demand	35.06	38.62	38.01	40.13	39.36	40.04
Customer numbers	19.24	21.18	20.85	22.02	21.59	21.97
Circuit length	40.65	44.77	44.06	46.53	45.63	46.42
CMOS	-3.86	-14.38	-12.58	-18.88	-16.58	-18.61
Total	100.00	100.00	100.00	100.00	100.00	100.00

Table A.5 Input cost share weights by State (%, average 2006 to 2022)

Input	*ACT*	*NSW*	*VIC*	*QLD*	*SA*	*TAS*
Real opex	39.30	38.64	38.35	37.30	35.67	36.27
O/H Sub-trans. lines	3.37	4.85	3.89	6.38	1.91	0.42
O/H Distribution lines	12.13	11.36	21.78	16.65	10.32	27.35
U/G Sub-trans. cables	0.06	3.27	1.32	2.56	0.31	0.34
U/G Distribution cables	18.16	11.30	12.83	7.37	17.55	11.49
Transformers	26.98	30.59	21.82	29.73	34.24	24.12
Total	100.00	100.00	100.00	100.00	100.00	100.00

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 the methods used, we begin by defining the following notation:

C = nominal opex;

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

$K = (K_1, K_2, \dots, K_H)$ = a $H \times 1$ vector of capital quantities;[22]

$Z = (Z_1, Z_2, \dots, Z_R)$ = a $R \times 1$ vector of operating environment factors;[23] and

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

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

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

[22] 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.

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

Lower case notation is used to define the natural logarithms of variables. For example, $x_1 = \ln(X_1)$.

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:

$$c_{it} = \beta_0 + \sum_{m=1}^{M} \beta_m x_{mit} + \lambda_1 t + v_{it} \tag{6}$$

while the Translog cost frontier may be specified as:

$$c_{it} = \beta_0 + \sum_{m=1}^{M} \beta_m x_{mit} + 0.5 \sum_{m=1}^{M} \sum_{l=1}^{M} \beta_{ml} x_{mit} x_{lit} + \lambda_1 t + v_{it} \tag{7}$$

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 of the two approaches used to measure comparative efficiency of DNSPs in econometric opex cost function is to use fixed effects. One can then include a set of $N – 1$ dummy variables into models (6) and (7) 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, $(n = 2,\ldots,N)$.

Including these dummy variables into model (6) we obtain:

$$c_{it} = \beta_0 + \sum_{m=1}^{M} \beta_m x_{mit} + \sum_{n=2}^{N} \delta_n D_{nit} + \lambda_1 t + v_{it} \tag{8}$$

And with the dummy variables, model (7) becomes:

$$c_{it} = \beta_0 + \sum_{m=1}^{M} \beta_m x_{mit} + 0.5 \sum_{m=1}^{M} \sum_{l=1}^{M} \beta_{ml} x_{mit} x_{lit} \tag{9}$$

$$+ \sum_{n=2}^{N} \delta_n D_{nit} + \lambda_1 t + v_{it}$$

In this study, the models in equations (8) and (9) 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). Following Economic Insights, we 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:

$$CE_n = \exp\left[\min\left(\hat{\delta}_n\right) - \hat{\delta}_n\right] \tag{10}$$

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). 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 model in (6) to obtain a Cobb–Douglas stochastic cost frontier:

$$c_{it} = \beta_0 + \sum_{m=1}^{M} \beta_m x_{mit} + \lambda_1 t + v_{it} + u_i \tag{11}$$

and to model (7) to obtain a Translog stochastic cost frontier:

$$c_{it} = \beta_0 + \sum_{m=1}^{M} \beta_m x_{mit} + 0.5 \sum_{m=1}^{M} \sum_{l=1}^{M} \beta_{ml} x_{mit} x_{lit} + \lambda_1 t + v_{it} + u_i \qquad (12)$$

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 $|N(\mu, \sigma_u^2)|$. With these distributional assumptions, the unknown parameters in models (11) and (12) 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:

$$CE_n = \exp[u_n] \qquad (n = 1,2, \ldots, N) \qquad (13)$$

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:

$$CE_n = E[\exp(u_n)|(v_n + u_n)] \qquad (n = 1,2, \ldots, N) \qquad (14)$$

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

A5 Input index weights with Opex including CCOs

In the consultation on the effects of capitalisation differences on benchmarking (AER 2023), the AER decided to adopt 'Option 5', which involves reallocating capitalised corporate overhead (CCO) from capex to opex for benchmarking purposes. The MTFP and MPFP analysis uses input and output quantities, nominal values of costs for calculating input index weights, fixed revenue weights and the price and quantity of the reliability output. The implementation of 'Option 5' affects the opex input quantity and all cost share weights:

- The opex input quantity is calculated as nominal opex divided by a price index for opex inputs. Under Option 5, nominal opex is equal to reported opex plus CCO.
- The nominal cost variables used to calculate the cost share weights include opex and the annual user cost (AUC) of each of the five capital inputs. AUC is measured by multiplying the regulatory asset base (RAB) by the rental price of capital. The exclusion of CCO from capex affects RAB values, and hence it affects AUC values.

AUC is calculated for each DNSP and year, by asset type. For a specific DNSP, the formulas for calculating AUC for asset type *i* in period *t* are:

$$AUC_{it} = WACC_t . RAB_{it}^B + Reg.Depreciation_{it} + Benchmark\ Tax\ Liability \qquad (15)$$

where RAB_{it}^{B} refers to the RAB at the beginning of period t for asset type i. Both RAB and Regulatory Depreciation are affected by the change in capex values under Option 5. They are each defined as follows:

$$Reg.Depreciation_{it} = SL\ Depreciation_{it} - Inflation\ Addition_{it} \quad (16)$$

$$RAB_{it}^{B} = RAB_{i,t-1}^{B} + Capex_{i,t-1} - Disposals_{i,t-1} - Reg.Depreciation_{i,t-1} \quad (17)$$

Hereafter, the average depreciation rate of asset type i in period t (for a given DNSP) as can be defined as $\delta_{it} \equiv SL\ Depreciation_{it}/RAB_{it}^{B}$, and the rate of asset inflation as denoted as $\dot{p}$. These two parameters are obtained from the standard RAB roll-forward and used in the restated RAB roll-forward to recalculate weights when Opex includes CCOs. Hence, the equations for AUC and RAB can be written as:

$$AUC_{it} = RAB_{it}^{B}(WACC_{t} + \delta_{it} - \dot{p}_{it}) + Benchmark\ Tax\ Liability_{\ it} \quad (18)$$

$$RAB_{it}^{B} = RAB_{i,t-1}^{B}\left(1 - \delta_{i,t-1} + \dot{p}_{it}\right) + Capex_{i,t-1} - Disposals_{i,t-1} \quad (19)$$

To address the impact of including the CCO in opex and consequently excluding it from capex, it is assumed that $RAB_{i,2006}^{B}$, is unaffected. Capex for each year within a specific asset category ($Capex_{i,t}$) is restated by subtracting CCO, after it is allocated to asset types in proportion to standard capex. Equations (17) and (18) are used for the RAB roll-forward under this scenario, with $WACC_{t}$ and $Disposals_{i,t-1}$ unchanged from the standard RAB roll-forward.[24] The benchmark tax liability is not adjusted because sensitivity analysis indicates that any such adjustment to this element of the AUC has very small impact, and the preliminary method presented here has sought to maintain a degree of simplicity.

[24] In the standard approach, the AER adjusts the AUC for transformers and other capital by excluding an estimate of that part associated with first-stage zone substations for those DNSPs with two-stage transformation. We use the ratio of adjusted to unadjusted AUC for transformers and other capital to make a corresponding adjustment in the case where opex includes CCO.

Appendix B: Regression–based trend growth rates[25]

Table B.1 Output, input, TFP and PFP index trend annual growth rates, 2006–2022

DNSP	*Output*	*Input*	*TFP*	*PFP Index*	
Period	*Index*	*Index*	*Index*	*Opex*	*Capital*
Industry					
Growth Rate 2006–22	0.8%	1.1%	-0.4%	0.6%	-1.0%
Growth Rate 2006–12	1.6%	3.5%	-1.9%	-3.4%	-1.0%
Growth Rate 2012–22	0.5%	-0.2%	0.6%	2.9%	-0.8%
EVO/ACT					
Growth Rate 2006–22	1.5%	1.0%	0.5%	1.3%	0.0%
Growth Rate 2006–12	1.2%	3.7%	-2.5%	-5.5%	-0.5%
Growth Rate 2012–22	1.4%	-0.8%	2.3%	5.4%	0.1%
AGD					
Growth Rate 2006–22	0.5%	0.0%	0.5%	3.0%	-1.0%
Growth Rate 2006–12	1.1%	3.5%	-2.4%	-4.2%	-1.5%
Growth Rate 2012–22	0.2%	-2.1%	2.3%	7.0%	-0.4%
CIT					
Growth Rate 2006–22	0.8%	1.3%	-0.5%	-0.3%	-0.6%
Growth Rate 2006–12	1.2%	3.8%	-2.6%	-5.9%	-1.5%
Growth Rate 2012–22	0.7%	-0.4%	1.1%	3.5%	0.1%
END					
Growth Rate 2006–22	1.2%	1.4%	-0.2%	1.7%	-1.4%
Growth Rate 2006–12	1.7%	3.1%	-1.4%	-1.0%	-1.8%
Growth Rate 2012–22	1.3%	0.2%	1.0%	3.6%	-0.7%
ENX					
Growth Rate 2006–22	1.3%	1.7%	-0.4%	0.3%	-0.9%
Growth Rate 2006–12	3.6%	4.6%	-1.0%	-2.2%	-0.4%
Growth Rate 2012–22	0.5%	0.3%	0.2%	2.0%	-0.9%
ERG					
Growth Rate 2006–22	0.7%	1.0%	-0.3%	0.9%	-1.0%
Growth Rate 2006–12	1.7%	2.4%	-0.7%	-0.9%	-0.7%
Growth Rate 2012–22	-0.1%	0.4%	-0.5%	0.9%	-1.4%
ESS					
Growth Rate 2006–22	0.8%	0.7%	0.2%	0.9%	-0.4%
Growth Rate 2006–12	0.8%	4.0%	-3.2%	-6.4%	-1.0%
Growth Rate 2012–22	0.7%	-0.7%	1.4%	3.6%	-0.3%
JEN					
Growth Rate 2006–22	1.2%	0.9%	0.2%	0.8%	-0.1%
Growth Rate 2006–12	2.2%	2.1%	0.1%	-0.9%	0.8%
Growth Rate 2012–22	1.0%	-0.3%	1.2%	3.7%	-0.4%

[25] The results presented in this section are based on Opex which does not include CCOs.

