Economic Benchmarking Results for the Australian Energy Regulator's 2020 DNSP Annual Benchmarking Report

Report prepared for
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Denis Lawrence, Tim Coelli and John Kain

Economic Insights Pty Ltd
Ph +61 438 299 811
Email denis@economicinsights.com.au
WEB www.economicinsights.com.au
ABN 52 060 723 631

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DNSP NAME ABBREVIATIONS

The following table lists the DNSP name abbreviations used in this report and the State in which the DNSP operates.

Abbreviation	*DNSP name*	*State*
ACT	Evoenergy	Australian Capital Territory
AGD	Ausgrid	New South Wales
AND	AusNet Services Distribution	Victoria
CIT	CitiPower	Victoria
END	Endeavour Energy	New South Wales
ENX	Energex	Queensland
ERG	Ergon Energy	Queensland
ESS	Essential Energy	New South Wales
JEN	Jemena Electricity Networks	Victoria
PCR	Powercor	Victoria
SAP	SA Power Networks	South Australia
TND	TasNetworks Distribution	Tasmania
UED	United Energy	Victoria

OTHER ABBREVIATIONS

Abbreviation	*Description*
AEMO	Australian Energy Market Operator
AUC	Annual user cost of capital
CAM	Cost allocation methodology
CMOS	Customer minutes off supply
DNSP	Distribution network service provider
EBRIN	Economic Benchmarking Regulatory Information Notice
LSECD	Least squares econometrics Cobb–Douglas model
LSETLG	Least squares econometrics translog model
MPFP	Multilateral partial factor productivity
MTFP	Multilateral total factor productivity
MVA	Megavolt ampere
MVAkms	Megavolt ampere kilometres
NEM	National Electricity Market
OMPP	Output multilateral partial productivity
PFP	Partial factor productivity
RMD	Ratcheted maximum demand
SFACD	Stochastic frontier analysis Cobb–Douglas model
SFATLG	Stochastic frontier analysis translog model
TFP	Total factor productivity
TNSP	Transmission network service provider
VCR	Value of customer reliability

1 INTRODUCTION

Economic Insights has been asked to update the electricity distribution network service provider (DNSP) multilateral total factor productivity (MTFP) and multilateral partial factor productivity (MPFP) results presented in the Australian Energy Regulator's 2019 DNSP Benchmarking Report (AER 2019a). We also update the detailed analysis of the drivers of DNSP productivity change presented for the first time in Economic insights (2017). This analysis examines the contribution of each individual output and input to total factor productivity (TFP) change. We also include three updates to the index number methodology which are discussed later in this section.

The annual update involves including data for the 2018–19 financial and 2019 calendar years (as relevant) reported by the DNSPs in their latest Economic Benchmarking Regulatory Information Notice (EBRIN) returns. It includes a small number of revisions to DNSP data, mainly relating to corrections to recent opex data for some Victorian DNSPs, corrections to JEN's customer numbers time–series and further refinement of megavolt ampere (MVA) capacity factors for lines and cables.

We also update and expand the opex cost function econometric results presented in Economic Insights (2014a, 2015a,b, 2017, 2018, 2019a) to include another year's data for the Australian DNSPs (2018–19 or 2019, as relevant) and for the New Zealand and Ontario DNSPs. This year we present results for the 14–year period from 2006 onwards as well as for the 8–year period from 2012 onwards.

1.1 Methods used for productivity and efficiency measurement

In this report we use two broad types of economic benchmarking techniques to measure DNSPs' productivity growth and efficiency levels: multilateral productivity index numbers and econometric opex cost functions.

We use multilateral productivity indexes to measure productivity growth at the Australian industry, State and individual DNSP levels. These indexes provide a second order approximation to any underlying production structure. This means they can accurately model both the level and shape of the underlying production function. They provide an accurate measure of productivity growth over time and provide a convenient way of decomposing overall TFP growth into components due to changes in individual outputs and inputs.

