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QUANTITATIVE ECONOMICS

Economic Benchmarking Results for the Australian Energy Regulator's 2024 DNSP Annual Benchmarking Report

Report prepared for Australian Energy Regulator

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Michael Cunningham, Joseph Hirschberg and Alice Giovani

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

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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 2023 DNSP Benchmarking Report (AER 2023a).

This annual update closely follows the methods used previously by Economic Insights (2021) and Quantonomics (2022; 2023a). It includes data for the 2022–23 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 18-year period from 2006 to 2023, and for the 12–year period from 2012 to 2023. This follows previous analyses by Economic Insights (2014; 2015b; 2015a; 2017; 2018; 2019; 2020; 2021) and Quantonomics (2022; 2023a).

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; 2023a) with some important exceptions relating to the definition of opex and the calculation of the annual user cost (AUC) of capital inputs. AUCs are used to determine the capital input weights – see section 1.3.3 for further discussion on how these weights are determined.

Firstly, whereas the 2023 report presented, alongside the standard method, results when opex is defined on a revised basis, this report exclusively presents results based on the revised opex definition. In 2023, the AER 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 Final Guidance Note (2023b) the AER decided to: (a) allocate 100 per cent 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 used for cost data in benchmarking. The results of the present analysis use only this revised definition of opex.

Second, the revised definition of Opex that includes CCOs has implications for the calculation of input weights. The reallocation of CCOs to Opex means that a consistent adjustment needs to be made to the AUC. The AER adopted a preliminary method in 2023, and has since consulted with electricity network providers on this proposed approach. It involves firstly removing from Capex for the purpose of calculating the AUC for each asset class. Using the adjusted Capex series, the RAB and depreciation series are also recalculated by asset class. The AUC is then calculated using the weighted average cost of capital (WACC) applied to this alternative RAB series, the restated depreciation and the benchmark tax liability. Further details are provided in section A3 of Appendix A.

A methodological issue that has arisen concerns the calculation of the AUC in a rapidly changing inflation environment. This has resulted in sharp falls in AUC values in 2023, with some AUC values being negative. In particular, this has been driven by a large discrepancy between inflation outcomes as measured by the consumer price index (CPI) and inflationary expectations embedded within nominal Commonwealth bond rates, and hence the weighted average cost of capital (WACC). Specifically an inconsistency between inflation used to determine:

- the return of capital via regulatory depreciation (the inflation addition component being based on CPI inflation outcomes), and
- the return on capital via the nominal WACC (which includes as a central parameter, the nominal Commonwealth bond rates).

In this report we have moved to an alternative method of calculating the AUC which removes the inflation addition from regulatory depreciation, resulting in straight-line depreciation being used, and uses the Real WACC, rather than the Nominal WACC. This removes both inflation-related components of the AUC. There is also a resulting change to the calculation of the benchmark tax liability. Further details are provided in section A5 of Appendix A.

1.2 Updates to data for the 2024 report

In regard to output variables the key revisions are:

- A change to AusNet's 2022 energy deliveries of approximately 0.5 per cent due to updated billing records;
- Revision of Evoenergy's circuit length data over the whole period 2006 to 2022, with an average difference of 15.2 per cent. During its recent Access Arrangement review, Evoenergy found an error in the basis of preparing the historical circuit length data.

In regard to input variables the revisions are:

- Changes to opex for a number of DNSPs related primarily to the shifting from 2014 Cost Allocation Methods (CAMs), used for all years, to 2022 CAMs used for all years and SaaS/lease adjustments. This affected Evoenergy (2015–2022), Ausgrid (2020–2022), Essential (2020–2022), AusNet (2019–2022) and United Energy (2017). The average sizes of the changes in the relevant years are: Evoenergy (2.0 per cent), Ausgrid (0.01 per cent), Essential (0.6 per cent), AusNet (–0.8 per cent) and United Energy (0.1 per cent).

- Energex's Opex for 2006–2008 is revised due to changes in estimated CCOs. These changes are very small. Both Energex's and Ergon's Opex for 2021–2022 are revised due to updated reported CCOs. The average changes in Opex in 2021–2022 are 0.2 per cent for Energex and –0.2 per cent for Ergon.
- There are significant changes over the whole period 2006–2022 in Evoenergy's variables for overhead subtransmission lines, overhead distribution lines, underground subtransmission lines, underground distribution lines, and the share of underground cables. These changes are all related to the corrections to line and cable lengths driving the changes to circuit length noted above. The average sizes of these changes are: overhead subtransmission lines (10.7 per cent), overhead distribution lines (4.1 per cent), underground subtransmission lines (24.5 per cent), underground distribution lines (32.8 per cent), and the share of underground cables (10.9 per cent).

The Ontario dataset has been updated for 2022 data and historical data has been revised for the following reasons. Since 2005, numerous mergers have taken place among Ontario DNSPs and in most cases we have consolidated these mergers by backcasting the merger in the dataset. That is, the data for the merging DNSPs is aggregated in the years preceding the merger. This results in a balanced panel and reduces distortions to the time trend coefficient due to structural changes.

(a) In previous benchmarking reports, not all past mergers were consistently back–cast, and consequently the Ontario data was not a balanced panel. The dataset used in the 2023 Annual Benchmarking Report (ABR) had 37 Ontario DNSPs, comprising only the larger DNSPs. When all past mergers are consistently consolidated, this reduces to 31;

(b) In 2022, six Ontario DNSPs were affected by mergers. Specifically, Energy Plus and Brantford Power Inc. merged to form GrandBridge Energy Inc.; Kitchener–Wilmot Hydro Inc. merged with Waterloo North Hydro Inc. to create Enova; and North Bay merged with Espanola (not in the 2023 dataset). These mergers further reduced the DNSPs in the sample from 31 to 29.

In addition to these two major changes, there were a number of minor data corrections.

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. Outputs (a) to (d) are referred to as the 'non–reliability outputs', and output (e) is the 'reliability' output. The weights of the non-reliability outputs are based on an econometric analysis of cost causation applied to total revenue, and the weight of the reliability output is based on the cost to consumers of non-reliability. Section A3.2 in Appendix A explains the derivation of the output weights for the non-reliability outputs and the reliability output. The outputs are:

(a) Energy throughput in GWh (accounting for 9.9 per cent of total revenue on average[1]),

(b) Ratcheted maximum demand (RMD) in Megawatts (MW) (accounting for 38.9 per cent of total revenue on average),

(c) Customer numbers (accounting for 21.3 per cent of total revenue on average),

(d) Circuit length in kms (accounting for 45.1 per cent of total revenue on average), and

(e) (minus) Customer Minutes Off–supply (CMOS) (with the weight based on current AER VCRs, accounting for –15.1 per cent of total revenue on average).[2]

With the exception of RMD, the outputs are all directly reported by the DNSPs, which also report Maximum Demand for each year in MVA from which RMD is derived. RMD, in any given year *t*, is the maximum of the series of maximum demands from 2006 up to and including year *t*.

The weights applied to the non–reliability outputs are based on estimated shares of marginal cost which the provision of each output accounts for. These are derived from the coefficients of an econometrically estimated Leontief cost function. This cost analysis was 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). The AER has commissioned an independent review of the output weights, and depending on the outcomes of that review, the output weights may need to be revised for the 2025 benchmarking report.

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 42.5 per cent of total costs on average,[3]

(b) Overhead subtransmission lines (quantity proxied by overhead subtransmission MVAkms), making up 4.3 per cent of total costs on average,

(c) Overhead distribution lines (quantity proxied by overhead distribution MVAkms), making up 14.1 per cent of total costs on average,

[1] This is the average across years for the aggregated industry, as per the last column of Table A.2 of Appendix A. This differs from the average across all observations (DNSPs and years) shown in Table A.1 of Appendix A. Table A.1, in section A3.2, assists in explaining the derivation of the output weights for the non-reliability outputs and the reliability output.

[2] 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.

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

(d) Underground subtransmission cables (quantity proxied by underground subtransmission MVAkms), making up 2.1 per cent of total costs on average,

(e) Underground distribution cables (quantity proxied by underground distribution MVAkms), making up 10.6 per cent of total costs on average, and

(f) Transformers and other capital (quantity proxied by distribution transformer MVA plus the sum of single stage and the second stage of two stage zone substation level transformer MVA), making up 26.4 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 AUC is taken to be the return on capital, the return of capital and the benchmark tax liability. These are calculated using the method set out in section A5 of Appendix A. As outlined in section 1.1, the return on capital is now measured by the real cost of capital, calculated consistently with AER guidelines, and the return of capital is straight-line depreciation calculated in the same way as used in the building blocks calculation. The AUC is calculated by asset class for each year using asset value data reported by DNSPs. The calculation of the WACC for 2020 to 2023 reflects the AER's Rate of Return Instrument 2018 (AER 2018:13–16 Table 1, col. 3).[4] For earlier years (2006 to 2019), the AUC calculations broadly reflect the 2013 rate of return guideline (AER 2018:13–16 Table 1, col. 2). See Appendix A (section A3) for further discussion of the input weights.

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,

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

which involves separate efficiency assessments of, and determinations on, DNSPs' 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, Least Squares Econometrics (LSE), uses a variant of ordinary least squares regression, incorporating dummy variables for 12 of the 13 Australian DNSPs.[5] The parameters of these dummy 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 2023 and the sample period from 2012 to 2023. The results of this analysis are presented in chapter 4 and Appendix C.

[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 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.

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 DNSPs' 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 2023b). The AER also applies a range of post-modelling OEF adjustments in the context of its opex efficiency analysis.

1.5 DNSP comments on draft report

In line with past practice, the AER released a draft version of this report to DNSPs for comment. Several DNSPs provided feedback on key aspects of the benchmarking process.

TasNetworks, Ergon, Energex, and Ausgrid identified potential errors and inconsistencies in the dataset. These included incorrect AUC values due to an error in linking the DNSP AUC Calculation with the DNSP Consolidated Benchmarking Data worksheets, as noted by Ausgrid. These issues were reviewed and corrected in the report and supporting datasets. Additionally, Ausgrid's capitalised corporate overhead values for 2014 to 2018 and 2023 were fixed, as well as the total circuit length and underground circuit length for TasNetworks in 2023. Other minor values were also updated, though they had little to no impact on the results.

Regarding the method for adjusting for different practices in the capitalisation of corporate overheads first adopted in 2023, Essential, Ausgrid, and Jemena confirmed their support the AER's approach and how it has been implemented.

Regarding the AUC methodology adopted in 2024 to deal with atypical inflation environments, Essential and AusNet supported the AER's refined approach. TasNetworks preferred aligning the methodology with the Post Tax Revenue Model (PTRM). It argued that using a 10-year glide path is inconsistent with the PTRM approach to calculating expected inflation and in the interests of maintaining consistency between methods, it suggested using a 5-year average; whilst recognising it would be unlikely to have a material effect. The AER's approach is to calculate expected inflation using a 10-year average up to 2020 and a 5-year average after 2020, in accordance with the applicable rate of return guideline. Given the acknowledged lack of materiality of the specific issues raised by TasNetworks, including in relation to the glide path, the AER's method is not reviewed for the current study but may be reviewed in the future.

Jemena raised concerns about output weights and recommended updating them to reflect data up to 2023, as the current weights are based on data from 2006–2018. As mentioned in section 3.3.2, an independent review of the output weights is currently underway, and the issues will be further explored for the 2025 Annual Benchmarking Report. Ausgrid expressed concern over the lack of consistency in benchmarking changes from year to year and suggested a more comprehensive review of benchmarking models to improve predictability.

Ausgrid and Evoenergy raised concerns relating to model non-convergence and suggested that non-convergence observed in the short period Stochastic frontier Analysis (SFA) Translog model may be due to an error in the Stata ado files underpinning the 'xtfrontier' package. It suggested the use of modified versions of these ado files as a potential starting point in understanding the issue at hand. This work had been undertaken by Frontier Economics. Quantonomics and the AER acknowledge Ausgrid and Evoenergy's feedback on the performance of the Translog model. Work on the TLG models is ongoing and will be reflected in future benchmarking reports. We do not consider the specific suggestion to be appropriate. Firstly, there is no quality assurance on the manual modifications made to the Stata code by Frontier Economics. Second, despite the minimal increase of the log-likelihood function obtained by Frontier Economics using its suggested approach, the resulting estimates of the DNSP efficiency scores were anomalous. Frontier Economics suggested that its 'asymptotic SFA-TLG' modelling results should not be used by the AER even though it was claimed the model converged (Frontier Economics 2023, 69).

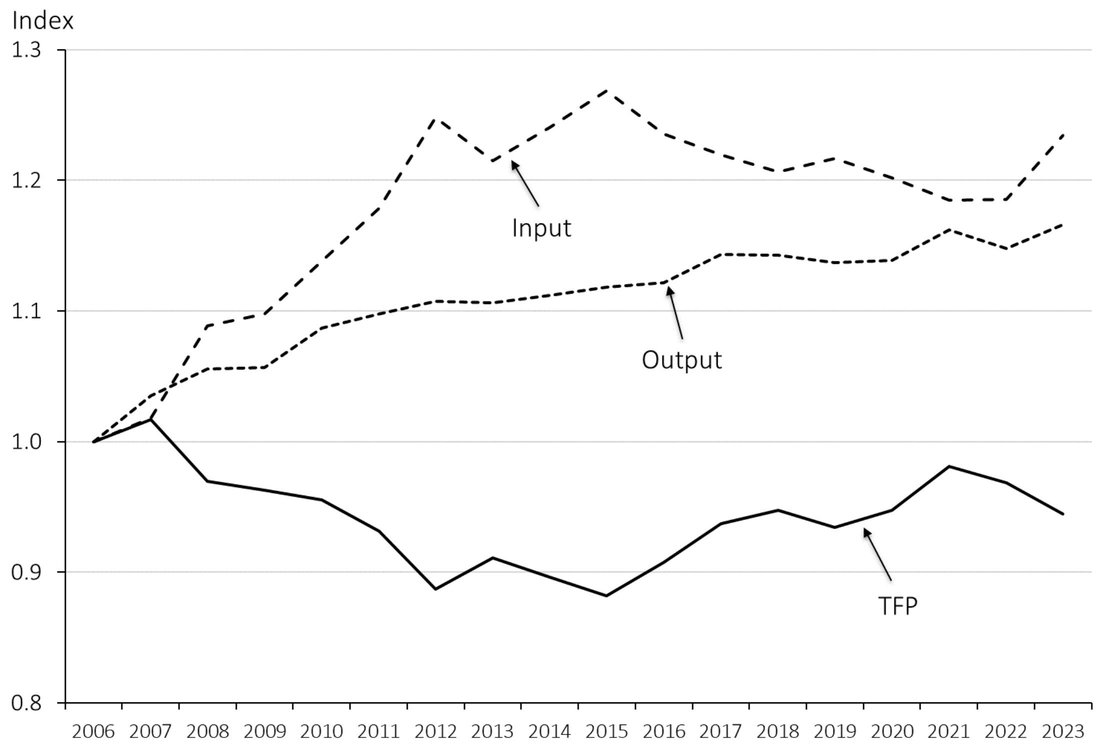
2 Industry–level Distribution Productivity Results

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

2.1 Industry TFP

Distribution industry–level total output, total input and TFP indexes are presented in Figure 2.1 and Table 2.1. Opex and capital partial factor productivity indexes are also presented in Table 2.1. Over the 18-year period 2006 to 2023, 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 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; however, it has been deteriorating since 2022, as shown in Figure 2.1.

Figure 2.1 DNSP industry output, input and TFP indexes, 2006–2023



[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 2.0 per cent. From 2012 to 2023, TFP increased at an average annual rate of 0.6 per cent. TFP *decreased* 1.3 per cent in 2022 and 2.5 per cent in 2023.

Table 2.1 DNSP industry output, input, TFP and PFP indexes, 2006–2023

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	1.035	1.018	1.017	1.035	1.004
2008	1.056	1.089	0.970	0.927	1.004
2009	1.057	1.098	0.963	0.945	0.975
2010	1.087	1.138	0.955	0.929	0.975
2011	1.098	1.178	0.931	0.885	0.964
2012	1.107	1.248	0.887	0.806	0.950
2013	1.106	1.215	0.911	0.883	0.931
2014	1.112	1.241	0.896	0.873	0.915
2015	1.118	1.268	0.882	0.851	0.907
2016	1.121	1.235	0.908	0.924	0.896
2017	1.143	1.220	0.937	0.983	0.905
2018	1.143	1.206	0.947	1.023	0.896
2019	1.137	1.217	0.934	1.011	0.882
2020	1.139	1.202	0.948	1.057	0.873
2021	1.162	1.185	0.981	1.122	0.882
2022	1.148	1.185	0.968	1.118	0.867
2023	1.166	1.234	0.945	1.059	0.871
Growth Rate 2006–2023	0.9%	1.2%	-0.3%	0.3%	-0.8%
Growth Rate 2006–2012	1.7%	3.7%	-2.0%	-3.6%	-0.9%
Growth Rate 2012–2023	0.5%	-0.1%	0.6%	2.5%	-0.8%
Growth Rate 2023	1.6%	4.0%	-2.5%	-5.4%	0.5%

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.

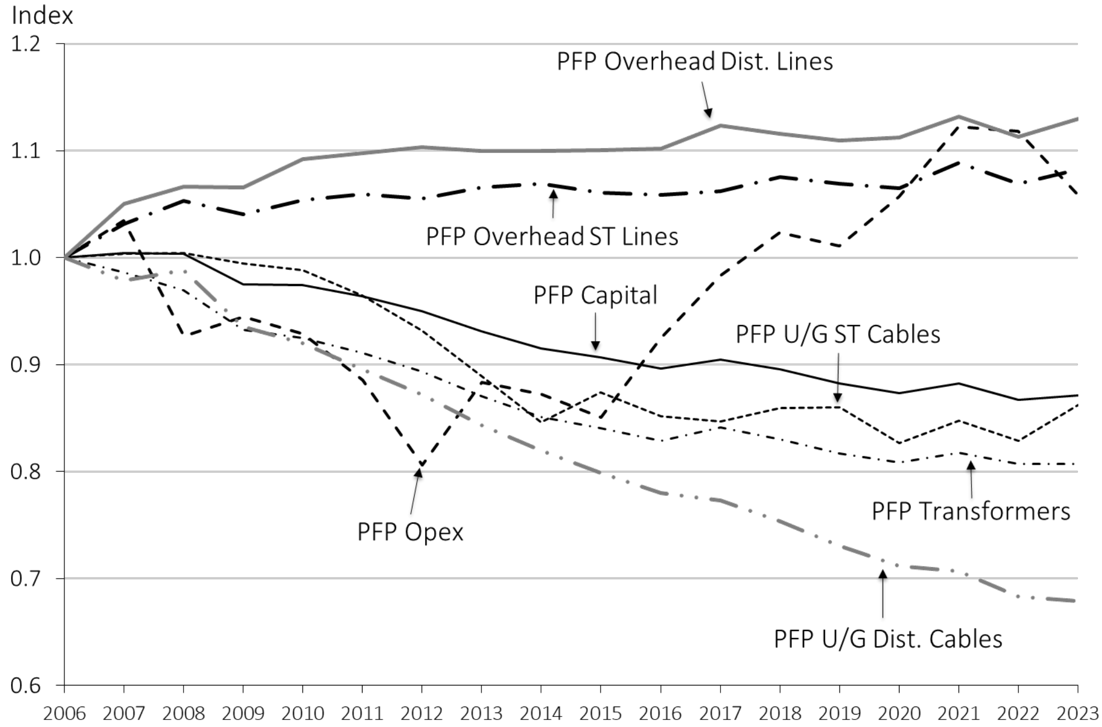
Opex PFP declined through to 2012 but has generally improved since then, as opex use has trended down. The PFP of opex inputs increased between 2006 and 2023, but only by 0.3 per cent per year. In 2023, opex PFP *decreased* 5.4 per cent and was 5.9 per cent above its 2006 level.

Movements in the aggregate capital PFP index declined reasonably steadily over the sample period, at an average annual rate of –0.8 per cent, 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 2023 was 13.0 per cent higher than in 2006, and the overhead subtransmission lines PFP was 8.2 per cent higher over the same period.
- Underground distribution cables PFP was 32.1 per cent *lower* in 2023 than in 2006, and underground subtransmission PFP *declined* by 13.7 per cent over this period. This is because underground cables have increased rapidly from a small base.
- Transformer PFP *declined* by 19.3 per cent between 2006 and 2023.

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, 2006–2023

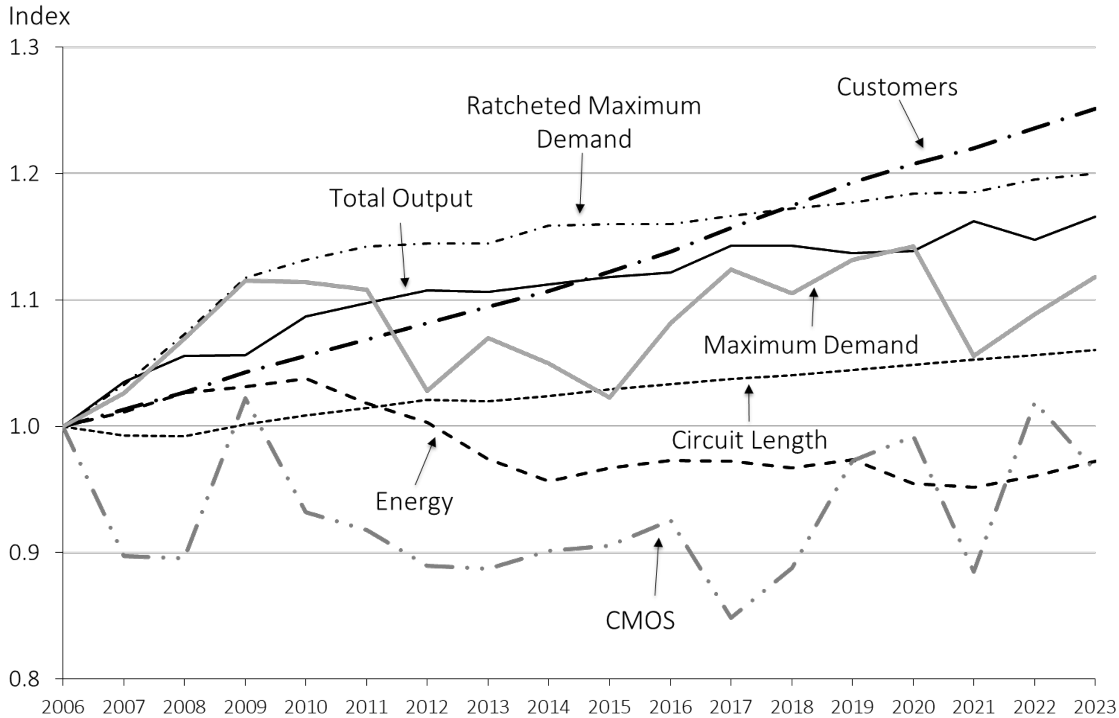


2.3 Distribution industry output and input quantity changes

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 18 years and by 2023 was only 6.0 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, 2006–2023



The customer numbers index increased steadily over the period and was 25.1 per cent higher in 2023 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 2023 energy throughput was slightly less than in 2013 and 2.8 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 2023, RMD was 20.0 per cent higher than in 2006. Also shown in Figure 2.3 is (non–ratcheted) maximum demand, which decreased from 2010 to 2015 in line with energy demand, but has since increased. Over the period from 2006 to 2023, there has been an increasing trend in the ratio of maximum demand to energy throughput. The main exception was the significant decrease in 2021, and although this ratio increased again in 2022 and 2023, it remained below the 2020 level. Over the whole period to 2023, the ratio of maximum demand to energy throughput increased by 15.0 per cent. The ratio between RMD and energy use increased more steadily and by 2023 was 23.5 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, except for 2009, 2014 and 2016, CMOS 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 interrupted by decreases in 2021 and 2023. By 2023, CMOS was 3.5 per cent *below* the 2006 level.

In Figure 2.3 we see that the total output index is largely bounded by circuit length and RMD output indexes, which together receive an average weight of 83.9 per cent of total revenue in forming the total output index.[8] 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 negatively impacts total output). CMOS 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

[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.

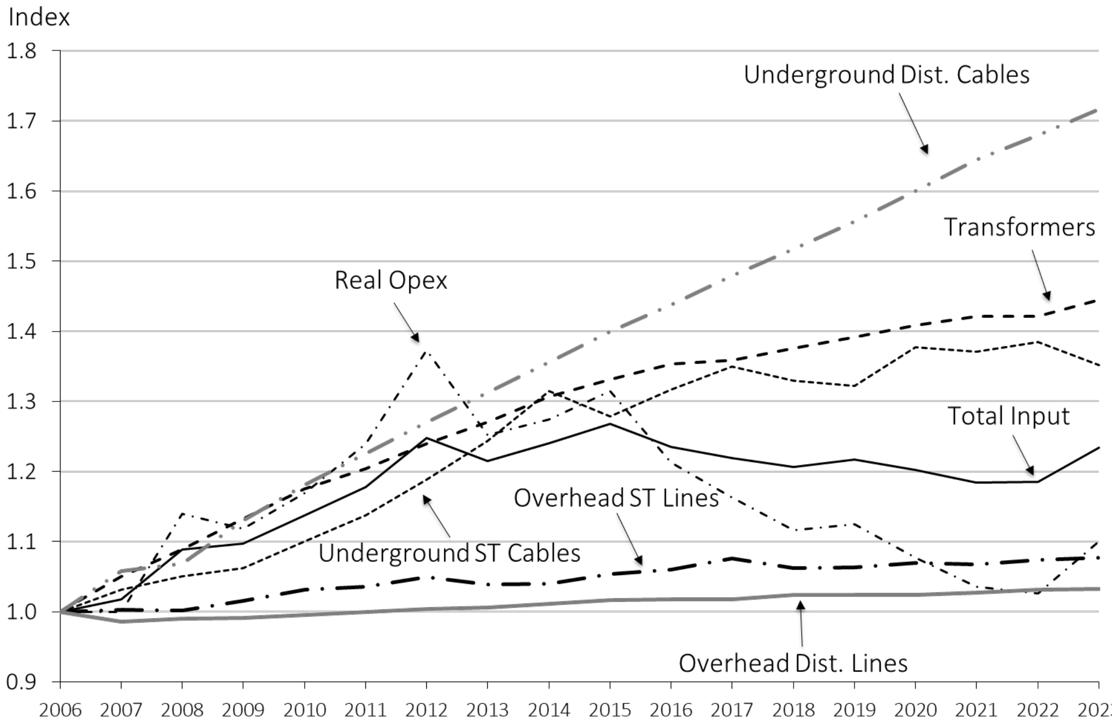
[8] The weights for outputs used in this chapter are those for the industry in Table A.2 in Appendix A which are based on the output value shares for the aggregated industry. Appendix A explains the difference between the aggregated industry value shares and those derived using a simple average over all observations as shown in Table A.1 of Appendix A.

output to decline slightly despite increases in the other four outputs. Energy throughput is given a comparatively small average weight of 9.9 per cent of total revenue, since changes in throughput generally have relatively low marginal cost. Hence, reductions in throughput after 2010 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 42.3 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 37.4 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 trended downward to 2022. However, in 2023 real opex sharply increased by 7.0 per cent.

Another input with a large weight is transformers, which accounts for 26.4 per cent of total cost for the industry. The quantity of transformers has increased steadily over the period and by 2023 was 44.5 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, 2006–2023



The next key components of DNSP input are the quantities of overhead distribution and overhead subtransmission lines (measured in MVA–km). These two input quantities have increased over the period from 2006 to 2023 to be 3.2 and 7.7 per cent higher than their respective 2006 levels. 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 subtransmission lines together account for 18.5 per cent of total DNSP costs on average.

The fastest growing input quantity is that of underground distribution cables whose quantity was 71.7 per cent higher in 2023 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 subtransmission quantity (which increased by 35.2 per cent over the period), again likely reflecting the increasing use of undergrounding in new subdivisions and land developments. The length of overhead lines for the electricity distribution industry remains, in 2023, approximately seven times the length of underground cables because underground cables are considerably more expensive to install per kilometre. Consequently, despite their relatively short length, underground distribution and subtransmission cables have a combined average share in total costs of 12.8 per cent.

From Figure 2.4 we see that the total input quantity index lies close to the quantity indexes for opex and transformers (which together have a weight of 68.8 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

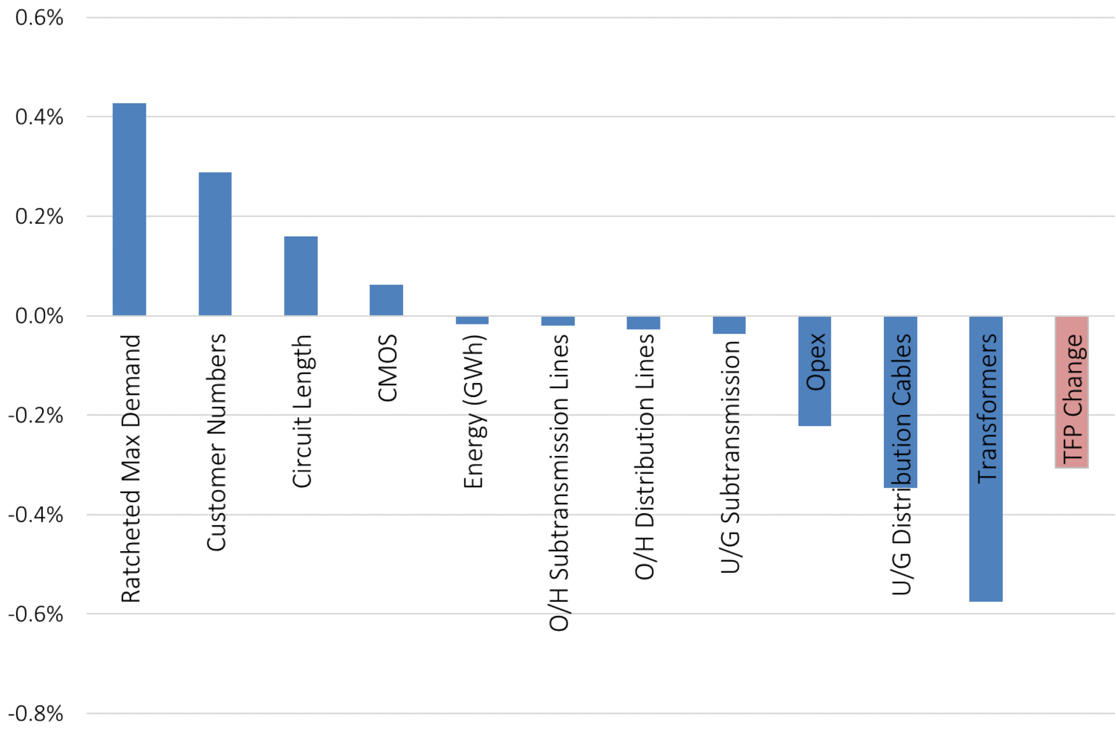
Having reviewed movements in individual output and input components in the preceding section, we now examine the contribution of each output and each input component to annual TFP change. Or, to put it another way, we want to decompose TFP change into its constituent parts. Since TFP change is the change 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 18 year 2006 to 2023. 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 18-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 0.43 percentage points to TFP change over the period.

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

Figure 2.5 Distribution industry output and input percentage point contributions to average annual TFP change, 2006–2023



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 –0.2 per cent, it made a marginal positive contribution to TFP of 0.06 percentage points. Energy throughput made a marginal negative contribution to TFP of –0.02 percentage points since this output fell over the 18-year period at an average annual rate of –0.2 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 18-year period. Overhead subtransmission 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 (4.3 per cent and 14.2 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 1.8 per cent, the underground subtransmission cables input only has a weight of 2.1 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 growth over the period at 3.2 per cent and having a weight of 10.6 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 26.4 per cent and 42.3 per cent, respectively. Since transformer inputs have the second highest input average annual growth rate at 2.2 per cent, they make the largest negative contribution to TFP change at –0.58 percentage points. Opex has the third lowest average annual growth rate at 0.6 per cent and makes the third most negative contribution to TFP change at –0.22 percentage points.

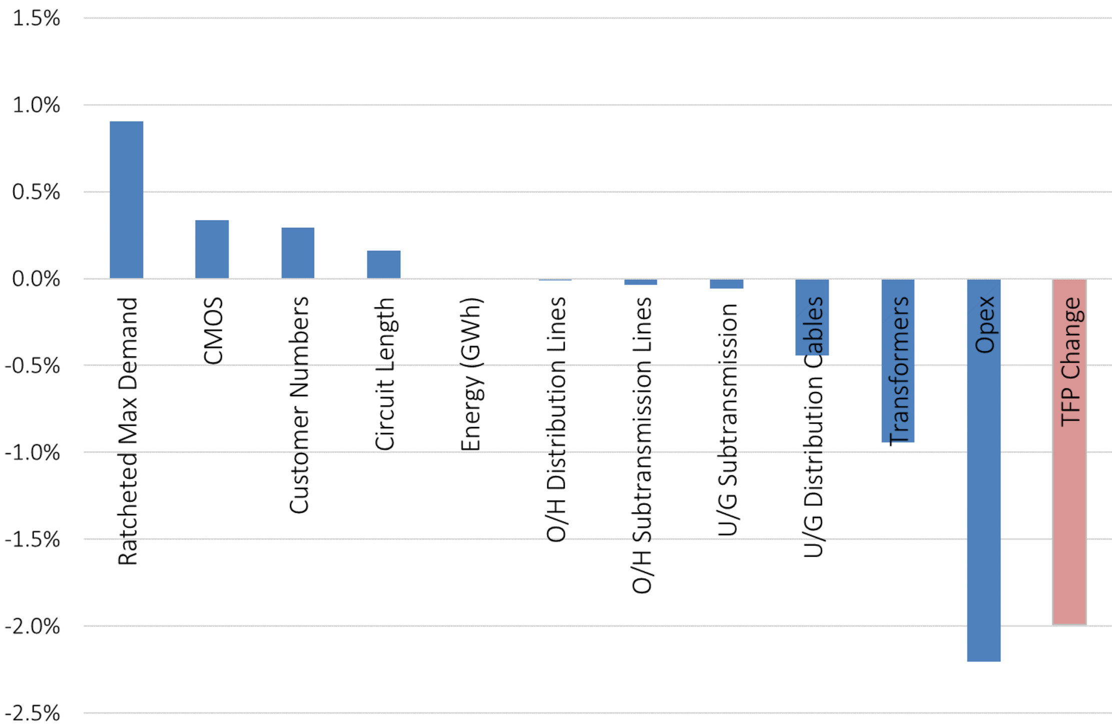
Table 2.2 Distribution industry output and input percentage point contributions to average annual TFP change: Various periods

Year	*2006 to 2023*	*2006 to 2012*	*2012 to 2023*	*2023*
Energy (GWh)	-0.02%	0.00%	-0.03%	0.12%
Ratcheted Max Demand	0.43%	0.90%	0.17%	0.16%
Customer Numbers	0.29%	0.29%	0.28%	0.26%
Circuit Length	0.16%	0.16%	0.16%	0.17%
CMOS	0.06%	0.34%	-0.09%	0.86%
Opex	-0.22%	-2.20%	0.86%	-3.18%
O/H Subtransmission Lines	-0.02%	-0.04%	-0.01%	-0.02%
O/H Distribution Lines	-0.03%	-0.01%	-0.04%	-0.04%
U/G Subtransmission	-0.04%	-0.06%	-0.03%	0.04%
U/G Distribution Cables	-0.35%	-0.44%	-0.29%	-0.36%
Transformers	-0.58%	-0.94%	-0.37%	-0.49%
TFP Change	-0.31%	-1.99%	0.61%	-2.48%

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 –2.0 per cent, which is more negative than the average for the whole period from 2006 to 2023. 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

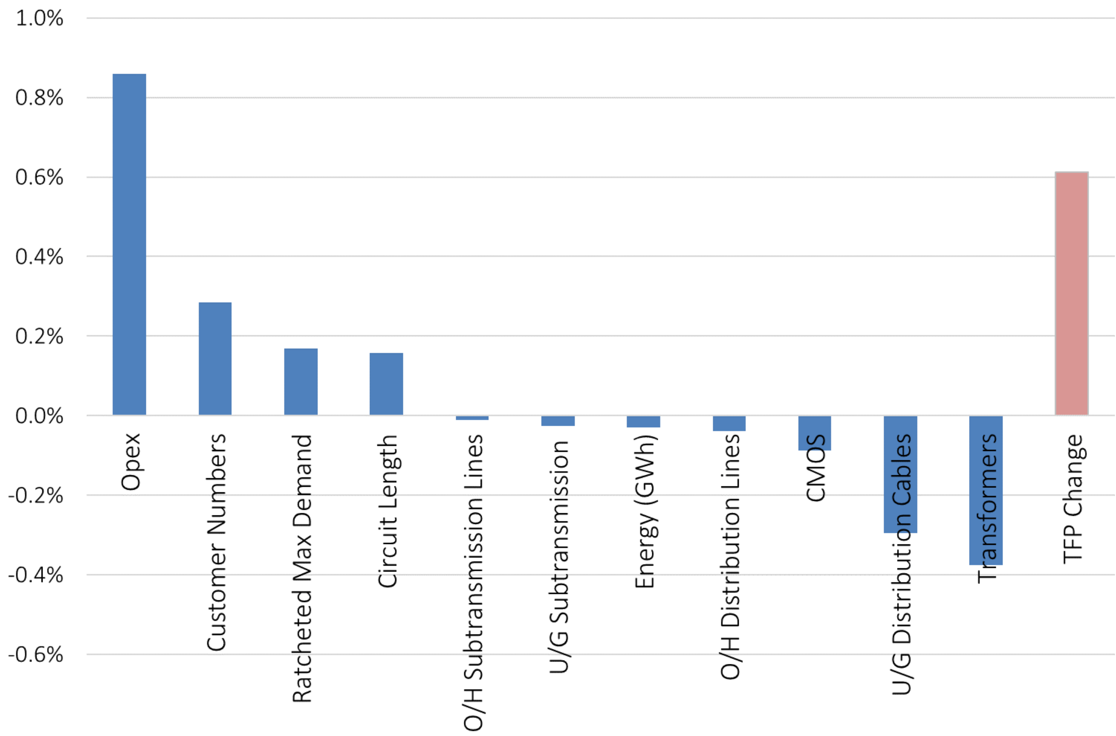


The second, and most significant, difference of the period up to 2012 relates to the contribution of opex to average annual TFP change. Opex increased rapidly from 2006 to 2012, and its average annual growth rate over this period was 5.3 per cent. This high growth rate in opex likely reflects responses 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 –2.20 percentage points to average annual TFP change over the period up to 2012.

In the period from 2012 to 2023, 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 –2.0 per cent. This has led to opex making a positive contribution of 0.86 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, 2012–2023



Other contributors to improved TFP performance after 2012 are reductions in the negative contributions to TFP change from (i) transformers whose contribution fell from –0.94 percentage points (pre–2012) to –0.37 after 2012; (ii) underground distribution cables, which decreased from –0.44 to –0.29 percentage points; (iii) underground subtransmission cables, which decreased from –0.06 to –0.03 percentage points; and (iv) overhead subtransmission lines, which decreased from –0.04 to –0.01 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 –0.09 percentage points. Reductions in energy throughput made its contribution to average annual TFP change marginally negative at –0.03 after 2012 (by comparison its contribution was zero pre–2012).

Table 2.2 also shows the contributions of individual outputs and inputs to the TFP growth of –2.5 per cent in 2023. In contrast to the 2012–2023 period, opex made a significant negative contribution, of –3.18 percentage points in 2023. Transformers and underground distribution cables also had a significant negative contribution of –0.49 and –0.36 percentage points respectively in 2023. The three other inputs had only minor effects, their combined contribution being –0.01 percentage points.

Regarding the contributions of outputs to TFP in 2023, CMOS was the largest positive contributing factor, contributing 0.86 percentage points, followed by customer numbers (0.26 percentage points), circuit length (0.17 percentage points), RMD (0.16 percentage points) and energy throughput (0.12 percentage points).

Tables 2.3 and 2.4 present the annual changes in each output and each input component and their percentage point contributions to annual TFP change for each of the years 2007 to 2023.

Table 2.3 Distribution industry output and input annual changes (%), 2006–2023

Year	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Energy (GWh)	1.11%	1.52%	0.42%	0.67%	-1.92%	-1.48%	-2.92%	-1.88%	1.10%
Ratcheted Max Demand	3.20%	3.83%	4.08%	1.24%	0.95%	0.20%	0.00%	1.23%	0.09%
Customer Numbers	1.30%	1.32%	1.57%	1.24%	1.23%	1.19%	1.20%	1.13%	1.34%
Circuit Length	-0.76%	-0.05%	0.97%	0.69%	0.60%	0.61%	-0.12%	0.42%	0.49%
CMOS	-10.86%	-0.18%	13.22%	-9.22%	-1.53%	-3.10%	-0.28%	1.57%	0.49%
Opex	0.03%	13.02%	-1.85%	4.50%	5.78%	10.26%	-9.23%	1.75%	3.13%
O/H Subtransmission Lines	0.34%	-0.10%	1.29%	1.59%	0.43%	1.30%	-1.06%	0.18%	1.29%
O/H Distribution Lines	-1.43%	0.41%	0.14%	0.40%	0.45%	0.39%	0.25%	0.49%	0.55%
U/G Subtransmission	3.12%	1.85%	1.12%	3.46%	3.40%	4.30%	4.60%	5.51%	-2.72%
U/G Distribution Cables	5.61%	1.01%	5.58%	4.47%	3.67%	3.59%	3.25%	3.27%	3.16%
Transformers	4.87%	3.66%	3.93%	3.69%	2.45%	2.87%	2.53%	2.77%	1.80%

Table 2.3 (cont.)

Year	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*
Energy (GWh)	0.63%	-0.06%	-0.56%	0.69%	-1.95%	-0.34%	0.87%	1.22%
Ratcheted Max Demand	0.02%	0.58%	0.47%	0.42%	0.59%	0.10%	0.84%	0.42%
Customer Numbers	1.41%	1.66%	1.53%	1.55%	1.20%	1.15%	1.33%	1.21%
Circuit Length	0.39%	0.42%	0.27%	0.41%	0.41%	0.39%	0.36%	0.38%
CMOS	2.16%	-8.69%	4.56%	9.08%	1.98%	-12.99%	14.11%	-5.46%
Opex	-8.04%	-4.24%	-4.07%	0.71%	-4.28%	-4.55%	-0.85%	7.00%
O/H Subtransmission Lines	0.54%	1.57%	-1.29%	0.03%	0.63%	-0.21%	0.53%	0.36%
O/H Distribution Lines	0.11%	-0.02%	0.67%	0.02%	-0.06%	0.35%	0.41%	0.09%
U/G Subtransmission	2.87%	2.48%	-1.46%	-0.61%	4.15%	-0.53%	0.97%	-2.40%
U/G Distribution Cables	2.67%	2.84%	2.55%	2.58%	2.76%	3.09%	2.12%	2.19%
Transformers	1.69%	0.40%	1.27%	1.11%	1.20%	1.08%	0.00%	1.59%

Table 2.4 Distribution industry output and input percentage point contributions to annual TFP change, 2006–2023

Year	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Energy (GWh)	0.11%	0.15%	0.05%	0.06%	-0.19%	-0.15%	-0.28%	-0.18%	0.11%
Ratcheted Max Demand	1.34%	1.52%	1.61%	0.50%	0.37%	0.08%	0.00%	0.47%	0.03%
Customer Numbers	0.32%	0.29%	0.33%	0.29%	0.28%	0.26%	0.26%	0.24%	0.28%
Circuit Length	-0.33%	-0.02%	0.44%	0.33%	0.28%	0.28%	-0.05%	0.19%	0.22%
CMOS	2.02%	0.02%	-2.35%	1.66%	0.24%	0.42%	0.00%	-0.21%	-0.06%
Opex	0.02%	-5.45%	0.75%	-1.86%	-2.34%	-4.33%	3.81%	-0.83%	-1.33%
O/H Subtransmission Lines	-0.02%	0.00%	-0.05%	-0.08%	-0.02%	-0.06%	0.05%	-0.01%	-0.06%
O/H Distribution Lines	0.20%	-0.06%	-0.01%	-0.06%	-0.06%	-0.06%	-0.04%	-0.07%	-0.08%
U/G Subtransmission	-0.06%	-0.04%	-0.01%	-0.08%	-0.06%	-0.09%	-0.10%	-0.12%	0.06%
U/G Distribution Cables	-0.66%	-0.14%	-0.52%	-0.54%	-0.38%	-0.41%	-0.36%	-0.35%	-0.33%
Transformers	-1.26%	-1.04%	-0.96%	-0.99%	-0.63%	-0.78%	-0.68%	-0.74%	-0.46%

Table 2.4 (cont.)

Year	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*
Energy (GWh)	0.06%	0.00%	-0.06%	0.07%	-0.19%	-0.03%	0.08%	0.12%
Ratcheted Max Demand	0.02%	0.22%	0.18%	0.17%	0.23%	0.03%	0.34%	0.16%
Customer Numbers	0.30%	0.35%	0.33%	0.34%	0.26%	0.24%	0.30%	0.26%
Circuit Length	0.18%	0.19%	0.12%	0.19%	0.19%	0.17%	0.18%	0.17%
CMOS	-0.27%	1.16%	-0.59%	-1.29%	-0.30%	1.90%	-2.14%	0.86%
Opex	3.43%	1.83%	1.72%	-0.30%	1.87%	2.13%	0.30%	-3.18%
O/H Subtransmission Lines	-0.02%	-0.07%	0.05%	0.00%	-0.03%	0.01%	-0.02%	-0.02%
O/H Distribution Lines	-0.02%	0.00%	-0.10%	0.00%	0.01%	-0.04%	-0.06%	-0.04%
U/G Subtransmission	-0.06%	-0.05%	0.03%	0.01%	-0.09%	0.02%	-0.02%	0.04%
U/G Distribution Cables	-0.27%	-0.31%	-0.27%	-0.28%	-0.27%	-0.22%	-0.22%	-0.36%
Transformers	-0.44%	-0.13%	-0.33%	-0.30%	-0.26%	-0.26%	-0.05%	-0.49%

3 DNSP multilateral total and partial factor productivity analysis

As outlined in chapter 1, MTFP and MPFP indexes can yield comparisons of productivity levels between DNSPs, as well as comparative productivity growth rates, when a pooled group of DNSPs is included in the index analysis. This chapter presents a summary of MTFP and MPFP results for each DNSP using the pooled analysis. As stated earlier, Opex includes capitalised corporate overheads (CCOs).

3.1 Pooled Multilateral TFP Indexes

MTFP indexes for each DNSP over the period 2006 to 2023 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, 2006–2023

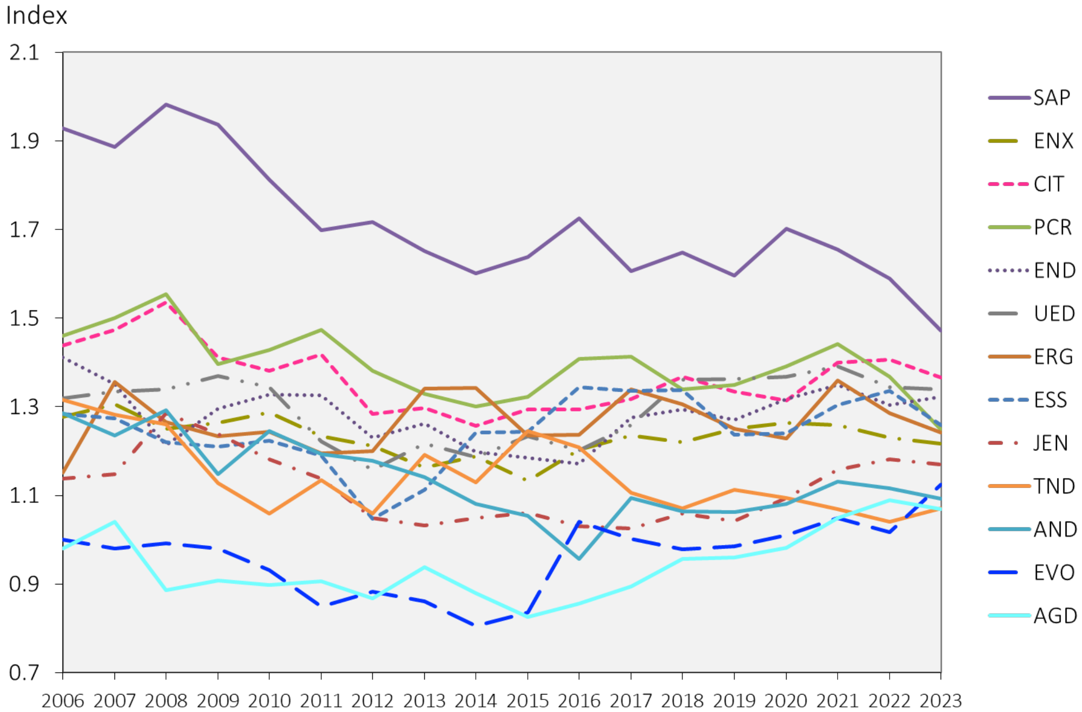


Table 3.1 DNSP multilateral total factor productivity indexes, 2006–2023

Year	EVO	AGD	CIT	END	ENX	ERG	ESS
2006	1.000	0.981	1.439	1.411	1.278	1.152	1.284
2007	0.980	1.041	1.473	1.351	1.307	1.356	1.275
2008	0.993	0.886	1.535	1.213	1.250	1.265	1.221
2009	0.980	0.908	1.412	1.296	1.264	1.234	1.211
2010	0.931	0.899	1.381	1.327	1.288	1.243	1.224
2011	0.850	0.905	1.417	1.326	1.234	1.196	1.189
2012	0.882	0.868	1.283	1.230	1.212	1.199	1.048
2013	0.861	0.938	1.298	1.262	1.164	1.342	1.113
2014	0.805	0.880	1.257	1.198	1.188	1.343	1.242
2015	0.836	0.826	1.294	1.185	1.133	1.236	1.244
2016	1.040	0.855	1.294	1.172	1.203	1.238	1.345
2017	1.002	0.895	1.317	1.276	1.235	1.339	1.336
2018	0.978	0.956	1.367	1.294	1.220	1.306	1.338
2019	0.984	0.961	1.335	1.270	1.251	1.251	1.237
2020	1.011	0.982	1.315	1.318	1.264	1.229	1.240
2021	1.048	1.048	1.401	1.350	1.258	1.359	1.304
2022	1.018	1.089	1.407	1.305	1.231	1.286	1.336
2023	1.125	1.069	1.366	1.322	1.216	1.242	1.259

Table 3.1 (cont.)