Table B2 (cont.)

DNSP	*Output*	*Input*	*TFP*	*PFP Index*	
Period	*Index*	*Index*	*Index*	*Opex*	*Capital*
PCR					
Growth Rate 2006–22	1.0%	1.6%	-0.6%	-0.1%	-1.0%
Growth Rate 2006–12	1.6%	2.6%	-1.0%	-1.1%	-0.9%
Growth Rate 2012–22	1.0%	0.7%	0.4%	2.2%	-0.9%
SAP					
Growth Rate 2006–22	0.6%	2.0%	-1.4%	-2.0%	-1.2%
Growth Rate 2006–12	1.7%	4.3%	-2.5%	-5.6%	-1.0%
Growth Rate 2012–22	0.2%	0.7%	-0.5%	0.6%	-1.1%
AND					
Growth Rate 2006–22	0.9%	2.3%	-1.3%	-2.0%	-0.9%
Growth Rate 2006–12	2.7%	4.3%	-1.5%	-3.8%	0.1%
Growth Rate 2012–22	0.5%	1.1%	-0.5%	0.0%	-0.9%
TND/TAS					
Growth Rate 2006–22	0.4%	1.2%	-0.8%	-0.3%	-1.0%
Growth Rate 2006–12	0.5%	3.8%	-3.3%	-5.9%	-1.8%
Growth Rate 2012–22	0.0%	0.6%	-0.6%	0.0%	-1.0%
UED					
Growth Rate 2006–22	1.0%	0.9%	0.1%	1.0%	-0.5%
Growth Rate 2006–12	1.3%	3.4%	-2.1%	-3.2%	-1.3%
Growth Rate 2012–22	1.3%	-0.3%	1.6%	3.7%	0.3%

Appendix C: Opex Cost Function Regression Results

This appendix presents the detailed results of estimating the models using the standard method of defining opex (presented in section 3.2), and the detailed results of estimating models using a revised definition of opex which includes capitalised overheads (presented in section 3.3).

C1 Standard method of defining opex: Full sample results

C1.1 Regression outputs

The models in this section all have 1,137 observations over 69 DNSPs. The LSE models use panel-corrected standard errors. Table C.1 shows that LSE Cobb-Douglas cost frontier model.

Table C.1 LSE Cobb–Douglas cost function estimates using 2006–2022 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.565	0.068	8.305
ln(CircLen)	0.170	0.030	5.706
ln(RMDemand)	0.238	0.062	3.868
ln(ShareUGC)	-0.138	0.023	-5.899
Year	0.010	0.002	6.515
Country dummy variables:			
New Zealand	-0.204	0.144	-1.415
Ontario	-0.056	0.142	-0.398
DNSP dummy variables:			
AGD	-0.011	0.199	-0.057
CIT	-0.638	0.165	-3.878
END	-0.232	0.163	-1.428
ENX	-0.230	0.153	-1.498
ERG	-0.163	0.171	-0.951
ESS	-0.317	0.180	-1.761
JEN	-0.342	0.171	-1.999
PCR	-0.713	0.161	-4.413
SAP	-0.481	0.162	-2.969
AND	-0.401	0.160	-2.504
TND	-0.459	0.170	-2.696
UED	-0.490	0.164	-2.993
Constant	-10.727	3.208	-3.344
R–Square			0.991

In this model, the coefficients on the output variables (Custnum, CircLen, RMDemand) represent the cost elasticities with respect to each output. They are all statistically significant and positive. The sum of these three elasticities is 0.97, which suggests that a proportionate increase in all three outputs by 1 per cent would raise operating costs by almost 1 per cent.

Table C.2 shows that LSE Translog cost frontier model. The elasticities of cost with respect to each output are not constant in the Translog model, but vary with the values of the outputs. These elasticities are calculated for both the LSE and SFA Translog models at the sample means of outputs and at various sub-sample means of outputs in Tables C.5 and C.6.

Table C.2 LSE Translog cost function estimates using 2006–2022 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.401	0.072	5.559
ln(CircLen)=x2	0.182	0.030	6.010
ln(RMDemand)=x3	0.373	0.060	6.212
x1*x1/2	-0.656	0.474	-1.385
x1*x2	0.313	0.115	2.726
x1*x3	0.266	0.366	0.726
x2*x2/2	-0.024	0.042	-0.574
x2*x3	-0.259	0.093	-2.803
x3*x3/2	0.084	0.285	0.295
ln(ShareUGC)	-0.126	0.027	-4.717
Year	0.012	0.002	7.471
Country dummy variables:			
New Zealand	-0.286	0.137	-2.089
Ontario	-0.174	0.135	-1.288
DNSP dummy variables:			
AGD	-0.078	0.200	-0.390
CIT	-0.653	0.158	-4.142
END	-0.344	0.159	-2.172
ENX	-0.313	0.154	-2.030
ERG	-0.303	0.184	-1.651
ESS	-0.521	0.192	-2.711
JEN	-0.197	0.172	-1.150
PCR	-0.821	0.158	-5.185
SAP	-0.623	0.161	-3.857
AND	-0.429	0.158	-2.719
TND	-0.508	0.163	-3.124
UED	-0.367	0.169	-2.174
Constant	-13.518	3.179	-4.253
R–Square			0.992

The SFA models assume time-invariant inefficiencies with a truncated normal distribution. Table C.3 shows the Cobb-Douglas SFA cost model and Table C.4 shows the Translog SFA cost model. In the SFA Cobb-Douglas model the sum of output elasticities is 0.97, which is similar to the LSE Cobb-Douglas model. However, the SFACD model has much smaller elasticities for customer numbers and larger elasticity for RMD compared to the LSECD model.

Table C.3 SFA Cobb–Douglas cost frontier estimates using 2006–2022 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.364	0.078	4.656
ln(CircLen)	0.132	0.042	3.181
ln(RMDemand)	0.475	0.067	7.133
ln(ShareUGC)	-0.170	0.032	-5.385
Year	0.012	0.001	13.009
Country dummy variables:			
New Zealand	0.195	0.089	2.184
Ontario	0.211	0.076	2.769
Constant	-14.310	1.844	-7.759
Variance parameters:			
Mu	0.350	0.064	5.480
SigmaU squared	0.039	0.010	3.966
SigmaV squared	0.015	0.001	23.093
LLF			646.001

Table C.4 SFA Translog cost function estimates using 2006–2022 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.369	0.080	4.585
ln(CircLen)=x2	0.092	0.049	1.866
ln(RMDemand)=x3	0.445	0.079	5.628
x1*x1/2	0.529	0.476	1.111
x1*x2	-0.175	0.118	-1.481
x1*x3	-0.505	0.395	-1.280
x2*x2/2	0.065	0.056	1.156
x2*x3	0.231	0.105	2.206
x3*x3/2	0.166	0.331	0.501
ln(ShareUGC)	-0.153	0.042	-3.631
Year	0.012	0.001	10.710
Country dummy variables:			
New Zealand	0.140	0.115	1.220
Ontario	0.028	0.123	0.225
Constant	-13.504	2.191	-6.164
Variance parameters:			
Mu	-1.178	2.507	-0.470
SigmaU squared	0.645	0.926	0.697
SigmaV squared	0.014	0.001	22.690
LLF			655.358

C1.2 Cost elasticities

Table C.5 shows the cost elasticities with respect to each of the outputs for the two Translog cost models, in total and for country sub-samples. The patterns of the output elasticities between outputs on average are broadly similar to those for the corresponding Cobb-Douglas model. Table C.6 shows the cost elasticities with respect to each of the outputs for the two Translog cost models, on average for individual Australian DNSPs.

Table C.5 Average DNSP output elasticities by country 2006–2022

	SFATLG model			*LSETLG model*		
Sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
Australia	0.113	0.303	0.273	0.293	0.267	0.470
New Zealand	0.443	0.016	0.659	0.642	0.216	0.075
Ontario	0.424	0.055	0.392	0.311	0.131	0.499
Full sample	0.369	0.092	0.445	0.401	0.182	0.373

Table C.6 Average DNSP output elasticities by Aust. DNSP, 2006–2022

	SFATLG model			*LSETLG model*		
Sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
EVO	0.382	0.127	0.260	0.193	0.227	0.544
AGD	0.055	0.391	0.017	0.016	0.297	0.744
CIT	0.336	0.187	0.077	-0.010	0.226	0.766
END	0.008	0.377	0.195	0.223	0.240	0.592
ENX	0.031	0.386	0.127	0.151	0.292	0.614
ERG	-0.263	0.459	0.631	0.795	0.184	0.118
ESS	-0.136	0.411	0.565	0.705	0.273	0.099
JEN	0.470	0.121	0.090	-0.007	0.319	0.645
PCR	0.024	0.344	0.385	0.454	0.288	0.306
SAP	-0.064	0.389	0.410	0.500	0.258	0.307
AND	0.192	0.269	0.274	0.290	0.335	0.391
TND	0.092	0.264	0.490	0.536	0.201	0.283
UED	0.341	0.216	0.029	-0.040	0.330	0.702
Total (Aust.)	0.113	0.303	0.273	0.293	0.267	0.470

C1.3 Monotonicity Performance

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, all else being constant, 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 2022 report. Tables C.7 and C.8 show the proportions of observations for which there are monotonicity violations in models estimated using the full sample.

