Annual Benchmarking Report

Electricity transmission network service providers

November 2023

AUSTRALIAN ENERGY REGULATOR

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Executive Summary

We report annually on the productivity growth and efficiency of transmission network service providers (TNSPs) in the National Electricity Market (NEM). These service providers operate high voltage transmission lines which transport electricity from generators to distribution networks in urban and regional areas. Transmission network costs typically account for between 5 to 10% of what customers pay for their electricity (with the remainder covering generation costs, distribution, and retailing, as well as environmental policies).

We use economic benchmarking to measure how productively efficient these networks are at delivering electricity transmission services over time and compared with their peers. Where transmission networks become more efficient, customers should benefit through downward pressure on network charges and customer bills. We draw on this analysis when setting the maximum revenues networks can recover from customers.

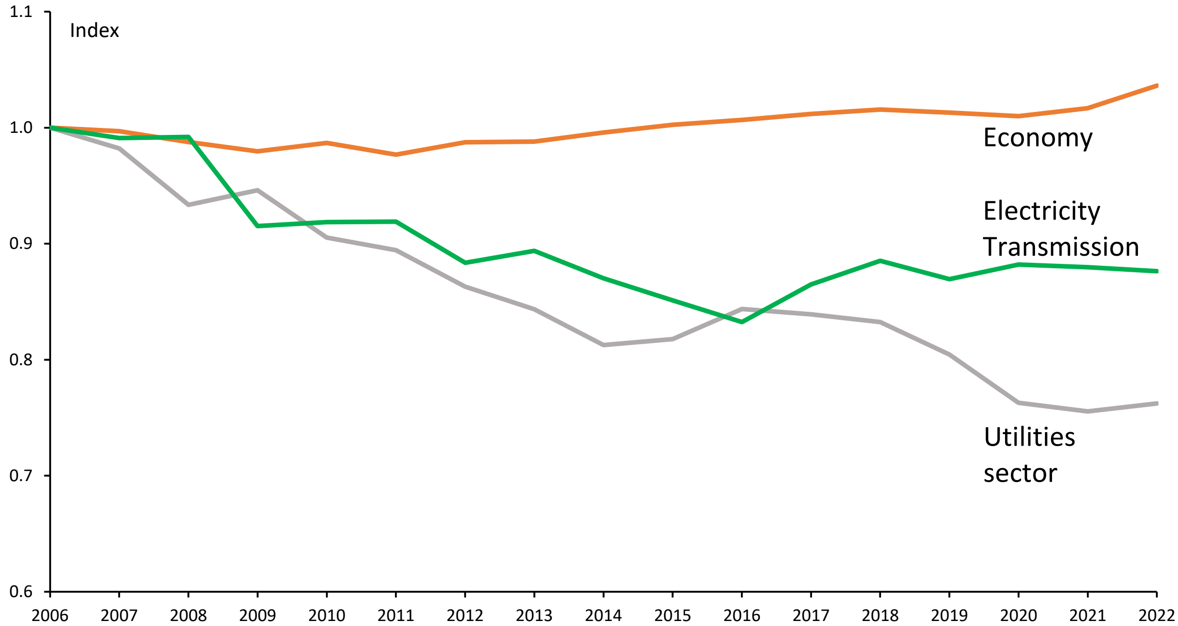
In preparing this benchmarking report, we have taken into account stakeholder views received through our consultation process.

Transmission industry productivity reduced slightly over 2022

Electricity transmission industry productivity as measured by times series multilateral total factor productivity (TFP) analysis decreased by 0.4% over 2022. This followed a similar reduction in 2021 after a general upward trend since 2016 (see Figure 1). This slight decline in 2022 was in contrast to the increased productivity in the overall Australian economy (1.9%) and the utilities sector (electricity, gas, water and waste services) (0.9%) over 2022.

The decrease in transmission industry productivity in 2022 (by 0.4%) is primarily due to reductions in reliability (increased energy not supplied due to storm events), contributing a 0.9 percentage point decrease to the overall TFP decrease. An increase in the operating expenditure (opex) input and reduction in the output for energy throughput, also contributed 0.4 and 0.1 percentage point decreases respectively to the overall TFP decrease. These negative contributions were largely offset by a decrease in the transformer input which positively contributed 1.0 percentage points to the productivity change.

Figure 1 Electricity transmission industry, utility sector, and economy TFP, 2006–22



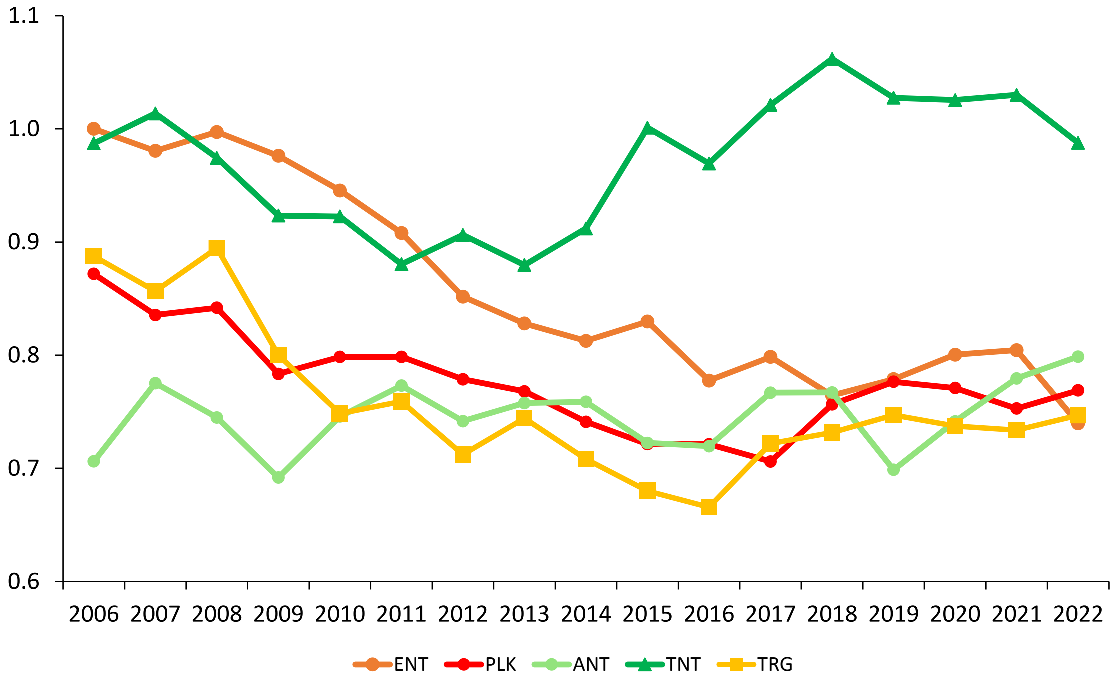
Changes in relative productivity of TNSPs in the NEM over 2022

There are five transmission networks in the NEM, with one in each state. In 2022, three TNSPs improved their productivity as measured by panel data multilateral total factor productivity (MTFP). As can be seen in Figure 2, AusNet had the largest increase of 2.4% in 2022. It has achieved productivity improvements over the last three consecutive years. Powerlink and TransGrid also achieved significant productivity improvements in 2022 (2.1% and 1.8% respectively). Conversely, ElectraNet and TasNetworks experienced significant decreases in productivity in 2022 (–8.4% and –4.2% respectively) driven by reduced network reliability due to storm events. TasNetworks remained the highest ranked TNSP in terms of productivity measured by MTFP in 2022.

Figure 2 highlights the variability in productivity observed for individual TNSPs over time and emphasises the importance of considering the changes in productivity in 2022 in the context of longer-term trends.

We note that our transmission benchmarking accounts for some but not all possible differences in operating environment factors in the measured productivities across TNSPs. Further, given the changes occurring in the transmission network environment, particularly driven by increasing connection of large-scale renewable generation and the need to manage how the transmission system is operated, our future development work will seek to understand whether the current outputs measured remain relevant and if there are any new material outputs that need to be incorporated.

Figure 2 Electricity transmission MTFP indexes by TNSP, 2006–22

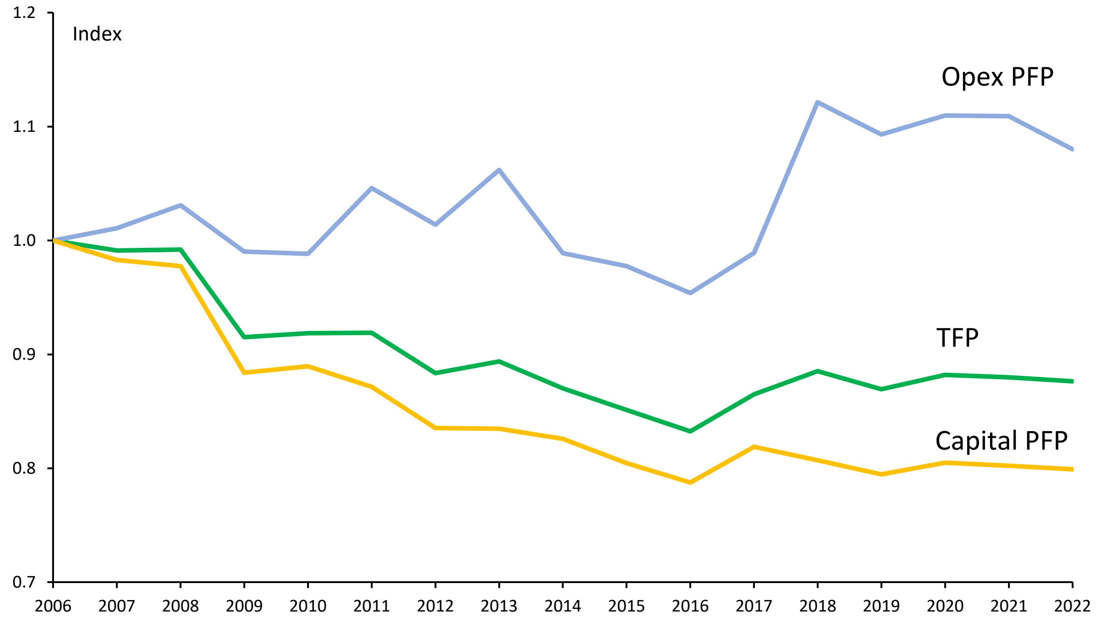


The long-term decline in transmission industry productivity is driven by declining capital partial factor productivity (PFP), while the upward trend since 2016 is due to increasing opex PFP

Measured over 2006-2022, transmission industry TFP has declined at an average annual rate of 0.8% (see Figure 3). Using time series multilateral partial factor productivity (PFP), capital PFP declined over this 17-year period at an average annual rate of 1.4% compared to average annual opex PFP growth of 0.5%.

The long-term decline in transmission industry productivity abated in 2016 with productivity trending slightly upward since then. This improvement since 2016 can be linked to reductions in the opex input and stabilisation of capital inputs (that is, less growth in capital assets relative to outputs compared to earlier years).

Figure 3 Transmission industry TFP, opex PFP and capital PFP over 2006–22



Updates in this year's report

We operate an ongoing transparent program to review and incrementally refine elements of the benchmarking methodology and data. In this year's report there were no updates to the methodology we use and some minor updates to the data, including adding the data for the additional year being updated (2022).

Contents

1. Our benchmarking report

The National Electricity Rules (NER) require the AER to publish network benchmarking results in an annual benchmarking report.[1] This is our tenth annual benchmarking report for TNSPs. This report is informed by expert advice provided by Quantonomics.[2]

National Electricity Rules reporting requirement

6A.31 Annual Benchmarking Report

(a) The AER must prepare and publish a network service provider performance report (an annual benchmarking report), the purpose of which is to describe, in reasonably plain language, the relative efficiency of each Transmission Network Service Provider in providing direct control services over a 12–month period.

Productivity benchmarking is a quantitative or data-driven approach used by governments and TNSPs around the world to measure how efficient firms are at producing outputs over time and compared with their peers.

Our benchmarking report considers the productive efficiency of TNSPs. TNSPs are productively efficient when they produce their goods and services at the least possible cost of inputs given their operating environments and prevailing input prices. We examine the change in productivity in 2022[3] compared to 2021,[4] and trends in productivity over the full period of our benchmarking analysis (2006–22) as well as shorter time periods (2006 to 2012 and 2012 to 2022).

Our benchmarking report presents results from two types of 'top-down' benchmarking techniques.[5] Each technique uses a different method for relating outputs to inputs to measure and compare TNSP efficiency:

- **Productivity index numbers (PIN)**. These techniques use a mathematical index to measure the relationship between multiple outputs relative to multiple inputs, enabling comparison of productivity levels and trends over time. We use these PIN techniques for our:

1 NER, cll. 6A.31(a) and 6A.31(c).

2 The supplementary Quantonomics' report outlines the full set of results for this year's report, the data we use, the updates and our benchmarking techniques. It can be found on the AER's website – see the Annual Benchmarking Reports 2023 web page.

3 This is the financial year 2021–22 (April–March for AusNet and July–June for all the other TNSPs).

4 The 2020–21 financial year (July–June and April–March as relevant).

5 Top-down techniques measure a network's overall efficiency, based on high-level data aggregated to reflect a small number of key outputs and key inputs. They generally take into account any synergies and trade-offs that may exist between input components. Alternative bottom-up benchmarking techniques are more resource intensive in that they examine each input component separately. Bottom-up techniques do not take into account potential efficiency trade-offs that may exist between input components of a TNSP's operations.

  - Times series multilateral total factor productivity (TFP) and capital and operating expenditure (opex) multilateral partial factor productivity analysis (PFP). TFP and capital and opex PFP results are used in this report to measure and compare changes in the productivity level of a single entity over time (i.e. whether productivity of the transmission industry as a whole or an individual TNSP has increased or decreased over time).
  - Panel data multilateral total factor productivity (MTFP) and capital and opex multilateral partial factor productivity analysis (MPFP). MTFP and capital and opex MPFP results are used in this report to measure and compare changes in 'relative productivity' over time (i.e. whether a given TNSP has a higher or lower productivity level relative to other TNSPs at a point in time and over time).
- **Partial performance indicators (PPIs)**. These simple ratio methods relate one input to one output. We use PPIs to examine relative performance across TNSPs.

Being top-down measures, each benchmarking technique cannot readily incorporate every possible exogenous factor that may affect a TNSPs performance. For example, as further explained in section 2.2, certain factors in a TNSPs operating environment are beyond its control and not all of these have been captured in the benchmarking models. Therefore, the performance measures reflect, but do not precisely represent, the underlying efficiency of TNSPs. For this benchmarking report, our approach is to derive 'raw' benchmarking results and where possible, explain drivers for the performance differences and changes.

The time-series and panel data based PIN techniques are used in this report to measure the productivity performance of TNSPs in the NEM and both rely on multilateral productivity indexes. These indexes allow comparisons of absolute levels and growth rates of the measured productivity. Multilateral total factor productivity examines the overall productivity of using all inputs in producing all outputs we measure. Multilateral partial factor productivity examines the productivity of either opex or capital inputs in isolation.

What is multilateral total factor productivity?

TFP is a technique that measures the productivity of TNSPs over time by measuring the relationship between the inputs used and the outputs delivered. Where a TNSP is able to deliver more outputs for a given level of inputs, this reflects an increase in its productivity. MTFP allows us to extend this to compare productivity levels between networks.

The inputs we measure for TNSPs are:

- Three types of physical capital assets TNSPs invest in to replace, upgrade or expand their networks:
  - Transformers and other capital (quantity proxied by transformer MVA)
  - Overhead lines (quantity proxied by overhead MVAkms)
  - Underground cables (quantity proxied by underground MVAkms)
- Opex to operate and maintain the network.

The non-reliability outputs we measure for TNSPs, and the relative weighting we apply to each non-reliability output, are:

- Circuit line length (52.8%). Line length reflects the distances over which TNSPs transport electricity and is a significant driver of the services a TNSP must provide.
- Ratcheted maximum demand (RMD) (24.7%). TNSPs endeavour to meet the demand for energy from their customers when that demand is greatest. RMD recognises the highest maximum demand the TNSP has had to meet in the time period examined.
- Energy delivered (14.9%). Energy delivered or throughput is a measure of the amount of electricity that TNSPs deliver to their customers.
- End users (7.6%). The number of end users is a proxy for the complexity of the TNSP's network.

Reliability (energy not supplied (ENS)) is also an output. Reliability measures the extent to which networks can maintain a continuous supply of electricity. ENS enters as a negative output and is weighted by the value of customer reliability capped by 2.5% of total revenue.

The November 2014 Economic Insights report referenced in Appendix A details the rationale for the choice of these inputs and outputs. In its August 2017 report, Economic Insights updated the output specification and the weights applied to each output.[6] This output specification is used in this report, with the output weights as updated in 2020.[7]

To assist with the ability to understand these inputs and outputs, as well as how they are used in the benchmarking analysis, we have provided some further detail in relation to these variables.

In terms of the inputs being used in the benchmarking analysis:

- The opex input reflects the costs associated with the labour, materials and services that are purchased in a given year. These costs are deflated by a price index of these inputs to establish a quantity measure of opex inputs.
- The capital inputs, such as transformers and overhead lines and underground cables, measure the physical quantity of the assets. This is used as a proxy for annual capital service flow as we assume relatively constant flow of services over the life of an asset, and thus that the annual flow is proportionate to capital stock.

At the start of the benchmarking program, there was general agreement that outputs should be included on a functional rather than billed basis. This reflected that under the building block model approach to regulation there is not typically a direct link between the revenue requirement and how a TNSP structures its prices.[8] It was also noted that the outputs included should reflect services provided to customers, rather than activities undertaken by the TNSP which do not directly affect what the customer receives, even if, given the characteristics of transmission services they are also somewhat removed from the final

6 Economic Insights, *Review of Economic Benchmarking of Transmission Network Service Providers - Position Paper*, 9 August 2017, pp. 29–33.

7 AER, *Annual Benchmarking Report 2020 – Electricity transmission network service providers*, November 2020, pp. 3–5; Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Benchmarking Report,* November 2023.

8 The AER generally sets the revenue requirement for TNSPs and then separately prices are set to recover this revenue requirement.

interface with end users. In terms of the outputs being used in the benchmarking analysis and the services provided:

- Energy delivered reflects the energy delivered to the end-user and is the transmission service directly consumed by end users
- End users is a measure of the services and benefits ultimately provided to end users of the distribution networks, which connect to the transmission networks, even though not a direct output of transmission networks. It is an indicator of network complexity and connectivity
- Circuit length has output related dimensions because it reflects the geographic distribution of end users that TNSPs need to construct networks to connect to deliver energy. In combination with end users, it reflects the impact of different levels of network density within an area on transmission costs
- RMD reflects the (non-coincident system) maximum demand from customers on the transmission network. The highest peak demand observed in the period (up to the year in question) is used to give credit for the provision of capacity to meet higher maximum demand in the earlier years
- Reliability (ENS) reflects the extent to which networks are able to maintain a continuous supply of electricity.