Year	JEN	PCR	SAP	AND	TND	UED	AVG
2006	1.138	1.460	1.929	1.285	1.317	1.319	1.307
2007	1.148	1.501	1.887	1.235	1.282	1.334	1.321
2008	1.286	1.555	1.982	1.293	1.260	1.339	1.314
2009	1.238	1.397	1.937	1.148	1.127	1.370	1.271
2010	1.181	1.428	1.812	1.246	1.059	1.344	1.259
2011	1.138	1.474	1.699	1.194	1.135	1.222	1.229
2012	1.049	1.382	1.718	1.178	1.059	1.158	1.174
2013	1.032	1.330	1.651	1.141	1.192	1.217	1.195
2014	1.049	1.300	1.601	1.081	1.129	1.186	1.174
2015	1.061	1.323	1.637	1.054	1.245	1.234	1.177
2016	1.030	1.408	1.726	0.957	1.208	1.202	1.206
2017	1.026	1.414	1.606	1.095	1.106	1.258	1.223
2018	1.059	1.340	1.648	1.064	1.071	1.361	1.231
2019	1.043	1.349	1.596	1.062	1.113	1.363	1.216
2020	1.094	1.392	1.702	1.081	1.094	1.367	1.238
2021	1.158	1.442	1.655	1.131	1.069	1.392	1.278
2022	1.182	1.368	1.589	1.116	1.041	1.345	1.255
2023	1.169	1.249	1.473	1.092	1.071	1.339	1.230

In 2006 the average MTFP index (relative to EVO in 2006) was 1.31, and it reduced to 1.23 in 2023, reflecting the average industry decrease in TFP over the intervening period. There was also a narrowing of MTFP scores, in that the difference between the highest and lowest MTFP indexes decreased from 0.95 in 2006 to 0.40 in 2023. Comparing MTFP levels in 2023:

- SAP has the highest MTFP level followed by CIT and UED. AGD 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 1.47), CIT (1.37), UED (1.34), END (1.32), ESS (1.26), PCR (1.25) and ERG (1.24);
- Those with below–average MTFP indexes were (from smallest to largest) AGD (1.07), TND (1.07), AND (1.09), EVO (1.13), JEN (1.17), and ENX (1.22).

For most DNSPs, total factor productivity decreased in 2023. Of the DNSPs with above–average MTFP in 2023, only one increased its productivity from 2022 to 2023, END. Among the DNSPs with below–average MTFP in 2023, those which increased their MTFP in 2023 were EVO, and TND. For the remaining DNSPs (SAP, CIT, UED, ESS, PCR, END, ERG, ENX, JEN, AND and AGD), MTFP decreased in 2023.

Comparing the rankings of MTFP levels in 2023 to those in 2022, EVO had the largest increase in its ranking, from 13th to 10th. It was followed by END, which increased from 6th to 4th and UED, which increased from 4th to 3rd. On the other hand, the DNSPs whose ranking decreased were PCR from 3rd to 6th, AGD from 11th to 13th and AND from 10th to 11th. SAP, CIT, ESS, ERG, ENX, JEN and TND did not experience changes in their ranking positions from 2022 to 2023.

Comparing the rankings of MTFP levels in 2023 to those in 2006, ESS and ERG had the largest increases in their rankings: 8th to 5th for ESS and from 10th to 7th for ERG. UED, JEN and EVO increased by two places, from 5th to 3rd for UED, from 11th to 9th for JEN and 12th to 10th for EVO. Other increases in ranking included CIT, from 3rd to 2nd and ENX from 9th to 8th. DNSPs with the largest decreases in rankings between 2006 and 2023 were: TND from 6th to 12th, PCR from 2nd to 6th, and AND from 7th to 11th. The MTFP rankings of SAP, END, and AGD in 2023 were unchanged from their 2006 rankings.

3.2 Multilateral PFP Indexes

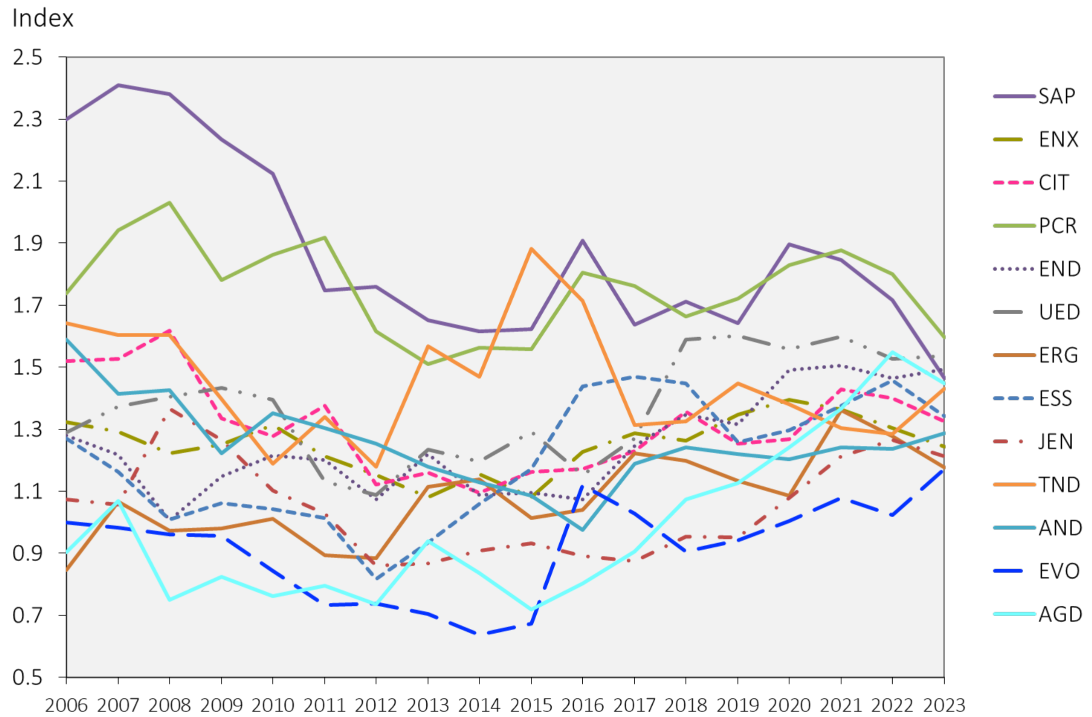
MTFP levels are an amalgam of Opex MPFP and Capital MPFP levels. Updated Opex MPFP indexes are presented in Figure 3.2 and Table 3.2 while updated Capital MPFP indexes are presented in Figure 3.3 and Table 3.3.

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 2013 to 2015, and up to 2021 Opex MPFP increased. However, in 2022 and 2023 there has been a downtrend in Opex MPFP on average across DNSPs. Figure 3.2 and Table 3.2 shows that five DNSPs increased Opex MPFP levels in 2023, namely EVO (13.8 per cent), TND (10.9 per cent), AND (3.9 per cent), END (2.1 per cent) and UED (0.7 per cent). The Opex MPFP levels of eight DNSPs decreased in 2023, including SAP (–15.8 per cent), PCR (–12.0 per cent), ERG (–8.2 per cent), ESS (–8.2 per cent), AGD (–6.8 per cent), CIT (–5.4 per cent), ENX (–4.6 per cent) and JEN (–4.3 per cent).[9]

PCR ranked highest in terms of Opex MPFP levels in 2023 followed by UED and END. EVO ranked lowest in terms of Opex MPFP levels in 2023, followed by ERG, JEN and ENX.

Compared to 2022, TND and AND improved their Opex MPFP ranking by three places in 2023 (from 9th to 6th, and 12th to 9th respectively). Other improved rankings included UED from 4th to 2nd place, and END from 5th to 3rd. The DNSPs that decreased their Opex MPFP rankings in 2023 compared to 2022 were: SAP from 2nd to 4th place, AGD from 3rd to 5th, ENX from 8th to 10th, ERG from 10th to 12th, ESS from 6th to 7th, and CIT from 7th to 8th. PCR, JEN, and EVO did not experience changes in their ranking positions from 2022 to 2023.

Figure 3.2 DNSP multilateral opex partial factor productivity indexes, 2006–2023



[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, 2006–2023

Year	EVO	AGD	CIT	END	ENX	ERG	ESS
2006	1.000	0.903	1.519	1.280	1.324	0.847	1.271
2007	0.981	1.069	1.526	1.218	1.291	1.066	1.161
2008	0.961	0.750	1.617	1.006	1.223	0.973	1.010
2009	0.956	0.824	1.335	1.148	1.250	0.981	1.061
2010	0.844	0.762	1.279	1.214	1.314	1.012	1.042
2011	0.734	0.796	1.375	1.202	1.212	0.895	1.013
2012	0.738	0.735	1.121	1.073	1.153	0.885	0.818
2013	0.703	0.940	1.160	1.220	1.080	1.114	0.934
2014	0.638	0.837	1.095	1.088	1.156	1.138	1.060
2015	0.674	0.719	1.162	1.094	1.080	1.013	1.173
2016	1.118	0.804	1.172	1.073	1.227	1.041	1.437
2017	1.028	0.906	1.230	1.247	1.287	1.222	1.469
2018	0.906	1.073	1.356	1.347	1.264	1.198	1.448
2019	0.941	1.126	1.254	1.316	1.347	1.134	1.259
2020	1.003	1.240	1.268	1.492	1.395	1.085	1.297
2021	1.078	1.366	1.428	1.506	1.364	1.361	1.375
2022	1.022	1.548	1.400	1.464	1.304	1.278	1.458
2023	1.173	1.447	1.327	1.494	1.245	1.178	1.342

Table 3.2 (cont.)

Year	JEN	PCR	SAP	AND	TND	UED	AVG
2006	1.073	1.738	2.300	1.590	1.642	1.291	1.368
2007	1.056	1.943	2.410	1.413	1.605	1.374	1.393
2008	1.366	2.031	2.381	1.425	1.604	1.405	1.366
2009	1.265	1.782	2.235	1.223	1.396	1.433	1.299
2010	1.104	1.863	2.124	1.353	1.190	1.395	1.269
2011	1.029	1.919	1.749	1.304	1.341	1.131	1.208
2012	0.860	1.615	1.759	1.253	1.180	1.089	1.098
2013	0.867	1.509	1.651	1.178	1.567	1.235	1.166
2014	0.908	1.563	1.615	1.129	1.470	1.196	1.146
2015	0.931	1.559	1.623	1.086	1.883	1.293	1.176
2016	0.891	1.804	1.909	0.977	1.713	1.152	1.255
2017	0.874	1.763	1.638	1.189	1.312	1.270	1.264
2018	0.954	1.663	1.713	1.243	1.327	1.590	1.314
2019	0.952	1.722	1.643	1.220	1.449	1.600	1.305
2020	1.077	1.829	1.896	1.203	1.382	1.558	1.363
2021	1.212	1.877	1.846	1.241	1.305	1.599	1.428
2022	1.267	1.801	1.716	1.237	1.284	1.527	1.408
2023	1.213	1.596	1.465	1.287	1.432	1.537	1.364

Turning to Capital MPFP, we can see from Figure 3.3 and Table 3.3 that there has generally been a steadily declining trend in capital MPFP levels, without the reversal seen in Opex

MTFP movements. The relative steadiness of the trend is to be expected given the largely sunk and long-lived nature of DNSP capital assets.

In 2023, eight DNSPs improved their Capital MPFP levels compared to 2022, namely EVO (7.9 per cent), AGD (3.7 per cent), ENX (3.1 per cent), END (2.6 per cent), JEN (1.5 per cent), TND (0.9 per cent), ERG (0.6 per cent) and UED (0.4 per cent). The DNSPs with reductions in capital MPFP levels in 2023 were: AND (–4.4 per cent), PCR (– 3.8 per cent), ESS (–2.5 per cent) and SAP (–1.6 per cent). CIT did not have change in its Capital MPFP.

The highest ranked DNSPs in terms of capital productivity in 2023 were SAP followed by CIT, ERG, and UED (in that order), while TND ranked lowest followed by AGD, AND, and PCR. Comparing rankings in 2023 with 2006, six DNSPs increased their Capital PFP ranking: EVO from 13th to 9th, CIT from 3rd to 2nd, ERG from 4th to 3th, UED from 5th to 4th, ENX from 7th to 6th and JEN, from 9th to 8th. The DNSPs with decreases in Capital MPFP ranking were TND (3 places from 10th to 13th), END (3 places from 2nd to 5th), PCR (2 places from 8th to 10th) and ESS (1 place from 6th to 7th). The remaining DNSPs (SAP, AND and AGD), had the same ranking in 2023 as in 2006.

Figure 3.3 DNSP multilateral capital partial factor productivity indexes, 2006–2023

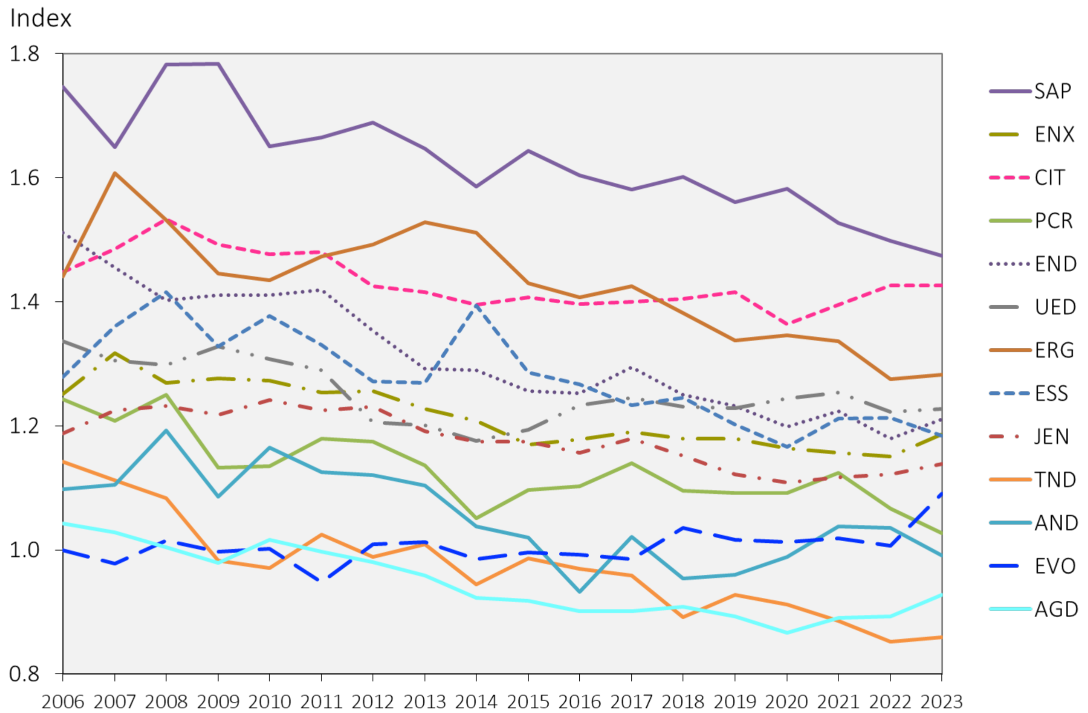


Table 3.3 DNSP multilateral capital partial factor productivity indexes, 2006–2023

Year	EVO	AGD	CIT	END	ENX	ERG	ESS
2006	1.000	1.043	1.448	1.511	1.252	1.441	1.278
2007	0.978	1.028	1.485	1.455	1.317	1.608	1.360
2008	1.014	1.005	1.534	1.402	1.269	1.532	1.415
2009	0.997	0.979	1.492	1.410	1.277	1.445	1.328
2010	1.001	1.017	1.477	1.411	1.272	1.435	1.377
2011	0.948	0.997	1.480	1.418	1.254	1.473	1.331
2012	1.009	0.980	1.425	1.353	1.256	1.492	1.272
2013	1.013	0.958	1.416	1.292	1.228	1.528	1.269
2014	0.986	0.922	1.395	1.289	1.208	1.512	1.394
2015	0.996	0.918	1.407	1.256	1.170	1.430	1.286
2016	0.993	0.902	1.396	1.253	1.178	1.407	1.266
2017	0.985	0.901	1.400	1.294	1.190	1.425	1.234
2018	1.035	0.908	1.404	1.250	1.180	1.382	1.245
2019	1.016	0.893	1.415	1.231	1.179	1.337	1.202
2020	1.012	0.867	1.364	1.198	1.164	1.346	1.167
2021	1.019	0.891	1.395	1.224	1.156	1.337	1.212
2022	1.007	0.893	1.426	1.179	1.150	1.275	1.213
2023	1.090	0.927	1.426	1.210	1.186	1.283	1.184

Table 3.3 (cont.)

Year	JEN	PCR	SAP	AND	TND	UED	AVG
2006	1.188	1.243	1.746	1.097	1.143	1.336	1.287
2007	1.224	1.208	1.649	1.105	1.113	1.305	1.295
2008	1.231	1.250	1.782	1.192	1.083	1.297	1.308
2009	1.217	1.132	1.784	1.086	0.982	1.328	1.266
2010	1.242	1.135	1.650	1.165	0.971	1.308	1.266
2011	1.224	1.179	1.665	1.126	1.025	1.289	1.262
2012	1.230	1.174	1.689	1.121	0.989	1.206	1.246
2013	1.191	1.137	1.647	1.104	1.008	1.200	1.230
2014	1.174	1.051	1.586	1.038	0.945	1.175	1.206
2015	1.175	1.096	1.644	1.019	0.986	1.193	1.198
2016	1.157	1.103	1.604	0.932	0.969	1.234	1.184
2017	1.180	1.140	1.581	1.021	0.959	1.245	1.196
2018	1.151	1.095	1.601	0.953	0.892	1.231	1.179
2019	1.121	1.092	1.561	0.960	0.928	1.228	1.166
2020	1.108	1.092	1.582	0.988	0.912	1.244	1.157
2021	1.117	1.124	1.527	1.038	0.885	1.253	1.167
2022	1.122	1.067	1.498	1.036	0.852	1.223	1.149
2023	1.138	1.027	1.475	0.991	0.859	1.228	1.156

4 Econometric opex cost function analysis

This chapter presents the update of the econometric opex cost function models. This analysis includes data for the 13 Australian DNSPs, together with 19 New Zealand DNSPs and 29 Ontario DNSPs. Opex for Australian DNSPs incorporates CCOs.

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 adjustments for operating environment factors. In this section we update the models in Economic Insights (2020, 2021) and Quantonomics (2022; 2023a) to include data for the financial years 2023 for the Australian and New Zealand DNSPs and 2022 data for the Ontario DNSPs.[10]

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 specifications are used:

- 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),[11]
- a stochastic frontier analysis model using the Cobb–Douglas functional form (SFACD), and
- a stochastic frontier analysis model using the Translog functional form (SFATLG).

These models are estimated for two sample periods: 2006 to 2023 and 2012 to 2023. Detailed regression results are presented in Appendix C. In this section, we present summary information on the monotonicity performance and the average opex efficiency scores.

4.1 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 coefficient for each output (which is the output's elasticity at the mean of the sample used for

[10] Throughout this section and appendix C, when a sample is described as 2006 to 2023, it includes Ontario data for 2005 to 2022; and a sample described as 2012 to 2023 includes Ontario data for 2011 to 2022.

[11] The two least–squares models are estimated with panel–corrected standard errors.

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; 2023a). 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 2023 (see Tables C.7 and C.8 of Appendix C) the LSETLG model has monotonicity violations in 22.2 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 (AGD, CIT, and UED) and for these three DNSPs, the LSETLG model is not included in the average efficiency scores for the 2006 to 2023.

The SFATLG model has monotonicity violations 79.5 per cent of the observations on Australian DNSPs. In 46.2 per cent of the observations, there is a negative elasticity for Customer Numbers and 34.6 per cent of observations have a negative elasticity for Ratcheted Maximum Demand. Eleven Australian DNSPs (AGD, CIT, END, ENX, ERG, ESS, JEN, PCR, SAP, TND and UED) had monotonicity violations in more than half of the observations, and as a result, none of the SFATLG model results are included in the average of efficiency scores for the 2006 to 2023 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 2023 and 2022. In the 2023 study, the SFATLG model has excessive monotonicity violations for five of the Australian DNSPs, and the LSETLG model had excessive monotonicity violations for one Australian DNSPs. 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. [12]

[12] Note that while the results of this present study and 2023 study were obtained using opex including CCO, the results of 2022 study were obtained using opex excluding CCOs.

For the models applied to the shorter sample period from 2012 to 2023 (see Table C.15 of Appendix C), the LSETLG model has monotonicity violations in 48.7 per cent of Australian DNSP observations, with all violations relating to the Customer Number variable. Six Australian DNSPs (AGD, CIT, END, ENX, JEN, 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 2023 period.

The SFATLG truncated normal model did not converge in the short sample.[13] Non-convergence implies that the parameter estimates, cost elasticities and inefficiency scores can be unreliable. Hence, the SFATLG model for the short-sample period has been omitted.

The monotonicity results obtained using the LSETLG model and the shorter period from 2012 to 2023 are broadly similar to the results obtained for the same model in the shorter sample period in the previous reports (Quantonomics 2022; 2023a). In the 2023 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 ten Australian DNSPs. In the 2022 analysis, the short–term LSETLG and SFATLG models had excessive monotonicity violations for five and nine Australian DNSPs, respectively.

4.2 Summary results for the sample period 2006–2023

Opex efficiency scores for each of the 13 NEM DNSPs across the 18-year period 2006 to 2023 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 and LSETLG models 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 all 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 all models, and for the econometric models only, are presented in Figure 4.2. The opex efficiency scores averaged over all methods indicate:

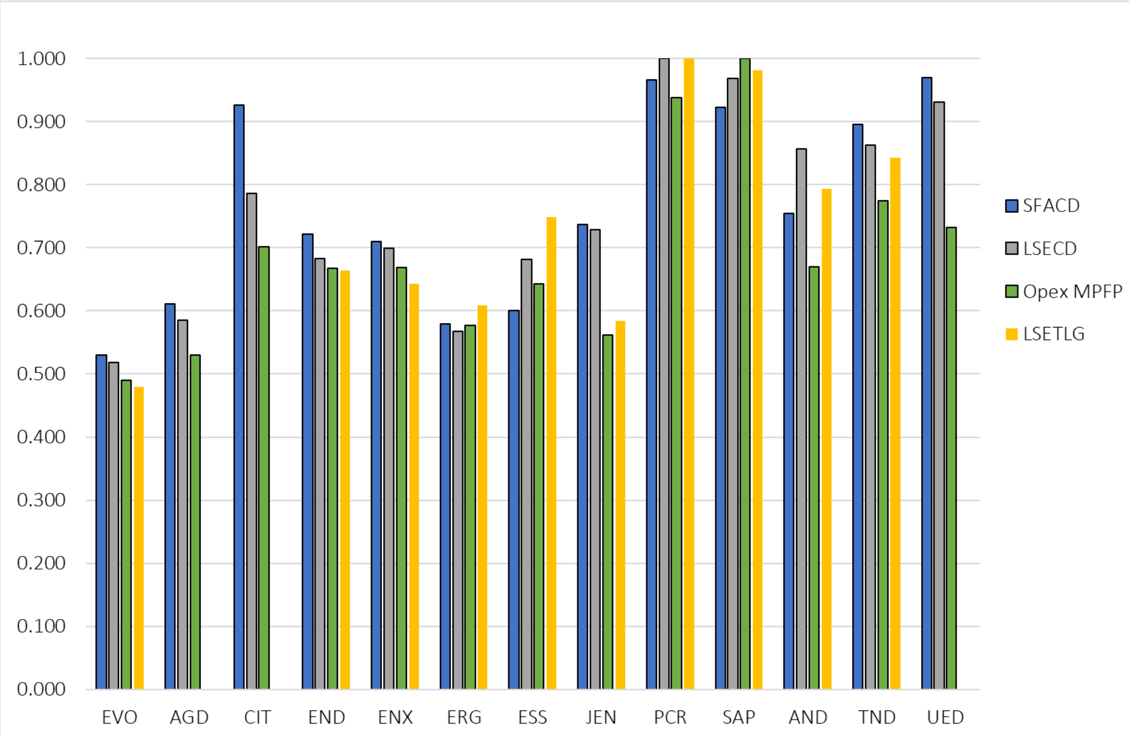
- PCR and SAP have the highest average efficiency scores (0.976 and 0.968 respectively);
- UED, TND and CIT also had an efficiency score above the average (0.878, 0.844 and 0.805 respectively);

[13] See Section C2.2 for further discussion.

- The sample average opex efficiency score is 0.737, and the DNSP with opex efficiency closest to the average is AND (0.769);
- Several DNSPs are below average but not the lowest in terms of opex efficiency. These include END (0.684), ENX (0.680), ESS (0.668) and JEN (0.653);
- The three DNSPs with lowest opex efficiency are EVO (0.504), AGD (0.575) and ERG (0.583).

These rankings are similar to those in Quantonomics (2023a).

Figure 4.1 DNSP opex cost efficiency scores, 2006–2023



The overall average efficiency scores are also similar between models. The average efficiency score of the SFACD is 0.763 and the average efficiency scores of the LSECD and LSETLG models are 0.759 and 0.734, 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 0.689, which is broadly similar to the econometric analysis.

Compared to the results in the 2023 report, and using the average of five methods, JEN's average efficiency score *decreased* by 1.2 per cent. All the other 12 DNSPs' average efficiency scores improved in 2023 compared to 2022. Specifically: END (9.4 per cent), ENX (8.4 per cent), CIT (4.8 per cent), EVO (5.8 per cent), AGD (4.6 per cent), AND (3.4 per cent), ERG (3.0 per cent), SAP (2.3 per cent), ESS (1.9 per cent), UED (1.4 per cent), TND (0.7 per cent) and PCR (0.2 per cent).

Table 4.1 DNSP average opex cost efficiency scores, 2006–2023

DNSP	*SFACD* (1)	*SFATLG* (2)[14]	*LSECD* (3)	*LSETLG* (4)	*Opex MPFP* (5)	*Average all Methods***	*Average econometric Models***
EVO	0.530	0.549	0.518	0.479	0.490	0.504	0.509
AGD	0.611	0.265	0.585	0.522	0.530	0.575*	0.598*
CIT	0.926	0.707	0.787	0.717	0.702	0.805*	0.857*
END	0.722	0.458	0.683	0.664	0.668	0.684	0.690
ENX	0.709	0.405	0.699	0.643	0.669	0.680	0.684
ERG	0.579	0.784	0.567	0.609	0.577	0.583	0.585
ESS	0.601	0.761	0.682	0.748	0.642	0.668	0.677
JEN	0.737	0.743	0.728	0.584	0.561	0.653	0.683
PCR	0.967	0.965	1.000	1.000	0.938	0.976	0.989
SAP	0.923	0.908	0.969	0.981	1.000	0.968	0.957
AND	0.754	0.738	0.857	0.793	0.670	0.769	0.801
TND	0.896	0.976	0.862	0.843	0.775	0.844	0.867
UED	0.969	0.749	0.931	0.741	0.733	0.878*	0.950*

Note: * Excludes LSETLG; ** Excludes SFATLG.

Table 4.2 summarises 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.

Table 4.2 Average DNSP output elasticities by country and overall, 2006–2023

Sub–sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
	SFACD model			*LSECD model*		
All	0.280	0.129	0.553	0.536	0.228	0.199
	SFATLG model			*LSETLG model*		
Australia	0.071	0.389	0.192	0.212	0.321	0.446
New Zealand	0.465	0.053	0.660	0.662	0.241	0.049
Ontario	0.333	0.140	0.414	0.221	0.198	0.528
Full sample	0.318	0.166	0.443	0.357	0.238	0.361

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

[14] SFATLG model has monotonicity violations for 79.5 per cent of the observations on Australian DNSPs and monotonicity violations for more than half of the observations for eleven Australian DNSPs in this long period, and while reported here these results are not included in the average efficiency scores for the 2006 to 2023 period.

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 0.071 for Australian DNSPs, and 0.318 for the whole sample; and in the LSETLG model, the customer numbers elasticity is 0.212 for Australian DNSPs, and 0.357 for the whole sample;
- the circuit length elasticity for Australian DNSPs in the SFATLG model is 0.389, compared to 0.166 for the whole sample; and in the LSETLG model, the circuit length elasticity is 0.321 for Australian DNSPs compared to 0.238 for the whole sample.

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.

Figure 4.2 DNSP opex cost efficiency scores, 2006–2023, average of models

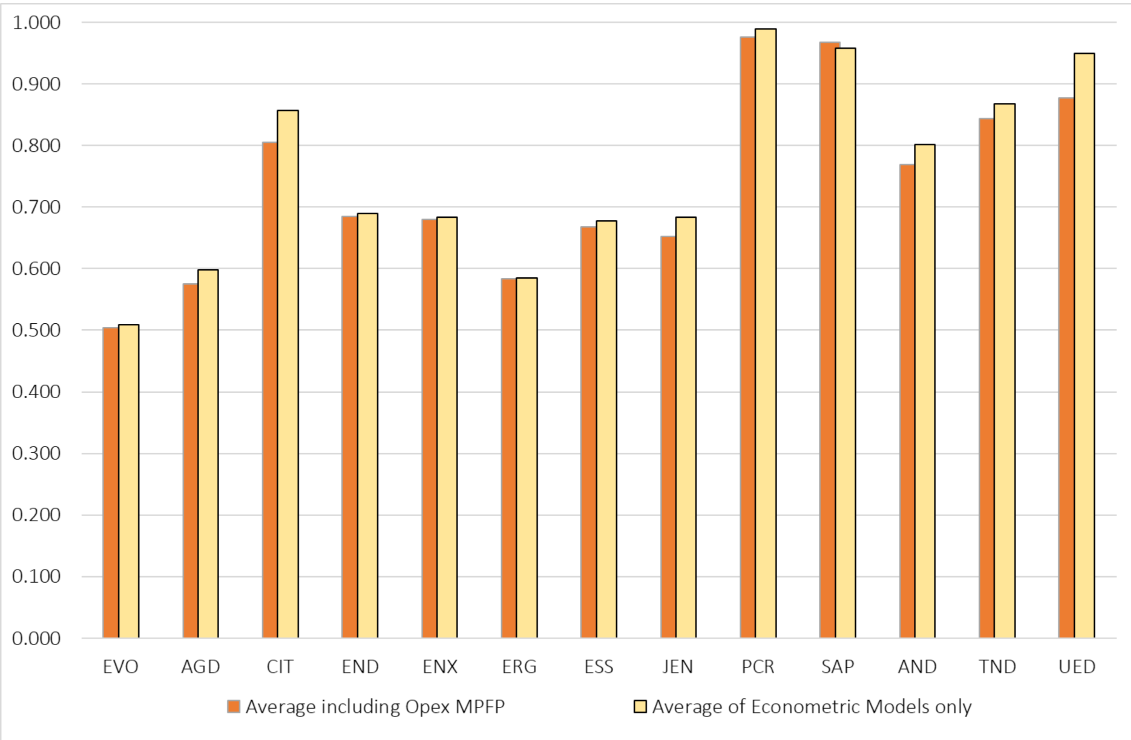
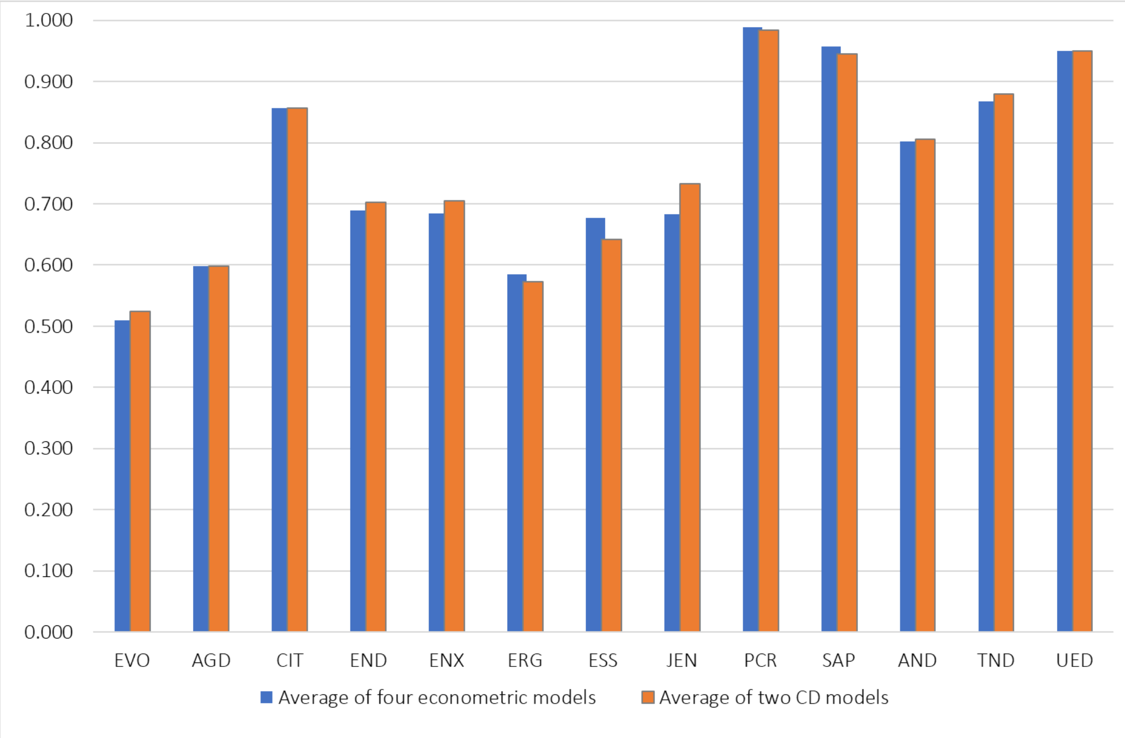


Figure 4.3 compares the average efficiency scores using all the valid econometric models (excluding the SFATLG model or the LSETLG model when necessary) against the average efficiency scores obtained by averaging only the two Cobb–Douglas models, SFACD and LSECD. This shows that whether the average of 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, 2006–2023, average of four econometric models compared to the average of CD models



4.3 Summary results for the sample period 2012–2023

We turn now to the opex efficiency scores based on the more recent period, 2012 to 2023. 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 three opex cost function models and opex MPFP, with the SFATLG model excluded due to non-convergence.[15] For each DNSP, opex efficiency scores are 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 4.5 compares the efficiency scores averaged over all methods (including opex PFP) compared to the average over the included econometric models.

[15] See section C2.2 in Appendix C.

Figure 4.4 DNSP opex cost efficiency scores, 2012–2023

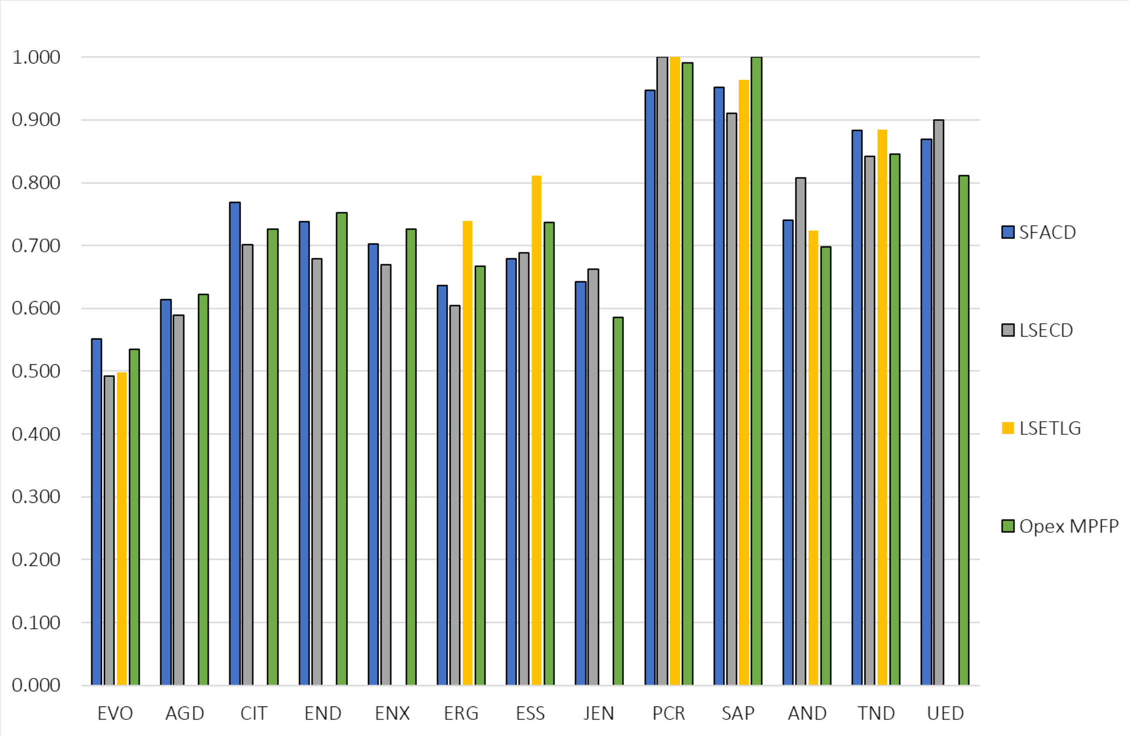


Table 4.3 DNSP average opex cost efficiency scores, 2012–2023

DNSP	*SFACD* (1)	*SFATLG* (2)[16]	*LSECD* (3)	*LSETLG* (4)	*Opex MPFP* (5)	*Average all methods***	*Average econometric Models***
EVO	0.551	na	0.493	0.498	0.535	0.519	0.514
AGD	0.613	na	0.589	0.527	0.622	0.608*	0.601*
CIT	0.769	na	0.702	0.717	0.726	0.732*	0.735*
END	0.738	na	0.679	0.692	0.752	0.723*	0.708*
ENX	0.703	na	0.670	0.616	0.727	0.700*	0.686*
ERG	0.636	na	0.604	0.739	0.667	0.662	0.660
ESS	0.679	na	0.688	0.811	0.737	0.729	0.726
JEN	0.642	na	0.662	0.549	0.585	0.630*	0.652*
PCR	0.947	na	1.000	1.000	0.991	0.985	0.982
SAP	0.952	na	0.910	0.964	1.000	0.956	0.942
AND	0.740	na	0.807	0.724	0.698	0.742	0.757
TND	0.884	na	0.842	0.884	0.846	0.864	0.870
UED	0.870	na	0.899	0.726	0.812	0.860*	0.885*

Note: * Excludes LSETLG; ** Excludes SFATLG.

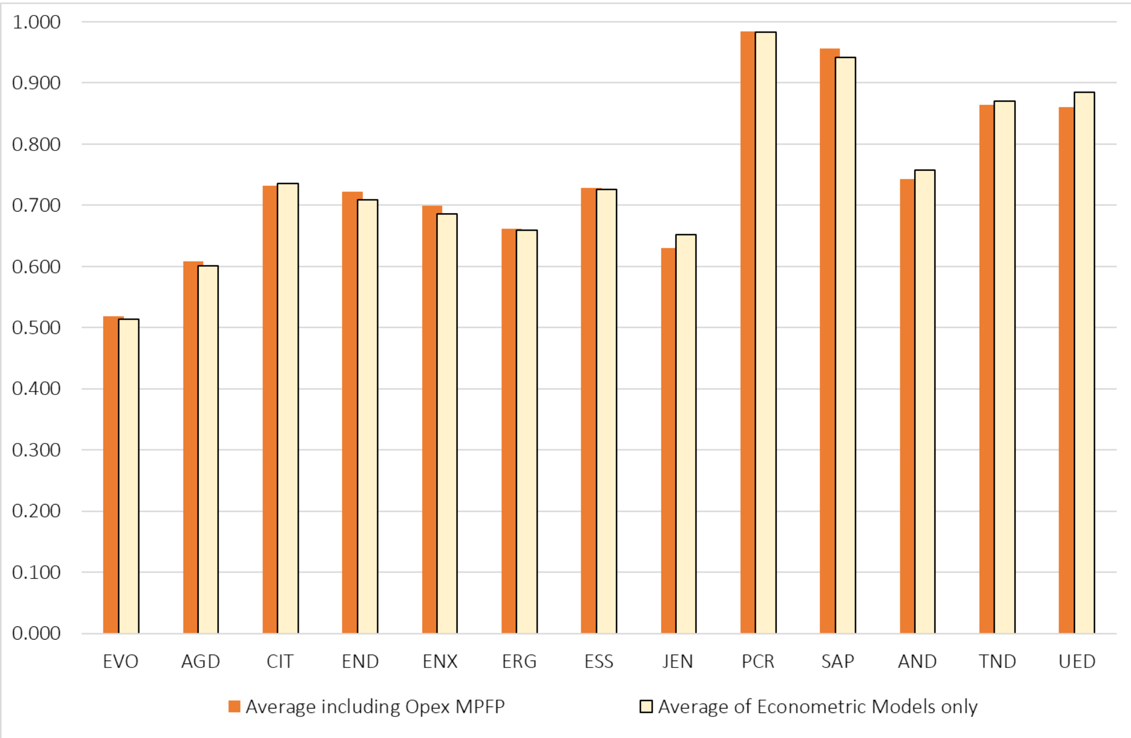
[16] The SFATLG model is excluded due to non-convergence. See section C2.2 in Appendix C.

From Figure 4.4 and Table 4.3 we see that the rankings are reasonably similar to the full sample period. Using the average of five methods, PCR and SAP have the highest opex efficiency measures, 0.985 and 0.956 respectively. The next highest ranked in terms of opex efficiency are TND (0.864) and UED (0.860). The two lowest ranked DNSPs in terms of opex efficiency are EVO (0.519) and AGD (0.608), 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 2023 is 0.747, 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 0.748 and; the LSECD and LSETLG models have average efficiency scores of 0.734 and 0.803 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.

Figure 4.5 DNSP opex cost efficiency scores, 2012–2023, average of models



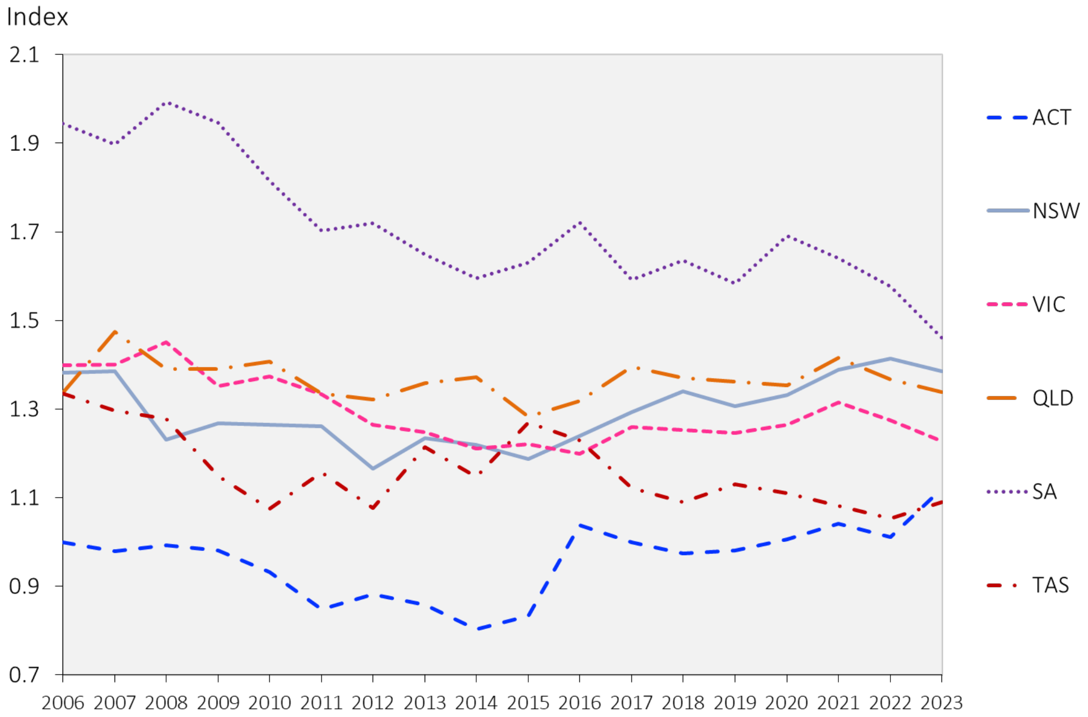
5 State–level Distribution Productivity Results

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, 2006–2023



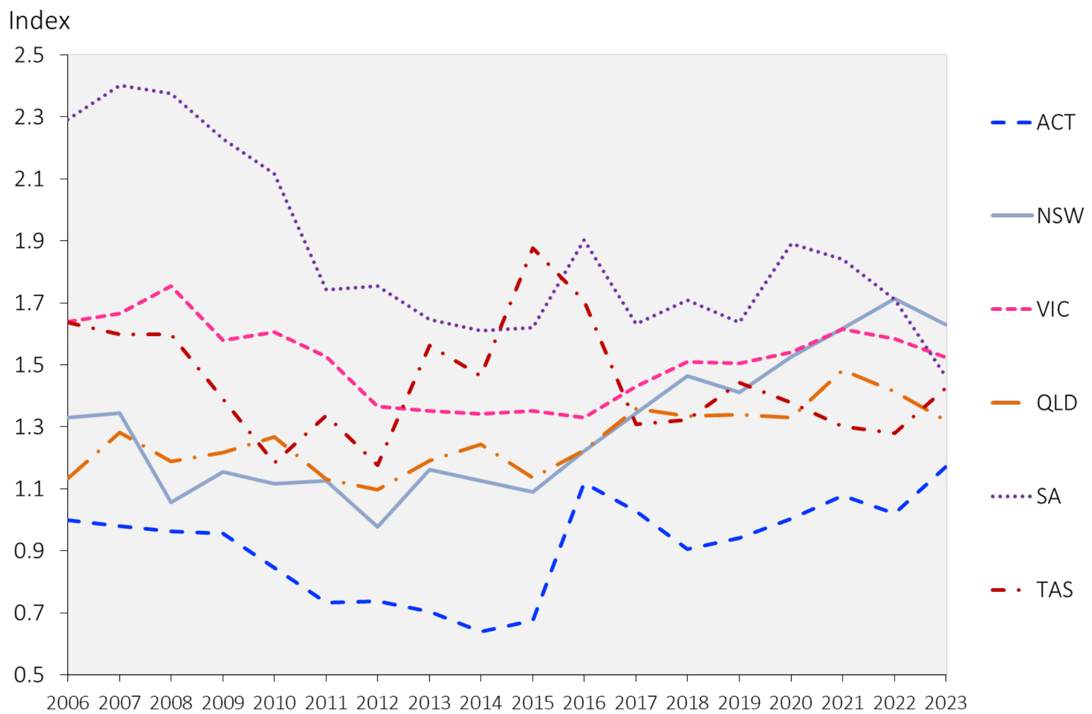
In 2023, South Australia (SA) had the highest MTFP level followed by New South Wales (NSW) in second place. Queensland (QLD) and Victoria (VIC) placed third and fourth position, close to the average for the NEM states. Australian Capital Territory (ACT) was in fifth place in 2023, marking the first year it did not rank last. Tasmania (TAS) had the lowest MTFP level.

ACT had the largest MTFP increase in 2023 by 10.3 per cent, whilst TAS had an MTFP increase of 3.4 per cent in 2023. The remaining states all had reduced MTFP in 2023 compared to 2022. For SA the decrease was –7.6 per cent, VIC –3.8 per cent, and for QLD and NSW the MTFP changes in 2023 were –2.1 and–2.0 per cent respectively.

Table 5.1 State–level DNSP multilateral TFP indexes, 2006–2023

Year	ACT	NSW	VIC	QLD	SA	TAS
2006	1.000	1.382	1.399	1.337	1.945	1.335
2007	0.979	1.386	1.401	1.475	1.898	1.297
2008	0.993	1.231	1.451	1.391	1.993	1.277
2009	0.981	1.268	1.352	1.391	1.947	1.148
2010	0.932	1.265	1.374	1.407	1.815	1.075
2011	0.848	1.260	1.333	1.335	1.702	1.156
2012	0.881	1.166	1.265	1.321	1.720	1.077
2013	0.858	1.235	1.247	1.358	1.648	1.214
2014	0.802	1.219	1.212	1.371	1.595	1.147
2015	0.832	1.188	1.220	1.283	1.631	1.269
2016	1.037	1.239	1.199	1.319	1.721	1.229
2017	0.999	1.292	1.259	1.395	1.592	1.122
2018	0.974	1.339	1.252	1.371	1.636	1.090
2019	0.981	1.306	1.246	1.362	1.584	1.130
2020	1.006	1.332	1.265	1.353	1.692	1.111
2021	1.042	1.389	1.314	1.415	1.641	1.082
2022	1.011	1.413	1.275	1.367	1.576	1.053
2023	1.120	1.385	1.228	1.338	1.461	1.090

Figure 5.2 State–level DNSP multilateral Opex PFP indexes, 2006–2023



Opex MPFP levels by State are shown in Figure 5.2 and Table 5.2. In 2023, NSW had the highest Opex MTFP level. The states with average Opex MTFP levels were VIC, SA, TAS and QLD, whereas the ACT had much lower level of Opex MTFP in 2023 than the other states.

In 2023 ACT's Opex MPFP grew by 13.8 per cent and TAS's Opex MPFP grew by 10.9 per cent. All the other DNSPs' Opex MPFP decreased. SA, which had the highest Opex MTFP level from 2016 to 2021, decreased by the largest amount in 2023 (–15.8 per cent), followed by QLD (–6.8 per cent), NSW (–5.0 per cent), and VIC (–3.9 per cent).

Table 5.2 State–level DNSP multilateral Opex PFP indexes, 2006–2023

Year	ACT	NSW	VIC	QLD	SA	TAS
2006	1.000	1.331	1.640	1.133	2.292	1.638
2007	0.981	1.345	1.666	1.283	2.401	1.599
2008	0.962	1.056	1.754	1.189	2.375	1.599
2009	0.957	1.156	1.579	1.218	2.229	1.391
2010	0.845	1.116	1.605	1.268	2.116	1.185
2011	0.733	1.127	1.527	1.130	1.743	1.337
2012	0.738	0.978	1.367	1.096	1.754	1.176
2013	0.704	1.162	1.352	1.192	1.646	1.562
2014	0.639	1.125	1.341	1.244	1.610	1.465
2015	0.674	1.090	1.351	1.135	1.619	1.877
2016	1.118	1.221	1.330	1.225	1.903	1.707
2017	1.028	1.345	1.430	1.358	1.633	1.309
2018	0.906	1.465	1.510	1.335	1.708	1.322
2019	0.941	1.412	1.504	1.340	1.638	1.444
2020	1.003	1.526	1.542	1.329	1.891	1.377
2021	1.078	1.617	1.615	1.484	1.841	1.300
2022	1.021	1.714	1.584	1.414	1.711	1.279
2023	1.173	1.630	1.524	1.321	1.461	1.427

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 2023 ACT delivered 2,981 GWh to 221,429 customers over 5,743 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 18-year period 2006 to 2023, ACT's average annual rate of TFP change was 0.6 per cent. Between 2006 and 2012, TFP *fell* at an average annual rate of 2.4 per cent (more than

10 per cent in total). Then, from 2012 to 2023, the ACT's TFP increased at an average annual rate of 2.2 per cent, and was over 10 per cent above the 2006 level by 2023.

Total output increased reasonably steadily over the period 2006 to 2023 at an average annual rate of 1.8 per cent, above the industry average rate of 0.9 per cent seen in chapter 3. In 2006–2012 period, output increased, on average by 1.5 per cent per year, similar to the industry average rate in this period of 1.7 per cent, and in 2012–2023 period output increased at 2.0 per cent per year, which is above the 0.5 per cent industry average annual growth for the same period. Total input use increased at an average rate of 3.9 per cent per year up to 2012, similar to the industry average rate in this period of 3.7 per cent. The average annual growth rate of input use was –0.2 between 2012 and 2023, again similar to the industry average (which *decreased* by 0.1 per cent per year over the same period).

In 2023, the ACT's TFP increased significantly by 9.3 per cent, driven by a 7.6 per cent increase in output and a 1.7 *decrease* in input. This performance far exceeded the industry's TFP growth in 2023, which was –2.5 per cent. This result is partly attributable to a large decrease in Opex in 2023, reflected in the strong increase in Opex PFP of 12.8 per cent in 2023 shown in Table 5.3.