We also use the multilateral productivity indexes for time–series, cross–section (or panel data) comparisons of productivity levels. This ensures that a comparison between any two observations in the sample is invariant to whether the comparison is made directly or indirectly via any number of other observations.

We adopt a 'functional' rather than 'billed' approach to measuring outputs in the TFP and MTFP methods. As DNSPs operate in largely non–competitive environments, charging practices have often evolved on an ease of implementation basis rather than being cost–reflective of the key aspects of supply valued by customers or considered by regulators in establishing revenue requirements. As a result, items charged for by the DNSP and associated revenue shares do not necessarily provide a good guide to what customers value and what regulators allow funds for. The functional outputs approach identifies key high level outputs valued by customers and considered in the setting of building blocks revenue requirements. To weight these outputs together in the indexing method we require a set of cost–reflective output shares. These are derived from a simple Leontief cost function model.

Technical details of the productivity indexes are presented in appendix A.

Productivity indexes are non–parametric methods. This means they adopt a mechanical approach and so have the important advantage that they are not dependent on sample size and can be accurately applied to as few as two observations. To allow for noise in the data and to provide information on associated confidence intervals, we need to move to parametric or statistical methods and so our third economic benchmarking method is the estimation of econometric opex cost function models. We estimate opex cost function models rather than total cost function models as opex efficiency assessment is a key component of implementing building blocks regulation. To implement these parametric models sample size and data variation become important considerations.

The four opex cost function models estimated for this report are:

- a least squares econometrics model using the Cobb–Douglas functional form (LSECD)
- a least squares econometrics model using the more flexible translog functional form (LSETLG)
- a stochastic frontier analysis model using the Cobb–Douglas functional form (SFACD), and
- a stochastic frontier analysis model using the translog functional form (SFATLG).

A technical description of the models can be found in appendix A and Economic Insights (2014a). DNSP–specific dummy variables are included in the LSE models and opex efficiency scores are derived from these. In the SFA models opex efficiency scores are calculated in the model relative to the directly estimated efficient frontier.

Because there is insufficient time–series variation in the Australian data and an inadequate number of cross–sections to produce robust parameter estimates, we include data on New Zealand and Ontario DNSPs. We include country dummy variables for New Zealand and Ontario to pick up systematic differences across the jurisdictions, including particularly differences in opex coverage and systematic differences in operating environment factors (OEFs), such as the impact of harsher winter conditions in Ontario. Because we include country dummy variables, it is not possible to benchmark the Australian DNSPs against DNSPs in New Zealand or Ontario, nor is this the objective of the AER's benchmarking. Rather, the inclusion of the overseas data was used to increase the number of observations in the sample to improve the robustness and accuracy of the parameter estimates.

1.2 Updates to productivity index methodology

In this report updates are made to three elements of the productivity index number methodology:

- the weights used to combine non–reliability outputs
- the value of consumer reliability used in weighting the reliability output, and

- the index number method used.

Updated weights for non–reliability outputs

As noted above, TFP/MTFP models can be calculated on either a ‘billed’ output or a ‘functional’ output basis. The billed output basis only includes the outputs the firm directly charges customers for and the output weights used to form the total output quantity are then the revenue shares of the various billed outputs. This approach is appropriate for competitive industries where revenues can be expected to approximate the costs of providing the various outputs. However, many utilities provide a wider range of services and dimensions of output to customers than those they directly charge for. And, charges are usually implemented on the basis of convenience and historical precedence rather than being cost–reflective. For these industries, outputs in productivity analysis are specified on a functional basis which attempts to quantify the attributes valued by customers. This approach is also necessary where the firm’s total revenue allowed by the regulator is designed to cover a wider range of activities than those the firm charges for, as is the case with building blocks regulation.

To form weights for the output quantities included, we can either do a detailed accounting exercise to allocate costs to each output quantity or else estimate the cost shares of each output econometrically. The accounting approach would be prohibitively resource intensive and would suffer from the usual cost allocation problems in any case. This leaves econometric estimation as the only tractable option.