Appendix A provides reference material about the development and application of our economic benchmarking techniques. Appendix B provides more information about the specific models used and the data required.

1.1. Updates in this benchmarking report

The 2023 Annual Benchmarking Report uses the methods set out in previous reports, with no updates to the methods used in the 2022 report.

As set out in section 3.2 and Appendix C, we have, however, investigated a small number of TFP results that are anomalous, e.g. an increase in the opex input results in a positive contribution to TFP change when a negative contribution would be expected. These anomalies are not widespread and largely occur in 2022, reflecting a key driver is the changing inflation environment, which impacts input shares under the current multilateral Tornqvist indexing approach.

Through sensitivity testing we have established that our current indexing method is sensitive to the current changes in inflation, which impact the Annual user cost of capital and hence the input weights. This testing used an alternative indexing approach, under which the input weights depend only on the average cost shares for two adjacent observations and thus are fixed for calculating annual changes in the index. In contrast, under the current method the input weights applied to the two observations being compared depend partly on observation specific cost shares and thus differ across observations. Under this alternative indexing approach there were no anomalous results for output and input contributions to TFP change, although we note that it does produce time series TFP results of a different magnitude. However, this alternative indexing approach does not have the same methodological advantage of the current indexing approach. In particular, it does not prevent significant volatility in outputs, such as reliability, having undue impact on the industry TFP results. Further, when we return to a more stable inflationary environment, we consider it unlikely there will be anomalous results under our current indexing method.

In relation to benchmarking data, for this report we have adjusted some of AusNet's 2020, 2021 and 2022 data after considering potential inconsistencies in how lease and Software as a Service (SaaS) implementation costs are reported by TNSPs. Accounting standard AASB16,[9] which became effective for periods beginning on or after 1 January 2019, states that leases are to be considered as capital expenditure (capex). Guidance from the International Financial Reporting Standards (IFRS) noted in April 2021[10] that SaaS configuration costs, under some circumstances, are considered as opex.

We have come to understand, after consultation with TNSPs, that adoption of new accounting standards is often delayed for the purpose of regulatory reporting (which we rely on as the source of our benchmarking data). These delays are to maintain consistency over each TNSP's regulatory control period which are used for their revenue determinations. Due to the staggered starting dates of regulatory control periods for TNSPs in the NEM, the adoption of the accounting standards discussed has only occurred for AusNet.

Our benchmarking relies on the assumption that benchmarking data is reported consistently across TNSPs in accordance with instructions provided with our Regulatory Information Notice (RIN) templates. We consider that to have data consistency for benchmarking, leases and SaaS implementation costs should be considered under the legacy standards for the purpose of benchmarking. This is until a future date at which most or all TNSPs have transitioned onto the current reporting standards and an approach to recasting the historical cost to be on a consistent basis has been determined.

For this reason, AusNet informally provided amended economic benchmarking RINs using the legacy accounting standards, which made adjustments to its 2019–20, 2020–21 and 2021–22 data.[11] Specifically, it provided lease costs as opex, rather than as reported on a capitalised basis, and reported SaaS implementation costs as capital expenditure rather than opex. AusNet Services' adjustments resulted in increases to its opex in 2019–20, 2020–21 and 2021–22 as a result of the addition of leases, which in 2021–22 was offset by the removal of SaaS implementation costs from opex.

We will continue to monitor the basis upon which leases and SaaS implementation costs are reported by TNSPs, while consulting with individual TNSPs in circumstances where we require adjusted data to maintain cross-TNSP consistency.

9 Australian Accounting Standards Board, *Accounting Standards AASB 16 – Leases*, December 2019.

10 International Financial Reporting Standards (IFRS) – Interpretations Committee, *Configuration or Customisation Costs in a Cloud Computing Arrangement (IAS 38 Intangible Assets) – Agenda Paper 2*, 20 April 2021.

11 AusNet, *Response to AER considerations on mid-period accounting changes (SaaS and leases),* received 7 June 2023.

1.2. Benchmarking development program

We operate an ongoing transparent program to review and incrementally refine elements of the benchmarking methodology and data.

Our benchmarking development program takes into account issues arising across both the distribution and transmission reports. There are a variety of factors which inform the development work we progress, including:

- Feedback from stakeholders
- The materiality and impact of the development work on the robustness of the benchmarking
- The materiality and impact of the development work in relation to upcoming revenue determinations in which the benchmarking results will be used
- The ability to progress this work, including any sequencing issues and available data
- The resources available to undertake this work.

An important piece of work in this regard is an independent review of the non-reliability output weights. In the 2020 Annual Benchmarking Report we corrected an error identified in the non-reliability output weights used in the PIN benchmarking and committed to independently reviewing these weights. We scoped this review and included these details in our 2021 Annual Benchmarking Report. As noted in our 2022 Annual Benchmarking Report,[12] this remains a development priority and we aim to complete the review in the 2023–24 financial year.

Also noted in our 2022 Annual Benchmarking report was the key issue of improving measurement and associated data of some benchmarking variables, particularly transformer and overhead line inputs. This is connected in part to advancing the development work to review the economic benchmarking model specifications to account for new obligations relating to TNSPs' changing operating environment (including system strength and inertia requirements). These issues were also raised in submissions during the development of this year's benchmarking report:

- Powerlink noted that given the AER's Network Information Requirements Review is underway, it would welcome the opportunity to work with the AER to ensure measurement issues that have been identified as part of the benchmarking process can be addressed and data series that better capture the range of services provided by networks can be collected through annual reporting requirements.[13]
- ElectraNet considered the current outputs in the economic benchmarking models do a poor job of capturing the output of a modern TNSP, noting that this will get worse over time as new investment is undertaken to support the transformation of the transmission

[12] AER, *2022 Annual Benchmarking Report – Electricity transmission network service reports*. November 2022. p. 4.

[13] Powerlink, *Email to AER – Preliminary Annual Benchmarking Report 2023 – Electricity transmission network service providers – Consultation stage 1,* 25 July 2023.

system. ElectraNet specifically noted that including energy throughput in the economic benchmarking model suggests that a network is less productive when its customers choose to become energy efficient, or that a network ought to respond to rising energy efficiency by reducing the size and maintenance requirements of its network. It considered that while this may be possible over time to some extent, where customers locate would constrain this.[14]

- ElectraNet also submitted that the economic benchmarking model does not take account of additional transmission services now being offered which were not on offer when the model was originally developed. As an example, it noted that it has made investment in four synchronous condensers and while this will become apparent in the benchmarking model inputs, it is not recognised in terms of measured outputs.[15] Further, that as a result of changes to the way it provides network support, moving from an opex to capex solution, will cause changes in its partial total factor productivity results.
- ElectraNet considered that in this context, the limitations and development work in relation to transmission benchmarking analysis must be clearly acknowledged.[16]

In the 2020 Annual Benchmarking Report we set out why we considered energy throughput was an appropriate output measure. This included that it meets the three criteria we have used to select outputs for inclusion in the benchmarking model, including that it aligns with the National Electricity Law (NEL) and NER objectives, reflects services provided to consumers and in regard to economic analysis has been shown to be a significant output measure. We also noted that while throughput has a small direct impact on TNSP costs, it reflects the main output of value to customers.[17]

We acknowledge the significant changes occurring in the transmission network environment, particularly driven by increasing connection of large-scale renewable generation. This is resulting in new transmission network investment and the need to manage how the transmission system is operated, including to ensure system strength and reliability requirements are maintained. We recognise that while this new transmission network investment is likely to be largely captured through the current economic benchmarking model inputs (opex and capital), it is less clear that this is the case for all relevant outputs. We will closely monitor developments in the transmission network environment and note that a key area for development work could include seeking to understand whether current outputs remain relevant and if there are any new material outputs that need to be incorporated. This is similar to the recent review we undertook into if and how to incorporate export services into

[14] ElectraNet, *Email to AER – Preliminary Annual Benchmarking Report 2023 – Electricity transmission network service providers – Consultation stage 1,* 7 August 2023; ElectraNet, *Email to AER – AER 2023 Annual Benchmarking Report for transmission - draft AER benchmarking report for consultation,* 16 October 2023.

[15] ElectraNet, *Email to AER – Preliminary Annual Benchmarking Report 2023 – Electricity transmission network service providers – Consultation stage 1,* 7 August 2023; ElectraNet, *Email to AER – AER 2023 Annual Benchmarking Report for transmission - draft AER benchmarking report for consultation,* 16 October 2023.

[16] ElectraNet, *Email to AER – AER 2023 Annual Benchmarking Report for transmission - draft AER benchmarking report for consultation,* 16 October 2023.

[17] AER, *Annual Benchmarking Report 2020 – Electricity transmission network service providers*, November 2020, pp. 46–50.

our distribution benchmarking.[18] In this context, the lack of relevant export services data was a key factor limiting immediate progress of this work.

We are considering when would be an opportune time to undertake such a review, not least to determine whether there is specific information and data that we should start collecting to inform these considerations.

1.3. Consultation

In developing this report, we have undertaken consultation with external stakeholders in two stages, consistent with the approach we adopted in previous years. Firstly, this involved consultation with transmission networks in relation to the preliminary benchmarking results and report prepared by our consultant, Quantonomics.[19] Secondly, there was further consultation with these networks and other stakeholders in relation to a draft of this year's annual benchmarking report.[20] Minor corrections and changes were made to the reports to address this feedback as was appropriate.

We received feedback in relation to five main areas:

- The need to develop a *customer friendly* benchmarking overview that is available on the AER's website to assist stakeholders to better understand the economic benchmarking,

[18] AER, *Incentivising and measuring export service performance, Final report*, March 2023.

[19] Powerlink, *Email to AER – Preliminary Annual Benchmarking Report 2023 – Electricity transmission network service providers – Consultation stage 1,* 25 July 2023; TasNetworks, *Email to AER – Preliminary Annual Benchmarking Report 2023 – Electricity transmission network service providers – Consultation stage 1,* 28 July 2023; ElectraNet, *Email to AER – Preliminary Annual Benchmarking Report 2023 – Electricity transmission network service providers – Consultation stage 1,* 7 August 2023; AusNet, *Email to AER – Preliminary Annual Benchmarking Report 2023 – Electricity transmission network service providers – Consultation stage 1,* 2 August 2023; TransGrid, *Email to AER – Preliminary Annual Benchmarking Report 2023 – Electricity transmission network service providers – Consultation stage 1,* 11 August 2023. Energy Users Association of Australia, Email to the AER – *Preliminary Annual Benchmarking Report 2023 – Electricity transmission network service providers – Consultation stage 1,* 17 July 2023; Energy Networks Australia, Email to the AER – *Preliminary Annual Benchmarking Report 2023 – Electricity transmission network service providers – Consultation stage 1,* 17 July 2023.

[20] Powerlink, *Email to AER – AER 2023 Annual Benchmarking Report for transmission - draft AER benchmarking report for consultation,* 18 October 2023; TasNetworks, *Email to AER – AER 2023 Annual Benchmarking Report for transmission - draft AER benchmarking report for consultation,* 18 October 2023; ElectraNet, *Email to AER – AER 2023 Annual Benchmarking Report for transmission - draft AER benchmarking report for consultation,* 16 October 2023; AusNet, *Email to AER – AER 2023 Annual Benchmarking Report for transmission - draft AER benchmarking report for consultation*, 9 October, 2023; Energy Users Association of Australia, *Email to the AER – AER 2023 Annual Benchmarking Report for transmission - draft AER benchmarking report for consultation*, 23 October, 2023; Energy Networks Australia, *Email to the AER – AER 2023 Annual Benchmarking Report for transmission - draft AER benchmarking report for consultation,* 20 October, 2023.

how it is used and the results.[21] We thought this was a good idea and have published on the AER's benchmarking website 'easy to understand' fact sheets to accompany this year's distribution and transmission reports, which summarise what productivity benchmarking is, how we use it, and present some key benchmarking results and trends over the 2006 to 2022 time period.

- The need to review and reconsider the transmission economic benchmarking model specification and underpinning data. As noted in section 1.2 around the discussion of future development work, Powerlink and ElectraNet considered such a review was important in terms of both the outputs and inputs used in the benchmarking, noting also the links to the AER's Network Information Requirements Review and the underpinning data.[22] We set out above our views in relation to undertaking this development work.
- The need to identify and explain results across the benchmarking models that appear to be counter-intuitive or anomalous. [23] As noted in section 1.1, we have included in section 3.2 and Appendix C an explanation of the drivers of a small number of counter-intuitive TFP results, e.g. where an increase in the opex input results in a positive contribution to TFP change when a negative contribution would be expected.
- The need to examine the volatility in the outputs used in the benchmarking, and particularly reliability (ENS) and the impact of the volatility of this output on the productivity results.[24] This is discussed further below.
- Options for streamlining the benchmarking reports by removing 'Appendix B Benchmarking models and data' and providing the information contained in other ways.[25] This is also discussed further below.

[21] Powerlink, *Email to AER – Preliminary Annual Benchmarking Report 2023 – Electricity transmission network service providers – Consultation stage 1,* 25 July 2023. Powerlink, *Email to AER – AER 2023 Annual Benchmarking Report for transmission - draft AER benchmarking report for consultation,* 18 October 2023.

[22] ElectraNet, *Email to AER – Preliminary Annual Benchmarking Report 2023 – Electricity transmission network service providers – Consultation stage 1,* 7 August 2023; Powerlink, *Email to AER – Preliminary Annual Benchmarking Report 2023 – Electricity transmission network service providers – Consultation stage 1,* 25 July 2023. ElectraNet, *Email to AER – AER 2023 Annual Benchmarking Report for transmission - draft AER benchmarking report for consultation,* 16 October 2023.

[23] Powerlink, *Email to AER – AER 2023 Annual Benchmarking Report for transmission - draft AER benchmarking report for consultation*, 18 October 2023

[24] ElectraNet, *Email to AER – Preliminary Annual Benchmarking Report 2023 – Electricity transmission network service providers – Consultation stage 1,* 7 August 2023. ElectraNet, *Email to AER – AER 2023 Annual Benchmarking Report for transmission - draft AER benchmarking report for consultation,* 16 October 2023.

[25] Powerlink, *Email to AER – AER 2023 Annual Benchmarking Report for transmission - draft AER benchmarking report for consultation,* 18 October 2023; AusNet, *Email to AER – AER 2023 Annual Benchmarking Report for transmission - draft AER benchmarking report for consultation*, 9 October, 2023; Energy Users Association of Australia, *Email to the AER – AER 2023 Annual Benchmarking Report for transmission - draft AER benchmarking report for consultation*, 23 October, 2023. TasNetworks, *Email to AER – AER 2023 Annual Benchmarking Report for distribution - draft AER benchmarking report for consultation,* 18 October 2023.

Sensitivity of the productivity results, particularly to volatility in the energy not supplied output measure

ElectraNet submitted it was concerned with the volatility in the outputs used in the economic benchmarking, particularly the reliability output and the impact this has on its MTFP benchmarking results.[26] In this regard, it noted that in terms of its MTFP ranking it had lost three places in 2022 (moving from second position in 2021 to fifth in 2022) due, it appeared, to a return to more normal storm conditions and ENS. It raised the possibility of using a five-year rolling average of the outputs to reflect regulatory cycles and to 'iron out' volatility, but questioned whether such an approach was theoretically consistent with the underlying benchmarking model.

Our consultant, Quantonomics, reviewed this concern, particularly as it related to volatility in the reliability output, and noted that ElectraNet's MTFP growth in 2022 decreased by 7.9% largely due reduced reliability – its TFP change in 2022 would have been 0.0% without the effect of the change in reliability.[27] Quantonomics noted, however, that ElectraNet's fall in the MTFP rankings in 2022 is only partly due to its reduced reliability:

- ElectraNet's MTFP level is similar to that of three other TNSPs and its abnormally high reliability / lower levels of ENS in 2021 led to it having a favourable ranking of second. This did not continue in 2022 and ElectraNet experienced reduced reliability / higher levels of ENS than its historical average.
- In 2022 the MTFP of some of the three TNSPs with similar MTFP levels improved modestly, which is not the case for ElectraNet, who even when reliability is excluded did not have a positive TFP change.

Further, Quantonomics noted that productivity growth rates are regularly reported as averages over series of years. In this regard, ElectraNet's annual average rate of change in TFP from 2012 to 2022 is –1.0% and when ENS is excluded it is –1.1%. This illustrates there is little effect of reliability on the measured TFP growth rates over the averaging period.

Quantonomics also noted that previous concerns over volatility in the reliability output led to the adoption of changes to the economic benchmarking approach. These include capping the reliability output weight at 2.5% of total revenue,[28] and a change to use the multilateral Törnqvist index method which has the methodological advantage of preventing large fluctuations in outputs or inputs, such as network reliability, impacting the accuracy of TFP

[26] ElectraNet, *Email to AER – Preliminary Annual Benchmarking Report 2023 – Electricity transmission network service providers – Consultation stage 1,* 7 August 2023.

[27] Quantonomics, *Memorandum ElectraNet submission on ENS Volatility,* 23 August 2023.

[28] This is described in section 1 and in further detail in the supplementary documentation of: Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2022 TNSP Benchmarking Report, November 2022,* pp. 59–60.

measured.[29] Further, as outlined above, the productivity results are reported in terms of including and excluding reliability to provide transparency around the impact.

Given this, at this stage we do not intend to examine an averaging approach specifically in relation to the reliability output. We will continue to monitor the issue given we consider reliability is an important output that should be included in the benchmarking analysis despite the fact it can change significantly from year to year.

Consolidation of Appendix B: Benchmarking models and data

As a possible way to streamline the benchmarking reports, we also consulted stakeholders on whether Appendix B, which provides an overview of the economic benchmarking techniques and data we use, could be removed from these reports. We suggested options for consolidating some of the information in the appendix into the main body of the report, or referencing where it could be found in other supporting documents we publish.

There was a limited and mixed response in submissions to the idea. Of the transmission businesses, Powerlink supported removing the appendix while Ausnet did not have any concerns with the idea. TasNetworks Distribution did not support removal, noting the appendix provided useful context for readers and a concise summary of our benchmarking techniques. The Energy Users Association of Australia also supported retaining the appendix, noting it is helpful to have all this information on the benchmarking techniques in one place.[30]

Given these responses, we have retained the appendix in this year's report. We will reconsider options for presenting a more concise overview of our benchmarking techniques and data, and consult more widely on a way forward, as part of next year's reports.

[29] Economic Insights, *Economic Benchmarking Results for the Australian Energy Regulator's 2021 TNSP Annual Benchmarking Report, Report prepared for Australian Energy Regulator*, 17 July 2020, pp. 3–4.

[30] Powerlink, *Email to AER – AER 2023 Annual Benchmarking Report for transmission - draft AER benchmarking report for consultation,* 18 October 2023; AusNet, *Email to AER – AER 2023 Annual Benchmarking Report for transmission - draft AER benchmarking report for consultation*, 9 October, 2023; Energy Users Association of Australia, *Email to the AER – AER 2023 Annual Benchmarking Report for transmission - draft AER benchmarking report for consultation*, 23 October, 2023. TasNetworks, *Email to AER – AER 2023 Annual Benchmarking Report for distribution - draft AER benchmarking report for consultation,* 18 October 2023.