Figure 5.3 ACT output, input and TFP indexes, 2006–2023

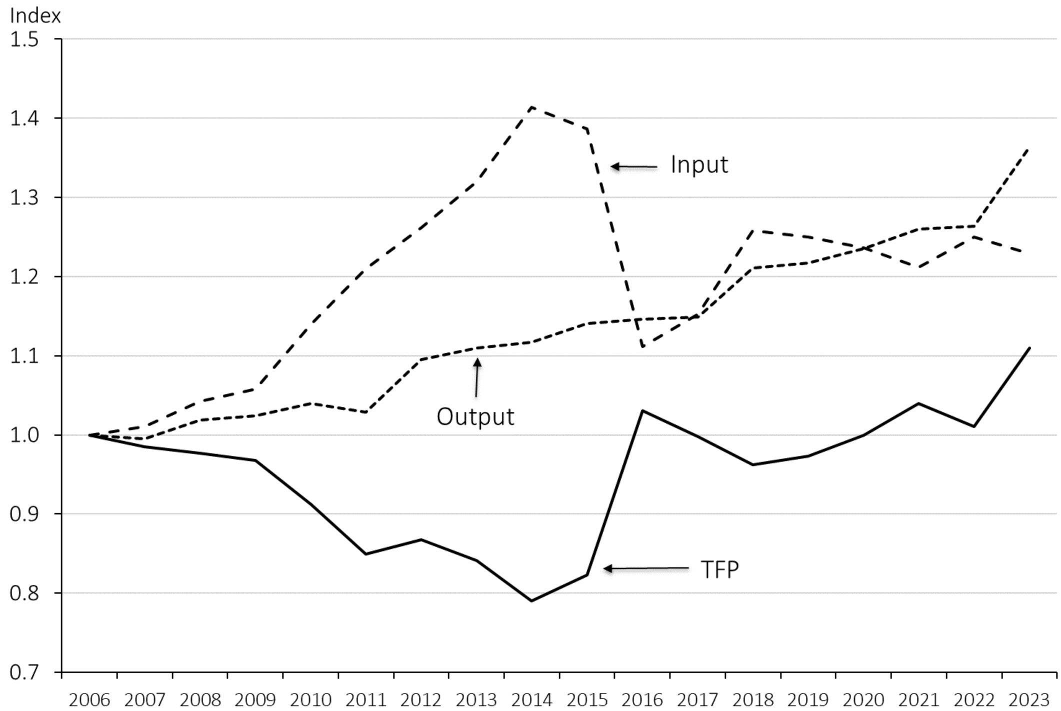


Table 5.3 ACT output, input, TFP and PFP indexes, 2006–2023

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	0.995	1.010	0.985	0.988	0.981
2008	1.019	1.042	0.977	0.952	0.996
2009	1.024	1.058	0.967	0.953	0.979
2010	1.040	1.140	0.912	0.839	0.975
2011	1.028	1.210	0.850	0.746	0.943
2012	1.095	1.262	0.868	0.740	0.987
2013	1.110	1.320	0.841	0.703	0.983
2014	1.117	1.414	0.790	0.636	0.967
2015	1.141	1.387	0.823	0.675	0.977
2016	1.146	1.112	1.031	1.120	0.972
2017	1.149	1.152	0.997	1.035	0.969
2018	1.211	1.259	0.962	0.904	1.010
2019	1.217	1.250	0.973	0.943	0.996
2020	1.236	1.236	0.999	1.005	0.990
2021	1.260	1.212	1.040	1.084	0.996
2022	1.264	1.250	1.011	1.030	0.987
2023	1.363	1.229	1.110	1.171	1.062
Growth Rate 2006–2023	1.8%	1.2%	0.6%	0.9%	0.4%
Growth Rate 2006–2012	1.5%	3.9%	-2.4%	-5.0%	-0.2%
Growth Rate 2012–2023	2.0%	-0.2%	2.2%	4.2%	0.7%
Growth Rate 2023	7.6%	-1.7%	9.3%	12.8%	7.3%

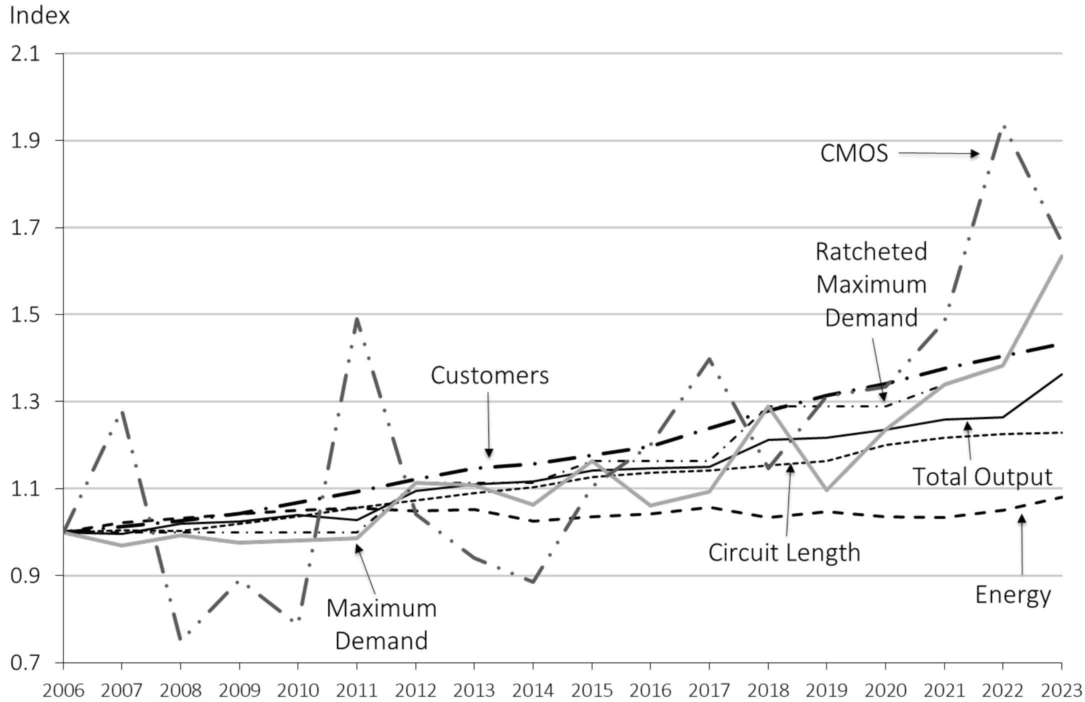
ACT output and input quantity changes

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 43.3 per cent higher in 2023 than it was in 2006;
- Energy throughput increased slightly over the period 2006 to 2023, and in 2023 was 8.1 per cent higher than in 2006;
- The ACT's maximum demand did not exceed its 2006 level until 2012 and there were further increases in ratcheted maximum demand (RMD) in 2015, 2018, and in each year from 2021 to 2023, so that in 2023, RMD was 63.4 per cent higher than in 2006;
- The ACT's circuit length output grew much more over the 18-year period than occurred for the industry overall and by 2023 was 23.0 per cent higher than it was in 2006 compared to an increase of 6.0 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 4.02

per cent of total revenue weight on average in ACT's total output.[17] In 2023, CMOS for the ACT was 66.5 per cent higher than in 2006, after a 15.2 per cent *decrease* in 2023.

Figure 5.4 ACT output quantity indexes, 2006–2023



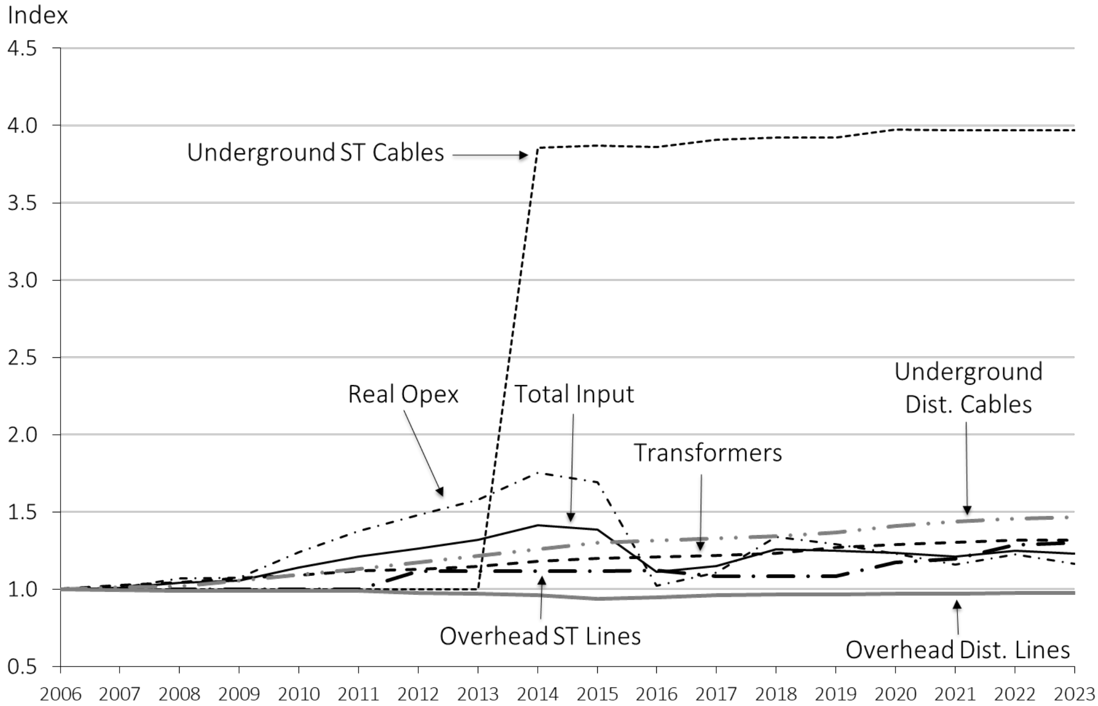
Turning to the input side, Figure 5.5 shows ACT's six individual inputs and total input. The quantity of opex increased rapidly between 2008 and 2014, being 75.6 per cent higher in 2014 than it was in 2006. It *fell* sharply in 2016 (by approximately 40 per cent) following the AER's price determination, but half of that decrease was reversed in the two years to 2018. Since then ACT's opex has trended down, except for 2022. It decreased by 5.2 per cent in 2023. By 2023, opex was 16.4 per cent higher than in 2006. Opex has the largest average share in ACT's total costs at 45.4 per cent and so is an important driver of its total input quantity index.

Except for underground subtransmission cables, the ACT's other input component quantities increased at reasonably steady rates over the 2006–2023 period. Although underground subtransmission cables in 2023 were four times their level in 2006 – due to an almost doubling of the MVA capacity rating in 2014 – the total length in 2023 is only 6 km, and this input has a negligible share in total cost (0.05 per cent). The quantity of transformer inputs, which have

[17] On average over the 2006 to 2023 period, EVO's CMOS is lowest whereas its CMOS per customer is second lowest after CIT. EVO's CMOS per customer is 70 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 –4.02 per cent is the lowest in the sample, being slightly lower than that of CIT of –4.16.

an average share of 24.2 per cent in ACT's total cost, increased by 31.7 per cent over the 18-year period.

Figure 5.5 ACT input quantity indexes, 2006–2023



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 18-year period, for the periods up to and after 2012, and for 2023. ACT's drivers of TFP change over the whole 18-year period show the following patterns. RMD, Customer numbers and circuit length outputs contributed the most to TFP growth – a combined contribution of 1.9 percentage points per year (which compares favourably to the industry average of 0.9 percentage points). CMOS was a small negative contributor to TFP growth for the ACT (–0.15 percentage points) rather than a small positive contributor as it was for the industry (0.06 percentage points).

Among the inputs' contributions to TFP growth for ACT from 2006 to 2023:

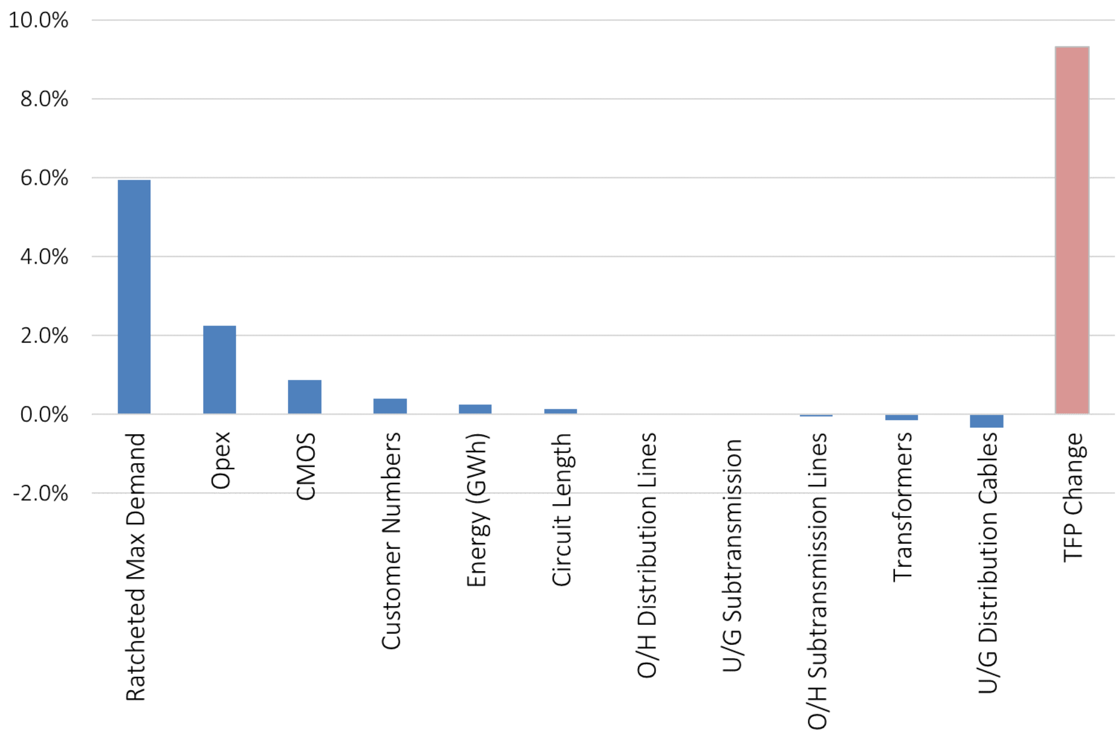
- Transformer input use contributes –0.40 percentage points (compared to –0.58 for the industry);
- Opex usage contributes –0.38 percentage points (compared to –0.22 for the industry);
- The four inputs for overhead and underground subtransmission and distribution lines together contributed –0.43 percentage points (identical to their –0.43 percentage point contribution to the industry's TFP growth).

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

Year	*2006 to 2023*	*2006 to 2012*	*2012 to 2023*	*2023*
Energy (GWh)	0.04%	0.07%	0.03%	0.26%
Ratcheted Max Demand	1.02%	0.63%	1.24%	5.94%
Customer Numbers	0.41%	0.37%	0.43%	0.40%
Circuit Length	0.50%	0.48%	0.51%	0.14%
CMOS	-0.15%	-0.04%	-0.21%	0.86%
Opex	-0.38%	-2.88%	0.98%	2.25%
O/H Subtransmission Lines	-0.05%	-0.06%	-0.04%	-0.06%
O/H Distribution Lines	0.02%	0.04%	0.00%	0.01%
U/G Subtransmission Cables	0.00%	0.00%	-0.01%	0.00%
U/G Distribution Cables	-0.39%	-0.51%	-0.33%	-0.33%
Transformers	-0.40%	-0.47%	-0.36%	-0.15%
TFP Change	0.61%	-2.36%	2.23%	9.31%

Figure 5.6 shows the contributions to TFP growth in 2023. The 16.7 per cent increase in RMD, along with *decreases* of 5.2 per cent in opex and 15.2 per cent in CMOS, contributed 5.9, 2.2 and 0.9 percentage points, respectively, to the ACT's TFP change of 9.3 per cent in 2023. Growth of customer numbers, circuit length and energy throughput in 2023 together contributed 0.8 percentage points to TFP growth while growth in transformer capacity, overhead subtransmission lines and underground distribution cables contributed –0.5 percentage points.

Figure 5.6 ACT output and input percentage point contributions to TFP change, 2023



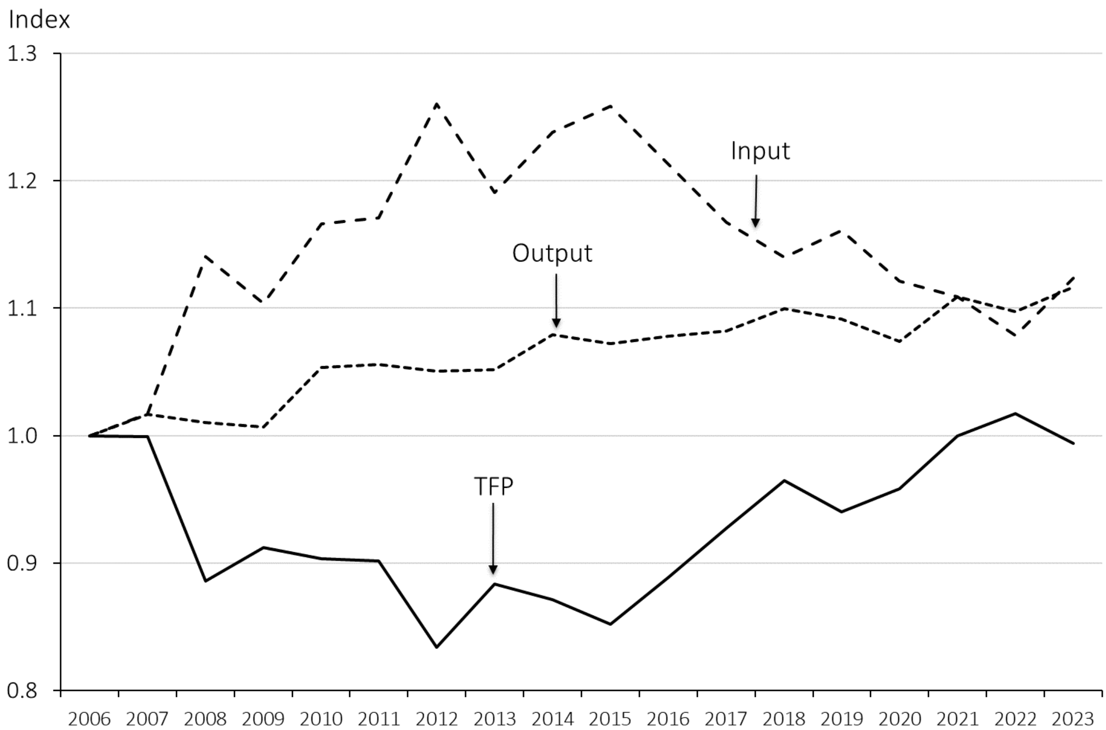
5.2.2 New South Wales (NSW)

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 2023, the three NSW DNSPs delivered 54,094 GWh to 3.84 million customers over 276,312 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 18-year period 2006 to 2023, the NSW DNSPs' TFP increased at an average annual rate of zero per cent. This growth is attributed to a 0.6 per cent increase in the annual growth rate of total output and a 0.7 per cent increase in the annual growth rate of total input.

Figure 5.7 NSW DNSP output, input and TFP indexes, 2006–2023



From 2006 and 2012, input use increased at an average annual rate of 3.9 per cent, which was followed by a *reduction* of 1.0 per cent per annum in input use from 2012 to 2023. This shift in the trend of input use was the main determinant of the turnaround in the TFP trend in NSW from –3.0 per cent per annum on average between 2006 and 2012, to a positive TFP growth of 1.6 per cent per year from 2012 to 2023. 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, 2006–2023

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	1.017	0.999	1.011	0.991
2008	1.011	1.140	0.886	0.793	0.973
2009	1.007	1.104	0.912	0.868	0.943
2010	1.054	1.166	0.904	0.837	0.956
2011	1.056	1.171	0.902	0.845	0.940
2012	1.050	1.260	0.834	0.733	0.911
2013	1.052	1.191	0.884	0.871	0.889
2014	1.079	1.238	0.872	0.843	0.891
2015	1.072	1.258	0.852	0.817	0.878
2016	1.078	1.213	0.889	0.916	0.869
2017	1.082	1.167	0.927	1.009	0.872
2018	1.100	1.140	0.965	1.099	0.880
2019	1.091	1.161	0.940	1.060	0.863
2020	1.074	1.121	0.958	1.146	0.841
2021	1.109	1.109	1.000	1.213	0.861
2022	1.098	1.079	1.017	1.286	0.854
2023	1.117	1.124	0.994	1.224	0.863
Growth Rate 2006–2023	0.6%	0.7%	0.0%	1.2%	-0.9%
Growth Rate 2006–2012	0.8%	3.9%	-3.0%	-5.2%	-1.6%
Growth Rate 2012–2023	0.6%	-1.0%	1.6%	4.7%	-0.5%
Growth Rate 2023	1.7%	4.1%	-2.3%	-5.0%	1.0%

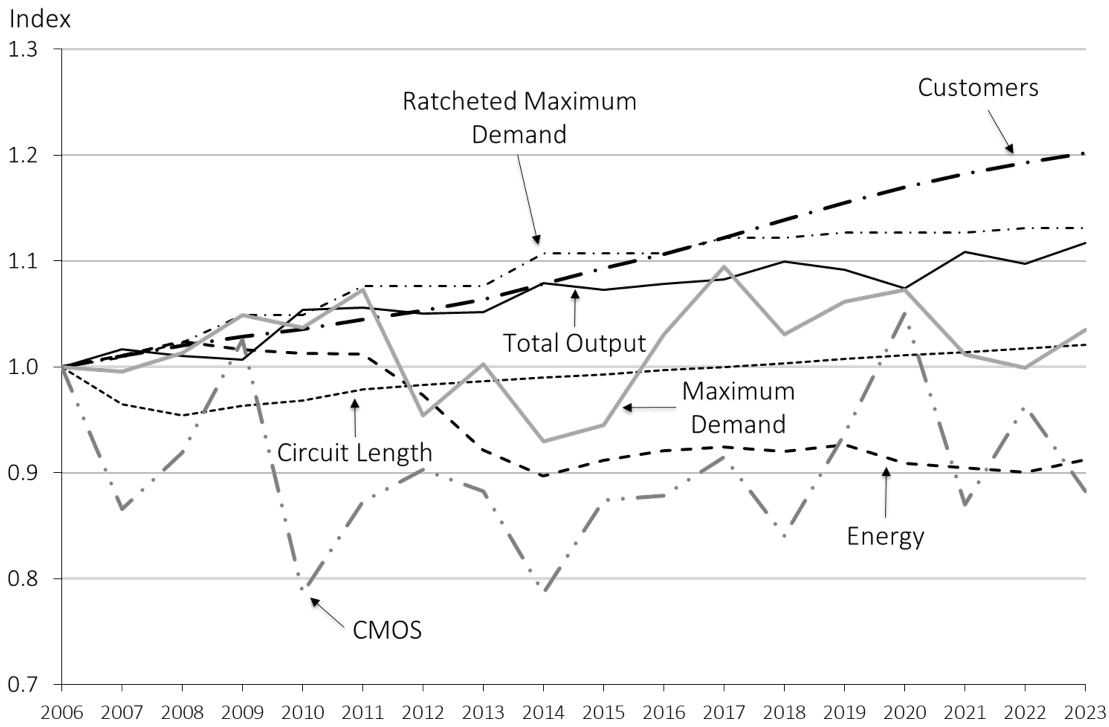
NSW DNSP output and input quantity changes

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 2023 the outputs of NSW DNSPs showed the following trends:

- Customer numbers increased steadily over the period and were 20.2 per cent higher in 2023 than in 2006;
- Energy throughput peaked in 2008 and has fallen since then. In 2023 it was 8.7 per cent *below* 2006;
- RMD increased from 2006 until 2017 and has since been relatively flat. In 2023 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 2.1 per cent in total over the whole 18-year period (compared to an increase of 6.0 per cent for the industry);
- Customer minutes off–supply (CMOS) experienced a *decrease* of 11.7 per cent in total from 2006 to 2023, which contrasts with the industry as a whole, where it *decreased* by

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

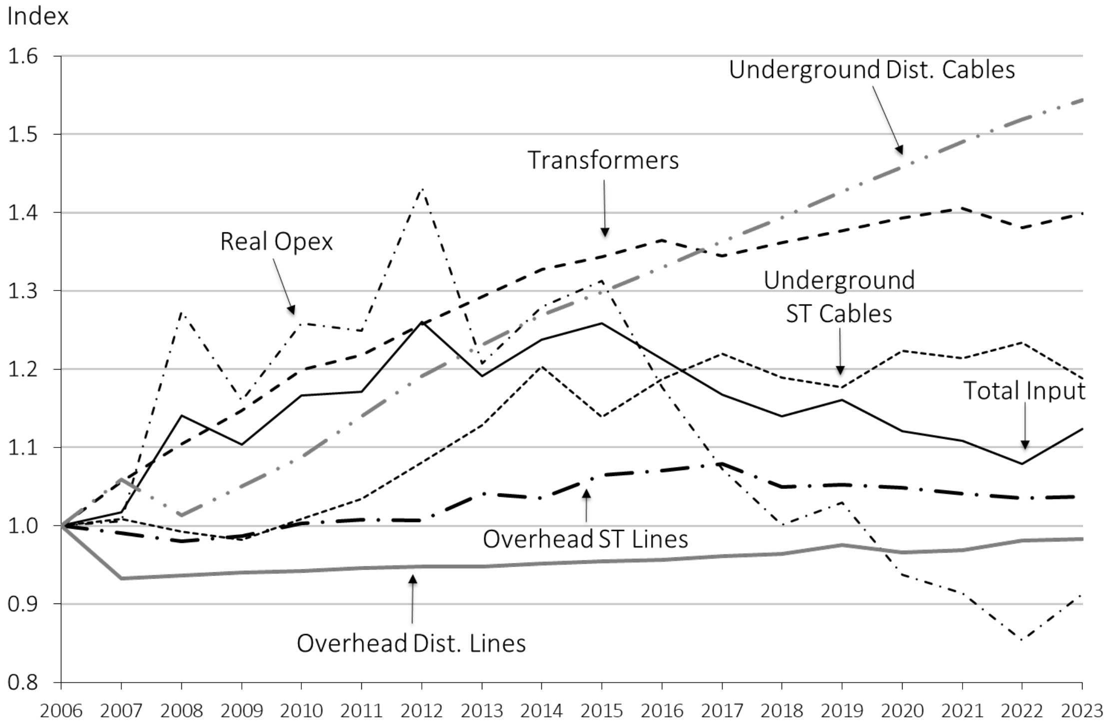
Figure 5.8 NSW output quantity indexes, 2006–2023



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 6.0 per cent from 2006 to 2012 and *decreased* at an average annual rate of 4.1 per cent from 2012 to 2023. In 2023, NSW opex input was 8.8 per cent below its 2006 level (compared to a 10.1 per cent increase for the industry);
- NSW's underground distribution cables and transformer inputs also increased strongly in the sub-period to 2012 and continued to increase but at a lower rate from 2012 to 2023. By 2023, these two inputs exceeded their 2006 levels by 54.4 per cent and 39.9 per cent respectively (compared to 71.7 per cent and 44.5 per cent respectively for the industry);
- Overhead distribution lines and overhead subtransmission lines inputs for NSW remained relatively stable from 2006 to 2023. By 2023, the total changes in these two inputs since 2006 were –1.7 per cent and 3.7 per cent, respectively (compared to 3.2 per cent and 8.0 per cent respectively for the whole industry);
- NSW's underground subtransmission cables input in 2023 was 18.8 per cent above its 2006 level (compared to 35.2 per cent for the industry).

Figure 5.9 NSW DNSP input quantity indexes, 2006–2023



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 18-year period, for the periods up to and after 2012, and for 2023. NSW's drivers of TFP change over the 18-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 0.57 percentage points annually to TFP growth in NSW, compared to their 0.87 percentage point contribution to industry-wide TFP growth.

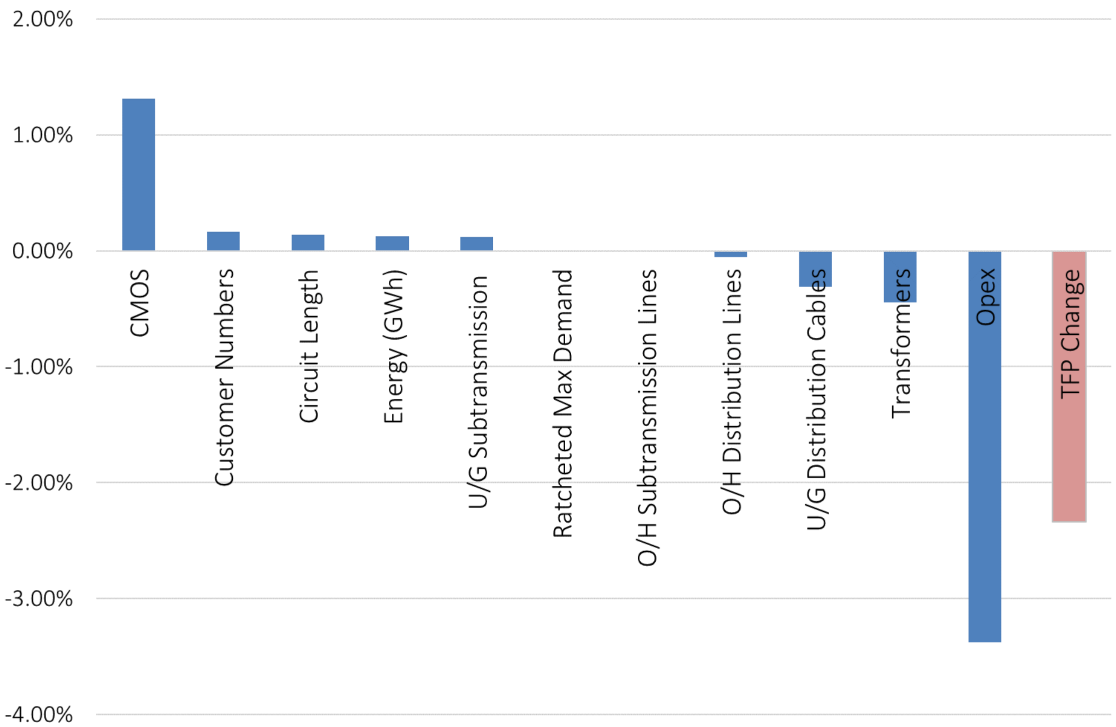
Opex has a positive contribution of 0.20 percentage points to TFP growth in NSW over the period 2006 to 2023 due to its average annual *decrease* of 0.5 per cent, whereas for the industry as a whole opex contributed –0.22 percentage points to TFP growth (see Table 2.2). The other inputs, namely overhead and underground subtransmission and distribution lines, and transformers, in total contributed –0.88 percentage points to annual TFP growth in NSW (compared to –1.01 percentage points for the industry overall).

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

Year	*2006 to 2023*	*2006 to 2012*	*2012 to 2023*	*2023*
Energy (GWh)	-0.05%	-0.05%	-0.06%	0.13%
Ratcheted Max Demand	0.29%	0.49%	0.17%	0.00%
Customer Numbers	0.23%	0.19%	0.26%	0.16%
Circuit Length	0.05%	-0.13%	0.15%	0.14%
CMOS	0.13%	0.31%	0.03%	1.31%
Opex	0.20%	-2.51%	1.67%	-3.38%
O/H Subtransmission Lines	-0.01%	-0.01%	-0.01%	-0.01%
O/H Distribution Lines	0.01%	0.09%	-0.04%	-0.05%
U/G Subtransmission Cables	-0.03%	-0.04%	-0.03%	0.12%
U/G Distribution Cables	-0.29%	-0.32%	-0.27%	-0.31%
Transformers	-0.56%	-1.07%	-0.28%	-0.45%
TFP Change	-0.04%	-3.03%	1.60%	-2.34%

Figure 5.10 shows the decomposition of TFP change of –2.34 per cent in 2023. The major negative contribution in 2023 came from the increase in opex of 6.7 per cent, which contributed –3.38 percentage points. The major positive effect on TFP came from increased reliability (ie, the decrease in CMOS of –8.7 per cent), contributing 1.31 percentage points. The contributions of all the other outputs and inputs in 2023 are individually small, and on balance negative, contributing together –0.27 percentage points.

Figure 5.10 NSW output and input percentage point contributions to TFP change, 2023



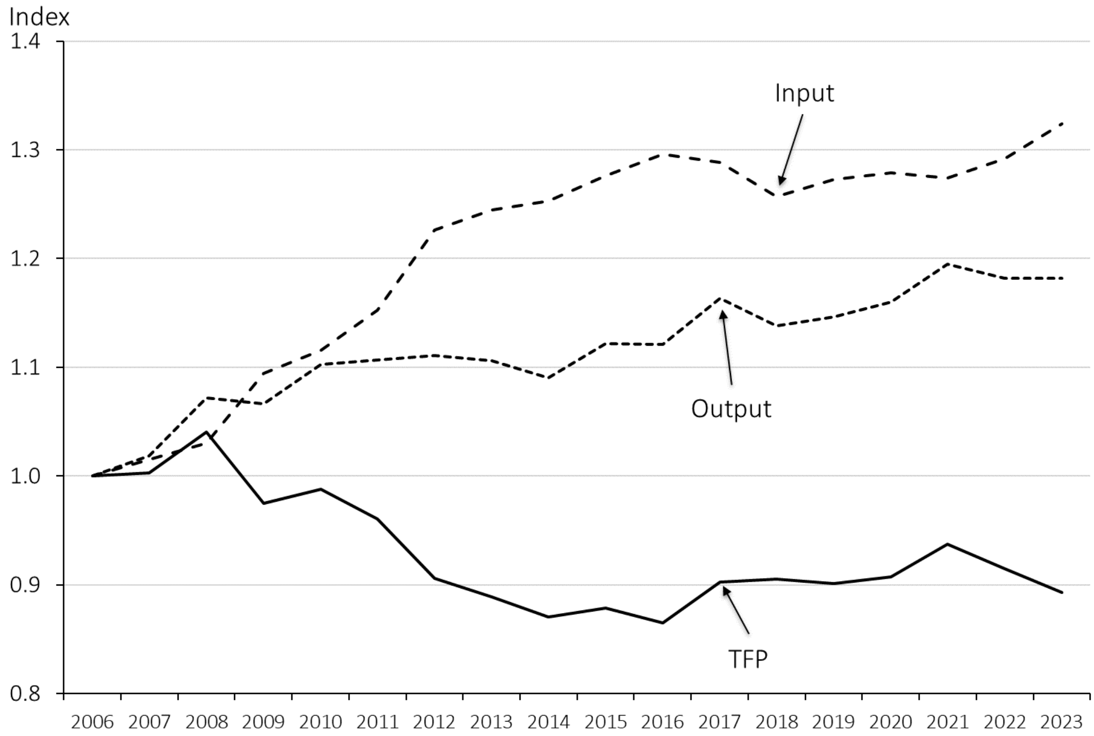
5.2.3 Victoria (VIC)

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 2023 the Victorian DNSPs delivered 36,055 GWh to 3.18 million customers over 148,749 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 18-year period 2006 to 2023, the Victorian DNSPs' TFP *decreased* at an average annual rate of 0.7 per cent. Although total output increased by an average annual rate of 1.0 per cent, total input use increased faster, at a rate of 1.7 per cent. Victoria had slightly higher output and input growth, and a similar rate of TFP decline, compared to the industry.

Figure 5.11 VIC DNSP output, input and TFP indexes, 2006–2023



The TFP average annual change for Victorian DNSPs for the period up to 2012, at –1.6 per cent per annum, compares to –0.1 per annum for the period 2012 to 2023. 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, 2006–2023

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.018	1.015	1.003	1.016	0.993
2008	1.072	1.030	1.041	1.068	1.022
2009	1.067	1.094	0.975	0.965	0.982
2010	1.102	1.116	0.988	0.978	0.995
2011	1.107	1.152	0.960	0.930	0.983
2012	1.111	1.226	0.906	0.833	0.967
2013	1.106	1.244	0.889	0.824	0.945
2014	1.090	1.253	0.870	0.818	0.914
2015	1.121	1.276	0.879	0.822	0.926
2016	1.121	1.296	0.865	0.810	0.911
2017	1.163	1.289	0.903	0.868	0.931
2018	1.138	1.257	0.905	0.920	0.895
2019	1.146	1.273	0.901	0.916	0.890
2020	1.160	1.279	0.907	0.938	0.883
2021	1.195	1.274	0.937	0.980	0.903
2022	1.182	1.292	0.915	0.963	0.880
2023	1.182	1.324	0.893	0.927	0.871
Growth Rate 2006–2023	1.0%	1.7%	-0.7%	-0.5%	-0.8%
Growth Rate 2006–2012	1.8%	3.4%	-1.6%	-3.1%	-0.6%
Growth Rate 2012–2023	0.6%	0.7%	-0.1%	1.0%	-1.0%
Growth Rate 2023	0.0%	2.5%	-2.5%	-3.8%	-1.1%

Victorian DNSP output and input quantity changes

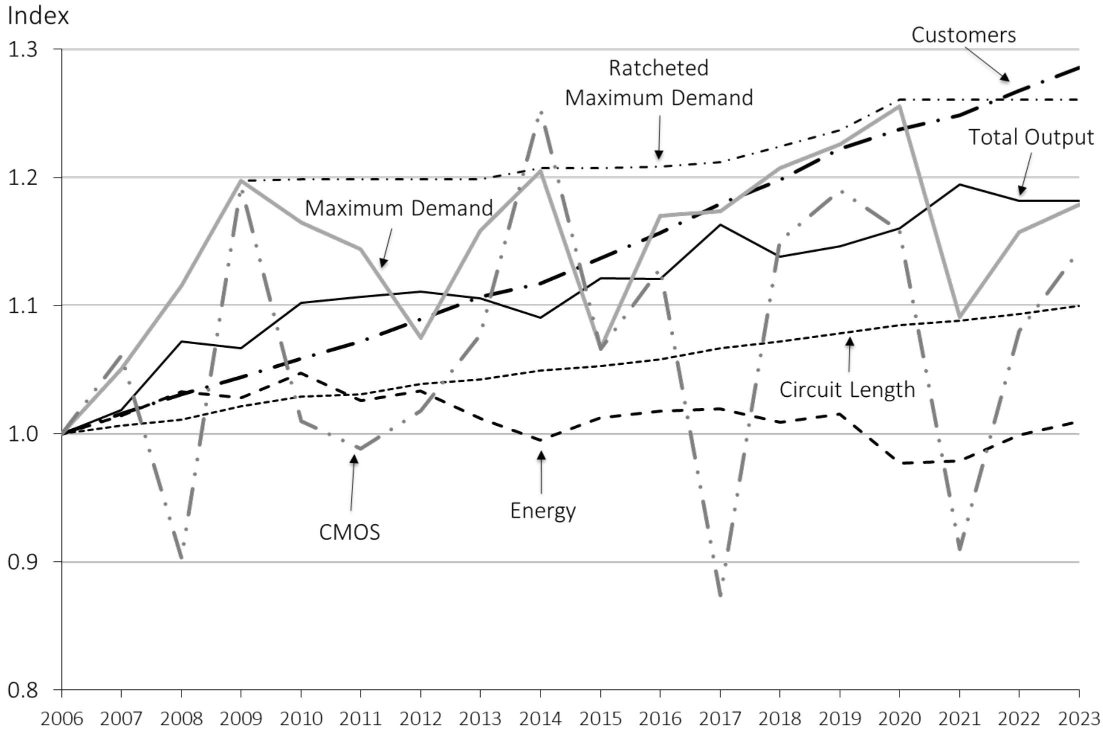
The quantity indexes for the Victorian DNSPs' individual outputs are plotted in Figure 5.12, and the six individual inputs are plotted in Figure 5.13. From Figure 5.12 we see that:

- Customer numbers increased steadily over the period and were 28.5 per cent higher in 2023 than in 2006 (similar to the 25.1 of industry as a whole);
- Energy throughput peaked in 2010 and has fallen slowly since then. In 2023 it was 1.0 per cent above 2006 (compared to a *decrease* of 2.8 per cent for the industry);
- VIC's RMD increased up to 2009, and again from 2014 onwards. By 2023, RMD was 26.1 per cent higher than in 2006 (more than the 20.0 per cent increase for the industry as a whole);
- VIC's circuit length output grew by 10.0 per cent in total over the whole 18-year period (compared to an increase of 6.0 per cent for the industry);
- VIC's total customer minutes off–supply (CMOS) increased by 14.3 per cent in total between 2006 and 2023 (compared to a *decrease* of 3.5 per cent for the industry over the

same period). CMOS receives an average weight of –12.5 per cent of total revenue for Victoria.

In 2023, customers and circuit length increased by 1.4 per cent and 0.6 per cent respectively. CMOS increased by 5.7 per cent, which contributed negatively to total output growth. Energy output also increased in 2023, by 1.0 per cent, whilst RMD remained unchanged. VIC total outputs in 2023 remained unchanged.

Figure 5.12 VIC output quantity indexes, 2006–2023

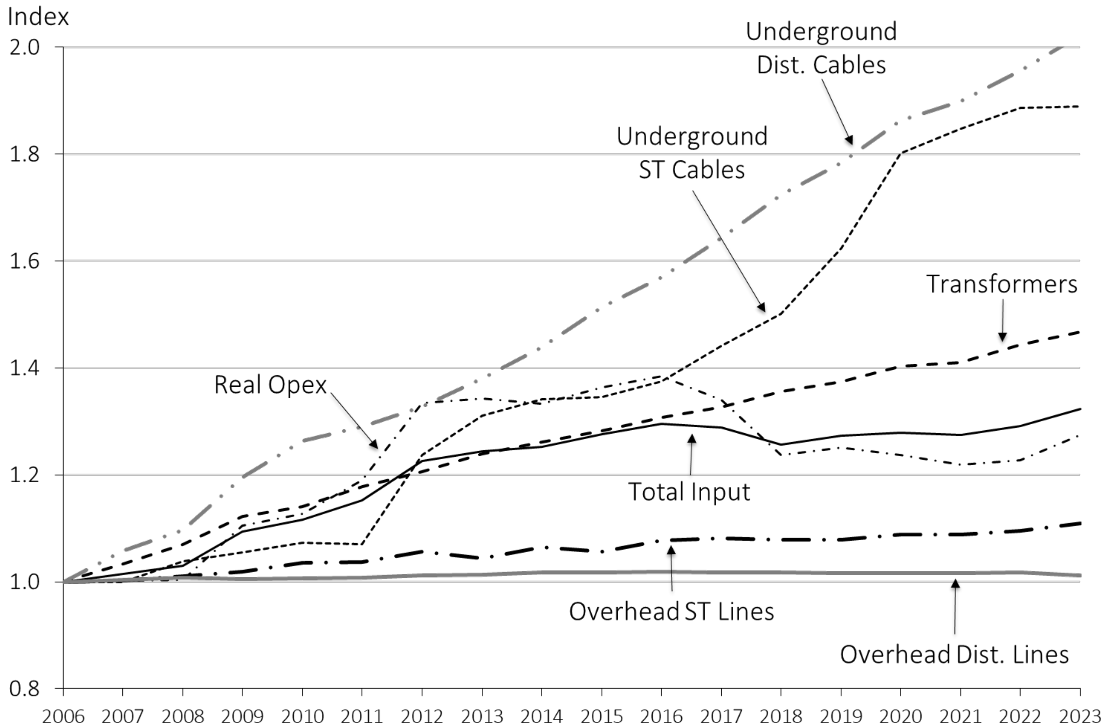


Victoria's six individual inputs and total input are shown Figure 5.13:

- VIC opex increased by 34.2 per cent in total up to 2013, and remained at a similar level up to 2017, after which it declined, so that in 2023 opex was 27.5 per cent above its 2006 level (compared to 10.1 per cent for the industry). Opex has the largest average share in VIC total costs at 43.1 per cent and so is an important driver of its total input quantity index;
- VIC's underground distribution and subtransmission cables increased at a much higher rate than that for the industry overall. By 2023, these two inputs exceeded their 2006 levels by 102.2 per cent and 89.0 per cent respectively (compared to 71.7 and 35.2 per cent for the industry);
- Transformers inputs in VIC increased at a similar rate to the industry as a whole. By 2023, VIC transformer inputs exceeded their 2006 levels by 46.7 per cent (compared to 44.5 per cent for the industry);

- By 2023, overhead subtransmission and distribution inputs exceeded their 2006 levels by 10.9 per cent and 1.2 per cent respectively (compared to 7.7per cent and 3.2 per cent respectively for the whole industry).

Figure 5.13 VIC DNSP input quantity indexes, 2006–2023



Victorian output and input contributions to TFP change

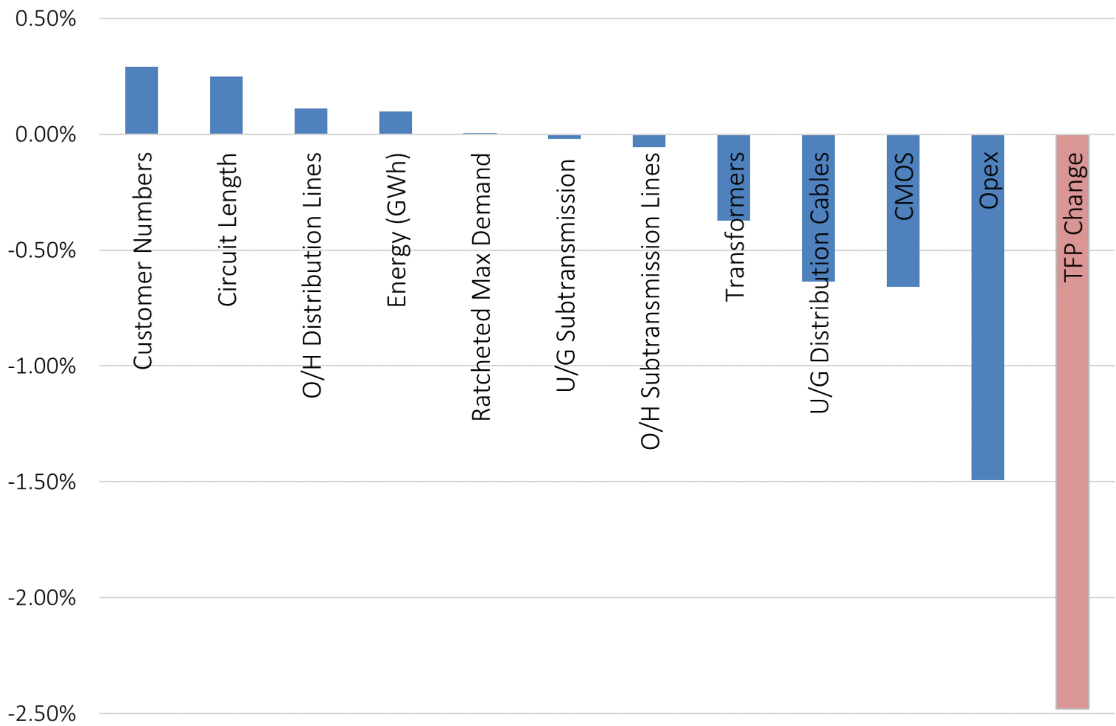
Table 5.8 decomposes VIC's annual TFP change into its constituent output and input contributions for the 18-year period, for the periods up to and after 2012, and for 2023. Victoria's drivers of TFP change for the 2006 to 2023 period are broadly similar to the industry, except that energy made a small positive contribution to VIC's TFP at 0.01 percentage points annually on average (compared to –0.02 percentage points for industry). Transformer inputs made a negative contribution to Victoria's TFP at –0.48 percentage points compared to –0.58 for the industry and underground distribution cables contributed negatively to Victoria's TFP at –0.51 compared to –0.35 for the industry.

Consistent with the industry, the biggest source of change in TFP between the sub-periods 2006 to 2012 and 2012 to 2023 is in opex input use. Growth in opex inputs in the former period contributed –2.05 percentage points to VIC TFP growth, and reductions in opex inputs in the latter period contributed 0.25 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 2023*	*2006 to 2012*	*2012 to 2023*	*2023*
Energy (GWh)	0.01%	0.05%	-0.02%	0.10%
Ratcheted Max Demand	0.52%	1.16%	0.17%	0.01%
Customer Numbers	0.32%	0.30%	0.33%	0.29%
Circuit Length	0.25%	0.28%	0.24%	0.25%
CMOS	0.06%	-0.04%	0.11%	-0.66%
Opex	-0.56%	-2.05%	0.25%	-1.49%
O/H Subtransmission Lines	-0.02%	-0.03%	-0.02%	-0.06%
O/H Distribution Lines	-0.01%	-0.04%	0.00%	0.11%
U/G Subtransmission Cables	-0.05%	-0.04%	-0.05%	-0.02%
U/G Distribution Cables	-0.51%	-0.58%	-0.47%	-0.64%
Transformers	-0.48%	-0.66%	-0.38%	-0.37%
TFP Change	-0.48%	-1.65%	0.16%	-2.48%

Figure 5.14 VIC output and input percentage point contributions to TFP change, 2023



In Figure 5.14 we see that the largest contributions to Victoria's TFP *decrease* of 2.48 per cent in 2023 were: increased opex, decline in reliability (i.e., increase in CMOS) and increased underground distribution cables the which together contributed –2.79 percentage points. Among the outputs, the other contributors were customer numbers, circuit length and energy throughput outputs, which combined contributed 0.64 percentage points. On the input side, overhead distribution lines was the only positive contributor to TFP growth, contributing 0.11

percentage points. Transformers, overhead and underground subtransmission lines and cables negatively contributed together –0.45.

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 2023 the two Queensland DNSPs delivered 35,584 GWh to 2.39 million customers over 210,713 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 18-year period 2006 to 2023, the average annual rate of TFP change of QLD DNSPs was 0.1 per cent. QLD's total output increased by an average annual rate of 1.4 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 1.4 per cent (which is less than for VIC, higher than for NSW and similar to the average for the industry).

