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Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Annual Benchmarking Report

Report prepared for Australian Energy Regulator

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Contents

Acronyms & Abbreviations

TNSP names

Abbreviation	*TNSP name*	*State*
ANT	AusNet Services Transmission	Victoria
ENT	ElectraNet	South Australia
PLK	Powerlink	Queensland
TNT	TasNetworks Transmission	Tasmania
TRG	TransGrid	New South Wales

Other Abbreviations

Abbreviation	*Description*
AEMO	Australian Energy Market Operator
AUC	Annual user cost of capital
CAM	Cost allocation methodology
EBRIN	Economic Benchmarking Regulatory Information Notice
ENS	Energy Not Supplied
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
TFP	Total factor productivity
TNSP	Transmission network service provider
VCR	Value of customer reliability

1 Introduction

Quantonomics has been asked by the Australian Energy Regulator (AER) to update the electricity transmission network service provider (TNSP) multilateral total factor productivity (MTFP) and multilateral partial factor productivity (MPFP) results presented in the AER's 2022 TNSP Benchmarking Report (AER 2022). This annual update closely follows the methods used previously by Economic Insights (2021). It includes data for the 2021-22 financial years ending June or March (as relevant) reported by the TNSPs 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 TNSP productivity change by quantifying the contribution of each individual output and input to total factor productivity (TFP) change.

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 briefly described below.

1.2 Specifications Used for Productivity Measurement

This report measures TFP using the multilateral Törnqvist TFP (MTFP) index method developed by Caves, Christensen and Diewert (1982), and explained in Appendix A. This method is used for the industry TFP indexes presented in chapter 2, the multilateral comparisons of productivity in chapter 3, and the individual TNSP indexes in chapter 4.

When the MTFP method is applied to data for a single TNSP, it provides information on the *changes over time* in productivity for the TNSP. The industry-level analysis in chapter 2 and the analysis of individual TNSPs in chapter 4, examine patterns of output, input and productivity over time. An analysis of *comparative productivity levels* of TNSPs is presented in chapter 3.

1.2.1 Defining Outputs

The output index for TNSPs is defined to include five outputs:[1]

(a) Energy throughput in GWh (with 14.9 per cent share of gross revenue),

(b) Ratcheted maximum demand (RMD) in Megawatts (MW) (with 24.7 per cent share of gross revenue),

(c) End-user numbers (with 7.6 per cent share of gross revenue),

[1] An exception arises in relation to Figure 2.1, and Figures 4.1, 4.5, 4.9, 4.13, and 4.17, which also show, for comparison, output and TFP indexes when output is defined to include only four outputs, not including Energy Not Supplied.

(d) Circuit length in kms (with 52.8 per cent share of gross revenue), and

(e) (minus) Energy not supplied (ENS) in MWh (with the weight based on current AER estimates of the Value of Customer Reliability (VCR) capped at a maximum absolute value of 2.5 per cent of total revenue).

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

Energy throughput is a measure of the size of the transport task. If an analogy to a road network is used, there is a distinction between the provision of the network (which has capacity, length and connectivity dimensions) and the amount of traffic, which influences maintenance requirements and the timing of asset renewal. Energy throughput is analogous to the latter. Important functions of a network include: the provision of capacity (i.e., the amount of flow that can be accommodated at particular points or over particular segments on the network); the spatial extension of the network which permits the energy to be transported over a given distance between specific places; and connectivity, which influences the complexity of the layout of a network. RMD is a measure of capacity. End-user numbers is an indicator of network connectivity or complexity. Circuit length is a measure of the spatial dimension of the supply activity.

The weights applied to non-reliability outputs are based on the estimated proportion of cost each output accounts for. These are derived from the coefficients of an econometrically-estimated Leontief cost function. This cost analysis was carried out by Economic Insights (2020b) and the same weights are used in this study. This report does not repeat that analysis because the weights are intended to be held constant for several years before updating them (Economic Insights 2020b, 1–2).

As discussed in more detail in Appendix A (section A3.2), the weight applying to the reliability output is based on the cost to end-users caused by lost supply; the quantity of ENS for each TNSP multiplied by the VCR in $/MWh, which varies by State. The VCR was estimated by the AER for 2019 (AER 2019b, p. 71), and is adjusted by CPI in all other years of the data sample.

1.2.2 Defining Inputs

There are four TNSP inputs:

(a) Operating expenditure (opex) in $'000 (2006 prices) (total opex deflated by a composite labour, materials and services price index), making up 27.8 per cent of total cost on average,

(b) Overhead lines (quantity proxied by overhead MVAkms), making 26.21 per cent of total cost on average,

(c) Underground cables (quantity proxied by underground MVAkms), making 1.63 per cent of total cost on average, and

(d) Transformers and other capital (quantity proxied by transformer MVA), making 44.17 per cent of total cost 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 (d) are together the 'capital inputs'. The capital inputs are aggregated for the purpose of calculating indexes of capital inputs and partial factor productivities (PFPs) for capital inputs.

As discussed in Economic Insights (2013), non-capital inputs are those consumed in a given year, whereas capital inputs are the productive services within the year from durable assets that last several years. Measuring the quantity of non-capital inputs is relatively straight-forward, being the cost of labour, materials and services purchased in the year, deflated by an index of the prices of these inputs. Measurement of capital inputs raises more complicated conceptual issues. The method adopted by Economic Insights, which is well established in the productivity literature, is to assume that the flow of productive services from capital is proportionate to the quantity of capital measured in appropriate physical units.

The weights applied to each input are based on estimated shares of total cost which each input accounts for. The cost of the non-capital input is measured by nominal opex. For the capital inputs taken together, the annual user cost of capital (AUC) is taken to be the return on capital, the return of capital and the benchmark tax liability, all calculated in a broadly similar way to that used in forming the building blocks revenue requirement. The AUC is calculated by asset class for each year using asset value data reported by TNSPs. The calculation of the weighted average cost of capital (WACC) for 2020, 2021 and 2022 reflect the AER's Rate of Return Instrument 2018 (AER 2018:13–16 Table 1, col. 3).[2] 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 A3.4) for further discussion on the input weights.

An opex price index is calculated from published ABS price indexes that approximate components of electricity TNSP costs, and it is used to deflate nominal opex to derive real opex. The opex price index differs depending on whether the TNSP reports data in financial April-to-March years for AusNet Services Transmission (AusNet) or July-to-June years (all

[2] 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.

other TNSPs). For the industry as a whole, a weighted average regulatory year opex price index is used.[3]

1.3 Limitations

Economic Insights (2020b) suggested caution when using the TNSP economic benchmarking results to compare productivity levels across TNSPs given the difficulty of specifying the outputs. Nevertheless, it noted the ongoing development and refinement of TNSP economic benchmarking, including in the 2020 report.

This study uses EBRIN data, which is generally of high quality. The main limitation of the study is that the TNSPs included in the sample may not be fully comparable as they operate in different operating environments which can influence the ability of an efficient TNSP to transform inputs into outputs. The index analysis presented in this report does not explicitly take account of operating environment factors, although the multilateral index method does so to some extent, because the weights applied to inputs vary between TNSPs, reflecting both their own cost shares as well as industry average cost shares. Nevertheless, operating environment factors are not fully accounted for in this benchmarking analysis.

1.4 TNSP comments on draft report

There were some minor changes in the report to address the TNSPs' suggestions. Comments that are addressed in this report include Powerlink's recommendation that "the columns labelled AVG (the arithmetic average of the TNSP multilateral indices) be removed from Tables 3.1, 3.2 and 3.3" to improve interpretation of the data.

Comments that are noted include criticisms by ElectraNet that the "output measures used in the analysis do a poor job of capturing the output of a modern TNSP." ElectraNet is also "troubled by the volatility in the outputs, in particular we have lost three places in terms of MTFP due, it appears, to a return to more normal storm conditions (and thus ENS)".

We acknowledge the ENS output can introduce volatility to the results. In the 2020 report, specific actions were taken to mitigate this issue, including the implementation of the Multilateral Törnqvist index method and the capping of the weight attributed to ENS at 2.5 per cent of total revenue. However, the decline in ElectraNet's ranking by three positions is not solely attributed to ENS volatility. It is also influenced by the improved productivity of other TNSPs. Moreover, the average annual rate of change in Electra's TFP index from 2012 to 2022 is –1.0 per cent, whereas if we exclude ENS from the calculation, this figure shifts only slightly to –1.1 per cent. This highlights how reporting average annual rates of change over

[3] The weights attached to the financial and calendar years are based on the opex quantities of each of the TNSPs. The weighted average opex price index is calculated as: the sum of all TNSPs' nominal opex divided by the sum of all TNSPs' real opex.

several years serves to mitigate the volatility of ENS. Furthermore, for comparison, we report TFP results when ENS is excluded.

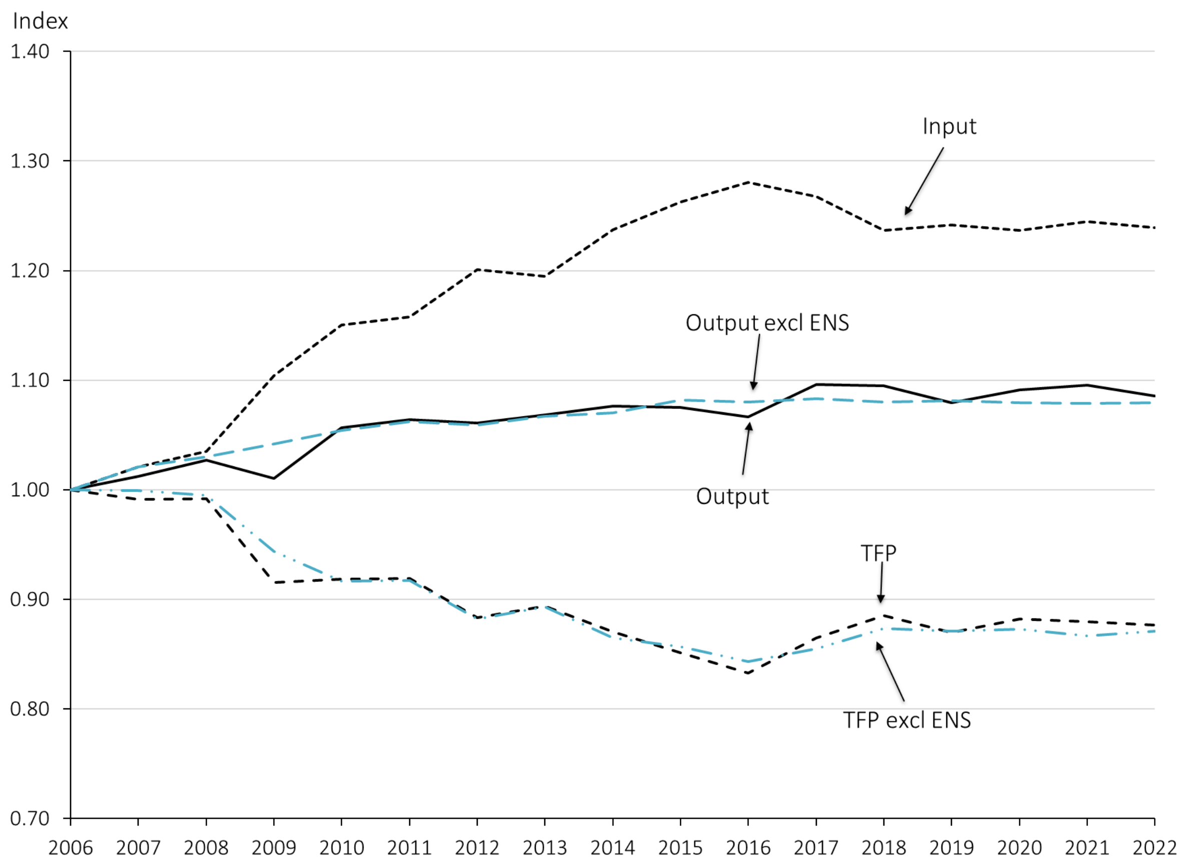
2 Industry–level Transmission Productivity Results

This chapter presents output, input and TFP indexes for the electricity transmission industry after aggregating across the five TNSPs; AusNet Services Transmission (ANT); ElectraNet (ENT); Powerlink (PLK); TasNetworks Transmission (TNT); and TransGrid (TRG).

2.1 Industry TFP

Transmission industry-level total output, total input and TFP indexes are presented in Figure 2.1 and Table 2.1. Opex and capital PFP indexes are also presented in Table 2.1. Figure 2.1 shows, for comparison, the industry output and TFP indexes if ENS was not included as an output. This highlights the effects of the ENS on movements in output and TFP.

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



Over the 17-year period 2006 to 2022, industry level TFP *declined* at an average annual rate of 0.8 per cent. Although total output increased by an average annual rate of 0.5 per cent, total input use increased faster, at a rate of 1.3 per cent. Since the average rate of change in TFP is equal to the average rate of change in total output less the average rate of change in total inputs, this produced a negative average rate of productivity change. TFP change was, however, positive in seven of the 17 years (2008, 2010, 2011, 2013, 2017, 2018 and 2020). In some instances (e.g., 2010), there was an abnormally high growth of output which resulted in TFP growth despite increased use of inputs. In some years (e.g., 2017), there was a combination of reduced inputs and stronger output growth. In several instances (e.g., 2018 and 2020) there were larger reductions in input use which resulted in strong TFP growth. In 2022, the input usage experienced a decline of 0.5 per cent; however, the decline in output growth was greater at 0.9 per cent, resulting in an annual rate of TFP growth of –0.4 per cent for the industry overall.

The average rate of growth of the industry output index from 2012 to 2022 is slightly lower than the 2006-2022 period at 0.2 per cent per year. Similarly, the average rate of growth of the industry input index from 2012 to 2022 is lower than the 2006-2022 period at 0.3 per cent per year. Consequently, the average annual rate of TFP growth from 2012 to 2022 was –0.1 per cent. The same TFP result is observed for the same period when ENS is excluded. However, in 2022, TFP increased by 0.5 per cent when ENS is excluded, compared to a decrease of 0.4 per cent when ENS is included.

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

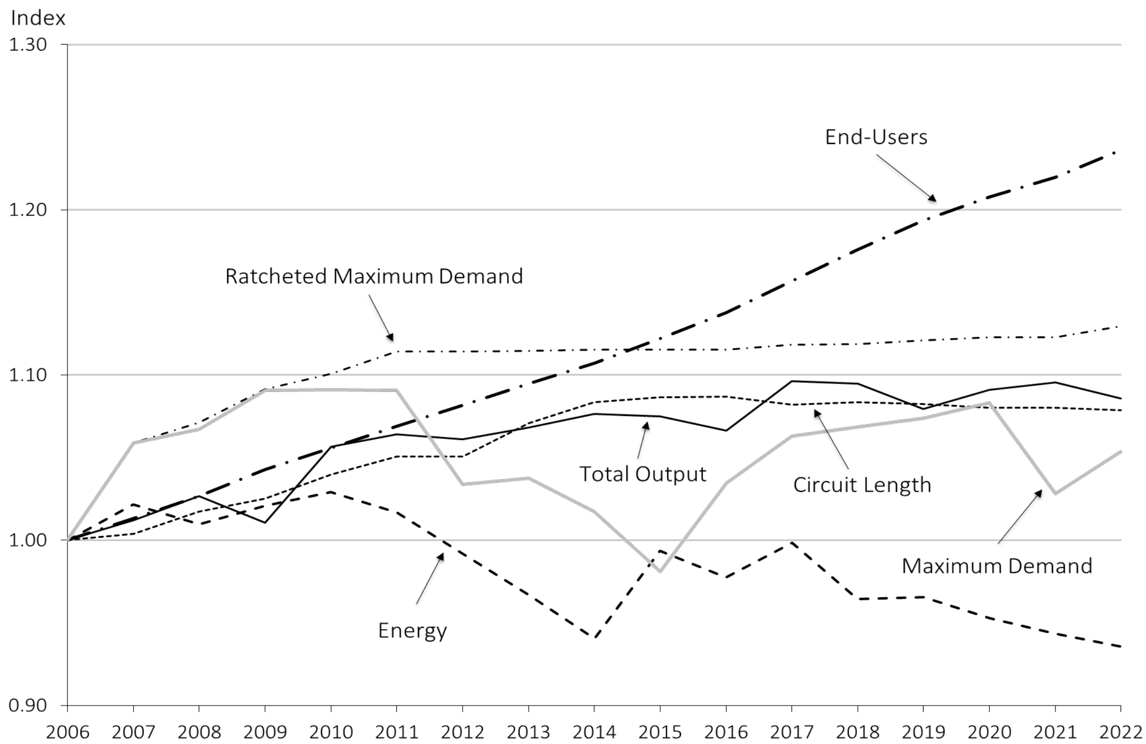
Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.012	1.021	0.991	1.011	0.983
2008	1.027	1.035	0.992	1.031	0.977
2009	1.010	1.104	0.915	0.990	0.884
2010	1.057	1.150	0.919	0.988	0.890
2011	1.064	1.158	0.919	1.046	0.871
2012	1.061	1.201	0.884	1.014	0.835
2013	1.068	1.195	0.894	1.062	0.835
2014	1.076	1.237	0.870	0.989	0.826
2015	1.075	1.263	0.851	0.978	0.805
2016	1.066	1.281	0.833	0.954	0.788
2017	1.096	1.267	0.865	0.989	0.819
2018	1.095	1.237	0.885	1.121	0.807
2019	1.079	1.241	0.869	1.093	0.795
2020	1.091	1.237	0.882	1.110	0.805
2021	1.095	1.245	0.880	1.109	0.802
2022	1.086	1.239	0.876	1.080	0.799
Growth Rate 2006-2022	0.5%	1.3%	-0.8%	0.5%	-1.4%
Growth Rate 2006-2012	1.0%	3.0%	-2.1%	0.2%	-3.0%
Growth Rate 2012-2022	0.2%	0.3%	-0.1%	0.6%	-0.4%
Growth Rate 2022	-0.9%	-0.5%	-0.4%	-2.6%	-0.4%

Table 2.1 also shows Partial Factor Productivity (PFP) indexes, which measure output relative to specific inputs, here the opex and aggregate capital inputs. The average rate of change in opex PFP in the period from 2006 to 2022 was 0.5 per cent per annum, with a substantial part of this growth occurring in the period from 2012 to 2022. Capital PFP declined on average at 1.4 per cent between 2006 and 2022. A substantial part of this decrease occurred in the period from 2006 to 2012. PFP trends for disaggregated inputs are presented in section 2.3.

2.2 Industry output and input quantity changes

To gain a more detailed understanding of what is driving these TFP changes, we need to look at the pattern of quantity change in the five transmission output components and the four transmission input components. We also need to consider the weight placed on each of these components in forming the total output and total input indexes. In section 2.4 we present the contributions of each output and each input to TFP change, taking account of the quantity change in each component over time and its weight in forming the TFP index. First, however, we will look at the quantity indexes for individual outputs in Figure 2.2 and for individual inputs in Figure 2.3. In each case the quantities are converted to an index number with a value of one in 2006 for ease of comparison. Tables showing growth rates of outputs and inputs are included in Appendix B.

Figure 2.2 TNSP industry output quantity indexes, 2006–2022



In Figure 2.2, ENS is not shown, because year-to-year movements are too large to show alongside the other outputs.[4] Maximum demand is shown for comparison with RMD. The figure shows that the total output index has moved in parallel with circuit length, which is the output with the largest weight in forming the aggregate output index. Circuit length increased steadily up to 2015 before levelling off. It was 7.9 per cent higher in 2022 than it was in 2006.

The relatively modest growth in the circuit length output compared to the growth in end-users reflects the fact that most of the increase in end-use customer numbers over the period has been able to be accommodated by 'in fill' off the existing TNSP networks without requiring large extensions of the transmission network length.

The output that increased the most over the period is end-user numbers. It was 23.6 per cent higher in 2022 than it was in 2006. Its steady increase is explained by the fact that the number of electricity end-users increases approximately in line with population growth. In 2022, end-users increased by 1.3 per cent, consistent with the long-term average annual growth rate of 1.3 per cent from 2006 to 2022.

By contrast to end-user numbers, we see that energy throughput for transmission peaked in 2010 and fell steadily through to 2014 before a partial recovery to 2017 and then a further significant downward trend. In 2022 transmission energy throughput was 6.4 per cent *less* than it was in 2006.[5]

Maximum demand has followed a broadly analogous pattern to energy throughput although it increased more rapidly than energy throughput between 2006 and 2009 before levelling off and then falling markedly from 2011 to 2015, broadly in line with the decline in energy throughput. Since 2016 it has increased significantly, even while energy throughput has declined. Transmission networks, thus, have to service a steadily increasing number of end-users whilst electricity throughput is declining, and maximum demand levels, although variable, have not shown a sustained downward trend to match electricity throughput. The absence of a sustained downward trend in Maximum Demand is once again evident in the most recent period, as the variable recorded a significant growth of 2.4 per cent in 2022.

In recognition of the variable nature of maximum demand, RMD is included as an output measure rather than maximum demand so that TNSPs get credit for having had to provide capacity to service the earlier higher maximum demands than may occur in subsequent years. The RMD 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

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[4] The largest of these movements was the upwards spike in 2009 associated with a transformer failure at ANT's South Morang Terminal Station. The next largest spike was in 2016.

[5] The decline in energy throughput since around 2010 partly reflects economic conditions being more subdued since the global financial crisis but, more importantly, the increasing impact of energy conservation initiatives, more energy efficient buildings and appliances and greater penetration of local distributed generation (Economic Insights 2019, 4).

vary with year-to-year variations in maximum demand. Industry RMD is the sum of ratcheted maximum demands across the five TNSPs (rather than first summing the maximum demands and then calculating the ratcheted quantity).[6] It increased up to 2011 and has been relatively flat until 2021. In 2022 it experienced a growth of 0.6 per cent and was 13.0 per cent above its 2006 level.

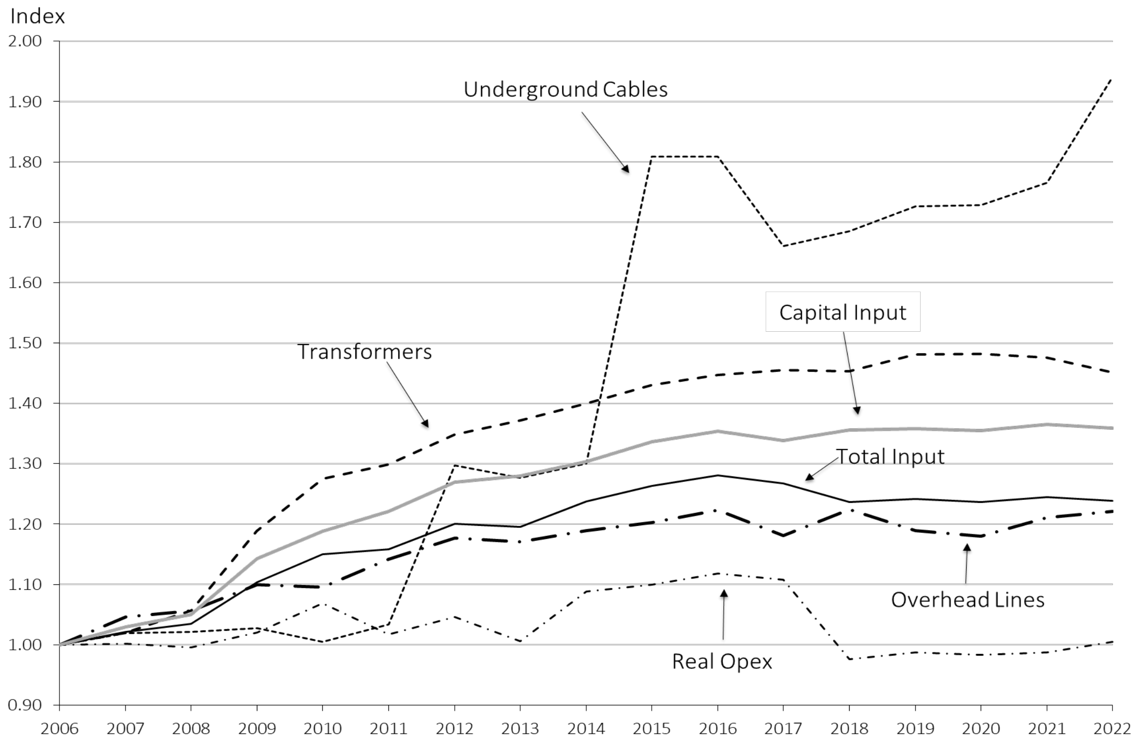
The last output is total ENS due to network limitations, which is an inverse measure of reliability. This enters the total output index as a negative output since a reduction in ENS represents an improvement and a higher level of service for end-users. Conversely, an increase in ENS reduces total output as end-users are inconvenienced more by not having supply over a wider area and/or for a longer period. Despite periodic large spikes, ENS has generally trended downwards and, hence, contributed more to total output than was the case in 2006, holding all else constant. In 2022 ENS was 35.9 per cent *lower* than the level it had been in 2006. Nevertheless, in 2022, it substantially increased by 136.9 per cent. This needs to be viewed from the perspective that transmission outage rates are usually very low so they can appear to be volatile in years where unusual events happen.