The most notable observation is that there is a significant number of monotonicity violations for the Australian DNSPs in the period 2006 to 2022, unlike the results of the 2022 study in the long sample period. Both the TLG models have monotonicity violations in more than 50 per cent of the observations for three Australian DNSPs, although the DNSPs affected differ between the models. The monotonicity violations affecting Australian DNSPs mainly relate to the customer numbers output, but the same is not true for overseas DNSPs.

Table C.7 Frequency of monotonicity violations by country 2006–2022

	SFATLG model			*LSETLG model*		
Sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
Australia	28.1%	0.0%	1.4%	19.5%	0.0%	0.0%
New Zealand	0.0%	44.6%	0.0%	0.0%	0.0%	40.9%
Ontario	5.9%	44.7%	0.0%	0.0%	0.0%	0.0%
Full sample	8.5%	36.0%	0.3%	3.8%	0.0%	11.6%

Table C.8 Frequency of monotonicity violations by DNSP (Aust.) 2006-2022

	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%	17.6%	23.5%	0.0%	0.0%
CIT	0.0%	0.0%	0.0%	76.5%	0.0%	0.0%
END	35.3%	0.0%	0.0%	0.0%	0.0%	0.0%
ENX	11.8%	0.0%	0.0%	0.0%	0.0%	0.0%
ERG	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ESS	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
JEN	0.0%	0.0%	0.0%	52.9%	0.0%	0.0%
PCR	17.6%	0.0%	0.0%	0.0%	0.0%	0.0%
SAP	100.0%	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.)	28.1%	0.0%	1.4%	19.5%	0.0%	0.0%

C1.4 Tests of Translog versus Cobb-Douglas Specifications

It can also be informative to have regard to statistical criteria, and so we test the null hypothesis that the additional variables in the Translog model, which do not appear in the Cobb-Douglas model, are jointly equal to zero.

- In the LSETLG model, the Wald test for the null hypothesis that coefficients on the higher-order terms (ie, those parameters in table C.2 which don't appear in C.1), are jointly equal to zero yields a p-value of 0.0000. This is less than 0.05, hence the null hypothesis can be rejected at the usual significance level.

- In the SFATLG model, the Wald test for the null hypothesis that coefficients on the higher-order terms are jointly equal to zero yields a p-value of 0.0008. This is less than 0.05, hence the null hypothesis can be rejected at the usual significance level.

These results imply that the independent variables added in the Translog models (ie, the higher order terms and interactions between log outputs) have a relationship with the dependent variable (log real opex). That is, at least some of the additional effects included in the Translog model are statistically significant explanatory variables. Hence, the Translog models do capture some element of nonlinearity in the relationship between log real opex and the log outputs.

C2 Standard method of defining opex: Sample from 2012 to 2022

C2.1 Regression results

This section presents the cost function econometric results using a shorter sample period from 2012 to 2022. The models in this section all have 729 observations over 69 DNSPs. Tables C.9 and C.10 present the results for the LSE Cobb-Douglas model and the LSE Translog model respectively.

Table C.9 LSE Cobb–Douglas cost function estimates using 2012–2022 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.591	0.073	8.140
ln(CircLen)	0.195	0.031	6.370
ln(RMDemand)	0.193	0.069	2.814
ln(ShareUGC)	-0.142	0.025	-5.584
Year	0.003	0.002	1.375
Country dummy variables:			
New Zealand	-0.210	0.171	-1.227
Ontario	-0.048	0.169	-0.283
DNSP dummy variables:			
AGD	-0.076	0.218	-0.349
CIT	-0.565	0.184	-3.072
END	-0.286	0.185	-1.545
ENX	-0.237	0.179	-1.318
ERG	-0.253	0.193	-1.316
ESS	-0.348	0.199	-1.748
JEN	-0.360	0.191	-1.879
PCR	-0.767	0.182	-4.212
SAP	-0.465	0.182	-2.554
AND	-0.378	0.180	-2.104
TND	-0.488	0.198	-2.466
UED	-0.518	0.188	-2.750
Constant	3.734	4.706	0.793
R–Square			0.995

Table C.10 LSE Translog cost function estimates using 2012–2022 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.375	0.076	4.911
ln(CircLen)=x2	0.223	0.030	7.519
ln(RMDemand)=x3	0.362	0.064	5.679
x1*x1/2	-0.989	0.535	-1.849
x1*x2	0.304	0.123	2.480
x1*x3	0.523	0.410	1.275
x2*x2/2	0.031	0.042	0.737
x2*x3	-0.305	0.098	-3.106
x3*x3/2	-0.060	0.315	-0.192
ln(ShareUGC)	-0.111	0.026	-4.302
Year	0.005	0.002	2.384
Country dummy variables:			
New Zealand	-0.314	0.158	-1.989
Ontario	-0.161	0.156	-1.032
DNSP dummy variables:			
AGD	-0.047	0.212	-0.223
CIT	-0.598	0.172	-3.478
END	-0.356	0.174	-2.053
ENX	-0.233	0.174	-1.337
ERG	-0.436	0.198	-2.208
ESS	-0.549	0.207	-2.656
JEN	-0.143	0.186	-0.769
PCR	-0.797	0.175	-4.552
SAP	-0.571	0.176	-3.247
AND	-0.290	0.176	-1.643
TND	-0.528	0.184	-2.870
UED	-0.305	0.186	-1.640
Constant	-0.483	4.510	-0.107
R–Square			0.995

Tables C.11 and C.12 present the results for the SFA Cobb-Douglas model and the SFA Translog model respectively over this shorter period 2012-2022.

Table C.11 SFA Cobb–Douglas cost frontier estimates using 2012–2022 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.403	0.098	4.114
ln(CircLen)	0.231	0.048	4.766
ln(RMDemand)	0.325	0.091	3.589
ln(ShareUGC)	-0.080	0.041	-1.936
Year	0.003	0.002	2.036
Country dummy variables:			
New Zealand	0.109	0.092	1.192
Ontario	0.251	0.090	2.798
Constant	3.347	3.090	1.083
Variance parameters:			
Mu	0.345	0.066	5.210
SigmaU squared	0.034	0.008	4.129
SigmaV squared	0.012	0.001	18.150
LLF			465.268

Table C.12 SFA Translog cost function estimates using 2012–2022 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.334	0.121	2.757
ln(CircLen)=x2	0.243	0.059	4.096
ln(RMDemand)=x3	0.402	0.105	3.811
x1*x1/2	-1.083	0.634	-1.708
x1*x2	0.348	0.170	2.042
x1*x3	0.449	0.499	0.900
x2*x2/2	0.011	0.079	0.134
x2*x3	-0.304	0.130	-2.344
x3*x3/2	-0.002	0.411	-0.005
ln(ShareUGC)	-0.068	0.053	-1.298
Year	0.005	0.002	2.703
Country dummy variables:			
New Zealand	-0.021	0.121	-0.174
Ontario	0.099	0.105	0.943
Constant	0.544	3.396	0.160
Variance parameters:			
Mu	0.435	0.093	4.670
SigmaU squared	0.040	0.015	2.573
SigmaV squared	0.011	0.001	16.323
LLF			479.345

C2.2 Cost Elasticities

Tables C.13 and C.14 provide information on the average elasticities of real opex with respect to each of the outputs in the Translog models for the 2012-2022 period.

Table C.13 Average DNSP output elasticities by country 2012–2022

	SFATLG model			*LSETLG model*		
Sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
Australia	-0.191	0.391	0.605	0.062	0.330	0.601
New Zealand	0.682	0.297	0.061	0.597	0.308	0.027
Ontario	0.341	0.156	0.514	0.371	0.135	0.457
Full sample	0.334	0.243	0.402	0.375	0.223	0.362

Table C.14 Average DNSP output elasticities by Aust. DNSP, 2012–2022

	SFATLG model			*LSETLG model*		
Sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
EVO	-0.045	0.288	0.644	0.096	0.242	0.617
AGD	-0.677	0.418	0.949	-0.271	0.320	0.957
CIT	-0.358	0.279	0.900	-0.115	0.208	0.875
END	-0.322	0.358	0.742	0.006	0.282	0.734
ENX	-0.504	0.427	0.800	-0.140	0.341	0.807
ERG	0.360	0.356	0.183	0.578	0.322	0.169
ESS	0.195	0.454	0.195	0.413	0.416	0.201
JEN	-0.429	0.405	0.804	-0.226	0.340	0.803
PCR	-0.088	0.449	0.441	0.154	0.396	0.447
SAP	-0.022	0.415	0.425	0.236	0.362	0.425
AND	-0.267	0.485	0.549	-0.031	0.426	0.563
TND	0.257	0.320	0.340	0.396	0.289	0.318
UED	-0.584	0.425	0.889	-0.296	0.345	0.894
Total (Aust.)	-0.191	0.391	0.605	0.062	0.330	0.601

C2.3 Monotonicity Performance

Tables C.15 and C.16 show the proportions of observations for which there are monotonicity violations in the Translog models. The monotonicity performance of the Translog models estimated over the shorter period is worse than that for the models estimated over the longer period, which is consistent with the 2022 study.

Table C.15 Frequency of monotonicity violations by country 2012–2022

	SFATLG model			*LSETLG model*		
Sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
Australia	72.7%	0.0%	0.0%	46.9%	0.0%	0.0%
New Zealand	5.7%	0.0%	47.8%	2.9%	0.0%	55.5%
Ontario	14.9%	0.0%	2.4%	5.6%	0.5%	2.9%
Full sample	23.6%	0.0%	15.0%	12.9%	0.3%	17.4%

Table C.16 Frequency of monotonicity violations by DNSP (Aust.) 2012-2021

Sample	*SFATLG model*			*LSETLG model*		
	Customer numbers	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
EVO	90.9%	0.0%	0.0%	0.0%	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	100.0%	0.0%	0.0%	36.4%	0.0%	0.0%
ENX	100.0%	0.0%	0.0%	100.0%	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	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%
PCR	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SAP	54.5%	0.0%	0.0%	0.0%	0.0%	0.0%
AND	100.0%	0.0%	0.0%	72.7%	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.)	72.7%	0.0%	0.0%	46.9%	0.0%	0.0%

C2.4 Tests of 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 2022 report. That said, it can also be informative to test whether the additional variables in the Translog model, which do not 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 do not appear in C.9, are jointly equal to zero yields a p-value of 0.0011. 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 do not 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.