Figure 5.15 QLD DNSP output, input and TFP indexes, 2006–2023

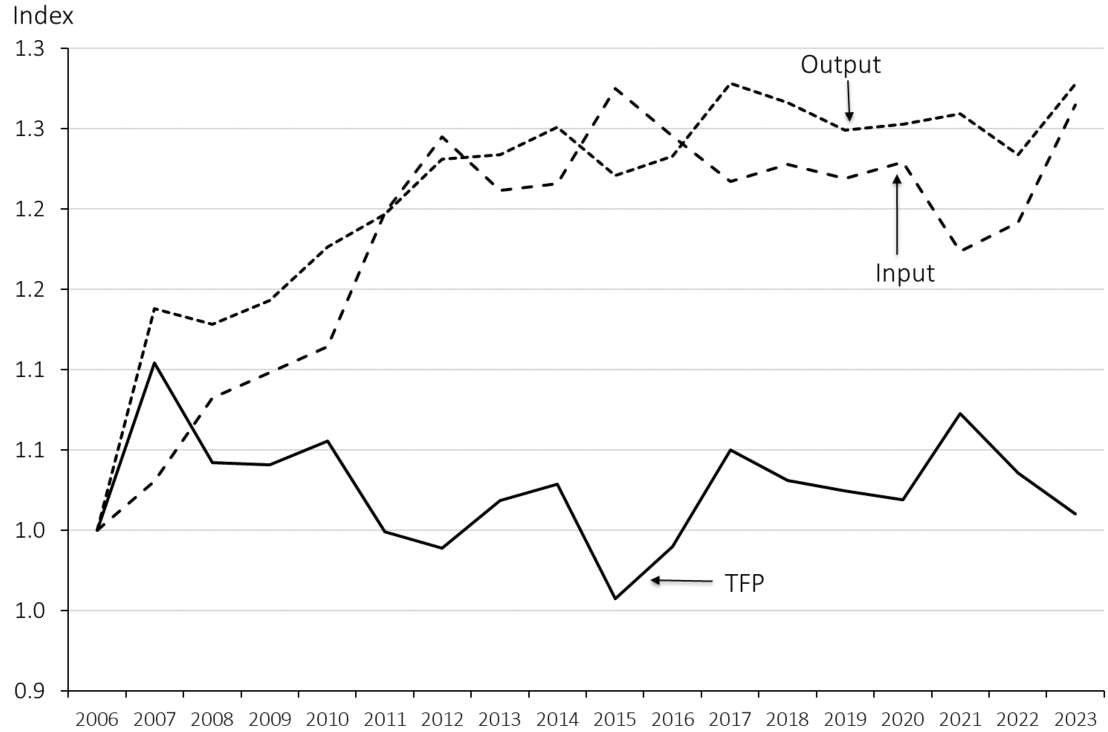


Table 5.9 QLD DNSP output, input, TFP and PFP indexes, 2006–2023

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index Opex*	*PFP Index Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.138	1.030	1.104	1.131	1.085
2008	1.128	1.083	1.042	1.047	1.040
2009	1.143	1.098	1.041	1.072	1.018
2010	1.176	1.115	1.055	1.114	1.014
2011	1.197	1.198	0.999	0.991	1.005
2012	1.231	1.245	0.989	0.961	1.009
2013	1.234	1.211	1.018	1.043	1.002
2014	1.251	1.216	1.029	1.089	0.988
2015	1.221	1.275	0.957	0.989	0.937
2016	1.233	1.245	0.990	1.070	0.934
2017	1.278	1.217	1.050	1.190	0.953
2018	1.266	1.228	1.031	1.169	0.935
2019	1.249	1.219	1.024	1.174	0.922
2020	1.253	1.229	1.019	1.164	0.917
2021	1.259	1.174	1.073	1.302	0.912
2022	1.234	1.192	1.036	1.240	0.890
2023	1.278	1.265	1.010	1.160	0.907
Growth Rate 2006–2023	1.4%	1.4%	0.1%	0.9%	-0.6%
Growth Rate 2006–2012	3.5%	3.7%	-0.2%	-0.7%	0.2%
Growth Rate 2012–2023	0.3%	0.1%	0.2%	1.7%	-1.0%
Growth Rate 2023	3.5%	6.0%	-2.5%	-6.6%	1.9%

Comparing the period before 2012 to that after 2012, TFP change of QLD DNSPs averaged –0.2 per cent per annum from 2006 to 2012 and 0.2 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.

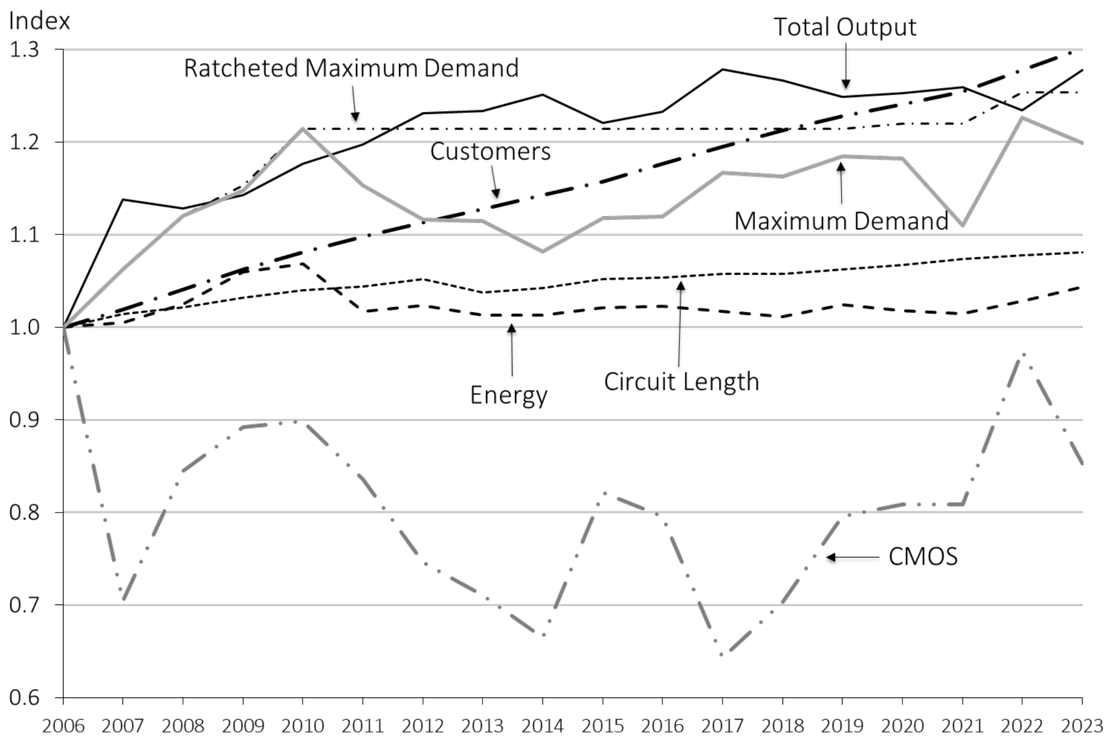
Queensland DNSP output and input quantity changes

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 2023 it was 4.3 per cent above 2006 (compared to 2.8 per cent *below* 2006 for the industry as a whole);

- Customer numbers increased steadily over the period and were 30.1 per cent higher in 2023 than in 2006;
- QLD's RMD increased mainly in the period up to 2010, thereafter having only incremental increases in 2020 and 2022. In 2023, it was 25.4 per cent higher than the level in 2006 (a slightly higher increase than the industry's 20.0 per cent increase);
- QLD's circuit length output grew by 8.1 per cent in total over the whole 18-year period (slightly above the increase of 6.0 per cent for the industry);
- Total customer minutes off–supply (CMOS) *decreased* by 14.8 per cent between 2006 and 2023 (compared to a 3.5 per cent *decrease* for the industry over the same period). It was aided by a *decrease* of 13.3 in 2023.

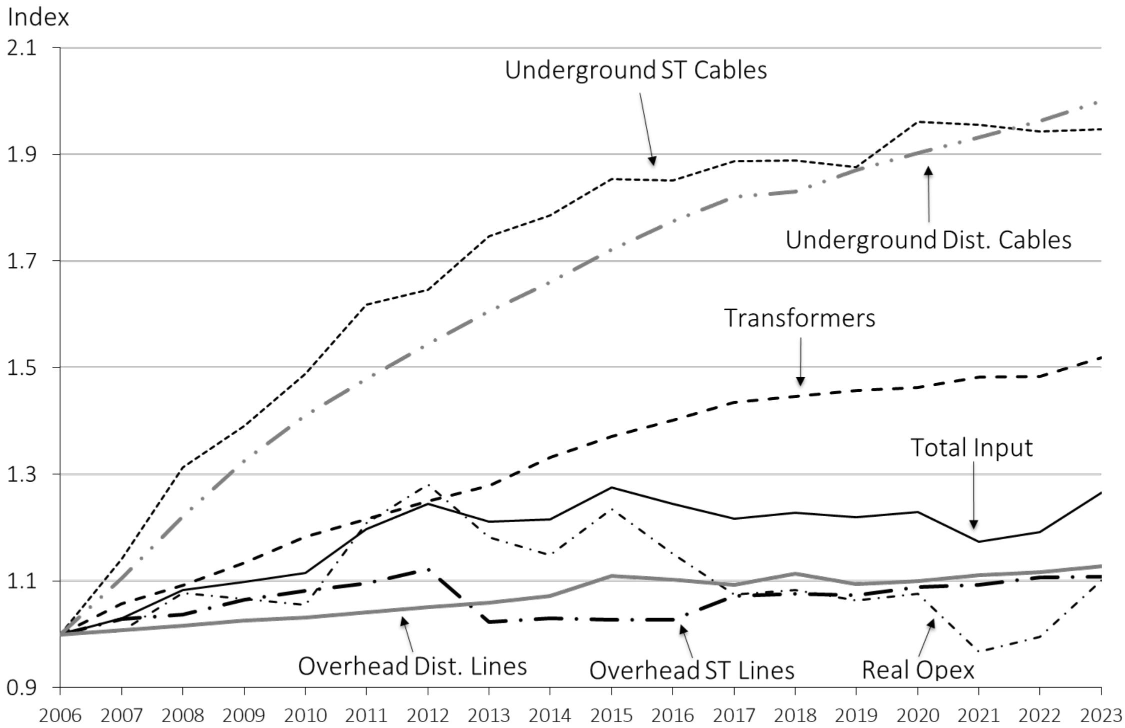
Figure 5.16 QLD output quantity indexes, 2006–2023



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 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 –19.0 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 subtransmission 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 number growth.

Figure 5.17 QLD DNSP input quantity indexes, 2006–2023



Opex in QLD increased at a similar rate to the industry average, and overhead lines increased somewhat faster than for the industry. QLD opex increased by 28.1 per cent in total up to 2012 (which was less than the corresponding increase for the industry of 37.4 per cent). It declined afterwards and in 2023 opex was 10.1 per cent above its 2006 level (identical to the industry average). Opex has the largest average share in QLD's total costs at 44.3 per cent and so is an important driver of its total input quantity index. Among the other inputs:

- Transformers inputs in QLD increased by 51.8 per cent between 2006 and 2023 (compared to 44.5 per cent for the industry over the same period);
- Overhead subtransmission and distribution lines in QLD increased by 10.8 per cent and 12.8 per cent, respectively, in total between 2006 and 2023 (compared to 7.7 per cent and 3.2 per cent respectively for the whole industry).
- Underground subtransmission and distribution cables in QLD increased 94.7 per cent and 100.0 per cent, respectively, in total between 2006 and 2023 (compared to 35.2 per cent and 71.7 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 full 18-year period, for the periods up to and after 2012, and for 2023. QLD’s drivers of TFP change for the period 2006 to 2023 are broadly similar to the industry as a whole, except that energy makes a slightly positive contribution of 0.03 percentage points (compared to –0.02 for the industry) and CMOS makes a larger positive contribution of 0.28 percentage points (compared to 0.06 for the industry). Regarding the contributions of other outputs and inputs in the 2006 to 2023 period:

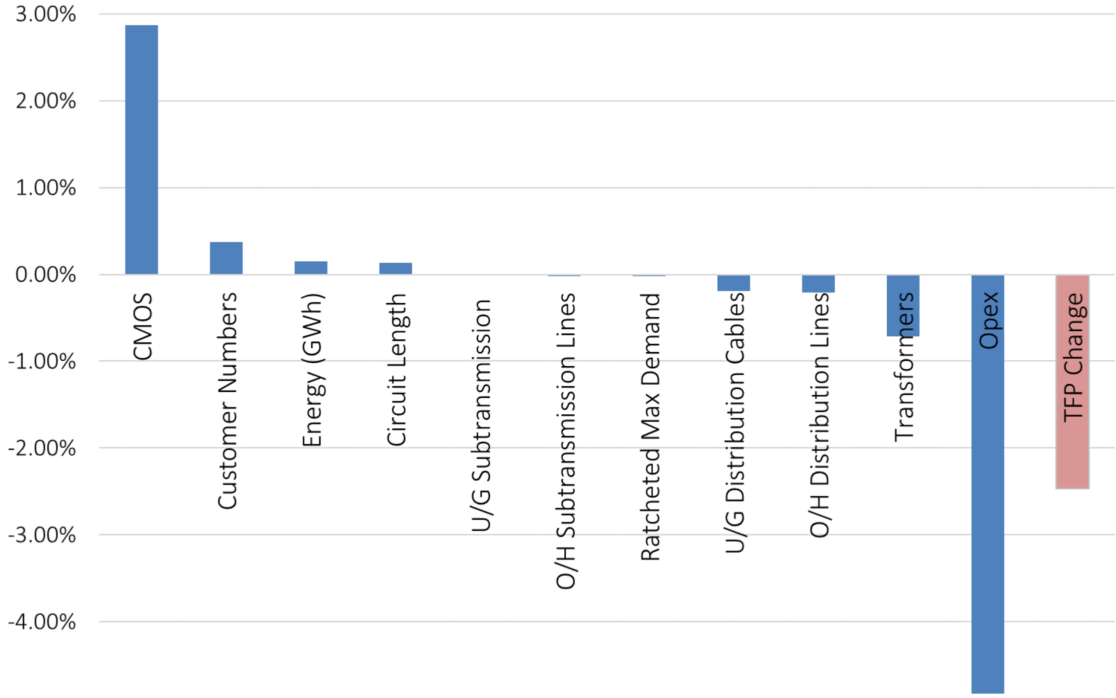
- RMD is the largest contributor to QLD's average TFP growth rate, at 0.56 percentage points.
- Customers and circuit length outputs together contributed 0.58 percentage points to QLD’s average TFP growth for the period 2006 to 2023 (compared to 0.45 for the whole industry);
- Overhead and underground subtransmission and distribution lines and cables together contributed –0.50 percentage points to QLD’s TFP growth (compared to –0.43 for the industry);
- Transformers input contributed –0.65 percentage points to QLD’s TFP rate of growth (compared to –0.58 for the industry).

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

Year	*2006 to 2023*	*2006 to 2012*	*2012 to 2023*	*2023*
Energy (GWh)	0.03%	0.04%	0.02%	0.15%
Ratcheted Max Demand	0.56%	1.37%	0.12%	-0.02%
Customer Numbers	0.35%	0.43%	0.31%	0.37%
Circuit Length	0.22%	0.42%	0.12%	0.13%
CMOS	0.28%	1.20%	-0.23%	2.87%
Opex	-0.24%	-1.75%	0.58%	-4.83%
O/H Subtransmission Lines	-0.04%	-0.12%	0.01%	-0.02%
O/H Distribution Lines	-0.11%	-0.13%	-0.10%	-0.21%
U/G Subtransmission Cables	-0.08%	-0.17%	-0.03%	-0.01%
U/G Distribution Cables	-0.27%	-0.48%	-0.15%	-0.19%
Transformers	-0.65%	-0.99%	-0.45%	-0.71%
TFP Change	0.06%	-0.19%	0.20%	-2.47%

Figure 5.18 shows the contributions of individual outputs and inputs to QLD’s TFP growth of –2.5 per cent in 2023. Among outputs, positive contributions were made by CMOS, customer numbers, energy and circuit length. Among inputs, opex made the largest negative contribution to TFP change, followed by transformers.

Figure 5.18 Qld output and input percentage point contributions to TFP change, 2023



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 2023 it delivered 9,809 GWh to 936,660 customers over 90,311 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 18-year period 2006 to 2023, the SA DNSP's TFP *decreased* at an average annual rate of 1.8 per cent. Although total output increased by an average annual rate of 0.6 per cent, total input use increased faster, at a rate of 2.4 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 2023 at an annual average rate of 1.5 per cent. Although the rate of output growth was also lower after 2012 (–0.1 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 2023 it averaged –1.6 per cent. In 2023 SA's TFP *decreased* 7.1 per cent, driven by an increase of 6.5 per cent in total input.

Figure 5.19 SA DNSP output, input and total factor productivity indexes, 2006–2023

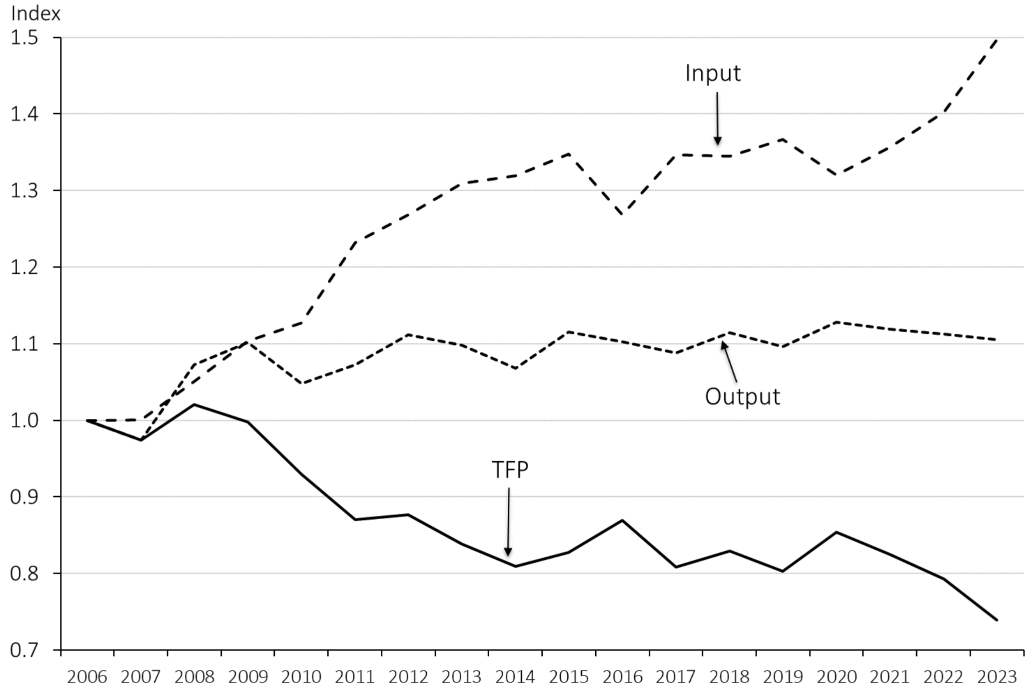


Table 5.11 SA DNSP output, input, TFP and PFP indexes, 2006–2023

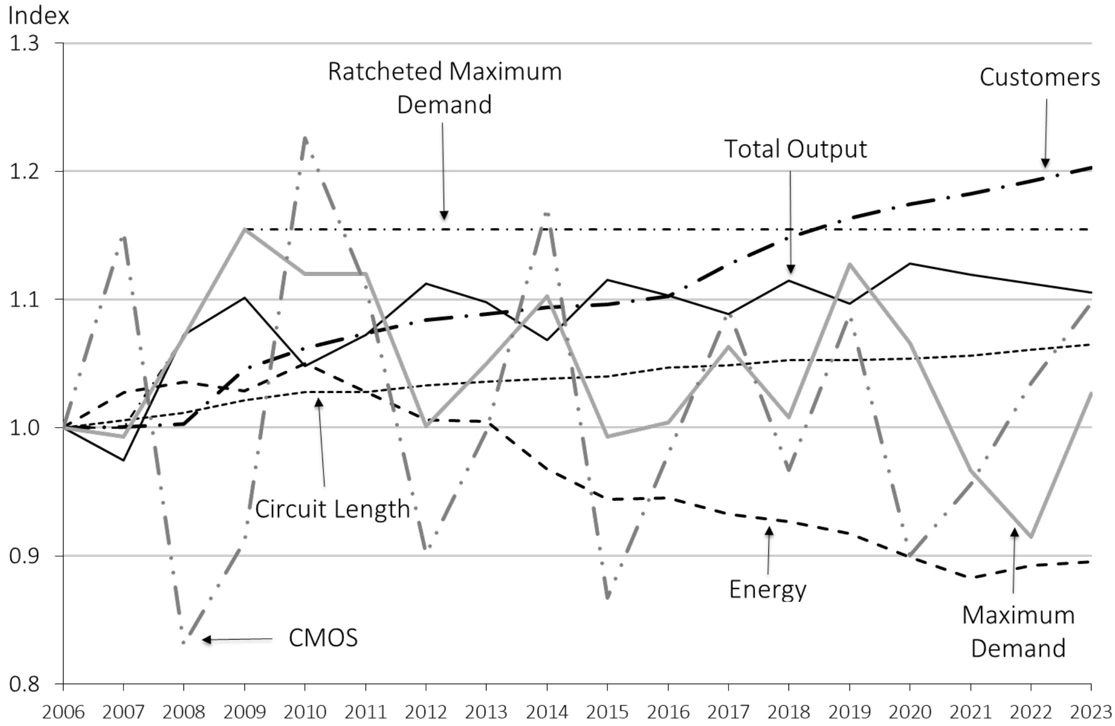
Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	0.975	1.001	0.974	1.049	0.940
2008	1.073	1.051	1.021	1.036	1.012
2009	1.102	1.104	0.998	0.972	1.011
2010	1.048	1.127	0.930	0.924	0.931
2011	1.073	1.232	0.871	0.759	0.935
2012	1.112	1.269	0.877	0.761	0.943
2013	1.098	1.309	0.839	0.714	0.916
2014	1.068	1.320	0.809	0.698	0.878
2015	1.115	1.347	0.828	0.701	0.906
2016	1.103	1.268	0.870	0.827	0.887
2017	1.088	1.347	0.808	0.708	0.867
2018	1.115	1.344	0.829	0.740	0.879
2019	1.097	1.366	0.803	0.710	0.856
2020	1.128	1.320	0.854	0.819	0.868
2021	1.119	1.357	0.825	0.797	0.833
2022	1.112	1.402	0.793	0.742	0.818
2023	1.106	1.497	0.739	0.634	0.805
Growth Rate 2006–2023	0.6%	2.4%	-1.8%	-2.7%	-1.3%
Growth Rate 2006–2012	1.8%	4.0%	-2.2%	-4.6%	-1.0%
Growth Rate 2012–2023	-0.1%	1.5%	-1.6%	-1.7%	-1.4%
Growth Rate 2023	-0.6%	6.5%	-7.1%	-15.7%	-1.6%

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 20.3 per cent higher in 2023 than in 2006 (compared to 25.1 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 2023 it was 10.5 per cent *below* 2006; a larger decrease than that for the industry as a whole over the same period (–2.8 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 20.0 per cent for the industry between 2006 and 2023;
- SA's circuit length output grew by 6.5 per cent in total over the 18-year period (compared to 6.0 per cent for the industry);
- SA's CMOS increased by 9.8 per cent in total between 2006 and 2023, thus making a greater contribution to output growth than for the industry (where CMOS *decreased* by 3.5 per cent over the same period). CMOS receives an average weight of –16.5 per cent of total revenue for SA.

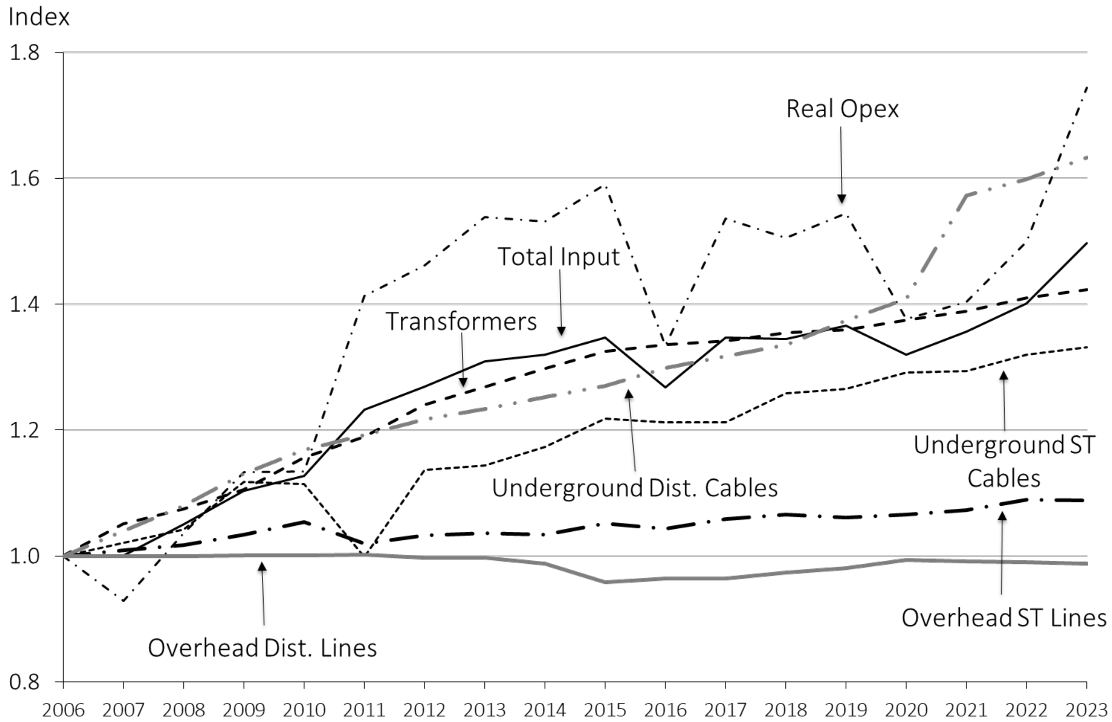
Figure 5.20 SA output quantity indexes, 2006–2023



Since the circuit length and RMD outputs receive a combined average weight of 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 10.6 per cent between 2006 and 2023 (less than the increase for the industry of 16.6 per cent over the same period).

Turning to Figure 5.21, which shows the SA DNSP's input indexes, SA's total input index increased by 49.7 per cent in total between 2006 and 2023, which is higher than the corresponding increase of 23.4 per cent for the industry.

Figure 5.21 SA DNSP input quantity indexes, 2006–2023



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

- SA's opex input increased by 74.4 per cent over the 18-year period, which is much greater than for the industry (an increase of 10.1 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 2020. Since 2020 opex has trended upward again and in 2023 it increased 15.1 per cent. Opex has the largest average share in SA's total costs at 36.6 per cent and so is an important driver of its total input quantity index;
- Underground distribution and subtransmission cables in SA increased by 63.2 per cent and 33.1 per cent respectively in total over the 18-year period to 2023 (compared to 71.7 and 35.2 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 42.4 per cent by 2023 (compared to 44.5 per cent for the industry);
- SA's overhead subtransmission increased between 2006 and 2023 by 8.9 per cent in total and its overhead distribution lines *decreased* by 1.2 per cent (compared to increases of 7.7 per cent and 3.2 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 18-year period, for the periods up to and after 2012, and for 2023. SA's drivers of TFP change for the 18-year period to 2023 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 –1.17 percentage points to the average TFP growth rate of –1.8 per cent from 2006 to 2023 (compared to a negative contribution of opex of –0.22 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 18 years to 2023 include:

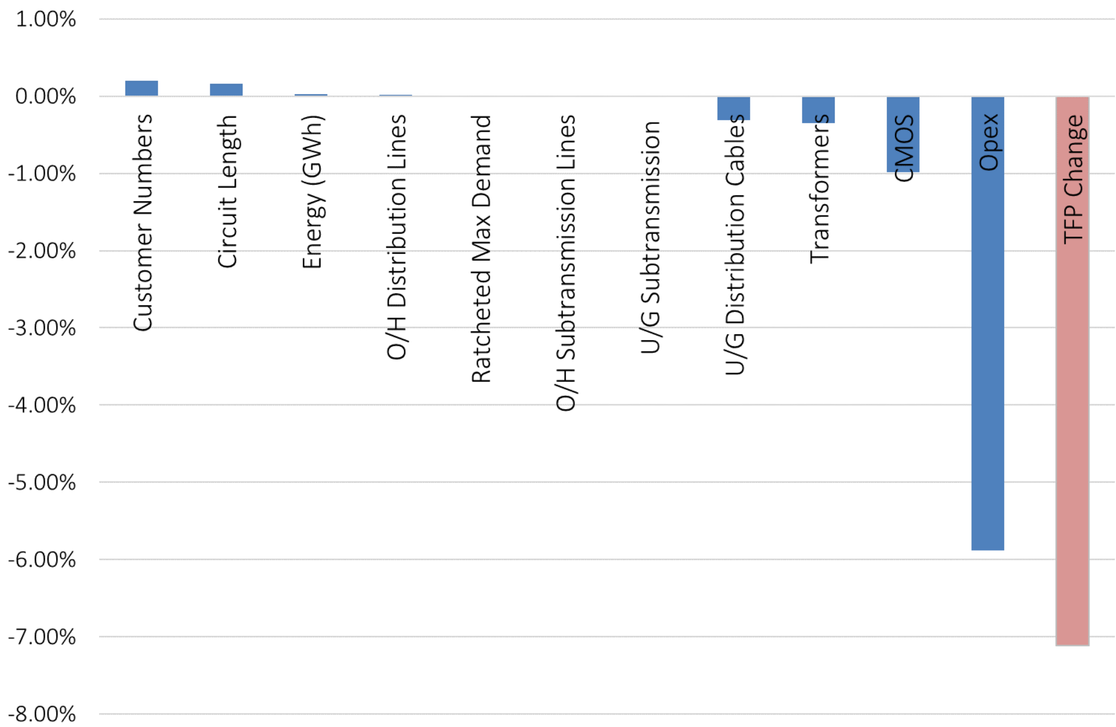
- Customers, RMD and circuit length outputs together contributed 0.75 percentage points (compared to 0.87 for the industry);
- Overhead and underground subtransmission and distribution lines together contributed –0.52 percentage points (compared to –0.43 for the industry);
- Transformers input contributed –0.69 percentage points (–0.58 for the industry); and
- CMOS contributed –0.09 percentage points (0.06 for the industry).

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

Year	*2006 to 2023*	*2006 to 2012*	*2012 to 2023*	*2023*
Energy (GWh)	-0.1%	0.01%	-0.11%	0.03%
Ratcheted Max Demand	0.3%	0.96%	0.00%	0.01%
Customer Numbers	0.2%	0.30%	0.20%	0.20%
Circuit Length	0.2%	0.26%	0.12%	0.16%
CMOS	-0.1%	0.25%	-0.28%	-0.98%
Opex	-1.2%	-2.12%	-0.65%	-5.88%
O/H Subtransmission Lines	0.0%	-0.01%	-0.01%	0.00%
O/H Distribution Lines	0.0%	0.01%	0.01%	0.02%
U/G Subtransmission Cables	0.0%	-0.01%	0.00%	0.00%
U/G Distribution Cables	-0.5%	-0.69%	-0.41%	-0.32%
Transformers	-0.7%	-1.15%	-0.44%	-0.35%
TFP Change	-1.8%	-2.20%	-1.55%	-7.12%

Figure 5.22 shows the percentage point contributions of individual outputs and inputs to SA's TFP growth in 2023. SA's large TFP *decrease* of 7.1 per cent in 2023 was driven mainly by a significant increase in opex and decreased reliability (ie, an increase in CMOS). The increase in opex contributed –5.88 percentage points, and the increase in CMOS contributed –0.98 percentage points to TFP growth in 2023. Circuit length, RMD, customer numbers and energy throughput together positively contributed to 0.40 to TFP growth. Transformers contributed –0.35 percentage points, and overhead and underground lines and cables together contributed –0.30 percentage points to TFP growth in 2023.

Figure 5.22 SA output and input percentage point contributions to TFP change, 2023



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 2023 it delivered 4,631 GWh to 304,340 customers over 22,711 circuit kilometres of lines and cables.[18]

[18] As previously indicated in Economic Insights (2015a, 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 Table 5.13 and Figure 5.23. Opex and capital PFP indexes are also presented in Table 5.13.

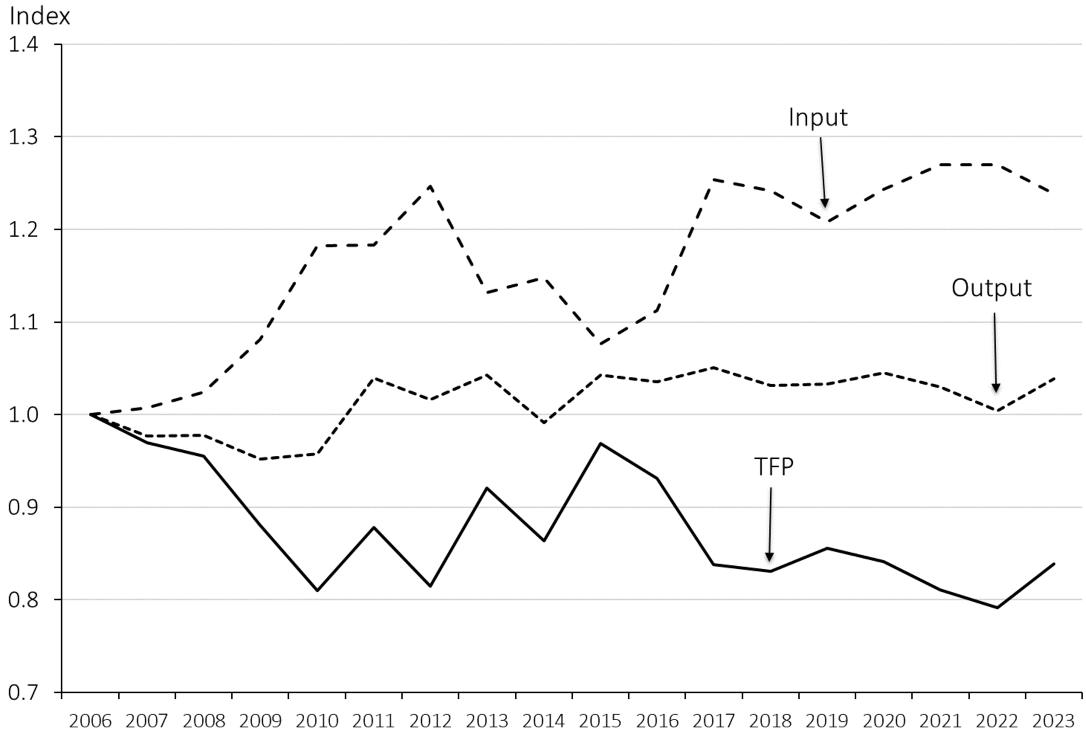
Over the 18-year period 2006 to 2023, the Tasmanian DNSP's TFP *decreased* at an average annual rate of 1.0 per cent. Total output has increased 0.2 per cent per annum on average. Total input use, on the other hand, increased at an average annual rate of 1.3 per cent over the 18-year period. Input use increased at a faster rate of 3.7 per cent between 2006 and 2012 and *decreased* at a rate of 0.1 per cent per year from 2012 to 2023. Output increased at an average annual rate of 0.3 per cent from 2006 to 2012, and by 0.2 per cent per annum thereafter. The net effect of these trends was that TFP *decreased* at an average rate of 3.4 per cent up to 2012 and increased at an average rate of 0.3 per cent from 2012 to 2023.

In 2023 TAS's TFP increased significantly by 5.9 per cent, driven by an increase in 3.4 per cent in the output index and a *decrease* of 2.5 per cent in input usage.

Table 5.13 TAS DNSP output, input, TFP and PFP indexes, 2006–2023

Year	*Output*	*Input*	*TFP*	*PFP Index*	
	Index	*Index*	*Index*	*Opex*	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	0.977	1.007	0.970	0.979	0.964
2008	0.978	1.024	0.955	0.970	0.946
2009	0.952	1.081	0.880	0.847	0.902
2010	0.957	1.182	0.810	0.718	0.880
2011	1.039	1.183	0.879	0.807	0.927
2012	1.016	1.247	0.815	0.709	0.892
2013	1.043	1.132	0.921	0.940	0.910
2014	0.992	1.148	0.864	0.881	0.853
2015	1.043	1.076	0.969	1.128	0.889
2016	1.035	1.112	0.931	1.025	0.877
2017	1.051	1.253	0.838	0.786	0.879
2018	1.032	1.242	0.831	0.799	0.855
2019	1.033	1.208	0.855	0.873	0.844
2020	1.045	1.243	0.841	0.833	0.846
2021	1.030	1.270	0.811	0.788	0.829
2022	1.004	1.270	0.791	0.776	0.803
2023	1.039	1.238	0.839	0.866	0.820
Growth Rate 2006–2023	0.2%	1.3%	-1.0%	-0.8%	-1.2%
Growth Rate 2006–2012	0.3%	3.7%	-3.4%	-5.7%	-1.9%
Growth Rate 2012–2023	0.2%	-0.1%	0.3%	1.8%	-0.8%
Growth Rate 2023	3.4%	-2.5%	5.9%	11.0%	2.1%

Figure 5.23 TAS DNSP output, input and TFP indexes, 2006–2023



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's outputs had the following trends:

- Customer numbers were 21.4 per cent higher in 2023 than in 2006 (compared to 25.1 per cent for the industry as a whole);
- Energy throughput increased from 2006 to 2009, then decreased to 2014 before subsequently returning to growth. It was 4.1 per cent higher in 2023 than in 2006 (compared to 2.8 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 2023 at 8.6 per cent higher than in 2006 (compared to the 20.0 per cent increase for the industry as a whole).
- TAS's circuit length output grew by 7.1 per cent in total over the 18-year period to 2023 (compared to an increase of 6.0 per cent for the industry);
- CMOS increased by 45.3 per cent in total between 2006 and 2023 (compared to a *decrease* of 3.5 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 –18.8 per cent of total revenue for Tasmania.

TAS's output index increased by 3.9 per cent in total from 2006 to 2023, compared to 16.6 per cent for the industry. 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 5.25 plots TAS's six individual inputs and the total input index:

- Opex input increased by 19.9 per cent from 2006 to 2023. A substantial increase occurred in the period up to 2012 (at an average annual rate of 6.0 per cent, or 43.4 per cent in total). This was followed by substantial decreases from 2013 to 2015, further large increases up to 2017, and some small declines since then. These movements resulted in a net decrease in the period from 2012 to 2023 (at an average annual rate of –1.6 per cent). The increase of opex over the whole 18-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 40.2 per cent and so is an important driver of total input quantity;
- Transformer inputs in TAS increased at a similar rate to the industry as a whole; by 2023 exceeding the 2006 level by 48.4 per cent (compared to 44.5 per cent for the industry);
- TAS's underground distribution cables input increased by 25.2 per cent in total over the 18 years to 2023 (compared to 71.7 per cent for the industry). TAS's underground subtransmission cables increased by 84.4 per cent over the 18-year period, off a low base;
- The total changes in overhead subtransmission and distribution lines in TAS from 2006 to 2023 were –2.5 per cent and 10.7 per cent respectively (compared to 7.7 per cent and 3.2 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 subtransmission lines. Total input quantity increased by 23.8 per cent in total over the 18 years to 2023, compared to 23.4 per cent for the industry overall.

Figure 5.24 TAS output quantity indexes, 2006–2023

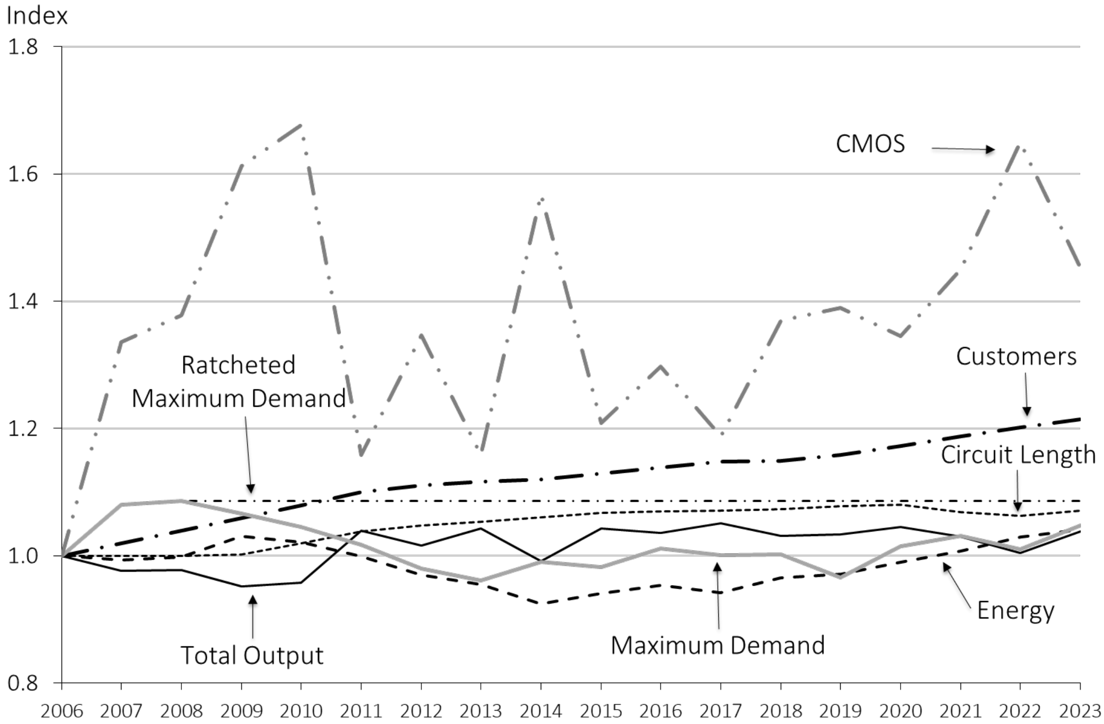
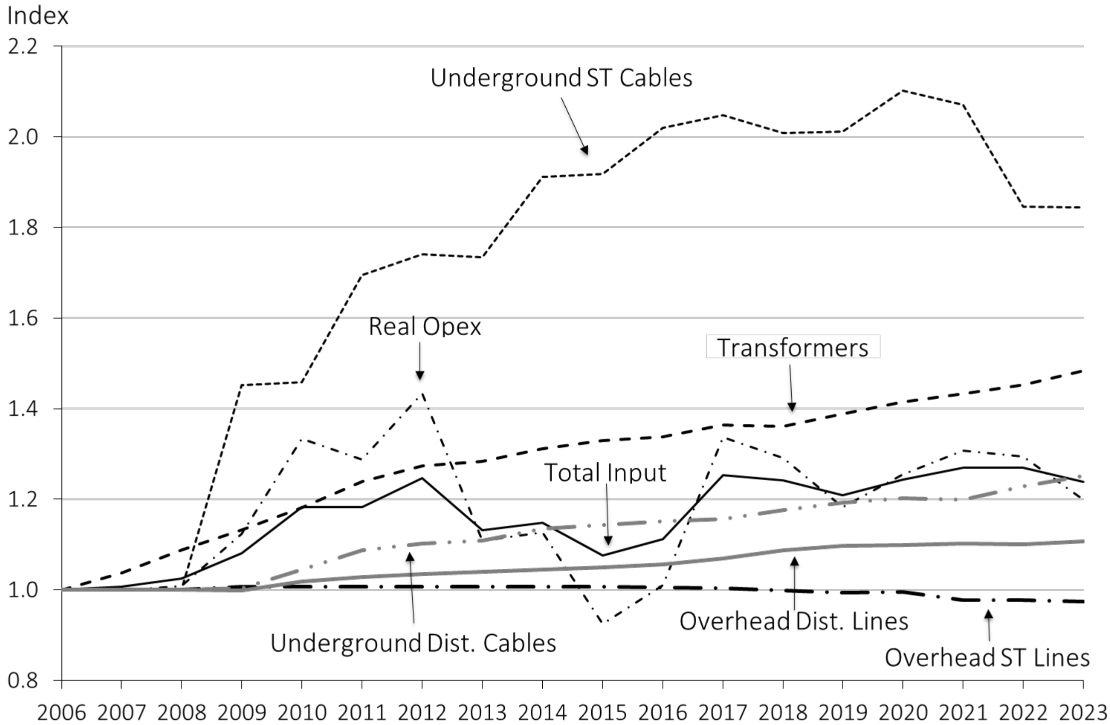


Figure 5.25 TAS DNSP input quantity indexes, 2006–2023



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 18-year period, for the periods up to and after 2012, and for 2023. Tasmania's drivers of TFP change for the whole 18-year period show several differences to those for the industry as a whole.

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

Year	*2006 to 2023*	*2006 to 2012*	*2012 to 2023*	*2023*
Energy (GWh)	0.02%	-0.05%	0.07%	0.11%
Ratcheted Max Demand	0.20%	0.55%	0.00%	0.00%
Customer Numbers	0.25%	0.39%	0.18%	0.23%
Circuit Length	0.19%	0.36%	0.09%	0.34%
CMOS	-0.44%	-0.99%	-0.14%	2.69%
Opex	-0.42%	-2.34%	0.63%	3.52%
O/H Subtransmission Lines	0.00%	0.00%	0.00%	0.00%
O/H Distribution Lines	-0.16%	-0.14%	-0.16%	-0.26%
U/G Sub-transmission Cables	-0.01%	-0.03%	0.00%	0.00%
U/G Distribution Cables	-0.14%	-0.18%	-0.12%	-0.29%
Transformers	-0.53%	-0.98%	-0.29%	-0.48%
TFP Change	-1.03%	-3.41%	0.26%	5.85%

Among the outputs:

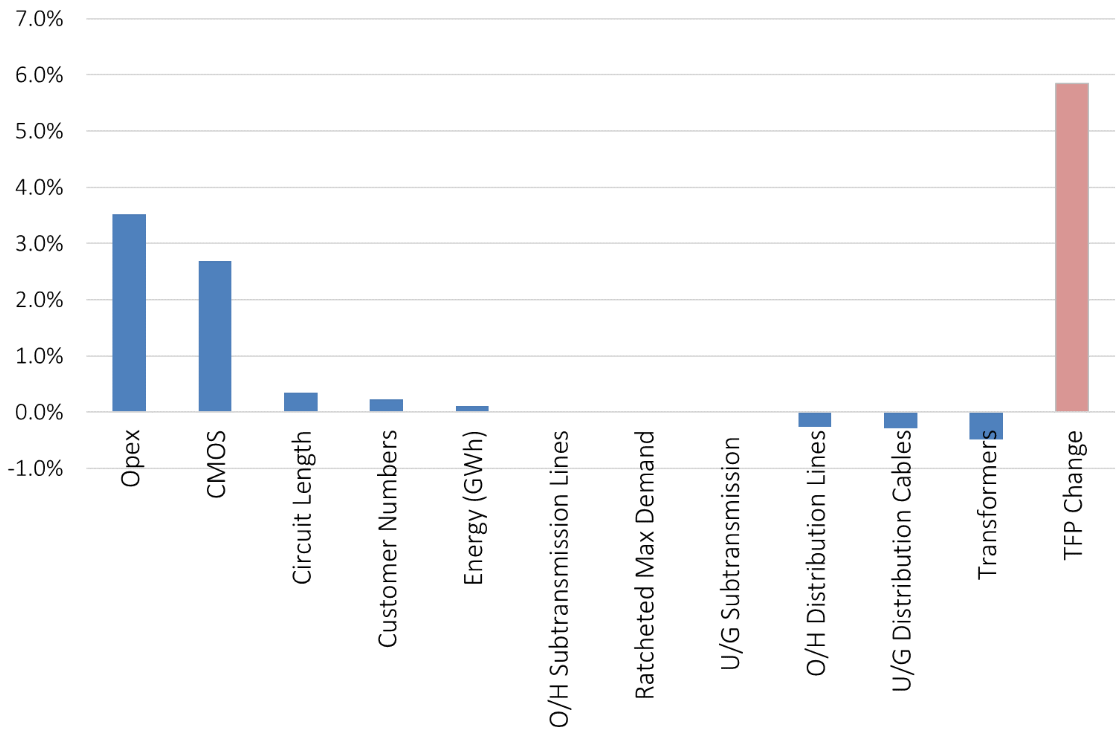
- RMD, customer numbers, energy and circuit length together contributed 0.66 percentage points to TAS's average TFP change of –1.0 per cent from 2006 to 2023, compared to a 0.86 percentage point contribution of these outputs to the industry TFP change; and
- CMOS contributed –0.44 percentage points to average TAS's TFP growth from 2006 to 2023, compared to 0.06 percentage points contribution for the industry.

Among the inputs:

- Opex growth contributed –0.42 percentage points to TAS average TFP growth, compared to –0.22 percentage points for the industry.
- Overhead and underground distribution and subtransmission lines, taken together contributed –0.31 percentage points to TAS TFP change, compared to –0.43 percentage points for the industry.
- Transformers contributed –0.53 percentage points to TAS's TFP growth rate, very similar to the –0.58 for the industry.

Figure 5.26 shows the contributions of individual inputs and outputs to TAS's TFP growth from 2022 to 2023 of 5.9 per cent. Reduction in opex and improvement in reliability were the main driver of this and contributed 3.52 percentage points and 2.69 percentage points, respectively, to the significatively high TFP growth.

Figure 5.26 TAS output and input percentage point contributions to TFP change, 2023



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.

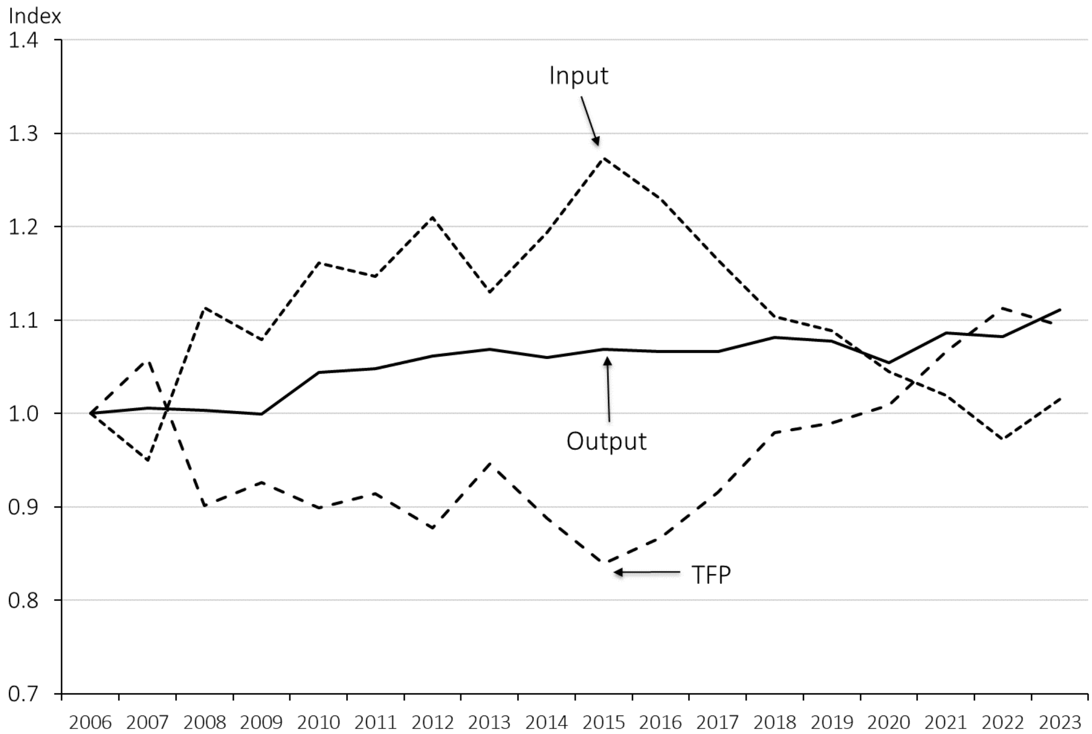
6.1 Ausgrid (AGD)

In 2023, AGD delivered 24,566 GWh to 1.79 million customers over 42,927 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, 2006–2023



Over the 18-year period 2006 to 2023, AGD's TFP averaged an annual rate of change of 0.5 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 0.6 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 input use increase of 0.1 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, 2006–2023

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	0.950	1.058	1.184	0.981
2008	1.004	1.113	0.902	0.833	0.956
2009	0.999	1.079	0.926	0.916	0.926
2010	1.044	1.161	0.899	0.841	0.938
2011	1.048	1.147	0.914	0.880	0.925
2012	1.062	1.210	0.878	0.810	0.908
2013	1.069	1.130	0.946	1.032	0.890
2014	1.060	1.194	0.888	0.922	0.861
2015	1.069	1.274	0.839	0.790	0.863
2016	1.067	1.230	0.867	0.886	0.849
2017	1.066	1.164	0.916	1.000	0.862
2018	1.081	1.104	0.979	1.181	0.872
2019	1.078	1.089	0.990	1.242	0.865
2020	1.055	1.045	1.009	1.375	0.840
2021	1.087	1.019	1.066	1.506	0.861
2022	1.083	0.973	1.113	1.709	0.868
2023	1.111	1.016	1.094	1.590	0.892
Growth Rate 2006–2023	0.6%	0.1%	0.5%	2.7%	-0.7%
Growth Rate 2006–2012	1.0%	3.2%	-2.2%	-3.5%	-1.6%
Growth Rate 2012–2023	0.4%	-1.6%	2.0%	6.1%	-0.2%
Growth Rate 2023	2.6%	4.3%	-1.7%	-7.2%	2.7%

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 2023, TFP increased in most years, and on average TFP increased at an annual rate of 2.0 per cent. In 2023, AGD's TFP *decreased* by 1.7 per cent.