2. Economic benchmarking and its uses

Electricity networks are 'natural monopolies', which do not face the typical commercial pressures experienced by firms in competitive markets. Unregulated network operators could increase their prices above efficient levels and would face limited pressure to control their operating costs or invest efficiently. As a result, electricity networks are regulated, and economic benchmarking is one tool we use to examine how efficiently they are operating.

Consumers pay for electricity network costs through their retail electricity bills. Transmission network costs typically account for between 5 to 10% of what consumers pay for their electricity, while distribution costs account for around one-third of the total bill in most jurisdictions.[31] The remainder covers the costs of generating, and retailing electricity, as well as various regulatory programs related to environmental policies. Figure 4 provides an overview of the typical electricity retail bill.

Figure 4 Network costs as a proportion of retail electricity bills, 2021

Source: AEMC, *Residential electricity price trends 2021, Final Report*, December 2021.

Note: Figures may differ slightly from the source due to rounding.

Under the NEL and the NER, the AER regulates electricity network revenues with the goal of ensuring that consumers pay no more than necessary for the safe and reliable delivery of

31 AEMC, *Residential electricity price trends 2021, Final Report*, November 2021. The AEMC noted it will publish its next Residential Electricity Price Trends report in late 2024. As this is not yet available, we have used its December 2021 report. See https://www.aemc.gov.au/news-centre/media-releases/update-residential-electricity-prices-report.

electricity services. This is done through a periodic regulatory process (known as revenue determinations or resets) which typically occurs every five years. Each electricity network provides the AER with a revenue proposal outlining its forecast expenditures or costs over the following five-year period. The AER assesses and, where necessary, amends each proposal to ensure it reflects efficient costs. On this basis, the AER then sets each network's revenue allowance for the five-year period, which is the maximum amount the network can recover from their customers.

In 2012, the Australian Energy Market Commission (AEMC) amended the rules to strengthen the AER's power to assess and amend network expenditure proposals.[32] The rule changes were made in response to concerns raised by the AER and other industry participants that restrictions in the NER had resulted in increases in capital and opex allowances of network service providers (NSPs) that were not necessarily efficient and resulted in higher charges for consumers.[33]

The rule changes required the AER to develop a benchmarking program to measure the relative efficiency of all electricity networks in the NEM and to have regard to the benchmarking results when assessing capex and opex allowances for network TNSPs. The rules also required the AER to publish the benchmarking results in an annual benchmarking report.[34]

2.1. The uses of economic benchmarking

We use the economic benchmarking techniques described in section 1 in a variety of holistic and targeted ways when assessing and amending network revenue proposals.[35] The TFP and MTFP techniques are primarily used to measure total input efficiency, opex PFP and MPFP techniques to test opex efficiency, while the capital PFP and MPFP results provide information on the efficiency of capital inputs. The PPIs provide supplementary information on how efficiently a network may be using particularly inputs. Taken together, these benchmarking techniques give us an additional source of information on the efficiency of historical network opex and capital inputs and the appropriateness of basing forecasts on them.

32 AEMC, *Rule Determination, National Electricity Amendment (Economic Regulation of Network Service Providers) Rule 2012; National Gas Amendment (Price and Revenue Regulation of Gas Services) Rule 2012*, 29 November 2012, p. vii.

33 AEMC, *Rule Determination*, *National Electricity Amendment (Economic Regulation of Network Service Providers) Rule 2012; National Gas Amendment (Price and Revenue Regulation of Gas Services) Rule 2012*, 29 November 2012, p. vii.

34 NER, cll. 6A.31(a) and 6A.31(c).

35 The benchmarking presented in this report is one of a number of factors we consider when making our revenue determinations. For a revenue determination, we examine the efficiency of an individual TNSP's forecast opex and capex. In this report we primarily examine the overall efficiency of transmission networks. Though the efficiency of networks as a whole is relevant to our determinations, we also undertake further analysis when reviewing opex and capex forecasts.

We also use these benchmarking techniques to understand the drivers of trends in network efficiency over time and changes in these trends. This can help us understand why network productivity is increasing or decreasing and where best to target our expenditure reviews.[36]

The benchmarking results provide network owners and investors with useful information on the relative productivity of the electricity networks they own and invest in. This information, in conjunction with the financial rewards available to businesses under the regulatory framework, and businesses' profit-maximising incentives, can facilitate reforms to improve network efficiency that can lead to lower network costs and retail prices.

Benchmarking also provides government policy makers (who set regulatory standards and obligations for networks) with information about the impacts of regulation on network costs, productivity and ultimately electricity prices. Additionally, benchmarking can provide information that may contribute to the assessment of the success of the regulatory regime over time.

Finally, benchmarking provides consumers with accessible information about the relative efficiency of the electricity networks they rely on. The breakdown of inputs and outputs driving network productivity, in particular, allows consumers to clearly see which factors are driving network efficiency and the network cost component of their retail electricity bills. This helps to inform their participation in our regulatory processes and in broader debates about energy policy and regulation.

2.2. Limitations of benchmarking transmission networks

While we have undertaken benchmarking of transmission network productivity for several years, top-down (whole-of-business) benchmarking of electricity transmission networks is a developing area. We are aware there have been ongoing studies on transmission. For example, European regulators, through the Council of European Economic Regulators have periodically conducted benchmarking studies of electricity and gas transmission system operators in Europe since 2005.[37] There has been greater use of TNSP benchmarking by economic regulators since 2014, but we consider that transmission benchmarking is still less developed than distribution benchmarking. The small number of electricity transmission networks in Australia (five) also makes efficiency comparisons at the aggregate level difficult.

We have primarily used the PIN techniques to measure TNSPs' productivity over time and relative to each other. It is important to recognise that the results do not necessarily account for all relevant, material differences in network operating environments. Certain factors arising from a TNSPs operating environment are beyond its control. These 'operating environment factors' (OEFs) may influence a TNSPs costs and, therefore, its benchmarking performance. The benchmarking techniques presented in this report capture key OEFs. For example, the MTFP analysis includes as outputs a TNSPs circuit length, number of end

[36] AER, *Explanatory Statement - Expenditure Forecast Assessment Guideline*, November 2013, pp. 78–79.

[37] Economic Insights, *Economic Benchmarking Results for the Australian Energy Regulator's 2021 TNSP Annual Benchmarking Report*, November 2021, pp. 3–4.

users, ratcheted maximum demand and energy throughput, and by doing so we also allow for key network density measures, including throughput per kilometre and maximum demand per customer. However, not all OEFs can be captured in the models and in section 1.2 we also note the need to review in the future whether current outputs in the economic benchmarking specification remain relevant and if there are any new material outputs that need to be incorporated.

However, we consider the benchmarking analysis presented in this report is reasoned and comprehensive. We have consulted with industry participants to refine our transmission benchmarking as part of our ongoing development work program and, as outlined in section 1.2, will continue to do so. We have also collected data on all major inputs and outputs for TNSPs, and we consider that the dataset used is robust.

3. The productivity of the electricity transmission industry as a whole

Key points

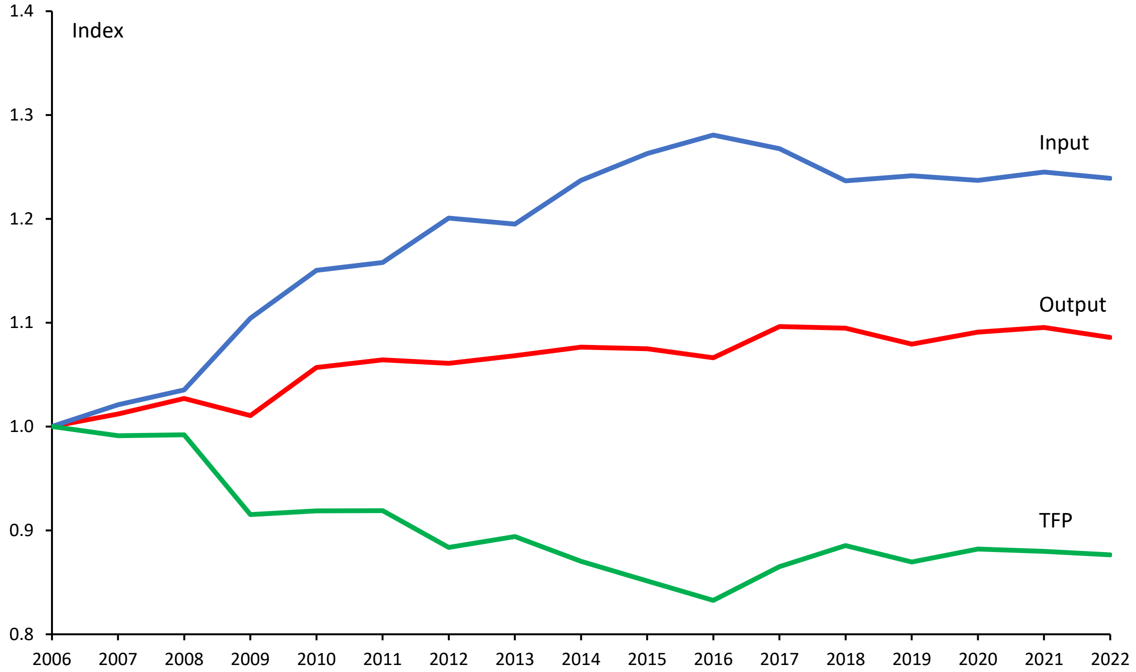
- Electricity transmission industry productivity as measured by TFP analysis decreased slightly by 0.4% over 2022.
- A reduction in network reliability, combined with an increase in the opex input and a fall in the output measure of energy throughput (GWh) were the main drivers of this slight productivity decrease over 2022. These were partially offset by a reduction in the transformer input.
- The decrease in electricity transmission industry productivity over 2022 contrasted with the increase in productivity in the Australian economy and utilities sector (1.9% and 0.9% respectively), over the same period.
- Electricity transmission industry TFP has decreased over the period 2006–22 (by 0.8%), with the long-term decline in capital PFP largely driving this result.
- The general improvement in transmission productivity from 2016 to 2020 can be linked to reductions in opex as reflected by improved opex PFP and slower growth in capital assets relative to outputs compared to earlier years. In 2021 and 2022, this trend of declining opex inputs was not observed and increased opex inputs contributed to the decline in TFP.

We present below time series TFP results for the electricity transmission industry over the 2006–22 period and for the 12–month period to 2022. As set out in section 1, TFP results are used in this report to measure and compare changes in productivity of a single entity (e.g. the transmission industry or a TNSP) over time. We also set out the input and output drivers, and their contribution to the industry-wide productivity change in 2022, as well as the major input and output contributions to the change in productivity for each TNSP level. The variability in productivity from year-to-year can be seen in the results below and emphasises the importance of considering the changes in productivity in 2022 in the context of longer-term trends.

3.1. Transmission industry productivity over time

Figure 5 presents TFP for the electricity transmission industry over the period 2006–22. Over this 17–year period, input use grew faster (1.3% per year on average) than outputs (0.5% per year on average). This resulted in a decline in long-term TFP by 0.8% per year on average.[38] There was an improvement in transmission industry productivity in 2017, 2018 and 2020, while there were declines in 2019, 2021 and 2022. Transmission productivity in these years was only slightly below the 2018 and 2020 levels. As can be seen in Figure 5, while there has been a general improvement in transmission productivity from 2016 to 2020, it has largely plateaued since 2018. In 2022, the slight decline in productivity (by 0.4%) was the result of a decrease in total outputs (0.9%) which exceeded the decrease in total inputs (0.5%).

Figure 5 Transmission industry input, output and TFP indices, 2006–22



Source: Quantonomics.

Figure 6 shows that the long-term decline in capital PFP is largely driving the long-term reduction in transmission industry productivity. Over the last 17 years (2006–22), capital PFP declined at an average annual rate of 1.4% compared to opex PFP which grew at an average annual rate of 0.5%. The improvement in transmission productivity from 2016 can be primarily linked to the increase in opex PFP, although stabilisation of capital PFP also contributed to the improvement (that is, less growth in capital assets compared to earlier years). Figure 6 shows that opex PFP increased significantly over 2017, 2018 and 2020 and

38 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Benchmarking Report*, 25 October 2023, p. 9. The rate of change is based on logarithmic endpoint-to-endpoint growth, using logarithmic difference method to calculate the annual average rate of growth. We have followed the Quantonomics approach to report log-difference annual growth rates by periodical percentage change in productivity indexes. For individual inputs and outputs (e.g. the opex input and energy throughput), as well as partial performance indicators, we have used the percentage change calculation for both annual and periodical rate of change.

capital PFP fluctuated but increased in 2017 and 2020. In 2022, opex PFP fell by 2.6% and capital PFP fell by 0.4% contributing to the overall decline of 0.4% in TFP.[39]

Examining changes in transmission industry TFP over the shorter time periods of 2006–12 and 2012–22, reveals a more rapid decrease in TFP over the earlier time period followed by a relative stabilisation in the rate of change in TFP over the later period. Over 2006–12, TFP decreased at an average annual rate of -2.1%, with the downward trend in TFP continuing until 2016.[40] The decrease over the 2006–12 period was primarily driven by growth in transformers and overhead lines and to a lesser extent opex, with the rate of decline partly offset by growth in RMD and a decrease in circuit line length.[41]

Over the 2012–22 period, TFP (while decreasing until 2016, then trending upward to 2022) was virtually unchanged overall, declining at an average annual rate of only -0.1%.[42] This decrease in the rate of decline in TFP between 2006–12 and 2012–22 (from an average annual rate of -2.1% to -0.1%) was driven primarily by:

- Decreasing opex in the later period, which made a positive contribution to TFP over the later period compared to a negative contribution over 2006–12
- A decrease in the rate of growth in transformers and overhead line inputs, which made smaller negative contributions to TFP over the later period compared to the earlier period.[43]

Figure 7 compares the TFP of the electricity transmission industry over time relative to the productivity estimates of the overall Australian economy and utilities sector.[44] Over the past 17 years, declining productivity in the electricity transmission industry was broadly consistent with the utilities sector. However, the average annual rate of decline of 0.8% was not as low as the average annual productivity decline reported for the utilities sector of 1.7%. In contrast, the Australian market economy's productivity grew slightly over the 2006–22 period with an average annual growth of 0.2%. In 2022, TFP for the economy and utilities sector grew by 1.9% and 0.9% respectively, in contrast to the decline of 0.4% for the electricity transmission industry.

39 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Benchmarking Report*, 25 October 2023, p. 10.

40 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Benchmarking Report*, 25 October 2023, p. 17.

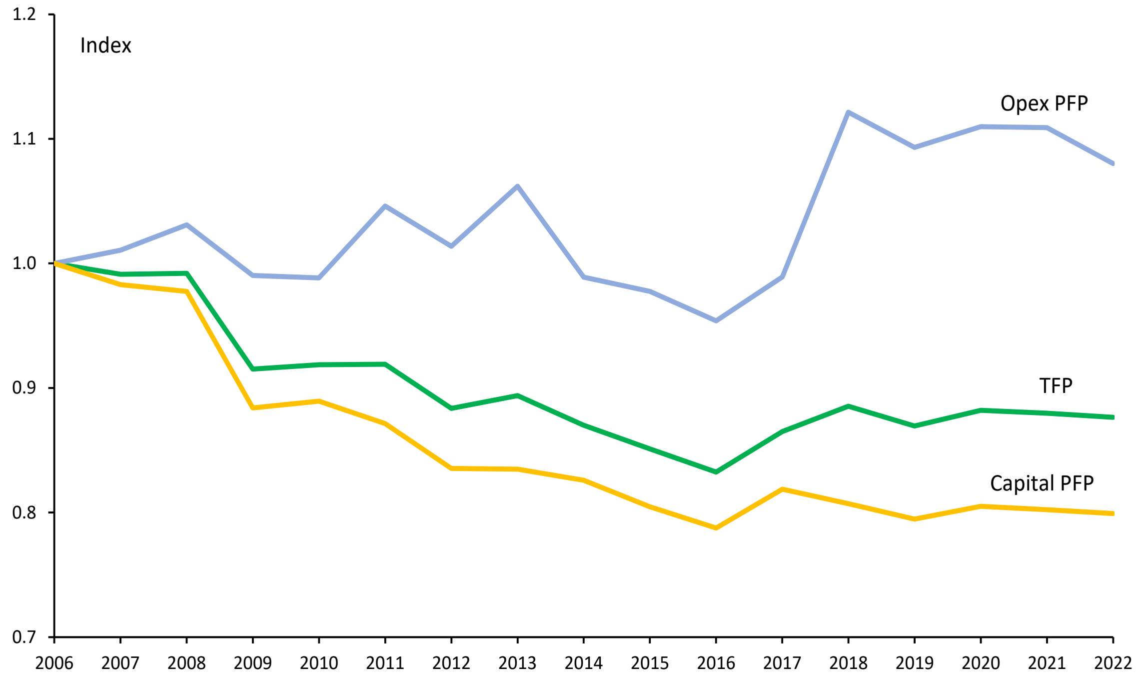
41 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Benchmarking Report*, 25 October 2023, p. 19.

42 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Benchmarking Report*, 25 October 2023, p. 17.

43 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Benchmarking Report*, 25 October 2023, p. 18.

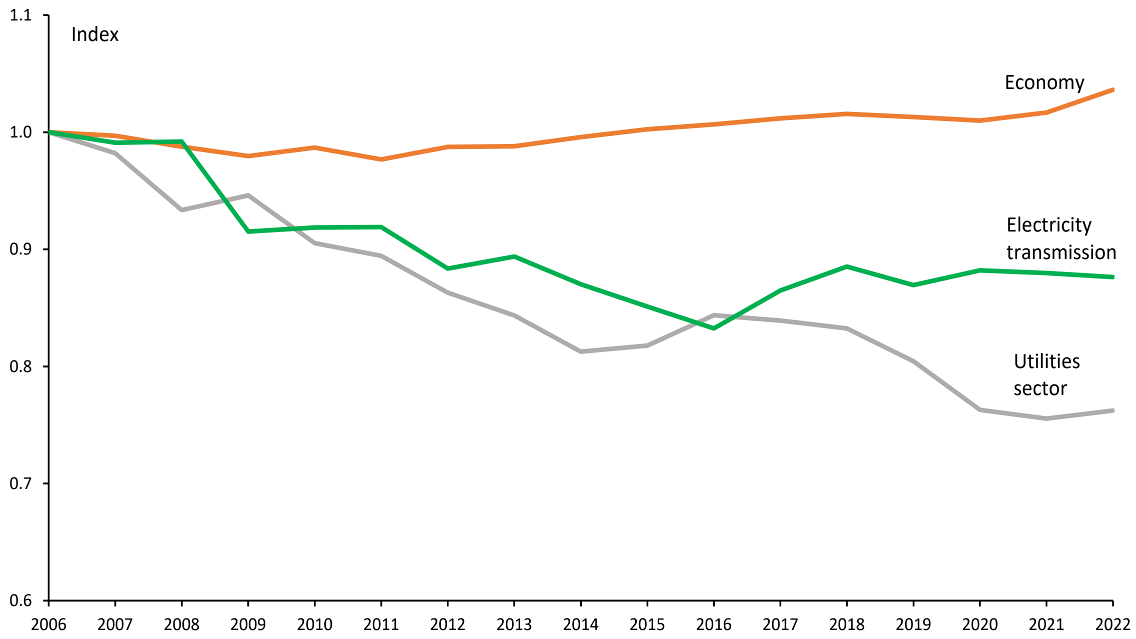
44 Electricity, gas, water and waste services (EGWWS).