TFP/MTFP indexes use output shares in total cost for aggregating output components into a measure of total output quantity. The partial productivity indexes measure movements in total output quantity relative to a particular input quantity such as opex and so generally use the same output shares in total cost applied to form the total output quantity. This way the TFP index is effectively a weighted average of the various partial productivity indexes. Conversely, the various partial productivity indexes can be consistently aggregated to form the TFP index. To form the output cost weights we thus require data on the prices and quantities of all inputs, both operating and capital.

Economic Insights (2014, pp.28–29) illustrated how the Australian electricity NSP data at the time exhibited insufficient cross–sectional variation to support robust parameter estimation for the sample as a whole, including for more complex, second–order cost functions such as the translog. Instead, we have used a much simpler cost function method, the Leontief, which can be applied on an NSP–by–NSP basis.

The Leontief cost function methodology is relatively simplistic. It is outlined in appendix section A4 and involves the estimation of 52 separate regressions – 4 input demand equations for each of the 13 DNSPs. The input demand equations cover opex, overhead lines, underground cables, and transformers. Each regression contains five parameters to be estimated – 4 input/output coefficients and a time trend coefficient. The purpose of the time trend coefficient is to allow for changes in technology over time. Thus, in panel data, there should be a common value of the time trend variable across DNSPs for each year. Normally the time trend variable starts from a common integer value and then increases by one for each subsequent year.

A report submitted to one of the AER's distribution determinations has identified a coding error in the formation of the time trend variables included in the Leontief input demand regressions from which the four non–reliability output weights previously used in Economic Insights (2014, 2018) have been derived (Frontier Economics 2019, p.11).

As noted, the time trends should have a common base or starting point for each DNSP and, by implication, for each of the 52 separate regressions. In early applications of this method the time trend variable was formed outside the Shazam econometrics program code and was instead read in as part of the data file (eg Lawrence 2003). However, in Economic Insights (2014) (which used data covering the 8 years 2006 to 2013) and Economic Insights (2018) (which used data covering the 12 years 2006 to 2017) the time trend was formed by Shazam code. Instead of resetting the time trend to a common base for the observations applying to each DNSP, the time trend was mistakenly formed over the entire sample. Thus, taking Economic Insights (2018) as an example, instead of the time trend running from 1 to 12 for the annual observations for all DNSPs, the time trend ran from 1 to 12 for the first DNSP in the database, from 13 to 24 for the second DNSP and so on. Because the models are non–linear, this could have a distorting effect on the results obtained, particularly for the time trend coefficient.

DNSP output cost weights were updated in 2018 after having been left constant since economic benchmarking commenced in 2014. The plan was to leave these weights unchanged for a period of around 5 years. Since an extra year of published economic benchmarking data is now available, we have undertaken the correction to the models using data covering the period 2006 to 2018. Regression results for the 52 input demand equations are presented in appendix B.

The effect of correcting the time trend error on the output cost weights is shown in table 1.1. The combined weight on customer numbers and circuit length is around 60 per cent in both cases but weight is transferred from customer numbers to circuit length within this total. The uncorrected weight on customer numbers is 31 per cent but this falls to just under 20 per cent with the correction. The uncorrected weight on circuit length is 29 per cent but this increases to around 39 per cent with the correction.

Table 1.1: **DNSP Leontief cost function output cost weights**

Output	*Uncorrected 2006-2017*	*Corrected 2006-2018*
Energy throughput	12.46%	8.58%
Ratcheted maximum demand	28.26%	33.76%
Customer numbers	30.29%	18.52%
Circuit length	28.99%	39.14%

The combined weight on energy throughput and ratcheted maximum demand (RMD) is around 40 per cent in both cases. However, the distribution of this weight between the two components varies somewhat. The corrected 2006 to 2018 period estimates allocate somewhat less weight to energy throughput and somewhat more to RMD compared to the uncorrected weights.