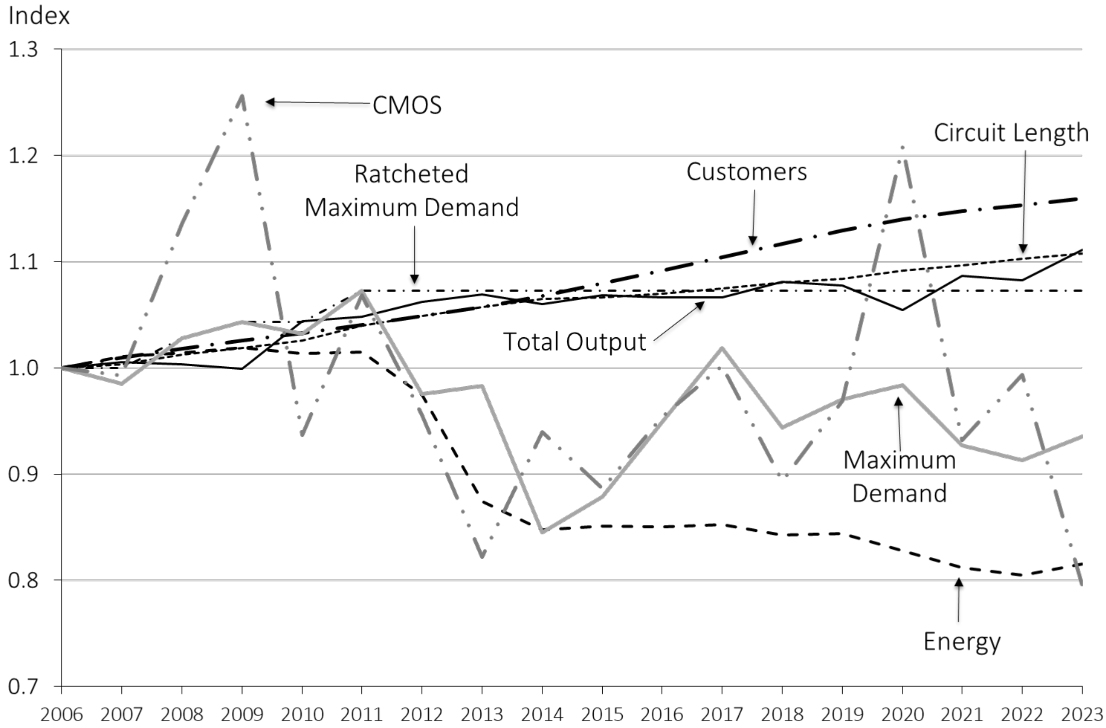
During the first part of the sample period, up to 2012, AGD's output increased comparatively strongly at 1.0 per cent per annum, whereas in the later period after 2012, the rate of change of the output index was 0.4 per cent. The effect of changing output trends on TFP was swamped by the much larger movements in input index growth. From 2006 to 2012, the input index increased at an average annual rate of 3.2 per cent, whereas in the period after 2012 the input index fell, averaging an annual rate of –1.6 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 turnaround 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.

Figure 6.2 AGD output quantity indexes, 2006–2023



Regarding outputs, in Figure 6.2, we see:

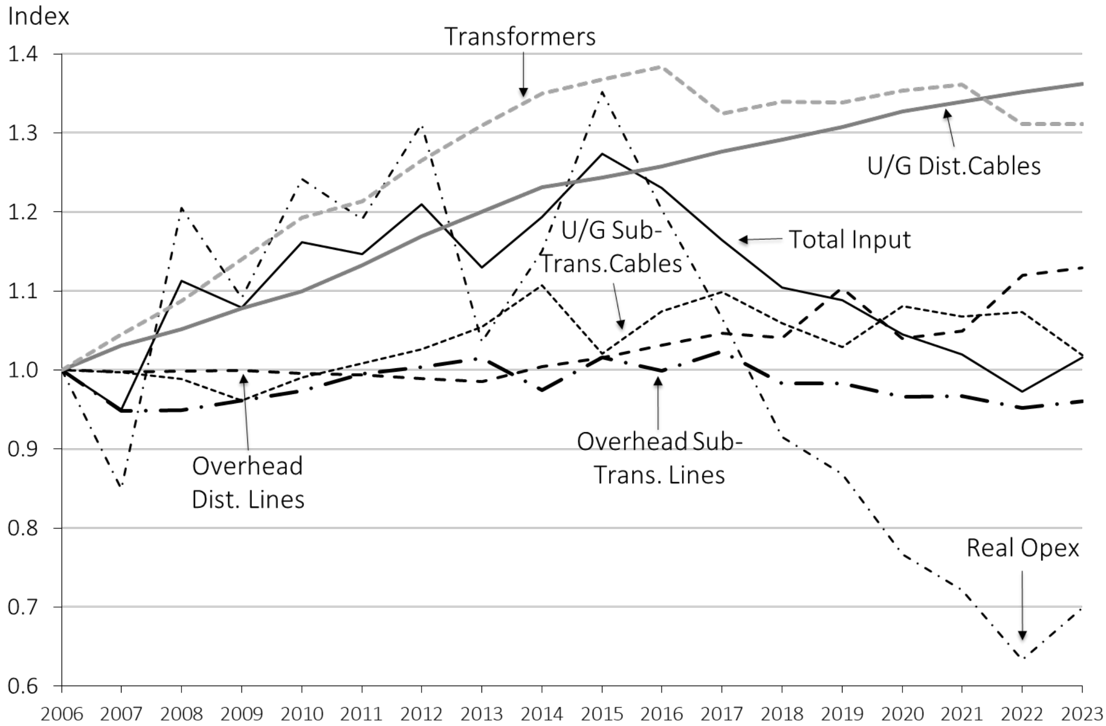
- AGD's circuit length (the output component that receives the largest weight in forming the output index, 43.2 per cent) has increased steadily and by 2023 was 10.8 per cent above the 2006 level (which is higher than the increase of 6.0 per cent, for the industry over the 18-year period).
- AGD's energy throughput decreased at a greater rate than for the industry. In 2023, AGD's energy throughput was 18.4 per cent *below* its 2006 level compared to the industry's throughput then being 2.8 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 throughput, but did not reach its 2011 level.

- AGD's customers increased by 15.9 per cent in total between 2006 and 2023 (or 0.9 per cent per year), which is less than the increase in customers for the industry over the same period (25.1 per cent in total, or 1.3 per cent per year).
- CMOS in 2023 was 20.5 per cent *lower* than in 2006, which is lower than the *decrease* of 3.5 per cent for the industry over the same period.

With regard to input movements, in Figure 6.3:

- Over the 18-year period to 2023, opex input *decreased* in total by 30.1 per cent. This compares favourably to the total increase of 10.1 per cent for the industry over the same period.
- Overhead subtransmission and distribution lines in 2023, compared to 2006, were 3.9 per cent *lower* and 12.9 per cent higher respectively (compared to 7.7 per cent and 3.2 per cent increases, respectively, for the industry over the same period).
- Underground subtransmission and distribution cables were, in 2023, 1.8 and 36.2 per cent higher than in 2006 respectively (compared to increases of 35.2 per cent and 71.7 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 2023. By 2023, transformer inputs were 31.1 per cent above the 2006 level, which is a smaller increase than the industry's 44.5 per cent.

Figure 6.3 AGD input quantity indexes, 2006–2023



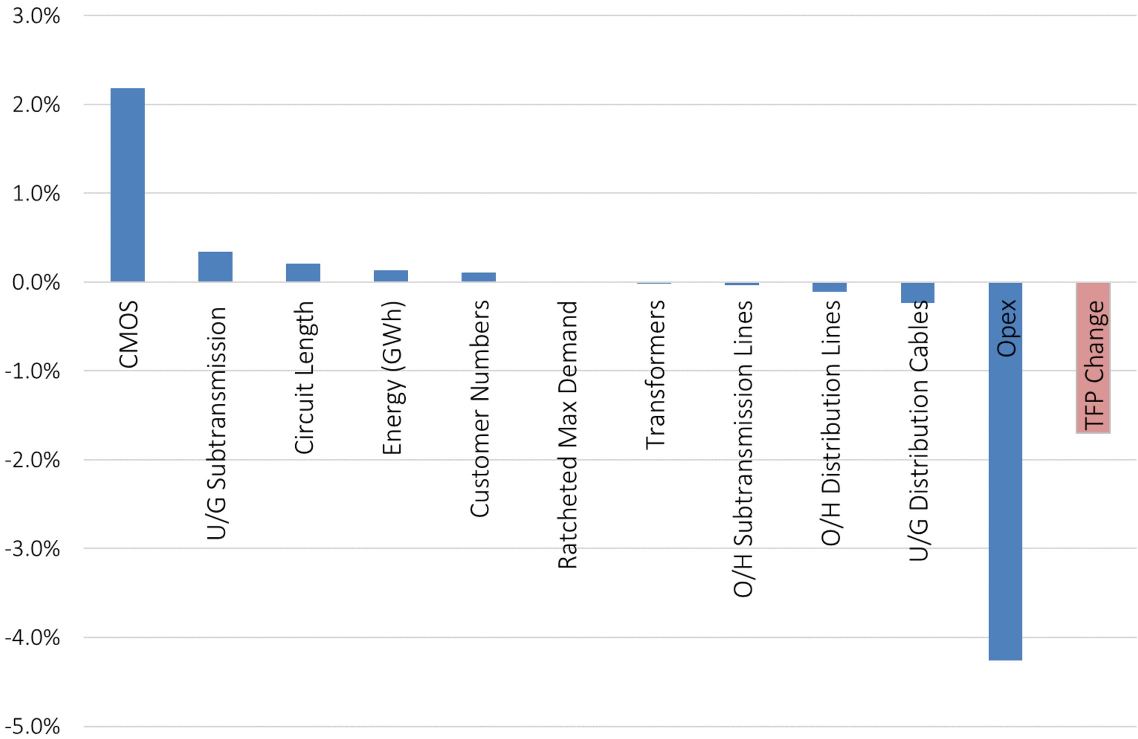
6.1.3 AGD's output and input contributions to TFP change

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 18-year period, for the periods up to and after 2012, and for 2023. Figure 6.4 shows the contributions of outputs and inputs to AGD's rate of TFP change of –1.7 per cent in 2023.

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

Year	*2006 to 2023*	*2006 to 2012*	*2012 to 2023*	*2023*
Energy (GWh)	-0.11%	-0.05%	-0.15%	0.13%
Ratcheted Max Demand	0.16%	0.44%	0.00%	0.00%
Customer Numbers	0.18%	0.17%	0.19%	0.10%
Circuit Length	0.26%	0.35%	0.21%	0.21%
CMOS	0.14%	0.08%	0.16%	2.18%
Opex	0.70%	-1.63%	1.98%	-4.26%
O/H Subtransmission Lines	0.01%	0.00%	0.02%	-0.03%
O/H Distribution Lines	-0.05%	0.01%	-0.08%	-0.11%
U/G Subtransmission Cables	0.00%	-0.02%	0.01%	0.34%
U/G Distribution Cables	-0.27%	-0.35%	-0.22%	-0.23%
Transformers	-0.49%	-1.18%	-0.11%	-0.02%
TFP Change	0.53%	-2.17%	2.00%	-1.70%

Figure 6.4 AGD output and input percentage point contributions to TFP change, 2023



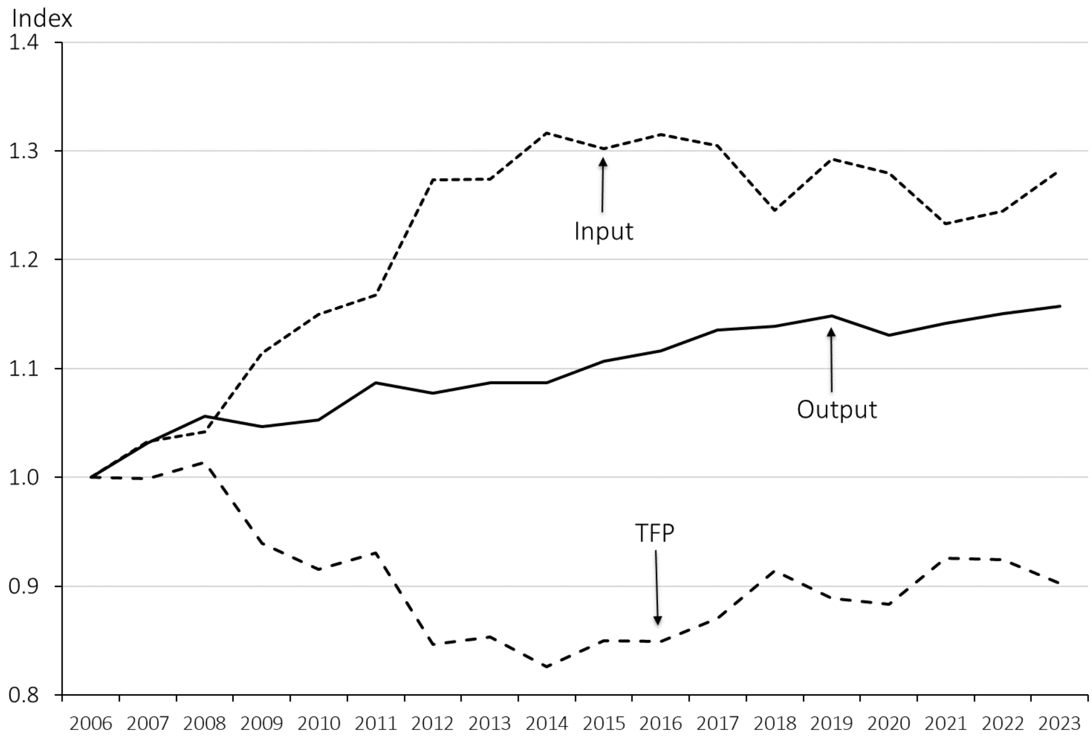
6.2 CitiPower (CIT)

In 2023, CIT delivered 5,420 GWh to 349,689 customers over 4,595 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, 2006–2023



Over the 18-year period 2006 to 2023, CIT's TFP *decreased* at an average annual rate of 0.6 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 18-year period at an average annual rate of 0.9 per cent, which is the same as for the industry. CIT's average annual rate of increase in input use of 1.5 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 4.0 per cent increase per year over this period. TFP *decreased* at average annual rate of 2.8 per cent over this period. Input use stabilised in the period 2012 to 2023, with an average annual rate of change of 0.1 per cent, and average TFP growth in this period was 0.6 per cent per annum.

Table 6.3 CIT’s output, input, TFP and PFP indexes, 2006–2023

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.032	1.033	0.999	1.000	0.996
2008	1.056	1.042	1.014	1.050	0.994
2009	1.047	1.114	0.939	0.881	0.970
2010	1.053	1.150	0.915	0.844	0.955
2011	1.087	1.168	0.931	0.899	0.945
2012	1.078	1.273	0.846	0.739	0.914
2013	1.087	1.274	0.854	0.765	0.909
2014	1.087	1.316	0.826	0.727	0.892
2015	1.107	1.302	0.850	0.769	0.900
2016	1.117	1.315	0.849	0.774	0.895
2017	1.136	1.305	0.870	0.807	0.906
2018	1.139	1.245	0.914	0.896	0.921
2019	1.148	1.292	0.889	0.825	0.924
2020	1.131	1.280	0.884	0.843	0.903
2021	1.142	1.233	0.926	0.941	0.909
2022	1.151	1.245	0.924	0.918	0.921
2023	1.157	1.282	0.903	0.869	0.919
Growth Rate 2006–2023	0.9%	1.5%	-0.6%	-0.9%	-0.5%
Growth Rate 2006–2012	1.2%	4.0%	-2.8%	-5.0%	-1.5%
Growth Rate 2012–2023	0.7%	0.1%	0.6%	1.5%	0.1%
Growth Rate 2023	0.6%	3.0%	-2.4%	-5.6%	-0.2%

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 2023. There was a strong rate of decline in the period up to 2012 and there was little change in the period after 2012.
- The PFP of opex input *declined* particularly strongly in the period up to 2012, at average annual rate of –5.0 per cent, whereas it increased at an average rate of 1.5 per cent per annum from 2012 to 2023.

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 2023 was 16.3 per cent above the 2006 level (higher than the increase of 6.0 per cent for the industry over the same period).

- CIT's energy throughput decreased over the 18-year period at a faster rate than for the industry, and in 2023, CIT's energy throughput was 9.3 per cent *below* its 2006 level (compared to a 2.8 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 2023 RMD was 17.5 per cent above its 2006 level which is similar to the industry as a whole (a 20.0 per cent increase over the same period).
- CIT's customers increased at an average rate of 1.0 per cent per annum from 2006 to 2023, or 18.6 per cent in total, which is slightly lower than the rate of customer growth for the industry over the same period.
- CMOS in 2023 was 12.4 per cent *lower* than in 2006. The compares favourably to the industry total change of –3.5 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 6.3 per cent (or 45.8 per cent in total) over the period from 2006 to 2012. Opex input subsequently declined over the period from 2012 to 2023, averaging –0.9 per cent per annum. In 2023, opex was 33.3 per cent above its 2006 level. This compares to the total increase of 10.1 per cent for the industry over the same period.
- Overhead subtransmission and distribution lines in 2023 were 2.0 per cent higher and 8.7 per cent *lower* respectively, than in 2006 (compared with increases of 7.7 per cent and 3.2 per cent respectively for the industry over the same period).
- Underground subtransmission and distribution cables in 2023, were 90.2 and 24.3 per cent higher than in 2006 respectively (compared to increases of 35.2 per cent and 71.7 per cent respectively for the industry over the same period).
- CIT's quantity of transformers increased steadily over most of the 18-year period and by 2023, transformer inputs were 26.1 per cent above the 2006 level, a smaller increase than the industry's 44.5 per cent.

Figure 6.6 CIT's output quantity indexes, 2006–2023

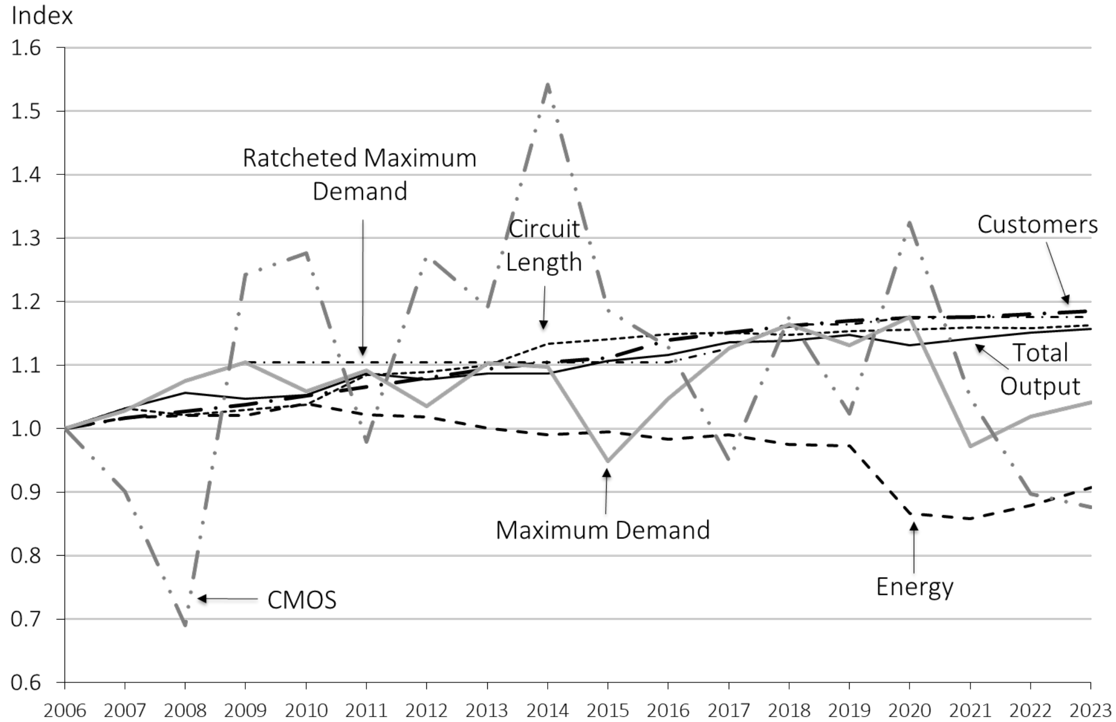
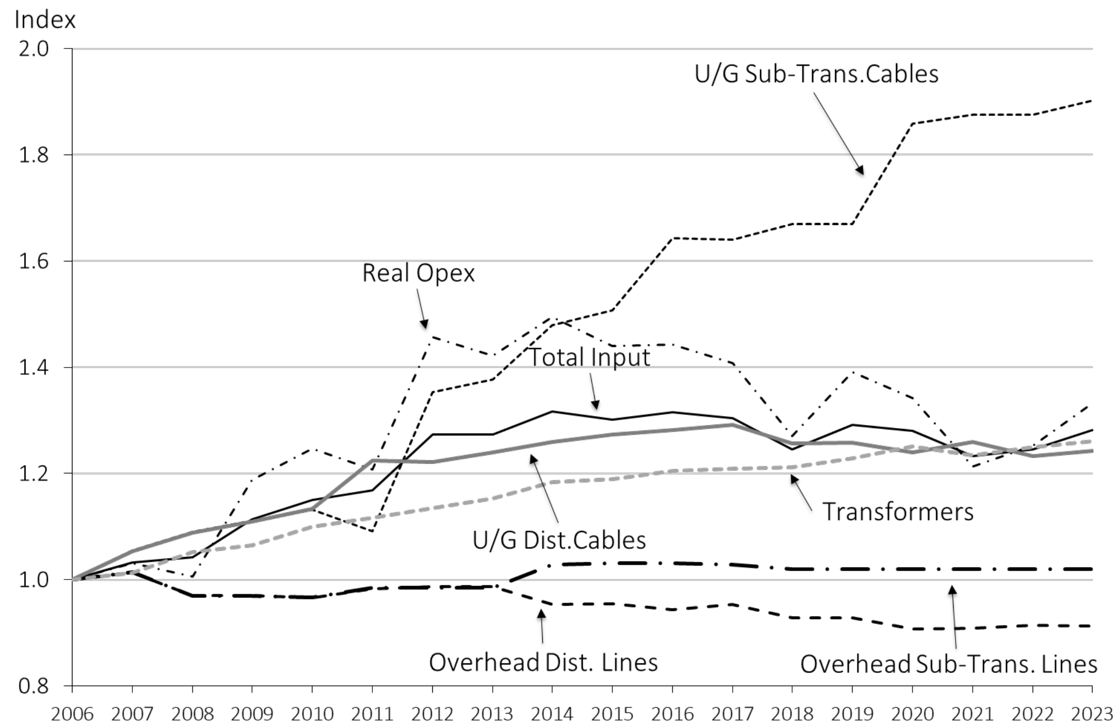


Figure 6.7 CIT's input quantity indexes, 2006–2023



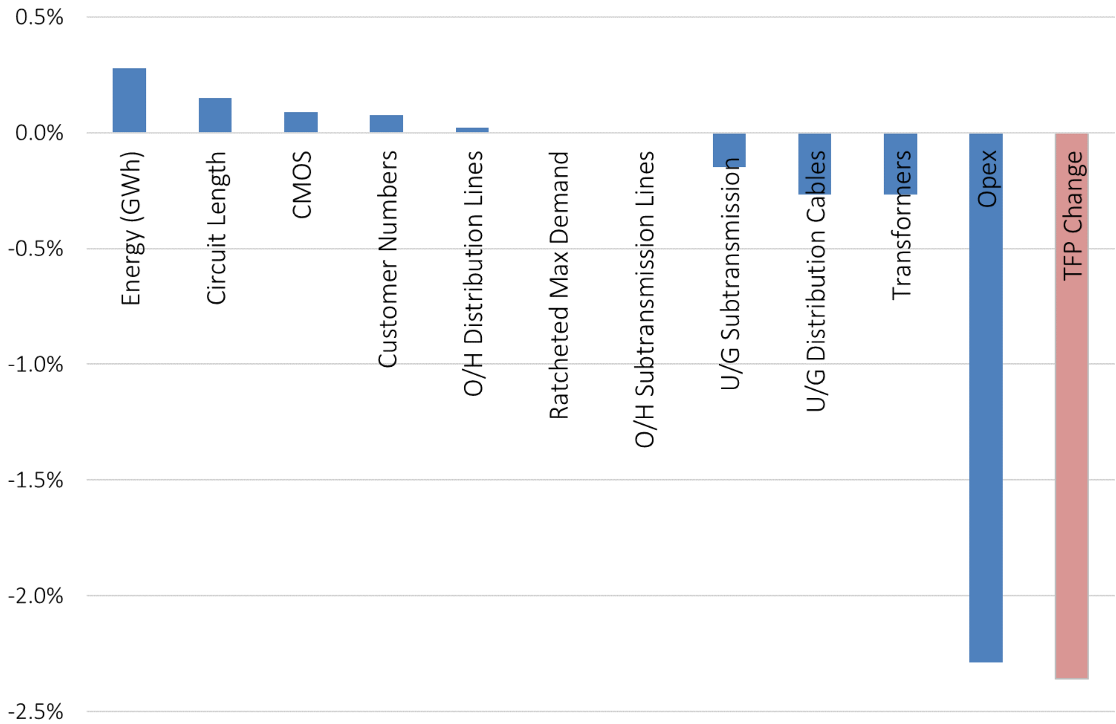
6.2.3 CIT's output and input contributions to TFP change

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 18-year period, for the periods up to and after 2012, and for 2023. Figure 6.8 shows the contributions of outputs and inputs to CIT's rate of TFP change of –2.4 per cent in 2023.

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

Year	*2006 to 2023*	*2006 to 2012*	*2012 to 2023*	*2023*
Energy (GWh)	-0.06%	0.03%	-0.10%	0.28%
Ratcheted Max Demand	0.33%	0.58%	0.20%	0.00%
Customer Numbers	0.19%	0.25%	0.16%	0.08%
Circuit Length	0.37%	0.58%	0.25%	0.15%
CMOS	0.08%	-0.19%	0.23%	0.09%
Opex	-0.34%	-2.19%	0.67%	-2.29%
O/H Subtransmission Lines	0.00%	0.00%	0.00%	0.00%
O/H Distribution Lines	0.03%	0.01%	0.04%	0.02%
U/G Subtransmission Cables	-0.23%	-0.30%	-0.19%	-0.15%
U/G Distribution Cables	-0.42%	-1.03%	-0.09%	-0.27%
Transformers	-0.29%	-0.52%	-0.16%	-0.27%
TFP Change	-0.33%	-2.78%	1.01%	-2.36%

Figure 6.8 CIT's output and input percentage point contributions to TFP change, 2023



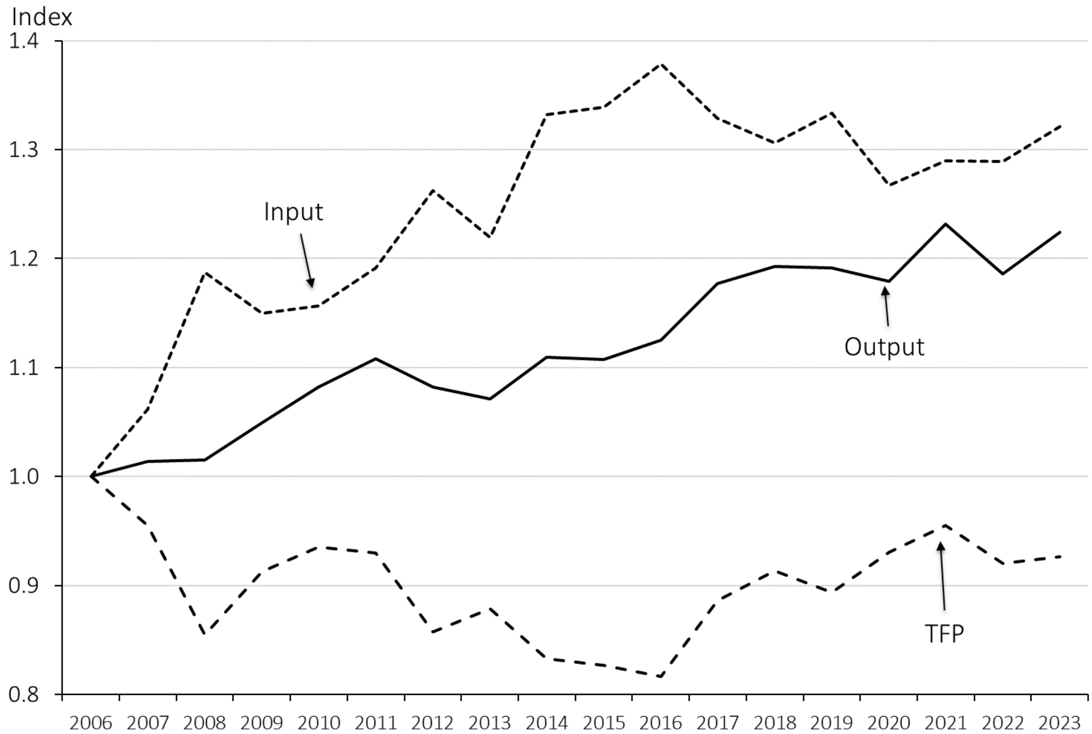
6.3 Endeavour Energy (END)

In 2023 END delivered 16,883 GWh to 1.10 million customers over 40,011 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, 2006–2023



Over the 18-year period 2006 to 2023, END's TFP *decreased* at an average annual rate of 0.4 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 1.2 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 1.6 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 –2.6 per cent, and over the period from 2012 to 2023 the average annual rate of TFP change was 0.7 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 3.9 per cent per year) than in the period 2012 to 2023 (averaging 0.4 per cent per year). The large change in input growth explains the turnaround in the TFP trend.

The PFP indexes in Table 6.5 show the following trends:

- Capital PFP *declined* at an average rate of 1.5 per cent per year over the 18-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 (–1.0 per cent).
- Opex PFP increased on average over the 18-year period (averaging 0.9 per cent per year), but this covers very different trends in the period up to 2012 (with an average annual rate of –2.9 per cent) and after 2012 (with an average increase of 3.0 per cent per annum).

Table 6.5 END's output, input, TFP and PFP indexes, 2006–2023

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	1.062	0.955	0.952	0.959
2008	1.015	1.188	0.855	0.786	0.921
2009	1.049	1.149	0.913	0.897	0.923
2010	1.082	1.157	0.935	0.950	0.922
2011	1.108	1.191	0.930	0.941	0.920
2012	1.082	1.262	0.857	0.840	0.869
2013	1.071	1.219	0.878	0.955	0.826
2014	1.109	1.332	0.833	0.852	0.822
2015	1.107	1.339	0.827	0.857	0.808
2016	1.125	1.379	0.816	0.840	0.803
2017	1.177	1.329	0.886	0.976	0.823
2018	1.193	1.306	0.913	1.055	0.818
2019	1.191	1.334	0.893	1.030	0.801
2020	1.179	1.267	0.931	1.167	0.783
2021	1.232	1.290	0.955	1.179	0.805
2022	1.186	1.289	0.920	1.144	0.772
2023	1.224	1.321	0.926	1.169	0.779
Growth Rate 2006–2023	1.2%	1.6%	-0.4%	0.9%	-1.5%
Growth Rate 2006–2012	1.3%	3.9%	-2.6%	-2.9%	-2.3%
Growth Rate 2012–2023	1.1%	0.4%	0.7%	3.0%	-1.0%
Growth Rate 2023	3.2%	2.5%	0.7%	2.1%	0.9%

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 2023 was 23.4 per cent above the 2006 level (compared to a 6.0 per cent increase for the industry over the same period).
- END's energy throughput decreased marginally over the 18-year period, following a similar pattern to the industry. In 2023, END's energy throughput was 1.8 per cent *below* its level in 2006 (compared to a total *decrease* of 2.8 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 2023, RMD was 15.0 per cent above its 2006 level. This pattern is similar to the industry as a whole (an increase of 20.0 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 2023, or 29.5 per cent in total, which is similar to the rate of customer growth for the industry (25.1 per cent in total over the same period).
- CMOS's annual growth rate in 2023 was –15.4 per cent, and in that year, CMOS was only 0.8 per cent higher than in 2006. This marginal increase between 2006 to 2023 was greater than that for the industry (–3.5 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 0.3 per cent over the period from 2006 to 2023, or 4.7 per cent in total over that period. This compares favourably to the industry, for which opex input increased by 10.1 per cent in total over the same period. END's opex increased in the period 2006 to 2012 (averaging 4.2 per cent per annum), substantially offset by a decrease after 2012 (at an average rate of –1.9 per cent per annum).
- Overhead subtransmission and distribution lines were 1.2 and 3.7 per cent *lower* respectively in 2023 compared to 2006. This contrasts with the industry total increases in these two inputs of 7.7 per cent and 3.2 per cent respectively over the same period. END's underground subtransmission and distribution cables inputs in 2023 were 142.8 and 138.3 per cent higher than in 2006 respectively. These increases are much higher than those for the industry as a whole for these two inputs (35.2 per cent and 71.7 per cent respectively).
- END's quantity of transformers increased steadily over the 18-year period at an average annual rate of 2.5 per cent, and by 2023 transformer inputs were 52.3 per cent above the 2006 level, which is a larger increase than the industry's 44.5 per cent.

Figure 6.10 END's output quantity indexes, 2006–2023

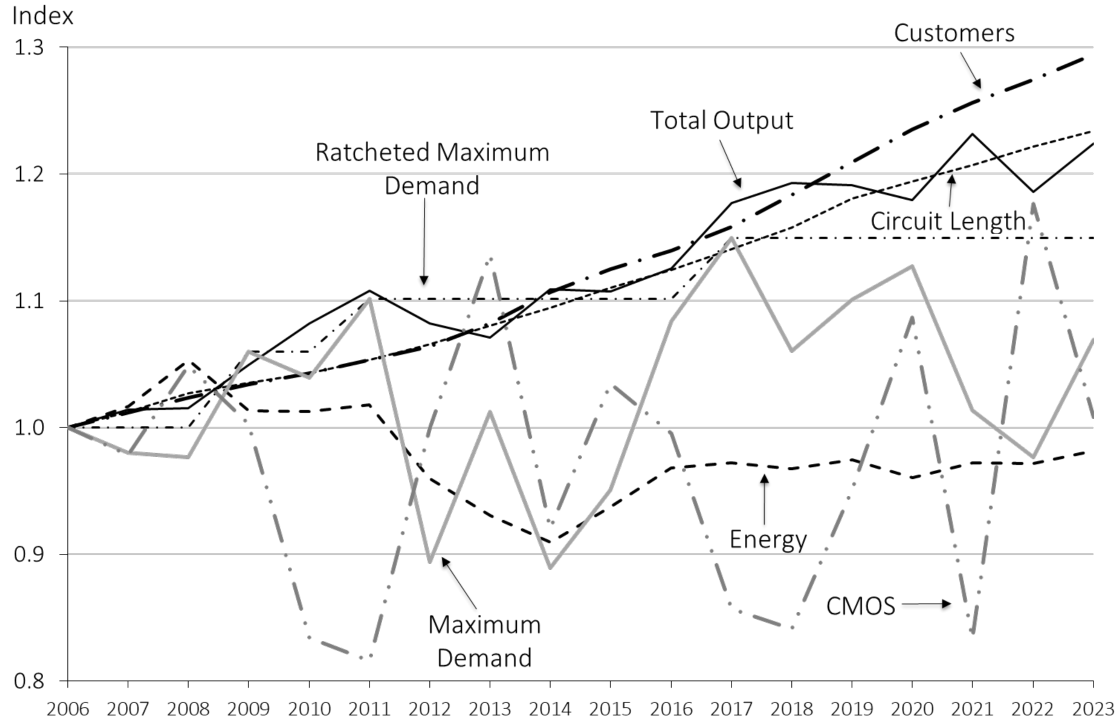
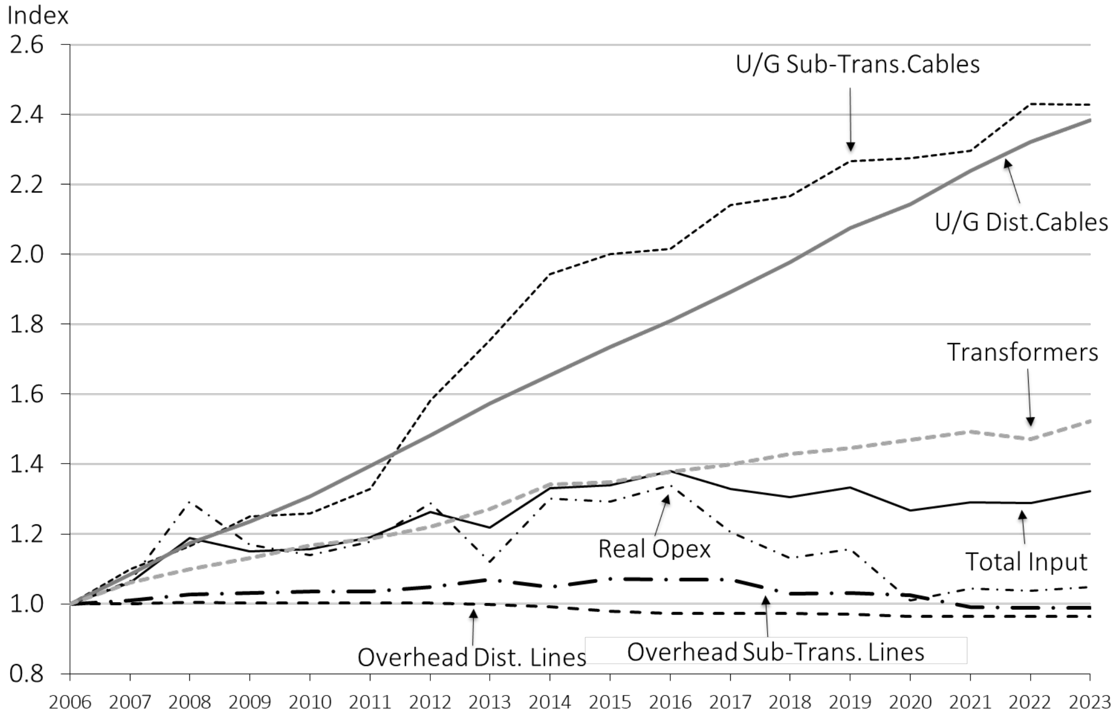


Figure 6.11 END's input quantity indexes, 2006–2023



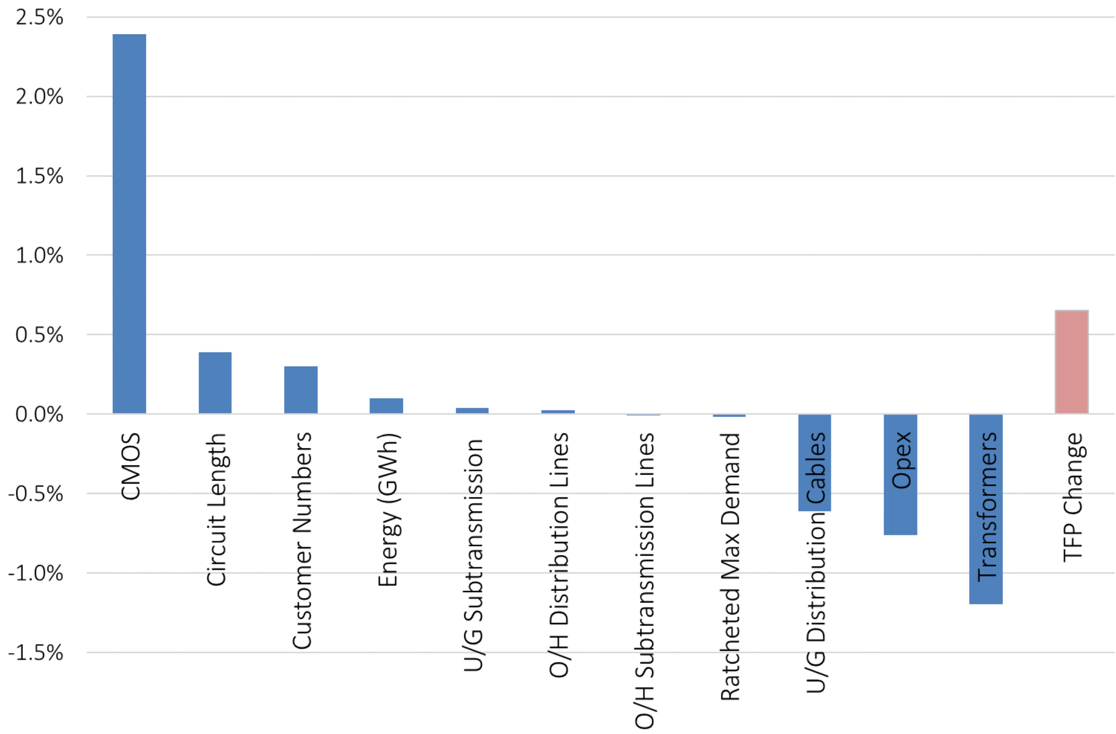
6.3.3 END's output and input contributions to TFP change

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 18-year period, for the periods up to and after 2012, and for 2023. Figure 6.12 shows the contributions of outputs and inputs to END's rate of TFP change of 0.7 per cent in 2023.

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

Year	*2006 to 2023*	*2006 to 2012*	*2012 to 2023*	*2023*
Energy (GWh)	-0.01%	-0.07%	0.02%	0.10%
Ratcheted Max Demand	0.32%	0.63%	0.15%	-0.02%
Customer Numbers	0.32%	0.23%	0.38%	0.30%
Circuit Length	0.56%	0.50%	0.59%	0.39%
CMOS	0.00%	0.02%	-0.02%	2.39%
Opex	-0.11%	-1.78%	0.80%	-0.76%
O/H Subtransmission Lines	0.00%	-0.03%	0.02%	-0.01%
O/H Distribution Lines	0.02%	0.00%	0.03%	0.02%
U/G Subtransmission Cables	-0.09%	-0.14%	-0.07%	0.04%
U/G Distribution Cables	-0.78%	-1.04%	-0.64%	-0.61%
Transformers	-0.67%	-0.89%	-0.56%	-1.19%
TFP Change	-0.45%	-2.56%	0.70%	0.65%

Figure 6.12 END's output and input percentage point contributions to TFP change, 2023



6.4 Energex (ENX)

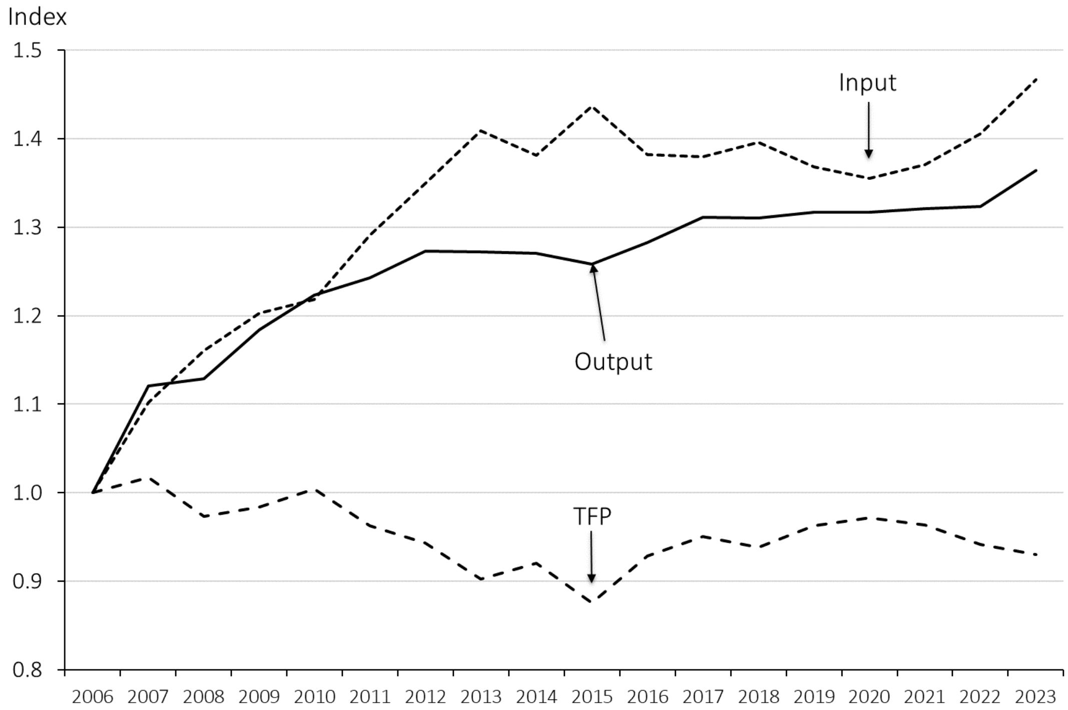
In 2023, ENX delivered 21,716 GWh to 1.60 million customers over 56,276 circuit kilometres of lines and cables. ENX distributes electricity in Southeast Queensland including the major urban areas of Brisbane, Gold Coast, Sunshine Coast, Logan, Ipswich, Redlands and Moreton Bay. ENX's electricity distribution 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 2023, ENX's TFP *decreased* at an annual rate of 0.4 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 2023, an average growth rate of –0.1 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, 2006–2023



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 0.6 per cent per annum after 2012. The average output growth of 1.8 per cent per annum over the whole 18-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 2023. The average rate of increase in inputs of 2.3 per cent per annum over the 18-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 0.5 per cent per year from 2006 to 2023, 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 –2.4 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 –0.4 per cent.

Table 6.7 ENX's output, input, TFP and PFP indexes, 2006–2023

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.121	1.102	1.017	0.972	1.049
2008	1.129	1.160	0.973	0.922	1.010
2009	1.184	1.203	0.984	0.942	1.013
2010	1.223	1.219	1.004	0.990	1.013
2011	1.243	1.291	0.963	0.912	0.998
2012	1.273	1.349	0.943	0.866	0.999
2013	1.272	1.409	0.903	0.812	0.977
2014	1.271	1.381	0.920	0.870	0.959
2015	1.258	1.437	0.876	0.815	0.924
2016	1.283	1.382	0.928	0.924	0.930
2017	1.311	1.379	0.951	0.967	0.936
2018	1.310	1.396	0.939	0.951	0.927
2019	1.317	1.368	0.963	1.013	0.924
2020	1.317	1.355	0.972	1.050	0.912
2021	1.321	1.370	0.964	1.027	0.907
2022	1.323	1.405	0.942	0.983	0.901
2023	1.364	1.467	0.930	0.937	0.922
Growth Rate 2006–2023	1.8%	2.3%	-0.4%	-0.4%	-0.5%
Growth Rate 2006–2012	4.0%	5.0%	-1.0%	-2.4%	0.0%
Growth Rate 2012–2023	0.6%	0.8%	-0.1%	0.7%	-0.7%
Growth Rate 2023	3.0%	4.3%	-1.3%	-4.8%	2.3%

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 20.6 per cent between 2006 to 2023 (which is higher than the industry increase of 6.0 per cent over the same period).
- ENX's energy throughput increased by 5.3 per cent in total from 2006 to 2023 (compared to a *decline* of 2.8 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 2023. In 2023 it was 32.0 per cent above its level in 2006. This is a larger increase than for the industry as a whole (20.0 per cent over the same period).
- ENX's customers output increased by 32.2 per cent in total from 2006 to 2023, or 1.6 per cent per year, which is higher than industry customer growth (25.1 per cent in total, or 1.3 per cent per annum).
- CMOS *decreased* over the 18-year period 2006 to 2023 by 25.5 per cent in total. This compares to the industry average *decrease* in CMOS of 3.5 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 2.2 per cent from 2006 to 2023. In 2023 opex input was 45.6 per cent above its 2006 level. This compares unfavourably to the industry, for which opex input increased by 10.1 per cent in total over the same period.
- Overhead subtransmission and distribution lines in 2023 were 25.5 per cent and 2.7 per cent higher respectively, than in 2006 (compared to the industry increases of 7.7 per cent and 3.2 per cent respectively over the same period).
- ENX's underground subtransmission and distribution cables in 2023 were 96.3 and 92.5 per cent higher than in 2006 respectively (compared to increases of 35.2 per cent and 71.7 per cent respectively for the industry as a whole over the same period).
- ENX's quantity of transformer inputs increased strongly over the 18-year period at an average annual rate of 2.5 per cent, and by 2023 transformer inputs were 51.9 per cent above the 2006 level; a larger increase than the industry's 44.5 per cent over the same period.