Circuit length, RMD and energy throughput outputs receive a combined weight on average of 93.5 per cent of total revenue (see Table A.2 in Appendix A), and thus have greatest influence on total output movements. Hence, as seen in Figure 2.2, the total output index tends to lie close to the circuit length output index and is bounded by the RMD and energy throughput indexes. Although ENS has a comparatively small weight of –1.2 per cent of total revenue on average, the more extreme variation in ENS means that total output movements are significantly influenced by the pattern of movement in the ENS output (noting that an increase in ENS has a negative impact on total output). However, the impact of extreme ENS events on total output is limited by capping this output's weight (in absolute terms) for each TNSP at 2.5 per cent of total revenue of the TNSP.

Turning to the input side, quantity indexes for the four inputs and the aggregate input index are presented in Figure 2.3. The quantity of opex (i.e., opex in constant 2006 prices) remained relatively constant over the whole of the 17-year period with some exceptions. From about 2009 to 2016, opex usage increased on balance, although at a slower rate than other inputs. Since then, opex use has declined, including a marked fall in 2018, since which it has remained relatively level. In 2022, opex usage increased 1.8 per cent and was 0.5 per cent higher than in 2006. Opex has the third largest average share in total costs at 27.7 per cent (see Table A.3 in Appendix A).

[6] For this reason, the RMD for the industry can increase in a year when aggregate maximum demands did not increase as seen for 2011 in Figure 2.2.

Figure 2.3 TNSP industry input quantity indexes, 2006–2022



The input with the largest average share of total cost, at 42.6 per cent, is transformers. The quantity of transformer input has increased steadily over the period to 2021, with only a marginal decrease in 2018, but has levelled off since 2019. This input declined by 1.7 per cent in 2022. By 2022, transformer input was 45.1 per cent above its 2006 level. Given its large share of total costs, transformer input is an important driver of the total input quantity index.

The next key component of TNSP input is the quantity of overhead lines. This input quantity increased the second least over the period, being 22.1 per cent higher in 2022 than it was in 2006. It should be noted that overhead line input quantities take account of both the length of lines and the overall 'carrying capacity' of the lines (in MVA). The fact that the overhead lines input quantity has increased substantially more than network length reflects the fact that the average capacity of overhead lines has increased over the period as new lines and replacement of old lines are both of higher carrying capacity than older lines. Overhead lines account for 28.0 per cent of total TNSP costs on average (see Appendix A, Table A.3).

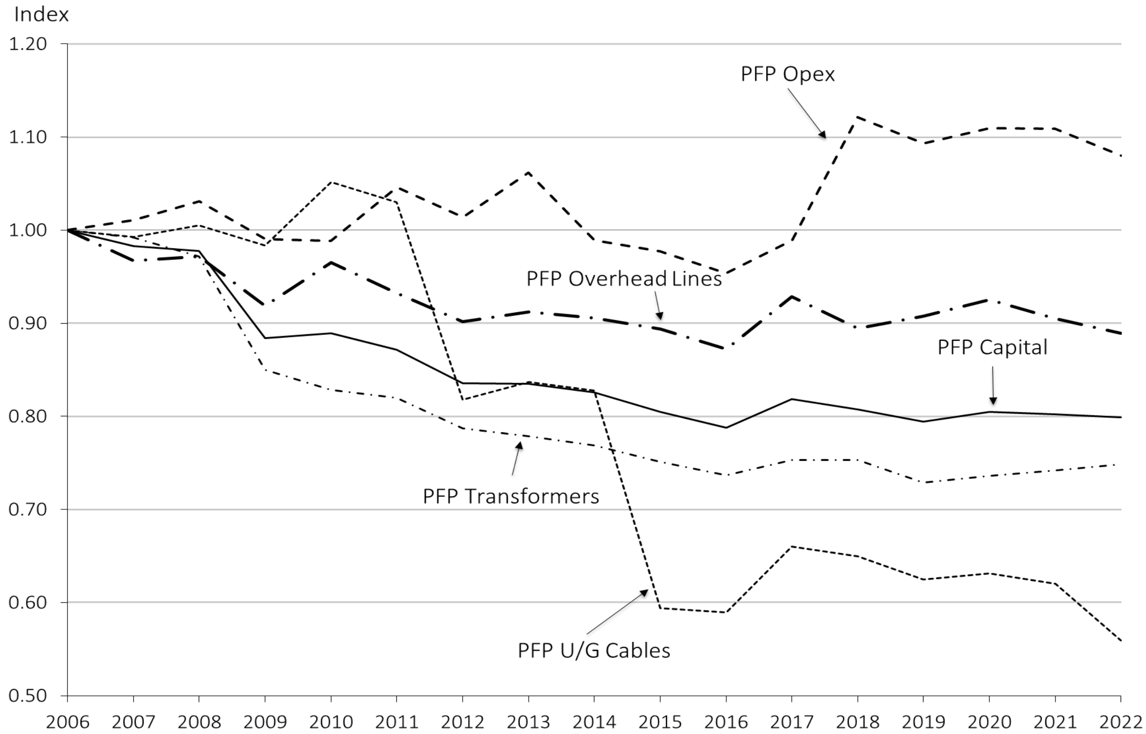
The fastest growing input quantity is that of underground cables whose quantity was 94.1 per cent higher in 2022 than it was in 2006. However, this growth starts from a quite small base and so a higher growth rate is to be expected. Most of the increase in length and/or capacity of transmission underground cables has occurred since 2011, with a significant growth rate of 9.4 per cent occurring in 2022. The scope to put significant parts of the transmission network underground is considerably less than it is for distribution and the cost relativity greater.

Underground cable inputs in transmission have an average share of total costs of only 1.7 per cent for the industry, compared to a share in total costs of 13.8 per cent for distribution (Quantonomics 2022, 130 Table A.3).

2.3 Detailed partial factor productivity trends

Figure 2.4 shows transmission industry PFP indexes: (a) for two broad categories of inputs, opex inputs and capital inputs; and (b) for each of the three capital inputs individually. From Figure 2.4 we see that movements in transmission industry-level PFP indexes follow an essentially inverse pattern to input quantities shown in Figure 2.3. This is because outputs increased *comparatively* steadily over the 2006 to 2022 period (i.e., compared to movements of inputs). For example, Figure 2.3 shows a large decrease in the industry's real opex in 2018, and this is matched by a large increase in opex PFP in the same year.

Figure 2.4 TNSP industry partial factor productivity indexes, 2006–2022



Consequently, the opex PFP index is the highest, and in 2022 is 8.0 per cent above its 2006 level. The PFP of capital inputs decreased fairly steadily up to 2016, but since that time it levelled out. In 2022, the capital PFP is 20.1 per cent *below* its 2006 level. Among the PFP indexes for specific capital inputs:

- Underground cables PFP decreased sharply in 2012 and 2015, and by 2022 it was 44.0 per cent *lower* than in 2006;

- Transformers PFP and overhead lines PFP both declined over the period to 2016 but have flattened or increased slightly since then. Transformer PFP was 25.2 per cent *lower* in 2022 than in 2006. Overhead lines PFP in 2022 was 11.1 per cent *lower* than in 2006.

Average growth rates for PFP by individual input are presented in Appendix B, together with average growth rates of individual outputs and inputs.

2.4 Transmission industry output and input contributions to TFP change

By decomposing TFP change into its constituent parts, contributions of individual output and inputs to that change can be ascertained. Appendix A presents the methodology that allows the change in productivity (i.e., the change in the MTFP index) to be decomposed into the contributions of changes in each output and each input.[7]

Figure 2.5 presents the percentage point contributions of each output and each input to the average annual rate of TFP change of –0.8 per cent over the 17-year period 2006 to 2022. Table 2.2 presents the contributions of individual inputs and outputs to the rate of TFP change over the whole period, and for the two subperiods, and for 2022. In Figure 2.5 the blue columns represent the percentage point contributions of each of the outputs and inputs to average annual TFP change, which is shown by the red bar at the far right of the graph. The contributions are ranked from most positive on the left to most negative on the right. If all the positive and negative contributions (blue columns) are added together, the sum will equal the TFP change (red column).

Outputs with the largest contribution were:

- Growth in circuit length provided the highest positive contribution to TFP change over the 17-year period. Although the rate of growth of circuit length was only moderate (averaging 0.5 per cent per year), it has a high weight in the output index, and thus contributed 0.3 percentage points to TFP change;

- RMD made the second highest contribution to TFP change. Despite flattening out after 2011, RMD's average annual growth rate over the 17-year period of 0.8 per cent, combined with its substantial weight, resulted in a contribution 0.2 percentage points to average TFP change.

Of the other outputs, end-user numbers have grown steadily, averaging 1.3 per cent annually over the whole period, but their relatively low weight in the output index means this output contributed just 0.1 percentage points to TFP change over the period. Although ENS *declined* at an average annual rate of 2.8 per cent over the same period, its small weight in the output index means that it contributed only 0.03 percentage points to TFP change. Energy

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

throughput has a weight of 15.1 per cent in the output index (Appendix A, Table A.2), and it declined at an average rate of 0.4 per cent over the 17-year period. However, this decline did not have a large effect on the average TFP change (contributing –0.06 percentage points).

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

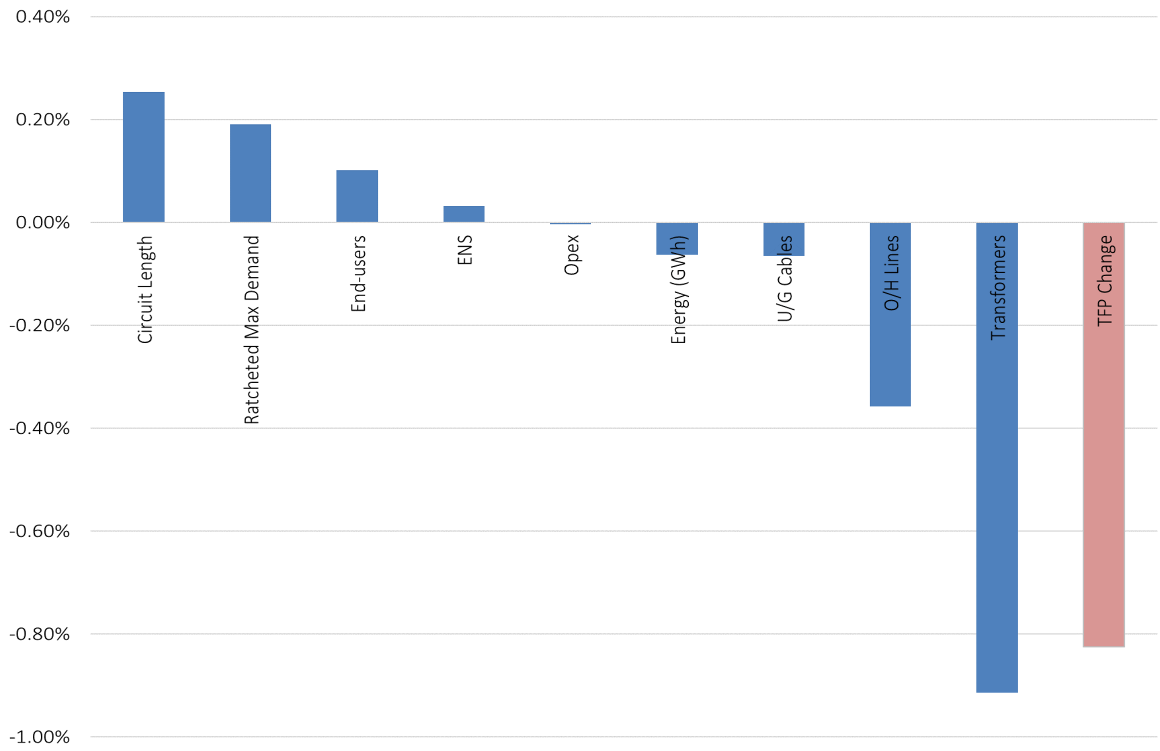


Table 2.2 Transmission industry output and input percentage point contributions to average annual TFP change: various periods

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2022*
Energy (GWh)	-0.06%	-0.02%	-0.09%	-0.13%
Ratcheted Max Demand	0.19%	0.45%	0.03%	0.15%
End-users	0.10%	0.10%	0.10%	0.10%
Circuit Length	0.25%	0.44%	0.14%	-0.06%
ENS	0.03%	0.02%	0.04%	-0.93%
Opex	0.00%	-0.21%	0.12%	-0.36%
O/H Lines	-0.36%	-0.83%	-0.07%	-0.07%
U/G Cables	-0.07%	-0.08%	-0.06%	-0.08%
Transformers	-0.91%	-1.93%	-0.31%	1.00%
TFP Change	-0.82%	-2.06%	-0.08%	-0.39%

Most of the inputs made a negative contribution to TFP change over the 17-year period, except that non-capital (opex) input made a zero contribution. The use of all three capital inputs increased, resulting in negative contributions to the average annual TFP change. The two inputs with the largest shares in the total input index are transformers and overhead lines, which have a combined weight of 70.7 per cent (Appendix A, Table A.3). Since transformers had a comparatively high rate of growth of 2.3 per cent per annum from 2006 to 2022 (and a comparatively large weight), this input made a large *negative* contribution to TFP of 0.9 percentage points. Overhead lines had a lower average annual growth rate at 1.3 per cent and made the second most negative contribution to TFP change at –0.4 percentage points.

Despite having the highest input average annual growth rate of 4.1 per cent, underground cables has only a small weight and so made a small *negative* contribution to TFP of 0.07 percentage points. The average growth of opex over the 17-year period was 0.0 percent. Hence, it did not contribute to TFP growth.

Figures 2.6 and 2.7 show the contributions of individual outputs and inputs to average TFP change in two sub-periods, from 2006 to 2012 and from 2012 to 2022 respectively. In the first of these two periods, TFP *declined* at an average annual rate of 2.1 per cent, whereas in the second period TFP was virtually unchanged (an average rate of –0.08 per cent). Figure 2.6 suggests a similar pattern of contributions to TFP change for most outputs and inputs for the period up to 2012 as for the whole period, except that:

(i) RMD and Circuit length made more pronounced positive contributions;

(ii) Transformers and overhead lines made much larger negative contributions; and

(iii) The contribution of opex was negative in the period up to 2012.

In the period from 2012 to 2022, the contributions to average annual TFP change presented in Figure 2.7 indicate the following different patterns:

- Opex changed from making a negative contribution up to 2012 to being a positive contributor to TFP change after 2012;
- RMD, which was a substantial contributor to TFP change in the period up to 2012, made only a marginal contribution after 2012;
- Overhead lines had a substantial negative contribution in the period to 2012, but only a marginal negative contribution in the period after 2012.
- Although there was a reduction in the negative contribution of transformers, it remained the largest negative contributor.

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

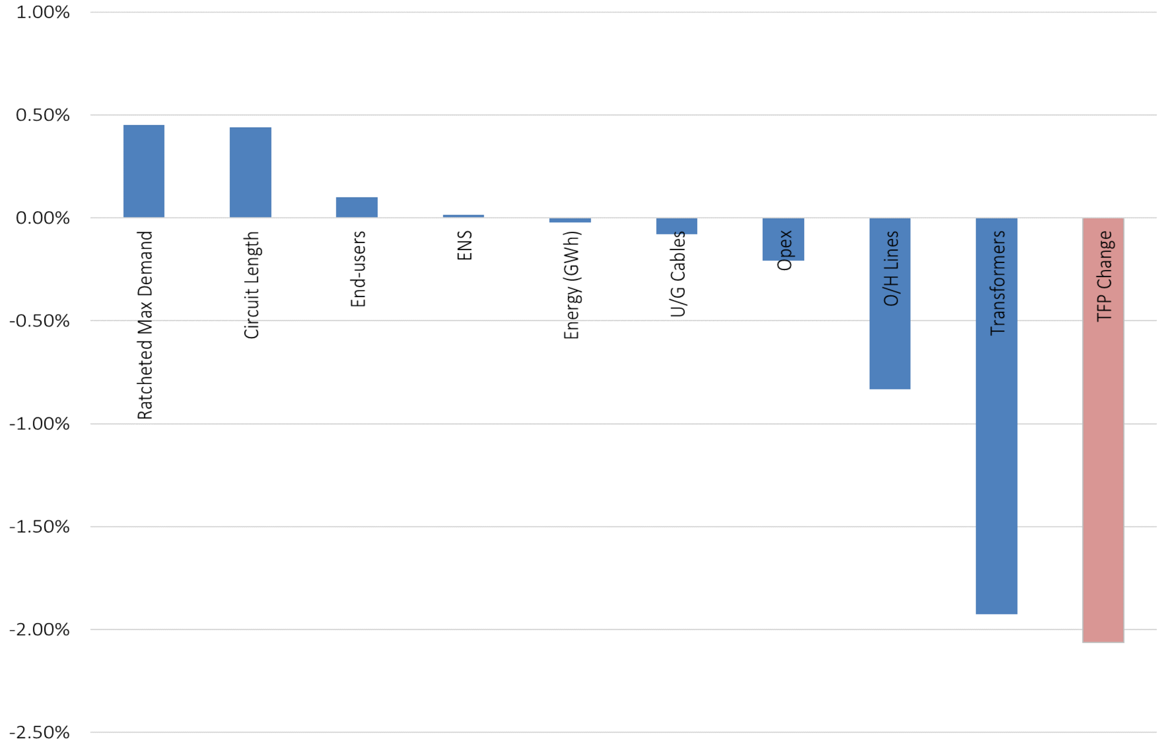


Figure 2.7 Transmission industry output and input percentage point contributions to average annual TFP change, 2012–2022

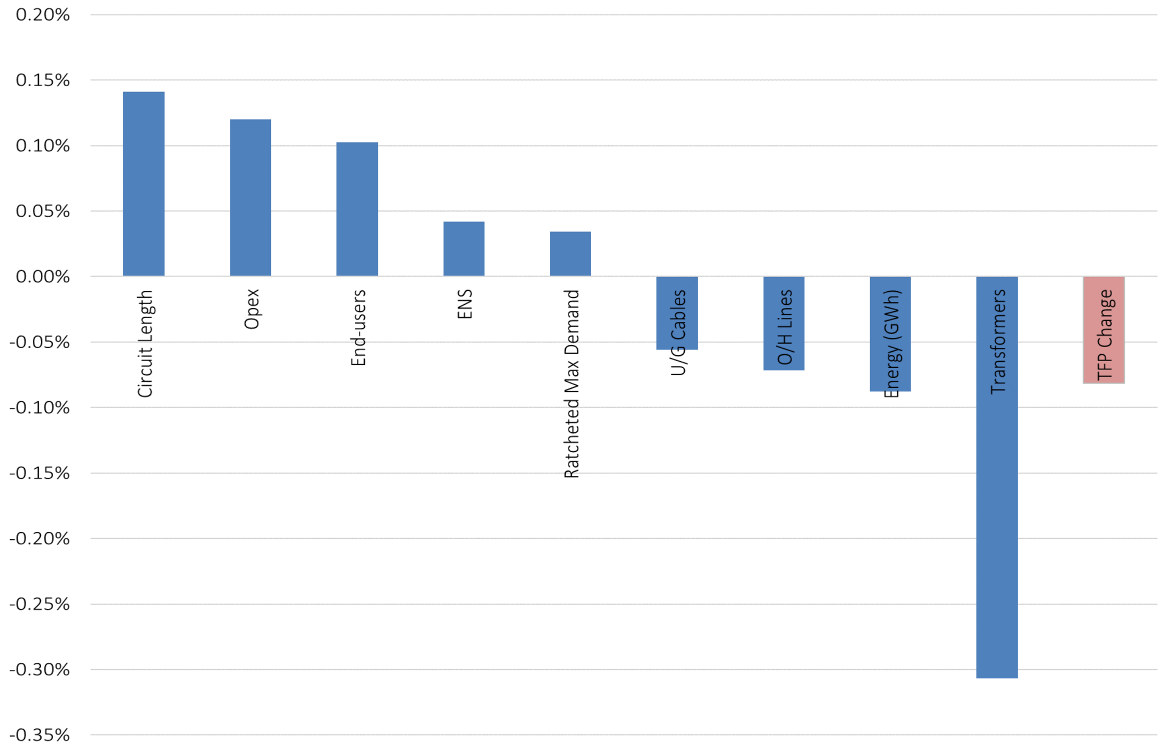


Table 2.3 presents the annual changes in each output and input from 2006 to 2022, and Table 2.4 presents their percentage point contributions to annual TFP change in the same years.[8]

Having regard to the contributions of individual outputs and inputs to TFP change in 2022 of –0.4 per cent, Table 2.4 shows that the main factors making a positive contribution to TFP growth were: (a) a *reduction* in transformer input of 1.7 per cent contributed 1.0 percentage points, and (b) an *increase* in Ratcheted Max Demand output of 0.6 per cent contributed 0.2 percentage points. The main negative contributors were: (a) an increase in ENS of 136.9 per cent contributing –0.9 percentage points; (b) an increase in opex input (1.8 per cent) contributing –0.4 percentage points, and (c) a *decline* in energy output of 0.9 per cent contributing –0.1 percentage points.

[8] Consistent with Economic Insights (2020), growth rates in indexes are generally expressed in this report as logarithmic growth measures. That is, the growth rate of a variable Y between period $t-1$ and period t is calculated as: $g_t^Y = \ln Y_t - \ln Y_{t-1}$. 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 a mid-point between periods $t-1$ and t. The log-difference growth rate can be related to the more common growth rate measure based on the first period as follows: $(Y_t - Y_{t-1})/Y_{t-1} = \exp(g_t^Y) - 1$.

Table 2.3 Transmission industry output and input annual changes, 2006–2022

Year	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*
Energy (GWh)	2.13%	-1.17%	1.12%	0.80%	-1.22%	-2.49%	-2.52%	-2.79%
RMD	5.72%	1.17%	1.87%	0.83%	1.21%	0.00%	0.05%	0.04%
End-users	1.30%	1.32%	1.57%	1.24%	1.23%	1.19%	1.20%	1.13%
Circuit Length	0.40%	1.32%	0.78%	1.39%	1.03%	0.00%	1.93%	1.16%
ENS	55.43%	-28.54%	162.04%	-202.04%	5.50%	1.84%	7.40%	-44.34%
Opex	0.13%	-0.54%	2.42%	4.68%	-4.97%	2.82%	-3.96%	7.90%
O/H Lines	4.55%	0.96%	3.98%	-0.41%	4.16%	3.05%	-0.50%	1.51%
U/G Cables	1.96%	0.18%	0.56%	-2.21%	2.79%	22.73%	-1.60%	1.83%
Transformers	1.97%	3.52%	11.80%	7.02%	1.79%	3.76%	1.76%	2.02%

Year	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*
Energy (GWh)	5.49%	-1.62%	2.12%	-3.45%	0.08%	-1.30%	-0.99%	-0.85%
RMD	0.00%	0.00%	0.29%	0.02%	0.22%	0.18%	0.00%	0.59%
End-users	1.34%	1.41%	1.66%	1.61%	1.51%	1.16%	1.01%	1.33%
Circuit Length	0.30%	0.01%	-0.43%	0.13%	-0.10%	-0.19%	-0.02%	-0.13%
ENS	96.76%	50.36%	-222.29%	-28.28%	174.07%	-119.56%	-89.82%	136.94%
Opex	1.01%	1.65%	-0.85%	-12.69%	1.13%	-0.44%	0.46%	1.77%
O/H Lines	1.12%	1.68%	-3.50%	3.61%	-2.85%	-0.86%	2.59%	0.91%
U/G Cables	33.05%	-0.01%	-8.52%	1.46%	2.43%	0.10%	2.13%	9.44%
Transformers	2.14%	1.14%	0.57%	-0.12%	1.88%	0.06%	-0.41%	-1.67%

Notes: The rates of change in this table represent year-on-year changes, and 2006 is not presented because data for 2005 is not available.