In assessing the corrected output weights, it is important to remember that, unlike opex cost functions, output weights in partial productivity index number methods are based on shares in total cost. In this context, the reallocation of weight away from energy throughput and customer numbers towards circuit length and RMD in the corrected weights is consistent with what we would expect conceptually from both an engineering and an economic perspective. The main function of the distribution network is the transport of electricity from bulk supply points to end users. As such, we would expect circuit length to be the most important output in terms of total cost as it is closely aligned, as is the RMD output, to the fixed costs of lines, cable and transformer inputs which make up the bulk of a DNSP's total costs.

The customer numbers output will be more closely aligned to the fixed and variable costs associated with having a customer connected such as service lines, local street access and responding to customer requests and complaints. While it provides information on the additional functions the DNSP has to perform, it can arguably be expected to be of secondary importance compared to the primary transport function as the customer–end assets will be a smaller proportion of total asset fixed costs and some of opex will be associated with line, cable and transformers as reflected in the circuit length and RMD outputs. Similarly, the capacity of the lines and transformers the DNSP has to provide can be expected to be primarily influenced by ratcheted maximum demand with energy throughput playing a secondary role.

It is useful to consider these issues in the context of the road network analogy presented in Economic Insights (2013, p.iii–iv). A DNSP will need to provide a range of assets equivalent to arterial roads, major suburban and country roads and local access roads to transport electricity from bulk supply points to customers. The DNSP will need to provide and maintain the length and capacity of these roads that was necessary to meet peak demands, regardless of the amount of traffic on those roads and whether those peak demands are current or from several years ago. This will cause both capital costs and operating and maintenance expenditure to be incurred. Construction of the network over a long distance and of sufficient capacity is capital intensive and is aligned with the outputs of circuit line length and RMD, and thus these outputs are likely to cause relatively more capital costs than operating costs. Operating and maintaining the network involves inspections and minor repairs of connection–side assets (eg local distribution transformers and low voltage mains), and customer services, primarily associated with customer numbers connected, as well maintaining major access roads (distribution and subtransmission lines and transformers) which will be associated with the circuit length and RMD outputs.

When new customers in brownfield sites are connected to the existing network, the impact is largely on opex rather than the capital cost. In contrast, when the network is developed or extended to connect new customers in greenfield sites that are remotely located, the impact falls largely on capital. HoTherefore, short run opex costs can be more responsive to changes in customer numbers and less responsive to circuit length. The variation in customer numbers can explain considerable variation of opex costs, potentially relating to costs caused as a result of customer services including billing and collections, and inquiries, and connection-side repairs. However, capital inputs and their costs (which are considerably larger overall than opex) are more responsive to functional outputs relating to the employment of capital inputs, such as circuit line length and RMD, but relatively less responsive to functional outputs that more likely cause short run cost changes, such as customer numbers.

The corrected output weight relativities observed in table 1.1 are in line with these expectations with circuit length and RMD having the bulk of importance followed further back by customer numbers and, lastly, throughput.

Updated VCR estimates used to proxy the cost of reliability

The second element updated in this study is the value of consumer reliability used to assign a value to the reliability output. Up until now the AER's economic benchmarking has relied on value of customer reliability (VCR) estimates compiled by the Australian Energy Market Operator (AEMO 2014). A VCR time–series is formed by indexing these point estimates backwards and forwards using an appropriate price index. AER (2019b) has recently compiled updated VCR estimates and these are used in this report.