Figure 6 Transmission industry opex PFP and capex PFP, 2006–22



Source: Quantonomics.

Figure 7 Electricity transmission industry, utilities sector, and economy productivity indexes, 2006–22



Source: Quantonomics; Australian Bureau of Statistics.

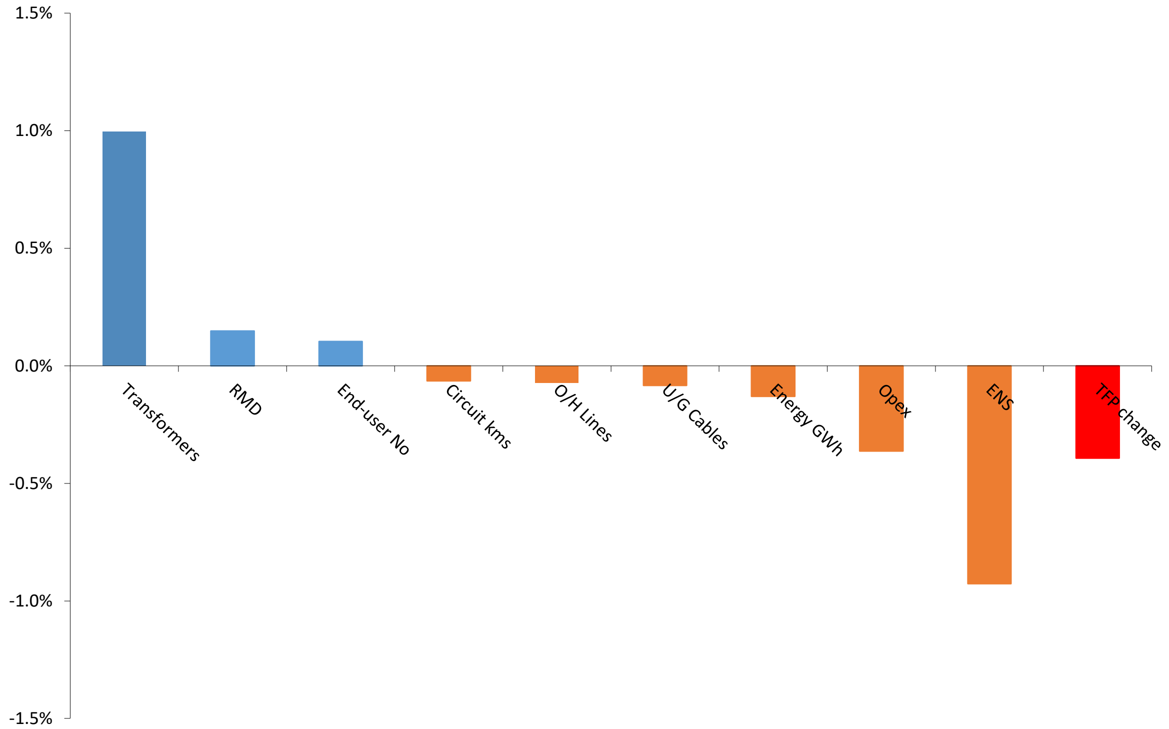
Note: The productivity of the Australian market economy and the utility industry is from the ABS indices within 5260.0.55.002 Estimates of Industry Multifactor Productivity, Australia, Table 1: Gross value added based multifactor productivity indexes (a). We have rebased the ABS indices to 1 in 2006.

3.2. Transmission industry productivity over 2022

As set out above, transmission industry TFP decreased by 0.4% over 2022.

Figure 8 shows the drivers of change in electricity transmission productivity in 2022 in terms of the contributions of each output and each input to the change in TFP. The contributions are ordered from the most positive on the left to the most negative on the right. If all the positive (blue bars) and negative contributions (orange bars) in Figure 8 are added together, they sum to the TFP change given by the red bar on the right of the figure.

Figure 8 Transmission industry output and input percentage point contributions to annual TFP change, 2022



Source: Quantonomics.

Figure 8 shows that the primary driver of decreased productivity for the transmission industry in 2022 was reduced reliability (or increased ENS). This in isolation contributed a 0.9 percentage point decrease to the TFP change. ENS enters the total output index as a negative output such that a reduction in ENS represents an improvement in reliability 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. In 2022, reliability decreased as there was an increase in ENS. The growth of TFP for the transmission industry in 2022 excluding ENS was significantly higher than when ENS is included (0.5% and –0.4%, respectively).[45] The change in reliability in 2022 largely reflects the reduced reliability performance of three of the five TNSPs (ElectraNet, Powerlink

[45] Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Benchmarking Report*, 25 October 2023, p. 10.

and TasNetworks), who had large reductions in network reliability (i.e. an increase in ENS).[46] AusNet and TransGrid reported increases in network reliability (i.e. a decrease in ENS) in 2022.[47]

Other drivers of reduced transmission industry TFP in 2022 included the increase in opex input and the reduction in the output for energy throughput (GWh), both negatively contributing 0.4 and 0.1 percentage points, respectively.[48]

Partially offsetting the negative contributions to productivity change in 2022, was a reduction in transformer input. This in isolation positively contributed 1.0 percentage points to the TFP change. In addition to the reduced transformer input, minor positive contributions to transmission industry TFP in 2022 included an increase in the outputs for RMD and end user numbers, both contributing 0.1 percentage points.[49]

Output and input contributions to productivity growth over 2022 – by industry and TNSP

Table 1 presents the industry and each TNSP's time series TFP growth in 2022, and decomposition into the individual input and output contributions that were most material to this growth. In this light, we have focused on reliability (ENS), transformers, opex and energy throughput contributions given their materiality in driving TFP growth in 2022.

Table 1 Selected input and output contributions to TFP growth rates by TNSP, 2022

	Annual change in TFP (%)	Energy not supplied (ppts)	Transformers (ppts)	Opex (ppts)	Energy Throughput (ppts)
Transmission industry	–0.4	–0.9	1.0	–0.4	–0.1
Powerlink	1.6	–1.0	0.6	1.3	–0.2
AusNet	0.1	1.1	0.6	–1.3	0.6
TransGrid	–1.0	0.1	1.8	–2.2	–0.7
TasNetworks	–1.6	–3.6	0.1	1.1	0.4
ElectraNet	–7.0	–7.0	0.4	0.0	0.0

Source: Quantonomics

The productivity of two TNSPs as measured by time series TFP growth improved in 2022 (Powerlink and AusNet) while that of three TNSPs (ElectraNet, TasNetworks and TransGrid)

46 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Benchmarking Report*, 25 October 2023, pages 38, 44 and 49.

47 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Benchmarking Report*, 25 October 2023, pages 33 and 55.

48 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Benchmarking Report*, 25 October 2023, p. 17.

49 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Benchmarking Report*, 25 October 2023, p. 17.

declined. The productivity of Powerlink and AusNet grew over 2022 by 1.6% and 0.1%, respectively.

As noted, Powerlink's productivity as measured by times series TFP improved in 2022 by 1.6%. This was in contrast to the decline of 2.0% over 2021.[50] A reduction in opex input was the key driver of the increased TFP growth for Powerlink in 2022, which had the largest positive contribution of 1.3 percentage points. A reduction in the transformer inputs also had a positive contribution of 0.6 percentage points to Powerlink's TFP change in 2022. Powerlink reported that the largest contributor to the net reduction in transformer capacity in 2022 was the result of decommissioning several transformers for which replacements had been commissioned in previous years.[51]

A decrease in network reliability (i.e. an increase in ENS) had the largest negative contribution of 1.0 percentage point to Powerlink's TFP change. Powerlink reported a decrease in network reliability over 2022, with an increase in ENS to 301.6 MWh from 160.9 MWh in 2021. This was due to two material loss of supply events in 2022.[52] The growth of TFP for Powerlink in 2022 excluding ENS is significantly higher compared to when ENS is included (2.6% and 1.6%, respectively).[53] A decrease in the energy throughput output also had a negative contribution of 0.2 percentage points to Powerlink's TFP change in 2022.

An improvement in reliability was a key driver of AusNet's slight TFP growth in 2022 of 0.1%, making a positive 1.1 percentage point contribution. AusNet reported that the duration of events in 2022 was less than the duration of events in 2021 resulting in the reduction of ENS.[54] An increase of 4.2% in the energy throughput output in 2022 compared to 2021 also positively contributed 0.6 percentage points to AusNet's TFP growth. This was due to an increase in exports from Victoria to New South Wales compared to the previous year due to higher pricing in the northern states.[55]

Offsetting these positive contributions, AusNet's reported increase in the opex input of 8.1% in 2022 compared 2021, results in a negative contribution of 1.3 percentage points to AusNet's TFP growth. This was driven by an increase in strategic projects arising from payroll remediation adjustments and vegetation management (network maintenance) costs.[56] A decrease in the circuit length output also has a negative contribution of 0.8 percentage

50 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Benchmarking Report*, 25 October 2023, p. 40; AER analysis.

51 Powerlink, *Email to the AER – Response to questions on Powerlink's 2021–22 EB RIN data*. Received 3 April 2023.

52 Powerlink, *Email to the AER – Response to questions on Powerlink's 2021–22 EB RIN data*. Received 3 April 2023.

53 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Benchmarking Report*, 25 October 2023, p. 39.

54 AusNet, Email to the AER – *Response to questions on AusNet's 2021–22 EB RIN data*. Received 29 March 2023.

55 AEMO, Email to the AER *Response to questions on AEMOs 2021–22 EB RIN data*. Received 13 April 2023.

56 AusNet, *Email to the AER – Response to questions on AusNet's 2021–22 EB RIN data*. Received 30 March 2023.

points to AusNet's TFP change in 2022.[57] The reduction in circuit length was equal to 1.6% in 2022 compared to 2021, noting this output receives the largest weight in forming the TFP index.[58]

ElectraNet's productivity as measured by TFP growth declined in 2022 by 7.0%. A decrease in network reliability (i.e. an increase in ENS) had the largest negative contribution of 7.0 percentage points. This was due to a large decrease in network reliability over 2022, with an increase in ENS to 234.0 MWh from 0.2 MWh in 2021. The change in reliability was driven by an increase in the number of significant loss of supply events from 2 in 2021 to 8 in 2022 (mainly due to more heightened storm activity in 2022).[59] The growth of TFP for ElectraNet in 2022 excluding ENS is significantly improved compared to when ENS is included (0.0% and –7.0%, respectively).[60] An increase in the overhead line input also had a negative contribution of 0.7 percentage points to ElectraNet's TFP change in 2022. This was driven by an increase in overhead line weighted average capacity due to capacity 'upratings' for some of ElectraNet's 132kV and 275kV lines.[61]

These negative contributions were partly offset by a reduction in the transformers input and no change to the underground cable input for ElectraNet, which had positive contributions of 0.4 and 0.2 percentage points respectively to its TFP growth in 2022.[62] ElectraNet reported a minor reduction in the capacity of transformers (0.2% reduction over 2022 compared to 2021) and no change in length or capacity for underground cables. However, the positive contributions of the underground cable input is an anomalous result as its quantity did not change in 2022 and should not result in any contribution to TFP growth. As this result is counter-intuitive (along with a small number of other examples set out below) we have investigated this as discussed in Appendix C. A further example of these anomalous results can be seen as ElectraNet's opex input fell by 1.6% in 2022, but made a negative contribution to its TFP change by 0.03 percentage points (when a positive contribution would be expected).[63] Notably ElectraNet's underground cable input cost share fell from 2.2% in 2021 to 1.4% in 2022, while the opex cost share rose from 33.4% in 2021 to 42.7% in 2022.

TasNetworks' productivity as measured by TFP decreased in 2022 by 1.6%. Reduced reliability made the largest and only negative contribution of 3.6 percentage points to its TFP change. This was due to three loss of supply events in 2022, one at New Norfolk which was

57 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Benchmarking Report*, 25 October 2023, p. 32.

58 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Benchmarking Report*, 25 October 2023, p. 30.

59 ElectraNet, *Email to the AER – Response to questions on ElectraNet's 2021–22 EB RIN data*. Received 3 April 2023.

60 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Benchmarking Report*, 25 October 2023, pp. 34.

61 ElectraNet, *Email to the AER – Response to questions on ElectraNet's 2021–22 EB RIN data*. Received 3 April 2023.

62 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Benchmarking Report*, 25 October 2023, p. 38.

63 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Benchmarking Report*, 25 October 2023, p. 38.

caused by a complicated mal-operation of a protection scheme, the second at Boyer which was caused by protection tripping a circuit breaker at the New Norfolk substation and the third which was the result of severe weather, damaging winds that led to excessive insulator swinging on a transmission tower. [64] This was a significant increase from 2021, when TasNetworks noted a reduction in the duration and frequency of outage events.[65] The TFP growth for TasNetworks in 2022 excluding ENS is significantly improved compared to when ENS is included (2.0% and –1.6%, respectively).[66]

The negative contribution of reduced reliability to TasNetworks' TFP reduction in 2022 was partly offset by the opex input contributing 1.1 percentage points, and an increase in energy throughput output, contributing 0.4 percentage points. However, the positive contribution of opex is anomalous, as opex increased in 2022 and therefore it would have been expected to make a negative contribution.[67] As this contribution, and that of its transformer input, which also increased and made a small positive contribution to TFP change, are counter-intuitive we have investigated these anomalies, which as noted above is discussed further in Appendix C.

TransGrid's productivity as measured by TFP declined in 2022 by 1.0%. An increase in opex input made the largest negative contribution of 2.2 percentage points to TransGrid's TFP change. This was driven by a range of factors including increased expenditure on environmental factors (safety training, increase in staff and environment strategy planning), outsourced facilities maintenance, grid planning and maintenance for bushfire remediation.[68] Also contributing to TransGrid's TFP decline in 2022 was a reduction in the energy throughput output, which made a negative contribution of 0.7 percentage points. Lower energy transported in 2022 was due to a combination of factors, including lockdowns and disruptions in major sectors of the economy due to the COVID–19 pandemic, exponential uptake of behind the meter rooftop PV (reducing energy consumed from the grid), out of trend energy efficiency uptake and an increase in power prices due to internal and external economic disruptions.[69]

Partially offsetting the negative contributions to TransGrid's decline in productivity was a reduction in the transformers input. This positively contributed to TransGrid TFP change by 1.8 percentage points.

[64] TasNetworks, *Email to the AER – Response to questions on TasNetworks' 2021–22 EB RIN data*. Received 28 March 2023.

[65] TasNetworks, *Email to the AER – follow up questions on TasNetworks' 2020–21 EB RIN data.* Received 15 September 2022.

[66] Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Benchmarking Report*, 25 October 2023, p. 45.

[67] Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Benchmarking Report*, 25 October 2023, p. 49.

[68] TransGrid, *Email to the AER – Response to questions on TransGrid's 2021–22 EB RIN data*. Received 28 March 2023.

[69] TransGrid, *Email to the AER – Response to questions on TransGrid's 2021–22 EB RIN data*. Received 28 March 2023.

Two of the TNSPs (Powerlink and AusNet) achieved productivity change in 2022 at a rate (1.6% and 0.1% respectively) that is greater than the average annual industry TFP change over the 2006–22 period (–0.8%).

In terms of the small number of anomalous results outlined above, and discussed further in Appendix C, we consider a key driver of these is that the input weights applied to the two consecutive years in comparison (i.e. 2021 and 2022) are impacted by the changing inflation environment, particularly given the large rise in inflation in 2022. These inflation changes have led to more significant changes in the Annual user cost of capital than in previous years. This impacts the relative opex and capital input weights as the capital input weights are based on the Annual user cost of capital.

The full set of input and output contributions to TFP for the industry over the 2006–22 period and for 2022 can be found in the Quantonomics report, including discussion in relation to the anomalous results in Appendix C.[70]

70 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Annual Benchmarking Report,* 25 October 2023, pp. 9-22, 28-50 and 67-70.

4. Relative productivity of individual transmission networks

Key points

- TasNetworks continued to be the highest ranking TNSP as measured by MTFP in 2022, however it had a decline in productivity growth in 2022 to be at a similar level to 2006 and 2016. TasNetworks has remained the top ranked TNSP since 2012, but we note that our transmission benchmarking does not account for all possible differences in OEFs.
- Three TNSPs (AusNet, Powerlink, and TransGrid) improved their productivity as measured by MTFP in 2022. AusNet had the largest productivity growth in 2022 relative to other TNSPs, continuing the growth it achieved in 2020 and 2021. Powerlink and TransGrid both achieved productivity growth in 2022 following declines in 2020 and 2021.
- ElectraNet's productivity as measured by MTFP was lower in 2022 compared to 2021 following productivity growth since 2019.
- The productivity of ElectraNet, Powerlink and TransGrid has deteriorated when viewed over 2006–22, while Ausnet's productivity has trended upwards over the same time period.

Below we present the economic benchmarking results that we use to measure and compare the productivity of individual TNSPs over the period 2006–22 and for the 2022 regulatory year. We also provide our key observations on the reasons for changes in the relative productivity of each TNSP in the NEM. In particular:

- Section 4.1 presents the results of the panel data MTFP benchmarking, which relates total inputs to total outputs and provides a measure of overall network productivity relative to other networks. MTFP is the headline technique we use to measure and compare the relative productivity performance of individual TNSPs over time. This is supported by the corresponding partial factor productivity measures of opex and capital inputs (i.e. opex MPFP and capital MPFP).
- Section 4.2 presents the PPIs, which provide a general indication of comparative performance in delivering one type of output.

Being a top-down analysis, the results discussed in this section, particularly the MTFP results, are only indicative of relative performance across the TNSPs. While the analysis accounts for some factors that are beyond a TNSP's control, such as network density and some system structure factors, additional OEFs can affect a TNSP's costs and benchmarking performance. At this stage, and as noted in section 2.2, our transmission benchmarking analysis does not incorporate additional OEFs beyond the network density differences.

4.1. MTFP results for TNSPs

The relative productivity levels of TNSPs as measured by MTFP over the 2006–22 period are presented in Figure 9.[71] It shows a general clustering of four TNSPs below TasNetworks, since around 2013 and 2014. In this regard we note that our transmission benchmarking does not account for all possible differences in OEFs.