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

Year	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*
Energy	0.32%	-0.18%	0.17%	0.12%	-0.19%	-0.38%	-0.38%	-0.42%
RMD	1.43%	0.30%	0.47%	0.21%	0.30%	0.00%	0.01%	0.01%
End-users	0.10%	0.10%	0.12%	0.10%	0.10%	0.09%	0.09%	0.09%
Circuit Length	0.21%	0.71%	0.41%	0.75%	0.55%	0.00%	1.03%	0.62%
ENS	-0.86%	0.52%	-2.78%	3.31%	-0.07%	-0.03%	-0.07%	0.48%
Opex	-0.04%	0.18%	-0.74%	-1.26%	1.33%	-0.72%	1.02%	-2.21%
O/H Lines	-1.46%	-0.47%	-1.06%	0.10%	-1.21%	-0.91%	0.16%	-0.39%
U/G Cables	-0.02%	-0.05%	-0.01%	0.01%	-0.04%	-0.38%	0.04%	-0.04%
Transformers	-0.56%	-1.03%	-4.65%	-2.95%	-0.75%	-1.63%	-0.73%	-0.82%
TFP change	-0.88%	0.08%	-8.07%	0.39%	0.04%	-3.94%	1.17%	-2.70%

Year	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*
Energy	0.83%	-0.24%	0.32%	-0.52%	0.01%	-0.20%	-0.15%	-0.13%
RMD	0.00%	0.00%	0.07%	0.00%	0.06%	0.04%	0.00%	0.15%
End-users	0.10%	0.11%	0.13%	0.12%	0.12%	0.09%	0.08%	0.10%
Circuit Length	0.16%	0.00%	-0.24%	0.07%	-0.05%	-0.10%	-0.01%	-0.06%
ENS	-1.24%	-0.67%	2.50%	0.19%	-1.56%	1.24%	0.48%	-0.93%
Opex	-0.12%	-0.52%	0.22%	3.45%	-0.30%	0.14%	-0.12%	-0.36%
O/H Lines	-0.35%	-0.42%	0.98%	-0.98%	0.77%	0.25%	-0.67%	-0.07%
U/G Cables	-0.56%	0.02%	0.14%	-0.03%	-0.03%	0.01%	-0.03%	-0.08%
Transformers	-1.03%	-0.50%	-0.30%	0.02%	-0.83%	-0.05%	0.17%	1.00%
TFP change	-2.21%	-2.21%	3.82%	2.32%	-1.81%	1.43%	-0.24%	-0.39%

Note: Percentages may not add due to rounding.

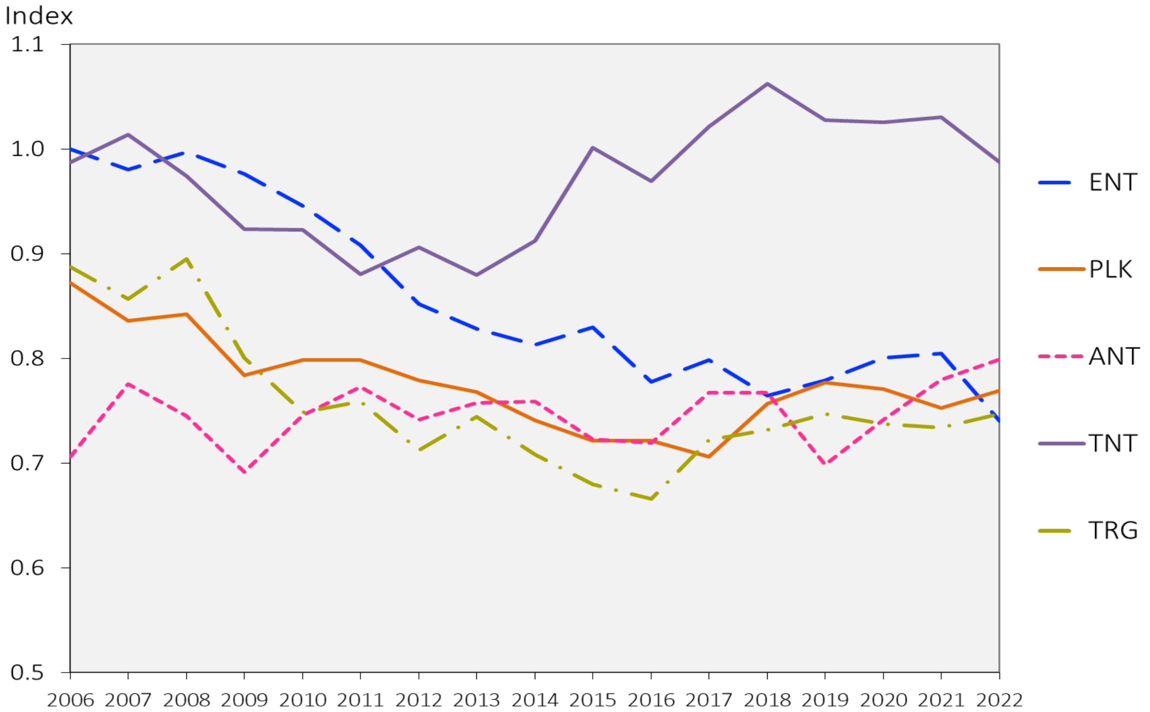
3 TNSP Comparative Productivity Results

In this chapter we present updated comparative results for TNSPs using MTFP and MPFP indexes. As outlined in chapter 1, MTFP and MPFP indexes calculated with pooled data allow comparisons of productivity levels as well as productivity growth to be made.[9] These indexes are presented in Figure 3.1 and Table 3.1.

3.1 Multilateral TFP Indexes

Figure 3.1 plots the MTFP indexes of each TNSP. It shows that, with the exception of TNT, differences between MTFP levels narrowed in the second half of the period.

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



The MTFP levels of three TNSPs—ENT, TRG and PLK—trended down to around 2016 before levelling out or increasing somewhat, while that of TNT generally trended down to around 2013 and has trended up since then. ANT's MTFP, on the other hand, fluctuated over the 17-year period, initially at a relatively low level, but with a small upward trend since 2019. ANT's MTFP level improved in 2022 by 2.4 per cent. This was similar to PLK's and TRG's MTFP level which increased by 2.1 and 1.8 per cent respectively in 2022. Whereas TNT's and ENT's MTFP levels *decreased* by 4.2 and 8.4 per cent in 2022.

[9] For convenience, index results are presented relative to ENT in 2006 having a value of one. The comparative results are invariant to which observation is used as the base.

Table 3.1 TNSP multilateral TFP indexes, 2006–2022

Year	ENT	PLK	ANT	TNT	TRG
2006	1.000	0.872	0.706	0.987	0.887
2007	0.981	0.836	0.775	1.014	0.857
2008	0.997	0.842	0.745	0.974	0.895
2009	0.976	0.783	0.692	0.923	0.800
2010	0.946	0.798	0.746	0.923	0.748
2011	0.908	0.799	0.773	0.880	0.759
2012	0.852	0.779	0.742	0.906	0.712
2013	0.828	0.768	0.758	0.880	0.744
2014	0.813	0.741	0.759	0.912	0.708
2015	0.830	0.721	0.722	1.001	0.680
2016	0.778	0.721	0.720	0.969	0.666
2017	0.798	0.706	0.767	1.021	0.722
2018	0.764	0.756	0.767	1.062	0.732
2019	0.779	0.777	0.699	1.027	0.747
2020	0.800	0.771	0.742	1.025	0.737
2021	0.804	0.753	0.779	1.030	0.734
2022	0.740	0.769	0.799	0.988	0.747
Av increase 2006-2022	-1.9%	-0.8%	0.8%	0.0%	-1.1%
Avg increase 2022	-8.4%	2.1%	2.4%	-4.2%	1.8%

The MTFP of the individual TNSPs can be summarised as follows:

- TNT's productivity level was generally ranked second up until 2011 (except for 2007 when TNT briefly ranked first) but increased noticeably in 2014 and 2015 with the introduction of restructuring and reform initiatives. TNT has remained the highest ranked TNSP in terms of productivity level from 2012 to 2022 despite the decrease of 4.2 per cent observed in 2022. Its TFP level in 2022 of 0.99 was virtually the same as its productivity level in 2006 (both indexes being relative to ENT in 2006 equal to 1.00).
- ANT started the period in 2006 with the lowest MTFP level at 0.70. It initially improved its performance before falling back in 2008 and 2009 due to increases in ENS and increases in input usage. Its MTFP subsequently improved slightly. Over the period from 2006 to 2022, the rate of change in MTFP averaged 0.8 per cent per year. In 2022 it had the second highest ranking, at 0.80.
- PLK had the third highest MTFP index in 2022 at 0.77. PLK experienced declines from 2006 to 2017, a partial recovery from 2018 to 2020, and subsequent decreases in 2021 and 2022. PLK's MTFP level in 2022 remained below that of 2006 (0.87), representing an average rate of MTFP change of –0.8 per cent per year.
- In 2006, TRG had the third highest MTFP level, at 0.89. TRG experienced a relatively steady decline up to 2016 and a moderate recovery since then. Its MTFP level in 2022

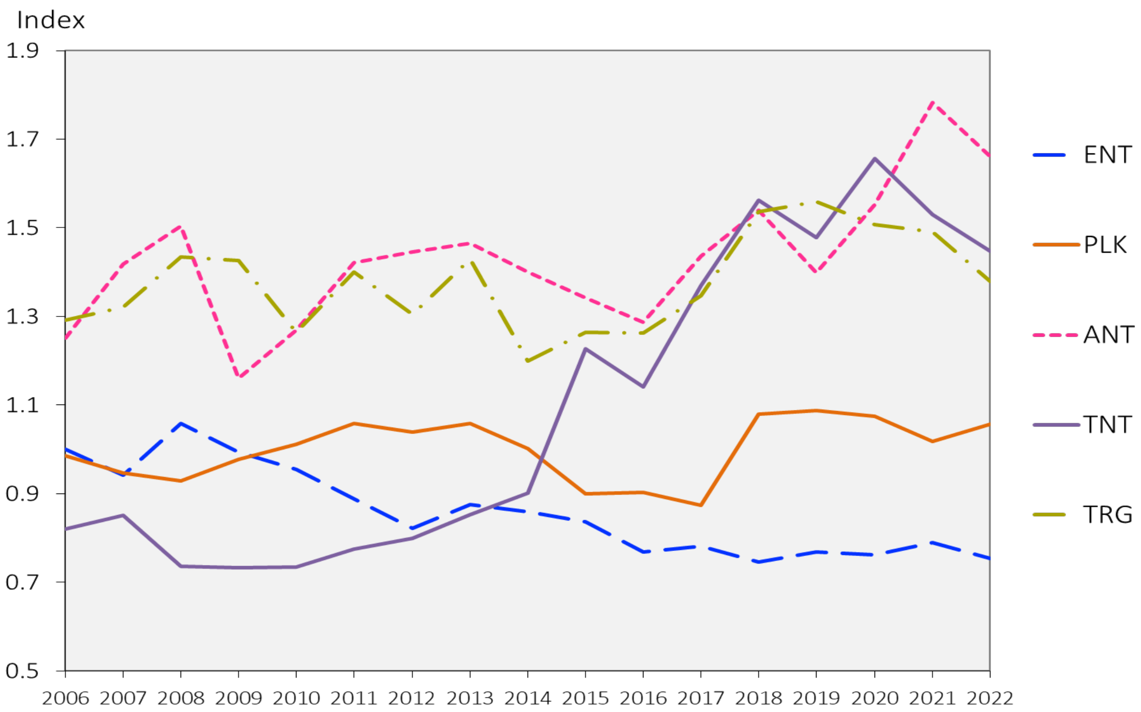
was at 0.74. It ranked fourth place among TNSPs in that year and represented an average annual *decline* in MTFP between 2006 and 2022 of 1.1 per cent.

- ENT started the period in 2006 having marginally the highest ranking in terms of MTFP level, slightly above that of TNT. In 2021, ENT held the second position in the ranking. However, in 2022, it dropped to last place with a decrease in MTFP of 8.4 per cent. Overall, its MTFP index decreased to 0.74 in 2022, indicating an average *decrease* of 1.9 per cent per year in MTFP.

3.2 Multilateral PFP Indexes

MTFP levels are an amalgam of opex MPFP and capital MPFP levels. Opex MPFP indexes are presented in Figure 3.2 and Table 3.2 while capital MPFP indexes are presented in Figure 3.3 and Table 3.3.

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



From Figure 3.2 we see that ANT and TRG had the highest opex MPFP levels over the first half of the 17-year period but have been joined at the top by TNT since 2015. TNT had the lowest opex MPFP levels from 2006 to 2013 but marked increases in opex MPFP in 2015 and again in 2017, 2018 and 2020 have taken it to the second highest ranking in 2022 despite consecutive declines in 2021 and 2022. It had an average annual opex MPFP growth rate for the full period (2006 to 2022) of 3.6 per cent. ANT has the highest opex MPFP level in 2022, despite a large *decline* in opex MPFP growth in 2022 of 7.1 per cent. Its increase in opex MPFP from 2006 to 2022 averaged 1.8 per cent per annum. TRG had the third highest opex MPFP in 2022, and over the period 2006 to 2022, this increased at an average annual rate of 0.4 per cent. TRG has been experiencing a downward trend in opex MPFP since 2020, and in 2022 there was a large *decline* of 7.9 percent.

PLK ranked the second-lowest in opex MPFP in 2022, and had an average annual change of 0.4 per cent over the period 2006 to 2022, the same as TRG. However, PLK experienced considerable growth in 2022 of 3.8 per cent. The TNSP with the lowest opex MPFP in 2022, ENT, also had the lowest opex MPFP average annual change over the period 2006 to 2022, at –1.8 per cent. For the year 2022, its opex MPFP decreased by 4.6 per cent.

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

Year	ENT	PLK	ANT	TNT	TRG
2006	1.000	0.986	1.251	0.820	1.292
2007	0.941	0.946	1.417	0.852	1.321
2008	1.058	0.929	1.504	0.736	1.435
2009	0.993	0.978	1.161	0.733	1.426
2010	0.955	1.011	1.270	0.734	1.264
2011	0.889	1.058	1.422	0.776	1.401
2012	0.822	1.040	1.445	0.799	1.304
2013	0.876	1.058	1.465	0.852	1.430
2014	0.859	1.002	1.400	0.902	1.199
2015	0.837	0.900	1.341	1.226	1.264
2016	0.769	0.904	1.286	1.141	1.263
2017	0.781	0.874	1.437	1.370	1.347
2018	0.746	1.079	1.540	1.563	1.537
2019	0.769	1.088	1.399	1.478	1.559
2020	0.762	1.074	1.552	1.656	1.507
2021	0.789	1.018	1.783	1.530	1.492
2022	0.754	1.057	1.661	1.448	1.379
Av increase 2006-2022	-1.8%	0.4%	1.8%	3.6%	0.4%
Avg increase 2022	-4.6%	3.8%	-7.1%	-5.5%	-7.9%

From Figure 3.3 we can see that capital MPFP levels have generally declined over the 17-year period. The one exception is ANT whose capital MPFP has fluctuated over time but had no underlying trend (an average annual rate of change of 0.2 per cent). In 2022, ANT's capital MPFP increased by 0.9 per cent.

On average, the annual rates of change of capital MPFP for the other TNSPs over the 17-year period were as follows: PLK's was at –1.3 per cent; TNT's was at –1.6 per cent; ENT's and TRG's were –1.8 and –1.9 respectively, the largest capital MPFP declines. In 2022, capital MPFP change was positive for ANT as mentioned, and for PLK and TRG (both at 1.2 per cent). It was negative for ENT at –7.2 per cent and for TNT at –4.7 per cent.

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

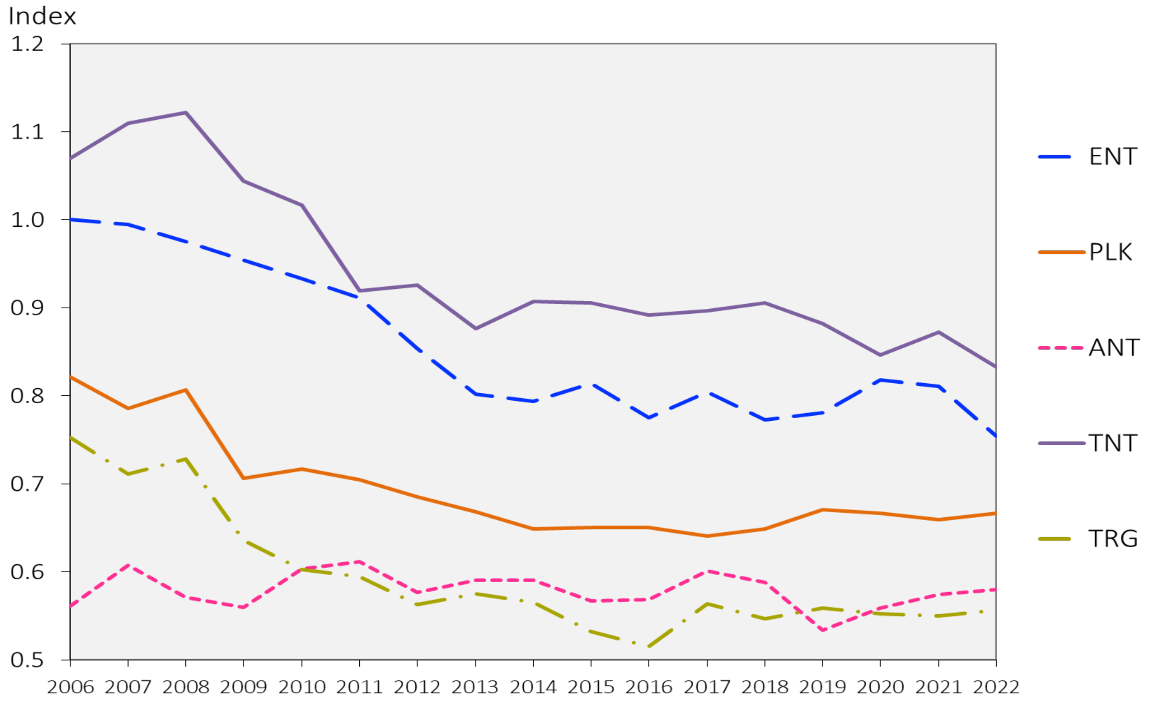


Table 3.3 TNSP multilateral capital partial factor productivity indexes, 2006–2022

Year	ENT	PLK	ANT	TNT	TRG
2006	1.000	0.822	0.562	1.070	0.753
2007	0.995	0.786	0.608	1.110	0.711
2008	0.975	0.807	0.571	1.122	0.728
2009	0.955	0.706	0.559	1.044	0.636
2010	0.933	0.717	0.604	1.017	0.603
2011	0.911	0.705	0.611	0.919	0.595
2012	0.854	0.686	0.577	0.926	0.563
2013	0.802	0.669	0.590	0.876	0.575
2014	0.794	0.649	0.591	0.907	0.565
2015	0.814	0.651	0.567	0.906	0.533
2016	0.775	0.650	0.569	0.892	0.515
2017	0.805	0.641	0.601	0.897	0.564
2018	0.773	0.649	0.588	0.905	0.547
2019	0.781	0.671	0.534	0.882	0.559
2020	0.818	0.667	0.559	0.846	0.553
2021	0.811	0.659	0.575	0.872	0.550
2022	0.754	0.667	0.580	0.832	0.556
Av increase 2006-2022	-1.8%	-1.3%	0.2%	-1.6%	-1.9%
Avg increase 2022	-7.2%	1.2%	0.9%	-4.7%	1.2%

4 TNSP Outputs, Inputs and Productivity Change

In this chapter we review the outputs, inputs and productivity change results for the five NEM TNSPs. To provide context, individual TNSP results are generally compared with the corresponding transmission industry-level result presented earlier in section 2.

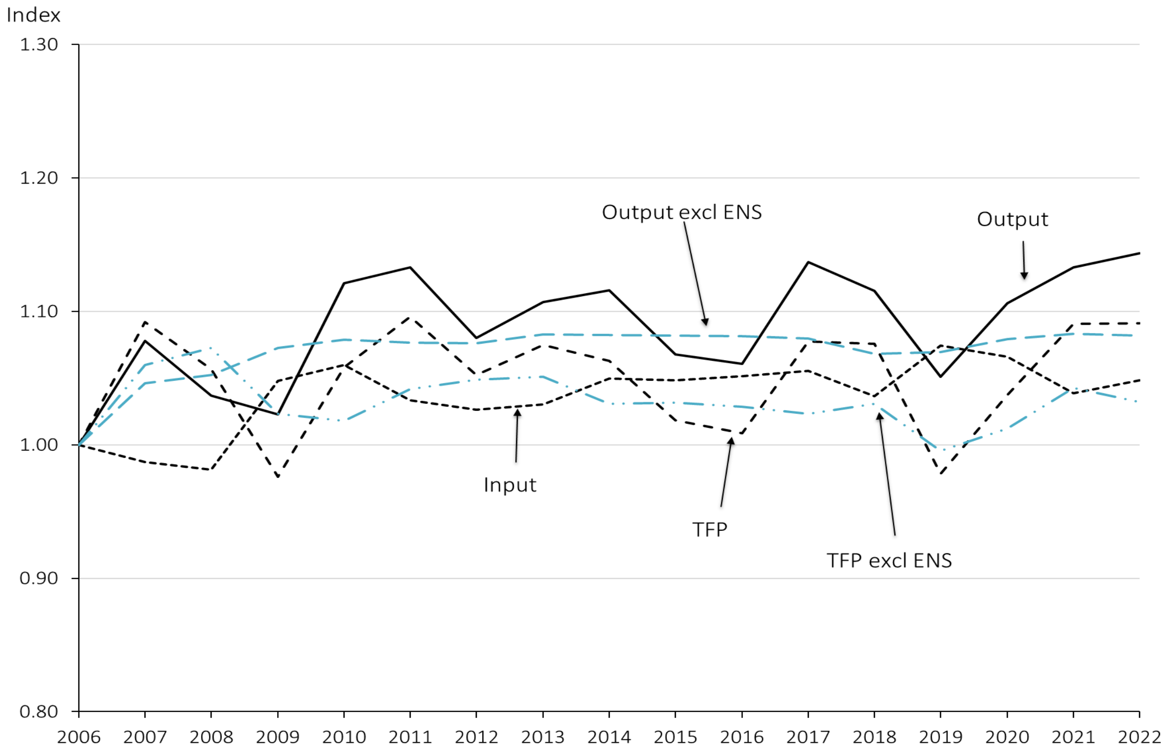
4.1 AusNet Services Transmission

In 2022 ANT transported 44,067 GWh of electricity over 6,629 circuit kilometres of lines and cables. It forms a critical part of Victoria's energy supply chain, serving 3.1 million end-users. ANT is the third largest TNSP in the NEM in terms of both energy throughput and circuit length, but it serves the second largest number of end-users.

4.1.1 ANT's productivity performance

ANT's total output, total input and TFP indexes are presented in Figure 4.1 and Table 4.1. Opex and capital PFP indexes are also presented in Table 4.1.

Figure 4.1 ANT output, input and TFP indexes, 2006–2022



Over the 17-year period from 2006 to 2022, ANT's TFP changed at an average annual rate of 0.5 per cent. Its total output increased by an average annual rate of 0.8 per cent, which is more than its rate of increase in total input use of 0.3 per cent. This differs from the situation for the transmission industry as a whole where input use increased considerably more than output growth over this period. ANT's TFP growth was reasonably consistent, in the first half of the period up to 2012 averaging 0.9 per cent per year, and in the second half from 2012 to 2022, averaging 0.4 per cent per year.