In both models the additional terms in the Translog model are jointly statistically significant. This implies that at least some of these variables have a statistically significant relationship with the dependent variable. Hence, the Translog models do capture some element of nonlinearity in the relationship between log real opex and the log outputs.

C3 Opex including Capitalised Overhead: Full sample results

C3.1 Regression outputs

The models in this section all have 1,137 observations over 69 DNSPs. The LSE models use panel-corrected standard errors. Table C.17 shows that LSE Cobb-Douglas cost frontier model.

Table C.17 LSE Cobb–Douglas cost function estimates using 2006–2022 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.561	0.069	8.152
ln(CircLen)	0.172	0.030	5.675
ln(RMDemand)	0.240	0.062	3.866
ln(ShareUGC)	-0.136	0.024	-5.746
Year	0.010	0.002	6.462
Country dummy variables:			
New Zealand	-0.391	0.132	-2.963
Ontario	-0.243	0.129	-1.879
DNSP dummy variables:			
AGD	-0.189	0.192	-0.983
CIT	-0.510	0.144	-3.529
END	-0.318	0.153	-2.069
ENX	-0.358	0.140	-2.556
ERG	-0.146	0.166	-0.884
ESS	-0.318	0.174	-1.832
JEN	-0.416	0.157	-2.649
PCR	-0.733	0.148	-4.959
SAP	-0.668	0.152	-4.390
AND	-0.537	0.146	-3.671
TND	-0.547	0.165	-3.321
UED	-0.674	0.154	-4.371
Constant	-10.401	3.212	-3.238
R–Square			0.991

In this model, the coefficients on the output variables (Custnum, CircLen, RMDemand) represent the cost elasticities with respect to each output. They are all statistically significant and positive. The sum of these three elasticities is 0.97, which suggests that a proportionate increase in all three outputs by 1 per cent would raise operating costs by almost 1 per cent.

Table C.18 shows that LSE Translog cost frontier model. The elasticities of cost with respect to each output are not constant in the Translog model, but vary with the values of the outputs. These elasticities are calculated for both the LSE and SFA Translog models at the sample means of outputs and at various sub-sample means of outputs in Tables C.21 and C.22.

Table C.18 LSE Translog cost function estimates using 2006–2022 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.403	0.073	5.559
ln(CircLen)=x2	0.183	0.031	5.956
ln(RMDemand)=x3	0.370	0.060	6.128
x1*x1/2	-0.590	0.475	-1.242
x1*x2	0.293	0.116	2.523
x1*x3	0.219	0.367	0.598
x2*x2/2	-0.016	0.043	-0.372
x2*x3	-0.247	0.094	-2.637
x3*x3/2	0.116	0.286	0.405
ln(ShareUGC)	-0.124	0.027	-4.561
Year	0.012	0.002	7.382
Country dummy variables:			
New Zealand	-0.473	0.125	-3.781
Ontario	-0.359	0.123	-2.923
DNSP dummy variables:			
AGD	-0.253	0.194	-1.305
CIT	-0.527	0.138	-3.806
END	-0.427	0.150	-2.842
ENX	-0.439	0.143	-3.074
ERG	-0.296	0.180	-1.644
ESS	-0.529	0.188	-2.821
JEN	-0.280	0.159	-1.758
PCR	-0.842	0.146	-5.777
SAP	-0.811	0.153	-5.312
AND	-0.567	0.145	-3.902
TND	-0.596	0.157	-3.795
UED	-0.555	0.160	-3.468
Constant	-13.131	3.189	-4.117
R–Square			0.992

The SFA models assume time-invariant inefficiencies with a truncated normal distribution. Table C.19 shows the Cobb-Douglas SFA cost model and Table C.20 shows the Translog SFA cost model. In the SFA Cobb-Douglas model the sum of output elasticities is 0.97, which is similar to the LSE Cobb-Douglas model. However, the SFACD model has much smaller elasticities for customer numbers and larger elasticity for RMD compared to the LSECD model.

Table C.19 SFA Cobb–Douglas cost frontier estimates using 2006–2022 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.376	0.076	4.983
ln(CircLen)	0.123	0.045	2.715
ln(RMDemand)	0.467	0.066	7.090
ln(ShareUGC)	-0.176	0.031	-5.764
Year	0.012	0.001	13.356
Country dummy variables:			
New Zealand	0.045	0.091	0.491
Ontario	0.068	0.086	0.783
Constant	-14.412	1.813	-7.951
Variance parameters:			
Mu	0.311	0.067	4.640
SigmaU squared	0.042	0.012	3.507
SigmaV squared	0.015	0.001	23.096
LLF			647.152

Table C.20 SFA Translog cost function estimates using 2006–2022 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.395	0.081	4.863
ln(CircLen)=x2	0.091	0.053	1.705
ln(RMDemand)=x3	0.429	0.079	5.460
x1*x1/2	0.759	0.473	1.606
x1*x2	-0.235	0.116	-2.022
x1*x3	-0.666	0.391	-1.704
x2*x2/2	0.094	0.056	1.699
x2*x3	0.263	0.105	2.493
x3*x3/2	0.291	0.328	0.888
ln(ShareUGC)	-0.151	0.043	-3.531
Year	0.011	0.001	10.544
Country dummy variables:			
New Zealand	0.018	0.086	0.215
Ontario	-0.082	0.099	-0.827
Constant	-13.075	2.204	-5.932
Variance parameters:			
Mu	-0.825	1.622	-0.510
SigmaU squared	0.498	0.590	0.843
SigmaV squared	0.014	0.001	22.626
LLF			659.143

C3.2 Cost elasticities

Table C.21 shows the cost elasticities with respect to each of the outputs for the two Translog cost models, in total and for country sub-samples. The patterns of the output elasticities between outputs on average are broadly similar to those for the corresponding Cobb-Douglas model.

Table C.21 Average DNSP output elasticities by country 2006–2022

	SFATLG model			*LSETLG model*		
Sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
Australia	0.166	0.307	0.241	0.296	0.270	0.463
New Zealand	0.456	0.031	0.638	0.639	0.220	0.075
Ontario	0.448	0.043	0.385	0.315	0.130	0.496
Full sample	0.395	0.091	0.429	0.403	0.183	0.370

Table C.22 shows the cost elasticities with respect to each of the outputs for the two Translog cost models, on average for individual Australian DNSPs.

Table C.22 Average DNSP output elasticities by Aust. DNSP, 2006–2022

	SFATLG model			*LSETLG model*		
Sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
EVO	0.451	0.111	0.221	0.207	0.224	0.533
AGD	0.150	0.378	-0.032	0.030	0.295	0.729
CIT	0.428	0.158	0.031	0.010	0.220	0.750
END	0.053	0.379	0.176	0.223	0.243	0.587
ENX	0.105	0.384	0.086	0.158	0.294	0.603
ERG	-0.329	0.514	0.671	0.759	0.202	0.136
ESS	-0.150	0.456	0.564	0.683	0.287	0.107
JEN	0.604	0.090	0.007	0.024	0.311	0.621
PCR	0.058	0.365	0.359	0.449	0.295	0.303
SAP	-0.052	0.415	0.401	0.488	0.267	0.309
AND	0.275	0.272	0.216	0.301	0.337	0.379
TND	0.089	0.285	0.491	0.525	0.209	0.287
UED	0.474	0.188	-0.051	-0.012	0.323	0.678
Total (Aust.)	0.166	0.307	0.241	0.296	0.270	0.463

C3.3 Monotonicity Performance

Tables C.23 and C.24 show the proportions of observations for which there are monotonicity violations in the Translog models estimated using the full sample.

The most notable observation is that there is a significant number of monotonicity violations for the Australian DNSPs in the period 2006 to 2022. Both the SFATLG and LSETLG models have monotonicity violations in more than 50 per cent of the observations for five and four Australian DNSPs, respectively, although the DNSPs affected differ between the models. The monotonicity violations affecting Australian DNSPs mainly relate to the customer numbers output, but the same is not true for overseas DNSPs.

Table C.23 Frequency of monotonicity violations by country 2006–2022

	SFATLG model			*LSETLG model*		
Sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
Australia	23.5%	0.0%	18.6%	10.0%	0.0%	0.0%
New Zealand	0.0%	38.4%	0.0%	0.0%	0.0%	37.2%
Ontario	5.9%	45.4%	0.0%	0.0%	0.0%	0.0%
Full sample	7.7%	34.6%	3.6%	1.9%	0.0%	10.6%

Table C.24 Frequency of monotonicity violations by DNSP (Aust.) 2006-2022

	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%	100.0%	0.0%	0.0%	0.0%
CIT	0.0%	0.0%	0.0%	29.4%	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	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ESS	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
JEN	0.0%	0.0%	41.2%	23.5%	0.0%	0.0%
PCR	5.9%	0.0%	0.0%	0.0%	0.0%	0.0%
SAP	100.0%	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%	100.0%	76.5%	0.0%	0.0%
Total (Aust.)	23.5%	0.0%	18.6%	10.0%	0.0%	0.0%

C3.4 Tests of Translog versus Cobb-Douglas Specifications

It can also be informative to have regard to statistical criteria, and so we test the null hypothesis that the additional variables in the Translog model, which do not appear in the Cobb-Douglas model, are jointly equal to zero.