Figure 9 also shows that three TNSPs recorded increases in relative productivity in 2022 (AusNet 2.4%, Powerlink 2.1%, and TransGrid 1.8%).[72] AusNet's relative productivity as measured by MTFP was 13.2% higher in 2022 than it was in 2006.[73] Its MTFP performance improved over the last 3 years (2020 to 2022) following a significant decline in 2019 (due to a single network outage event) and in 2022 it was ranked second. Over the period 2012 to 2018 AusNet's productivity was relatively stable with slight increases.

The relative productivity of Powerlink, Transgrid and ElectraNet as measured by MTFP has generally fallen over the 17–year period as shown in Figure 9, and in each case is significantly lower in 2022 than it was in 2006. This is despite, as noted above, Powerlink's and TransGrid's relative productivity increase in 2022 meaning that Powerlink's ranking improved from fourth in 2021 to third in 2022 and TransGrid's rating improved from fifth to fourth (see Table 2). For both Powerlink and TransGrid, improved productivity growth in 2022 followed declining productivity growth in 2020 and 2021. However, Powerlink's and TransGrid's 2022 MTFP scores remain higher than in 2017 and 2016 respectively, the lowest levels recorded over the 2006-22 time period.

ElectraNet's relative productivity declined in 2022 in line with its longer-term trend. ElectraNet recorded the largest reduction in productivity in 2022 (–8.4%), primarily driven by a decrease in reliability. This was a result of an increase in the number of significant outage events in 2022 largely due to heightened storm activity.[74] This meant ElectraNet's ranking dropped from second in 2021 to fifth in 2022 (see Table 2) following three years of small productivity growth (2019, 2020 and 2021). As noted in section 1.3, when examining ElectraNet's performance over longer timeframes the impact of reliability changes is less pronounced than when examined on a year-on-year basis.

TasNetworks' relative productivity, as measured by MTFP, decreased by 4.2% in 2022 to be approximately equal to the level it recorded at the start of the period in 2006 (and in 2016). TasNetworks' relative productivity declined from 2006 to 2013 before trending up from 2014

71 ElectraNet (ENT) in 2006 is set as the base (i.e. index = 1.00).

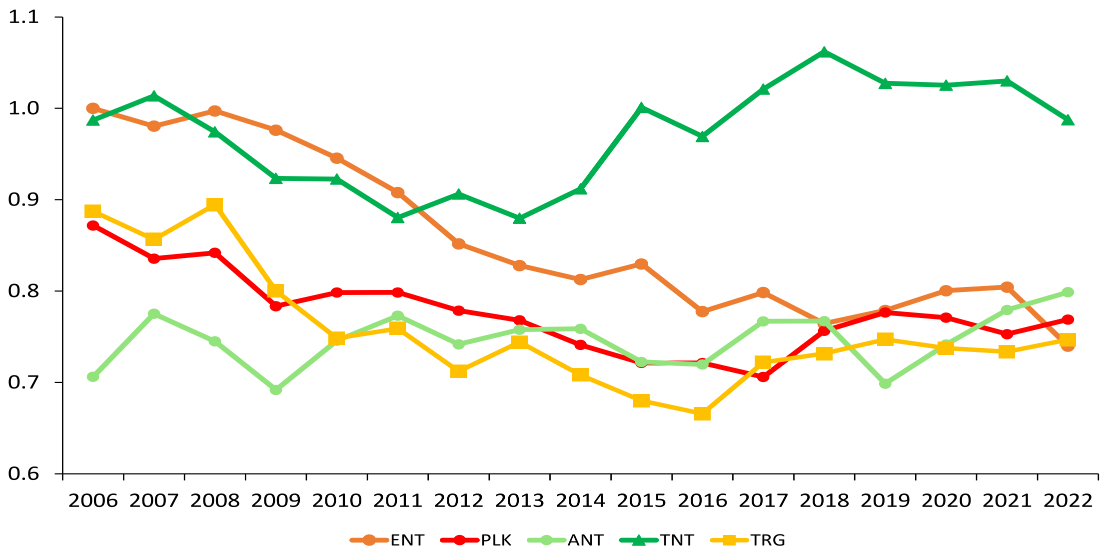
72 For AusNet and TransGrid the productivity changes in 2022 are quite different under TFP versus MTFP measures. This is primarily a methodological issue and specifically the comparisons that are being drawn – the TFP results are a measure of the TNSP's change in productivity from 2021 to 2022. The MTFP results are a measure relative to other TNSPs at a point in time (rather than a TNSP's change relative to itself in a year). Therefore, while both businesses may have had a reduction in TFP in 2022, relative to the other TNSPs in that year, their MTFP has improved.

73 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Annual Benchmarking Report,* 25 October 2023, p. 24; AER analysis.

74 ElectraNet's, *Email to the AER – Response to questions on ElectraNet's 2021–22 EB RIN data*. Received 28 March 2023.

to 2018 when it reported its highest productivity level. The positive trend from 2014 likely reflects efficiencies resulting from the merger of Tasmanian distribution and transmission networks.[75] TasNetworks has remained the most productive TNSP since 2012.

Figure 9 Electricity transmission MTFP indexes by TNSP, 2006–22



Source: Quantonomics.

Table 2 presents the MTFP rankings for individual TNSPs in 2021 and 2022, the change in rankings between 2021 and 2022, and the annual growth in relative productivity (as measured by the logarithmic change in their MTFP productivity scores) between 2021 and 2022.[76] It shows that TasNetworks maintained its first rankings, whilst ElectraNet's ranking fell from second to fifth. AusNet, Powerlink and TransGrid each improved their ranking by one position in 2022.

Table 2 TNSP MTFP scores, rankings and growth rate, 2021 and 2022

	Rank (2022)	Rank (2021)	MTFP Score (2022)	MTFP Score (2021)	Change between 2021 and 2022
TasNetworks	1	1	0.99	1.03	–4.2%
AusNet	2↑	3	0.80	0.78	2.4%
Powerlink	3↑	4	0.77	0.75	2.1%
TransGrid	4↑	5	0.75	0.73	1.8%
ElectraNet	5↓	2	0.74	0.80	–8.4%

Source: Quantonomics

75 TasNetworks was formed on 1 July 2014 from a merger between Aurora and Transend.

76 The rankings in this table are indicative only because, as outlined earlier, there may be other operating environment variables not captured in the MTFP model.

In addition to MTFP, we also present the results of two MPFP measures:

- Capital MPFP, which considers the productivity of the TNSPs' use of overhead lines, underground cables and transformers.
- Opex MPFP, which considers the productivity of the TNSPs' opex.

These partial productivity measures assist in interpreting the MTFP results by examining the contribution of capital assets and opex to overall productivity. They use the same output specification as MTFP but relate the aggregated output to the individual components of capital and opex separately to measure partial factor productivity. However, they do not account for synergies between capital and opex like the MTFP model. As noted in section 1 these partial measures provide a way of gaining insight into the factors driving MTFP trends.

Figure 10 and Figure 11 present capital MPFP and opex MPFP results respectively for all TNSPs over the 2006–22 period.[77] Powerlink achieved positive growth in 2022 in both capital MPFP and opex MPFP (1.2% and 3.8%, respectively). This is consistent with its overall 2.1% growth in MTFP in 2022. TransGrid achieved a mixed outcome in 2022 with positive growth in capital MPFP (1.2%) and a decline in its opex MPFP (–7.9%). Similarly, AusNet achieved a positive growth in capital MPFP (0.9%) and a decline in its opex MPFP over 2022 (–7.1%). Both ElectraNet and TasNetworks had negative growth in capital MPFP (–7.2% and –4.7%, respectively) and opex MPFP (–4.6% and –5.5%, respectively) in 2022, consistent with their overall –8.4% and –4.2% growth in MTFP, respectively.[78]

Figure 10 shows that capital productivity has declined since 2006 for all TNSPs (by between 18.8% to 26.2% in total between 2006 and 2022) except for AusNet where it increased marginally by 3.2% over the 17–year period. For the four TNSPs with declining capital MPFP (TransGrid, ElectraNet, TasNetworks and Powerlink), the average annual rate of decline was significantly lower in the more recent period 2012 to 2022 than in the period from 2006 to 2012.[79]

The declining trend in capital MPFP over the benchmarking period for these TNSPs is due to network capital inputs (length and capacity) growing more than outputs as measured by customers, demand, line length and energy consumption. Although MTFP and MPFP measures do not capture the impact of all material OEFs, this ongoing decline in capital MPFP continues to be a cause for concern.

TasNetworks has remained the highest ranked TNSP in terms of capital MPFP since 2006. We note that TasNetworks operates a relatively lower voltage transmission network compared to other TNSPs. Generally, TNSPs have networks with voltage class at 132kV and above, but the majority of TasNetworks transmission network is of 110kV and 220kV.

Figure 11 shows that in terms of opex MPFP over the 17–year period, AusNet, TasNetworks and TransGrid remained relatively higher performers and Powerlink and ElectraNet relatively

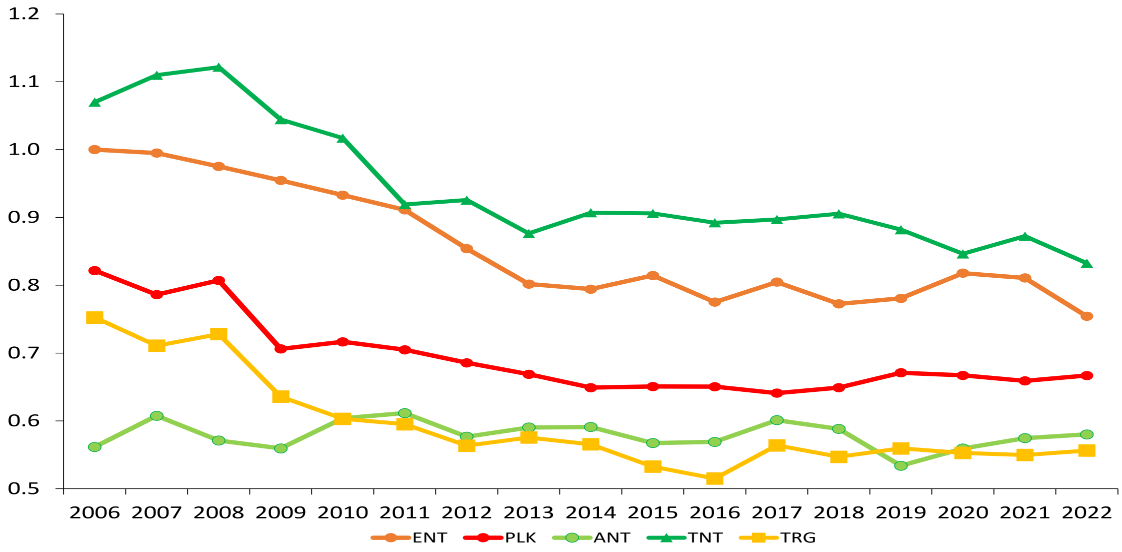
77 ElectraNet in 2006 is set as the base (i.e., index = 1.00).

78 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Annual Benchmarking Report,* 25 October 2023, pages 24-27.

79 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Annual Benchmarking Report,* 25 October 2023, p. 27; AER analysis.

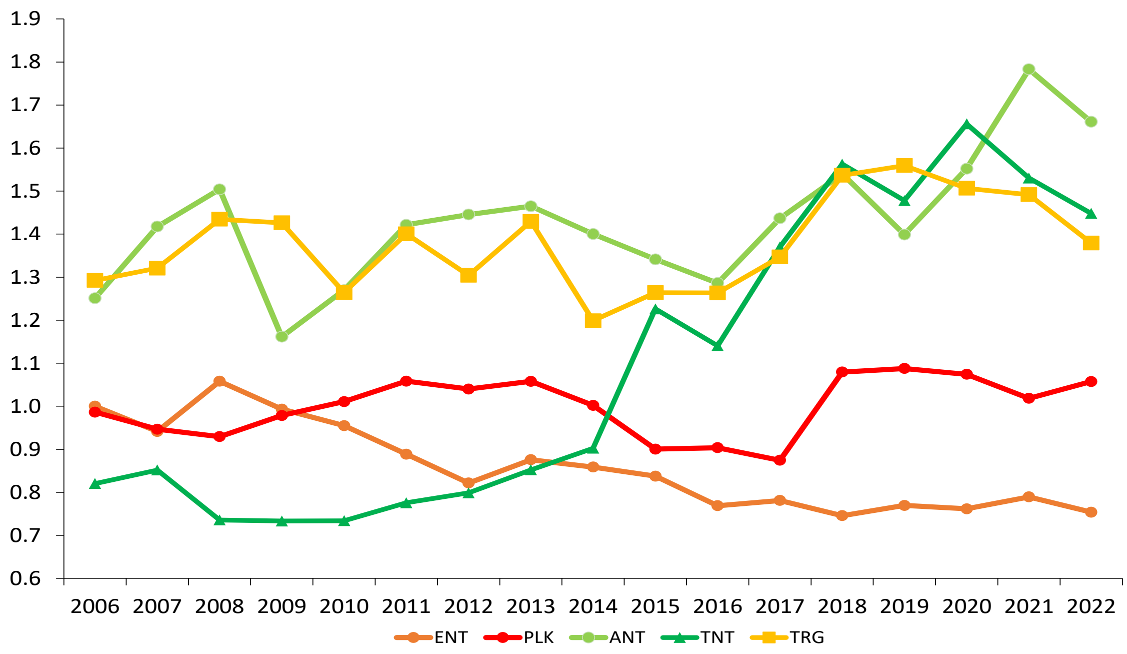
lower performers. Despite recording the lowest opex MPFP at the start of the period, TasNetworks joined the higher performing group in 2015, with opex MPFP in 2022 higher than the 2006 level by 76.6%[80]

Figure 10 Capital MPFP index, 2006–22 ($2022)



Source: Quantonomics

Figure 11 Opex MPFP index, 2006–22 ($2022)



Source: Quantonomics

80 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Annual Benchmarking Report,* 25 October 2023, p. 26; AER analysis. We note that our transmission benchmarking does not account for all possible differences in OEFs.

4.2. Partial performance indicator results of TNSPs

PPIs provide a simple representation of the input costs relative to a particular output. The PPIs used here support the MTFP analysis by providing a general indication of comparative performance in delivering one type of output. However, PPIs do not take into account the interrelationships between outputs. Therefore, PPIs are most useful when used in conjunction with other top-down benchmarking techniques, such as MTFP.

The inputs we use are the TNSPs' total costs, made up of opex and asset costs. Asset cost is measured by the Annual user cost of capital. The Annual user cost of capital equals the return on capital (return on the TNSPs regulatory asset base) less the return of capital (annual regulatory depreciation of the TNSPs regulatory asset base) plus benchmark tax liability, as calculated under the building block model approach.[81] This measure has the advantage of reflecting the total cost of assets for which customers are billed on an annual basis, using the average return on capital over the period. This accounts for variations in the return on capital across TNSPs and over time.

We note that in 2022 there has been a significant reduction in Annual user cost of capital due to the reduction in the 'return of capital' which is a measure of straight-line depreciation adjusted for inflation. Historically the adjustment for 'inflation addition' has been small, resulting in a larger return of capital and Annual user cost of capital. In 2022 with the significant increase in the inflation adjustment this has resulted in a smaller return of capital and Annual user cost of capital. As noted below, this reduction can be observed in the PPIs which include total costs and are therefore impacted by the lower Annual user cost of capital.

The outputs we use are the number of end users, circuit line length, maximum demand served and energy transported (see Appendix B for further details). We examine each of these outputs below.

Total cost per end user

We present total cost per end user in Figure 12.[82] AusNet maintained the lowest total costs per end user in 2022. Conversely, TasNetworks continued to have the highest total costs per end user of all TNSPs, although its total cost per end user has reduced significantly since 2012, and more recently in 2020 and 2022.

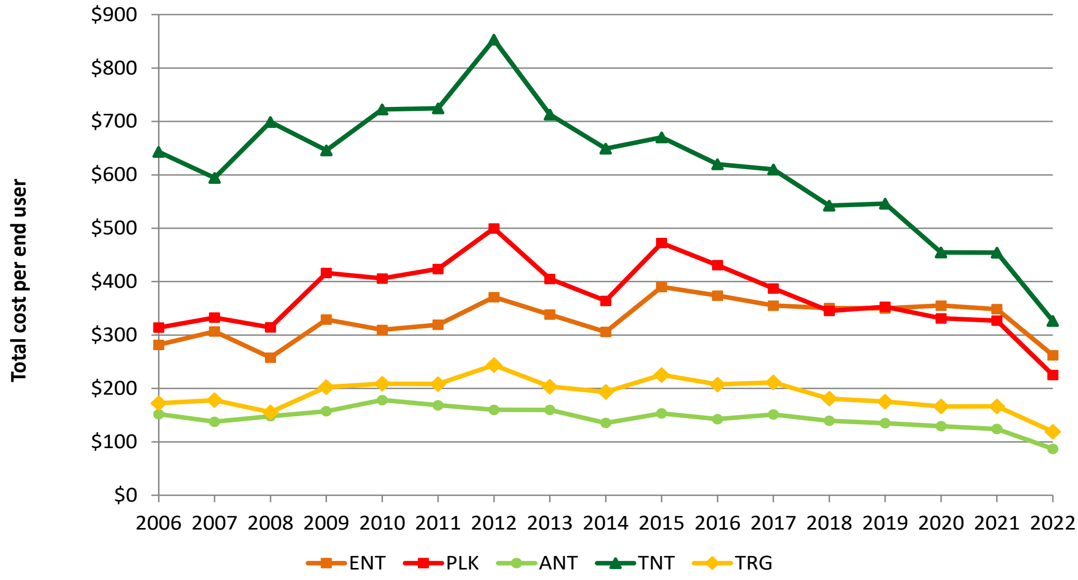
Total costs per end user for all TNSPs are lower in 2022 than they were in 2006, ranging from –6.9% for ElectraNet to –49.3% recorded for TasNetworks. This is influenced by all TNSPs having large declines in total cost per end user in 2022. Powerlink had the largest decrease of 31.1% and ElectraNet recorded the smallest decrease of 24.8%. These large

[81] We have applied to the PPI calculations the same Annual user cost of capital approach we applied to MTFP and MPFP analysis. We updated the calculation of the Annual user cost of capital in 2021 and 2022 to reflect the AER's Rate of Return Instrument 2018. In previous years the Annual user cost of capital calculations broadly reflected the 2013 rate of return guideline. See: https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/rate-of-return-instrument-2018/final-decision.

[82] This, and all PPIs presented below, are in dollar values as at the end of June quarter 2022.

reductions in total cost per end users in 2022 are largely driven by significant reductions in the Annual user cost of capital, which are primarily driven by larger 'returns of capital' as a result of higher 'inflation additions' in the current environment of relatively significant inflation changes. The reason for the reduced Annual user cost of capital in 2022 is set out above.