Change to the indexing method

The third element of the methodology updated this year concerns the indexing method used. This update is being introduced to be consistent with the response to an issue that has emerged in our companion transmission network service provider (TNSP) economic benchmarking analysis (see Economic Insights 2020). Prior to now the examination of each NSP's and the corresponding industry's TFP growth and the contributions of each output and input to that growth has been based on standard time–series index number methods such as the Törnqvist and Fisher indexes. These indexes satisfy a number of desirable properties for index numbers to be used in time–series analyses but they do not satisfy the property of transitivity – the property that the results of comparison of two observations should be the same regardless of whether the comparison is done directly or indirectly through other observations. This is not normally an issue in time–series analysis where output and input quantities change in a non–erratic manner over time. However, in the case of transmission, the TNSP energy not supplied (ENS) output has continued to exhibit very large annual percentage changes. The fact that TNSPs generally operate at very high levels of reliability means that relatively small changes in ENS (relative to total energy supplied) translate to very large percentage changes in ENS.

The standard time–series indexes are less able to accurately capture the impact of these large percentage changes because they do not satisfy the transitivity property. This can lead to the standard time–series indexes being subject to some degree of 'drifting' higher or lower after a spike in the ENS variable[1]. All else equal, we would expect the output index including reliability to lie above (below) the output index excluding reliability in years where reliability is significantly better (worse) than in the base year. For an output index subject to drift, this property may not hold following a spike (in either direction) in the reliability variable.

To provide improved accuracy in the face of these large ENS percentage changes (albeit generally from small bases) we change to using the multilateral Törnqvist index method used in our panel data comparisons for both our TNSP and DNSP productivity growth and

[1] This is analogous to the problem of chained index drifting in highly seasonal data discussed in Australian Bureau of Statistics (ABS 1996).

contributions to growth analyses as well[2]. This index does satisfy the transitivity property and is not subject to drifting following reliability variable spikes. As well as providing consistency across our DNSP and TNSP analyses, this change provides scope to make future treatment of the DNSP customer minutes off supply (CMOS) more consistent with the AER's Service Target Performance Incentive Scheme (STPIS), as discussed below. This change means we now use the one index method throughout both our DNSP and TNSP reports. For the productivity growth and contributions analyses the multilateral Törnqvist index is applied to the 14 annual time–series observations sample for the relevant DNSP or the industry as a whole whereas for the panel data comparisons the index is applied across the full sample of 182 observations (ie 13 DNSPs over 14 years each).

Because the multilateral Törnqvist indexes focus on preserving comparability over time by doing all comparisons through the sample mean (rather than directly between pairs of observations as done by traditional time–series index number methods), there may sometimes be minor changes in historical results as the sample is updated and, hence, the sample mean changes over time (as the annual updates are undertaken).[3] This is a necessary trade–off for the multilateral indexes to satisfy the technical property of transitivity which allow more accurate comparisons over time when we have erratically moving outputs. We intend to monitor the extent of these changes as the economic benchmarking database is updated each year.

Information on the impact of these three methodology changes is provided in appendix D where we present industry level productivity index and panel data MTFP and opex MPFP results for 2006 to 2019 using:

- the methodology used in Economic Insights (2019a)
- the Economic Insights (2019a) methodology with the revised output weights
- the Economic Insights (2019a) methodology with the updated VCR estimates, and
- for the industry level productivity indexes, the Economic Insights (2019a) methodology with the revised index number method.

1.3 DNSP comments on draft report

In line with previous practice, the AER made the draft version of this report available to the 13 included DNSPs for comment. A major focus of DNSP comments was the corrected output cost weights used in the productivity indexes. There were differing opinions on, firstly, whether the corrected output weights should be included in this report and, secondly, the merits of the corrected output weights.

A number of DNSPs supported inclusion of the corrected output weights. AGD noted 'we acknowledge that once an error has been identified the AER should, as far as reasonably practicable, take steps to correct it'. SAP noted it was 'supportive of the correction of the time trend error which impacts the non–reliability output weights'. The joint comments of CIT/PCR/UED (hereafter CPU) noted 'we agree with correcting identified errors as part of

[2] In earlier reports the alternative terminology of multilateral translog index has been used.
[3] It is also possible there could be minor differences in results obtained from individual DNSP analysis and the panel data analysis due to differences in sample means.

continuous improvement' but noted the benchmarking results should be 'stable over time'. JEN, on the other hand, noted that it believed 'a substantial output weight change in the MTFP/MPFP … should warrant … consultation with all DNSPs before making the change'. And END noted 'such a change from the outcome of the extensive process in 2013 may warrant a more fulsome review'.