Figure 6.14 ENX's output quantity indexes, 2006–2023

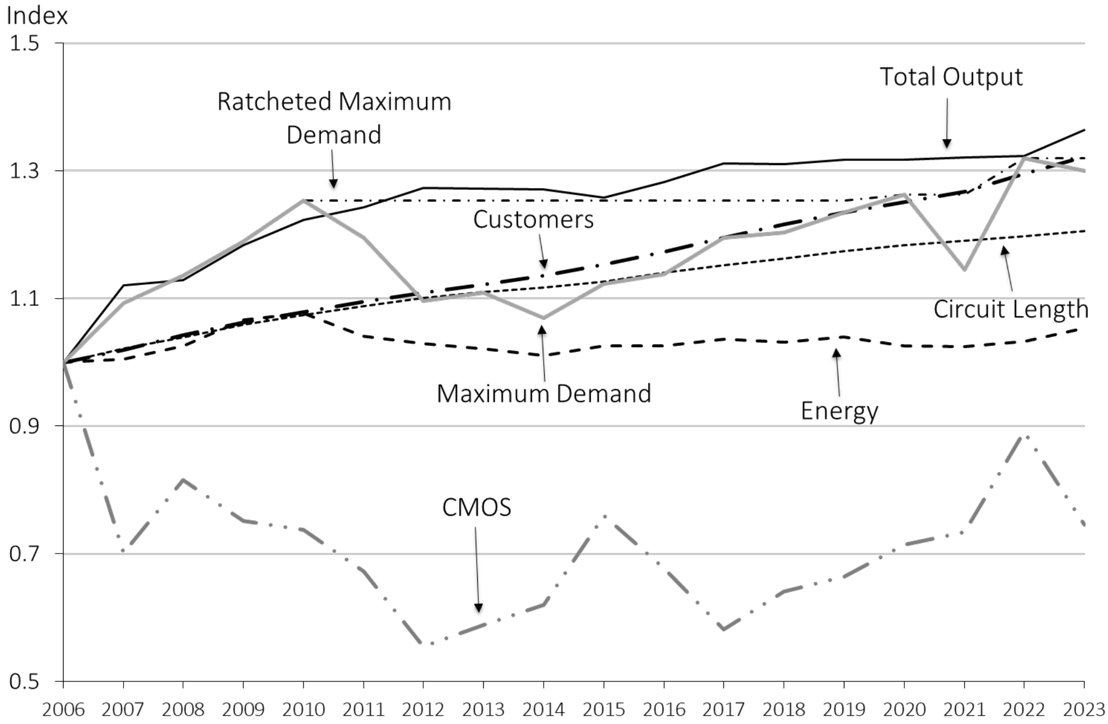
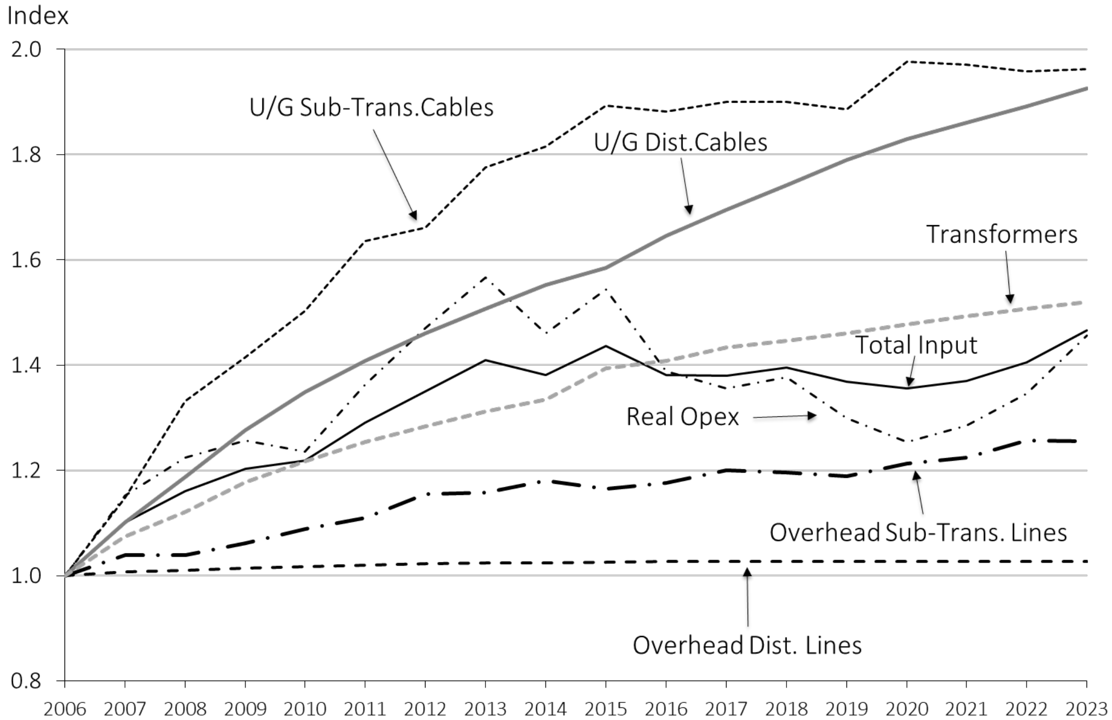


Figure 6.15 ENX's input quantity indexes, 2006–2023



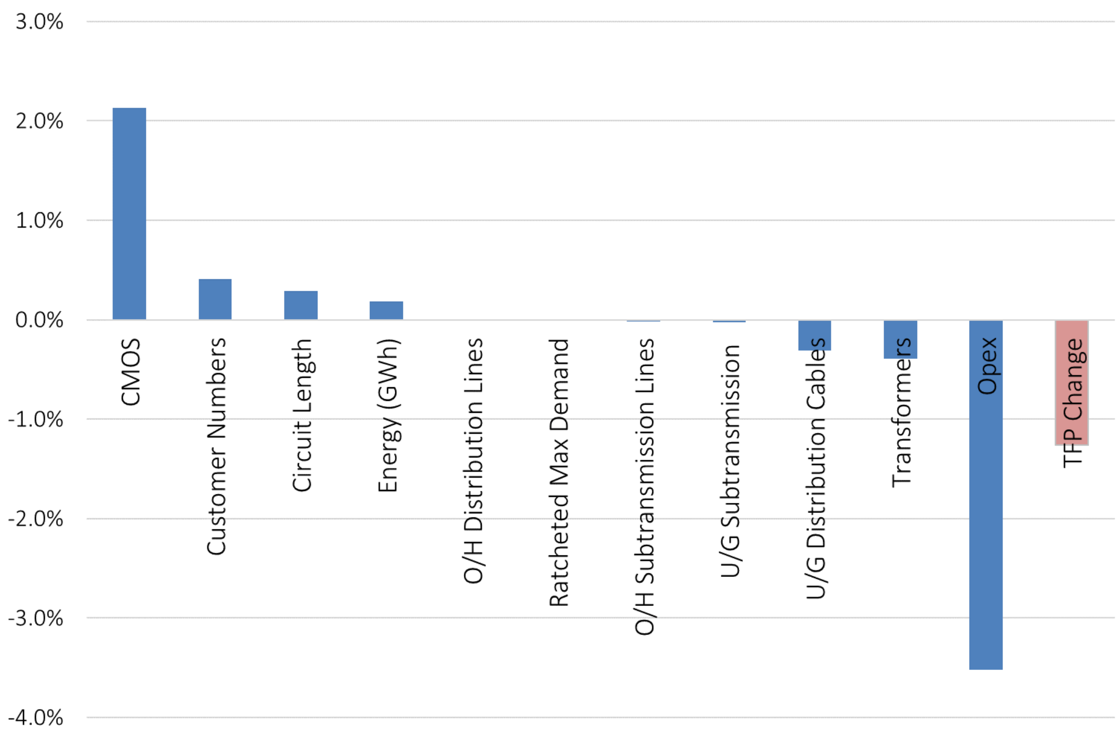
6.4.3 ENX's output and input contributions to TFP change

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 18-year period, for the periods up to and after 2012, and for 2023. Figure 6.16 shows the contributions of outputs and inputs to ENX's rate of TFP change of –1.3 per cent between 2022 and 2023.

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

Year	*2006 to 2023*	*2006 to 2012*	*2012 to 2023*	*2023*
Energy (GWh)	0.03%	0.05%	0.02%	0.19%
Ratcheted Max Demand	0.64%	1.48%	0.18%	-0.01%
Customer Numbers	0.35%	0.38%	0.33%	0.41%
Circuit Length	0.50%	0.74%	0.36%	0.29%
CMOS	0.32%	1.37%	-0.26%	2.13%
Opex	-0.90%	-2.55%	-0.01%	-3.52%
O/H Subtransmission Lines	-0.04%	-0.08%	-0.02%	-0.02%
O/H Distribution Lines	-0.02%	-0.04%	0.00%	0.00%
U/G Subtransmission Cables	-0.16%	-0.35%	-0.06%	-0.03%
U/G Distribution Cables	-0.42%	-0.72%	-0.26%	-0.31%
Transformers	-0.70%	-1.25%	-0.41%	-0.39%
TFP Change	-0.43%	-0.97%	-0.13%	-1.26%

Figure 6.16 ENX's output and input percentage point contributions to TFP change in 2023



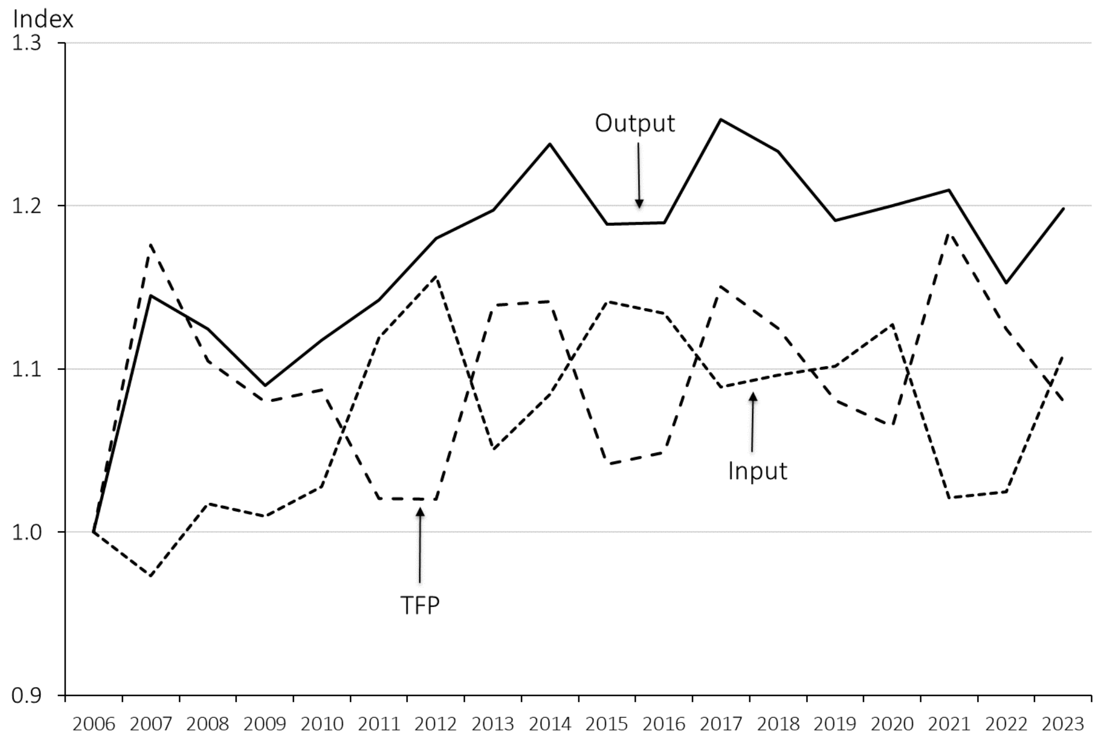
6.5 Ergon Energy (ERG)

In 2023, ERG delivered 13,868 GWh to 786,523 customers over 154,437 circuit kilometres of lines and cables. ERG distributes electricity throughout regional Queensland, excluding South East Queensland. ERG is 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, 2006–2023



Over the 18-year period 2006 to 2023, ERG's TFP increased at an average annual rate of change of 0.5 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, 2017 and 2021, and other years have seen substantial decreases, including 2008, 2011, 2015, 2019, 2022 and 2023.

ERG's total output increased over the 18-year period at an average annual rate 1.1 per cent, which is similar to the 0.9 per cent of industry average output growth rate per annum. ERG's average annual rate of increase in input use of 0.6 per cent over the 18-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 2.4 per cent per year respectively) than in the period 2012 to 2023 (where they averaged 0.1 and –0.4 per cent per year respectively). The average rate of TFP change from 2006 to 2012 was 0.3 per cent per year, while from 2012 to 2023 it averaged an increase of 0.5 per cent per annum.

The PFP indexes in Table 6.9 show that Opex PFP has improved at an average annual rate of 1.8 per cent over the 18-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 –1.2 per cent per annum. The average trend growth rate in capital MPFP over the 18-year period was –0.6 per cent per annum.

Table 6.9 ERG's output, input, TFP and PFP indexes, 2006–2023

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	0.973	1.176	1.251	1.117
2008	1.125	1.018	1.105	1.141	1.078
2009	1.090	1.010	1.080	1.149	1.023
2010	1.118	1.028	1.087	1.184	1.013
2011	1.142	1.119	1.021	1.026	1.014
2012	1.180	1.157	1.020	1.014	1.023
2013	1.197	1.051	1.139	1.267	1.045
2014	1.238	1.084	1.142	1.295	1.031
2015	1.189	1.141	1.042	1.140	0.969
2016	1.190	1.134	1.049	1.183	0.951
2017	1.253	1.089	1.151	1.393	0.983
2018	1.233	1.096	1.125	1.369	0.956
2019	1.191	1.102	1.081	1.297	0.930
2020	1.200	1.127	1.065	1.241	0.937
2021	1.210	1.021	1.185	1.572	0.930
2022	1.153	1.025	1.124	1.481	0.889
2023	1.198	1.109	1.080	1.359	0.897
Growth Rate 2006–2023	1.1%	0.6%	0.5%	1.8%	-0.6%
Growth Rate 2006–2012	2.8%	2.4%	0.3%	0.2%	0.4%
Growth Rate 2012–2023	0.1%	-0.4%	0.5%	2.7%	-1.2%
Growth Rate 2023	3.9%	7.9%	-4.0%	-8.7%	1.0%

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 4.1 per cent in total between 2006 and 2023 (compared to a total increase of 6.0 per cent for the industry over the same period).
- ERG's energy throughput in 2023 was 2.8 per cent higher than in 2006. This compares to the industry's total *reduction* in energy throughput of 2.8 per cent over the same period.
- The increase of ERG's RMD output from 2006 to 2023 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 20.0 per cent increase over the period 2006 to 2023, concentrated in the period before 2012).
- ERG's customers increased at an average annual rate of 1.4 per cent from 2006 to 2023, or 26.0 per cent in total, which is similar to customer growth for the industry over the same period (1.3 per cent per annum, or 25.1 per cent in total).
- CMOS *decreased* for ERG over the 18-year period to 2023 by 7.8 per cent in total, which is comparable to the industry CMOS *decrease* of 3.5 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 11.8 per cent in total between 2006 and 2023, 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 10.1 per cent in total over the 18-year period. ERG's opex increased in the period 2006 to 2012 at an average rate of 2.5 per cent per annum, and it *decreased* after 2012 at an average rate of 2.5 per cent per annum.
- Overhead subtransmission and distribution lines in 2023 were 3.1 per cent and 18.1 per cent higher respectively, than in 2006. These changes compare to the industry increases of 7.7 per cent and 3.2 per cent respectively over the same period.
- ERG's underground subtransmission and distribution cables in 2023 were 75.3 and 114.9 per cent higher than in 2006 respectively. These increases are higher than those for the industry as a whole, of 35.2 per cent and 71.7 per cent respectively over the same period.
- ERG's quantity of transformer inputs increased steadily over most of the 18-year period, plateauing from 2017. The average annual rate of change from 2006 to 2023 was 2.4 per cent, an increase of 51.6 per cent in total (compared to the industry's 44.5 per cent increase over the same period). Transformers is the input with the largest weight in the capital input index (24.4 per cent of the costs).

Figure 6.18 ERG's output quantity indexes, 2006–2023

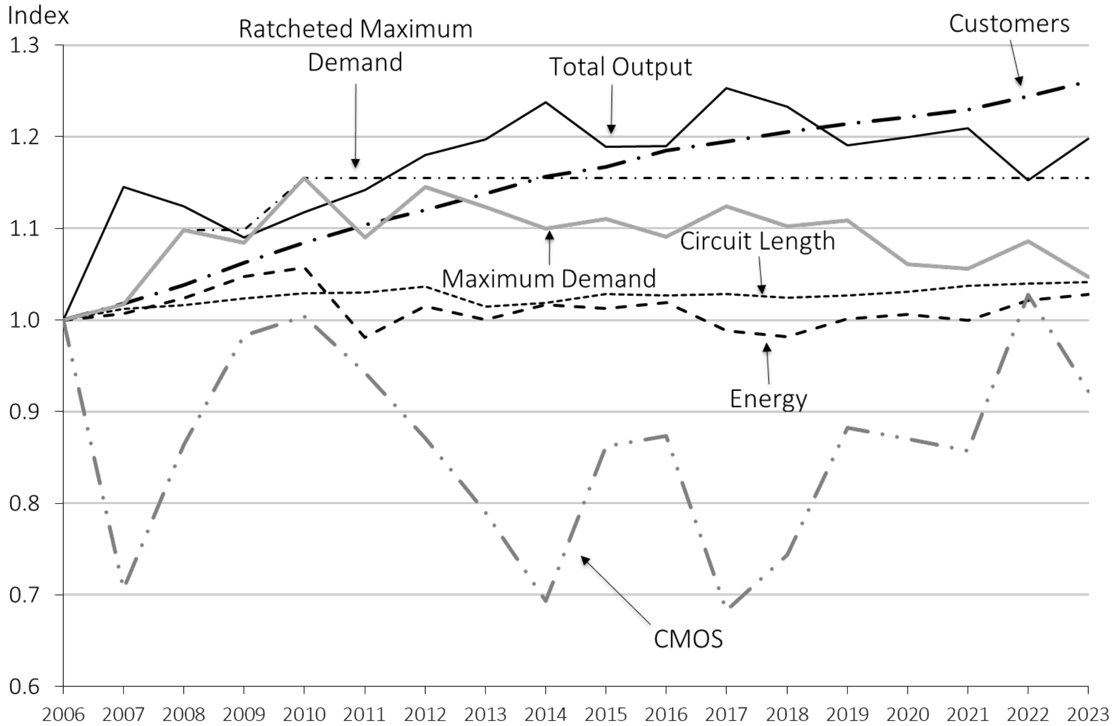
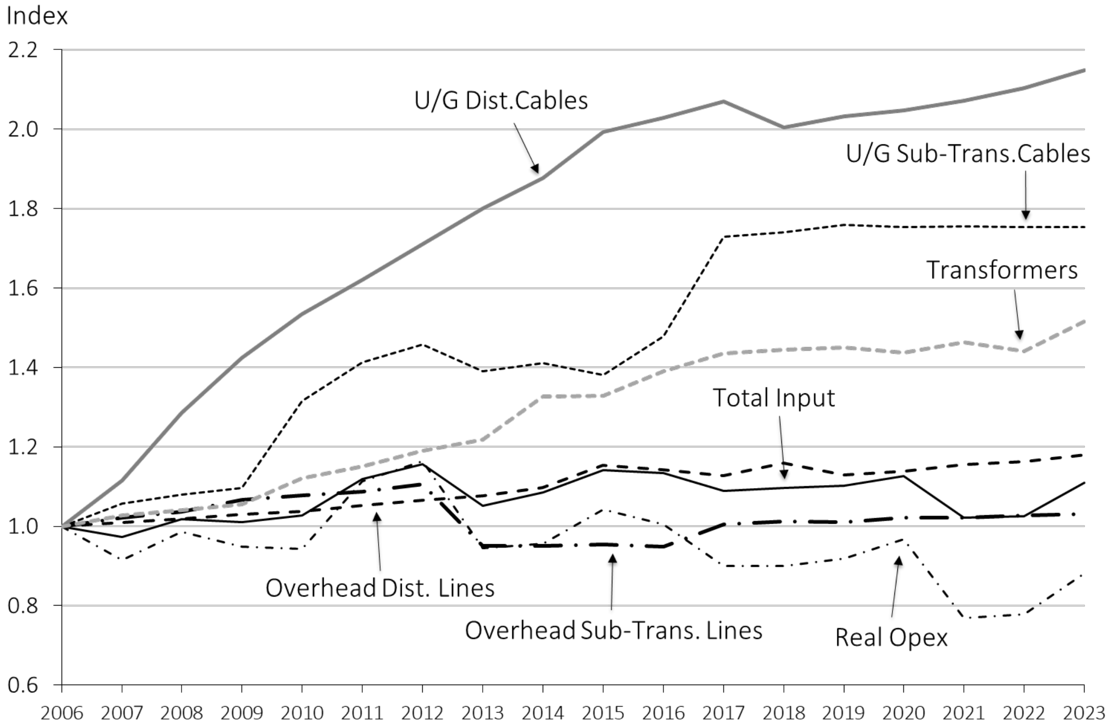


Figure 6.19 ERG's input quantity indexes, 2006–2023



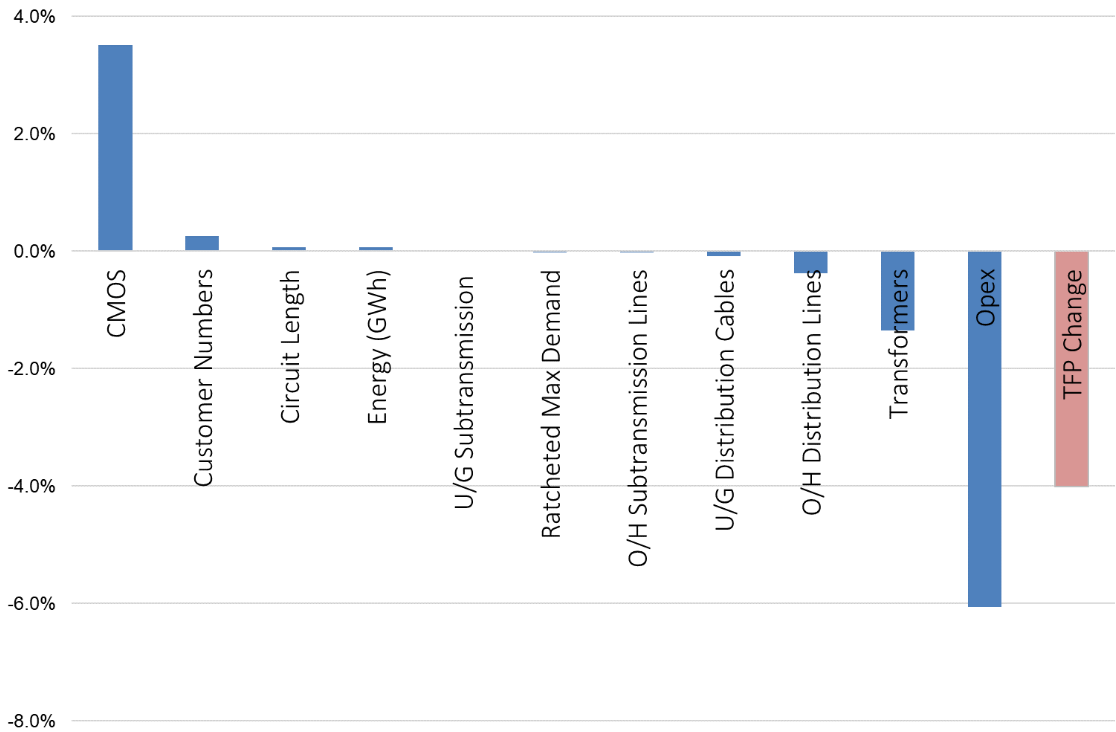
6.5.3 ERG's output and input contributions to TFP change

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 18-year period, for the periods up to and after 2012, and for 2023. Figure 6.20 shows the contributions of outputs and inputs to ERG's rate of TFP change of –4.0 per cent in 2023.

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

Year	*2006 to 2023*	*2006 to 2012*	*2012 to 2023*	*2023*
Energy (GWh)	0.02%	0.03%	0.01%	0.07%
Ratcheted Max Demand	0.38%	1.09%	0.00%	–0.02%
Customer Numbers	0.33%	0.48%	0.25%	0.26%
Circuit Length	0.12%	0.31%	0.02%	0.07%
CMOS	0.20%	0.85%	–0.15%	3.51%
Opex	0.33%	–1.11%	1.12%	–6.06%
O/H Subtransmission Lines	–0.01%	–0.15%	0.06%	–0.02%
O/H Distribution Lines	–0.19%	–0.21%	–0.18%	–0.38%
U/G Subtransmission Cables	–0.01%	–0.02%	–0.01%	0.00%
U/G Distribution Cables	–0.12%	–0.25%	–0.06%	–0.09%
Transformers	–0.60%	–0.69%	–0.55%	–1.34%
TFP Change	0.45%	0.33%	0.52%	–4.00%

Figure 6.20 ERG's output and input percentage point contributions to TFP change, 2023



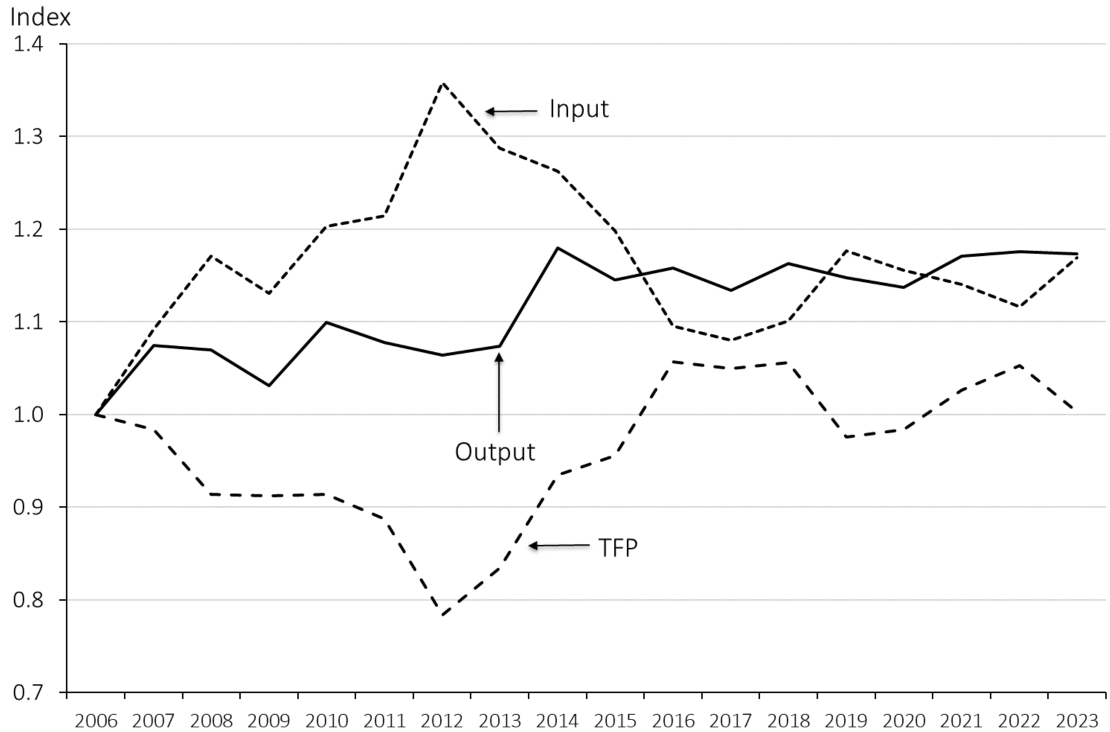
6.6 Essential Energy (ESS)

In 2023, ESS delivered 12,646 GWh to 948,225 customers over 193,373 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, 2006–2023



Over the 18-year period 2006 to 2023, 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. ESS's TFP mostly declined in the period up to 2012, where the average rate of TFP change was –4.1 per cent per year. In the period 2012 to 2023, ESS's TFP increased at an average rate of 2.2 per cent per year. ESS's TFP in 2023 *decreased* by 4.8 per cent.

ESS's total output increased over the 18-year period at an average annual rate of 0.9 per cent (the same for industry average over the same period). ESS's average annual rate of increase in input use was 0.9 per cent in the period 2006 to 2023, 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 strongly in the period up to 2012 (at an average annual rate of 5.1 per cent) and then *decreased* at an average rate of 1.4 from 2012 to 2023.

The PFP indexes in Table 6.11 show the following trends:

- Capital PFP *declined* at an average rate of 0.2 per cent per year from 2006 to 2023. 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 –7.8 per cent per annum, whereas it increased at a rate of 4.7 per cent per annum after 2012. Over the full period, Opex PFP averaged growth of 0.3 per cent per annum.

Table 6.11 ESS's output, input, TFP and PFP indexes, 2006–2023

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	1.092	0.984	0.908	1.062
2008	1.070	1.171	0.914	0.788	1.058
2009	1.031	1.131	0.912	0.827	0.996
2010	1.100	1.203	0.914	0.808	1.024
2011	1.077	1.214	0.887	0.782	0.991
2012	1.064	1.358	0.783	0.627	0.966
2013	1.074	1.287	0.834	0.714	0.964
2014	1.180	1.262	0.934	0.817	1.054
2015	1.145	1.198	0.956	0.902	1.008
2016	1.158	1.095	1.057	1.123	1.006
2017	1.134	1.080	1.050	1.143	0.980
2018	1.163	1.101	1.056	1.127	1.000
2019	1.148	1.176	0.975	0.981	0.970
2020	1.137	1.156	0.984	1.011	0.955
2021	1.171	1.140	1.027	1.071	0.976
2022	1.176	1.117	1.053	1.136	0.974
2023	1.173	1.170	1.003	1.049	0.965
Growth Rate 2006–2023	0.9%	0.9%	0.0%	0.3%	-0.2%
Growth Rate 2006–2012	1.0%	5.1%	-4.1%	-7.8%	-0.6%
Growth Rate 2012–2023	0.9%	-1.4%	2.2%	4.7%	0.0%
Growth Rate 2023	-0.2%	4.6%	-4.8%	-7.9%	-0.8%

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 (47.7 per cent). ESS's circuit length *decreased* by 3.1 per cent in total between 2006 and 2023. This compares to a total increase of 6.0 per cent for the industry over the same period.
- ESS's energy throughput increased at an average annual rate of 0.3 per cent per year over the 18-year period, or 5.7 per cent in total (compared to a total *decline* of 2.8 per cent for the industry over the same period).
- ESS's RMD increased by 24.5 per cent in total between 2006 and 2023. This shows that maximum demand has grown much more strongly than energy throughput, especially in the period from 2012 to 2023. Consequently, RMD grew at an average annual rate of 1.6 per cent from 2012 to 2023, whereas energy throughput increased at an average annual rate of 0.6 per cent over this period.
- ESS's customers output increased at an average rate of 1.0 per cent per annum over the 18-year period, or 18.7 per cent in total, which is less than the average rate of customer growth for the industry over the same period (25.1 per cent in total).
- CMOS *decreased* over the 18-year period by 11.2 per cent in total, which is more than the industry *decrease* of 3.5 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 0.7 per cent over the period from 2006 to 2023, or 11.9 per cent in total. This compares to the industry, for which opex input increased by 10.1 per cent in total over the same period. ESS's opex increased strongly in the period 2006 to 2012, at an average rate of 8.8 per cent per annum, and it decreased after 2012 at an average rate of –3.8 per cent per annum.
- Overhead subtransmission and distribution lines in 2023 were 12.3 per cent higher and 4.3 per cent *lower*, respectively, than in 2006. These changes are compared to the industry increases of 7.7 per cent and 3.2 per cent respectively over the same period.
- ESS's underground subtransmission and distribution cables inputs in 2023 were 59.3 and 39.5 per cent higher than in 2006 respectively. These changes are compared to the industry as a whole, increases of 35.2 per cent and 71.7 per cent respectively over the same period.
- ESS's quantity of transformer inputs increased over the 18-year period at an average annual rate of 2.1 per cent, and by 2023, transformer inputs were 42.8 per cent above the 2006 level, similar to the industry's 44.5 per cent increase.

Figure 6.22 ESS's output quantity indexes, 2006–2023

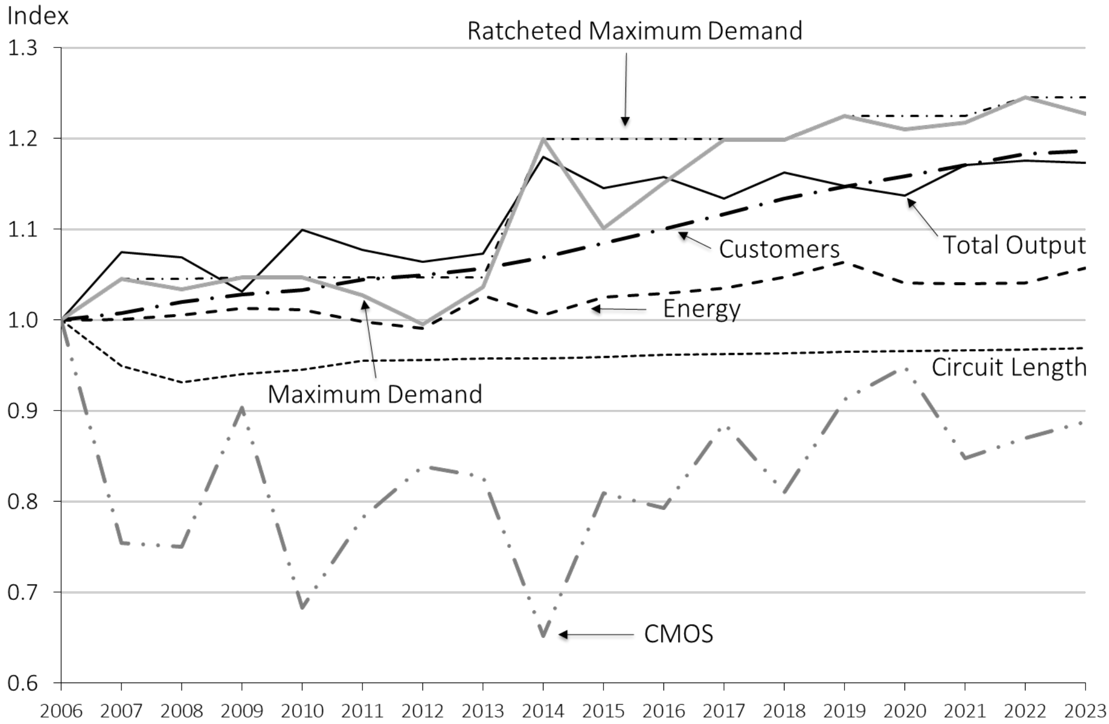
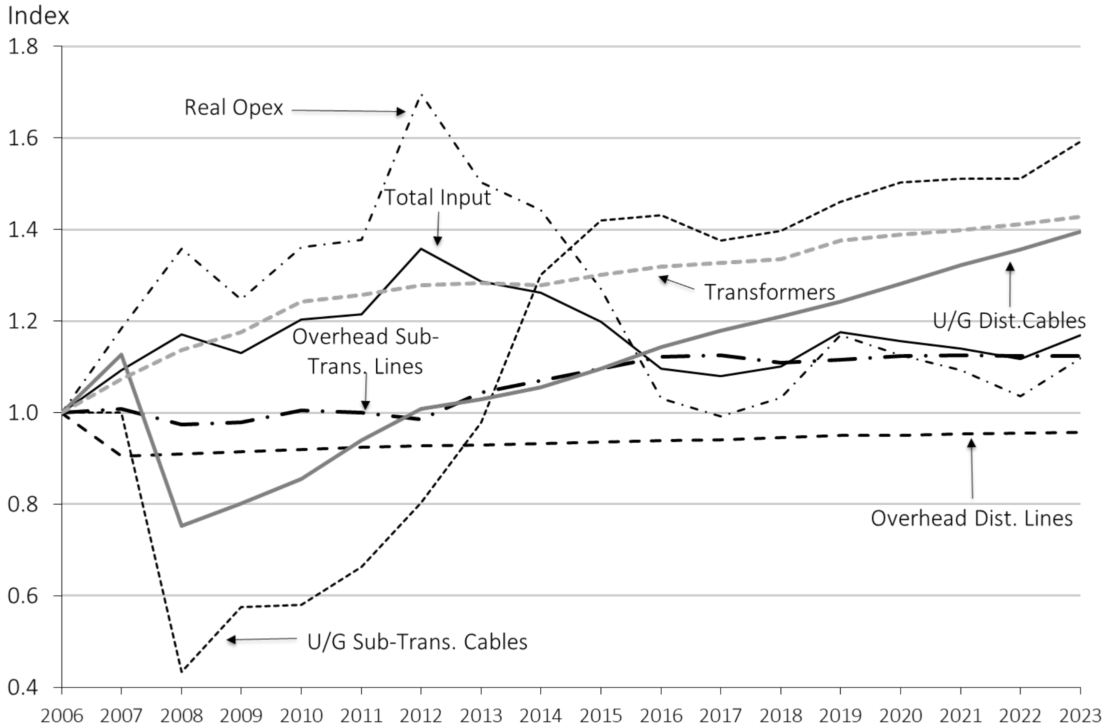


Figure 6.23 ESS's input quantity indexes, 2006–2023



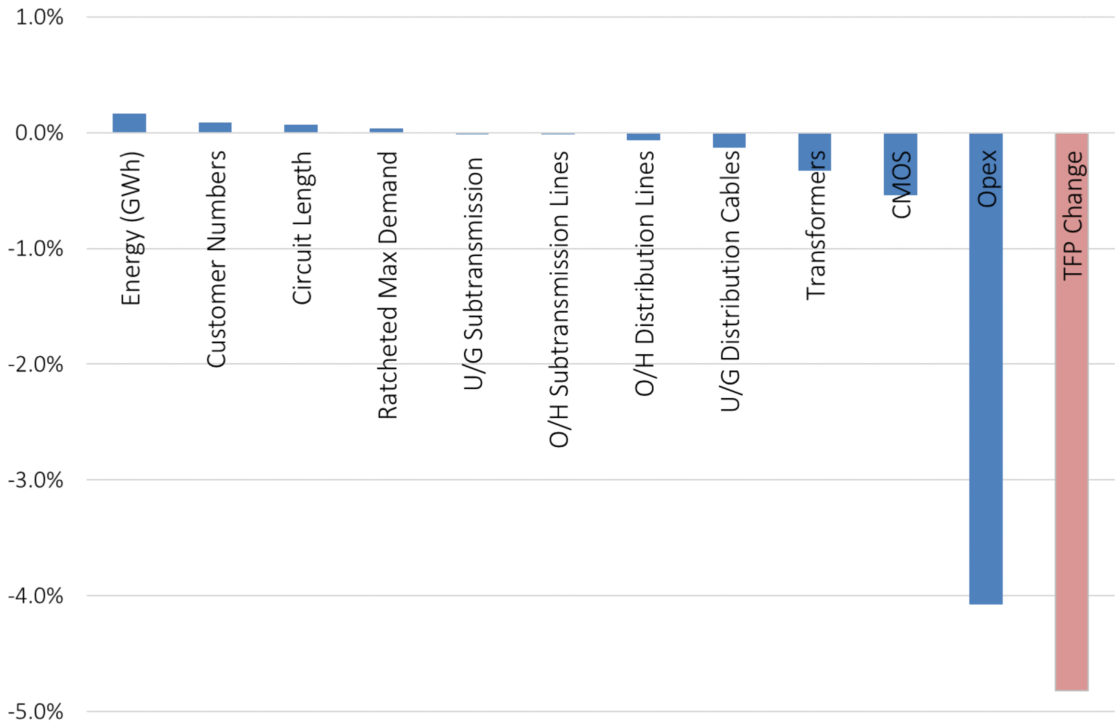
6.6.3 ESS's output and input contributions to TFP change

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 18-year period, for the periods up to and after 2012, and for 2023. Figure 6.24 shows the contributions of outputs and inputs to ESS's rate of TFP change of –4.8 per cent in 2023.

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

Year	*2006 to 2023*	*2006 to 2012*	*2012 to 2023*	*2023*
Energy (GWh)	0.04%	-0.01%	0.06%	0.17%
Ratcheted Max Demand	0.55%	0.37%	0.65%	0.04%
Customer Numbers	0.23%	0.20%	0.25%	0.09%
Circuit Length	-0.09%	-0.37%	0.06%	0.07%
CMOS	0.22%	0.85%	-0.13%	-0.54%
Opex	-0.32%	-4.26%	1.83%	-4.07%
O/H Subtransmission Lines	-0.04%	0.01%	-0.07%	-0.02%
O/H Distribution Lines	0.04%	0.21%	-0.05%	-0.06%
U/G Subtransmission Cables	0.00%	0.01%	-0.01%	-0.01%
U/G Distribution Cables	-0.06%	0.00%	-0.10%	-0.13%
Transformers	-0.53%	-1.06%	-0.24%	-0.33%
TFP Change	0.02%	-4.07%	2.25%	-4.82%

Figure 6.24 ESS's output and input percentage point contributions to TFP change, 2023



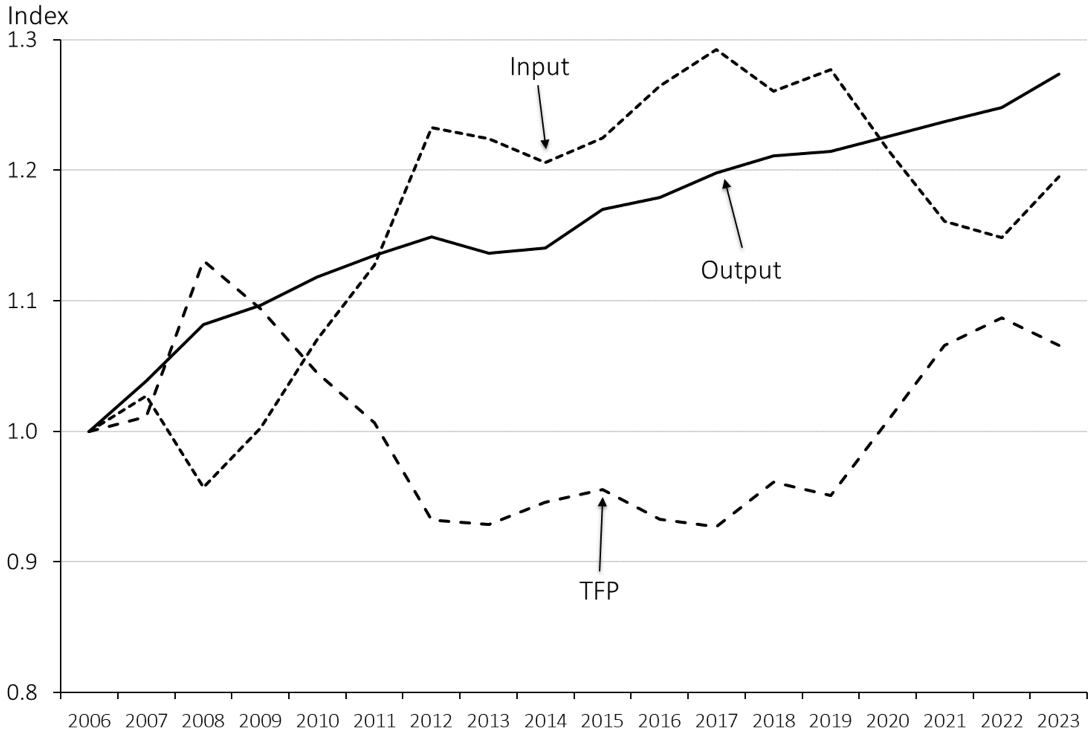
6.7 Jemena Electricity Networks (JEN)

In 2023, JEN delivered 4,374 GWh to 378,889 customers over 6,899 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, 2006–2023



Over the 18-year period 2006 to 2023, JEN's TFP increased at an average annual rate of change of 0.4 per cent per annum. This compares favourably to the industry's average annual change of –0.3 per cent over the same period. Over the period from 2006 to 2012, the rate of change in TFP was –1.2 per cent per annum, and in the period from 2012 to 2023, the rate of increase was 1.3 per cent per annum.

JEN's total output increased over 18-year period at an average annual rate of 1.5 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 1.1 per cent over the same period is similar to 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 1.0 per cent per annum). Its rate of input growth was also higher in the period up to 2012 (at 3.5 per cent per annum) than in the period after 2012 (at –0.3 per cent per annum).

The PFP indexes in Table 6.13 show the following trends:

- Capital PFP increased marginally, at an average rate of 0.2 per cent per year, from 2006 to 2023. In the period up to 2012, Capital PFP increased at a rate of 1.1 per cent per annum, whilst in the period after 2012, the rate of change in Capital PFP averaged –0.3 per cent per annum.
- Opex PFP increased on average at a rate of 0.7 per cent per annum from 2006 to 2023. In the period up to 2012, Opex PFP *decreased* by 3.8 per cent per annum on average, whereas it has increased at a rate of 3.2 per cent per annum after 2012.

Table 6.13 JEN's output, input, TFP and PFP indexes, 2006–2023

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	1.027	1.011	0.984	1.034
2008	1.082	0.957	1.131	1.269	1.044
2009	1.097	1.003	1.094	1.179	1.038
2010	1.118	1.070	1.045	1.025	1.062
2011	1.135	1.127	1.006	0.953	1.052
2012	1.149	1.233	0.932	0.795	1.066
2013	1.136	1.224	0.928	0.806	1.048
2014	1.140	1.206	0.945	0.845	1.038
2015	1.170	1.224	0.955	0.861	1.041
2016	1.179	1.264	0.932	0.823	1.034
2017	1.198	1.292	0.927	0.807	1.048
2018	1.211	1.260	0.961	0.881	1.033
2019	1.214	1.277	0.951	0.881	1.013
2020	1.226	1.216	1.008	1.000	1.015
2021	1.237	1.161	1.066	1.122	1.019
2022	1.248	1.148	1.087	1.172	1.021
2023	1.274	1.195	1.066	1.118	1.034
Growth Rate 2006–2023	1.5%	1.1%	0.4%	0.7%	0.2%
Growth Rate 2006–2012	2.3%	3.5%	-1.2%	-3.8%	1.1%
Growth Rate 2012–2023	1.0%	-0.3%	1.3%	3.2%	-0.3%
Growth Rate 2023	2.0%	4.0%	-2.0%	-4.8%	1.2%

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 (42.2 per cent), increased steadily at an average rate of 1.1 per cent per annum from 2006 to 2023; a total increase of 20.6 per cent (which is much higher than the increase of 6.0 per cent for the industry over the 18-year period).
- JEN's energy throughput had an average growth rate of 0.1 per cent per annum between 2006 and 2023; compared to –0.2 per cent per annum for the industry. In 2023, JEN's energy throughput was 2.2 per cent above 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 2023. This is greater than that of the industry (20.0 per cent in total).
- JEN's customers increased at an average rate of 1.6 per cent per annum between 2006 and 2023, or 29.2 per cent in total (compared to total customer growth of 25.1 per cent for the industry over the same period).
- CMOS *decreased* by 26.8 per cent in total over the period from 2006 to 2023 (compared to a *decrease* in CMOS of 3.5 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 increased between 2006 and 2023, averaging an annual rate of change of 0.8 per cent. By 2023, opex was 14.0 per cent above its level in 2006. This is similar to the total increase of industry opex inputs of 10.1 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 6.1 per cent per annum, whereas from 2012 to 2023, JEN's opex *decreased* at a rate of 2.3 per cent per annum.
- Overhead subtransmission and distribution lines in 2023 were 15.3 and 3.4 per cent higher, respectively, than their 2006 level. These outcomes compare with 7.7 per cent and 3.2 per cent increases, respectively, for the industry over the same period.
- Underground subtransmission and distribution cables in 2023 were 68.0 and 119.0 per cent higher than in 2006 respectively. This can be compared to increases of 35.2 per cent and 71.7 per cent respectively for the industry over the same period.
- JEN's quantity of transformers increased reasonably steadily over the 18-year period, at an average rate of 2.6 per cent per annum. By 2023, transformer inputs were 52.6 per cent above the 2006 level, which is a larger increase than the industry's 44.5 per cent.

Figure 6.26 JEN's output quantity indexes, 2006–2023

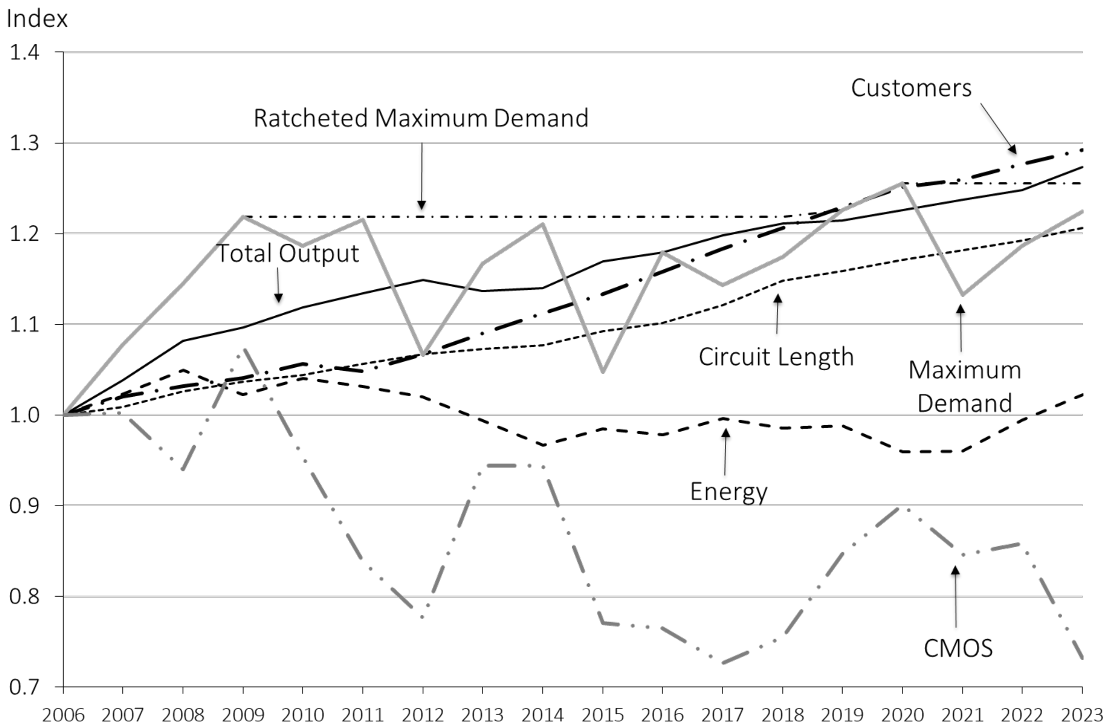
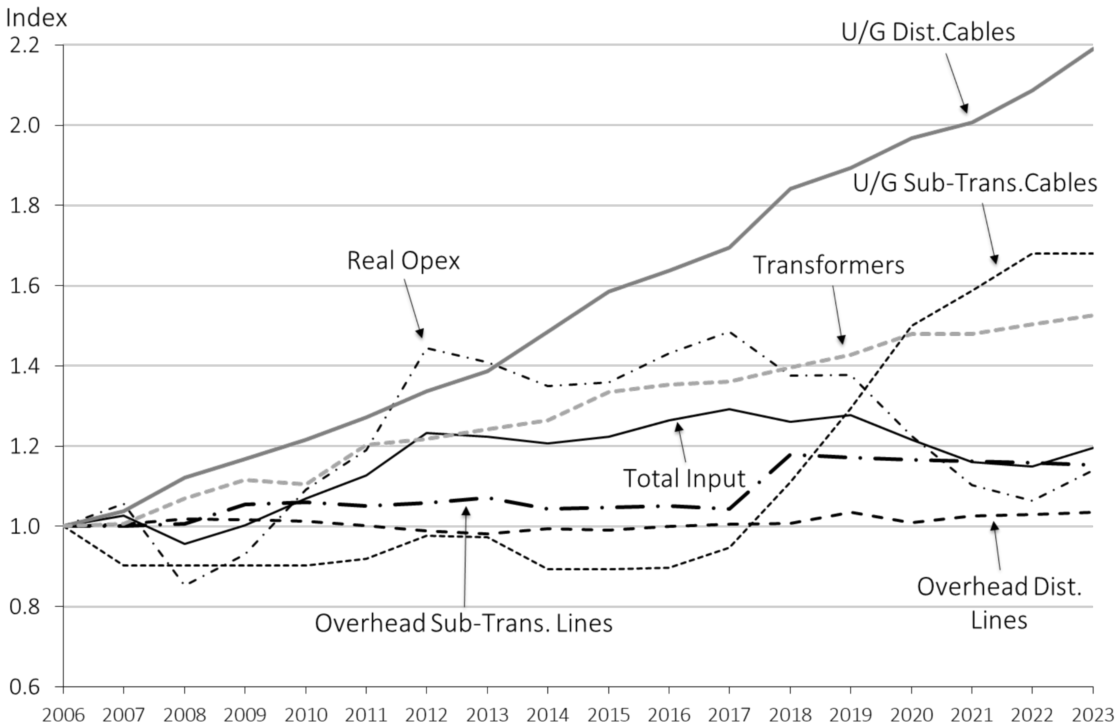


Figure 6.27 JEN's DNSP input quantity indexes, 2006–2023



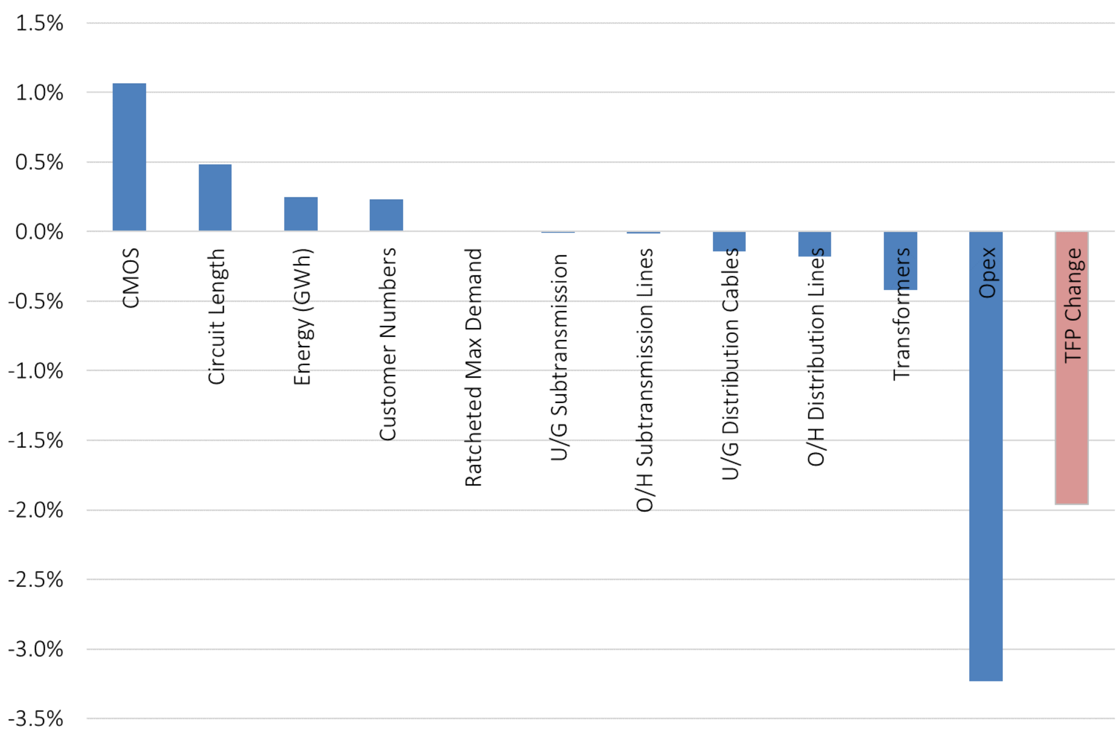
6.7.3 JEN's output and input contributions to TFP change

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 18-year period, for the periods up to and after 2012, and for 2023. Figure 6.28 shows the contributions of outputs and inputs to JEN's rate of TFP change of –2.0 per cent between 2021 and 2023.