Figure 4.1 also shows the output and TFP indexes when ENS is excluded. This highlights the effect of ENS, showing that the year-to-year volatility of output, which is apparent in Figure 4.1, is almost entirely driven by ENS. Poor reliability outcomes can sharply reduce the output index, and since total input is relatively steady with a small upward trend, the effect of ENS on output is to also produce fluctuations in TFP. When ENS is excluded, ANT's TFP *decreased* by 1.0 per cent in 2022, compared to 0.1 per cent growth with ENS included. The 1.0 per cent increase in output in 2022, shown in Table 4.1, is almost entirely due to reliability improvement. When ENS is excluded, the output increase in 2022 is –0.1 per cent. Hence, the TFP *decrease* of 1.0 per cent in 2022 when ENS is excluded, is mainly due to increased use of inputs.

Table 4.1 ANT output, input, TFP and PFP indexes, 2006–2022

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.078	0.987	1.092	1.133	1.079
2008	1.037	0.981	1.057	1.203	1.015
2009	1.023	1.048	0.976	0.929	0.993
2010	1.121	1.060	1.058	1.014	1.071
2011	1.133	1.034	1.096	1.135	1.083
2012	1.080	1.026	1.052	1.155	1.022
2013	1.107	1.030	1.075	1.171	1.046
2014	1.116	1.050	1.063	1.119	1.046
2015	1.068	1.049	1.018	1.073	1.001
2016	1.061	1.052	1.009	1.029	1.003
2017	1.137	1.055	1.077	1.147	1.056
2018	1.115	1.037	1.076	1.230	1.031
2019	1.051	1.074	0.978	1.119	0.937
2020	1.106	1.066	1.037	1.240	0.981
2021	1.133	1.039	1.091	1.424	1.006
2022	1.144	1.048	1.091	1.325	1.016
Growth Rate 2006-2022	0.8%	0.3%	0.5%	1.8%	0.1%
Growth Rate 2006-2012	1.3%	0.4%	0.9%	2.4%	0.4%
Growth Rate 2012-2022	0.6%	0.2%	0.4%	1.4%	-0.1%
Growth Rate 2022	1.0%	0.9%	0.1%	-7.2%	1.0%

Table 4.1 also shows PFP indexes. The average rate of change in opex PFP in the period from 2006 to 2022 was 1.8 per cent per annum, with similar rates of growth of 2.4 per cent in in the first half of the period and 1.4 per cent in the second. ANT's opex PFP *decreased* significantly by 7.2 per cent in 2022.

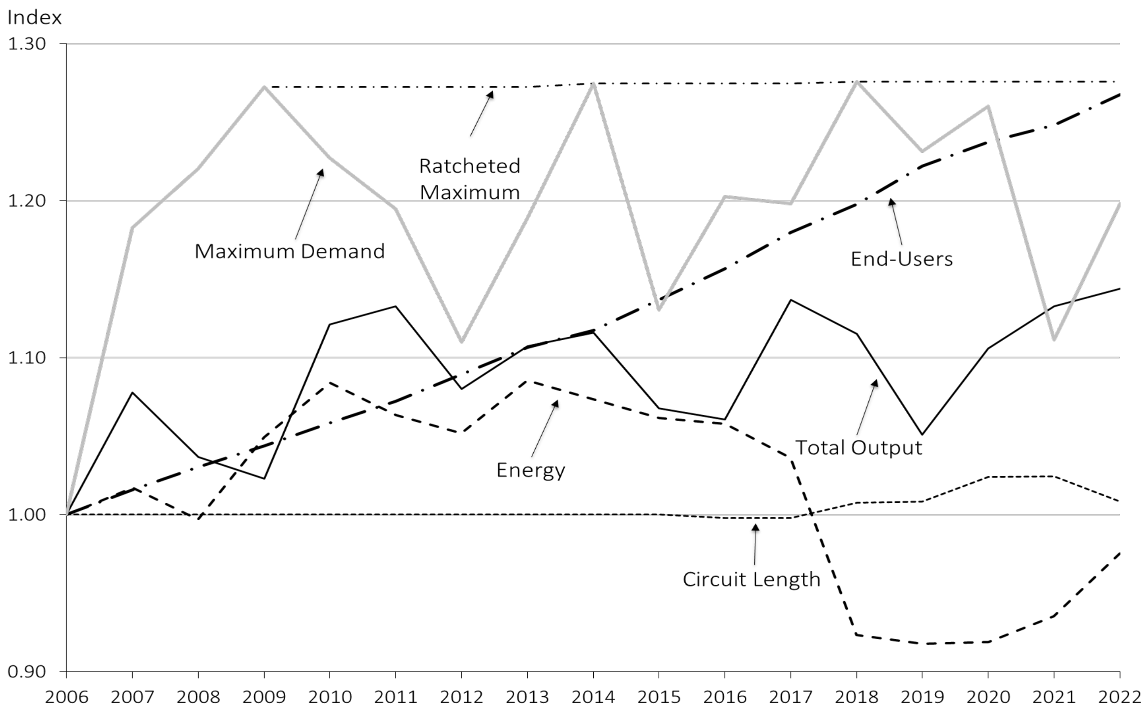
Capital PFP had 0.1 per cent growth on average between 2006 and 2022. This is a net effect of an increase in the period 2006 to 2012, in which capital PFP grew on average by 0.4 per cent per annum, and a decrease in the period 2012 to 2022, in which capital PFP growth *declined* by 0.1 per cent per annum. ANT's capital PFP increased by 1.0 per cent in 2022.

4.1.2 ANT's output and input quantity changes

Quantity indexes for ANT's individual outputs are presented in Figure 4.2 and for individual inputs in Figure 4.3. In each case the quantities are converted to index format with a value of one in 2006 for ease of comparison. Average growth rates for selected periods are shown in Appendix B.

From Figure 4.2 we see that the output component that receives the largest weight in forming ANT's TFP index, circuit length, increased by 0.8 per cent in total over the 17-year period. This contrasts with the transmission industry as a whole where circuit length was 7.9 per cent higher in 2022 than it was in 2006.

Figure 4.2 ANT output quantity indexes, 2006–2022



ANT's RMD output has grown at a considerably higher rate than for the industry as a whole (1.5 per cent versus 0.8 per cent per annum, respectively). Between 2006 and 2022, ANT's RMD increased by 27.6 per cent in total compared to 13.0 per cent for the industry. Almost all of this growth occurred in the period from 2006 to 2009. Figure 4.2 shows that maximum demand has fluctuated in the period after 2009, with peaks in 2014 and 2018 which slightly increased RMD.

End-user numbers for ANT grew over the period 2006 to 2022 by almost the same proportion as RMD—an increase of 26.8 per cent, which is comparable to the increase of 23.6 per cent for the industry. In the period up to about 2017, ANT's energy throughput showed a steadier pattern than that for the industry as a whole, since the latter was steadily declining over the same period. However, ANT's energy throughput fell sharply in 2018 due to reduced energy exports and has remained at the reduced level showing a recovery from 2021. In 2022 ANT's transmission energy throughput was 2.5 per cent *below* its 2006 level while for the industry it was 6.4 per cent *below* its 2006 level.

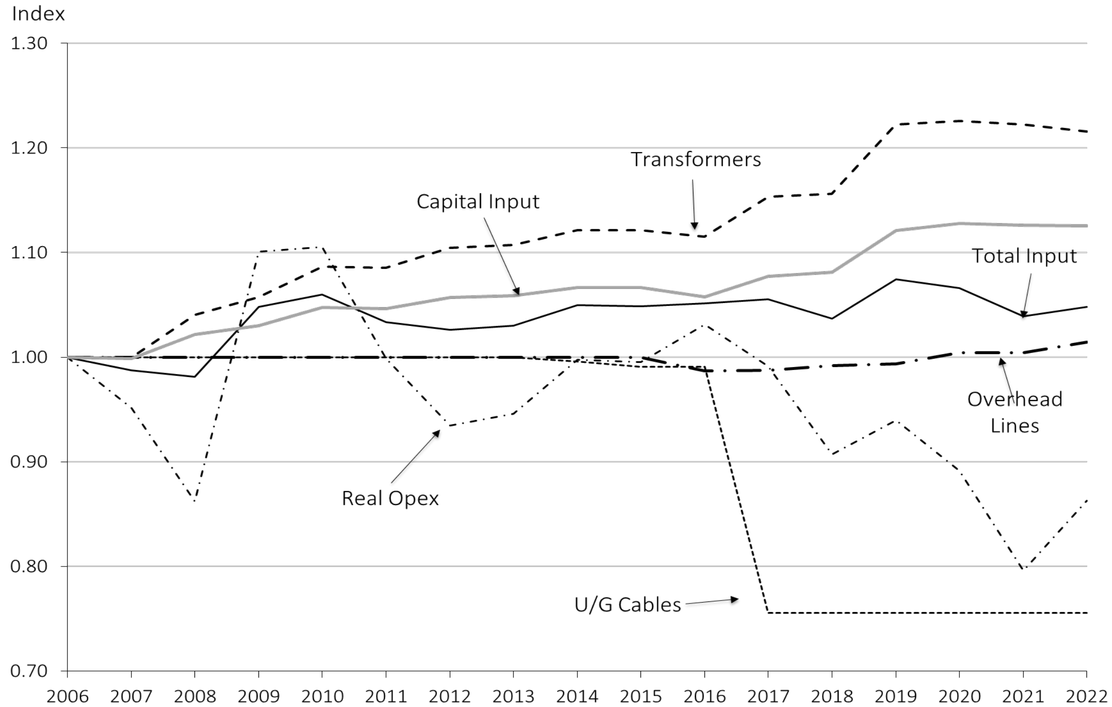
The output not shown in Figure 4.2 is ANT's ENS which spiked upwards in 2009 to 13 times its 2006 level associated with the transformer failure at the South Morang Terminal Station. With the exception of 2009, ANT's ENS generally trended downwards to 2014 and, hence, contributed to an increase in total output relative to 2006, all else equal. However, ENS again increased in 2015 and 2016 before falling to near zero in 2017 and remaining low in 2018 before increasing significantly in 2019 and falling again to be close to zero in 2022. Despite its small weight, the size of the percentage changes in ENS means it still has a significant impact on total output and, hence, TFP growth.

Turning to the input side, quantity indexes for ANT's four input components and total input are shown in Figure 4.3. In line with its near constant circuit length output, ANT's input quantities for both overhead lines and underground cables have remained virtually constant over the whole period although the (relatively small) quantity of underground cables input reduces in 2017 as cable length fell from 11 to 9 kilometres.

After underground cables, opex had the next largest decrease among ANT's inputs over the 17-year period. It was 13.7 per cent lower in 2022 compared to 2006 but with significant variation over the intervening years. In 2022 there was a significant increase of 8.1 per cent. This pattern differed from the industry which had a 0.5 per cent overall increase in opex between 2006 and 2022. Opex has an average share of ANT's total costs at 24.0 per cent (see Appendix A, Table A.3).

The input component with the largest average share of total cost, at 46.4 per cent for ANT on average, is transformers. ANT's quantity of transformers increased steadily, at an average rate of 1.7 per cent per year in the period 2006 to 2012, and again at an average annual rate of 1.0 per cent in the period 2012 to 2022. In 2022, ANT's transformers input was 21.6 per cent above its 2006 level; considerably smaller than the 45.1 per cent increase for the industry over the same period. Given their large share of total costs, transformer inputs are an 31mportantt driver of the total input quantity index.

Figure 4.3 ANT input quantity indexes, 2006–2022



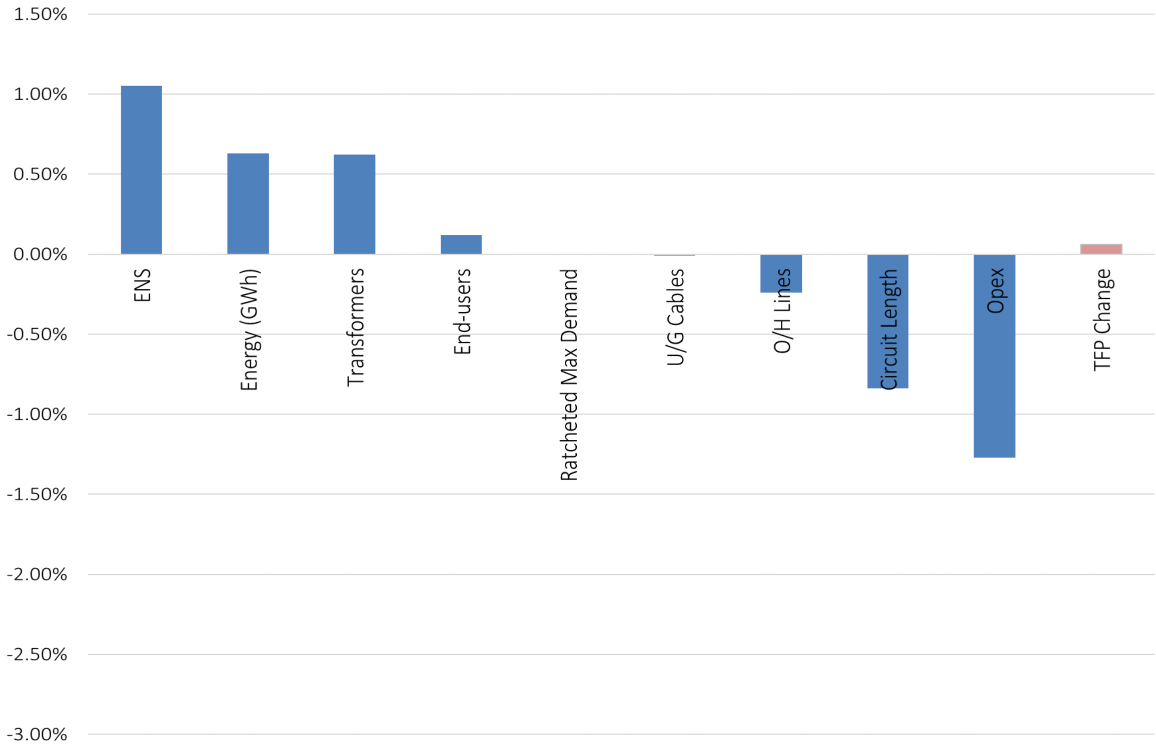
4.1.3 ANT's output and input contributions to TFP change

Table 4.2 shows the decomposition of ANT's average rates of TFP change into the contributions of the individual outputs and inputs for the whole 17-year period and for the periods up to and after 2012, and for 2022. Figure 4.4 shows the contributions of outputs and inputs to ANT's average rate of TFP change in 2022.

Table 4.2 ANT output and input percentage point contributions to average annual TFP change: various periods

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2022*
Energy	-0.02%	0.13%	-0.11%	0.63%
Ratcheted Max Demand	0.38%	1.01%	0.01%	0.00%
End-users	0.11%	0.11%	0.12%	0.12%
Circuit Length	0.03%	0.00%	0.04%	-0.84%
ENS	0.34%	0.03%	0.52%	1.05%
Opex	0.25%	0.27%	0.24%	-1.27%
O/H Lines	-0.02%	0.00%	-0.03%	-0.24%
U/G Cables	0.02%	0.00%	0.03%	-0.01%
Transformers	-0.54%	-0.70%	-0.44%	0.62%
TFP Change	0.55%	0.85%	0.36%	0.06%

Figure 4.4 ANT output and input percentage point contributions to TFP change in 2022



4.2 ElectraNet (ENT)

In 2022 ENT transported 13,616 GWh of electricity over 5,518 circuit kilometres of lines and cables. It forms a critical part of South Australia's energy supply chain serving 928,729 end-users. ENT is the fourth largest of the five TNSPs in the NEM in terms of energy throughput, circuit length and the number of end-users.

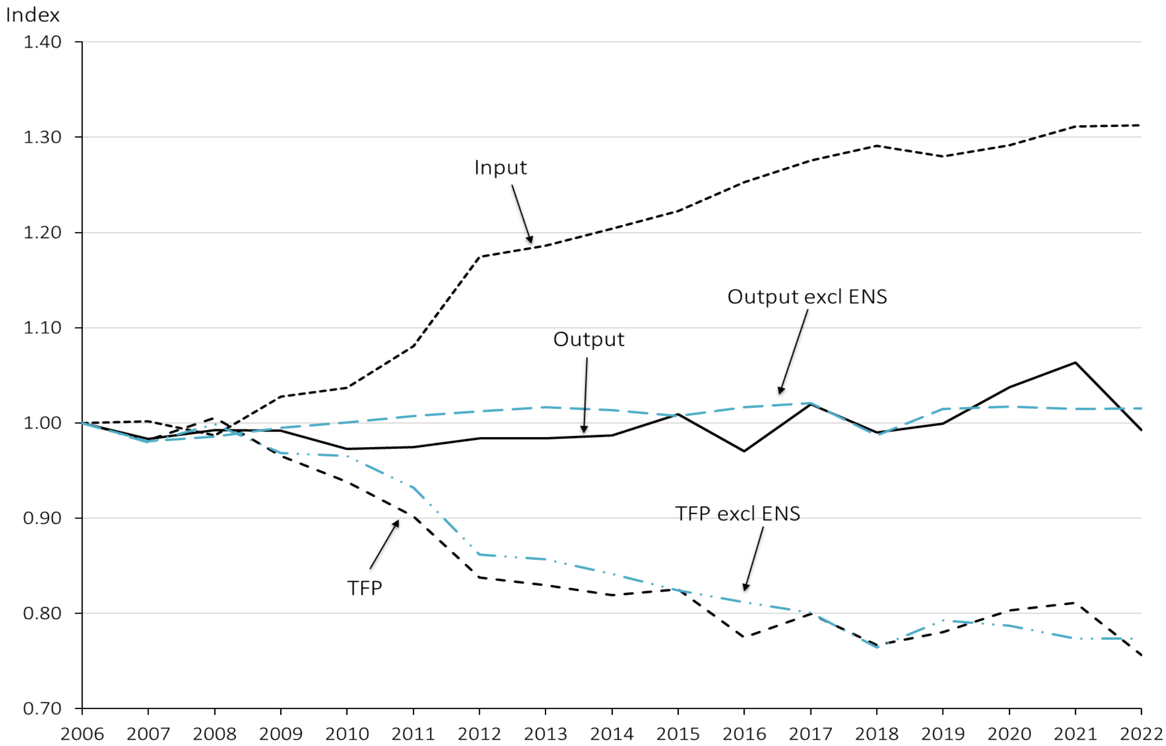
4.2.1 ENT's productivity performance

ENT's total output, total input and TFP indexes are presented in Figure 4.5 and Table 4.3. Opex and capital PFP indexes are also presented in Table 4.3. Figure 4.5 also shows the output and TFP indexes when ENS is excluded, which highlights the effect of ENS.

Over the 17-year period 2006 to 2022, ENT's TFP decreased, averaging an annual rate of change of –1.7 per cent. This can be compared to the industry's average annual TFP change of –0.8 per cent over the same period. ENT's total output over the same period averaged annual rate of 0.0 per cent. This is lower than the industry average rate of growth in output of 0.5 per cent per annum. ENT's average annual rate of increase in input use of 1.7 per cent was slightly higher than the rate of increase in total input use for the industry (average 1.3 per cent per year).

While in most years ENT's TFP has decreased, there have been some years when there was a small increase in TFP, including the period 2019 to 2021. However, ENT's TFP *decreased* by 7.0 per cent in 2022, which was driven by output growth *decrease* of 6.9 per cent in the same year.

Figure 4.5 ENT's output, input and TFP indexes, 2006–2022



It is also notable that the rate of growth of input usage is much higher in the period 2006 to 2012 (averaging 2.7 per cent per year) than in the period 2012 to 2022 (averaging 1.1 per cent per year). Accordingly, the average rate of change in TFP between 2006 and 2012 was –3.0 per cent per year, while after 2012 the rate of decline was not as strong, averaging –1.0 per cent per annum between 2012 and 2022.

The small output growth in the period from 2012 to 2022, which averaged 0.1 per cent per year, is entirely attributable to improvement in reliability. When ENS is excluded, there was zero output growth over this period. The rate of TFP change over the same period, when ENS is excluded, is –1.1 per cent, which is very similar to when ENS is included (–1.0 per cent).

The PFP indexes in Table 4.3 show that the moderation in negative average annual rates of change of TFP after 2012 was mirrored in reduced rates of decrease in both opex PFP and capital PFP.

Table 4.3 ENT's output, input, TFP and PFP indexes, 2006–2022

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	0.983	1.002	0.982	0.941	1.002
2008	0.993	0.987	1.006	1.058	0.980
2009	0.992	1.028	0.965	0.993	0.954
2010	0.973	1.037	0.938	0.954	0.932
2011	0.975	1.081	0.902	0.888	0.909
2012	0.984	1.175	0.838	0.821	0.845
2013	0.984	1.186	0.830	0.875	0.810
2014	0.987	1.204	0.819	0.858	0.800
2015	1.009	1.222	0.825	0.837	0.821
2016	0.970	1.253	0.775	0.767	0.778
2017	1.020	1.275	0.799	0.781	0.809
2018	0.990	1.291	0.767	0.745	0.778
2019	0.999	1.280	0.781	0.769	0.786
2020	1.038	1.292	0.803	0.763	0.824
2021	1.063	1.311	0.811	0.794	0.819
2022	0.993	1.313	0.756	0.753	0.757
Growth Rate 2006-2022	0.0%	1.7%	-1.7%	-1.8%	-1.7%
Growth Rate 2006-2012	-0.3%	2.7%	-3.0%	-3.3%	-2.8%
Growth Rate 2012-2022	0.1%	1.1%	-1.0%	-0.9%	-1.1%
Growth Rate 2022	-6.9%	0.1%	-7.0%	-5.3%	-7.9%

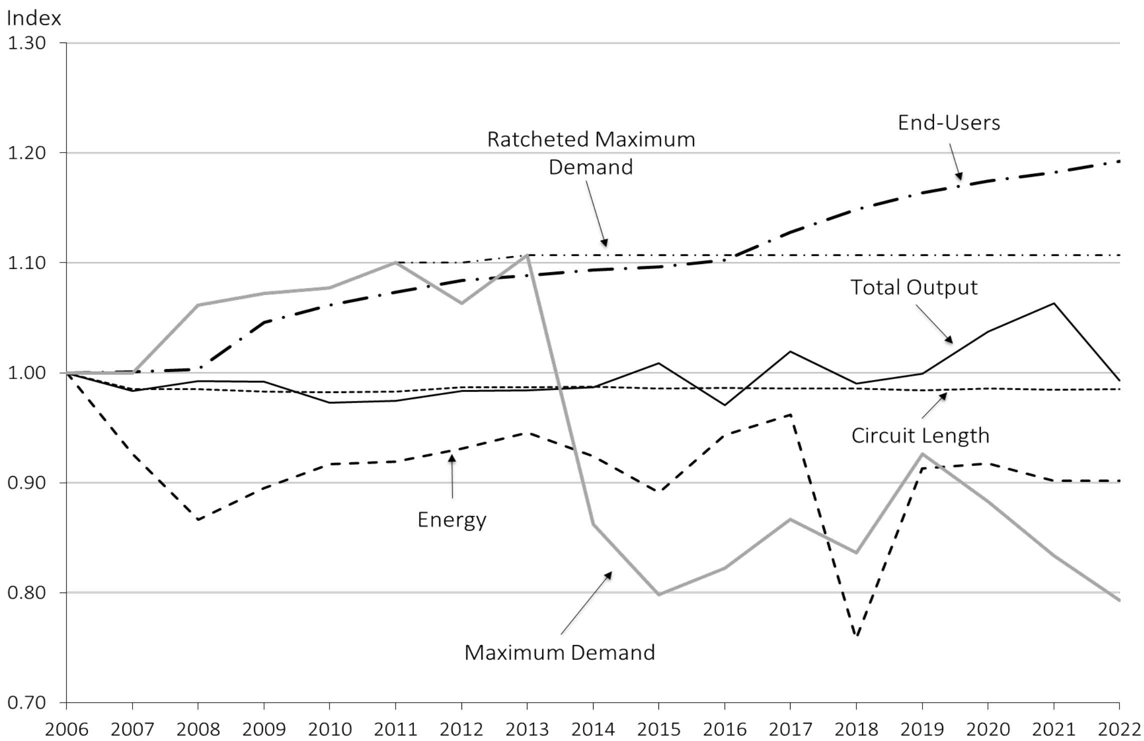
4.2.2 ENT's output and input quantity changes

Quantity indexes for ENT's individual outputs are presented in Figure 4.6 and for individual inputs in Figure 4.7. From Figure 4.6 we see that circuit length, the output component that receives the largest weight in forming the TFP index (see Appendix A, Table A.2), declined marginally in 2007 and has then remained virtually unchanged for the remainder of the 17-year period. This contrasts with the transmission industry as whole where circuit length was 7.9 per cent higher in 2022 than it was in 2006.