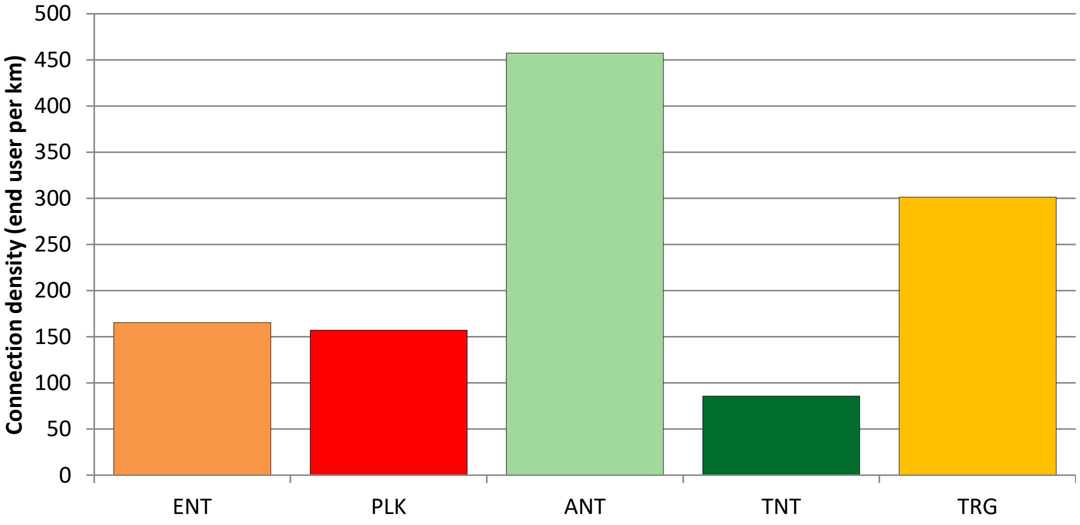
Figure 12 TNSP cost per end user, 2006–22 ($2022)



Source: Economic Benchmarking RINs; AER analysis.

We note the total cost per end user PPI potentially favours TNSPs with denser transmission networks (where density is measured in terms of end users per circuit kilometre). This is because denser transmission networks tend to have more customers per kilometre and hence are required to build and maintain fewer lines per end user connection point. The average connection density of TNSPs over 2018–22 is presented in Figure 13. This shows that AusNet has the highest average connection density, followed by TransGrid, ElectraNet, Powerlink and TasNetworks respectively. This is broadly consistent with the cost per end user rankings in Figure 12.

Figure 13 TNSP connection density (end user per circuit kilometre, 2018–22 average)



Source: Economic Benchmarking RINs; AER analysis.

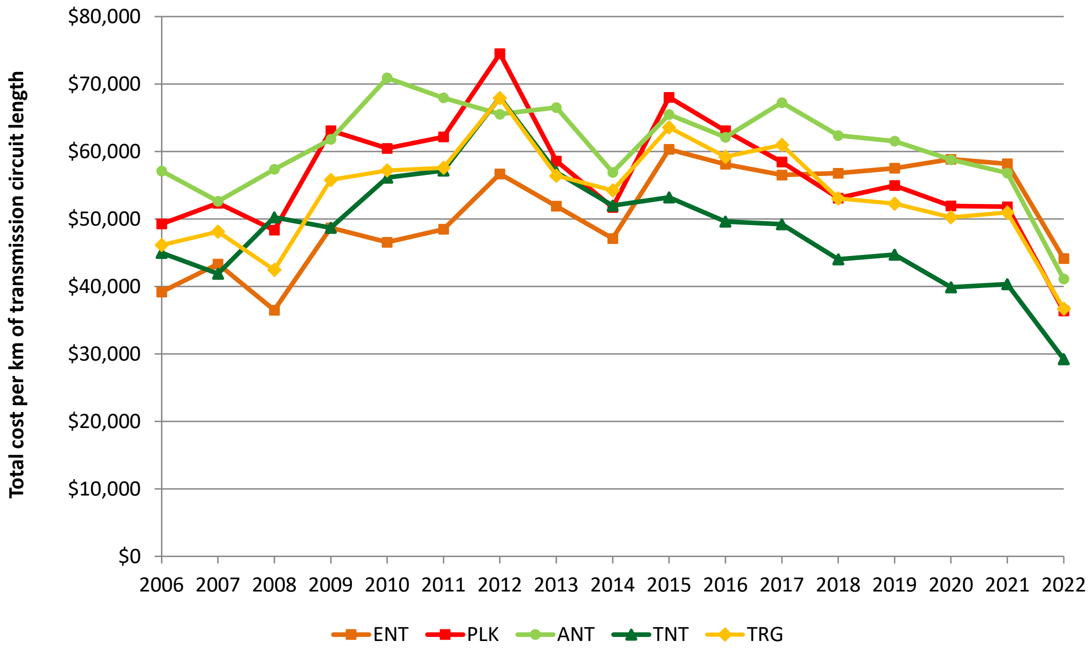
Total cost per kilometre of transmission circuit length

In Figure 14 we can see that TasNetworks has the lowest cost per kilometre of circuit length in 2022, while ElectraNet has the highest cost per kilometre of circuit length (slightly above AusNet).

ElectraNet was the only TNSP to experience growth in total costs per kilometre of transmission circuit length between 2006 and 2022 by 12.7%. This is due to increases in Annual user cost exceeding the growth in transmission circuit length, but is also influenced by ElectraNet's total cost per kilometre of transmission circuit length in 2006 being lower than the other TNSPs. The largest decline in cost per kilometre of circuit length over this period was by TasNetworks (–35.0%), followed by AusNet (–28.0%), Powerlink (–26.2%) and TransGrid (–20.5%). As with the total cost per end user PPI, these results are influenced by the large reductions in total cost in 2022, driven by significant reductions in the Annual user cost of capital in a changing inflation environment.

Since 2014 the difference in the cost per kilometre of transmission circuit length between the highest and lowest ranking TNSPs has widened, largely as a result of a sharp decline in costs by TasNetworks. For the other TNSPs, there was a step up in 2015 followed by a steady decline, such that in 2022 each TNSP's total cost per kilometre of transmission circuit length is at or below its 2014 level. In 2022, the difference between ElectraNet (highest cost) and TasNetworks (lowest cost) was $14 913 ($2022) whereas in 2014 the difference between AusNet (highest cost) and ElectraNet (lowest cost) was $9 794 ($2022). While ElectraNet reported no changes in circuit length from 2014 to 2021, it had the largest reported increase in total asset cost out of all the networks by 24.7% over this period.

Figure 14 TNSP total cost per kilometre of transmission circuit length ($2022), 2006–22



Source: Economic Benchmarking RINs; AER analysis.

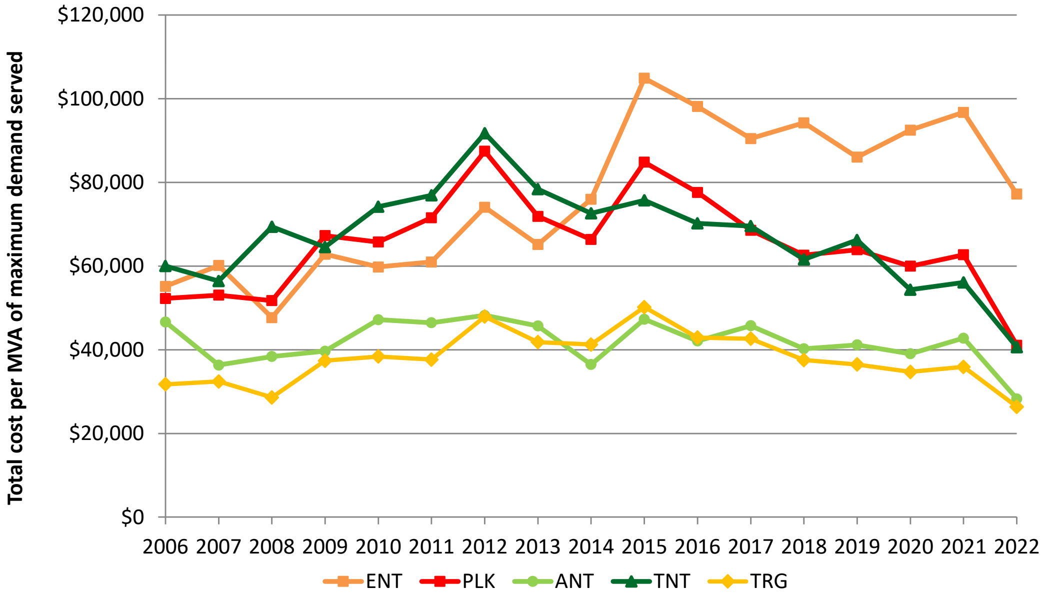
Total cost per Mega Volt Amp (MVA) of non-coincident maximum demand

Figure 15 shows TNSPs total costs per MVA of non-coincident maximum demand. All TNSPs reported reductions in total costs per MVA in 2022 from 2021 levels, ranging from a decline of 20.2% to 34.5% reported for ElectraNet and Powerlink respectively. As with the PPIs reported above, these results are influenced by the large reductions in total cost in 2022, which are largely driven by significant reductions in the Annual user cost of capital in a changing inflation environment.

ElectraNet reported the highest cost per MVA of maximum demand in 2022. This follows large growth between 2013 and 2015 because of a substantial drop in maximum demand without an offsetting decrease in its total costs. ElectraNet's costs per MVA of maximum demand decreased in 2022 by 20.2% (from $96 770/MVA ($2022) in 2021 to $77 210/MVA ($2022) in 2022). Its costs per MVA in 2022 are more than two and a half times greater than the two best performing networks, TransGrid ($26 376/MVA, ($2022)) and AusNet ($28 265/MVA, ($2022)).

Since 2006 four TNSPs have reported declines in total costs per MVA of maximum demand (AusNet, Powerlink, TasNetworks and TransGrid), ranging from a decline of 16.9% and 39.4% reported for TransGrid and AusNet respectively. ElectraNet's total costs per MVA of maximum demand increased by 40.0% between 2006 and 2022, largely due to the surge between 2013 and 2015.

Figure 15 TNSP total cost per MVA of maximum demand served ($2022), 2006–22



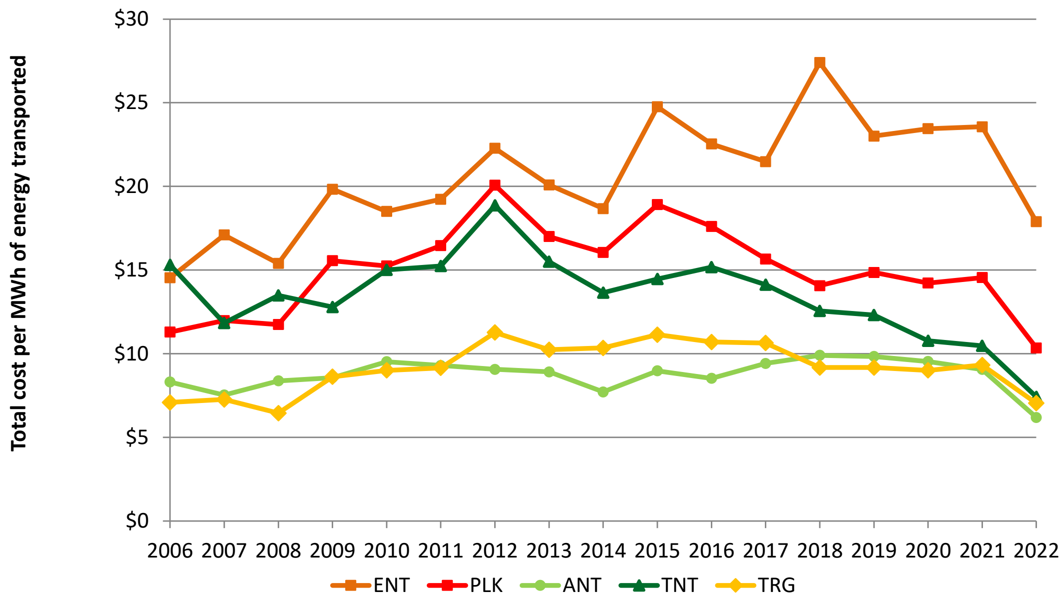
Source: Economic Benchmarking RINs; AER analysis.

Total cost per MWh of energy transported

As can be seen in Figure 16, ElectraNet recorded the highest cost per MWh of energy transported in 2022 at $17.89/MWh. ElectraNet's costs were over two and a half times greater than the two best performing networks TransGrid ($7.04/MWh, ($2022)) and AusNet ($6.18/MWh, ($2022)). As with the PPIs reported above, these results are influenced by the large reductions in total cost in 2022, which are largely driven by significant reductions in the Annual user cost of capital in a changing inflation environment.

Costs per MWh of energy transported have fallen over the 2006–22 period for most TNSPs, except for ElectraNet. ElectraNet's costs per MWh of energy transported have risen by 23.1% over the 2006–22 period. TransGrid reported a modest decline of 0.7% over the same period. Powerlink, AusNet and TasNetworks' costs have decreased by 8.4%, 25.6% and 51.5% respectively, despite following a similar upward trend to ElectraNet between the years 2006 to 2012. ElectraNet's increase in costs per MWh has resulted in an increase in the gap between TNSPs since around 2014 and 2015.

Figure 16 TNSP total cost per MWh of energy transported ($2022), 2006–22



Source: Economic Benchmarking RINs, AER analysis.

4.3. Explaining differences between the MTFP and PPI results

In previous Annual Benchmarking Reports for transmission, we received feedback that the differences in the MTFP and PPI benchmarking results do not make sense. For example, AusNet noted that in three out of the four PPIs, it had either the lowest or second-lowest costs, but this is in contrast to the MTFP results, where at the time it ranked fourth.[83] While AusNet's MTFP performance improved in 2022 and it ranked second, we consider it is useful to provide a conceptual explanation of these differences.

We note that we use the top-down economic benchmarking for different purposes from the PPI analysis. The MTFP / MPFP benchmarking approach examines the efficiency in the use of inputs to produce total outputs where the TNSPs are multiple-input users and multiple-output producers. In contrast, the PPI analysis considers the efficiency in terms of the input costs (i.e. total cost, opex and capital cost) relative to a particular output delivered. We have used MTFP analysis as our primary tool to examine the overall efficiency and productivity of TNSPs while using the MPFP and PPI analysis as supporting tools to reveal potential sources of inefficiencies in some aspects.

The MPFP and PPI analysis are partial as they examine a single input or output in isolation rather than a combination of inputs or outputs. Depending on the output considered, PPIs may favour TNSPs with certain network characteristics and thus need to be normalised for density factors. We have found that PPIs measured in terms of circuit length tend to favour TNSPs with lower customer / connection density and PPIs measured on end user (or

83 AusNet, *Submission to the AER's 2021 draft Annual Benchmarking Report*, 20 October 2020, pp. 1–2.

maximum demand, energy transported) tend to favour TNSPs with higher end user / demand / energy densities.

In terms of measurement, they differ in the following aspects:

- Using MTFP / MPFP, five outputs are measured and aggregated by output weighting based on cost share. As MTFP / MPFP measures a weighted average output quantity, it accounts for the combination of the five outputs rather than a single output at a time as under the PPIs. Under the PPIs, the per-unit cost is only measured in terms of one output. While AusNet is measured as having relatively low cost in terms of end user, maximum demand and energy transported PPI, it is found to incur the highest cost in terms of circuit length. When considering all the outputs together in delivering transmission services using all inputs, AusNet's relative position changes depending on the weighting allocated to circuit length relative to other outputs. Under the corrected output weights, as updated in the 2020 Annual Benchmarking Report, the weight applied to circuit length is 52.8% of gross revenue. Ausnet considers this weight is too high and that it has an outsized impact on the results.[84] This issue of output weights will be subject to an independent review as outlined in section 1.2, and their estimation will be updated on a periodical basis.
- Under the MTFP / MPFP analysis four inputs (i.e., opex, overhead lines, underground cables, transformers) are measured in terms of physical quantity. In contrast, the PPI analysis considers input costs (instead of quantities) and measures the opex and Annual user cost of capital in real dollar value. The cost measure differs from the input quantity measure, particularly in relation to capital.[85] As the Annual user cost of capital equals the return on capital less the return on capital (depreciation) plus benchmarking tax liability, for TNSPs with the same physical quantity of capital inputs in place, their Annual user cost of capital can differ substantially due to differences in asset valuation and prices actually paid, investment cycles and asset lives.

For the above reasons, we do not expect the MTFP / MPFP and PPI analyses to present the same or similar results. The use of the PPI analysis is to provide further insights into the efficiency performance of TNSPs.

We also note that our Annual Benchmarking Reports present cost-based PPI analysis rather than RAB-based PPI analysis. As with the Annual user cost of capital measure, RAB values can differ substantially across TNSPs due to differences in asset valuation and prices, as well as asset age and lives.

84 Using the output quantity index from the MTFP analysis, AusNet's total cost per unit of total output is below the average for the other four TNSPs.

85 We consider that opex input prices and opportunity costs of capital can be expected to be similar between TNSPs.

Shortened forms

Shortened form	Description
AEMC	Australian Energy Market Commission
AER	Australian Energy Regulator
ANT	AusNet Services (transmission)
Capex	Capital expenditure
ENT	ElectraNet
MW	Megawatt
MVA	Mega Volt Amp
NEL	National Electricity Law
NEM	National Electricity Market
NER	National Electricity Rules
Opex	Operating expenditure
PLK	Powerlink
RAB	Regulatory asset base
RIN	Regulatory Information Notice
STPIS	Service target performance incentive scheme
TNSP	Transmission network service provider
TNT	TasNetworks (Transmission)
TRG	TransGrid

Glossary

Term	Description
Efficiency	A TNSPs benchmarking results relative to other TNSPs reflect that network's relative efficiency, specifically their cost efficiency. TNSPs are cost efficient when they produce services at least possible cost given their operating environments and prevailing input prices.
Inputs	Inputs are the resources TNSPs use to provide services.
MPFP	Multilateral partial factor productivity is a PIN technique that measures the relationship between total output and one input. It allows both partial productivity levels and growth rates to be compared between entities (networks) and over time.
MTFP	Multilateral total factor productivity is a PIN technique that measures the relationship between total output and total input. It allows both total productivity levels and growth rates to be compared between entities (networks) and over time. These results are used in this report to measure and compare changes in 'relative productivity' over time.
Prescribed transmission services	Prescribed transmission services are the services that are shared across the users of transmission networks. These capture the services that TNSPs must provide under legislation.
OEFs	Operating environment factors are factors beyond a TNSPs control that can affect its costs and benchmarking performance.
Opex	Operation and maintenance expenditure
Outputs	Outputs are quantitative or qualitative measures that represent the services TNSPs provide.
PIN	Productivity index number techniques determine the relationship between inputs and outputs using a mathematical index.
PPI	Partial performance indicator are simple techniques that measure the relationship between one input and one output.
RMD	Ratcheted maximum demand is the highest value of maximum demand for each TNSP, observed in the time period up to the year in question. It recognises capacity that has been used to satisfy demand and gives the TNSP credit for this capacity in subsequent years, even though annual maximum demand may be lower in subsequent years.
TFP	Total factor productivity is a PIN technique that measures the relationship between total output and total input over time. It allows total productivity changes of a single entity (e.g. transmission industry or TNSP) to be compared over time ..
VCR	Value of Customer Reliability. VCR represents a customer's willingness to pay for the reliable supply of electricity.