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

Year	*2006 to 2023*	*2006 to 2012*	*2012 to 2023*	*2023*
Energy (GWh)	0.01%	0.03%	0.00%	0.25%
Ratcheted Max Demand	0.49%	1.22%	0.10%	0.00%
Customer Numbers	0.31%	0.22%	0.36%	0.23%
Circuit Length	0.49%	0.47%	0.50%	0.49%
CMOS	0.17%	0.37%	0.07%	1.07%
Opex	-0.07%	-2.79%	1.41%	-3.23%
O/H Subtransmission Lines	-0.04%	-0.04%	-0.04%	-0.01%
O/H Distribution Lines	-0.08%	0.05%	-0.15%	-0.18%
U/G Subtransmission Cables	-0.01%	0.00%	-0.01%	-0.01%
U/G Distribution Cables	-0.10%	-0.11%	-0.10%	-0.14%
Transformers	-0.48%	-0.59%	-0.42%	-0.42%
TFP Change	0.70%	-1.17%	1.72%	-1.96%

Figure 6.28 JEN's output and input percentage point contributions to TFP change, 2023



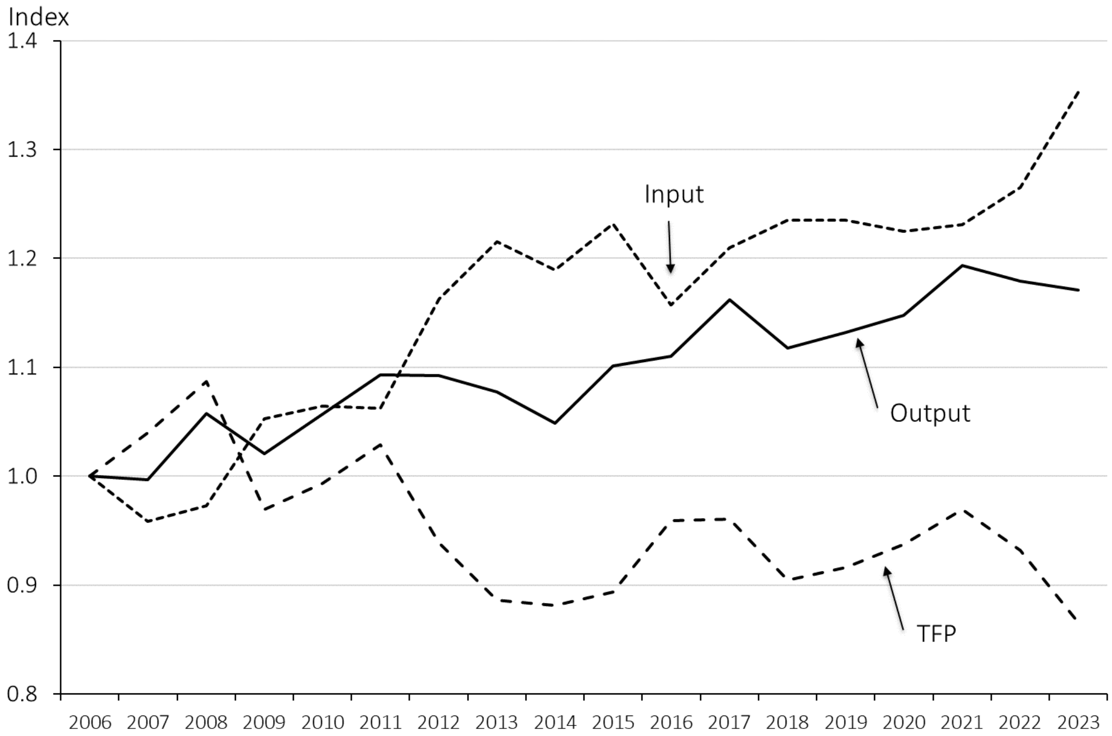
6.8 Powercor (PCR)

In 2023, PCR delivered 11,026 GWh to 920,608 customers over 77,438 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, 2006–2023



Over the 18-year period PCR's TFP decreased, averaging an annual rate of change of –0.9 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 PCR's TFP *decline* at an average rate of 1.0 per cent per year, while in the period from 2012 to 2023, TFP again *decreased* at an average annual rate of 0.8 per cent.

PCR's total output increased over the 18-year period at an average annual rate of 1.0 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 1.8 per cent over the same period was higher than 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 0.7 per cent per year. PCR's input usage increased at an average rate of 2.5 per cent per year from 2006 to 2012, and by 1.4 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 –1.2 per cent per annum.
- Opex PFP *decreased* on average at a rate of 0.5 per cent per annum from 2006 to 2023. In the period up to 2012, Opex PFP *decreased* by 1.2 per cent per annum, on average, and *decreased* at a rate of 0.1 per cent per annum from 2012 to 2023.

Table 6.15 PCR's output, input, TFP and PFP indexes, 2006–2023

Year	*Output*	*Input*	*TFP*	*PFP Index*	
	Index	*Index*	*Index*	*Opex*	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	0.997	0.959	1.040	1.116	0.975
2008	1.058	0.973	1.087	1.170	1.017
2009	1.021	1.053	0.970	1.022	0.924
2010	1.057	1.064	0.993	1.071	0.927
2011	1.093	1.062	1.029	1.105	0.965
2012	1.092	1.163	0.939	0.928	0.954
2013	1.077	1.215	0.886	0.865	0.918
2014	1.048	1.190	0.881	0.893	0.876
2015	1.101	1.232	0.894	0.893	0.902
2016	1.110	1.157	0.959	1.034	0.894
2017	1.162	1.210	0.961	1.014	0.914
2018	1.118	1.235	0.905	0.952	0.864
2019	1.132	1.235	0.916	0.986	0.857
2020	1.148	1.225	0.937	1.046	0.846
2021	1.194	1.231	0.970	1.078	0.876
2022	1.179	1.265	0.932	1.031	0.847
2023	1.171	1.352	0.866	0.914	0.824
Growth Rate 2006–2023	1.0%	1.8%	-0.9%	-0.5%	-1.2%
Growth Rate 2006–2012	1.5%	2.5%	-1.0%	-1.2%	-0.8%
Growth Rate 2012–2023	0.7%	1.4%	-0.8%	-0.1%	-1.4%
Growth Rate 2023	-0.7%	6.7%	-7.3%	-12.1%	-2.7%

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 2023; and by 2023 was 8.0 per cent above the 2006 level (slightly higher than the increase of 6.0 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 2023 (compared to –0.2 per cent per annum for the industry). PCR's energy throughput in 2023 was 8.7 per cent above its 2006 level (compared to a *decrease* of 2.8 per cent for the industry).
- RMD increased at an average annual rate of 1.6 per cent per annum on average over the 18-year period to 2023. In 2023, RMD was 29.4 per cent higher than it was in 2006 (a greater increase than the industry RMD increase of 20.0 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 2023, or 38.7 per cent in total. This is higher than the 25.1 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 2023, PCR's CMOS increased by 39.4 per cent in total (compared to –3.5 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 1.5 per cent from 2006 to 2023, so that opex input in 2023 was 28.1 per cent above its level in 2006 (compared to 10.1 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 2.7 per cent per annum. After 2012, opex input increased at an average rate of 0.8 per cent per annum.
- Overhead subtransmission and distribution lines in 2023 were 3.1 and 1.9 per cent higher, respectively, than their 2006 level. These increases were lower than the 7.7 per cent and 3.2 per cent increases, respectively, for the industry over the same period.
- Underground subtransmission and distribution cables in 2023 were 367.6 per cent and 155.4 per cent higher than in 2006 respectively. This can be compared to increases of 35.2 per cent and 71.7 per cent respectively for the industry over the same period.
- PCR's quantity of transformers increased steadily over the 18-year period, at an average rate of 2.7 per cent per annum. By 2023, transformer inputs were 55.7 per cent above the 2006 level (comparable to the industry increase of 44.5 per cent over the same period).

Figure 6.30 PCR's output quantity indexes, 2006–2023

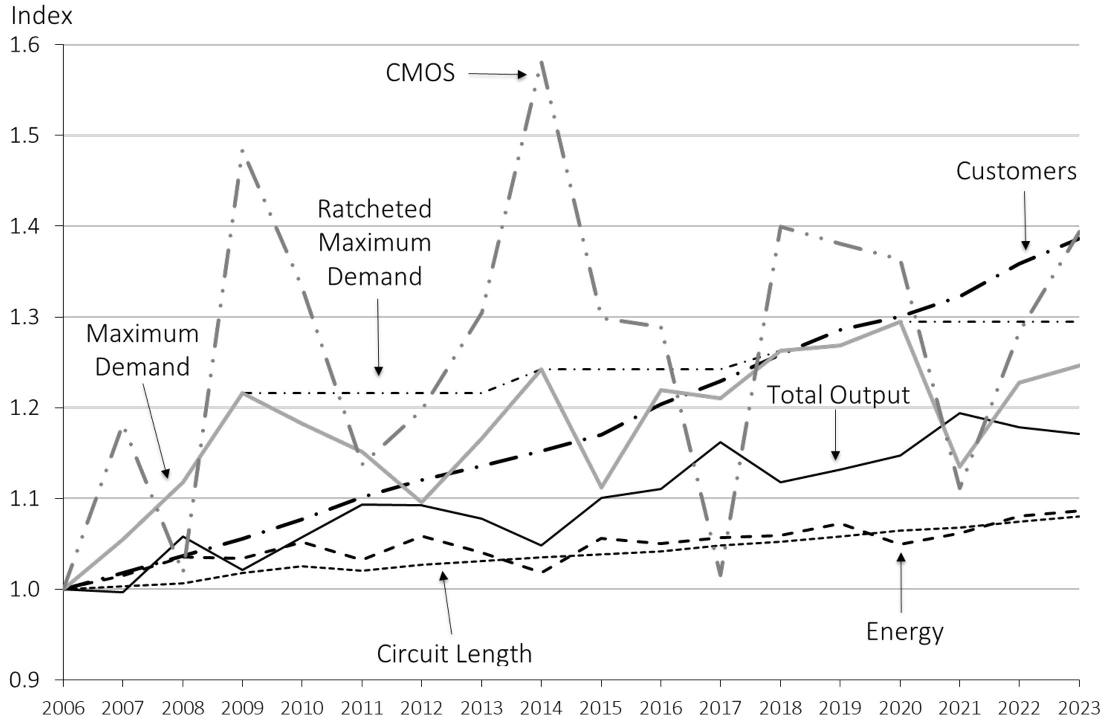
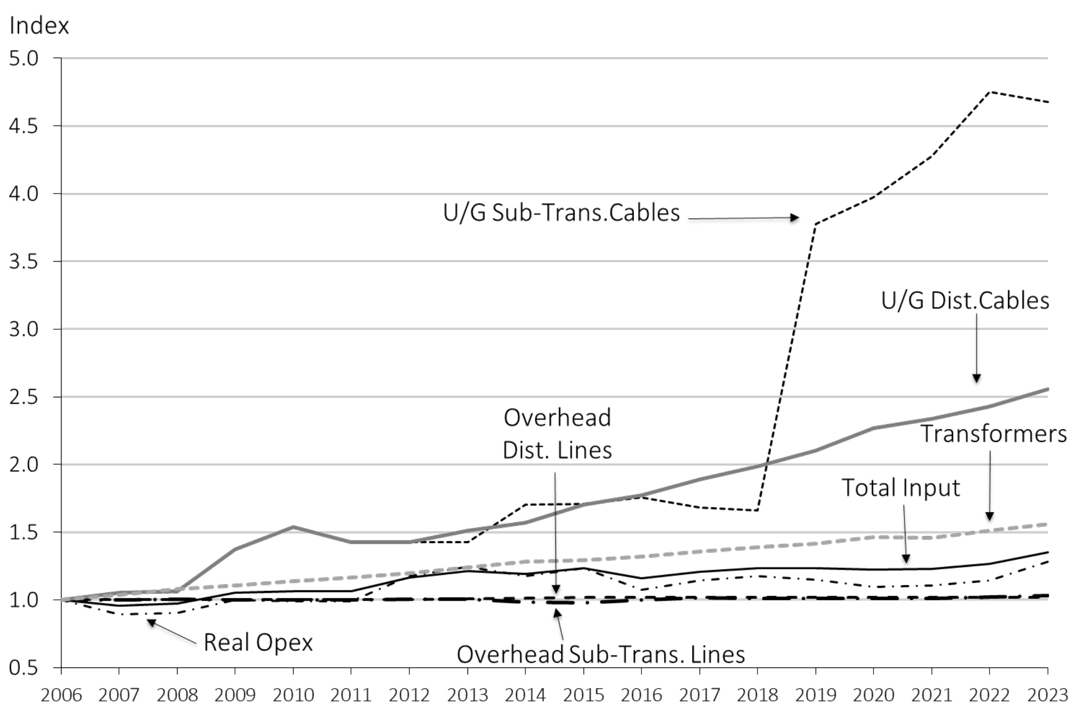


Figure 6.31 PCR's DNSP input quantity indexes, 2006–2023



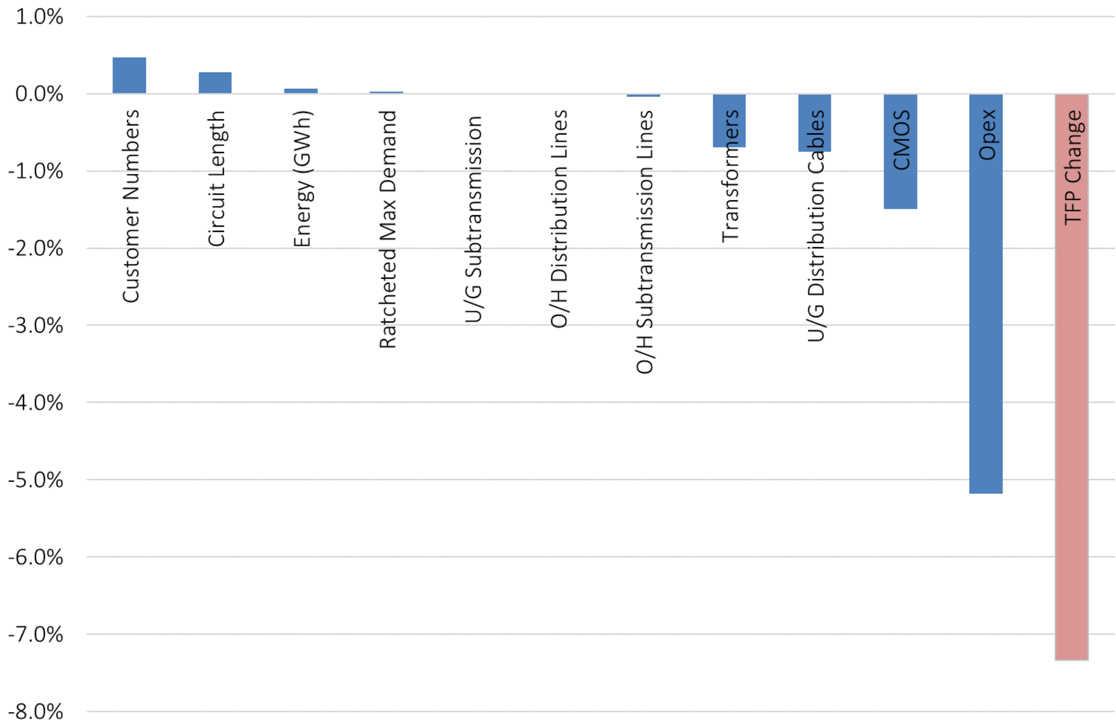
6.8.3 PCR's output and input contributions to TFP change

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 18-year period, for the periods up to and after 2012, and for 2023. Figure 5.32 shows the contributions of outputs and inputs to PCR's rate of TFP change of –7.3 per cent in 2023.

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

Year	*2006 to 2023*	*2006 to 2012*	*2012 to 2023*	*2023*
Energy (GWh)	0.06%	0.10%	0.03%	0.06%
Ratcheted Max Demand	0.61%	1.31%	0.22%	0.02%
Customer Numbers	0.44%	0.41%	0.46%	0.47%
Circuit Length	0.22%	0.20%	0.23%	0.28%
CMOS	-0.16%	-0.55%	0.05%	-1.49%
Opex	-0.71%	-1.32%	-0.38%	-5.18%
O/H Sub-transmission Lines	-0.01%	0.00%	-0.01%	-0.04%
O/H Distribution Lines	-0.02%	-0.02%	-0.03%	-0.01%
U/G Sub-transmission Cables	-0.01%	-0.01%	-0.01%	0.00%
U/G Distribution Cables	-0.58%	-0.63%	-0.56%	-0.76%
Transformers	-0.47%	-0.54%	-0.44%	-0.70%
TFP Change	-0.65%	-1.05%	-0.43%	-7.34%

Figure 6.32 PCR's output and input percentage point contributions to TFP change, 2023



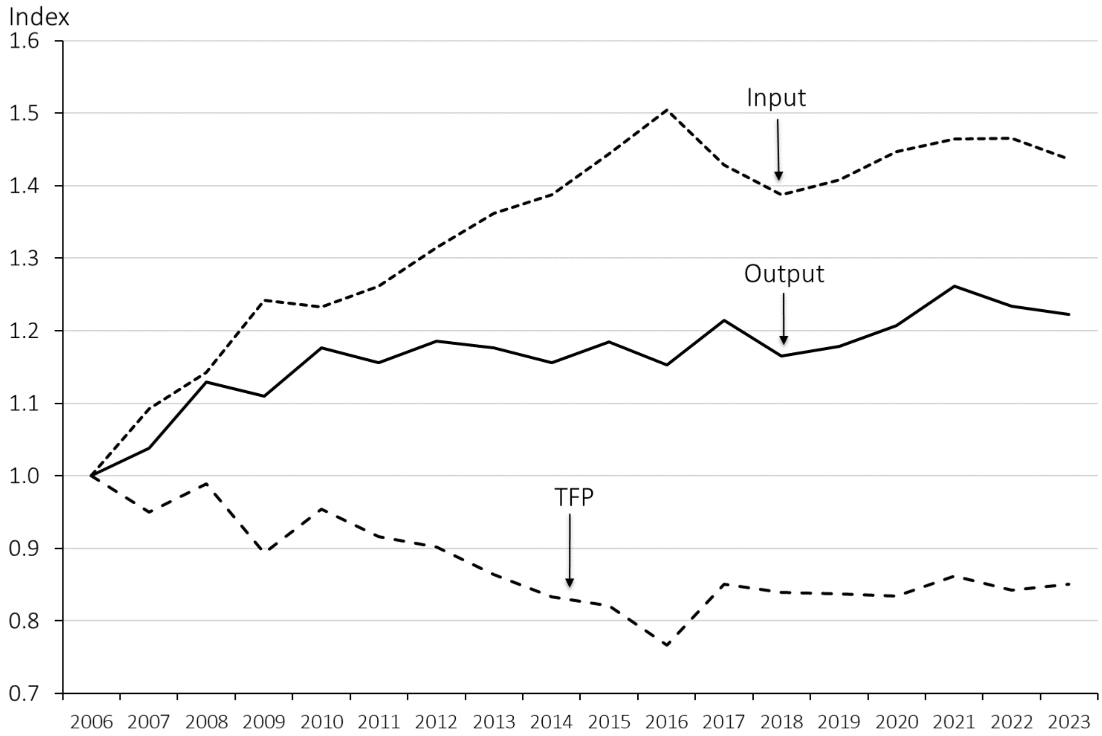
6.9 AusNet Services Distribution (AND)

In 2023, AND delivered 7,628 GWh to 810,580 customers over 46,322 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, 2006–2023



Over the 18-year period 2006 to 2023, AND's TFP *decreased* at an average annual rate of 1.0 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 18-year period.

AND's total output increased over the 18-year period at an average annual rate of 1.2 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 2023 (averaging 0.3 per cent per year). AND's average annual rate of increase in input use of 2.2 per cent from 2006 to 2023 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 0.8 per cent per year). By 2023, the input index was 43.6 per cent higher than in 2006 (compared to 23.4 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 18-year period, the average rate of change in capital PFP was –0.6 per cent per annum.
- Opex PFP declined over the 18-year period, the average rate of change being –1.4 per cent per annum. This contrasts with the industry overall, for which opex PFP increased at an average rate of 0.3 per cent per year over the same period.

Table 6.17 AND's output, input, TFP and PFP indexes, 2006–2023

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.038	1.093	0.950	0.884	0.999
2008	1.130	1.142	0.989	0.883	1.072
2009	1.109	1.242	0.893	0.767	0.997
2010	1.176	1.233	0.954	0.834	1.051
2011	1.156	1.261	0.916	0.805	1.006
2012	1.186	1.314	0.902	0.768	1.013
2013	1.177	1.361	0.864	0.720	0.988
2014	1.156	1.388	0.833	0.691	0.955
2015	1.185	1.444	0.821	0.660	0.964
2016	1.153	1.504	0.766	0.600	0.921
2017	1.215	1.428	0.850	0.722	0.957
2018	1.165	1.388	0.840	0.762	0.901
2019	1.179	1.408	0.837	0.748	0.908
2020	1.207	1.447	0.835	0.735	0.914
2021	1.261	1.464	0.862	0.754	0.948
2022	1.234	1.465	0.842	0.756	0.910
2023	1.222	1.436	0.851	0.787	0.905
Growth Rate 2006–2023	1.2%	2.2%	-1.0%	-1.4%	-0.6%
Growth Rate 2006–2012	2.8%	4.6%	-1.7%	-4.4%	0.2%
Growth Rate 2012–2023	0.3%	0.8%	-0.6%	0.2%	-1.1%
Growth Rate 2023	-0.9%	-2.0%	1.1%	4.0%	-0.6%

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 (45.0 per cent), increased at an average rate of 0.7 per cent per annum from 2006 to 2023, and was 11.6 per cent higher than the 2006 level in 2023 (which is higher than the increase of 6.0 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 2023, and by 2023 was 3.1 per cent above its 2006 level.
- RMD increased between 2006 and 2023 in total by 30.8 per cent, representing an average annual growth rate of 1.6 per cent. This is a larger increase than the 20.0 per cent total increase in RMD for the industry between 2006 and 2023.
- Customers increased at an average rate of 1.8 per cent per annum between 2006 and 2023, or 33.9 per cent in total. This is higher than total customer growth for the industry over the same period of 25.1 per cent.
- CMOS increased by 10.8 per cent in 2023 and was 20.6 per cent above the 2006 level, contrasting to the industry, which in 2023 was 3.5 per cent *below* 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 2.7 per cent from 2006 to 2023, and in the latter year it was 55.3 per cent above its level in 2006, which compares to the total increase of 10.1 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 7.2 per cent per annum, and from 2012 to 2023 it increased marginally at an average rate of 0.1 per cent per annum.
- Overhead subtransmission and distribution lines in 2023 were 16.5 per cent above and 2.5 per cent *below*, respectively, their 2006 levels. These increases compare to the 7.7 per cent and 3.2 per cent increases respectively for the industry over the same period.
- Underground subtransmission and distribution cables in 2023 were 205.2 per cent and 122.5 per cent higher than in 2006 respectively, compared to increases of 35.2 per cent and 71.7 per cent respectively for the industry over the same period.
- Transformer inputs increased over the 18-year period at an average rate of 2.4 per cent per annum. By 2023, transformer inputs were 49.2 per cent above the 2006 level, similar to the industry increase of 44.5 per cent over the same period.

Figure 6.34 AND's output quantity indexes, 2006–2023

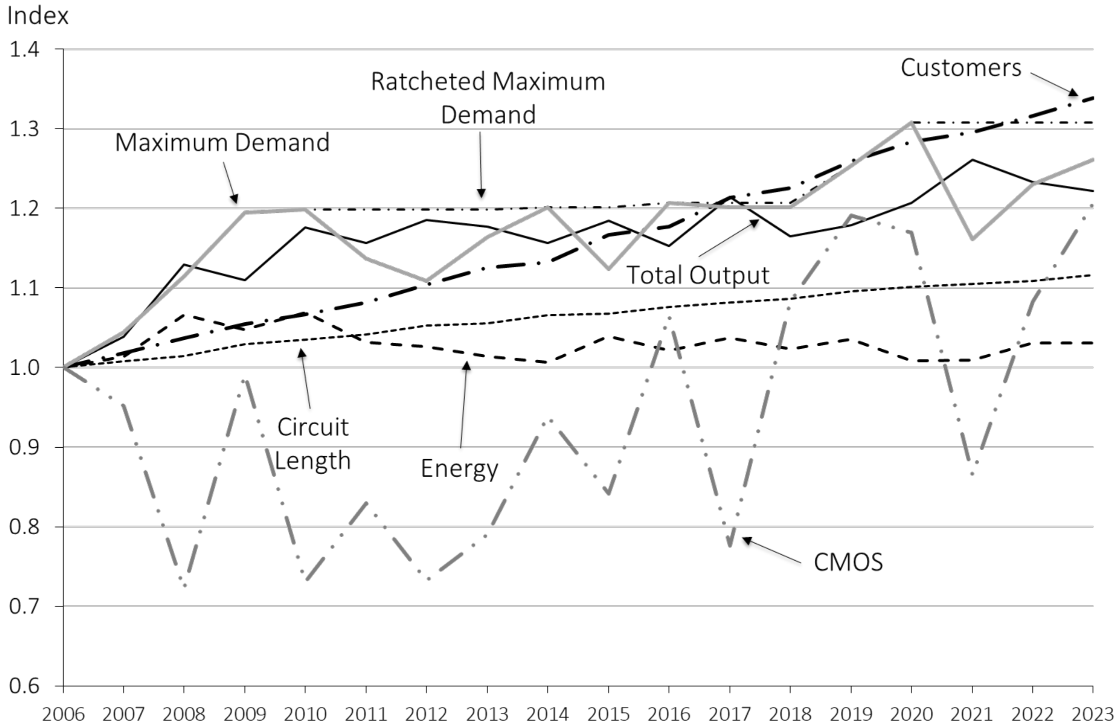
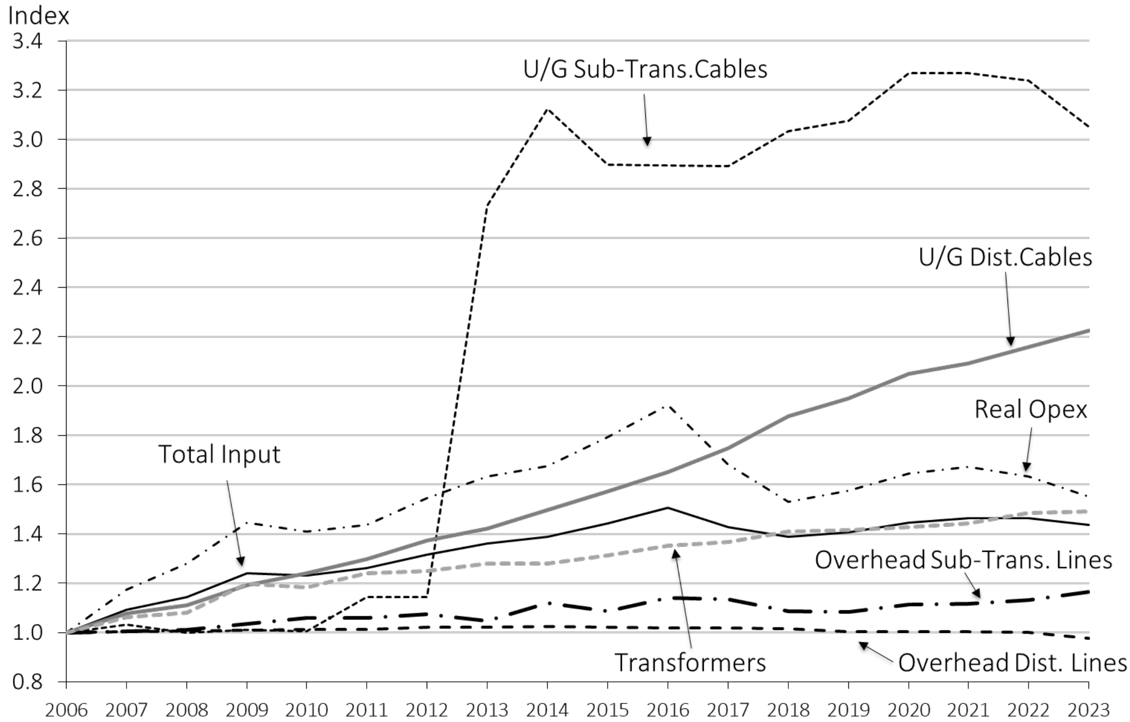


Figure 6.35 AND's input quantity indexes, 2006–2023



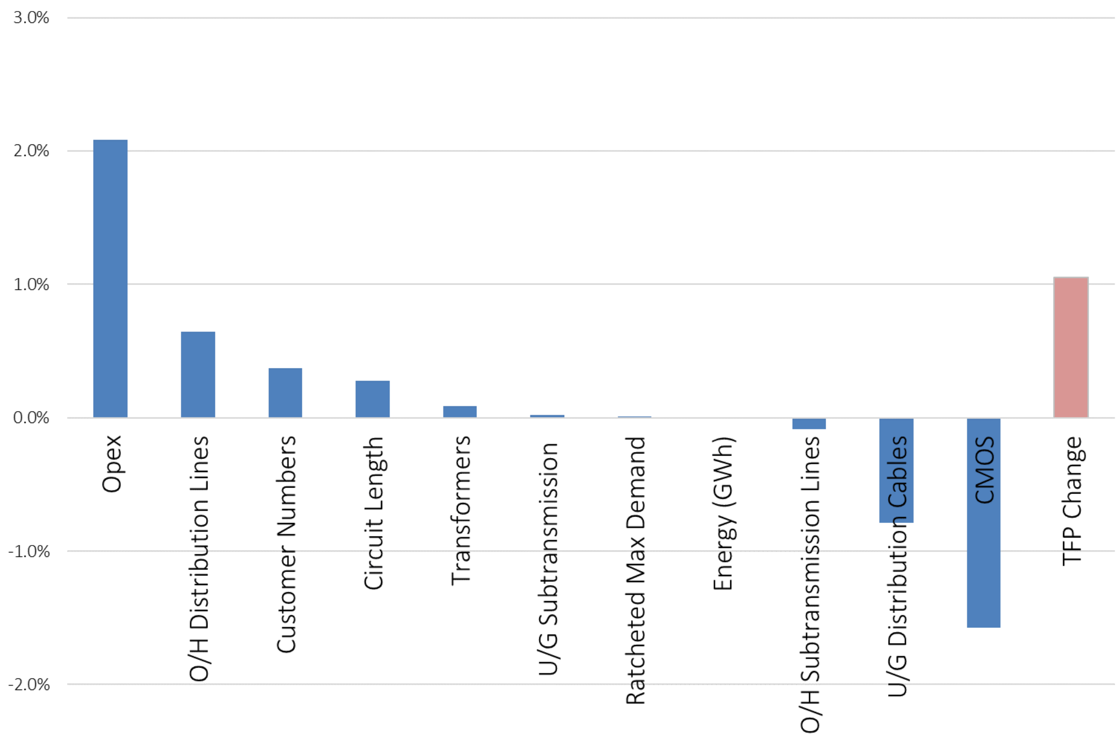
6.9.3 AND's output and input contributions to TFP change

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 18-year period, for the periods up to and after 2012, and for 2023. Figure 6.36 shows the contributions of outputs and inputs to AND's rate of TFP change of 1.1 per cent between 2021 and 2023.

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

Year	*2006 to 2023*	*2006 to 2012*	*2012 to 2023*	*2023*
Energy (GWh)	0.02%	0.04%	0.00%	0.00%
Ratcheted Max Demand	0.63%	1.22%	0.30%	0.01%
Customer Numbers	0.38%	0.37%	0.39%	0.37%
Circuit Length	0.30%	0.41%	0.25%	0.28%
CMOS	0.11%	0.79%	-0.27%	-1.57%
Opex	-1.13%	-3.02%	-0.09%	2.08%
O/H Subtransmission Lines	-0.02%	-0.03%	-0.02%	-0.08%
O/H Distribution Lines	0.04%	-0.08%	0.11%	0.65%
U/G Subtransmission Cables	-0.01%	-0.01%	-0.01%	0.02%
U/G Distribution Cables	-0.56%	-0.65%	-0.51%	-0.79%
Transformers	-0.52%	-0.77%	-0.39%	0.09%
TFP Change	-0.76%	-1.72%	-0.24%	1.05%

Figure 6.36 AND's output and input percentage point contributions to TFP change, 2023



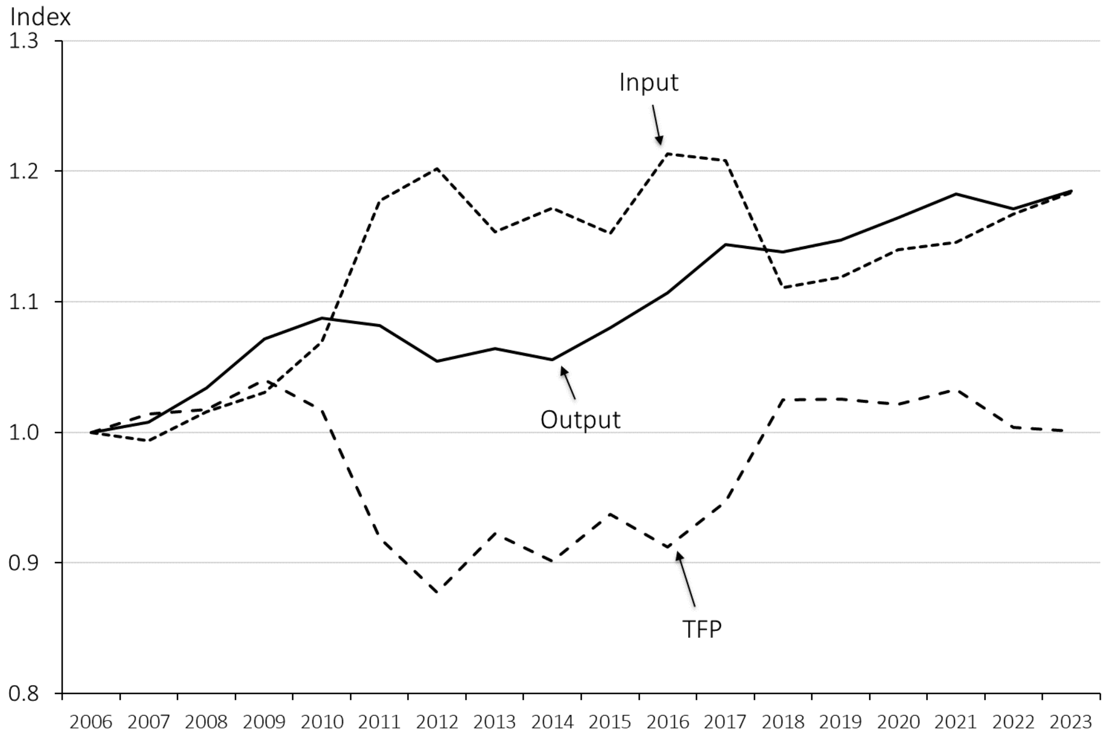
6.10 United Energy (UED)

In 2023, UED delivered 7,607 GWh to 715,652 customers over 13,495 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, 2006–2023



Over the 18-year period 2006 to 2023, 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 1.3 per cent per year from 2012 to 2023.

UED's total output increased over the period from 2006 to 2023 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 2023 (averaging –0.1 per cent per year).

The PFP indexes in Table 6.19 show the following trends:

- Capital PFP *declined* on average over the 18-year period by 0.6 per cent per annum. This decline was concentrated in the period from 2006 to 2012, with an average rate of –1.8 per cent per annum, whereas after 2012 its average rate of change increased by 0.1 per cent per annum.
- Opex PFP increased over the 18-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 3.1 per cent per annum.

Table 6.19 UED's output, input, TFP and PFP indexes, 2006–2023

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	0.994	1.014	1.069	0.981
2008	1.034	1.016	1.018	1.092	0.973
2009	1.072	1.030	1.040	1.113	0.996
2010	1.087	1.069	1.017	1.082	0.978
2011	1.082	1.177	0.919	0.878	0.952
2012	1.054	1.202	0.877	0.851	0.899
2013	1.064	1.154	0.922	0.964	0.898
2014	1.056	1.171	0.901	0.935	0.881
2015	1.080	1.152	0.937	1.008	0.895
2016	1.107	1.213	0.912	0.894	0.927
2017	1.144	1.208	0.947	0.980	0.928
2018	1.138	1.111	1.025	1.230	0.917
2019	1.147	1.119	1.025	1.236	0.915
2020	1.164	1.140	1.021	1.197	0.923
2021	1.183	1.145	1.033	1.221	0.925
2022	1.171	1.167	1.004	1.173	0.907
2023	1.185	1.183	1.001	1.176	0.909
Growth Rate 2006–2023	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 2012–2023	1.1%	-0.1%	1.3%	3.1%	0.1%
Growth Rate 2023	1.1%	1.4%	-0.3%	0.3%	0.2%

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 2023; with a total increase of 9.0 per cent over this period (which is higher than the 6.0 per cent total increase for the industry over the same period).

- UED's energy throughput decreased between 2006 and 2023, averaging an annual rate of –0.2 per cent per annum (the same than industry growth rate). UED's energy throughput in 2023 was 3.9 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 2023, UED's RMD was 24.3 per cent higher than it was in 2006, similar to the 20.0 per cent total increase in RMD for the industry.
- UED's customers increased at an average rate of 0.9 per cent per annum between 2006 and 2023, or 16.8 per cent in total, which is less than the average rate of customer growth for the industry over the same period of 1.3 per cent per annum, or 25.1 per cent in total.
- CMOS increased in the period up to 2012 but subsequently declined. In 2023, UED's level of CMOS was 35.3 per cent *below* its level in 2006. This contrasts to a *decrease* of 3.5 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 2023, and by 2023 opex was 0.7 per cent above its level in 2006, which compares favourably to the total increase of 10.1 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 2.0 per cent per annum.
- Overhead subtransmission and distribution lines in 2023 were 23.9 and 6.0 per cent higher, respectively, than their 2006 level. These increases can be compared to the 7.7 per cent and 3.2 per cent increases, respectively, for the industry over the same period.
- Underground subtransmission and distribution cables in 2023 were 16.8 per cent and 59.2 per cent higher than in 2006 respectively. This can be compared to increases of 35.2 per cent and 71.7 per cent respectively for the industry over the same period.
- UED's quantity of transformers increased, at an average rate of 2.4 per cent per annum over the 18-year period. By 2023, transformer inputs were 49.0 per cent above the 2006 level, which is similar to the increase for the industry (at 44.5 per cent).

Figure 6.38 UED's output quantity indexes, 2006–2023

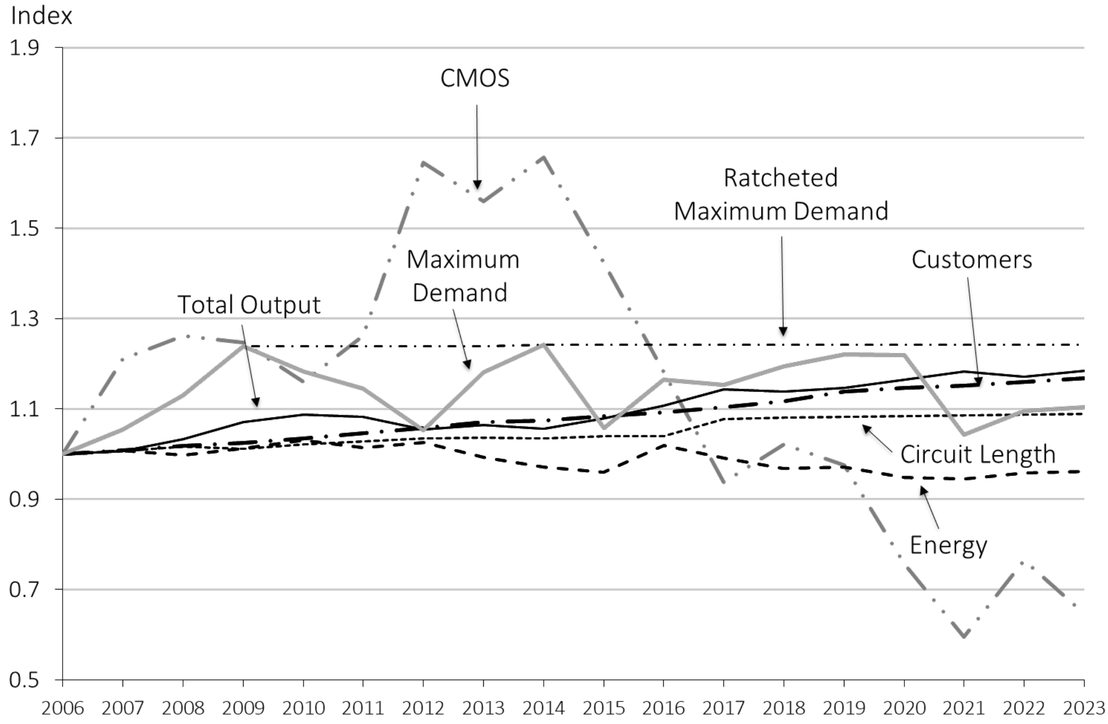
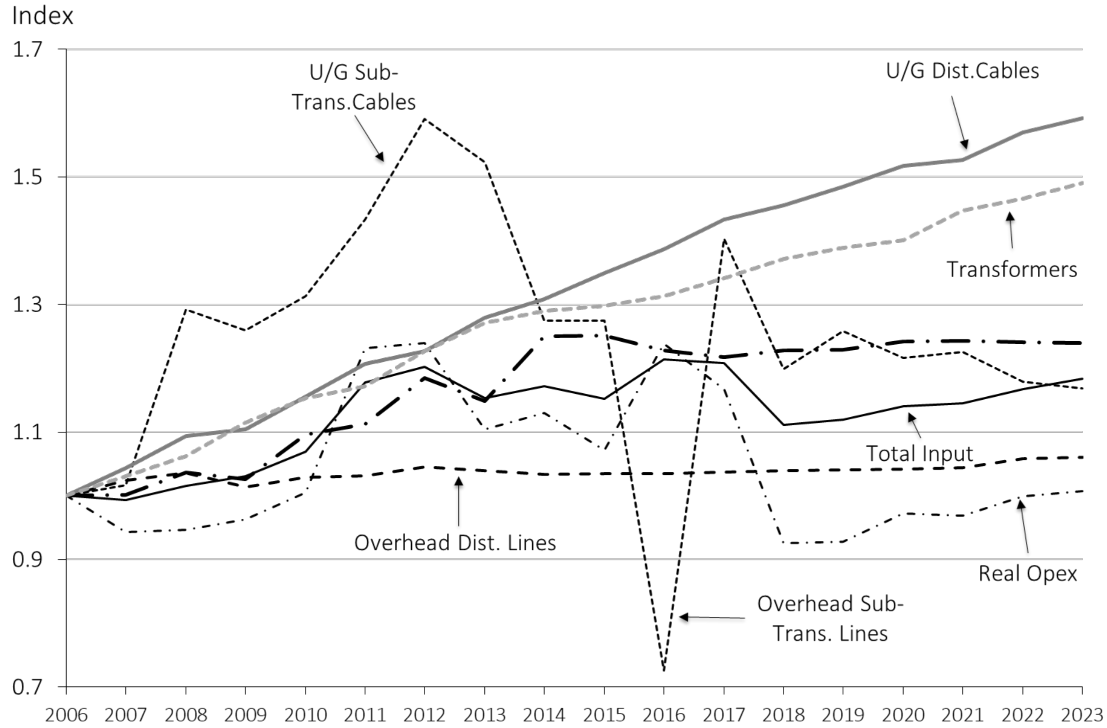


Figure 6.39 UED's input quantity indexes, 2006–2023



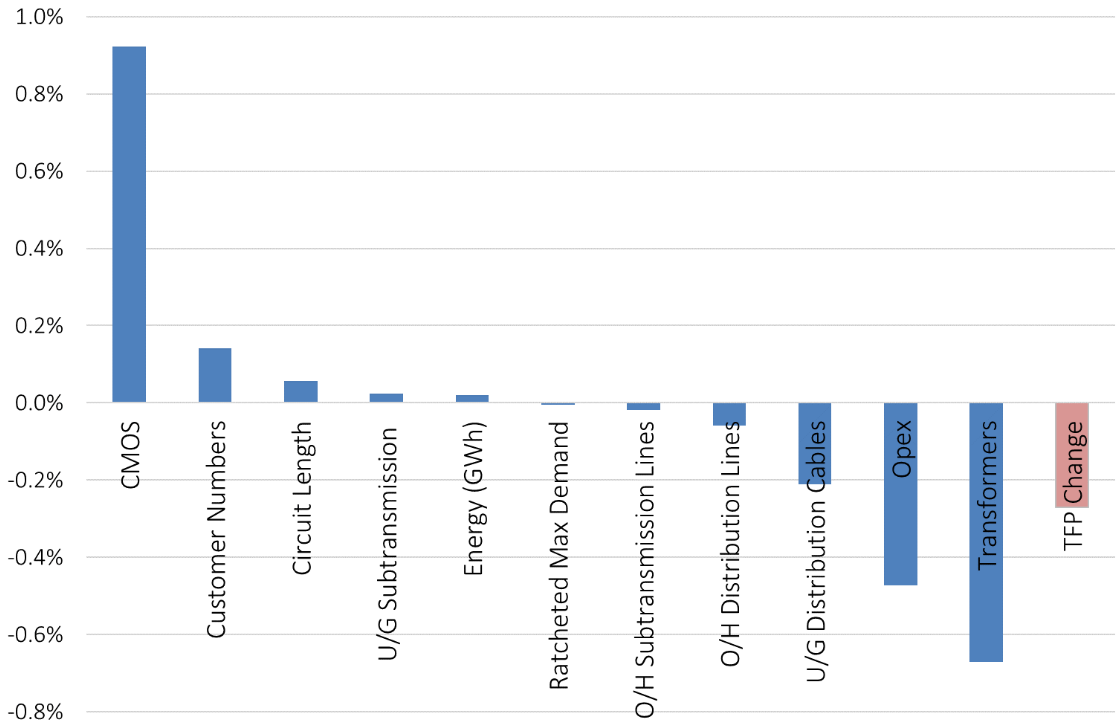
6.10.3 UED's output and input contributions to TFP change

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 18-year period, for the periods up to and after 2012, and for 2023. Figure 6.40 shows the contributions of outputs and inputs to UED's rate of TFP change of –0.3 per cent between 2022 and 2023.

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

Year	*2006 to 2023*	*2006 to 2012*	*2012 to 2023*	*2023*
Energy (GWh)	-0.02%	0.04%	-0.06%	0.02%
Ratcheted Max Demand	0.47%	1.31%	0.01%	0.00%
Customer Numbers	0.19%	0.19%	0.19%	0.14%
Circuit Length	0.22%	0.24%	0.20%	0.06%
CMOS	0.24%	-0.90%	0.86%	0.92%
Opex	-0.01%	-1.44%	0.77%	-0.47%
O/H Subtransmission Lines	-0.08%	-0.17%	-0.03%	-0.02%
O/H Distribution Lines	-0.07%	-0.15%	-0.03%	-0.06%
U/G Subtransmission Cables	-0.01%	-0.14%	0.06%	0.02%
U/G Distribution Cables	-0.26%	-0.31%	-0.23%	-0.21%
Transformers	-0.58%	-0.85%	-0.43%	-0.67%
TFP Change	0.07%	-2.18%	1.30%	-0.27%

Figure 6.40 UED's output and input percentage point contributions to TFP change, 2023



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 234 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 108 observations.

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

where m and n are two adjacent observations;[19] i denotes individual outputs; j denotes individual inputs; and

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

[19] 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;[20]
- 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.[21] 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:

[20] 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.