- In the LSETLG model, the Wald test for the null hypothesis that coefficients on the higher-order terms (ie, those parameters in table C.18 which don't appear in C.17), are jointly equal to zero yields a p-value of 0.0000. This is less than 0.05, hence the null hypothesis can be rejected at the usual significance level.
- In the SFATLG model, the Wald test for the null hypothesis that coefficients on the higher-order terms are jointly equal to zero yields a p-value of 0.0004. This is less than 0.05, hence the null hypothesis can be rejected at the usual significance level .

As the Wald test rejected the null hypothesis for both Translog models, this implies that the independent variables added in the Translog models (ie, the higher order terms and interactions between log outputs) have a relationship with the dependent variable (log real opex). That is, at least some of the additional effects included in the Translog model are statistically significant explanatory variables. Hence, the Translog models do capture some element of nonlinearity in the relationship between log real opex and the log outputs.

C4 Opex including Capitalised Overhead: Sample from 2012 to 2022

C4.1 Regression results

This section presents the cost function econometric results using a shorter sample period from 2012 to 2022. The models in this section all have 729 observations over 69 DNSPs. Tables C.25 and C.26 present the results for the LSE Cobb-Douglas model and the LSE Translog model respectively.

Table C.25 LSE Cobb–Douglas cost function estimates using 2012–2022 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.588	0.074	7.973
ln(CircLen)	0.195	0.031	6.260
ln(RMDemand)	0.195	0.069	2.813
ln(ShareUGC)	-0.142	0.026	-5.466
Year	0.003	0.002	1.278
Country dummy variables:			
New Zealand	-0.407	0.156	-2.601
Ontario	-0.246	0.153	-1.603
DNSP dummy variables:			
AGD	-0.263	0.209	-1.261
CIT	-0.459	0.163	-2.819
END	-0.368	0.173	-2.123
ENX	-0.378	0.163	-2.327
ERG	-0.260	0.188	-1.384
ESS	-0.384	0.194	-1.985
JEN	-0.386	0.170	-2.277
PCR	-0.795	0.165	-4.812
SAP	-0.662	0.169	-3.917
AND	-0.537	0.165	-3.252
TND	-0.578	0.191	-3.018
UED	-0.713	0.176	-4.048
Constant	4.396	4.698	0.936
R–Square			0.995

Table C.26 LSE Translog cost function estimates using 2012–2022 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.375	0.077	4.855
ln(CircLen)=x2	0.223	0.030	7.388
ln(RMDemand)=x3	0.362	0.064	5.620
x1*x1/2	-0.973	0.538	-1.810
x1*x2	0.291	0.124	2.346
x1*x3	0.512	0.413	1.239
x2*x2/2	0.037	0.043	0.850
x2*x3	-0.296	0.099	-2.978
x3*x3/2	-0.053	0.318	-0.167
ln(ShareUGC)	-0.110	0.026	-4.168
Year	0.005	0.002	2.262
Country dummy variables:			
New Zealand	-0.511	0.143	-3.575
Ontario	-0.359	0.141	-2.550
DNSP dummy variables:			
AGD	-0.228	0.203	-1.121
CIT	-0.493	0.151	-3.257
END	-0.436	0.162	-2.689
ENX	-0.368	0.158	-2.320
ERG	-0.453	0.194	-2.332
ESS	-0.591	0.203	-2.916
JEN	-0.172	0.166	-1.038
PCR	-0.823	0.160	-5.157
SAP	-0.769	0.164	-4.692
AND	-0.445	0.163	-2.729
TND	-0.620	0.177	-3.501
UED	-0.497	0.174	-2.849
Constant	0.234	4.522	0.052
R–Square			0.995

Tables C.27 and C.28 present the results for the SFA Cobb-Douglas model and the SFA Translog model respectively over this shorter period 2012-2022.

Table C.27 SFA Cobb–Douglas cost frontier estimates using 2012–2022 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.401	0.091	4.402
ln(CircLen)	0.214	0.044	4.827
ln(RMDemand)	0.342	0.087	3.940
ln(ShareUGC)	-0.100	0.039	-2.561
Year	0.003	0.001	2.210
Country dummy variables:			
New Zealand	-0.018	0.084	-0.213
Ontario	0.109	0.088	1.238
Constant	3.075	3.031	1.014
Variance parameters:			
Mu	0.305	0.059	5.180
SigmaU squared	0.037	0.010	3.804
SigmaV squared	0.012	0.001	18.165
LLF			468.264

Table C.28 SFA Translog cost function estimates using 2012–2022 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.349	0.125	2.799
ln(CircLen)=x2	0.232	0.065	3.553
ln(RMDemand)=x3	0.401	0.107	3.752
x1*x1/2	-0.933	0.650	-1.435
x1*x2	0.277	0.175	1.579
x1*x3	0.334	0.519	0.644
x2*x2/2	0.065	0.085	0.769
x2*x3	-0.277	0.134	-2.065
x3*x3/2	0.086	0.423	0.202
ln(ShareUGC)	-0.075	0.054	-1.405
Year	0.004	0.002	2.683
Country dummy variables:			
New Zealand	-0.147	0.139	-1.056
Ontario	-0.045	0.099	-0.449
Constant	0.912	3.357	0.272
Variance parameters:			
Mu	0.398	0.126	3.150
SigmaU squared	0.044	0.022	2.015
SigmaV squared	0.011	0.001	15.681
LLF			485.594

C4.2 Cost Elasticities

Tables C.28 and C.29 provide information on the average elasticities of real opex with respect to each of the outputs in the Translog models for the 2012-2022 period.

Table C.29 Average DNSP output elasticities by country 2012–2022

	SFATLG model			*LSETLG model*		
Sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
Australia	-0.246	0.408	0.596	0.046	0.334	0.610
New Zealand	0.685	0.321	0.061	0.593	0.311	0.030
Ontario	0.388	0.116	0.515	0.378	0.133	0.452
Full sample	0.349	0.232	0.401	0.375	0.223	0.362

Table C.30 Average DNSP output elasticities by Aust. DNSP, 2012–2022

	SFATLG model			*LSETLG model*		
Sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
EVO	-0.016	0.257	0.626	0.097	0.241	0.616
AGD	-0.725	0.409	0.928	-0.287	0.322	0.965
CIT	-0.320	0.225	0.875	-0.112	0.205	0.872
END	-0.394	0.371	0.742	-0.012	0.286	0.745
ENX	-0.571	0.438	0.785	-0.159	0.344	0.818
ERG	0.175	0.459	0.230	0.541	0.336	0.193
ESS	0.034	0.554	0.218	0.377	0.428	0.224
JEN	-0.370	0.359	0.753	-0.223	0.336	0.800
PCR	-0.183	0.500	0.439	0.130	0.402	0.463
SAP	-0.140	0.476	0.436	0.208	0.370	0.442
AND	-0.311	0.509	0.522	-0.048	0.429	0.573
TND	0.186	0.359	0.354	0.379	0.295	0.329
UED	-0.559	0.389	0.844	-0.299	0.342	0.896
Total (Aust.)	-0.246	0.408	0.596	0.046	0.334	0.610

C4.3 Monotonicity Performance

Tables C.31 and C.32 show the proportions of observations for which there are monotonicity violations in the Translog models.

Table C.31 Frequency of monotonicity violations by country 2012–2022

	SFATLG model			*LSETLG model*		
Sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
Australia	74.1%	0.0%	0.0%	49.7%	0.0%	0.0%
New Zealand	5.3%	0.0%	47.4%	3.8%	0.0%	55.0%
Ontario	13.3%	7.4%	0.0%	5.8%	0.5%	2.9%
Full sample	22.9%	3.8%	13.6%	13.9%	0.3%	17.3%

Table C.32 Frequency of monotonicity violations by DNSP (Aust.) 2012-2021

Sample	*SFATLG model*			*LSETLG model*		
	Customer numbers	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
EVO	54.5%	0.0%	0.0%	0.0%	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	100.0%	0.0%	0.0%	54.5%	0.0%	0.0%
ENX	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%
ERG	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ESS	9.1%	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%	0.0%	0.0%	0.0%
SAP	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AND	100.0%	0.0%	0.0%	90.9%	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.)	74.1%	0.0%	0.0%	49.7%	0.0%	0.0%

C4.4 Tests of 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 2022 report. That said, it can also be informative to test whether the additional variables in the Translog model, which do not 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.26, which do not appear in C.25, are jointly equal to zero yields a p-value of 0.0003. 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.28, which do not appear in C.27, 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.

In both models the additional terms in the Translog model are jointly statistically significant. This implies that at least some of these variables have a statistically significant relationship with the dependent variable. Hence, the Translog models do capture some element of nonlinearity in the relationship between log real opex and the log outputs.