ENT's RMD output shows a similar pattern to the industry as a whole. ENT's RMD increased though to 2011 by 10.0 per cent overall, and then remained essentially constant thereafter. The industry's RMD increased by the same amount up to 2011, and whilst relatively flat thereafter, there were further incremental increases from 2017 to 2021.

ENT's energy throughput has decreased at a greater rate than for the industry as a whole. ENT's throughput *decreased* an average rate of 0.6 per cent per annum between 2006 and 2022, while industry energy throughput *decreased* at an annual average rate of 0.4 per cent over the same period. For ENT, energy throughput in 2022 was 9.8 per cent *below* its 2006 level compared to the industry's throughput being 6.4 per cent *less* than it was in 2006. The output that increased most over the period for ENT is end-user numbers with an overall increase of 19.2 per cent between 2006 and 2022, which is slightly less than the increase of 23.6 per cent for the industry.

Figure 4.6 ENT's output quantity indexes, 2006–2022



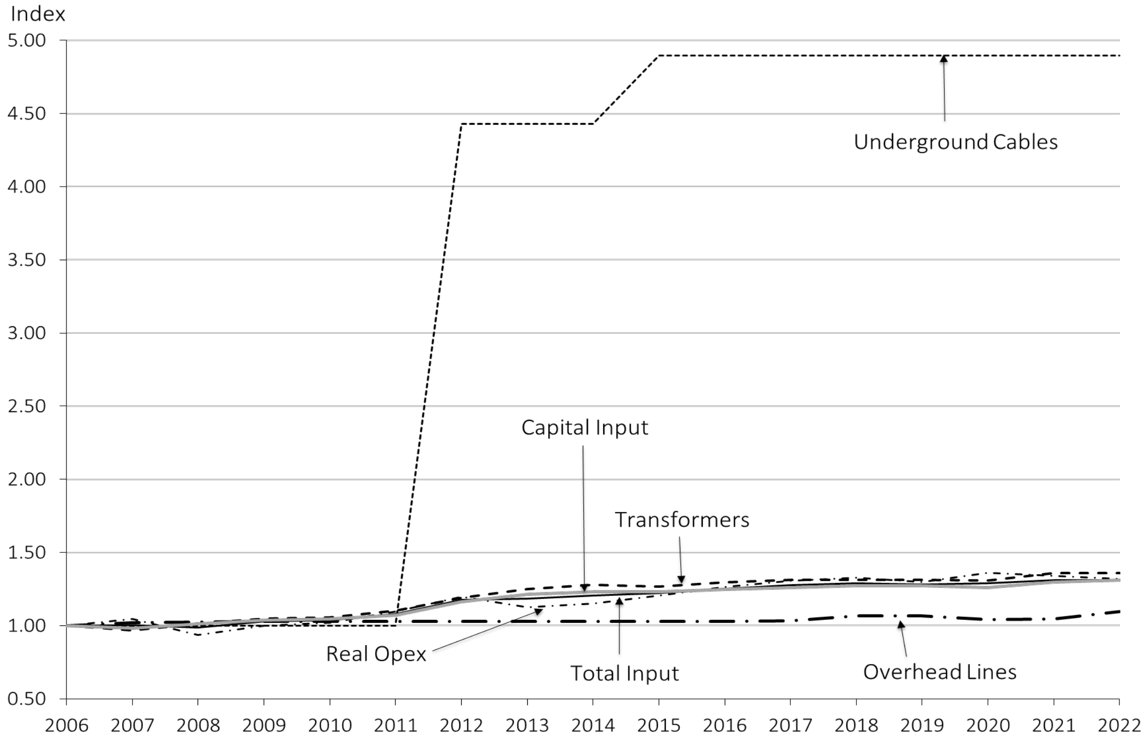
The output that is not shown in Figure 4.6 is ENS. ENT's ENS has been relatively volatile and spiked upwards in 2016 to 10 times its 2006 level after having been less than its 2006 level in 2015. In 2022, ENT's ENS increased to three times the 2006 level (i.e., a 212.9 per cent increase). Overall, ENS had a substantial negative impact on ENT's total output over most of the period, with the exception of 2020 and 2021, as shown in Figure 4.5.

Since the circuit length, end-user numbers and energy throughput outputs receive a combined average weight of 76.5 per cent in forming ENT's total output index (Appendix A, Table A.2), in Figure 4.6 we see that the total output index tends to lie close to the circuit length output index and is bounded by the end-user numbers and energy throughput indexes. Total output movements are also influenced by the pattern of movement in the ENS output, with the spike in ENS in 2016 and 2022 causing a pronounced drop in output in those years, and the large reduction in ENS in 2020 and 2021 causing a substantial increase in output.

Turning to the input side, quantity indexes for ENT's four inputs and aggregate inputs are shown in Figure 4.7. In line with ENT's near constant circuit length output, ENT's input quantity for overhead lines only increased slowly over the whole period (9.8 per cent in total).

Its underground cables input quantity increased by 389.8 per cent overall between 2006 and 2022, but the length of underground cables remains small.

Figure 4.7 ENT's input quantity indexes, 2006–2022



The quantity of opex increased over the 17-year period to 2022 by 31.8 per cent. This was a considerably higher increase than for the industry, where opex quantity increased only 0.5 per cent over the same period. Opex has the second largest average share in total costs, representing 32.4 per cent of ENT's costs. ENT's opex usage *decreased* by 1.6 per cent in 2022.

The input component with the largest average share of ENT's total cost, at 44.9 per cent, is transformers (Appendix A, Table A.3). ENT's quantity of transformers increased reasonably steadily over most of the 17-year period. By 2022, ENT's transformer inputs were 35.9 per cent above the 2006 level, which is a smaller increase than the industry's 45.1 per cent. Given their large share of total costs, transformer inputs are an important driver of the total input quantity index.

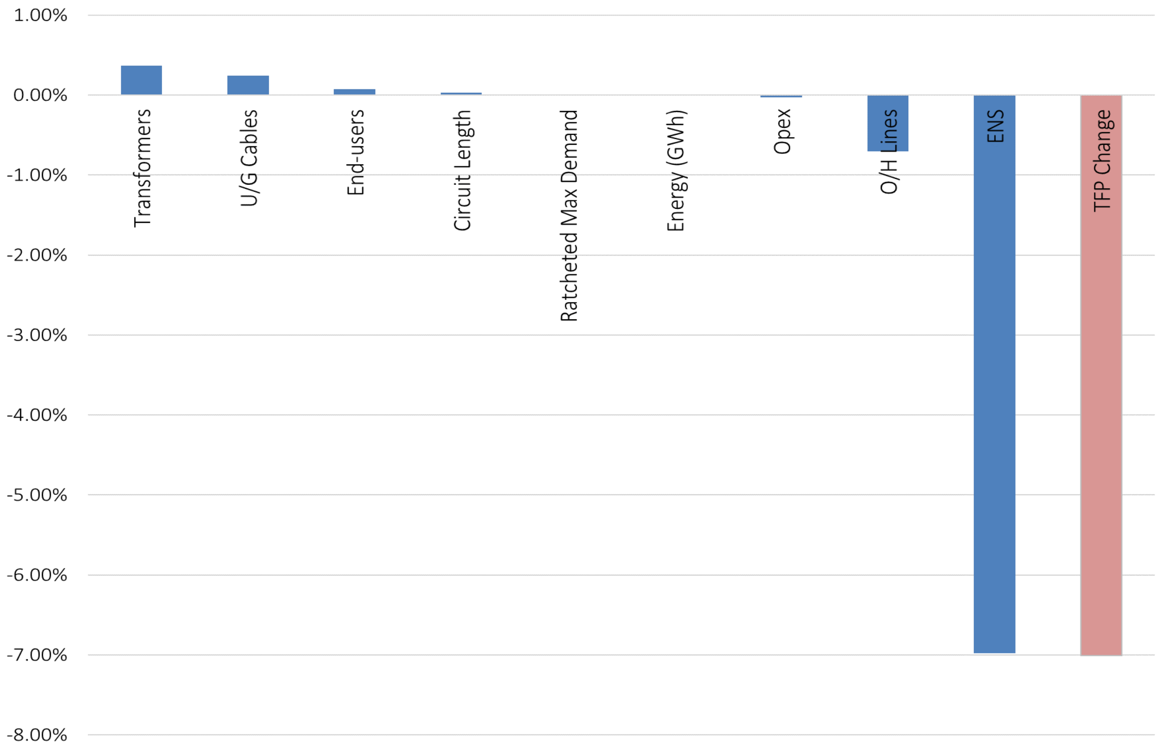
4.2.3 ENT's output and input contributions to TFP change

Table 4.4 shows the decomposition of ENT's average rates of TFP change into the contributions of the individual outputs and inputs for the whole 17-year period and for the periods up to and after 2012, and for 2022. Figure 4.8 shows the contributions of outputs and inputs to ENT's average rate of TFP change in 2022.

Table 4.4 ENT's output and input percentage point contributions to average annual TFP change: various periods

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2022*
Energy	-0.10%	-0.18%	-0.05%	-0.01%
Ratcheted Max Demand	0.16%	0.40%	0.02%	0.01%
End-users	0.08%	0.10%	0.07%	0.07%
Circuit Length	-0.05%	-0.12%	-0.01%	0.03%
ENS	-0.14%	-0.48%	0.06%	-6.98%
Opex	-0.60%	-0.98%	-0.37%	-0.03%
O/H Lines	-0.11%	-0.11%	-0.10%	-0.70%
U/G Cables	-0.16%	-0.38%	-0.03%	0.24%
Transformers	-0.83%	-1.21%	-0.60%	0.37%
TFP Change	-1.75%	-2.95%	-1.02%	-7.01%

Figure 4.8 ENT's output and input percentage point contributions to TFP change, 2022



4.3 Powerlink (PLK)

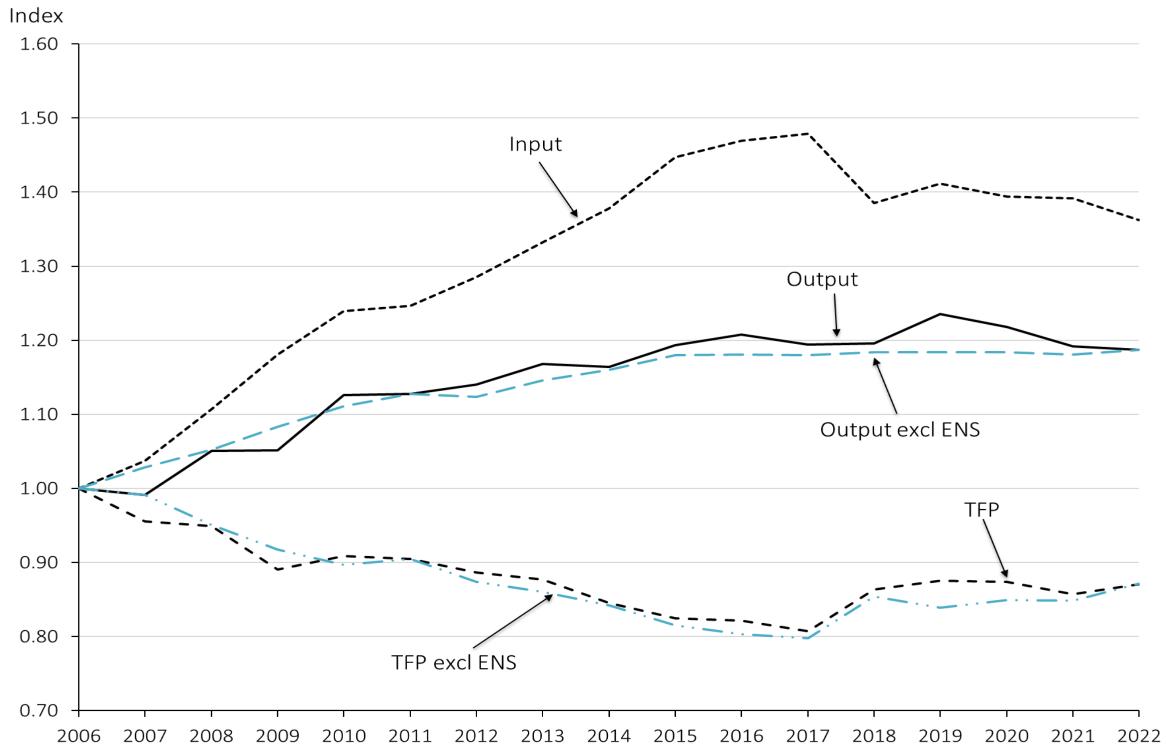
In 2022, PLK transported 51,132 GWh of electricity over 14,535 circuit kilometres of lines and cables. It forms a critical part of Queensland's energy supply chain serving 2.3 million end-users. PLK is the second largest of the five TNSPs in the NEM in terms of energy throughput but is the largest in terms of circuit length. It serves the third largest number of end-users.

4.3.1 PLK's productivity performance

PLK's total output, total input and TFP indexes are presented in Figure 4.9 and Table 4.5. Opex and capital PFP indexes are also presented in Table 4.5. Figure 4.9 also shows the output and TFP indexes when ENS is excluded, which highlights the effect of ENS.[10]

After a steady decline over the period up to 2017, PLK's TFP increased strongly in 2018 and has largely levelled off since then. In 2022, PLK's TFP increased by 1.6 per cent. The key to these trends is the growth rates of the input index. By 2017, the input index was 47.9 per cent higher than its level in 2006, but there was a substantial decrease in the input index in 2018. Consequently, in 2022, the input index was 36.2 per cent higher than in 2006. This remains a larger increase in inputs compared to the total industry, for which inputs increased by 23.9 per cent between 2006 and 2022. The increase in TFP in 2022 at 1.6 per cent was driven by a substantial *decrease* in input index at 2.1 in 2022, outweighing a *reduction* in output index of 0.5 per cent. Figure 4.9 shows that the TFP series excluding ENS was also relatively flat between 2018 and 2022. The growth of TFP excluding ENS in 2022 was 2.6 per cent, indicating the negative impact of the ENS.

Figure 4.9 PLK's output, input and TFP indexes, 2006–2022



[10] To ensure non-zero values of ENS, Economic Insights (2021) imposed a minimum ENS value of 1.0 MWh. In this study a lower minimum value of 0.2 has been adopted. In 2019 PLK's ENS was zero, and this was set at 1.0 previously, but is now reset at 0.2 MWh. This affects comparisons for PLK in 2019 between this and the previous benchmarking study.

Over the 17-year period from 2006 to 2022, PLK's TFP decreased at an average annual rate of change of –0.9 per cent. Its total output increased over the period with an average annual rate of change of 1.1 per cent. This was considerably higher than the industry average annual growth in output of 0.5 per cent. However, PLK's average annual rate of increase in input use of 1.9 per cent was above the rate of increase in total input use for the industry of 1.3 per cent. The net effect of these two differences is that PLK had a similar rate of decline in TFP to the industry average (–0.9 and –0.8 per cent, respectively).

For the period from 2006 to 2012, PLK's rate of average annual growth in TFP was –2.0 per cent. Whereas in the period from 2012 to 2022, its average annual growth in TFP was –0.2 per cent. The PFP indexes in Table 4.5 show that in the period from 2006 to 2012, the rate of capital PFP growth averaged –3.2 per cent per annum, while in the period from 2012 to 2022, the average growth of capital PFP was –0.4 per cent per annum. This stabilisation of capital PFP strongly influenced the TFP trend but was partly offset by the reduced average annual opex PFP rate of growth, from 0.9 per cent in the period up to 2012 to 0.1 per cent in the period after 2012.

Table 4.5 PLK's output, input, TFP and PFP indexes, 2006–2022

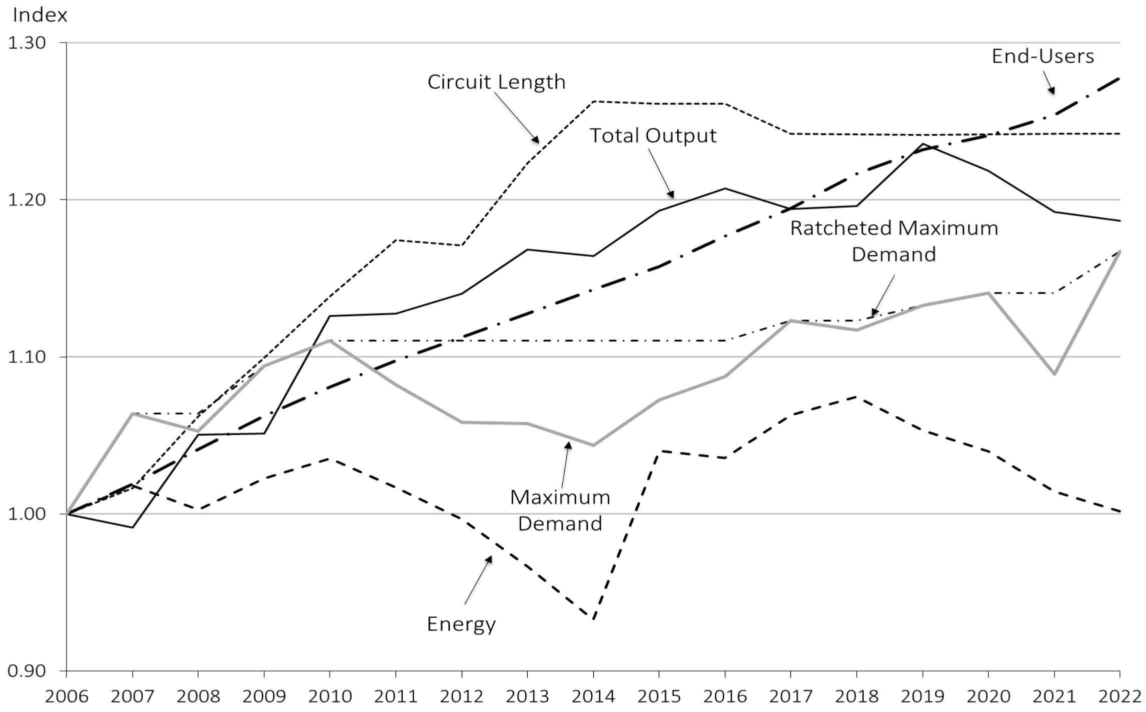
Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	0.991	1.037	0.956	0.960	0.953
2008	1.050	1.107	0.949	0.942	0.956
2009	1.051	1.181	0.890	0.992	0.850
2010	1.126	1.239	0.908	1.027	0.863
2011	1.128	1.246	0.905	1.074	0.844
2012	1.140	1.286	0.887	1.056	0.828
2013	1.168	1.332	0.877	1.073	0.809
2014	1.164	1.378	0.845	1.018	0.783
2015	1.193	1.447	0.824	0.915	0.788
2016	1.207	1.469	0.822	0.916	0.785
2017	1.194	1.479	0.807	0.888	0.776
2018	1.196	1.385	0.863	1.096	0.784
2019	1.236	1.411	0.875	1.092	0.800
2020	1.218	1.394	0.874	1.086	0.799
2021	1.192	1.391	0.857	1.034	0.792
2022	1.187	1.362	0.871	1.072	0.792
Growth Rate 2006-2022	1.1%	1.9%	-0.9%	0.4%	-1.5%
Growth Rate 2006-2012	2.2%	4.2%	-2.0%	0.9%	-3.2%
Growth Rate 2012-2022	0.4%	0.6%	-0.2%	0.1%	-0.4%
Growth Rate 2022	-0.5%	-2.1%	1.6%	3.6%	0.0%

4.3.2 PLK's output and input quantity changes

Quantity indexes for PLK's individual outputs are presented in Figure 4.10 and for individual inputs in Figure 4.11. The quantities are converted to index format with a value of one in 2006 for ease of comparison. Growth rates for PLK's individual outputs and inputs, and of PFPs defined in terms of individual inputs, are shown in Appendix B.

From Figure 4.10 we see that circuit length (the output component that receives the largest weight in forming the TFP index), increased relatively steadily through to 2014 before levelling off. In 2022, PLK's circuit length was 24.2 per cent higher than it was in 2006. This is a much larger increase than for the transmission industry as a whole where circuit length was 7.9 per cent higher in 2022 than it was in 2006. PLK's ratcheted maximum demand (RMD) output shows a similar pattern to the industry as a whole in that it increased by 11.0 per cent from 2006 to 2010 and remained unchanged in the following years through 2016, with some small increases thereafter. In 2022, PLK's RMD was 16.7 per cent above its 2006 level (compared to 13.0 per cent for the industry).

Figure 4.10 PLK's output quantity indexes, 2006–2022



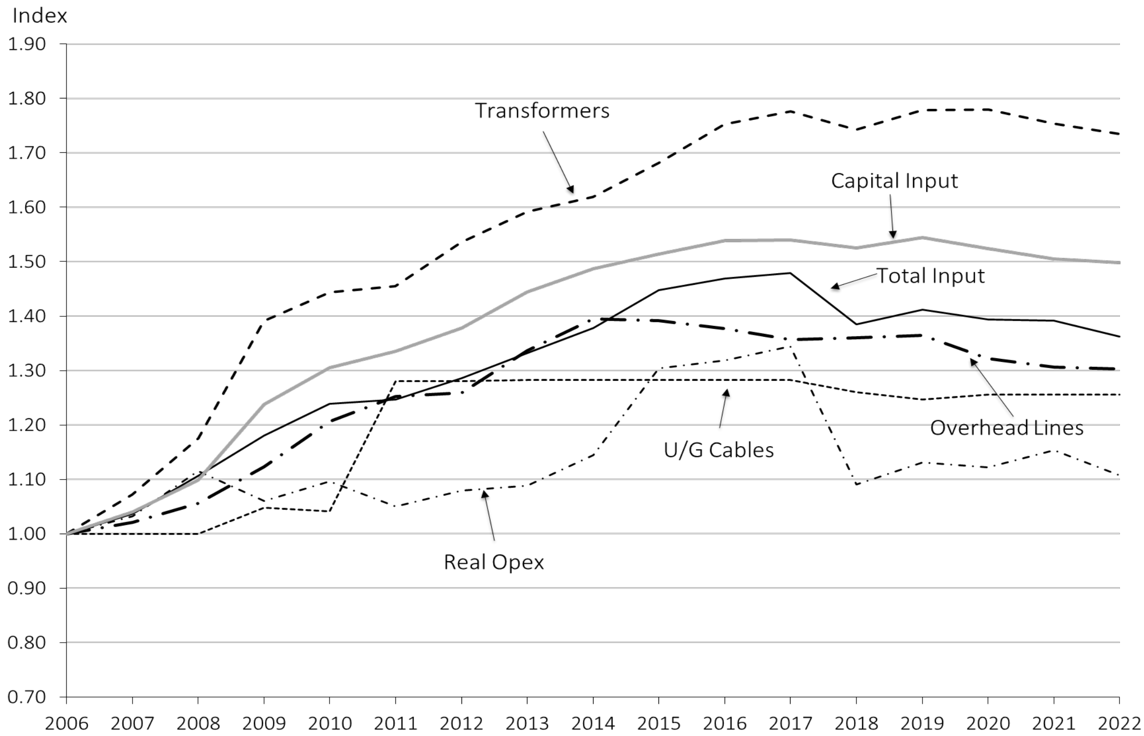
PLK's energy throughput decreased from 2010 to 2014 but it recovered strongly up to 2018 before again declining. By 2022, PLK's energy throughput was 0.2 per cent above its 2006 level, compared to the industry's energy throughput being 6.4 per cent *below* its level in 2006. The end-user numbers output increased over the period by a percentage approximately equal to circuit length, with an increase of 27.8 per cent between 2006 and 2022, and slightly higher than the increase in end-users of 23.6 per cent for the industry. PLK's end-user numbers have increased steadily over the period reflecting Queensland's strong rate of population growth. Since the circuit length, end-user numbers and energy throughput outputs receive a combined weight of around 76.0 per cent of PLK's total revenue in forming the total output index, the trend of the total output index is also strongly influenced by these series.