Our view is that errors, once identified, should be corrected as soon as possible. Consequently, we have moved to incorporate the corrected results in this report. We note that some of the concerns expressed over whether the changes should be made now or after further consultation relate to the potential size of changes in the output weights, particularly compared to those initially used in Economic Insights (2014) and the subsequent three annual economic benchmarking updates. However, since the same error was present in the initial weights, we are of the view that this comparison is less relevant and correcting the error should take priority.

A number of DNSPs expressed support for the changed relativities in the corrected output weights. SAP noted 'the corrected weightings more closely align with SA Power Networks' expectations of underlying cost sharing, with circuit length and ratcheted maximum demand the primary drivers of cost for DNSPs'. ESS stated it was 'supportive of the updated methodology which results in a more balanced approach to customer numbers and circuit length'. TND stated it 'supports the amendments that have been made to the productivity index methodology'. Energy Queensland (representing ENX and ERG) stated it had 'no issues with the preliminary benchmarking'.

CPU, on the other hand, noted that 'the size of the customer base is the most significant cost driver of operating and capital expenditure', 'only spatial demand is relevant to our capital expenditure' and 'energy throughput has no bearing on … operating or capital expenditure'. It went on to state 'from an economic and engineering perspective we would expect customer numbers to have the highest weighting followed by line length and peak demand'.

AGD noted 'the inclusion of customer numbers as an output measure is intended to reflect [DNSPs'] fixed costs' and 'the reduction in the weighting of customer numbers therefore requires further explanation'. AND also sought further explanation of the rationale for the reduced weight on customer numbers. JEN noted there was a 'large discrepancy between the new output weights used in MTFP/MPFP and econometric [opex cost function] models' and suggested a case may exist to use the latter to form the productivity index output weights. JEN also suggested the expected increase in Distributed Energy Resources (DER) might be expected to increase the weight on customer numbers and reduce that on RMD going forward.

In considering the comments of CPU on output weights, it is important to recognise that output weights in the MTFP/MPFP framework are based on shares of total cost, not total expenditure ('totex' comprising the sum of opex and capex). As noted in the preceding section, the MTFP/MPFP framework requires there to be consistent aggregation of partial productivities up to total productivity and, conversely, total productivity is effectively a weighted average of the partial productivity measures. Similarly, because capital quantity measures included in the MTFP/MPFP framework are measures of their annual contribution to production (which is usually proxied by capital stock measures), the appropriate capital cost measure included is the annual cost of capital, not the flow component of capital expenditure (capex). This framework fundamentally differs from the opex cost function framework which focuses solely on opex which, by definition, is a flow concept. In a total cost framework we are effectively combining the cost of a purely flow–based input (ie opex) with the costs and annual input quantities of inputs which last many years or, in this case, many decades (ie lines, cables and transformer capital inputs). It is therefore misguided to try and assess total cost output weights using notions of weights in total expenditure as CPU did in its comments. It would similarly be inappropriate to use opex cost function–based output shares in an MTFP/MPFP framework, as suggested by CPU and JEN, despite the potential statistical performance attractions of doing so.

To assess the likely distribution of total costs across outputs, it is useful to examine the shares of the main input components in total cost. For the industry as a whole, in 2019 opex made up around 35 per cent of total costs, lines and cables inputs made up around 35 per cent and transformer and other capital inputs made up around 30 per cent. We would expect the lines and cables input costs to mainly be associated with the circuit length output although some would also be associated with customer numbers (representing more low voltage mains being required for more customers) and RMD. It is important to note that RMD is included as an output to capture system capacity that was installed to meet previous peak demands even though it may now be underutilised given the tendency for maximum demand to have fallen, or at least not reattained, its previous peaks over time. This ensures the DNSP still gets credit for that output despite the assets now being underutilised.