Appendix D: Individual Output, Input and PFP Growth Rates[26]

Table D.1 Industry individual output, input and PFP growth rates

Year	*2006-2022*	*2006-2012*	*2012-2022*	*2021-2022*
Outputs:				
Energy (GWh)	-0.3%	0.1%	-0.4%	0.8%
Ratcheted Max Demand (MVA)	1.1%	2.3%	0.4%	0.8%
Customer Numbers	1.3%	1.3%	1.4%	1.3%
Circuit Length (km)	0.3%	0.3%	0.3%	0.4%
CMOS	0.1%	-1.9%	1.4%	14.1%
Inputs:				
Real Opex ($'000 2006)	0.4%	5.2%	-2.5%	-1.6%
O/H Sub-tran. Lines (MVA-kms)	0.4%	0.8%	0.2%	0.6%
O/H Distr. Lines (MVA-kms)	0.2%	0.1%	0.3%	0.4%
U/G Sub-tran. Lines (MVA-kms)	2.1%	2.9%	1.5%	1.0%
U/G Sub-tran. Lines (MVA-kms)	3.3%	4.0%	2.8%	2.1%
Transformers (MVA)	2.3%	3.6%	1.5%	0.7%
All Capital inputs	1.8%	2.6%	1.3%	0.8%
Partial factor productivity:				
Output / Real Opex	0.5%	-3.5%	2.9%	0.3%
Output / OH Sub-tran. Lines	0.4%	0.9%	0.1%	-1.9%
Output / OH Distr. Lines	0.7%	1.6%	0.1%	-1.6%
Output / UG Sub-tran. Lines	-1.2%	-1.2%	-1.2%	-2.2%
Output / UG Distr. Lines	-2.4%	-2.3%	-2.5%	-3.4%
Output / Transformers	-1.4%	-1.9%	-1.1%	-1.9%
Output / Capital	-0.9%	-0.9%	-0.9%	-2.0%

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

Year	*2006-2022*	*2006-2012*	*2012-2022*	*2021-2022*
Outputs:				
Energy (GWh)	0.3%	0.8%	0.0%	1.6%
Ratcheted Max Demand (MVA)	2.0%	1.8%	2.2%	3.1%
Customer Numbers	2.1%	1.9%	2.3%	2.1%
Circuit Length (km)	1.0%	1.1%	1.0%	0.3%
CMOS	4.1%	0.7%	6.2%	26.6%
Inputs:				
Real Opex ($'000 2006)	1.1%	6.2%	-2.0%	6.3%
O/H Sub-tran. Lines (MVA-kms)	1.3%	0.6%	1.8%	11.7%
O/H Distr. Lines (MVA-kms)	0.0%	-0.4%	0.2%	-0.2%
U/G Sub-tran. Lines (MVA-kms)	8.7%	7.0%	9.7%	0.0%
U/G Sub-tran. Lines (MVA-kms)	2.2%	2.6%	1.9%	0.8%
Transformers (MVA)	1.7%	2.0%	1.6%	0.8%
All Capital inputs	1.5%	1.6%	1.4%	1.3%

[26] The results presented in this section are based on Opex which does not include CCOs.

Table D.2 (cont.)

Year	*2006-2022*	*2006-2012*	*2012-2022*	*2021-2022*
Partial factor productivity:				
Output / Real Opex	0.3%	-4.7%	3.3%	-6.1%
Output / OH Sub-tran. Lines	0.0%	0.9%	-0.5%	-11.5%
Output / OH Distr. Lines	1.4%	1.9%	1.1%	0.3%
Output / UG Sub-tran. Lines	-7.3%	-5.5%	-8.4%	0.2%
Output / UG Distr. Lines	-0.8%	-1.1%	-0.6%	-0.6%
Output / Transformers	-0.3%	-0.5%	-0.2%	-0.7%
Output / Capital	-0.1%	-0.2%	-0.1%	-1.1%

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

Year	*2006-2022*	*2006-2012*	*2012-2022*	*2021-2022*
Outputs:				
Energy (GWh)	-1.4%	-0.4%	-1.9%	-0.9%
Ratcheted Max Demand (MVA)	0.4%	1.2%	0.0%	0.0%
Customer Numbers	0.9%	0.8%	0.9%	0.5%
Circuit Length (km)	0.6%	0.8%	0.5%	0.5%
CMOS	0.0%	-0.8%	0.4%	6.4%
Inputs:				
Real Opex ($'000 2006)	-2.9%	4.4%	-7.3%	-13.2%
O/H Sub-tran. Lines (MVA-kms)	-0.3%	0.1%	-0.5%	-1.6%
O/H Distr. Lines (MVA-kms)	0.7%	-0.2%	1.2%	6.4%
U/G Sub-tran. Lines (MVA-kms)	0.4%	0.4%	0.4%	0.5%
U/G Sub-tran. Lines (MVA-kms)	1.9%	2.6%	1.5%	0.9%
Transformers (MVA)	1.9%	3.9%	0.7%	0.0%
All Capital inputs	1.5%	2.6%	0.8%	0.7%
Partial factor productivity:				
Output / Real Opex	3.4%	-3.4%	7.5%	12.8%
Output / OH Sub-tran. Lines	0.8%	0.9%	0.7%	1.3%
Output / OH Distr. Lines	-0.2%	1.2%	-1.0%	-6.8%
Output / UG Sub-tran. Lines	0.1%	0.6%	-0.3%	-0.9%
Output / UG Distr. Lines	-1.4%	-1.6%	-1.3%	-1.3%
Output / Transformers	-1.4%	-2.9%	-0.5%	-0.4%
Output / Capital	-1.0%	-1.6%	-0.6%	-1.1%

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

Year	*2006-2022*	*2006-2012*	*2012-2022*	*2021-2022*
Outputs:				
Energy (GWh)	-1.0%	0.3%	-1.8%	-1.1%
Ratcheted Max Demand (MVA)	1.0%	1.7%	0.7%	0.0%
Customer Numbers	1.0%	1.3%	0.9%	0.1%
Circuit Length (km)	1.0%	1.4%	0.7%	0.3%
CMOS	-0.7%	4.0%	-3.7%	-23.4%

Table D.4 (cont.)

Year	2006-2022	2006-2012	2012-2022	2021-2022
Inputs:				
Real Opex ($'000 2006)	1.5%	8.1%	-2.7%	-14.2%
O/H Sub-tran. Lines (MVA-kms)	0.1%	-0.3%	0.4%	-0.1%
O/H Distr. Lines (MVA-kms)	-0.6%	-0.2%	-0.8%	0.2%
U/G Sub-tran. Lines (MVA-kms)	4.1%	5.0%	3.4%	0.9%
U/G Sub-tran. Lines (MVA-kms)	1.4%	3.3%	0.1%	1.6%
Transformers (MVA)	1.4%	2.1%	1.0%	-1.4%
All Capital inputs	1.4%	2.7%	0.6%	0.3%
Partial factor productivity:				
Output / Real Opex	-0.6%	-6.9%	3.4%	15.1%
Output / OH Sub-tran. Lines	0.8%	1.5%	0.3%	1.1%
Output / OH Distr. Lines	1.5%	1.5%	1.5%	0.8%
Output / UG Sub-tran. Lines	-3.2%	-3.8%	-2.7%	0.1%
Output / UG Distr. Lines	-0.4%	-2.1%	0.6%	-0.6%
Output / Transformers	-0.5%	-0.9%	-0.3%	2.3%
Output / Capital	-0.5%	-1.5%	0.1%	0.7%

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

Year	2006-2022	2006-2012	2012-2022	2021-2022
Outputs:				
Energy (GWh)	-0.2%	-0.7%	0.1%	0.0%
Ratcheted Max Demand (MVA)	0.9%	1.6%	0.4%	0.0%
Customer Numbers	1.5%	1.0%	1.8%	1.4%
Circuit Length (km)	1.3%	1.1%	1.4%	1.2%
CMOS	1.0%	0.0%	1.6%	34.5%
Inputs:				
Real Opex ($'000 2006)	0.1%	3.6%	-2.0%	-2.0%
O/H Sub-tran. Lines (MVA-kms)	-0.1%	0.8%	-0.6%	-0.2%
O/H Distr. Lines (MVA-kms)	-0.2%	0.0%	-0.4%	0.0%
U/G Sub-tran. Lines (MVA-kms)	5.6%	7.6%	4.3%	5.7%
U/G Sub-tran. Lines (MVA-kms)	5.3%	6.6%	4.5%	3.7%
Transformers (MVA)	2.4%	3.3%	1.9%	-1.4%
All Capital inputs	2.7%	3.6%	2.1%	0.4%
Partial factor productivity:				
Output / Real Opex	1.0%	-2.3%	2.9%	-1.8%
Output / OH Sub-tran. Lines	1.1%	0.5%	1.5%	-3.6%
Output / OH Distr. Lines	1.3%	1.3%	1.3%	-3.7%
Output / UG Sub-tran. Lines	-4.5%	-6.3%	-3.4%	-9.5%
Output / UG Distr. Lines	-4.2%	-5.2%	-3.6%	-7.4%
Output / Transformers	-1.3%	-2.0%	-1.0%	-2.3%
Output / Capital	-1.6%	-2.3%	-1.2%	-4.2%

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

Year	*2006-2022*	*2006-2012*	*2012-2022*	*2021-2022*
Outputs:				
Energy (GWh)	0.2%	0.5%	0.0%	0.8%
Ratcheted Max Demand (MVA)	1.7%	3.8%	0.5%	4.4%
Customer Numbers	1.6%	1.7%	1.6%	2.2%
Circuit Length (km)	1.1%	1.6%	0.8%	0.6%
CMOS	-0.7%	-9.8%	4.7%	19.5%
Inputs:				
Real Opex ($'000 2006)	2.3%	6.7%	-0.3%	4.7%
O/H Sub-tran. Lines (MVA-kms)	1.4%	2.4%	0.8%	2.7%
O/H Distr. Lines (MVA-kms)	0.2%	0.4%	0.0%	0.0%
U/G Sub-tran. Lines (MVA-kms)	4.2%	8.5%	1.6%	-0.7%
U/G Sub-tran. Lines (MVA-kms)	4.0%	6.3%	2.6%	1.7%
Transformers (MVA)	2.6%	4.2%	1.6%	1.0%
All Capital inputs	2.4%	4.0%	1.4%	0.7%
Partial factor productivity:				
Output / Real Opex	-0.6%	-2.7%	0.7%	-4.5%
Output / OH Sub-tran. Lines	0.3%	1.6%	-0.5%	-2.5%
Output / OH Distr. Lines	1.6%	3.6%	0.3%	0.2%
Output / UG Sub-tran. Lines	-2.4%	-4.4%	-1.3%	0.9%
Output / UG Distr. Lines	-2.2%	-2.3%	-2.2%	-1.5%
Output / Transformers	-0.8%	-0.1%	-1.2%	-0.8%
Output / Capital	-0.6%	0.0%	-1.0%	-0.5%

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

Year	*2006-2022*	*2006-2012*	*2012-2022*	*2021-2022*
Outputs:				
Energy (GWh)	0.1%	0.3%	0.1%	2.2%
Ratcheted Max Demand (MVA)	0.9%	2.4%	0.0%	0.0%
Customer Numbers	1.4%	1.9%	1.0%	1.2%
Circuit Length (km)	0.2%	0.6%	0.0%	0.2%
CMOS	0.2%	-2.3%	1.7%	18.2%
Inputs:				
Real Opex ($'000 2006)	-0.7%	2.0%	-2.3%	1.8%
O/H Sub-tran. Lines (MVA-kms)	0.2%	1.7%	-0.7%	0.5%
O/H Distr. Lines (MVA-kms)	0.9%	1.1%	0.9%	0.7%
U/G Sub-tran. Lines (MVA-kms)	3.5%	6.3%	1.9%	0.0%
U/G Sub-tran. Lines (MVA-kms)	4.6%	8.9%	2.1%	1.5%
Transformers (MVA)	2.3%	2.9%	1.9%	-1.6%
All Capital inputs	1.6%	2.4%	1.2%	-0.2%

Table D.7 (cont.)