The output not shown in Figure 4.10 is ENS. PLK's ENS spiked upwards sharply in 2007 and 2009 to six times and five times, respectively, its 2006 level. However, since then PLK's ENS levels have tended to reduce and the peaks in the output series in Figure 4.10 in 2013, 2015, 2016 and 2019 correspond to large reductions in ENS in those years. Figure 4.9 shows that the underlying output trend was smoother. In 2019 PLK's ENS was zero, but in 2022 it was 18.6 per cent above the 2006 level. Overall, PLK's ENS growth rate averaged 1.1 per cent per year in the entire 17-year period.

Turning to the input side, the quantity indexes for PLK's four inputs and the total input index are shown in Figure 4.11. As with its higher increase in circuit length output, PLK's input quantity for overhead lines (in MVA-km) increased more than that for the industry (1.7 per cent per year on average compared to 1.3 per cent), but its underground cables input quantity increased less than that for the industry (1.4 per cent per year compared to 4.1 per cent). PLK's overhead lines input increased by 30.3 per cent and its underground cables input quantity increased by 25.5 per cent between 2006 and 2022. This compares to corresponding increases for the industry of 22.1 per cent and 94.1 per cent over the same period.

PLK's real opex usage increased only modestly through to 2013 but increased substantially between 2014 and 2017, returning to its previous level in 2018 before rising slightly again up to 2021. However, it declined again in 2022. The opex input index increased less than PLK's other three inputs over the 17-year period and was 10.7 per cent higher in 2022 than it was in 2006. This can be compared to the increase for the industry of 0.5 per cent over the same period. Opex has an average share in PLK's total costs at 28.1 per cent (see Appendix A, Table A.3). The input component with the largest average share of total cost, at 37.0 per cent, is transformers. PLK's quantity of transformers increased steadily up to 2017, levelling off after that. By 2022 it was 73.5 per cent above its 2006 level – a much larger increase than the industry's 45.1 per cent.

Figure 4.11 PLK's input quantity indexes, 2006–2022



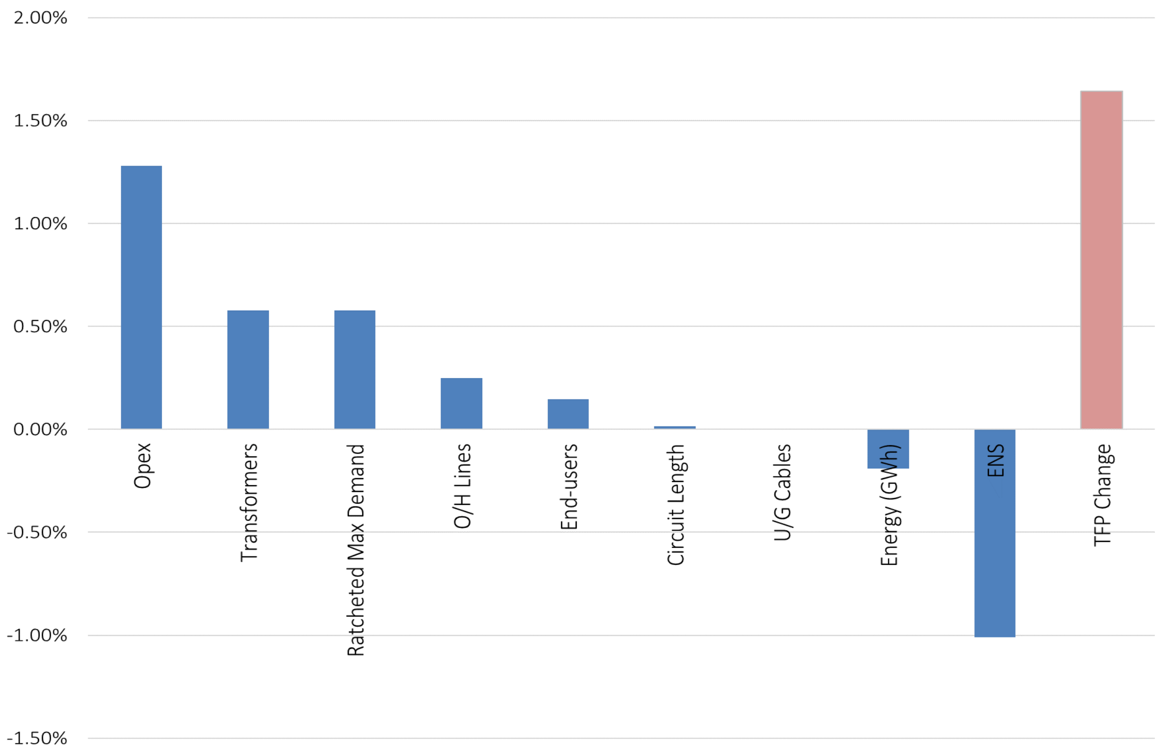
4.3.3 PLK's output and input contributions to TFP change

Table 4.6 shows the decomposition of PLK's average rates of TFP change into the contributions of the individual outputs and inputs for the whole 17-year period and for the periods up to and after 2012, and for 2022. Figure 4.12 shows the contributions of outputs and inputs to PLK's average rate of TFP change in 2022.

Table 4.6 PLK's output and input percentage point contributions to average annual TFP change: various periods

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2022*
Energy	0.00%	-0.01%	0.01%	-0.19%
Ratcheted Max Demand	0.24%	0.44%	0.13%	0.58%
End-users	0.12%	0.14%	0.11%	0.15%
Circuit Length	0.72%	1.41%	0.32%	0.01%
ENS	-0.02%	0.22%	-0.15%	-1.01%
Opex	-0.18%	-0.42%	-0.04%	1.28%
O/H Lines	-0.60%	-1.45%	-0.09%	0.25%
U/G Cables	-0.01%	-0.03%	0.00%	0.00%
Transformers	-1.14%	-2.29%	-0.45%	0.58%
TFP Change	-0.86%	-2.00%	-0.18%	1.64%

Figure 4.12 PLK's output and input percentage point contributions to TFP change, 2022



4.4 TasNetworks Transmission (TNT)

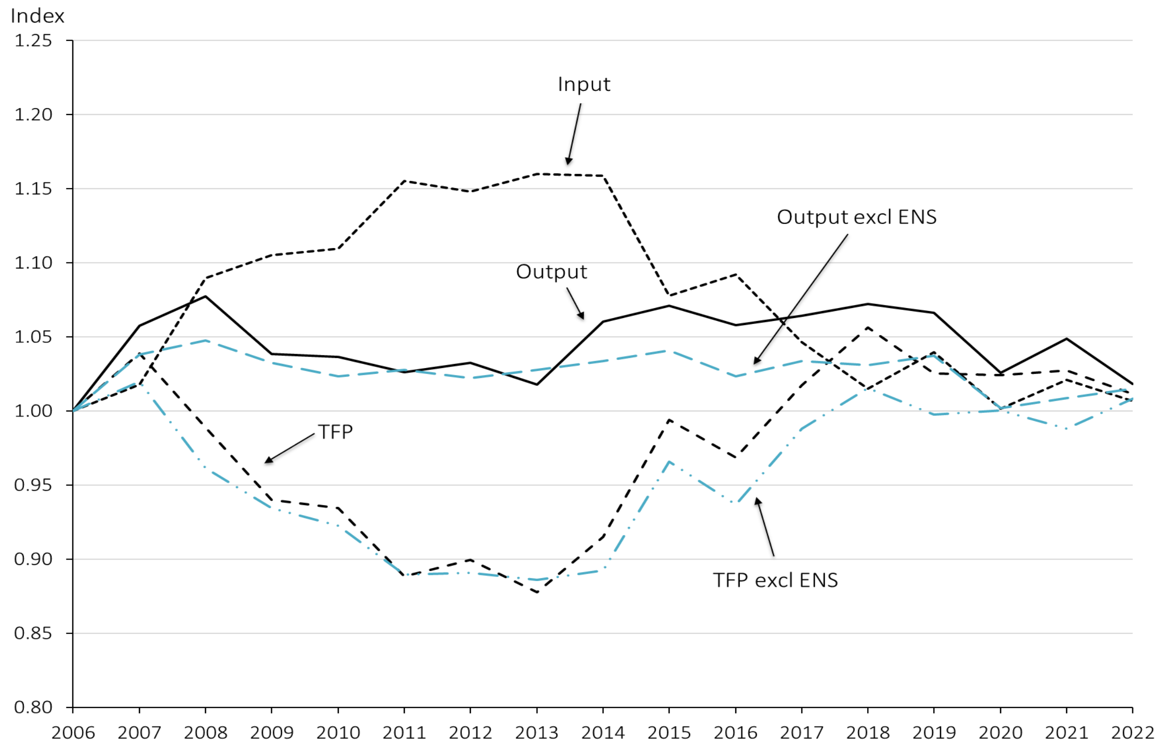
In 2021 TNT transported 13,237 GWh of electricity over 3,361 circuit kilometres of lines and cables. It forms a critical part of Tasmania's energy supply chain serving 301,064 end-users. TNT is the smallest TNSP in the NEM in terms of energy throughput, circuit length and the number of end-users.

4.4.1 TNT's productivity performance

TNT's total output, total input and TFP indexes are presented in Figure 4.13 and Table 4.7. Opex and capital PFP indexes are also presented in Table 4.7. Figure 4.13 also shows the output and TFP indexes when ENS is excluded, which highlights the effect of ENS.

Over the 17-year period 2006 to 2022, TNT's TFP increased at an average annual rate of 0.1 per cent. This outcome was the combined effect of its total output having increased by an average annual rate of 0.1 per cent while its total input growth was zero per cent per year over the same period. This differs from the situation for the transmission industry as a whole where input use increased faster (1.3 per cent per annum on average from 2006 to 2022) and output also increased faster (0.5 per cent per annum), resulting in a decline in TFP (a rate of change of –0.8 per cent per annum).

Figure 4.13 TNT's output, input and TFP indexes, 2006–2022



TNT's average output growth over the period from 2006 to 2012 of 0.5 per cent per year compares to the average rate of change in the period from 2012 to 2022 of –0.1 per cent. Input usage and TFP also had different trends in these two sub-periods. The input index increased in the period from 2006 to 2012 at an average annual rate of 2.3 per cent, whereas in the period from 2012 to 2022 it *decreased* at an average annual rate of 1.3 per cent. Conversely, the TFP index average annual rate *decreased* from 2006 to 2012 by 1.8 per cent and *increased* at an average annual rate of 1.2 per cent from 2012 to 2022.

TFP *decreased* in 2022 by 1.6 per cent, due to a significant *decrease* in outputs of 3.0 per cent offset by a *decrease* in inputs of 1.4 per cent. If ENS is excluded, the average rate of TFP growth from 2012 to 2022 is the same at 1.2 per cent per annum. The decrease in outputs in 2022 is mostly due to reduced reliability. When ENS is excluded the 2022 output growth is 0.6 per cent, and the 2022 rate of TFP change is 2.0 per cent.

The PFP indexes in Table 4.7 show a substantial improvement in opex PFP in the latter half of the period, from an average change of –0.4 per cent per annum before 2012 to 5.9 per cent per annum after 2012. There was also an improvement in capital PFP from a rate of change of –2.6 per cent up to 2012, to a rate of –0.8 per cent after 2012. These were important reasons for the improvement in TFP performance in the period from 2012 to 2022. In 2022, there was a substantial decline in opex PFP (of 5.2 per cent), joined by a *decrease* in capital PFP by 3.1 per cent.

Table 4.7 TNT's output, input, TFP and PFP indexes, 2006–2022

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.058	1.018	1.039	1.041	1.047
2008	1.077	1.090	0.989	0.896	1.044
2009	1.039	1.105	0.940	0.895	0.973
2010	1.037	1.109	0.934	0.896	0.951
2011	1.026	1.155	0.888	0.945	0.860
2012	1.032	1.148	0.899	0.975	0.856
2013	1.018	1.160	0.877	1.038	0.811
2014	1.060	1.159	0.915	1.097	0.843
2015	1.071	1.078	0.994	1.491	0.845
2016	1.058	1.092	0.969	1.385	0.834
2017	1.064	1.046	1.017	1.667	0.841
2018	1.072	1.015	1.056	1.897	0.847
2019	1.066	1.040	1.025	1.801	0.827
2020	1.026	1.002	1.024	2.024	0.793
2021	1.049	1.021	1.027	1.860	0.813
2022	1.018	1.007	1.011	1.766	0.789
Growth Rate 2006-2022	0.1%	0.0%	0.1%	3.6%	-1.5%
Growth Rate 2006-2012	0.5%	2.3%	-1.8%	-0.4%	-2.6%
Growth Rate 2012-2022	-0.1%	-1.3%	1.2%	5.9%	-0.8%
Growth Rate 2022	-3.0%	-1.4%	-1.6%	-5.2%	-3.1%

4.4.2 TNT's output and input quantity changes

Quantity indexes for TNT's individual outputs are presented in Figure 4.14 and for individual inputs in Figure 4.15. Growth rates of individual outputs and individual inputs, and of partial factor productivities defined in terms of individual inputs, are presented in Appendix B.

From Figure 4.14 we see that circuit length (the output that receives the largest weight in the output index) has fluctuated somewhat but remained largely unchanged except for a large decrease in 2020. In 2022, TNT's circuit length was 6.2 per cent *less* than it was in 2006. This contrasts with the transmission industry as a whole where circuit length was 7.9 per cent higher in 2022 than it was in 2006. Another of TNT's outputs which did not show any growth was RMD, which essentially remained constant over the whole of the 17-year period – in 2022 it was 0.2 per cent above its 2006 level. This contrasts with the industry, where the 2022 RMD was 13.0 per cent above its 2006 level.

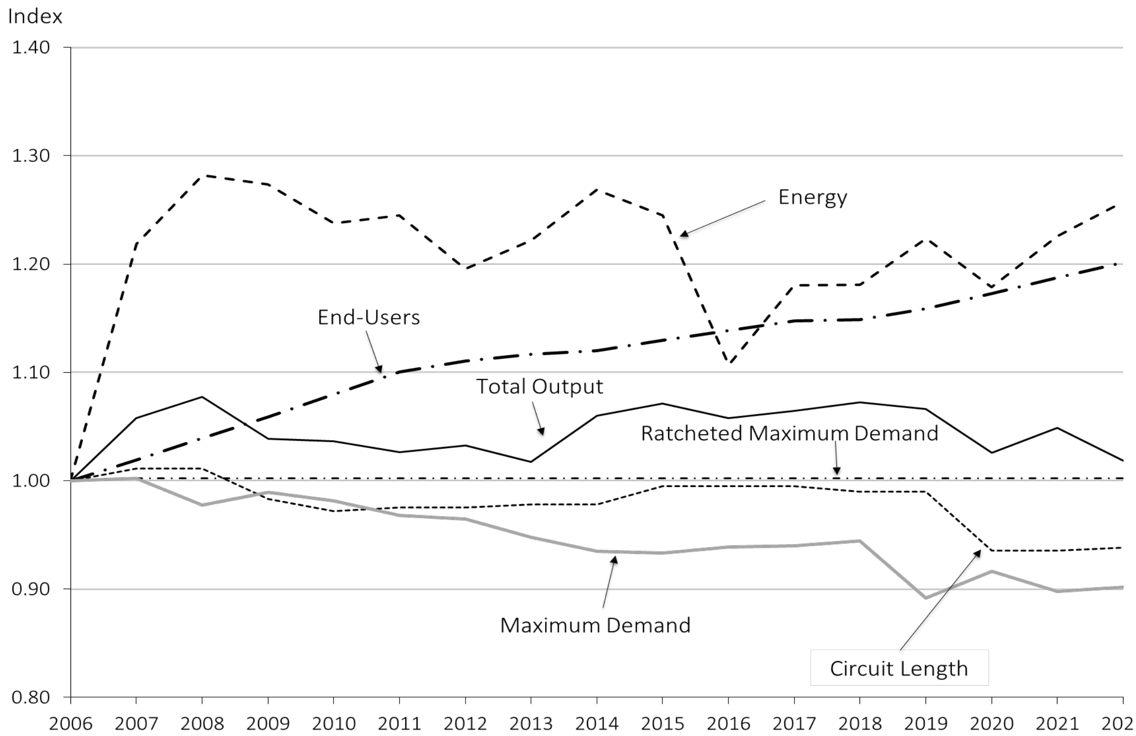
The outputs that had the largest increases over the period for TNT were energy throughput and end-user numbers, at average annual rates of 1.4 per cent and 1.1 per cent, respectively. TNT's energy throughput has had a very different pattern to that for the industry as a whole. It increased by 28.2 per cent between 2006 and 2008 before fluctuating at a relatively constant level over the remainder of the period to 2022. In 2022 energy throughput for TNT was 25.7

per cent above its 2006 level, whereas for the transmission industry it was 6.4 per cent *lower* than it was in 2006. TNT's energy throughput is particularly affected by exports to the mainland and demand from large industrial users. In 2022, energy throughput increased by 2.5 per cent.

TNT's end-user numbers increased by 20.1 per cent between 2006 and 2022, a little less than that of the industry (23.6 per cent). Again, this steady increase is to be expected as the number of electricity end-users will increase approximately in line with population growth.

The output not shown in Figure 4.14 is ENS. TNT's ENS has been relatively volatile but within a much smaller range than most other TNSPs. ENS fell from 2006 through to 2008 before trending up to be approximately 60 per cent above its 2006 level in 2013. Since then, it has reduced in most years and was 11.8 per cent *below* its 2006 level in 2022. A significant part of this reduction in ENS occurred in 2021, which made a substantial contribution to output in that year.

Figure 4.14 TNT's output quantity indexes, 2006–2022



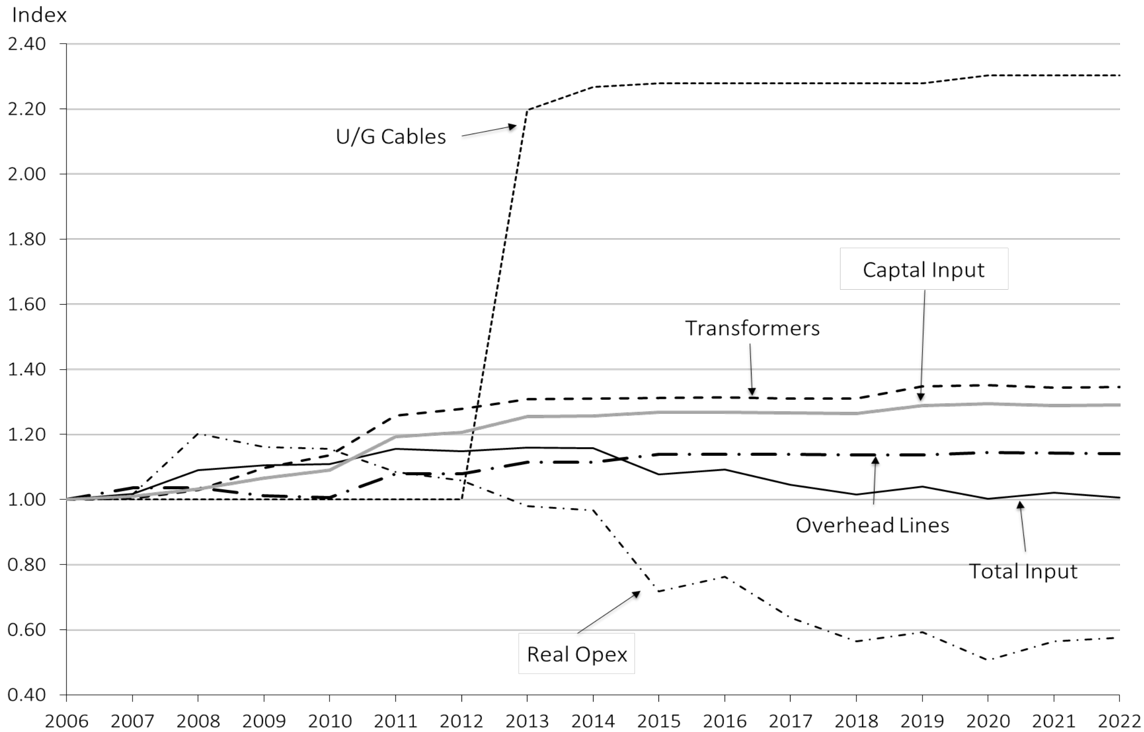
Turning to the input side, Figure 4.15 presents quantity indexes for TNT's four inputs and its total input index and the combined capital input index. TNT's input usage trends are similar to those for the industry, except that opex input decreases much more for TNT over the period and transformer and overhead lines inputs grow less for TNT than for the industry.

The quantity of TNT's opex input had a large decrease between 2006 and 2022, so that the 2022 level was 42.3 per cent *lower* than the 2006 level. This contrasts with the industry's increase in opex usage of 0.5 per cent over the same period. Opex has the second-largest average share in TNT's total costs at 28.2 per cent (Appendix A, Table A.3).

Despite TNT's relatively steady circuit length output (excepting 2020), TNT's input quantity for overhead lines has increased reflecting the use of higher capacity lines. Underground cables input more than doubled in 2013 but the length of underground cables grows from only 13 kilometres to 23 kilometres with the new cables being of considerably higher capacity.

The input component with the largest average share of TNT's total cost, at 48.1 per cent, is transformers (see Appendix A, Table A.3). TNT's quantity of transformers increased steadily to 2012 at an average annual rate of 4.1 per cent. It then largely levelled off, increasing at an average annual rate of 0.5 per cent per year between 2012 and 2022. By 2022 the quantity of transformers was 34.7 per cent above its 2006 level – a smaller increase than the industry's 45.1 per cent.

Figure 4.15 TNT's input quantity indexes, 2006–2022



From Figure 4.15 we see that TNT's total input quantity index generally lies close to the quantity indexes for transformers and overhead lines (which have a combined weight of 70.5 per cent of TNT's total costs), and fluctuations in the total inputs index are mainly driven by variations in opex use.

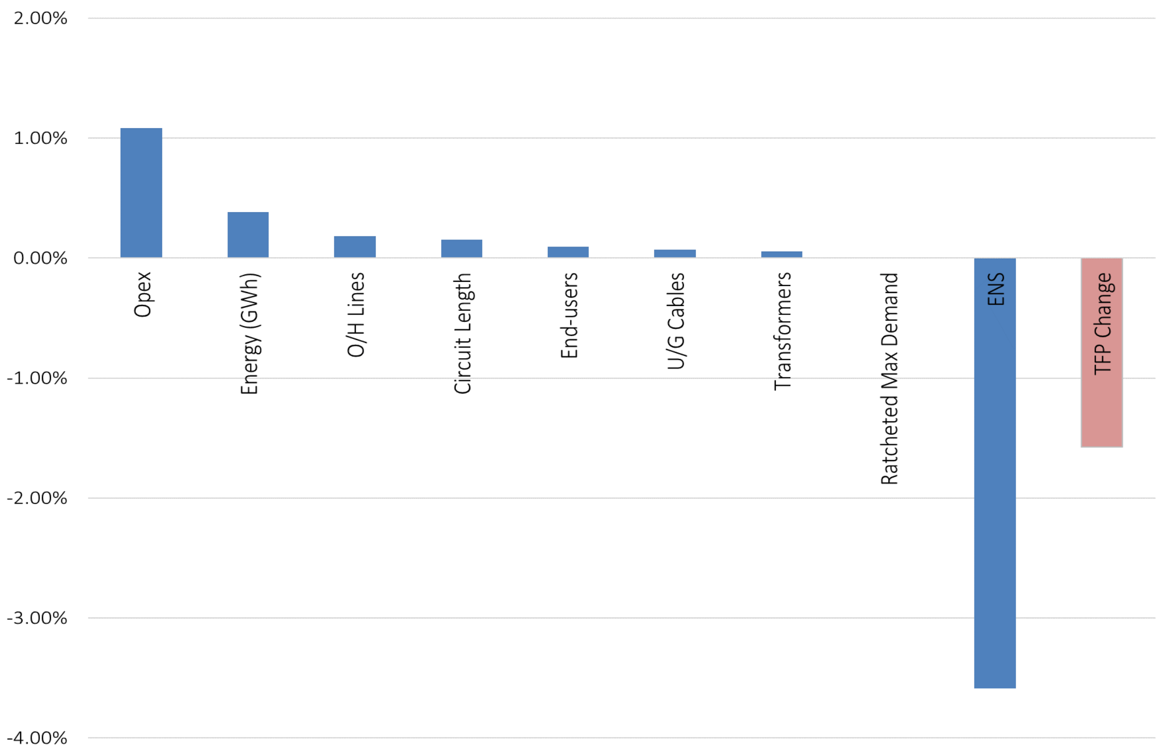
4.4.3 TNT's output and input contributions to TFP change

Table 4.8 shows the decomposition of TNT's average rates of TFP change into the contributions of the individual outputs and inputs for the whole 17-year period and for the periods up to and after 2012, and for 2022. Figure 4.16 shows the contributions of outputs and inputs to TNT's average rate of TFP change in 2022.