We would expect the transformer and other capital input costs to be spread across the circuit length, customer numbers and RMD outputs. More transformers will generally be required with more line length and capacity and more customers will require more connection–related transformers. Similarly, we would expect some transformer costs to be from now underutilised capacity given falls in peak demand over time and so would be associated with the RMD output. And, of course, some portion of both transformer and line and cable input costs would be associated with throughput although, as noted in Economic Insights (2013), we would expect this to generally be small.

Opex can be expected to be associated with the customer numbers output and, to a lesser extent, with the circuit length and RMD outputs. Repairs and maintenance activities can be expected to be responsive to complaints by customers and to action customer requests for service. Preventative line and cable maintenance tasks will be associated with circuit length and RMD outputs and transformer maintenance will be associated with customer numbers (particularly for distribution transformers) and line length and RMD (particularly for zone substation transformers).

Based on these expectations of how the key input costs can be expected to be attributed to the main functional output components, we consider it entirely reasonable for opex to be primarily associated with customer numbers and, to a lesser extent, with circuit length and RMD as we find in our econometric opex cost function estimates where the customer numbers output weight is generally 50 per cent or larger. However, we would expect total costs to be more closely associated with circuit length and RMD given the importance of long–lived fixed assets in the distribution industry although customer numbers will also play an important role. The total cost output weights produced by the corrected Leontief input demand function models are thus also entirely reasonable as they recognise the importance of fixed costs in distribution industry total costs.

For the avoidance of doubt before leaving this topic, we are not saying that benchmarking of total expenditure ('totex' comprising the sum of opex and capex) has no role to play in regulatory analysis. Rather, we are noting that it is a different framework to and should not be confused with the productivity index framework. Totex analysis has been used in the United Kingdom and parts of Europe whereas productivity index analysis has been more commonly used in the United States and Canada. There would be scope to include totex benchmarking in the AER's Annual Benchmarking Report just as other partial performance indicators (PPIs) are currently included in addition to the productivity index and opex cost function analyses.

A number of DNSPs expressed support for expansion of the functional outputs included in the productivity index analysis to include an output representing DER which is growing in most States and potentially changing the ways DNSPs are required to operate. As noted in the following section we also view this as a priority for future development. It should be borne in mind that inclusion of such an output will require further changes to be made to output weights. It will also provide an opportunity to reassess the functional outputs currently included and methods for estimating output weights.

We note that AGD questioned the weight applied to RMD in the corrected productivity index output weights as it 'runs counter' to current initiatives to facilitate DER which will likely reduce maximum demands going forward. However, as noted above, the purpose of the RMD output is to recognise past investment in capacity that in many cases is now underutilised due to more recent energy efficiency developments. Inclusion of the output is designed to stop DNSPs being disadvantaged by subsequent demand reductions which were beyond their control.

In its comments CPU criticised the correction of the time trend error identified in the Leontief input demand analysis as being 'insufficient' to address criticisms of the MTFP/MPFP analysis made in earlier reports it had commissioned from NERA (2018) and Frontier Economics (FE 2019). Economic Insights (2019b) has previously reviewed NERA (2018) and shown that it contains many incorrect statements, flawed reasoning and fundamental errors in its calculations. Consequently, we believe little, if any, weight should be placed on NERA (2018).

Economic Insights (2020b) reviewed FE (2019). Apart from identifying the time trend coding error, FE's major criticisms of the previous Leontief estimates related to lack of significance among the input/output coefficients and the magnitude of the estimated time trend coefficients. As noted above, the Leontief input demand function methodology is relatively simplistic and has been adopted as one of the few tractable ways of obtaining total cost output weights from Australian DNSP data given that data's lack of variation and the prevalence of multicollinearity issues when attempting to use more sophisticated methods.