Year	*2006-2022*	*2006-2012*	*2012-2022*	*2021-2022*
Partial factor productivity:				
Output / Real Opex	1.5%	0.7%	2.0%	-6.6%
Output / OH Sub-tran. Lines	0.7%	1.1%	0.5%	-5.3%
Output / OH Distr. Lines	-0.1%	1.7%	-1.1%	-5.5%
Output / UG Sub-tran. Lines	-2.6%	-3.5%	-2.1%	-4.8%
Output / UG Distr. Lines	-3.8%	-6.2%	-2.3%	-6.3%
Output / Transformers	-1.4%	-0.1%	-2.1%	-3.2%
Output / Capital	-0.8%	0.4%	-1.4%	-4.6%

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

Year	*2006-2022*	*2006-2012*	*2012-2022*	*2021-2022*
Outputs:				
Energy (GWh)	0.2%	-0.2%	0.5%	0.1%
Ratcheted Max Demand (MVA)	1.4%	0.8%	1.7%	1.6%
Customer Numbers	1.1%	0.8%	1.2%	1.1%
Circuit Length (km)	-0.2%	-0.7%	0.1%	0.1%
CMOS	-0.9%	-2.9%	0.4%	2.5%
Inputs:				
Real Opex ($'000 2006)	1.0%	9.3%	-3.9%	-8.8%
O/H Sub-tran. Lines (MVA-kms)	0.7%	-0.3%	1.3%	-0.1%
O/H Distr. Lines (MVA-kms)	-0.3%	-1.3%	0.3%	0.3%
U/G Sub-tran. Lines (MVA-kms)	2.9%	-3.6%	6.7%	0.0%
U/G Sub-tran. Lines (MVA-kms)	1.9%	0.1%	3.0%	2.6%
Transformers (MVA)	2.2%	4.1%	1.0%	0.9%
All Capital inputs	1.2%	1.6%	0.9%	1.0%
Partial factor productivity:				
Output / Real Opex	0.0%	-8.3%	4.9%	9.3%
Output / OH Sub-tran. Lines	0.3%	1.3%	-0.3%	0.5%
Output / OH Distr. Lines	1.3%	2.3%	0.7%	0.1%
Output / UG Sub-tran. Lines	-1.8%	4.7%	-5.8%	0.4%
Output / UG Distr. Lines	-0.9%	0.9%	-2.0%	-2.2%
Output / Transformers	-1.1%	-3.1%	0.0%	-0.5%
Output / Capital	-0.2%	-0.6%	0.0%	-0.6%

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

Year	*2006-2022*	*2006-2012*	*2012-2022*	*2021-2022*
Outputs:				
Energy (GWh)	0.0%	0.3%	-0.3%	3.5%
Ratcheted Max Demand (MVA)	1.5%	3.3%	0.3%	0.0%
Customer Numbers	1.6%	1.1%	1.9%	1.4%
Circuit Length (km)	1.1%	1.1%	1.2%	0.9%
CMOS	-1.0%	-4.2%	1.1%	1.5%

Table D.9 (cont.)

Year	2006-2022	2006-2012	2012-2022	2021-2022
Inputs:				
Real Opex ($'000 2006)	-1.2%	3.3%	-4.1%	-10.0%
O/H Sub-tran. Lines (MVA-kms)	1.0%	1.0%	0.9%	-0.3%
O/H Distr. Lines (MVA-kms)	0.2%	-0.2%	0.4%	0.3%
U/G Sub-tran. Lines (MVA-kms)	3.3%	-0.4%	5.7%	5.7%
U/G Sub-tran. Lines (MVA-kms)	4.7%	4.8%	4.7%	3.9%
Transformers (MVA)	2.6%	3.3%	2.2%	1.6%
All Capital inputs	1.3%	1.3%	1.3%	0.6%
Partial factor productivity:				
Output / Real Opex	2.6%	-1.0%	4.9%	10.8%
Output / OH Sub-tran. Lines	0.5%	1.4%	-0.1%	1.2%
Output / OH Distr. Lines	1.2%	2.5%	0.4%	0.6%
Output / UG Sub-tran. Lines	-1.9%	2.7%	-4.9%	-4.8%
Output / UG Distr. Lines	-3.3%	-2.5%	-3.8%	-3.0%
Output / Transformers	-1.2%	-1.0%	-1.4%	-0.7%
Output / Capital	0.1%	1.0%	-0.4%	0.3%

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

Year	2006-2022	2006-2012	2012-2022	2021-2022
Outputs:				
Energy (GWh)	0.5%	1.0%	0.2%	1.7%
Ratcheted Max Demand (MVA)	1.7%	3.3%	0.7%	0.0%
Customer Numbers	2.0%	1.9%	2.0%	2.7%
Circuit Length (km)	0.5%	0.4%	0.5%	0.6%
CMOS	1.6%	3.0%	0.7%	14.4%
Inputs:				
Real Opex ($'000 2006)	0.6%	2.6%	-0.7%	3.6%
O/H Sub-tran. Lines (MVA-kms)	0.1%	0.1%	0.1%	0.8%
O/H Distr. Lines (MVA-kms)	0.1%	0.1%	0.1%	0.1%
U/G Sub-tran. Lines (MVA-kms)	10.1%	5.9%	12.7%	10.5%
U/G Sub-tran. Lines (MVA-kms)	5.7%	5.9%	5.6%	3.9%
Transformers (MVA)	2.7%	3.0%	2.4%	3.4%
All Capital inputs	2.1%	2.3%	2.1%	2.1%
Partial factor productivity:				
Output / Real Opex	0.5%	-1.2%	1.5%	-4.8%
Output / OH Sub-tran. Lines	0.9%	1.3%	0.7%	-2.0%
Output / OH Distr. Lines	0.9%	1.4%	0.7%	-1.4%
Output / UG Sub-tran. Lines	-9.0%	-4.4%	-11.9%	-11.8%
Output / UG Distr. Lines	-4.7%	-4.5%	-4.8%	-5.2%
Output / Transformers	-1.6%	-1.6%	-1.6%	-4.7%
Output / Capital	-1.1%	-0.8%	-1.3%	-3.3%

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

Year	*2006-2022*	*2006-2012*	*2012-2022*	*2021-2022*
Outputs:				
Energy (GWh)	-0.7%	0.1%	-1.2%	1.1%
Ratcheted Max Demand (MVA)	0.9%	2.4%	0.0%	0.0%
Customer Numbers	1.1%	1.3%	1.0%	0.9%
Circuit Length (km)	0.4%	0.5%	0.3%	0.4%
CMOS	0.2%	-1.7%	1.4%	7.9%
Inputs:				
Real Opex ($'000 2006)	2.5%	6.3%	0.3%	6.6%
O/H Sub-tran. Lines (MVA-kms)	0.6%	0.5%	0.7%	1.6%
O/H Distr. Lines (MVA-kms)	-0.1%	0.0%	-0.1%	-0.1%
U/G Sub-tran. Lines (MVA-kms)	1.7%	2.1%	1.5%	2.0%
U/G Sub-tran. Lines (MVA-kms)	2.9%	3.3%	2.7%	1.6%
Transformers (MVA)	2.1%	3.6%	1.3%	1.5%
All Capital inputs	1.9%	2.7%	1.4%	1.2%
Partial factor productivity:				
Output / Real Opex	-1.9%	-4.5%	-0.3%	-7.2%
Output / OH Sub-tran. Lines	0.0%	1.2%	-0.7%	-2.2%
Output / OH Distr. Lines	0.7%	1.8%	0.1%	-0.5%
Output / UG Sub-tran. Lines	-1.1%	-0.4%	-1.5%	-2.6%
Output / UG Distr. Lines	-2.3%	-1.5%	-2.7%	-2.3%
Output / Transformers	-1.5%	-1.8%	-1.3%	-2.1%
Output / Capital	-1.3%	-1.0%	-1.4%	-1.8%

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

Year	*2006-2022*	*2006-2012*	*2012-2022*	*2021-2022*
Outputs:				
Energy (GWh)	0.2%	0.4%	0.0%	1.6%
Ratcheted Max Demand (MVA)	1.7%	3.0%	0.9%	0.0%
Customer Numbers	1.8%	1.7%	1.8%	1.6%
Circuit Length (km)	0.7%	0.9%	0.5%	0.4%
CMOS	0.5%	-5.2%	4.1%	22.4%
Inputs:				
Real Opex ($'000 2006)	3.7%	7.5%	1.3%	-4.1%
O/H Sub-tran. Lines (MVA-kms)	0.8%	1.2%	0.5%	1.4%
O/H Distr. Lines (MVA-kms)	0.0%	0.4%	-0.2%	-0.3%
U/G Sub-tran. Lines (MVA-kms)	7.6%	2.3%	10.9%	-0.9%
U/G Sub-tran. Lines (MVA-kms)	5.0%	5.3%	4.8%	3.1%
Transformers (MVA)	2.5%	3.7%	1.8%	2.8%
All Capital inputs	2.0%	2.6%	1.5%	1.8%

Table D.12 (cont.)