Table 4.8 TNT's output and input percentage point contributions to average annual TFP change: various periods

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2022*
Energy	0.22%	0.45%	0.08%	0.38%
Ratcheted Max Demand	0.00%	0.01%	0.00%	0.00%
End-users	0.09%	0.14%	0.06%	0.09%
Circuit Length	-0.21%	-0.22%	-0.21%	0.15%
ENS	0.02%	0.16%	-0.07%	-3.59%
Opex	1.06%	-0.12%	1.77%	1.08%
O/H Lines	-0.18%	-0.28%	-0.12%	0.18%
U/G Cables	-0.06%	0.00%	-0.09%	0.07%
Transformers	-0.87%	-1.90%	-0.25%	0.05%
TFP Change	0.07%	-1.77%	1.17%	-1.57%

Figure 4.16 TNT's output and input percentage point contributions to TFP change in 2022



4.5 TransGrid (TRG)

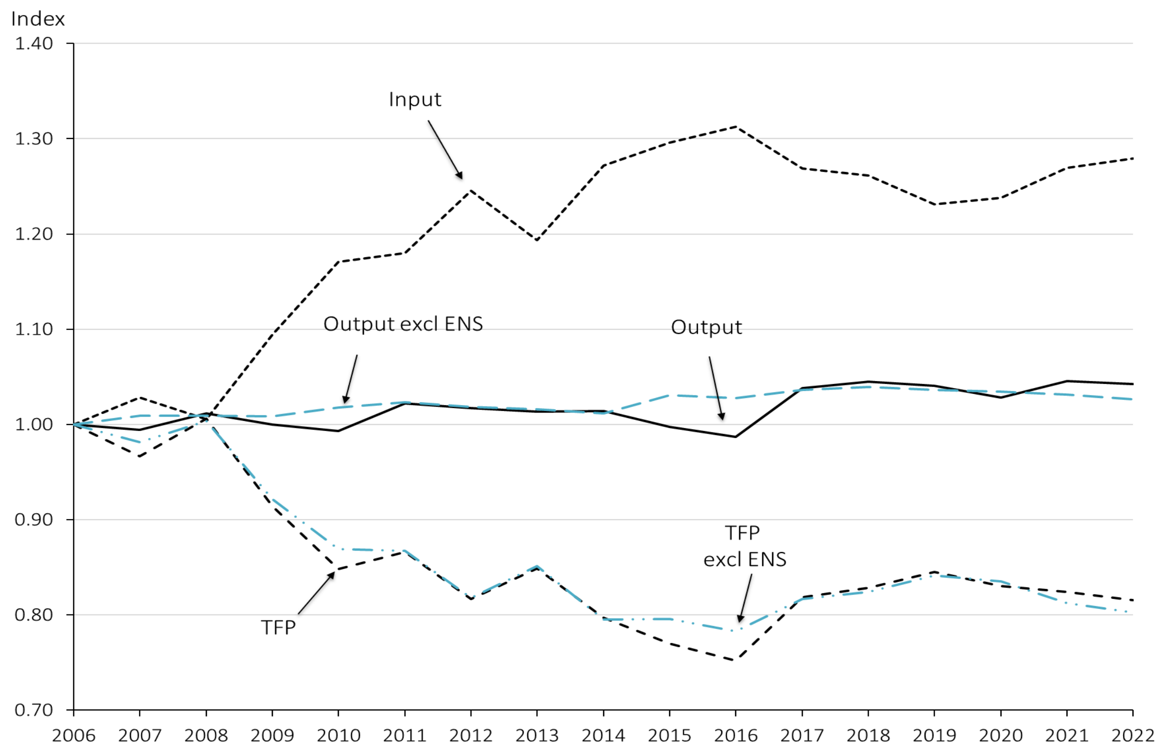
In 2022 TRG transported 68,200 GWh of electricity over 13,075 circuit kilometres of lines and cables. It forms a critical part of New South Wales' energy supply chain serving around 4.0 million end-users. TRG is the largest of the five TNSPs in the NEM in terms of energy throughput and the number of end-users and the second largest in terms of circuit length.

4.5.1 TRG's productivity performance

TRG's total output, total input and TFP indexes are presented in Figure 4.17 and Table 4.9. Opex and capital PFP indexes are also presented in Table 4.9. Figure 4.17 also shows the output and TFP indexes when ENS is excluded, which highlights the effect of ENS.

Over the 17-year period 2006 to 2022, TRG's TFP *decreased* at an average annual rate of 1.3 per cent. Its total output increased over this period at an average annual rate of 0.3 per cent. This compares to industry output growth of 0.5 per cent per annum on average. TRG's average annual rate of increase in input use of 1.5 per cent over the same period is similar to that of the industry's 1.3 per cent. The net effect of the output and input movements is TRG's annual rate of change in TFP of –1.3 per cent; which was a more pronounced decline than the industry's average annual TFP change of –0.8 per cent over the 2006 to 2022 period.

Figure 4.17 TRG's output, input and total factor productivity indexes, 2006–2022



Over the period from 2006 to 2012, the average growth rate of TRG's output was 0.3 per cent per annum. Over the same period the average annual growth rate of inputs was 3.7 per cent.

The net effect was a decline of TFP, averaging –3.4 per cent per year in this sub-period. For the period after 2012, the rate of average annual growth in output was 0.25 per cent per year, while the average annual change in input was similar at 0.27 per cent per year. The net effect was a -0.02 TFP growth per annum from 2012 to 2022. During this sub-period, TFP fell significantly from 2013 to 2016. This was accentuated by unusually high levels of outages in 2015 and 2016. From 2017 to 2019 TFP improved, followed by a decline up to 2022. In 2022, TFP *decreased* by 1.0 per cent. This adverse outcome occurred due to a *decrease* of 0.3 per cent in output and an increase of 0.7 per cent in inputs.

Table 4.9 TRG's output, input, TFP and PFP indexes, 2006–2021

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	0.994	1.028	0.967	1.020	0.943
2008	1.012	1.006	1.006	1.110	0.966
2009	1.000	1.094	0.914	1.103	0.844
2010	0.993	1.170	0.848	0.976	0.798
2011	1.022	1.180	0.866	1.085	0.790
2012	1.017	1.245	0.817	1.010	0.748
2013	1.013	1.194	0.849	1.107	0.763
2014	1.014	1.272	0.797	0.928	0.748
2015	0.998	1.296	0.770	0.976	0.699
2016	0.987	1.313	0.752	0.977	0.676
2017	1.038	1.269	0.818	1.043	0.741
2018	1.045	1.261	0.828	1.189	0.719
2019	1.040	1.231	0.845	1.207	0.735
2020	1.028	1.238	0.830	1.165	0.725
2021	1.046	1.269	0.824	1.152	0.720
2022	1.043	1.279	0.815	1.065	0.727
Growth Rate 2006-2022	0.3%	1.5%	-1.3%	0.4%	-2.0%
Growth Rate 2006-2012	0.3%	3.7%	-3.4%	0.2%	-4.8%
Growth Rate 2012-2022	0.2%	0.3%	0.0%	0.5%	-0.3%
Growth Rate 2022	-0.3%	0.7%	-1.0%	-7.9%	0.9%

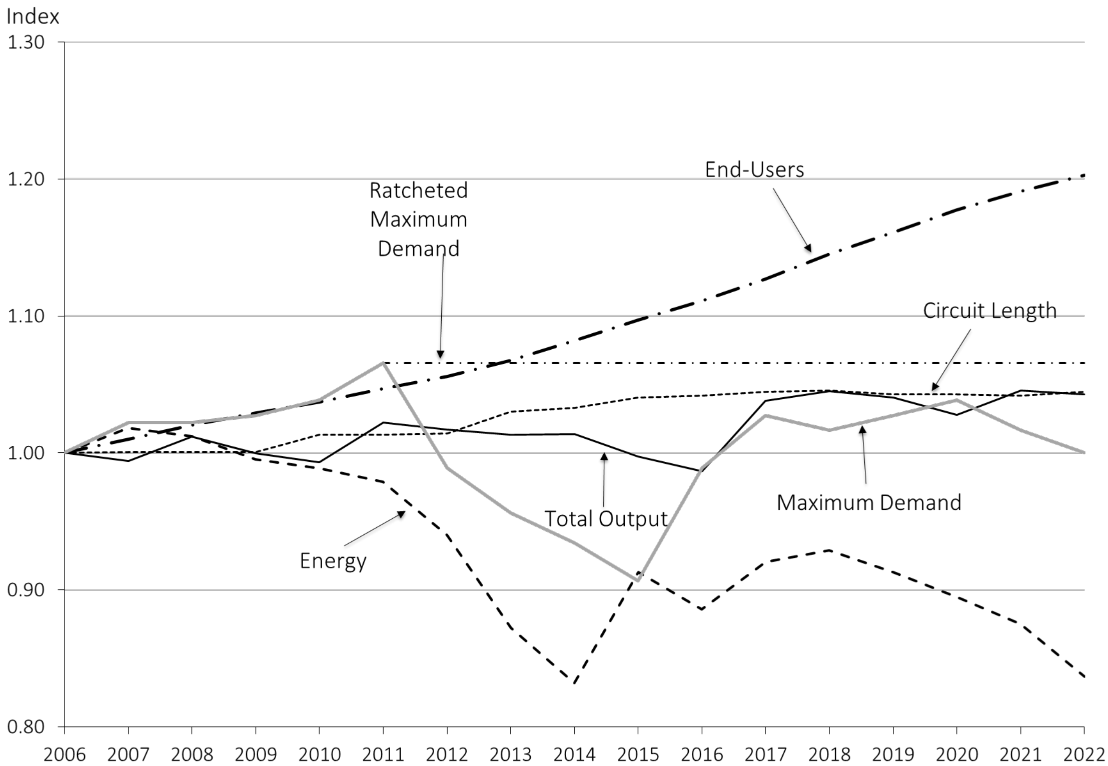
The PFP indexes in Table 4.9 show that the improvement in average annual rates of change of TFP after 2012 was associated with both an improvement in the trend of capital and opex PFP index. The average rate of change in opex PFP between 2006 and 2012 was 0.2 per cent per annum, and this increased between 2012 and 2022 to an average of 0.5 per cent. On the other hand, the rate of change per annum in capital PFP between 2006 and 2012 was –4.8 per cent, but this improved to an average rate of –0.3 per cent from 2012 to 2022.

4.5.2 TRG's output and input quantity changes

Quantity indexes for TRG's individual outputs are presented in Figure 4.18 and for individual inputs in Figure 4.19 (where the index base is 1.0 in 2006). From Figure 4.18 we see that circuit length (the output component with the largest weight in the output index), increased gradually after 2009 and flattened out from 2016. By 2022, TRG's circuit length was 4.5 per cent above its 2006 level. This compares to the transmission industry's corresponding increase in circuit length of 7.9 per cent.

TRG's RMD showed a broadly similar pattern to the industry as a whole, although with a smaller increase overall. TRG's RMD increased through to 2011 but then remained constant thereafter at 6.6 per cent above the 2006 level. Figure 4.18 also shows maximum demand declined from 2011 to 2015, and subsequently increased, but did not recover to its 2011 level.

Figure 4.18 TRG's output quantity indexes, 2006–2022



TRG's energy throughput *decreased* at an average rate of 1.1 per cent per year from 2006 to 2022. The annual rate of change of TRG's energy throughput was –1.0 per cent between 2006 and 2012, and from 2012 to 2022 it was –1.2 per cent per year. In 2022, TRG's energy throughput was 16.3 per cent *below* its 2006 level compared to the industry's throughput (which was 6.4 per cent *lower* than it was in 2006).

The output that increased the most over the period for TRG is end-user numbers with an increase of 20.3 per cent between 2006 and 2022, only slightly less than the increase of 23.6

per cent for the industry. TRG's end-user numbers increased steadily over the 17-year period in line with NSW's population growth.[11]

The output not shown in Figure 4.18 is ENS. TRG's ENS fluctuated around its 2006 level through to 2014, with the main exception being that in 2010 it spiked to be four times its 2006 level. TPG's ENS increased sharply in both 2015 and 2016. In 2015 it was seven times and in 2016 it was ten times its 2006 level after having been below its 2006 level in 2014. From 2017 to 2019, ENS was below the 2006 level. In 2022, it fell drastically to a level of 5.8 per cent of its 2006 level.

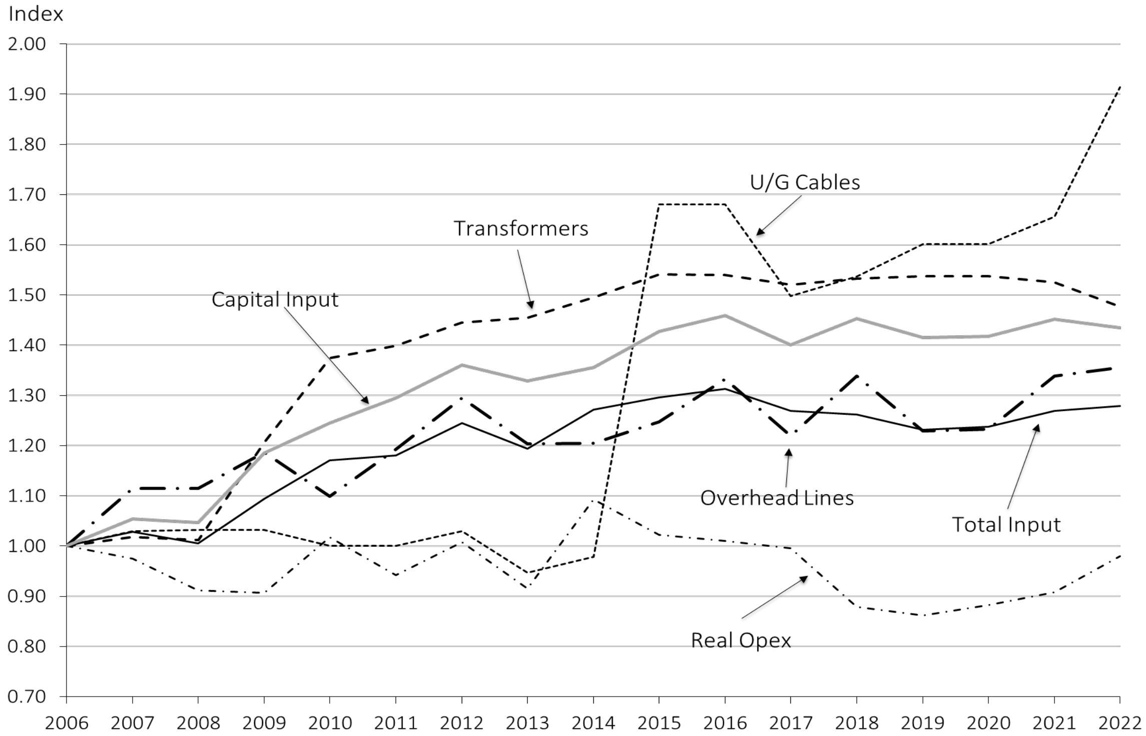
TRG's total output index follows a similar trend as circuit length, with the main exceptions being in 2015 and 2016, the years when ENS had its largest spikes. In these two years output decreased significantly, reflecting the impact of the ENS outcomes. This can be seen clearly in Figure 4.17, which also shows the output index when ENS is excluded. Total output has been relatively flat since 2017, although it *decreased* by 0.3 per cent in 2022.

Turning to the input side, Figure 4.19 presents quantity indexes for TRG's four inputs and for the total input index. We see that TRG's input quantity for overhead lines increased in the first half of the period before levelling off somewhat. This input has tended to fluctuate depending on whether the maximum demand occurred in summer or winter for the regulatory year. For example, the capacity of 132 kV overhead lines increased by 8.3 per cent from 2020 to 2021 due to the shift from summer rating in 2020 to winter rating in 2021, and the removal of 132 kV line constraints. Between 2006 and 2012, overhead lines increased at an average annual rate of 4.3 per cent. From 2012 to 2022, TRG's overhead lines increased at an annual average rate of 0.5 per cent.

TRG's underground cables input quantity increased by 54.1 per cent in 2015, as the length of underground cables increased from only 51.4 to 82.2 kilometres in that year. This input has a very small share of total costs (3.1 per cent, Appendix A, Table A.3) and thus a smaller influence on TFP.

[11] TRG's end-user annual average growth rate of 1.1 per cent between 2006 and 2021 is similar to the average rate of growth of the NSW population of 1.2 per cent over the same period. Australian Bureau of Statistics, *National, state and territory population* (Dec 2021). https://www.abs.gov.au/statistics/people/population/national-state-and-territory-population/latest-release.

Figure 4.19 TRG's input quantity indexes, 2006–2022



The quantity of opex was the only one of TRG's four inputs to decrease over the 17-year period, being 2.1 per cent *lower* in 2022 than it was in 2006 (compared to an increase for the industry of 0.5 per cent). Over the period from 2006 to 2022, opex usage averaged an annual rate of change of –0.1 per cent. Between 2006 and 2012 there was a small 0.1 per cent annual average rate of increase, but from 2012 to 2022 the annual average rate of change was –0.3 per cent. In 2022 opex usage increased by 7.6 per cent. Opex has the second largest average share in TRG's total costs at 26.2 per cent (see Appendix A, Table A.3).

The input component with the largest average share of TRG's total cost, at 44.4 per cent, is transformers. TRG's transformer input quantity increased more quickly in the first half of the period and more slowly thereafter. In the period from 2006 to 2012, TRG's transformer inputs increased at an average rate of 6.1 per cent per annum. From 2012 to 2022, transformer inputs increased at a rate of 0.2 per cent per annum. By 2022, TRG's transformer input was 47.7 per cent above its 2006 level—a slightly larger increase than the industry's 45.1 per cent increase.

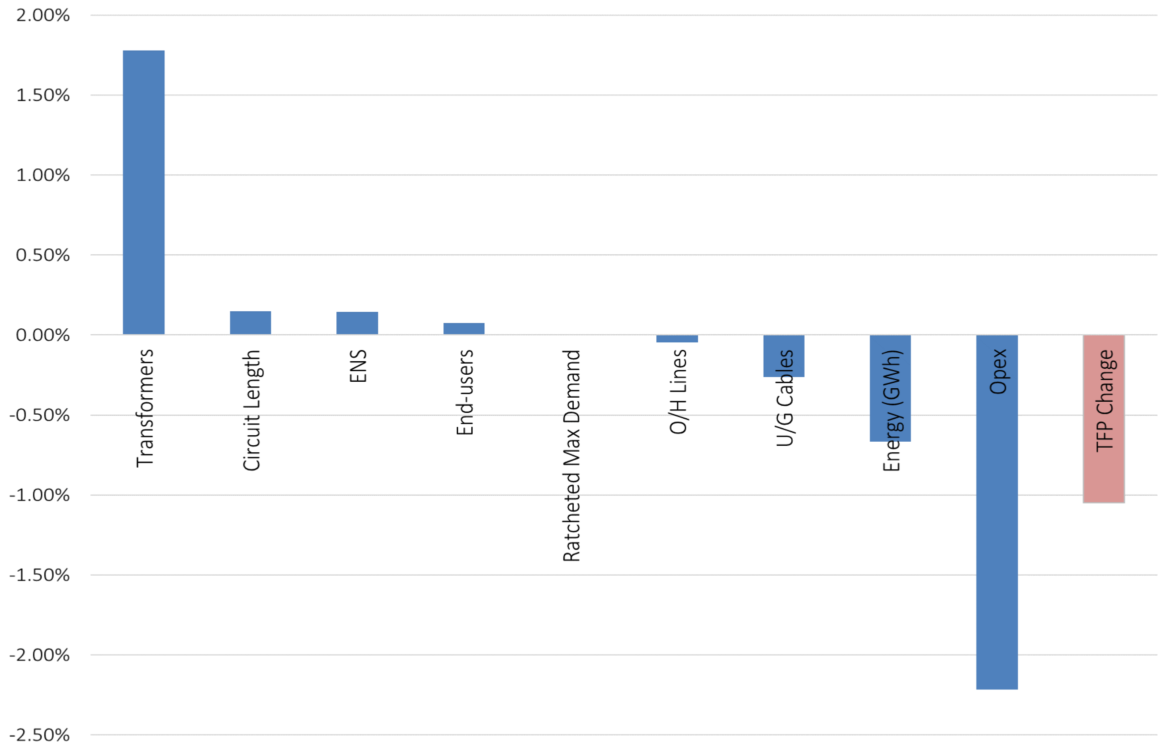
4.5.3 TRG's output and input contributions to TFP change

Table 4.10 shows the decomposition of TRG's average rates of TFP change into the contributions of the individual outputs and inputs for the whole 17-year period and for the periods up to and after 2012, and for 2022. Figure 4.20 shows the contributions of outputs and inputs to TRG's average rate of TFP change in 2022.

Table 4.10 TRG's output and input percentage point contributions to average annual TFP change: various sources

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2022*
Energy	-0.17%	-0.16%	-0.17%	-0.67%
Ratcheted Max Demand	0.10%	0.27%	0.00%	0.00%
End-users	0.09%	0.07%	0.10%	0.07%
Circuit Length	0.14%	0.13%	0.16%	0.15%
ENS	0.10%	-0.02%	0.17%	0.14%
Opex	0.03%	0.00%	0.05%	-2.22%
O/H Lines	-0.49%	-1.18%	-0.07%	-0.05%
U/G Cables	-0.11%	-0.03%	-0.17%	-0.26%
Transformers	-0.97%	-2.45%	-0.08%	1.78%
TFP Change	-1.28%	-3.37%	-0.02%	-1.05%

Figure 4.20 TRG's output and input percentage point contributions to TFP change, 2022



Appendix A: Methodology

A1 Indexing Methods

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

A1.1 Multilateral Törnqvist TFP index

The method for calculating time series TFP rates of change for individual TNSPs is the same method as that used for calculating the comparative levels of TFP between TNSPs, namely the multilateral Törnqvist TFP index (MTFP) of Caves, Christensen and Diewert (1982) shown in equation (A.1). For the productivity growth and contributions analyses the multilateral Törnqvist index is applied to the annual time-series observations for each of the five TNSPs individually or to the aggregated time-series for the industry as a whole. For productivity comparative analysis, for comparing between TNSPs, the data is pooled as panel data and the index is applied across the full sample of 80 observations.

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

where m and n are two adjacent observations;[12] i denotes individual outputs; j denotes individual inputs; and

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

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

- R_i^* is the revenue share of the *i*th output averaged over the whole sample;[13]
- 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.[14] 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 (A.1) can be separated into these two components. The rate of change in the output index is given by:

[13] 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.

[14] 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.

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

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

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

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 (A.2) or (A.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 PFP 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 (A.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: $g_t^Y = \ln Y_t - \ln Y_{t-1}$.[15] 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 (2020a Appendix C) also included, as supplementary information, trend measures of annual growth

[15] 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.[16] 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 (A.1) refer only to successive periods. To emphasise this, m is denoted t and n is denoted $t-1$. The *percentage point contribution* of output i to productivity change between years t and $t-1$ ($Cont_{i,t}^{Y}$) is given by the following equation:

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

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

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

where all variables in equations (A.4) and (A.5) have the same definition as those in equation (A.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 (A.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

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

as the basis for value-share weights. Economic Insights (2020a Appendix B) estimated the costs attributable to each output using the data and method described below. Those estimates are intended to apply for several years and are used in this study.