A. References and further reading

This benchmarking report is informed by several sources. This includes ACCC / AER research and expert advice provided by Quantonomics, and previously by Economic Insights as set out below.

Quantonomics publications

The following publication explains in detail how Quantonomics developed and applied the economic benchmarking techniques we used:

- Quantonomics Report – *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Benchmarking Report*, October 2023.
- Quantonomics Report – *Economic Benchmarking Results for the Australian Energy Regulator's 2022 TNSP Benchmarking Report*, November 2022. (here)

Economic Insights publications

The following publications explain in detail how Economic Insights, our previous consultant, developed and applied the economic benchmarking techniques we used:

- Economic Insights *Report – Economic Benchmarking Results for the Australian Energy* Regulator's *2021 TNSP Benchmarking Report*, November 2021 (link)
- Economic Insights *Report – Economic Benchmarking Results for the Australian Energy Regulator's 2020 TNSP Benchmarking Report*, 15 October 2020 (link)
- Economic Insights, AER Memo Revised 2019 TNSP EB Results, 24 August 2020
- Economic Insights *Report – Economic Benchmarking Results for the Australian Energy Regulator's 2019 TNSP Benchmarking Report*, September 2019 (link)
- Economic Insights *Report – Economic Benchmarking Results for the Australian Energy Regulator's 2018 TNSP Benchmarking Report*, November 2018 (link)
- Economic Insights *Report – Economic Benchmarking Results for the Australian Energy Regulator's 2017 TNSP* Benchmarking *Report*, November 2017 (link)
- Economic Insights, *Memorandum – TNSP MTFP Results*, November 2016 (link).
- Economic Insights*, Memorandum – TNSP MTFP Results*, 13 November 2015 (link).
- Economic Insights, *Economic Benchmarking Assessment of Operating Expenditure for NSW and Tasmanian Electricity TNSPs*, 10 November 2014 (link).
- Economic Insights, *AER Response to HoustonKemp for TransGrid determination*, 4 March 2015 (link)
- Economic Insights, Economic *Benchmarking of Electricity Network Service Providers*, 25 June 2013 (link).

AER 2017 TNSP Benchmarking Review

All documents related to the AER's 2017 TNSP Benchmarking Review can be found on line here.

ACCC/AER publications

These publications provide a comprehensive overview of the benchmarking approaches used by overseas regulators:

- ACCC / AER, *Benchmarking Opex and Capex in Energy Networks – Working Paper no. 6*, May 2012 (link).
- ACCC / AER, *Regulatory* Practices *in Other Countries – Benchmarking opex and capex in energy networks*, May 2012 (link).
- WIK Consult, Cost Benchmarking in Energy Regulation in European Countries, 14 December 2011 (link).

AER transmission determinations

The AER uses economic benchmarking to inform its regulatory determination decisions. A full list of these decisions to date can be found on the AER's website here.

B. Benchmarking models and data

This appendix contains further information on our economic benchmarking models, and the output and input data used in the benchmarking techniques.

B.1 Benchmarking techniques

This report presents results from two types of 'top-down' benchmarking techniques:

- Productivity index numbers (PIN). These techniques use a mathematical index to measure the relationship between outputs relative to inputs:
  - TFP relates total inputs to total outputs and provides a measure of overall productivity growth for a single entity (a network or the whole industry). It allows total productivity growth rates to be compared for different periods of time for the one entity using time series data. It also allows total factor productivity growth rates to be compared across networks but does not allow productivity levels to be compared across networks. It can be used to decompose productivity change into its constituent input and output parts.
  - MTFP relates total inputs to total outputs and provides a measure of overall network efficiency relative to other networks. It thus allows total productivity levels to be compared between networks and over time when it is applied to combined time-series and cross-section (or 'panel') data.
  - MPFP is a partial efficiency measure which uses the same output specification as MTFP but separately examines the productivity of opex and capital against total output. It allows partial productivity levels to be compared between networks.
- Partial Performance Indicators (PPIs). These techniques, also partial efficiency measures, relate one input to one output (contrasting with the above techniques that relate one or all inputs to total outputs). PPIs measure the average amount of an input (such as total cost) used to produce one unit of a given output (such as total end users, megawatts of maximum electricity demand or kilometres of circuit line length).

B.2 Benchmarking data

The inputs and outputs used in the benchmarking techniques for this report are described below. The inputs represent the resources (such as capital and labour) a TNSP uses to provide electricity transmission services. The outputs represent the electricity services delivered (such as the line length and how much electricity they transport).

Data for each of these input and output categories are provided each year by the TNSPs in response to EB RINs. The EB RINs require all TNSPs to provide a consistent set of data which is verified by the TNSPs chief executive officer and independently audited. We separately test and validate the data. The complete data sets for all inputs and outputs from

2006 to 2022, along with the Basis of Preparation provided by each TNSP, are published on our website.[86]

An overview of the inputs and outputs are in box 1 below.

Box 1: Categories of inputs and outputs used in TNSP benchmarking

Outputs

Outputs are measures that represent the services the TNSPs provide. The outputs we use to measure service provision are:

- Energy throughput (GWh)
- Ratcheted maximum demand (RMD)
- Circuit length (Circuit kms)
- End–user numbers (End User nos)
- (minus) Energy not supplied (ENS) (weight based on AER's 2022 estimates of the value of customer reliability (VCR) capped at a maximum absolute value of 2.5% of total revenue).

Inputs

TNSPs use a mix of physical assets and operational spending to deliver services.

- Capital stock (assets) include:
  - Overhead lines (quantity proxied by overhead MVAkms) (O/H lines)
  - Underground cables (quantity proxied by underground MVAkms) (U/G cables)
  - Transformers and other capital (quantity proxied by transformer MVA) (Trfs)
- Operating expenditure (expenditure TNSPs spend to operate and maintain their assets) (opex).

B.2.1 Outputs

Outputs are measures that represent the services the TNSPs provide. TNSPs exist to provide customers with access to a safe and reliable supply of electricity. We explain the outputs we use in more detail in this section.

Circuit length

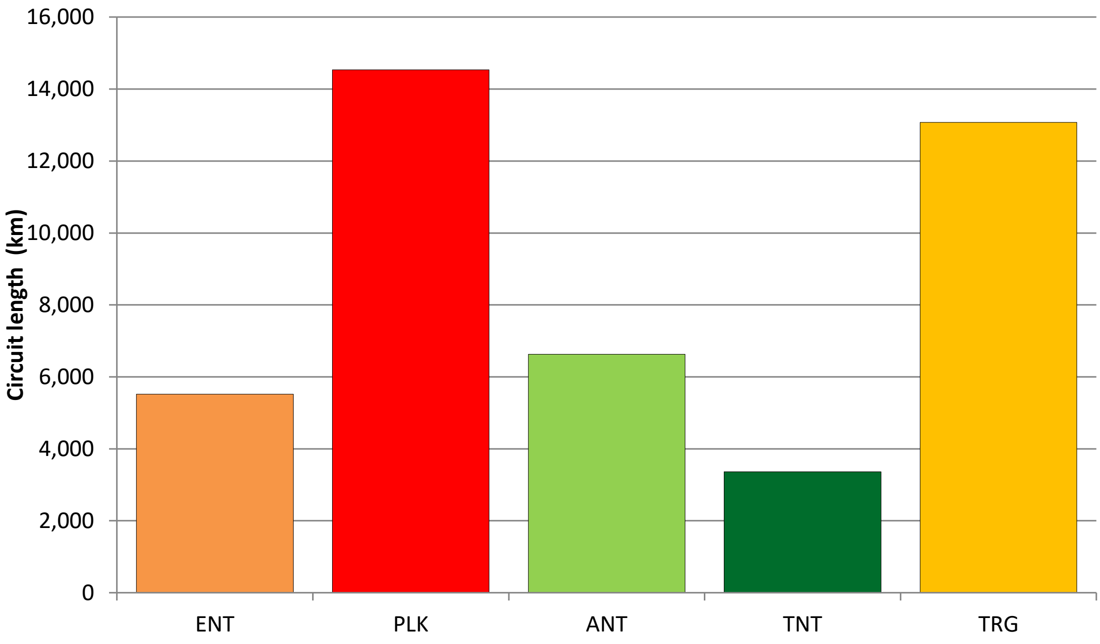
Circuit length reflects the distances over which TNSPs deliver electricity to downstream users from generators, which are typically over thousands of kilometres. We measure line length in terms of circuit line length. This is the length in kilometres of lines, measured as the length of each circuit span between poles and / or towers and underground. This represents the distance over which transmission networks are required to transport electricity.

We use circuit length because, in addition to measuring network size, it also approximates the line length dimension of system capacity. System capacity represents the amount of

[86] This dataset is available at www.aer.gov.au/networks-pipelines/performance-reporting.

network a TNSP must install and maintain to supply DNSPs, which in turn supply consumers with the quantity of electricity demanded at the places where they are located. Figure B.1 shows each TNSP's circuit length in 2022.

Figure B.1 Circuit length by TNSP in 2022 (kilometre)

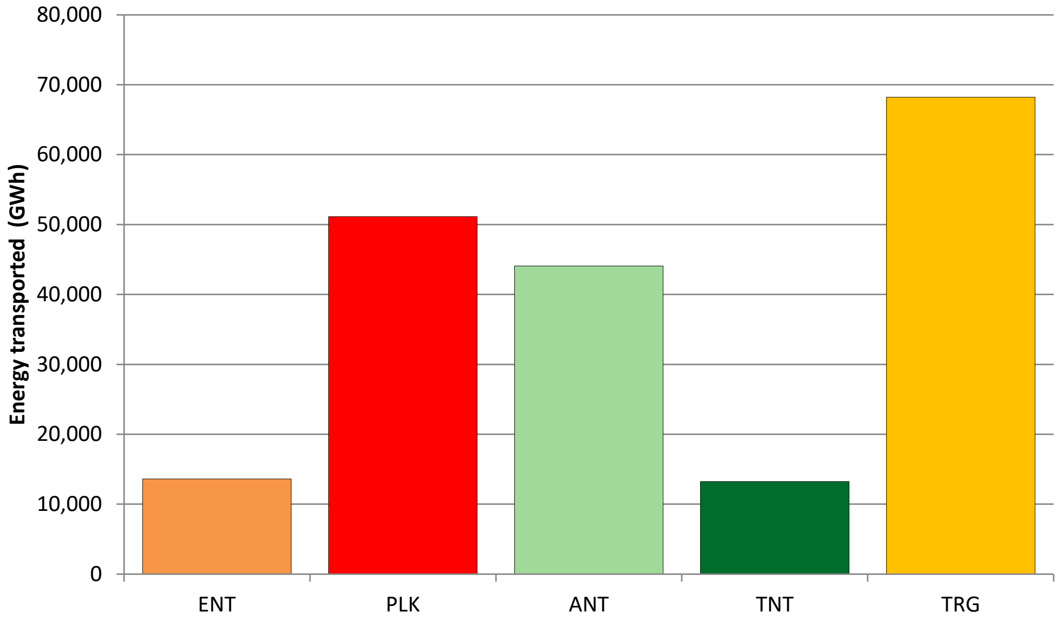


Source: Economic Benchmarking RINs.

Energy transported

Energy transported is the total volume of electricity throughput that is transported over time through the transmission network, measured in gigawatt hours (GWh). We use it because energy throughput is the TNSP service directly consumed by end–customers. Therefore, it reflects a key service provided to customers. However, if there is sufficient capacity to meet current energy throughput levels, changes in throughput are unlikely to have a significant impact on a TNSP's costs. Figure B.2 shows each TNSP's energy transported in 2022.

Figure B.2 Energy transported by TNSP in 2022 (GWh)



Source: Economic Benchmarking RINs

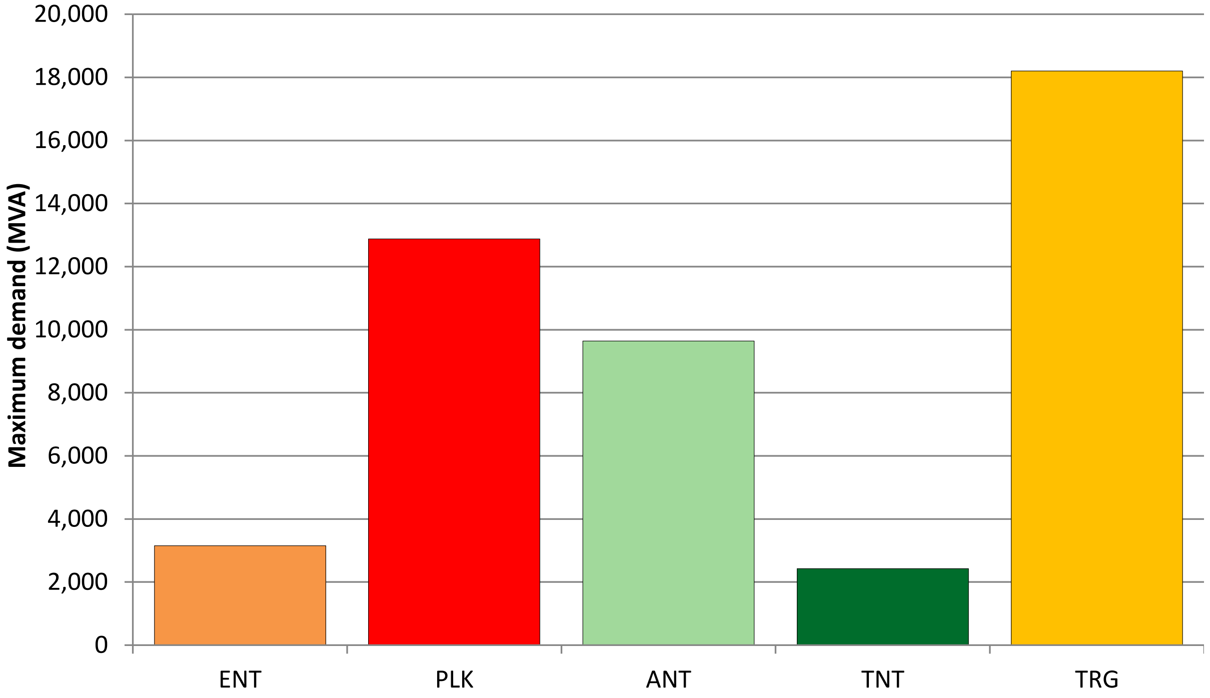
Maximum demand

TNSPs are required to meet and manage the demand of their customers. This means they must build and operate their networks with sufficient capacity to meet the expected peak demand for electricity. Maximum demand is a measure of the overall peak in demand experienced by the network. The maximum demand measure we use is non-coincident summated raw system annual maximum demand, at the transmission connection point.

The economic benchmarking techniques use 'ratcheted' maximum demand as an output rather than observed maximum demand. Ratcheted maximum demand is the highest value of peak demand observed in the benchmarking period up to the year in question for each TNSP.[87] It recognises capacity that has been used to satisfy demand and gives the TNSP credit for this capacity in subsequent years, even though annual maximum demand may be lower in subsequent years. Figure B.3 shows each TNSP's maximum demand in 2022.

87 For example, in 2022 ElectraNet's maximum demand was 3,355 MVA, while its ratcheted maximum demand occurred in 2013 and was 4,403 MVA.

Figure B.3 Maximum demand in 2022 (MVA)



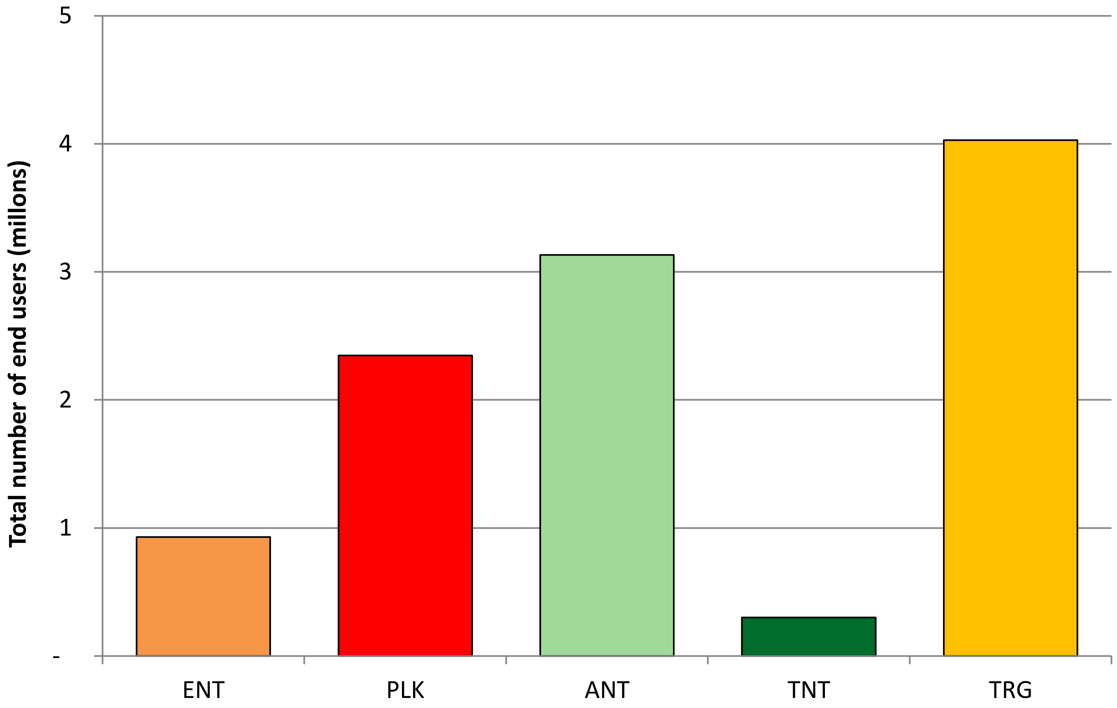
Source: Economic Benchmarking RINs.

End user numbers

The end user number output measures the number of customers for which TNSPs are required to provide a service. This is used to represent the size and complexity of the transmission network. Specifically, the greater the number of end users, the more complex the task facing the TNSP and the larger the market the TNSP serves. More complex networks will typically be more asset-intensive. Figure B.4 presents the number of end users serviced by each of the TNSPs in 2022.

As expected, the size of the network aligns with the population in each state. NSW is the largest network, with TransGrid providing services for 4.0 million end users in NSW, followed by Victoria, with AusNet servicing over 3.1 million end users. Tasmania has the smallest network, with TasNetworks servicing around 301,064 end users in 2022.

Figure B.4 End user numbers for 2022 (millions)



Source: Economic Benchmarking RINs.

Total outputs

Table B.1 presents the average network outputs over the most recent five-year period from 2018 to 2022 for TNSPs, with the exception of reliability.