Year	*2006-2022*	*2006-2012*	*2012-2022*	*2021-2022*
Partial factor productivity:				
Output / Real Opex	-2.3%	-4.6%	-0.9%	1.8%
Output / OH Sub-tran. Lines	0.6%	1.6%	-0.1%	-3.6%
Output / OH Distr. Lines	1.4%	2.5%	0.6%	-2.0%
Output / UG Sub-tran. Lines	-6.2%	0.6%	-10.5%	-1.4%
Output / UG Distr. Lines	-3.6%	-2.4%	-4.3%	-5.4%
Output / Transformers	-1.2%	-0.9%	-1.4%	-5.1%
Output / Capital	-0.6%	0.2%	-1.1%	-4.1%

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

Year	*2006-2022*	*2006-2012*	*2012-2022*	*2021-2022*
Outputs:				
Energy (GWh)	0.2%	-0.5%	0.6%	2.2%
Ratcheted Max Demand (MVA)	0.5%	1.4%	0.0%	0.0%
Customer Numbers	1.1%	1.8%	0.8%	1.1%
Circuit Length (km)	0.4%	0.8%	0.1%	-0.5%
CMOS	3.1%	5.0%	2.0%	12.9%
Inputs:				
Real Opex ($'000 2006)	1.2%	5.6%	-1.4%	-0.6%
O/H Sub-tran. Lines (MVA-kms)	-0.1%	0.1%	-0.3%	-0.1%
O/H Distr. Lines (MVA-kms)	0.6%	0.6%	0.6%	-0.2%
U/G Sub-tran. Lines (MVA-kms)	3.8%	9.2%	0.6%	-11.5%
U/G Sub-tran. Lines (MVA-kms)	1.3%	1.6%	1.1%	2.5%
Transformers (MVA)	2.3%	4.0%	1.3%	1.4%
All Capital inputs	1.4%	2.2%	0.9%	0.8%
Partial factor productivity:				
Output / Real Opex	-1.2%	-5.3%	1.3%	-1.8%
Output / OH Sub-tran. Lines	0.2%	0.2%	0.2%	-2.4%
Output / OH Distr. Lines	-0.6%	-0.3%	-0.7%	-2.2%
Output / UG Sub-tran. Lines	-3.8%	-9.0%	-0.7%	9.0%
Output / UG Distr. Lines	-1.3%	-1.3%	-1.2%	-4.9%
Output / Transformers	-2.3%	-3.8%	-1.4%	-3.9%
Output / Capital	-1.4%	-1.9%	-1.1%	-3.3%

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

Year	*2006-2022*	*2006-2012*	*2012-2022*	*2021-2022*
Outputs:				
Energy (GWh)	-0.3%	0.4%	-0.7%	1.4%
Ratcheted Max Demand (MVA)	1.4%	3.6%	0.0%	0.0%
Customer Numbers	1.0%	0.9%	1.0%	0.7%
Circuit Length (km)	0.5%	0.6%	0.5%	0.2%
CMOS	-1.7%	8.3%	-8.1%	25.2%

Table D.14 (cont.)

Year	*2006-2022*	*2006-2012*	*2012-2022*	*2021-2022*
Inputs:				
Real Opex ($'000 2006)	0.0%	3.6%	-2.3%	3.0%
O/H Sub-tran. Lines (MVA-kms)	1.4%	2.8%	0.5%	-0.2%
O/H Distr. Lines (MVA-kms)	0.4%	0.7%	0.1%	1.3%
U/G Sub-tran. Lines (MVA-kms)	1.1%	7.7%	-3.2%	-3.8%
U/G Sub-tran. Lines (MVA-kms)	2.9%	3.4%	2.6%	2.8%
Transformers (MVA)	2.5%	3.4%	1.9%	1.3%
All Capital inputs	1.7%	2.7%	1.0%	1.0%
Partial factor productivity:				
Output / Real Opex	1.0%	-2.7%	3.4%	-4.0%
Output / OH Sub-tran. Lines	-0.4%	-1.9%	0.6%	-0.8%
Output / OH Distr. Lines	0.7%	0.1%	1.0%	-2.3%
Output / UG Sub-tran. Lines	0.0%	-6.9%	4.3%	2.8%
Output / UG Distr. Lines	-1.9%	-2.5%	-1.5%	-3.8%
Output / Transformers	-1.4%	-2.5%	-0.8%	-2.3%
Output / Capital	-0.6%	-1.8%	0.1%	-2.0%

References

Aigner, Dennis J., C.A. Knox Lovell, and Peter Schmidt. 1977. 'Formulation and Estimation of Stochastic Frontier Production Function Models'. *Journal of Econometrics* 6: 21–37.

Australian Energy Regulator (AER). 2015. 'Final Decision: Ausgrid Distributiobn Determination 2014-15 to 2018-19 – Attachment 7: Operating Expenditure'.

———. 2019. 'Values of Customer Reliability: Final Report on VCR Values'.

———. 2022. 'Annual Benchmarking Report: Electricity Distribution Network Service Providers'.

———. 2023. 'How the AER Will Assess the Impact of Capitalisation Differences on Our Benchmarking: Final Guidance Note'.

Battese, George, and Tim Coelli. 1988. 'Prediction of Firm-Level Technical Efficiencies with a Generalized Frontier Function and Panel Data'. *Journal of Econometrics* 38: 387–99.

Beck, Nathaniel, and Jonathan N. Katz. 1995. 'What To Do (and Not to Do) with Time-Series Cross-Section Data'. *American Political Science Review* 89 (03): 634–47. https://doi.org/10.2307/2082979.

Caves, Douglas W., Laurits R. Christensen, and W. Erwin Diewert. 1982. 'Multilateral Comparisons of Output, Input, and Productivity Using Superlative Index Numbers'. *Economic Journal* 92: 73–86.

Economic Insights. 2014. 'Economic Benchmarking Assessment of Operating Expenditure for NSW and ACT Electricity DNSPs'. Report Prepared for Australian Energy Regulator by Denis Lawrence, Tim Coelli and John Kain.

———. 2015a. 'Response to Consultants' Reports on Economic Benchmarking of Electricity DNSPs'. Report Prepared by Denis Lawrence, Tim Coelli and John Kain for the Australian Energy Regulator.

———. 2015b. 'DNSP MTFP and Opex Cost Function Results'. Memorandum Prepared by Denis Lawrence, Tim Coelli and John Kain for the Australian Energy Regulator.

———. 2017. 'Economic Benchmarking Results for the Australian Energy Regulator's 2017 DNSP Benchmarking Report'. Prepared for the Australian Energy Regulator by Denis Lawrence, Tim Coelli and John Kain.

———. 2018. 'Economic Benchmarking Results for the Australian Energy Regulator's 2018 DNSP Annual Benchmarking Report'. Prepared for Australian Energy Regulator by Denis Lawrence, Tim Coelli and John Kain.

———. 2019. 'Economic Benchmarking Results for the Australian Energy Regulator's 2019 DNSP Annual Benchmarking Report'. Report Prepared by Denis Lawrence, Tim Coelli and John Kain for Australian Energy Regulator.

———. 2020. 'Economic Benchmarking Results for the Australian Energy Regulator's 2020 DNSP Annual Benchmarking Report'. Prepared for Australian Energy Regulator by Denis Lawrence, Tim Coelli and John Kain.

———. 2021. 'Economic Benchmarking Results for the Australian Energy Regulator's 2021 DNSP Annual Benchmarking Report'. Draft Report Prepared by Michael Cunningham, Denis Lawrence and Tim Coelli for Australian Energy Regulator.

Greene, William H. 2012. *Econometric Analysis*. 7th ed. Pearson.

Horrace, William C, and Peter Schmidt. 1996. ‘Confidence Statements for Efficiency Estimates from Stochastic Frontier Models’. *Journal of Productivity Analysis* 7: 257–82.

Kumbhakar, Subal C., and C. A. Knox Lovell. 2000. *Stochastic Frontier Analysis*. Cambridge University Press.

Lawrence, Denis. 2003. ‘Regulation of Electricity Lines Businesses, Analysis of Lines Business Performance – 1996–2003’. Meyrick & Associates Report Prepared for Commerce Commission, NZ.

Lawrence, Denis, and Erwin Diewert. 2006. ‘Regulating Electricity Networks: The ABC of Setting X in New Zealand’. In *Performance Measurement and Regulation of Network Utilities*, edited by Tim Coelli and Denis Lawrence. Edward Elgar.

Merryman, Scott. 2010. ‘FRONTIER_TECI: Stata Module to Generate Technical Efficiency Confidence Intervals’. Risk Management Agency, USDA.

OECD and Eurostat. 2012. *Eurostat-OECD Methodological Manual on Purchasing Power Parities*. OECD. https://doi.org/10.1787/9789264011335-en.

Pitt, M., and L. Lee. 1981. ‘The Measurement and Sources of Technical Inefficiency in the Indonesian Weaving Industry’. *Journal of Development Economics* 9: 43–64.

Pittman, Russell W. 1983. ‘Multilateral Productivity Comparisons with Undesirable Outputs’. *The Economic Journal* 93 (372): 883. https://doi.org/10.2307/2232753.

Quantonomics. 2022. ‘Economic Benchmarking Results for the Australian Energy Regulator’s 2022 DNSP Annual Benchmarking Report’. Report Prepared for Australian Energy Regulator by Michael Cunningham, Joseph Hirschberg and Melusine Quack.

———. 2023. ‘Evoenergy – Benchmarking Limitations’. Memorandum Prepared for AER by Michael Cunningham, Alice Giovani & Joe Hirschberg. https://www.aer.gov.au/system/files/AER%20-%20Evoenergy%202024-29%20-%20Draft%20Decision%20-%20Quantonomics%20-%20Benchmarking%20limitations%20-%20September%202023.pdf.

StataCorp. 2020. ‘Stata/MP, Release 16.1’.