A3.1 Leontief Cost Function Estimation

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 (2020a) 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 ENS

The fifth output is energy not supplied (ENS), the negative of which is a measure supply reliability. The formal way in which reliability is incorporated into the analysis is to treat ENS 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 energy not supplied (i.e. the cost imposed on consumers) as measured by the Values of Customer Reliability (VCR) published by the AER (2019a; 2019b). Since direct data are not readily available on the cost of improving TNSP reliability, economic benchmarking has relied on the VCR, which is a measure of how consumers value energy not supplied. The VCR, expressed on a per MWh basis, is multiplied by the quantity of ENS. That is, the cost of ENS is based on: $ENS \times VCR$. The VCR is estimated by the AER for 2019 (AER 2019b, p. 71), which is adjusted by CPI in all other years of the data sample.

In theory this measure could be expected to provide a proxy for TNSP costs of improving reliability since in equilibrium reliability would be improved to the point where the marginal cost of further improvement equals the marginal benefit of further improvement. However, unconstrained reliance on the VCR can produce some very large weights for the reliability output where unusual one-off outages occur. As a result, the 2017 review introduced a cap of 5.5 per cent of gross revenue (total revenue plus the value of the reliability output) on the reliability output weight. This cap was derived from statistical analysis of the energy not served (ENS) series. In 2020 this approach was reviewed and revised, to take account of incentives under the regulatory framework, which limits the ‘value at risk’ to a business under the Service

Target Performance Incentive Scheme (STPIS).[17] Having regard to this, the cap on the reliability output weight was reduced to 2.5 per cent of total revenue. This study uses the same cap.

A cap applies to the reliability output weight equal to 2.5 per cent of total revenue. The cap is needed because ENS can be highly volatile off a low base, and because TNSP's potential penalties for poor reliability and rewards for improved reliability are capped under the regulatory framework (Economic Insights 2021).

A3.2 Re-calibration of Output Weights

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

The ENS output has become very low, but also volatile, and is zero in some cases (specifically, for PLK in 2019). A minimum value of ENS equal to 0.2 MWh is imposed. This is a lower minimum threshold than that used in Economic Insights (2021) (which was 1 MWh). Also, sensitivity analysis on output and TFP indexes is carried out to show results when the reliability output, ENS, is excluded.[18]

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

Output	*Shares of gross revenue (%)*	*Shares of revenue (%)*
Energy throughput	14.91[(a)]	15.11
Ratcheted max. demand	24.71[(a)]	25.04
End-user numbers	7.59[(a)]	7.69
Circuit length	52.79[(a)]	53.51
Energy not supplied (minus)	-1.34	-1.36
Total		100.00

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

[17] The STPIS for transmission has three key components: (i) a service component designed to incentivise TNSPs to reduce unplanned circuit outage events and outage duration; (ii) market-impact component to incentivise TNSPs to reduce the impact of planned and unplanned outages on wholesale market outcomes; and (iii) a network-capability component to encourage TNSPs to undertake operational and minor capital expenditure projects to improve reliability (AER 2015). The first component is capped at ±1.25 per cent of annual maximum allowed revenue, and it is this component that is relevant to the capping of the cost of ENS for the purpose of benchmarking.

[18] In this report, unless otherwise specifically stated, ENS is included in the measurement of total outputs and TFP and PFP indexes.

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

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

Input	*ENT*	*PLK*	*ANT*	*TNT*	*TRG*	*Industry**
Energy throughput	15.15	15.05	15.10	15.19	15.07	15.09
Ratcheted max. demand	25.11	24.94	25.03	25.18	24.97	25.00
End-user numbers	7.71	7.66	7.69	7.73	7.67	7.68
Circuit length	53.64	53.29	53.47	53.79	53.34	53.41
Energy not supplied	-1.61	-0.94	-1.29	-1.89	-1.05	-1.18
Total	100.00	100.00	100.00	100.00	100.00	100.00

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

A3.4 Input weights and Asset Unit Costs

The input weights are the estimated cost shares of each input. The cost of the opex input is nominal opex. The cost of the capital inputs, in aggregate, is calculated by the AER from the other components of the building block calculation, namely: (a) the return on capital – i.e. the weighted average cost of capital (WACC) applied to the opening regulatory asset base (RAB); (b) the return of capital – the straight-line depreciation of the RAB less the inflation indexation of the RAB; and (c) benchmark tax liability. This aggregate cost of capital inputs is decomposed by the AER into the separate capital inputs using estimated shares of each capital asset type in the RAB for each TNSP in each year. The decomposed capital-related costs are referred to as the annual user cost (AUC) for each capital input. Table A.3 shows the average cost shares of each input for each TNSP.

Table A.3 Input cost share weights by TNSP (%, average 2006 to 2022)

Input	*ENT*	*PLK*	*ANT*	*TNT*	*TRG*	*Industry**
Real opex	32.41	28.09	24.03	28.16	27.24	27.68
Overhead lines	20.57	34.28	28.53	22.36	25.31	28.03
Underground cables	2.11	0.62	1.01	1.34	3.07	1.65
Transformers	44.91	37.01	46.42	48.14	44.38	42.63
Total	100.00	100.00	100.00	100.00	100.00	100.00

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

Appendix B: Individual Outputs & Inputs: Growth Rates & PFP

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

Year	*2006-2022*	*2006-2012*	*2012-2022*	*2022*
Outputs:				
Energy (GWh)	-0.4%	-0.1%	-0.6%	-0.8%
Ratcheted Max Demand (MVA)	0.8%	1.8%	0.1%	0.6%
End-users	1.3%	1.3%	1.3%	1.3%
Circuit Length (km)	0.5%	0.8%	0.3%	-0.1%
ENS (MWh)*	-2.8%	-1.0%	-3.9%	136.9%
Inputs:				
Real Opex ($'000 2006)	0.0%	0.8%	-0.4%	1.8%
O/H Lines (MVA-kms)	1.3%	2.7%	0.4%	0.9%
U/G Lines (MVA-kms)	4.1%	4.3%	4.0%	9.4%
Transformers (MVA)	2.3%	5.0%	0.7%	-1.7%
NB: Capital inputs	1.9%	4.0%	0.7%	-0.5%
Partial factor productivity:				
Output / Real Opex	0.5%	0.2%	0.6%	-2.6%
Output / OH Lines	-0.7%	-1.7%	-0.1%	-1.8%
Output / UG Lines	-3.6%	-3.3%	-3.8%	-10.3%
Output / Transformers	-1.8%	-4.0%	-0.5%	0.8%
NB: Output / Capital	-1.4%	-3.0%	-0.4%	-0.4%

Table B.2 ANT's individual output, input and PFP growth rates

Year	*2006-2022*	*2006-2012*	*2012-2022*	*2022*
Outputs:				
Energy (GWh)	-0.2%	0.8%	-0.8%	4.2%
Ratcheted Max Demand (MVA)	1.5%	4.0%	0.0%	0.0%
End-users	1.5%	1.4%	1.5%	1.5%
Circuit Length (km)	0.1%	0.0%	0.1%	-1.6%
ENS (MWh)*	-34.8%	-1.8%	-54.6%	-172.8%
Inputs:				
Real Opex ($'000 2006)	-0.9%	-1.1%	-0.8%	8.1%
O/H Lines (MVA-kms)	0.1%	0.0%	0.1%	1.0%
U/G Lines (MVA-kms)	-1.8%	0.0%	-2.8%	0.0%
Transformers (MVA)	1.2%	1.7%	1.0%	-0.5%
NB: Capital inputs	0.7%	0.9%	0.6%	0.0%
Partial factor productivity:				
Output / Real Opex	1.8%	2.4%	1.4%	-7.2%
Output / OH Lines	0.8%	1.3%	0.4%	0.0%
Output / UG Lines	2.6%	1.3%	3.4%	1.0%
Output / Transformers	-0.4%	-0.4%	-0.4%	1.5%
NB: Output / Capital	0.1%	0.4%	-0.1%	1.0%

Table B.3 ENT's individual output, input and PFP growth rates

Year	*2006-2022*	*2006-2012*	*2012-2022*	*2022*
Outputs:				
Energy (GWh)	-0.6%	-1.2%	-0.3%	0.0%
Ratcheted Max Demand (MVA)	0.6%	1.6%	0.1%	0.0%
End-users	1.1%	1.3%	1.0%	0.9%
Circuit Length (km)	-0.1%	-0.2%	0.0%	0.1%
ENS (MWh)*	7.1%	23.8%	-2.9%	710.1%
Inputs:				
Real Opex ($'000 2006)	1.7%	3.0%	1.0%	-1.6%
O/H Lines (MVA-kms)	0.6%	0.5%	0.7%	4.9%
U/G Lines (MVA-kms)	9.9%	24.8%	1.0%	0.0%
Transformers (MVA)	1.9%	2.9%	1.3%	-0.2%
NB: Capital inputs	1.7%	2.5%	1.2%	1.0%
Partial factor productivity:				
Output / Real Opex	-1.8%	-3.3%	-0.9%	-5.3%
Output / OH Lines	-0.6%	-0.7%	-0.6%	-11.8%
Output / UG Lines	-10.0%	-25.1%	-0.9%	-6.9%
Output / Transformers	-2.0%	-3.2%	-1.2%	-6.7%
NB: Output / Capital	-1.7%	-2.8%	-1.1%	-7.9%

Table B.4 PLK's individual output, input and PFP growth rates

Year	*2006-2022*	*2006-2012*	*2012-2022*	*2022*
Outputs:				
Energy (GWh)	0.0%	-0.1%	0.0%	-1.3%
Ratcheted Max Demand (MVA)	1.0%	1.7%	0.5%	2.3%
End-users	1.5%	1.8%	1.4%	1.9%
Circuit Length (km)	1.4%	2.6%	0.6%	0.0%
ENS (MWh)*	1.1%	-18.4%	12.8%	62.9%
Inputs:				
Real Opex ($'000 2006)	0.6%	1.3%	0.3%	-4.1%
O/H Lines (MVA-kms)	1.7%	3.8%	0.3%	-0.3%
U/G Lines (MVA-kms)	1.4%	4.1%	-0.2%	0.0%
Transformers (MVA)	3.4%	7.2%	1.2%	-1.1%
NB: Capital inputs	2.5%	5.3%	0.8%	-0.5%
Partial factor productivity:				
Output / Real Opex	0.4%	0.9%	0.1%	3.6%
Output / OH Lines	-0.6%	-1.6%	0.1%	-0.2%
Output / UG Lines	-0.4%	-1.9%	0.6%	-0.5%
Output / Transformers	-2.4%	-5.0%	-0.8%	0.6%
NB: Output / Capital	-1.5%	-3.2%	-0.4%	0.0%

Table B.5 TNT's individual output, input and PFP growth rates

Year	*2006-2022*	*2006-2012*	*2012-2022*	*2022*
Outputs:				
Energy (GWh)	1.4%	3.0%	0.5%	2.5%
Ratcheted Max Demand (MVA)	0.0%	0.0%	0.0%	0.0%
End-users	1.1%	1.8%	0.8%	1.1%
Circuit Length (km)	-0.4%	-0.4%	-0.4%	0.3%
ENS (MWh)*	-0.8%	-7.1%	3.0%	217.8%
Inputs:				
Real Opex ($'000 2006)	-3.4%	1.0%	-6.1%	2.2%
O/H Lines (MVA-kms)	0.8%	1.3%	0.6%	-0.2%
U/G Lines (MVA-kms)	5.2%	0.0%	8.3%	0.0%
Transformers (MVA)	1.9%	4.1%	0.5%	0.1%
NB: Capital inputs	1.6%	3.1%	0.7%	0.1%
Partial factor productivity:				
Output / Real Opex	3.6%	-0.4%	5.9%	-5.2%
Output / OH Lines	-0.7%	-0.7%	-0.7%	-2.8%
Output / UG Lines	-5.1%	0.5%	-8.5%	-3.0%
Output / Transformers	-1.7%	-3.6%	-0.7%	-3.1%
NB: Output / Capital	-1.5%	-2.6%	-0.8%	-3.1%

Table B.6 TRG's individual output, input and PFP growth rates

Year	*2006-2022*	*2006-2012*	*2012-2022*	*2022*
Outputs:				
Energy (GWh)	-1.1%	-1.0%	-1.2%	-4.4%
Ratcheted Max Demand (MVA)	0.4%	1.1%	0.0%	0.0%
End-users	1.2%	0.9%	1.3%	1.0%
Circuit Length (km)	0.3%	0.2%	0.3%	0.3%
ENS (MWh)*	-17.8%	2.4%	-29.9%	-29.3%
Inputs:				
Real Opex ($'000 2006)	-0.1%	0.1%	-0.3%	7.6%
O/H Lines (MVA-kms)	1.9%	4.3%	0.5%	1.2%
U/G Lines (MVA-kms)	4.1%	0.5%	6.2%	14.5%
Transformers (MVA)	2.4%	6.1%	0.2%	-3.2%
NB: Capital inputs	2.3%	5.1%	0.5%	-1.2%
Partial factor productivity:				
Output / Real Opex	0.4%	0.2%	0.5%	-7.9%
Output / OH Lines	-1.6%	-4.0%	-0.2%	-1.5%
Output / UG Lines	-3.8%	-0.2%	-5.9%	-14.8%
Output / Transformers	-2.2%	-5.8%	0.0%	2.9%
NB: Output / Capital	-2.0%	-4.8%	-0.3%	0.9%

Appendix C: Regression–based trend growth rates

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

TNSP	*Output*	*Input*	*TFP*	*PFP Index*	
Period	*Index*	*Index*	*Index*	*Opex*	*Capital*
Industry					
Growth Rate 2006–22	0.5%	1.3%	-0.8%	0.6%	-1.4%
Growth Rate 2006–12	1.1%	3.2%	-2.1%	0.2%	-3.1%
Growth Rate 2012–22	0.3%	0.2%	0.0%	1.1%	-0.4%
ANT					
Growth Rate 2006–22	0.5%	0.3%	0.1%	1.3%	-0.3%
Growth Rate 2006–12	1.5%	0.9%	0.6%	1.0%	0.4%
Growth Rate 2012–22	0.3%	0.2%	0.1%	1.9%	-0.4%
ENT					
Growth Rate 2006–22	0.2%	2.0%	-1.8%	-2.0%	-1.7%
Growth Rate 2006–12	-0.3%	2.4%	-2.8%	-2.9%	-2.7%
Growth Rate 2012–22	0.5%	1.2%	-0.7%	-1.2%	-0.5%
PLK					
Growth Rate 2006–22	1.2%	2.0%	-0.8%	0.4%	-1.3%
Growth Rate 2006–12	2.6%	4.4%	-1.8%	1.7%	-3.3%
Growth Rate 2012–22	0.4%	0.4%	0.1%	0.6%	-0.2%
TNT					
Growth Rate 2006–22	0.1%	-0.4%	0.4%	5.6%	-1.6%
Growth Rate 2006–12	0.0%	2.4%	-2.5%	-1.0%	-3.4%
Growth Rate 2012–22	0.0%	-1.6%	1.5%	7.1%	-0.6%
TRG					
Growth Rate 2006–22	0.3%	1.5%	-1.2%	0.6%	-1.9%
Growth Rate 2006–12	0.3%	3.9%	-3.6%	0.1%	-5.1%
Growth Rate 2012–22	0.4%	0.1%	0.3%	1.6%	-0.3%

Appendix D: Sensitivity Analysis

This appendix responds to certain anomalies in the contributions of outputs and inputs when using the Multilateral Törnqvist index, by calculating the contributions using the time series Törnqvist index method.

D1 Anomalous Findings in Total Factor Productivity Contributions

Production theory holds that an increase in an input, all else equal, results in decreased productivity, and conversely an increase in an output, all else equal, leads to increased productivity. These are the expected outcomes when analysing contributions to TFP changes. However, in this analysis, we encountered some unexpected results, including:

- the 2.2 per cent increase in TasNetwork's' Opex input in 2022 contributed to a 1.08 per cent increase in its TFP, and
- the zero per cent change in Electra's Underground Cables quantity in 2022 contributed to 0.24 per cent increase in its TFP.

These anomalous results can be attributed to the inflationary environment and its impact on AUC, together with the specifics of the Multilateral Törnqvist TFP index formula. As detailed in Appendix A1, the Multilateral Törnqvist index adheres to the properties of transitivity and characteristicity when comparing data points relative to the sample mean. This approach was adopted by Economics Insights in 2020 and has been consistently applied since then in all our analyses, to provide a more accurate representation of significant changes in ENS outputs.

In essence, the inflationary conditions significantly altered the cost allocation, favouring a substantial increase in the share of Opex costs at the capital inputs costs. Simultaneously, the deviation between the quantity of Opex inputs in 2022 and their historical average for the DNSP over the entire period was negative.[19] The application of the multilateral Törnqvist index in assessing TFP contributions assumes that firms will adapt their input quantities in response to price changes. However, due to the rapid fluctuations in the inflationary environment, firms were unable to adjust their inputs promptly. Consequently, depending on the magnitude of changes in Opex and capital cost allocations, the calculation could be adversely affected, as was the case with TasNetworks and Electra.

To comprehensively assess the ramifications of this matter, we have conducted a sensitivity analysis by applying the time series Törnqvist method for comparison.

[19] Our memo 'Benchmarking TNSP - Productivity Index Issues' expands on the reasons why the Multilateral Törnqvist index can give rise to this anomaly. An increase in input j can give rise to a positive contribution to TFP change if: there is a substantial increase in the cost share of the input *j* and, the difference between the quantity of input *j* in a period, and its average for the DNSP over the entire period, is negative.

D2 Traditional Törnqvist

The time series Törnqvist TFP index is given by the following equation:

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

where t is the period; y_i is the output quantity of the ith output (with N outputs); r_i is the value share weight of output i; x_j is the quantity of the jth input (with M inputs); s_i is the cost share of input j. The percentage point contributions of output i and input j to productivity change are given by the following equations:

$$Contribution\ of\ output\ i = \left(\frac{r_{it} + r_{i,t-1}}{2}\right)(\ln y_{in} - \ln y_{im}) \tag{D.2}$$

$$Contribution\ of\ input\ j = -\left(\frac{s_{it} + s_{i,t-1}}{2}\right)(\ln x_{jt} - \ln x_{j,t-1}) \tag{D.3}$$

In contrast to the multilateral Törnqvist index, the ordinary Törnqvist method assesses changes by comparing the current period to the preceding one. It does not compare two observations via a third observation (the sample means for each output and input and their weights), which is how the multilateral Törnqvist index works. The ordinary Törnqvist index does not facilitate comparisons of productivity levels between cross-sectional units in panel data, as does the multilateral Törnqvist index. When applied to time series data, the multilateral Törnqvist index is less susceptible to 'chain drift' and is thereby less susceptible to the volatility of ENS output, as is the ordinary Törnqvist method. The latter method does, however, have the advantage that it does not give rise to anomalies relating to contributions that are encountered in the multilateral Törnqvist index analysis.

D3 Traditional Törnqvist Results

In Tables D.1 to D.6, the time series TFP results and the percentage point contributions to the average annual TFP change using the Törnqvist index are presented. It is observed that in situations where anomalous results were identified using the multilateral Törnqvist index, specifically for TasNetworks and ElectraNet in 2022, the use of the time series Törnqvist index does not produce anomalies:

- the 2.2 per cent increase in TasNetwork's Opex input in 2022, contributed –0.65 percentage points in its TFP rate of change.

- the zero per cent change in the quantity of Electra's Underground Cables in 2022, resulted in a contribution of 0.00 percentage points to its change in its TFP.

Table D.1 Industry's output and input percentage point contributions to average annual TFP change

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2022*
Energy	-0.06%	-0.02%	-0.09%	-0.13%
Ratcheted Max Demand	0.19%	0.45%	0.03%	0.15%
End-users	0.10%	0.10%	0.10%	0.10%
Circuit Length	0.25%	0.44%	0.14%	-0.07%
ENS	0.02%	0.01%	0.02%	-0.85%
Opex	-0.02%	-0.20%	0.08%	-0.59%
O/H Lines	-0.37%	-0.84%	-0.09%	-0.19%
U/G Cables	-0.07%	-0.07%	-0.06%	-0.11%
Transformers	-0.96%	-2.01%	-0.32%	0.74%
TFP Change	-0.92%	-2.14%	-0.19%	-0.96%

Table D.2 ANT's output and input percentage point contributions to average annual TFP change

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2022*
Energy	-0.02%	0.13%	-0.11%	0.62%
Ratcheted Max Demand	0.38%	1.01%	0.01%	0.00%
End-users	0.11%	0.11%	0.12%	0.12%
Circuit Length	0.03%	0.00%	0.05%	-0.83%
ENS	0.04%	-0.70%	0.48%	0.07%
Opex	0.17%	0.23%	0.14%	-2.19%
O/H Lines	-0.02%	0.00%	-0.03%	-0.23%
U/G Cables	0.01%	0.00%	0.02%	0.00%
Transformers	-0.56%	-0.71%	-0.48%	0.27%
TFP Change	0.14%	0.07%	0.19%	-2.17%

Table D.3 ENT's output and input percentage point contributions to average annual TFP change

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2022*
Energy	-0.10%	-0.18%	-0.05%	-0.01%
Ratcheted Max Demand	0.16%	0.40%	0.02%	0.00%
End-users	0.08%	0.10%	0.07%	0.07%
Circuit Length	-0.05%	-0.12%	-0.01%	0.03%
ENS	-0.39%	-0.44%	-0.35%	-8.89%
Opex	-0.52%	-0.89%	-0.29%	0.61%
O/H Lines	-0.10%	-0.13%	-0.08%	-0.53%
U/G Cables	-0.09%	-0.18%	-0.03%	0.00%
Transformers	-0.84%	-1.21%	-0.61%	0.08%
TFP Change	-1.83%	-2.65%	-1.34%	-8.64%

Table D.4 PLK's output and input percentage point contributions to average annual TFP change

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2022*
Energy	0.00%	-0.01%	0.01%	-0.19%
Ratcheted Max Demand	0.24%	0.44%	0.12%	0.57%
End-users	0.12%	0.14%	0.11%	0.14%
Circuit Length	0.73%	1.41%	0.31%	0.00%
ENS	0.01%	0.11%	-0.04%	-0.78%
Opex	-0.14%	-0.39%	0.01%	1.44%
O/H Lines	-0.60%	-1.32%	-0.17%	0.08%
U/G Cables	-0.01%	-0.03%	0.00%	0.00%
Transformers	-1.26%	-2.62%	-0.45%	0.42%
TFP Change	-0.91%	-2.27%	-0.10%	1.68%

Table D.5 TNT's output and input percentage point contributions to average annual TFP change

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2022*
Energy	0.22%	0.45%	0.08%	0.38%
Ratcheted Max Demand	0.00%	0.01%	0.00%	0.00%
End-users	0.09%	0.14%	0.06%	0.09%
Circuit Length	-0.21%	-0.22%	-0.21%	0.17%
ENS	0.01%	0.21%	-0.11%	-3.55%
Opex	0.76%	-0.42%	1.46%	-0.65%
O/H Lines	-0.19%	-0.27%	-0.14%	0.03%
U/G Cables	-0.07%	0.00%	-0.11%	0.00%
Transformers	-0.84%	-1.81%	-0.26%	-0.06%
TFP Change	-0.23%	-1.90%	0.77%	-3.59%

Table D.6 TRG's output and input percentage point contributions to average annual TFP change

Year	*2006 to 2022*	*2006 to 2012*	*2012 to 2022*	*2022*
Energy	-0.17%	-0.16%	-0.17%	-0.66%
Ratcheted Max Demand	0.10%	0.27%	0.00%	0.00%
End-users	0.09%	0.07%	0.10%	0.07%
Circuit Length	0.15%	0.13%	0.16%	0.15%
ENS	0.06%	-0.02%	0.11%	0.01%
Opex	0.00%	0.08%	-0.05%	-2.56%
O/H Lines	-0.51%	-1.23%	-0.08%	-0.25%
U/G Cables	-0.10%	-0.02%	-0.15%	-0.28%
Transformers	-1.02%	-2.54%	-0.11%	1.42%
TFP Change	-1.40%	-3.42%	-0.19%	-2.10%

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