[21] 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: $g_t^Y = \ln Y_t - \ln Y_{t-1}$.[22] 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

[22] 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.[23] 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 $t-1$ ($Cont^Y_{i,t}$) is given by the following equation:

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

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

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

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

[23] 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 recalibrated 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 2023*)

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	–13.64
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 2023)

Output	*EVO*	*AGD*	*CIT*	*END*	*ENX*	*ERG*	*ESS*
Energy throughput	8.93	9.47	8.94	9.76	9.51	10.91	10.45
Ratcheted max. demand	35.12	37.27	35.17	38.39	37.43	42.92	41.11
Customer numbers	19.27	20.44	19.29	21.06	20.53	23.54	22.55
Circuit length	40.72	43.21	40.77	44.51	43.40	49.76	47.66
CMOS	–4.02	–10.39	–4.16	–13.73	–10.88	–27.13	–21.77
Total	100	100	100	100	100	100	100

Output	*JEN*	*PCR*	*SAP*	*AND*	*TND*	*UED*	*Industry**
Energy throughput	9.24	10.18	10.00	9.86	10.19	9.32	9.88
Ratcheted max. demand	36.37	40.06	39.35	38.81	40.10	36.68	38.87
Customer numbers	19.95	21.97	21.59	21.29	22.00	20.12	21.32
Circuit length	42.17	46.44	45.62	44.99	46.49	42.52	45.06
CMOS	–7.73	–18.65	–16.55	–14.95	–18.77	–8.64	–15.14
Total	100	100	100	100	100	100	100

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; 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 2023)

Input	*EVO*	*AGD*	*CIT*	*END*	*ENX*	*ERG*	*ESS*
Real opex	45.36	36.97	37.59	43.74	43.12	45.24	48.03
O/H Sub–trans. lines	3.04	3.90	0.49	3.77	3.19	8.26	6.05
O/H Distribution lines	10.87	6.26	6.07	8.93	11.06	18.79	17.62
U/G Sub–trans. cables	0.05	5.95	6.03	1.70	4.26	0.39	0.17
U/G Distribution cables	16.44	14.36	30.69	15.23	10.80	2.88	3.24
Transformers	24.24	32.56	19.12	26.63	27.56	24.45	24.88
Total	100	100	100	100	100	100	100

Input	*JEN*	*PCR*	*SAP*	*AND*	*TND*	*UED*	*Industry**
Real opex	45.01	48.92	36.57	42.32	40.22	38.97	42.34
O/H Sub–trans. lines	4.74	3.37	1.84	2.59	0.40	7.26	4.32
O/H Distribution lines	27.47	19.72	10.15	23.73	25.98	21.12	14.16
U/G Sub–trans. cables	0.18	0.09	0.30	0.19	0.32	1.94	2.13
U/G Distribution cables	1.98	10.04	17.18	10.90	10.76	9.48	10.63
Transformers	20.61	17.86	33.96	20.27	22.33	21.24	26.42
Total	100	100	100	100	100	100	100

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

As stated in section 1.1, this report uses a revised definition of Opex which includes capitalised corporate overhead (CCO). This has implications for the calculation on input weights. The reallocation of CCO to Opex means that an equivalent amount needs to be removed from Capex for the purpose of calculating the AUC.

For a specific DNSP, the AUC is equal to the return on capital, depreciation and the benchmark tax liability. From 2006, the RAB is recalculated for the purpose of calculating AUC, by removing capitalised corporate overhead (CCO) from Capex. To this end, CCO is first allocated to each asset category on a pro–rata basis, and then deducted from the Capex of each asset category. Second, the straight-line depreciation of each asset category is then recalculated using the same ratio to the opening RAB as for the original RAB series. The AUC is then calculated using the weighted average cost of capital applied to this alternative RAB series, the restated depreciation and the benchmark tax liability.

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 2023)

Output	*ACT*	*NSW*	*VIC*	*QLD*	*SA*	*TAS*
Energy throughput	8.93	9.82	9.65	10.21	10.00	10.19
Ratcheted max. demand	35.12	38.64	37.97	40.17	39.35	40.10
Customer numbers	19.27	21.20	20.83	22.04	21.59	22.00
Circuit length	40.72	44.79	44.02	46.57	45.62	46.49
CMOS	–4.02	–14.44	–12.47	–18.98	–16.55	–18.77
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 2023)

Input	*ACT*	*NSW*	*VIC*	*QLD*	*SA*	*TAS*
Real opex	45.36	41.97	43.14	44.27	36.57	40.22
O/H Sub–trans. lines	3.04	4.54	3.73	5.85	1.84	0.40
O/H Distribution lines	10.87	10.40	20.49	15.10	10.15	25.98
U/G Sub–trans. cables	0.05	3.20	1.20	2.23	0.30	0.32
U/G Distribution cables	16.44	11.03	11.67	6.65	17.18	10.76
Transformers	24.24	28.86	19.78	25.90	33.96	22.33
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;[24]

$Z = (Z_1, Z_2, \dots, Z_R)$ = a $R \times 1$ vector of operating environment factors;[25] and

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

[24] 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.

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

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

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

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:

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

while the Translog cost frontier may be specified as:

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

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:

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

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

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

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

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:

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

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:

$$c_{it} = \beta_0 + \sum_{m=1}^{M} \beta_m x_{mit} + \lambda_1 t + \nu_{it} + u_i \qquad (11)$$

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:

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

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:

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

where $v_n = (v_{n1}, v_{n2}, \dots, v_{nT})$. 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 Measuring AUC in a changing inflation environment

As discussed in section A3, AUC is used for calculating input index weights. Using the established method of calculation, there has been a sharp fall in AUC values in 2023, with some AUC values being negative. This anomaly appears to be caused by the very large difference in 2023 between:

- the lagged December-on-December CPI inflation outturn used to calculation the Inflation Addition (IA) component of Regulatory Depreciation (7.8 per cent), and
- the market inflation expectations embedded in the Nominal WACC, as evidenced by the relationship between nominal and indexed Commonwealth 10-year bond yields (2.2 per cent).

This section addresses the method adopted in this report to remedy this problem and calculate valid AUC weights.

A5.1 Previously used method for calculating AUC

AUC is the annual economic cost of holding the assets, which is the relevant cost of capital services. The method of calculating AUC follows Jorgenson (1967). The formula for calculating AUC used previously is:

$$AUC_t = NWACC_t \cdot RAB_t^B + RegDep_t + Tax_t \qquad (15)$$

where:

- RAB_t^B is the RAB at the beginning of period t
- $NWACC_t$ is the Nominal Vanilla WACC, and
- Tax_t is the benchmark tax liability, in period t
- *RegDep* is regulatory depreciation defined as:

$$RegDep_t = SLD_t - IA_t \qquad (16)$$

where:

- SLD_t is straight–line depreciation and
- IA_t is the Inflation Addition in period t.

Both IA_t and $NWACC_t$ depend on the rate of inflation, denoted here as $\dot{P}$. The Inflation Addition is defined as:

$$IA_t = RAB_t^B \cdot \dot{P}_t \qquad (17)$$

In the calculation of Inflation Addition, $\dot{P}_t$ is the December quarter on December quarter inflation rate for the previous year. For example, for t = 2023, $\dot{P}_t$ is the percentage change between the December 2021 CPI and the December 2020 CPI.

The Nominal Vanilla WACC can be expressed as:

$$NWACC_t = RWACC_t + \dot{P}_t^* \qquad (18)$$

where $RWACC_t$ is the Real Vanilla WACC, and $\dot{P}_t^*$ is the inflation rate expectation embodied in the nominal WACC.

A5.2 The effect of inflation rates

Using equations (2) to (4) in (1) shows the effect of inflation on the AUC.

$$AUC_t = RWACC_t \cdot RAB_t^B + SLD_t + Tax_t + (\dot{P}_t^* - \dot{P}_t)RAB_t^B \qquad (19)$$

The last term shows the effect of the discrepancy between the inflation rate used to calculate the Inflation Addition and the inflation rate expectation embedded in the Nominal WACC. If $\dot{P}_t^* = \dot{P}_t$, then the inflation rate does not directly affect AUC.

A5.3 Revised approach to calculating AUC

The revised approach is to impose $\dot{P}_t^* = \dot{P}_t$ in equation (19) for the purpose of calculating the AUC used in calculating input index weights for benchmarking. It is important to note that the RAB calculation does not change. The revised formula is:

$$AUC_t = RWACC_t \cdot RAB_t^B + SLD_t + Tax_t \qquad (20)$$

Implementing this formula requires calculating the Real WACC. This is derived from the Nominal WACC using a series for inflation expectations based on a similar method as the AER uses in its regulatory determinations.

From 2006 to 2019, the Nominal WACC is calculated consistent with the AER (2013) *Rate of Return Guideline*, and from 2020 in line with the AER (2018) *Rate of Return Instrument*. The Real WACC is calculated using the formula: $RWACC_t = \left((1 + NWACC_t)/\left(1 + \dot{P}_t^e\right)\right) - 1$, where $\dot{P}_t^e$ is the average rate of expected inflation calculated using AER's standard methods.

The expected rate of inflation is calculated based on the method used by the AER in its Final Position on the Regulatory Treatment of Inflation (2020). The expected rate of inflation is a 5 or 10-year average of the Reserve Bank of Australia's (RBA) headline rate forecasts. This average includes the forecast for 1 and 2 years ahead,[26] the mid–point of the RBA's target band —2.5 per cent— for year 5 or 10, with linear interpolation used from the RBA's forecasts of inflation for years 1 and 2 to the mid-point of the inflation target of 2.5 per cent in year 5 or 10.[27]

[26] The 2006-2008 period uses only a one-year headline rate forecast due to no available T+8 (quarter) forecasts in this period.

[27] From 2006-2019, the forward period over which inflation is averaged is over ten years to match the term of the rate of return. From 2020 onward, this forward period is five years to match the regulatory period.

Appendix B: Regression–based trend growth rates[28]

Table B.1 Output, input, TFP and PFP index trend annual growth rates, 2006–2023

DNSP	*Output*	*Input*	*TFP*	*PFP Index*	
Period	*Index*	*Index*	*Index*	*Opex*	*Capital*
Industry					
Growth Rate 2006–22	0.7%	0.9%	–0.2%	0.9%	–1.0%
Growth Rate 2006–12	1.6%	3.6%	–2.0%	–3.4%	–0.9%
Growth Rate 2012–22	0.5%	–0.3%	0.8%	2.9%	–0.7%
EVO/ACT					
Growth Rate 2006–22	1.7%	1.1%	0.6%	1.1%	0.2%
Growth Rate 2006–12	1.3%	4.1%	–2.8%	–5.7%	–0.5%
Growth Rate 2012–22	1.8%	–0.7%	2.5%	4.7%	0.4%
AGD					
Growth Rate 2006–22	0.5%	–0.2%	0.7%	3.3%	–0.8%
Growth Rate 2006–12	1.1%	3.5%	–2.5%	–4.3%	–1.5%
Growth Rate 2012–22	0.3%	–2.0%	2.3%	6.8%	–0.2%
CIT					
Growth Rate 2006–22	0.8%	1.3%	–0.5%	–0.5%	–0.5%
Growth Rate 2006–12	1.2%	3.8%	–2.7%	–4.8%	–1.5%
Growth Rate 2012–22	0.6%	–0.3%	0.9%	2.1%	0.2%
END					
Growth Rate 2006–22	1.2%	1.3%	–0.1%	1.6%	–1.4%
Growth Rate 2006–12	1.7%	3.2%	–1.5%	–1.3%	–1.8%
Growth Rate 2012–22	1.2%	0.1%	1.1%	3.4%	–0.7%
ENX					
Growth Rate 2006–22	1.3%	1.6%	–0.3%	0.3%	–0.8%
Growth Rate 2006–12	3.6%	4.5%	–0.9%	–1.7%	–0.4%
Growth Rate 2012–22	0.6%	0.2%	0.4%	1.8%	–0.7%
ERG					
Growth Rate 2006–22	0.7%	0.4%	0.2%	1.7%	–1.0%
Growth Rate 2006–12	1.7%	2.6%	–0.9%	–1.1%	–0.7%
Growth Rate 2012–22	–0.1%	–0.4%	0.3%	2.3%	–1.4%
ESS					
Growth Rate 2006–22	0.8%	0.0%	0.8%	2.0%	–0.4%
Growth Rate 2006–12	0.8%	4.1%	–3.4%	–6.0%	–1.0%
Growth Rate 2012–22	0.6%	–1.3%	1.9%	4.2%	–0.3%
JEN					
Growth Rate 2006–22	1.2%	1.2%	–0.1%	–0.1%	–0.1%
Growth Rate 2006–12	2.2%	3.3%	–1.1%	–3.4%	0.9%
Growth Rate 2012–22	1.0%	–0.4%	1.4%	3.5%	–0.3%

[28] 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%	1.7%	-0.7%	-0.4%	-1.0%
Growth Rate 2006–12	1.6%	2.7%	-1.1%	-1.2%	-0.9%
Growth Rate 2012–22	0.9%	0.9%	0.1%	1.2%	-1.0%
SAP					
Growth Rate 2006–22	0.5%	2.0%	-1.5%	-2.1%	-1.2%
Growth Rate 2006–12	1.7%	4.3%	-2.5%	-5.7%	-1.0%
Growth Rate 2012–22	0.2%	1.0%	-0.8%	-0.1%	-1.2%
AND					
Growth Rate 2006–22	0.9%	1.9%	-1.0%	-1.2%	-0.8%
Growth Rate 2006–12	2.7%	4.2%	-1.5%	-3.7%	0.1%
Growth Rate 2012–22	0.5%	0.6%	-0.1%	0.9%	-0.8%
TND/TAS					
Growth Rate 2006–22	0.4%	1.2%	-0.9%	-0.6%	-1.0%
Growth Rate 2006–12	0.5%	4.0%	-3.5%	-6.1%	-1.8%
Growth Rate 2012–22	0.1%	0.9%	-0.9%	-0.8%	-0.9%
UED					
Growth Rate 2006–22	0.9%	0.8%	0.1%	1.1%	-0.5%
Growth Rate 2006–12	1.3%	3.4%	-2.1%	-3.2%	-1.3%
Growth Rate 2012–22	1.2%	-0.2%	1.4%	3.2%	0.2%

Appendix C: Opex Cost Function Regression Results

This appendix presents the detailed results of estimating the models using the revised definition of opex which includes capitalised corporate overheads (presented in section 4).

C1 Full sample results

C1.1 Regression outputs

The models in this section all have 1,098 observations over 61 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 2006–2023 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.536	0.078	6.845
ln(CircLen)	0.228	0.036	6.306
ln(RMDemand)	0.199	0.067	2.982
ln(ShareUGC)	–0.089	0.026	–3.370
Year	0.010	0.002	6.228
Country dummy variables:			
New Zealand	–0.389	0.135	–2.889
Ontario	–0.159	0.133	–1.204
DNSP dummy variables:			
AGD	–0.121	0.196	–0.620
CIT	–0.417	0.149	–2.799
END	–0.276	0.157	–1.759
ENX	–0.299	0.143	–2.083
ERG	–0.090	0.170	–0.531
ESS	–0.274	0.177	–1.554
JEN	–0.340	0.162	–2.093
PCR	–0.657	0.152	–4.317
SAP	–0.625	0.158	–3.950
AND	–0.503	0.150	–3.344
TND	–0.509	0.169	–3.005
UED	–0.585	0.160	–3.649
Constant	–9.478	3.200	–2.962
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 0.96, 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 2006–2023 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.357	0.084	4.257
ln(CircLen)=x2	0.238	0.036	6.635
ln(RMDemand)=x3	0.361	0.07	5.136
x1*x1/2	-0.268	0.55	-0.487
x1*x2	0.261	0.13	2.011
x1*x3	-0.105	0.438	-0.24
x2*x2/2	-0.028	0.046	-0.606
x2*x3	-0.196	0.106	-1.856
x3*x3/2	0.392	0.35	1.12
ln(ShareUGC)	-0.099	0.029	-3.399
Year	0.012	0.002	7.222
Country dummy variables:			
New Zealand	-0.432	0.133	-3.248
Ontario	-0.264	0.131	-2.016
DNSP dummy variables:			
AGD	-0.085	0.201	-0.421
CIT	-0.404	0.149	-2.713
END	-0.326	0.157	-2.075
ENX	-0.294	0.151	-1.949
ERG	-0.24	0.19	-1.264
ESS	-0.446	0.197	-2.27
JEN	-0.198	0.171	-1.158
PCR	-0.736	0.156	-4.711
SAP	-0.717	0.163	-4.394
AND	-0.504	0.156	-3.238
TND	-0.565	0.167	-3.378
UED	-0.436	0.172	-2.54
Constant	-13.058	3.258	-4.008
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 0.96, 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 2006–2023 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.280	0.075	3.746
ln(CircLen)	0.129	0.043	2.975
ln(RMDemand)	0.553	0.076	7.299
ln(ShareUGC)	-0.137	0.032	-4.322
Year	0.010	0.001	11.480
Country dummy variables:			
New Zealand	0.022	0.091	0.240
Ontario	0.089	0.072	1.233
Constant	-11.226	1.848	-6.074
Variance parameters:			
Mu	0.096	0.208	0.464
SigmaU squared	0.082	0.052	1.577
SigmaV squared	0.016	0.001	22.714
LLF			590.009

Table C.4 SFA Translog cost function estimates using 2006–2023 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.318	0.085	3.730
ln(CircLen)=x2	0.166	0.054	3.040
ln(RMDemand)=x3	0.443	0.081	5.460
x1*x1/2	1.203	0.483	2.490
x1*x2	-0.287	0.116	-2.490
x1*x3	-1.089	0.400	-2.720
x2*x2/2	0.073	0.057	1.280
x2*x3	0.351	0.109	3.210
x3*x3/2	0.602	0.342	1.760
ln(ShareUGC)	-0.123	0.044	-2.790
Year	0.010	0.001	9.350
Country dummy variables:			
New Zealand	-0.002	0.074	-0.020
Ontario	0.041	0.088	0.460
Constant	-10.390	2.212	-4.700
Variance parameters:			
Mu	-18.544	161.568	-0.110
SigmaU squared	6.611	55.658	0.119
SigmaV squared	0.015	0.001	22.423
LLF			613.350

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 2006–2023

	SFATLG model			*LSETLG model*		
Sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
Australia	0.071	0.389	0.192	0.212	0.321	0.446
New Zealand	0.465	0.053	0.660	0.662	0.241	0.049
Ontario	0.333	0.140	0.414	0.221	0.198	0.528
Full sample	0.318	0.166	0.443	0.357	0.238	0.361

Table C.6 Average DNSP output elasticities by Aust. DNSP, 2006–2023

	SFATLG model			*LSETLG model*		
Sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
EVO	0.349	0.211	0.217	0.195	0.274	0.480
AGD	0.038	0.492	-0.151	-0.088	0.364	0.697
CIT	0.337	0.276	-0.055	-0.078	0.294	0.725
END	-0.110	0.487	0.142	0.074	0.310	0.607
ENX	-0.005	0.483	-0.006	0.046	0.355	0.581
ERG	-0.583	0.582	0.803	0.557	0.246	0.249
ESS	-0.281	0.499	0.598	0.577	0.315	0.135
JEN	0.664	0.166	-0.174	0.051	0.362	0.505
PCR	-0.021	0.423	0.319	0.371	0.335	0.289
SAP	-0.191	0.484	0.404	0.366	0.312	0.332
AND	0.284	0.325	0.095	0.291	0.372	0.301
TND	-0.049	0.354	0.536	0.413	0.256	0.326
UED	0.492	0.276	-0.233	-0.022	0.379	0.576
Total (Aust.)	0.071	0.389	0.192	0.212	0.321	0.446

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 2023 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 2023, unlike the results of the 2023 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 2006–2023

	SFATLG model			*LSETLG model*		
Sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
Australia	46.2%	0.0%	34.6%	22.2%	0.0%	0.0%
NZ	7.3%	33.9%	0.0%	0.0%	0.0%	40.6%
Ontario	12.3%	20.3%	0.4%	9.4%	0.0%	0.0%
Full sample	17.9%	20.2%	7.6%	9.2%	0.0%	12.7%

Table C.8 Frequency of monotonicity violations by DNSP (Aust.) 2006–2023

	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	11.1%	0.0%	100.0%	100.0%	0.0%	0.0%
CIT	0.0%	0.0%	100.0%	100.0%	0.0%	0.0%
END	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENX	50.0%	0.0%	50.0%	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%	100.0%	0.0%	0.0%	0.0%
PCR	55.6%	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	83.3%	0.0%	0.0%	0.0%	0.0%	0.0%
UED	0.0%	0.0%	100.0%	88.9%	0.0%	0.0%
Total (Aust.)	46.2%	0.0%	34.6%	22.2%	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 do not 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 0.0000. 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 Sample from 2012 to 2023

C2.1 Regression results

This section presents the cost function econometric results using a shorter sample period from 2012 to 2023. 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 2012–2023 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.539	0.079	6.833
ln(CircLen)	0.265	0.034	7.679
ln(RMDemand)	0.163	0.071	2.281
ln(ShareUGC)	–0.084	0.027	–3.153
Year	0.003	0.002	1.489
Country dummy variables:			
New Zealand	–0.408	0.148	–2.765
Ontario	–0.160	0.145	–1.100
DNSP dummy variables:			
AGD	–0.179	0.197	–0.908
CIT	–0.354	0.155	–2.282
END	–0.321	0.164	–1.950
ENX	–0.307	0.154	–1.991
ERG	–0.204	0.178	–1.144
ESS	–0.334	0.183	–1.823
JEN	–0.296	0.162	–1.821
PCR	–0.708	0.158	–4.474
SAP	–0.614	0.163	–3.769
AND	–0.494	0.158	–3.133
TND	–0.536	0.182	–2.954
UED	–0.602	0.169	–3.564
Constant	3.967	4.388	0.904
R–Square			0.995

Table C.10 LSE Translog cost function estimates using 2012–2023 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.301	0.086	3.499
ln(CircLen)=x2	0.279	0.033	8.467
ln(RMDemand)=x3	0.375	0.073	5.136
x1*x1/2	–0.360	0.592	–0.608
x1*x2	0.216	0.133	1.621
x1*x3	–0.061	0.460	–0.133
x2*x2/2	0.030	0.043	0.680
x2*x3	–0.206	0.109	–1.891
x3*x3/2	0.435	0.358	1.213
ln(ShareUGC)	–0.082	0.027	–3.040
Year	0.006	0.002	2.587
Country dummy variables:			
New Zealand	–0.461	0.141	–3.281
Ontario	–0.265	0.138	–1.915
DNSP dummy variables:			
AGD	–0.057	0.196	–0.290
CIT	–0.366	0.150	–2.440
END	–0.330	0.157	–2.102
ENX	–0.214	0.156	–1.374
ERG	–0.395	0.190	–2.077
ESS	–0.489	0.200	–2.449
JEN	–0.099	0.167	–0.591
PCR	–0.698	0.160	–4.357
SAP	–0.661	0.164	–4.034
AND	–0.375	0.164	–2.293
TND	–0.575	0.172	–3.333
UED	–0.378	0.175	–2.164
Constant	–0.683	4.329	–0.158
R–Square			0.995

Table C.11 presents the results for the SFA Cobb–Douglas model over this shorter period of 2012–2023.

Table C.11 SFA Cobb–Douglas cost frontier estimates using 2012–2023 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.251	0.115	2.190
ln(CircLen)	0.307	0.064	4.770
ln(RMDemand)	0.392	0.095	4.130
ln(ShareUGC)	–0.009	0.049	–0.170
Year	0.002	0.001	1.480
Country dummy variables:			
New Zealand	–0.095	0.091	–1.040
Ontario	0.144	0.090	1.600
Constant	5.619	2.960	1.900
Variance parameters:			
Mu	0.276	0.083	3.330
SigmaU squared	0.037	0.013	2.966
SigmaV squared	0.013	0.001	18.251
LLF			452.551

C2.2 Non-convergence of the SFATLG model

The SFATLG truncated normal model did not converge in the short sample using Stata's *xtfrontier* command, assuming a truncated-normal distribution of inefficiencies, and using OLS parameter estimates as starting values for maximum likelihood estimation. In 2023, the short-sample SFATLG also presented difficulties, in that case relating to the reliability of some efficiency score estimates (although the model was excluded on monotonicity grounds).

To examine the non-convergence, we tested 10 scenarios to determine whether it would converge under alternative maximum likelihood algorithms or other parameter starting values. Two scenarios used unchanged initial parameter values but used the Davidon-Fletcher-Powell (DFP) and Broyden-Fletcher-Goldfarb-Shanno (BFGS) algorithms. Eight further scenarios used a range of different initial values for the 'logit-gamma' and 'mu' parameters of the inefficiency distribution, together with the default Modified Newton-Raphson algorithm. In each scenario, a maximum of 5,000 iterations were used. Convergence was not achieved in any of the 10 scenarios.

We also tested the half-normal distribution of inefficiencies which involves restricting the 'mu' parameter to zero. This model did converge. This result suggests that use of the half-normal distribution for inefficiencies, as an alternative to the truncated-normal assumption, should be investigated further in the context of the AER's opex function development work.

Non-convergence implies that the estimation algorithm did not find a stable set of parameter values that satisfy the optimization criteria. This means the parameter estimates can be unreliable, leading to inaccurate or biased cost elasticities and inefficiency estimates, compromising the interpretation of the results, as mentioned in Section 4.1. For the purposes of this report the SFATLG model for the short-sample period has been omitted due to its non-convergence under the truncated-normal assumption.

C2.3 Cost Elasticities

Tables C.12 and C.13 provide information on the average elasticities of real opex with respect to the outputs in the LSE Translog model for the 2012–2023 period.

Table C.12 Average DNSP output elasticities by country 2012–2023

	LSETLG model		
Sample	*Customer numbers*	*Circuit length*	*RMD*
Australia	–0.030	0.381	0.592
New Zealand	0.617	0.325	0.006
Ontario	0.243	0.203	0.519
Full sample	0.301	0.279	0.375

Table C.13 Average DNSP output elasticities by Aust. DNSP, 2012–2023

	LSETLG model		
Sample	*Customer numbers*	*Circuit length*	*RMD*
EVO	0.090	0.294	0.554
AGD	–0.380	0.387	0.920
CIT	–0.185	0.275	0.837
END	–0.185	0.355	0.791
ENX	–0.256	0.401	0.790
ERG	0.242	0.390	0.398
ESS	0.232	0.457	0.297
JEN	–0.096	0.368	0.599
PCR	0.067	0.436	0.443
SAP	0.064	0.415	0.493
AND	0.012	0.451	0.443
TND	0.234	0.342	0.401
UED	–0.230	0.384	0.729
Total (Aust.)	–0.030	0.381	0.592

C2.4 Monotonicity Performance

Tables C.14 and C.15 show the proportions of observations for which there are monotonicity violations in the Translog models. The monotonicity performance of the Translog model estimated over the shorter period is worse than that for the models estimated over the longer period, which is consistent with the 2023 study.

Table C.14 Frequency of monotonicity violations by country 2012–2023

	LSETLG model		
Sample	*Customer numbers*	*Circuit length*	*RMD*
Australia	48.7%	0.0%	0.0%
New Zealand	5.3%	0.0%	57.9%
Ontario	13.8%	0.0%	0.0%
Full sample	18.6%	0.0%	18.0%

Table C.15 Frequency of monotonicity violations by DNSP (Aust.) 2012–2023

	LSETLG model		
Sample	*Customer numbers*	*Circuit length*	*RMD*
EVO	0.0%	0.0%	0.0%
AGD	100.0%	0.0%	0.0%
CIT	100.0%	0.0%	0.0%
END	100.0%	0.0%	0.0%
ENX	100.0%	0.0%	0.0%
ERG	0.0%	0.0%	0.0%
ESS	0.0%	0.0%	0.0%
JEN	100.0%	0.0%	0.0%
PCR	0.0%	0.0%	0.0%
SAP	0.0%	0.0%	0.0%
AND	33.3%	0.0%	0.0%
TND	0.0%	0.0%	0.0%
UED	100.0%	0.0%	0.0%
Total (Aust.)	48.7%	0.0%	0.0%

C2.5 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 2023 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.

In the LSE 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 0.0000. This means that the null hypothesis can be rejected at a significance level of 0.05. This means that the additional terms in the Translog model have a statistically significant relationship with the dependent variable. Hence, the Translog model does 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

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

Year	*2006–2023*	*2006–2012*	*2012–2023*	*2022–2023*
Outputs:				
Energy (GWh)	–0.2%	0.1%	–0.3%	1.2%
Ratcheted Max Demand (MVA)	1.1%	2.3%	0.4%	0.4%
Customer Numbers	1.3%	1.3%	1.3%	1.2%
Circuit Length (km)	0.3%	0.3%	0.3%	0.4%
CMOS	–0.2%	–1.9%	0.7%	–5.5%
Inputs:				
Real Opex ($'000 2006)	0.6%	5.3%	–2.0%	7.0%
O/H Subtran. Lines (MVA–kms)	0.4%	0.8%	0.2%	0.4%
O/H Distr. Lines (MVA–kms)	0.2%	0.1%	0.3%	0.1%
U/G Subtran. Lines (MVA–kms)	1.8%	2.9%	1.2%	–2.4%
U/G Subtran. Lines (MVA–kms)	3.2%	4.0%	2.8%	2.2%
Transformers (MVA)	2.2%	3.6%	1.4%	1.6%
All Capital inputs	1.7%	2.6%	1.3%	1.0%
Partial factor productivity:				
Output / Real Opex	0.3%	–3.6%	2.5%	–5.4%
Output / OH Subtran. Lines	0.5%	0.9%	0.2%	1.2%
Output / OH Distr. Lines	0.7%	1.6%	0.2%	1.5%
Output / UG Subtran. Lines	–0.9%	–1.2%	–0.7%	4.0%
Output / UG Distr. Lines	–2.3%	–2.3%	–2.3%	–0.6%
Output / Transformers	–1.3%	–1.9%	–0.9%	0.0%
Output / Capital	–0.8%	–0.9%	–0.8%	0.5%

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

Year	*2006–2023*	*2006–2012*	*2012–2023*	*2022–2023*
Outputs:				
Energy (GWh)	0.5%	0.8%	0.3%	2.8%
Ratcheted Max Demand (MVA)	2.9%	1.8%	3.5%	16.7%
Customer Numbers	2.1%	1.9%	2.2%	2.0%
Circuit Length (km)	1.2%	1.2%	1.2%	0.4%
CMOS	3.0%	0.7%	4.3%	–15.2%
Inputs:				
Real Opex ($'000 2006)	0.9%	6.5%	–2.2%	–5.2%
O/H Subtran. Lines (MVA–kms)	1.6%	1.8%	1.4%	1.3%
O/H Distr. Lines (MVA–kms)	–0.1%	–0.4%	0.0%	–0.1%
U/G Subtran. Lines (MVA–kms)	8.1%	0.0%	12.5%	0.0%
U/G Subtran. Lines (MVA–kms)	2.3%	2.7%	2.0%	0.9%
Transformers (MVA)	1.6%	2.0%	1.4%	0.0%
All Capital inputs	1.5%	1.7%	1.3%	0.3%

Table D.2 (cont.)

Year	2006–2023	2006–2012	2012–2023	2022–2023
Partial factor productivity:				
Output / Real Opex	0.9%	–5.0%	4.2%	12.8%
Output / OH Subtran. Lines	0.3%	–0.3%	0.6%	6.3%
Output / OH Distr. Lines	2.0%	1.9%	2.0%	7.7%
Output / UG Subtran. Lines	–6.3%	1.5%	–10.5%	7.6%
Output / UG Distr. Lines	–0.4%	–1.2%	0.0%	6.7%
Output / Transformers	0.2%	–0.5%	0.6%	7.6%
Output / Capital	0.4%	–0.2%	0.7%	7.3%

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

Year	2006–2023	2006–2012	2012–2023	2022–2023
Outputs:				
Energy (GWh)	–1.2%	–0.4%	–1.6%	1.4%
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	–1.4%	–0.8%	–1.7%	–22.3%
Inputs:				
Real Opex ($'000 2006)	–2.1%	4.5%	–5.7%	9.8%
O/H Subtran. Lines (MVA–kms)	–0.2%	0.1%	–0.4%	1.0%
O/H Distr. Lines (MVA–kms)	0.7%	–0.2%	1.2%	0.9%
U/G Subtran. Lines (MVA–kms)	0.1%	0.4%	–0.1%	–5.2%
U/G Subtran. Lines (MVA–kms)	1.8%	2.6%	1.4%	0.8%
Transformers (MVA)	1.6%	3.9%	0.3%	0.0%
All Capital inputs	1.3%	2.6%	0.6%	–0.1%
Partial factor productivity:				
Output / Real Opex	2.7%	–3.5%	6.1%	–7.2%
Output / OH Subtran. Lines	0.9%	0.9%	0.8%	1.7%
Output / OH Distr. Lines	–0.1%	1.2%	–0.8%	1.7%
Output / UG Subtran. Lines	0.5%	0.6%	0.5%	7.8%
Output / UG Distr. Lines	–1.2%	–1.6%	–1.0%	1.8%
Output / Transformers	–1.0%	–2.9%	0.1%	2.6%
Output / Capital	–0.7%	–1.6%	–0.2%	2.7%

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

Year	2006–2023	2006–2012	2012–2023	2022–2023
Outputs:				
Energy (GWh)	–0.6%	0.3%	–1.1%	3.1%
Ratcheted Max Demand (MVA)	1.0%	1.7%	0.6%	0.0%
Customer Numbers	1.0%	1.3%	0.9%	0.4%
Circuit Length (km)	0.9%	1.4%	0.6%	0.4%
CMOS	–0.8%	4.0%	–3.6%	–2.4%

Table D.4 (cont.)

Year	*2006–2023*	*2006–2012*	*2012–2023*	*2022–2023*
Inputs:				
Real Opex ($'000 2006)	1.7%	6.3%	–0.9%	6.2%
O/H Subtran. Lines (MVA–kms)	0.1%	–0.3%	0.3%	0.0%
O/H Distr. Lines (MVA–kms)	–0.6%	–0.2%	–0.7%	–0.2%
U/G Subtran. Lines (MVA–kms)	3.9%	5.0%	3.2%	1.4%
U/G Subtran. Lines (MVA–kms)	1.3%	3.3%	0.2%	0.8%
Transformers (MVA)	1.4%	2.1%	1.0%	0.9%
All Capital inputs	1.4%	2.7%	0.6%	0.8%
Partial factor productivity:				
Output / Real Opex	–0.9%	–5.0%	1.5%	–5.6%
Output / OH Subtran. Lines	0.8%	1.5%	0.3%	0.6%
Output / OH Distr. Lines	1.4%	1.5%	1.4%	0.8%
Output / UG Subtran. Lines	–3.0%	–3.8%	–2.6%	–0.8%
Output / UG Distr. Lines	–0.4%	–2.1%	0.5%	–0.2%
Output / Transformers	–0.5%	–0.9%	–0.3%	–0.3%
Output / Capital	–0.5%	–1.5%	0.1%	–0.2%

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

Year	*2006–2023*	*2006–2012*	*2012–2023*	*2022–2023*
Outputs:				
Energy (GWh)	–0.1%	–0.7%	0.2%	1.0%
Ratcheted Max Demand (MVA)	0.8%	1.6%	0.4%	0.0%
Customer Numbers	1.5%	1.0%	1.8%	1.6%
Circuit Length (km)	1.2%	1.1%	1.3%	1.0%
CMOS	0.0%	0.0%	0.1%	–15.4%
Inputs:				
Real Opex ($'000 2006)	0.3%	4.2%	–1.9%	1.0%
O/H Subtran. Lines (MVA–kms)	–0.1%	0.8%	–0.5%	–0.1%
O/H Distr. Lines (MVA–kms)	–0.2%	0.0%	–0.4%	–0.1%
U/G Subtran. Lines (MVA–kms)	5.2%	7.6%	3.9%	–0.1%
U/G Subtran. Lines (MVA–kms)	5.1%	6.6%	4.3%	2.6%
Transformers (MVA)	2.5%	3.3%	2.0%	3.5%
All Capital inputs	2.7%	3.7%	2.1%	2.2%
Partial factor productivity:				
Output / Real Opex	0.9%	–2.9%	3.0%	2.1%
Output / OH Subtran. Lines	1.3%	0.5%	1.7%	3.2%
Output / OH Distr. Lines	1.4%	1.3%	1.5%	3.2%
Output / UG Subtran. Lines	–4.0%	–6.3%	–2.8%	3.3%
Output / UG Distr. Lines	–3.9%	–5.2%	–3.2%	0.6%
Output / Transformers	–1.3%	–2.0%	–0.9%	–0.3%
Output / Capital	–1.5%	–2.3%	–1.0%	0.9%

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

Year	*2006–2023*	*2006–2012*	*2012–2023*	*2022–2023*
Outputs:				
Energy (GWh)	0.3%	0.5%	0.2%	2.0%
Ratcheted Max Demand (MVA)	1.6%	3.8%	0.5%	0.0%
Customer Numbers	1.6%	1.7%	1.6%	2.0%
Circuit Length (km)	1.1%	1.6%	0.8%	0.7%
CMOS	–1.7%	–9.8%	2.7%	–17.9%
Inputs:				
Real Opex ($'000 2006)	2.2%	6.4%	–0.1%	7.9%
O/H Subtran. Lines (MVA–kms)	1.3%	2.4%	0.8%	–0.2%
O/H Distr. Lines (MVA–kms)	0.2%	0.4%	0.0%	0.0%
U/G Subtran. Lines (MVA–kms)	4.0%	8.5%	1.5%	0.2%
U/G Subtran. Lines (MVA–kms)	3.9%	6.3%	2.5%	1.7%
Transformers (MVA)	2.5%	4.2%	1.5%	0.8%
All Capital inputs	2.3%	4.0%	1.4%	0.7%
Partial factor productivity:				
Output / Real Opex	–0.4%	–2.4%	0.7%	–4.8%
Output / OH Subtran. Lines	0.5%	1.6%	–0.1%	3.2%
Output / OH Distr. Lines	1.7%	3.7%	0.6%	3.0%
Output / UG Subtran. Lines	–2.1%	–4.4%	–0.9%	2.8%
Output / UG Distr. Lines	–2.0%	–2.3%	–1.9%	1.3%
Output / Transformers	–0.6%	–0.1%	–0.9%	2.2%
Output / Capital	–0.5%	0.0%	–0.7%	2.3%

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

Year	*2006–2023*	*2006–2012*	*2012–2023*	*2022–2023*
Outputs:				
Energy (GWh)	0.2%	0.3%	0.1%	0.6%
Ratcheted Max Demand (MVA)	0.8%	2.4%	0.0%	0.0%
Customer Numbers	1.4%	1.9%	1.1%	1.3%
Circuit Length (km)	0.2%	0.6%	0.0%	0.2%
CMOS	–0.5%	–2.3%	0.5%	–10.8%
Inputs:				
Real Opex ($'000 2006)	–0.7%	2.5%	–2.5%	12.5%
O/H Subtran. Lines (MVA–kms)	0.2%	1.7%	–0.6%	0.3%
O/H Distr. Lines (MVA–kms)	1.0%	1.1%	0.9%	1.5%
U/G Subtran. Lines (MVA–kms)	3.3%	6.3%	1.7%	–0.1%
U/G Subtran. Lines (MVA–kms)	4.5%	8.9%	2.1%	2.1%
Transformers (MVA)	2.4%	2.9%	2.2%	5.1%
All Capital inputs	1.7%	2.4%	1.3%	2.9%

Table D.7 (cont.)

Year	*2006–2023*	*2006–2012*	*2012–2023*	*2022–2023*
Partial factor productivity:				
Output / Real Opex	1.8%	0.2%	2.7%	–8.7%
Output / OH Subtran. Lines	0.9%	1.1%	0.8%	3.6%
Output / OH Distr. Lines	0.1%	1.7%	–0.8%	2.4%
Output / UG Subtran. Lines	–2.2%	–3.5%	–1.5%	4.0%
Output / UG Distr. Lines	–3.4%	–6.2%	–1.9%	1.8%
Output / Transformers	–1.4%	–0.1%	–2.1%	–1.2%
Output / Capital	–0.6%	0.4%	–1.2%	1.0%

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

Year	*2006–2023*	*2006–2012*	*2012–2023*	*2022–2023*
Outputs:				
Energy (GWh)	0.3%	–0.2%	0.6%	1.6%
Ratcheted Max Demand (MVA)	1.3%	0.8%	1.6%	0.0%
Customer Numbers	1.0%	0.8%	1.1%	0.3%
Circuit Length (km)	–0.2%	–0.7%	0.1%	0.1%
CMOS	–0.7%	–2.9%	0.5%	2.0%
Inputs:				
Real Opex ($'000 2006)	0.7%	8.8%	–3.8%	7.7%
O/H Subtran. Lines (MVA–kms)	0.7%	–0.3%	1.2%	–0.1%
O/H Distr. Lines (MVA–kms)	–0.3%	–1.3%	0.3%	0.2%
U/G Subtran. Lines (MVA–kms)	2.7%	–3.6%	6.2%	5.3%
U/G Subtran. Lines (MVA–kms)	2.0%	0.1%	3.0%	2.7%
Transformers (MVA)	2.1%	4.1%	1.0%	1.2%
All Capital inputs	1.1%	1.6%	0.9%	0.7%
Partial factor productivity:				
Output / Real Opex	0.3%	–7.8%	4.7%	–7.9%
Output / OH Subtran. Lines	0.3%	1.3%	–0.3%	–0.1%
Output / OH Distr. Lines	1.2%	2.3%	0.6%	–0.3%
Output / UG Subtran. Lines	–1.8%	4.7%	–5.3%	–5.5%
Output / UG Distr. Lines	–1.0%	0.9%	–2.1%	–2.9%
Output / Transformers	–1.2%	–3.1%	–0.1%	–1.4%
Output / Capital	–0.2%	–0.6%	0.0%	–0.8%

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

Year	*2006–2023*	*2006–2012*	*2012–2023*	*2022–2023*
Outputs:				
Energy (GWh)	0.1%	0.3%	0.0%	2.7%
Ratcheted Max Demand (MVA)	1.4%	3.3%	0.3%	0.0%
Customer Numbers	1.6%	1.1%	1.8%	1.2%
Circuit Length (km)	1.1%	1.1%	1.2%	1.2%
CMOS	–1.9%	–4.2%	–0.6%	–15.9%

Table D.9 (cont.)

Year	*2006–2023*	*2006–2012*	*2012–2023*	*2022–2023*
Inputs:				
Real Opex ($'000 2006)	0.8%	6.1%	–2.3%	6.8%
O/H Subtran. Lines (MVA–kms)	0.9%	1.0%	0.8%	–0.5%
O/H Distr. Lines (MVA–kms)	0.2%	–0.2%	0.4%	0.5%
U/G Subtran. Lines (MVA–kms)	3.1%	–0.4%	5.2%	0.0%
U/G Subtran. Lines (MVA–kms)	4.8%	4.8%	4.7%	4.8%
Transformers (MVA)	2.6%	3.3%	2.1%	1.5%
All Capital inputs	1.3%	1.3%	1.3%	0.8%
Partial factor productivity:				
Output / Real Opex	0.7%	–3.8%	3.2%	–4.8%
Output / OH Subtran. Lines	0.6%	1.4%	0.2%	2.5%
Output / OH Distr. Lines	1.3%	2.5%	0.6%	1.5%
Output / UG Subtran. Lines	–1.7%	2.7%	–4.2%	2.0%
Output / UG Distr. Lines	–3.3%	–2.5%	–3.7%	–2.8%
Output / Transformers	–1.1%	–1.0%	–1.2%	0.6%
Output / Capital	0.2%	1.1%	–0.3%	1.2%

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

Year	*2006–2023*	*2006–2012*	*2012–2023*	*2022–2023*
Outputs:				
Energy (GWh)	0.5%	1.0%	0.2%	0.6%
Ratcheted Max Demand (MVA)	1.6%	3.3%	0.6%	0.0%
Customer Numbers	2.0%	1.9%	2.0%	2.0%
Circuit Length (km)	0.5%	0.4%	0.5%	0.6%
CMOS	2.0%	3.0%	1.4%	8.3%
Inputs:				
Real Opex ($'000 2006)	1.5%	2.7%	0.8%	11.4%
O/H Subtran. Lines (MVA–kms)	0.2%	0.1%	0.2%	1.0%
O/H Distr. Lines (MVA–kms)	0.1%	0.1%	0.1%	0.0%
U/G Subtran. Lines (MVA–kms)	9.3%	5.9%	11.3%	–1.6%
U/G Subtran. Lines (MVA–kms)	5.7%	5.9%	5.5%	5.0%
Transformers (MVA)	2.7%	3.0%	2.5%	3.0%
All Capital inputs	2.1%	2.3%	2.1%	2.1%
Partial factor productivity:				
Output / Real Opex	–0.5%	–1.2%	–0.1%	–12.1%
Output / OH Subtran. Lines	0.8%	1.3%	0.4%	–1.7%
Output / OH Distr. Lines	0.8%	1.4%	0.5%	–0.6%
Output / UG Subtran. Lines	–8.4%	–4.4%	–10.6%	1.0%
Output / UG Distr. Lines	–4.7%	–4.5%	–4.9%	–5.6%
Output / Transformers	–1.7%	–1.6%	–1.8%	–3.7%
Output / Capital	–1.2%	–0.8%	–1.4%	–2.7%

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

Year	*2006–2023*	*2006–2012*	*2012–2023*	*2022–2023*
Outputs:				
Energy (GWh)	–0.6%	0.1%	–1.1%	0.3%
Ratcheted Max Demand (MVA)	0.8%	2.4%	0.0%	0.0%
Customer Numbers	1.1%	1.3%	0.9%	0.9%
Circuit Length (km)	0.4%	0.5%	0.3%	0.3%
CMOS	0.5%	–1.7%	1.8%	5.9%
Inputs:				
Real Opex ($'000 2006)	3.3%	6.3%	1.6%	15.1%
O/H Subtran. Lines (MVA–kms)	0.5%	0.5%	0.5%	–0.1%
O/H Distr. Lines (MVA–kms)	–0.1%	0.0%	–0.1%	–0.2%
U/G Subtran. Lines (MVA–kms)	1.7%	2.1%	1.4%	0.9%
U/G Subtran. Lines (MVA–kms)	2.9%	3.3%	2.7%	2.1%
Transformers (MVA)	2.1%	3.6%	1.3%	1.0%
All Capital inputs	1.9%	2.7%	1.4%	1.0%
Partial factor productivity:				
Output / Real Opex	–2.7%	–4.6%	–1.7%	–15.7%
Output / OH Subtran. Lines	0.1%	1.2%	–0.5%	–0.5%
Output / OH Distr. Lines	0.7%	1.8%	0.0%	–0.4%
Output / UG Subtran. Lines	–1.1%	–0.4%	–1.5%	–1.5%
Output / UG Distr. Lines	–2.3%	–1.5%	–2.7%	–2.7%
Output / Transformers	–1.5%	–1.8%	–1.3%	–1.6%
Output / Capital	–1.3%	–1.0%	–1.4%	–1.6%

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

Year	*2006–2023*	*2006–2012*	*2012–2023*	*2022–2023*
Outputs:				
Energy (GWh)	0.2%	0.4%	0.0%	0.0%
Ratcheted Max Demand (MVA)	1.6%	3.0%	0.8%	0.0%
Customer Numbers	1.8%	1.7%	1.8%	1.7%
Circuit Length (km)	0.7%	0.9%	0.6%	0.6%
CMOS	1.1%	–5.2%	4.8%	10.8%
Inputs:				
Real Opex ($'000 2006)	2.7%	7.2%	0.1%	–4.9%
O/H Subtran. Lines (MVA–kms)	0.9%	1.2%	0.8%	2.8%
O/H Distr. Lines (MVA–kms)	–0.2%	0.4%	–0.4%	–2.5%
U/G Subtran. Lines (MVA–kms)	6.8%	2.3%	9.3%	–5.9%
U/G Subtran. Lines (MVA–kms)	4.8%	5.3%	4.6%	3.1%
Transformers (MVA)	2.4%	3.7%	1.7%	0.5%
All Capital inputs	1.8%	2.6%	1.4%	–0.3%

Table D.12 (cont.)

Year	*2006–2023*	*2006–2012*	*2012–2023*	*2022–2023*
Partial factor productivity:				
Output / Real Opex	–1.4%	–4.4%	0.2%	4.0%
Output / OH Subtran. Lines	0.3%	1.6%	–0.5%	–3.7%
Output / OH Distr. Lines	1.4%	2.5%	0.7%	1.6%
Output / UG Subtran. Lines	–5.5%	0.6%	–9.1%	5.0%
Output / UG Distr. Lines	–3.6%	–2.4%	–4.3%	–4.0%
Output / Transformers	–1.2%	–0.9%	–1.4%	–1.5%
Output / Capital	–0.6%	0.2%	–1.1%	–0.6%

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

Year	*2006–2023*	*2006–2012*	*2012–2023*	*2022–2023*
Outputs:				
Energy (GWh)	0.2%	–0.5%	0.6%	1.1%
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%	0.2%	0.7%
CMOS	2.2%	5.0%	0.7%	–12.7%
Inputs:				
Real Opex ($'000 2006)	1.1%	6.0%	–1.6%	–7.6%
O/H Subtran. Lines (MVA–kms)	–0.2%	0.1%	–0.3%	–0.2%
O/H Distr. Lines (MVA–kms)	0.6%	0.6%	0.6%	0.6%
U/G Subtran. Lines (MVA–kms)	3.6%	9.2%	0.5%	–0.1%
U/G Subtran. Lines (MVA–kms)	1.3%	1.6%	1.2%	1.9%
Transformers (MVA)	2.3%	4.0%	1.4%	2.1%
All Capital inputs	1.4%	2.2%	1.0%	1.3%
Partial factor productivity:				
Output / Real Opex	–0.8%	–5.7%	1.8%	11.0%
Output / OH Subtran. Lines	0.4%	0.2%	0.5%	3.6%
Output / OH Distr. Lines	–0.4%	–0.3%	–0.4%	2.7%
Output / UG Subtran. Lines	–3.4%	–9.0%	–0.3%	3.4%
Output / UG Distr. Lines	–1.1%	–1.3%	–1.0%	1.5%
Output / Transformers	–2.1%	–3.8%	–1.2%	1.3%
Output / Capital	–1.2%	–1.9%	–0.8%	2.1%

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

Year	*2006–2023*	*2006–2012*	*2012–2023*	*2022–2023*
Outputs:				
Energy (GWh)	–0.2%	0.4%	–0.6%	0.2%
Ratcheted Max Demand (MVA)	1.3%	3.6%	0.0%	0.0%
Customer Numbers	0.9%	0.9%	0.9%	0.8%
Circuit Length (km)	0.5%	0.6%	0.5%	0.2%
CMOS	–2.6%	8.3%	–8.9%	–16.8%

Table D.14 (cont.)

Year	*2006–2023*	*2006–2012*	*2012–2023*	*2022–2023*
Inputs:				
Real Opex ($'000 2006)	0.0%	3.6%	–2.0%	0.9%
O/H Subtran. Lines (MVA–kms)	1.3%	2.8%	0.4%	–0.1%
O/H Distr. Lines (MVA–kms)	0.4%	0.7%	0.1%	0.2%
U/G Subtran. Lines (MVA–kms)	0.9%	7.7%	–2.9%	–0.9%
U/G Subtran. Lines (MVA–kms)	2.8%	3.4%	2.5%	1.4%
Transformers (MVA)	2.4%	3.4%	1.9%	1.7%
All Capital inputs	1.6%	2.7%	1.0%	0.9%
Partial factor productivity:				
Output / Real Opex	1.0%	–2.7%	3.1%	0.3%
Output / OH Subtran. Lines	–0.3%	–1.9%	0.7%	1.2%
Output / OH Distr. Lines	0.7%	0.1%	1.0%	1.0%
Output / UG Subtran. Lines	0.1%	–6.9%	4.1%	2.1%
Output / UG Distr. Lines	–1.8%	–2.5%	–1.4%	–0.3%
Output / Transformers	–1.4%	–2.5%	–0.7%	–0.6%
Output / Capital	–0.6%	–1.8%	0.1%	0.2%

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