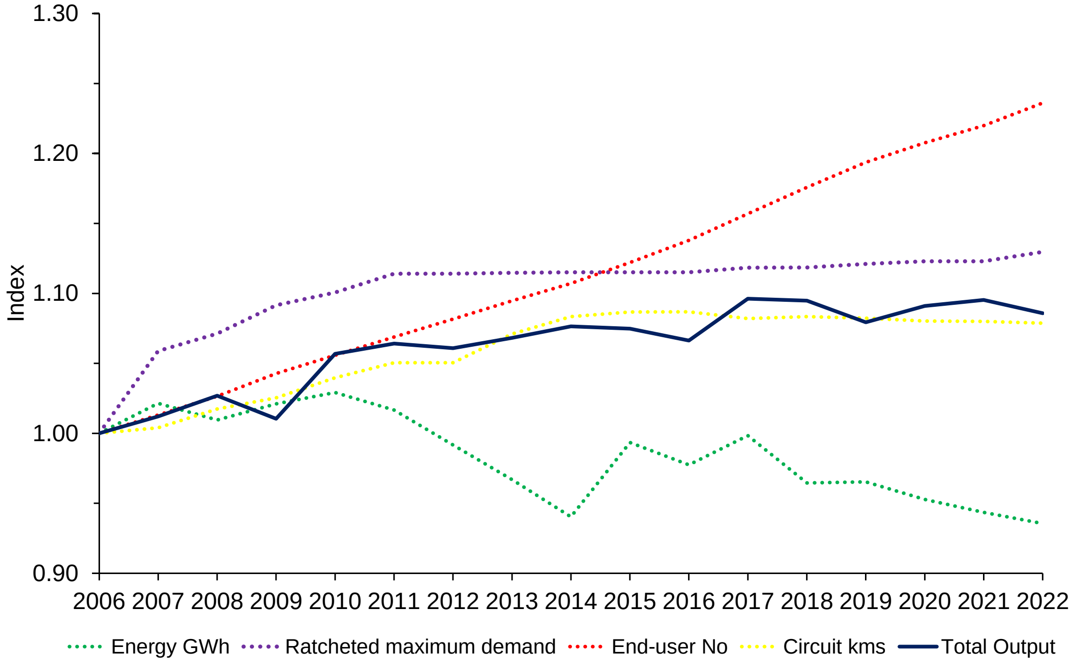
Table B.1 TNSP outputs 2018–2022 average

	Circuit line length (kilometre)	Energy transported (GWh)	Maximum demand (MVA)	Number of end users
ElectraNet	5,518	13,265	3,399	912,954
Powerlink	14,530	52,921	12,458	2,284,787
AusNet	6,669	42,212	9,780	3,050,095
TasNetworks	3,430	12,776	2,444	294,210
TransGrid	13,062	72,500	18,560	3,937,424

Source: Economic Benchmarking RINs.

Figure B.5 presents indexes of the key industry outputs over the 2006–22 period (with the exception of reliability) along with the total output index.

Figure B.5 Components of total output 2006–22



Source: Quantonomics

B.2.2 Inputs

The inputs used in this report are assets and opex. TNSPs use a mix of assets and opex to deliver services. Electricity assets can provide useful service over several decades. However, benchmarking studies typically focus on a shorter period of time.

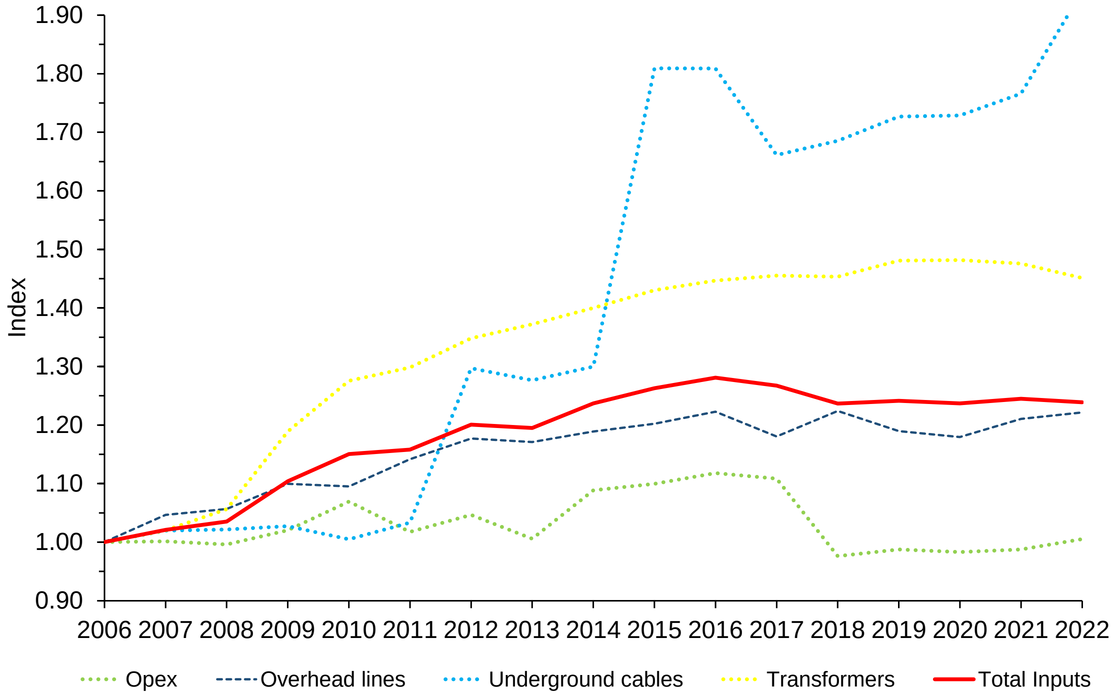
The two inputs we use in our TFP and MTFP techniques are:

- Operating expenditure (opex). This is the expenditure TNSPs spend on operating and maintaining their assets. We use the observed opex spent on prescribed transmission services. Nominal opex is deflated by an index of labour and other relevant prices to obtain a measure of the quantity of opex inputs.
- Capital stock (assets). TNSPs use physical assets to provide services and invest in them to replace, upgrade or expand their networks. We split capital into overhead lines, underground cables and transformers.
  - For our TFP and MTFP analysis we use physical measures of capital inputs. Using physical values for capital inputs has the advantage of best reflecting the physical depreciation profile of TNSP assets.[88]
  - For the PPIs we use the real value of the regulatory asset base as the proxy for assets to derive the real annual cost of using those assets.

[88] Economic Insights, *Memorandum – TNSP MTFP Results*, 31 July 2014, p. 5.

Figure B.6 presents the change in industry input over the 2006–22 period.

Figure B.6 Factors contributing to total inputs, 2006–22



Source: Quantonomics

Table B.2 presents measures of the cost of network inputs relevant to opex and assets for all TNSPs. We have presented the average annual network costs over the most recent five years in this table to moderate the effect of any one-off fluctuations in cost.

Table B.2 Average annual costs for network inputs for 2018–22 ($'000, 2022)

	Opex	Capex	RAB	Depreciation
ElectraNet	105,549	169,319	2,614,922	131,817
Powerlink	218,389	161,189	7,043,526	321,543
AusNet	88,659	176,943	3,313,196	193,099
TasNetworks	32,583	55,235	1,511,866	66,238
TransGrid	178,576	300,570	6,846,291	298,834

Source: Economic Benchmarking RINs.

C. Anomalous TFP results

C.1 Background and drivers of the issue

In the context of considering the TFP results in 2022, particularly for each TNSP as set out in section 3.2, and the contributions of each input and output to the change, we identified some results that were anomalous and did not reflect the expected direction of the impact / change. Most starkly, for example, we noted a situation where there was an increase in the opex input that resulted in a positive contribution to the TFP change when a negative contribution would be expected. This occurred for TasNetworks and ElectraNet. Similarly, we found instances where there was an increase in the transformer input and this also resulted in a positive or zero contribution to the TFP change when a negative change would be expected. This example occurred for TasNetworks.

While we did not detect a large number of anomalous results in the 2022, and we have not detected these previously, we further investigated to understand the reasons for them and how widespread they were. This is supported by further discussion in Appendix D of Quantonomics' 2023 benchmarking report.[89] The time series TFP results are currently determined using a multilateral Tornqvist index. This index computes output / input quantity changes, and therefore TFP changes, between two observations via an indirect comparison of those two observations with the sample average observation. The weight used to weigh the quantity change of an output / input (from the sample average), is the output / input cost share based on the average of the observation in comparison and the sample average observation. As a result, the weights vary between the two observations in comparison (as the observation-specific cost share is not fixed). This means that under the multilateral Tornqvist index the TFP change (and any contributions) are affected by both the output / input quantity changes and weight changes.

We have used the multilateral Tornqvist index for time series analysis since the 2020 Annual Benchmarking Report.[90] We had previously adopted a different time series index, the traditional time series indexes. We started to use the multilateral Tornqvist index in order to more accurately capture the impact of large percentage changes that were continuing to occur in the reliability output. We considered that this would assist to address drifting issues[91] and produce more accurate TFP results. This reflected the advice of our benchmarking consultant at the time, Economic Insights. As a result, we decided to apply this index to both the time series and panel data to determine transmission industry and TNSP productivity changes. This is noted in section 1.3 as one of the changes we adopted to address previous concerns over volatility in the reliability output.

89 Quantonomics, *Economic Benchmarking Results for the Australian Energy Regulator's 2023 TNSP Annual Benchmarking Report,* 25 October 2023, pages 67-70.

90 AER, *2020 Annual Benchmarking Report – Electricity transmission network service providers*, November 2020, p. 7.

91 'Drifting' refers large changes in outputs / inputs, and particularly reliability, leading to systematic deviations from the expected trend.

In considering possible reasons for the anomalous results, it is useful to understand the weight changes under the multilateral Tornqvist index. In general, the weights for outputs are relatively constant for the same network service provider over time. For example, the non-reliability output weights (derived from the Leontief Function) are fixed. Further, the reweighted output weighting incorporating the impact of reliability outputs is relatively constant. However, the weights for the inputs (opex and capital) are not constant over time.

Inflation changes impact the relative opex and capital input weights as the capital input weights are based on the Annual user cost of capital which is affected by inflation, WACC and other parameters. In particular, the Annual user cost of capital equals the return *on* capital less the return *of* capital plus the benchmark tax liability. The return *of* capital reflects straight-line depreciation net of an 'inflation addition'. The current relatively significant inflation rises (3.0 to 3.6% in 2022 as compared to 0.7% to 0.9% in 2021) mean a larger return *of* capital and therefore a lower Annual user cost of capital for each capital input in 2022. This in turn means that when considering the opex input, it has a relatively larger share compared to the capital inputs. (The impact of inflation on the Annual user cost of capital can be seen most starkly in the PPI total cost metrics for 2022, as reported in section 4.2, where total cost reflects the Annual user cost of capital of capital plus opex).

We consider a key driver of the anomalous results is that the input weights applied to the two consecutive years in comparison (i.e. 2021 and 2022) are not the same[92] and are impacted by the changing inflation environment, particularly given the large rise in inflation in 2022. These inflation changes have led to more significant changes in the opex to capital input shares than in previous years when we have used the multilateral Tornqvist index.

We have tested this by undertaking sensitivity analysis using an alternative indexing approach for time series analysis. Specifically, the traditional Tornqvist index. Under this method, the two observations in comparison – the two consecutive years for a TNSP or the industry – are directly compared to each other. The input weights applied to the consecutive years in comparison are the relevant cost shares averaged across the comparison years and thus the same between the two years in comparison. The contribution of an individual input to the TFP change, being positive or negative, will solely depend on the directional change in the input quantity. This sensitivity analysis allows us to examine how sensitive the measured output / input contribution is to the indexing method used, particularly in the presence of large inflation changes in 2022. The results of this sensitivity analysis at both the industry and TNSP level are set out in section C.2.

C.2 Transmission industry index sensitivity analysis

In Tables C.1 to C.6 we have set out the TFP results for the industry and each TNSP in 2022, including individual output and input contributions, under the multilateral Tornqvist index, as reported in section 3.2, and under the traditional Tornqvist index. What can be seen is that in those circumstances where anomalous results were identified (e.g. for TasNetworks

[92] And do not just depend on the cost shares for any two observations being compared but also partly on the sample average cost shares.

and ElectraNet), using the traditional Tornqvist index results in a change in the sign of the contribution reported for the relevant input.

For example, in Table C.2 it can be seen that for TasNetworks the positive contribution the increase in the opex input was making to the TFP change under the multilateral Tornqvist index becomes a negative contribution under the traditional Tornqvist index. This is as would be expected. Similarly, for the transformers input, under the multilateral Tornqvist index an increase in transformers was reported as having a small positive contribution on the TFP change. Under the traditional Tornqvist index this becomes a small negative contribution, again as would be expected. Both of these examples are shaded grey in Table C.2. Similarly, in Table C.3 the example for ElectraNet in relation to the opex input is also shaded in grey, where again under the traditional Tornqvist index the contribution from an increased input is as expected (negative).

In examining this issue, our consultant Quantonomics noted that when using the multilateral Tornqvist index, the anomalous result for TasNetworks in terms of its opex input (increased input being reported as making a positive contribution to TFP change) is due to:

- A large increase to the opex input weight (from 24.5% to 33.9%) due to the reduction in the capital input weight (reduced Annual user cost of capital).
- The difference between the quantity of the opex input in 2022 and its average for the entire benchmarking period being negative.

This illustrates that beyond the change in input weights, there are also possibly other interactions with the input changes that are leading to anomalous results in some cases.

In Table C.1 to Table C.6 the anomalous results are shaded grey. It can be seen that these are not widespread in 2022. Our broader testing suggests they are similarly infrequent in other years across the benchmarking times series (2006–22).

We consider that this sensitivity testing illustrates that under the multilateral Tornqvist index the changing inflation environment has had an impact on a small number of time series TFP results. In particular, opposite directional change in the measured individual input contributions from what is expected and measured under the traditional Tornqvist index. The opposite directional changes appear to be counter-intuitive and are considered to be anomalous results with the multilateral Tornqvist index.

We note that the measured TFP change can also be of different signs using alternative indexes, even when there are no directional changes in the measured individual input contributions. For example, for AusNet, its TFP change goes from being slightly positive under the multilateral Tornqvist index to negative under the traditional Tornqvist index. This is the result of smaller positive contribution from the reliability output in combination with larger negative contribution from the opex input under the traditional Tornqvist index.

We further note, from Table C.1 to Table C.6, that using alternative indexes also impacts the magnitude of the TFP changes, the reliability output contribution and the input contributions measured, even if there are no directional changes. The sensitivity of the measured TFP changes and input / output contributions is heightened in the 2022 results due to the large rise in annual inflation rate resulting in substantially different reliability and input weightings being applied to the two consecutive years in comparison.

Table C.1 Transmission industry TFP growth and contributions 2021 to 2022 (% and percentage point)

	TFP Change	Energy	RMD	End–users	Circuit length	ENS	Opex	O/H lines	U/G cables	Trans–formers
Multilateral Törnqvist Index	**–0.4**	–0.1	0.1	0.1	–0.1	–0.9	–0.4	–0.1	–0.1	1.0
Traditional Törnqvist Index	**–1.0**	–0.1	0.1	0.1	–0.1	–0.9	–0.6	–0.2	–0.1	0.7

Source: Quantonomics.

Table C.2 TasNetworks' TFP growth and contributions 2021 to 2022 (% and percentage point)

	TFP Change	Energy	RMD	End–users	Circuit length	ENS	Opex	O/H lines	U/G cables	Trans–formers
Multilateral Törnqvist Index	**–1.6**	0.4	0.0	0.1	0.2	–3.6	1.1	0.2	0.1	0.1
Traditional Törnqvist Index	**–3.6**	0.4	0.0	0.1	0.2	–3.6	–0.7	0.0	0.0	–0.1

Source: Quantonomics.

Table C.3 ElectraNet's TFP growth and contributions 2021 to 2022 (% and percentage point)

	TFP Change	Energy	RMD	End–users	Circuit length	ENS	Opex	O/H lines	U/G cables	Trans–formers
Multilateral Törnqvist Index	**–7.0**	0.0	0.0	0.1	0.0	–7.0	0.0	–0.7	0.2	0.4
Traditional Törnqvist Index	**–8.6**	0.0	0.0	0.1	0.0	–8.9	0.6	–0.5	0.0	0.1

Source: Quantonomics.

Table C.4 AusNet's TFP growth and contributions 2021 to 2022 (% and percentage point)

	TFP Change	Energy	RMD	End–users	Circuit length	ENS	Opex	O/H lines	U/G cables	Trans–formers
Multilateral Törnqvist Index	**0.1**	0.6	0.0	0.1	–0.8	1.1	–1.3	–0.2	0.0	0.6
Traditional Törnqvist Index	**–2.2**	0.6	0.0	0.1	–0.8	0.1	–2.2	–0.2	0.0	0.3

Source: Quantonomics.

Table C.5 Powerlink's TFP growth and contributions 2021 to 2022 (% and percentage point)

	TFP Change	Energy	RMD	End–users	Circuit length	ENS	Opex	O/H lines	U/G cables	Trans–formers
Multilateral Törnqvist Index	**1.6**	–0.2	0.6	0.1	0.0	–1.0	1.3	0.2	0.0	0.6
Traditional Törnqvist Index	**1.7**	–0.2	0.6	0.1	0.0	–0.8	1.4	0.1	0.0	0.4

Source: Quantonomics.

Table C.6 Transgrid TFP growth and contributions 2021 to 2022 (% and percentage point)

	TFP Change	Energy	RMD	End–users	Circuit length	ENS	Opex	O/H lines	U/G cables	Trans–formers
Multilateral Törnqvist Index	**–1.0**	–0.7	0.0	0.1	0.1	0.1	–2.2	0.0	–0.3	1.8
Traditional Törnqvist Index	**–2.1**	–0.7	0.0	0.1	0.1	0.0	–2.6	–0.3	–0.3	1.4

Source: Quantonomics.

C.3 Conclusion

Through sensitivity testing we have established that our current multilateral Tornqvist indexing method, under which the input weights are not held constant between the two observations in comparison, is sensitive to the current changes in inflation. This testing used the traditional Tornqvist indexing approach, under which the input weights are held constant between the two observations in comparison, removing the impact of the current changing inflation environment. The two alternative indexing methods produce time series TFP results of a different magnitude, as well as contributions from reliability and individual inputs of a different magnitude. While the traditional Tornqvist indexing approach has no anomalous results in terms of directional change in input contributions, it does not have the same methodological advantage of the multilateral Tornqvist index method. In particular, it does not prevent significant volatility in outputs, such as reliability, having undue impact on the TFP results. Further, when we return to a more stable inflation environment, we consider it unlikely there will be anomalous results under the multilateral Tornqvist method.

D. Map of the National Electricity Market

This benchmarking report examines the productivity of the five TNSPs in the NEM. The NEM connects electricity generators and customers from Queensland through to New South Wales, the Australian Capital Territory, Victoria, South Australia and Tasmania. Figure D.1 illustrates the network areas for which the TNSPs are responsible.

Figure D.1 Electricity transmission networks within the NEM