The Leontief model assumes there are fixed input proportions in each output. Stylistically, this can be thought of as fitting a right angle to the data rather than a smooth isoquant curve in two–dimensional space (ie in the case of two inputs and one output). As a result, the

Leontief cost function will never produce impressive–looking statistical results. For a 4–output model we, as practitioners, would normally expect to get at least one significant output coefficient per regression equation, occasionally 2 significant and, on very rare occasions, 3 significant coefficients – see, for example, Lawrence (2003) where this methodology was first applied. The statistical performance of a simple fixed proportions model cannot be judged by the same standards we would use for fitting smooth functions such as the Cobb–Douglas or translog.

The correction of the time trend error has substantially improved the statistical performance of the input demand regressions. In terms of output coefficients, 28 of the 52 regressions now have one significant output coefficient, 17 have two significant output coefficients and 2 have 3 significant output coefficients. Furthermore, the energy throughput output is now statistically significant in 10 of the regressions, including 4 of the opex input demand equations. In addition to the output coefficients, there are also 39 regressions that now have statistically significant time trend coefficients.

The time trend coefficients all now lie well within the range FE (2019, p.9) nominate as being reasonable, namely –10 per cent to 10 per cent. In fact, the estimated time trend coefficients all lie in a range of –1.11 per cent to 7.28 per cent. If the underground cable input demand equations are excluded, the range narrows further to –1.11 per cent to 4.81 per cent.

As a consequence of correcting the identified time trend error, the performance of the Leontief model is now reasonable given the constraints of what can be expected from a relatively simplistic model. Consequently, the other issues identified by FE (2019) are no longer relevant.

When the MTFP/MPFP productivity index analysis is viewed within the appropriate total cost framework context, rather than inappropriately within an expenditure framework context as CPU appears to do, and account is taken of the improved performance of the corrected Leontief input demand model, we believe there is no case for removing the productivity index model as suggested by CPU. We also note that CPU's comments on productivity index analysis are somewhat contradictory as they go on to state that the 'analysis Economic Insights currently provides for the TFP model, including the trends over time and the analysis of the key drivers – we understand this information provides valuable insights'.

Turning to other issues, JEN supported the exploration of additional opex cost function specifications to address statistical performance issues and suggested wider use be made of the two–output models included in appendix E2.

ACT noted that its opex MPFP level in 2019 would have been higher were it not for the transfer of responsibility to it for vegetation management on unleased land in urban areas of the Territory in July 2018 and associated attendance to accumulated foliage defects affecting lines passing over that land.

JEN recommended use of data supplied by DNSPs on the labour/non–labour split of opex as part of recent Reset RINs to form the opex price index used to deflate network services opex. The useability of this information source will be examined for the 2021 economic benchmarking reports. The current report uses purpose–specific data collected from DNSPs in 2017.

Finally, a number of DNSPs commented on cost allocation methodology and capitalisation issues, operating environment factors and partial performance indicators. These topics are beyond Economic Insights' current remit and will be addressed by the AER.

1.4 Priorities for future refinement

Development of the DNSP productivity index methodology over the coming year is likely to concentrate on three main measurement issues. Firstly, the share of total revenue attributed to the reliability output is relatively high for some DNSPs. It averages around 15 per cent for the industry and is up to 45 per cent for some rural DNSPs in some years. This is considerably higher than the range of revenue at risk under the Service Target Performance Incentive Scheme (STPIS) parameters DNSPs face which is more in the order of 9 per cent of total revenue.[4] Such high VCR–based output weights allocated to reliability have the potential to distort TFP results both for individual DNSPs over time and for levels comparisons across DNSPs. In the companion TNSP economic benchmarking report we have moved to more closely align the capped weight applied to the reliability output with relevant STPIS parameters. We plan to investigate the scope to make a similar link for DNSPs, which would likely also involve introducing a cap on the weight attributed to the DNSP reliability output.[5]

Secondly, as noted in the preceding section, distributed or embedded generation is becoming increasingly common in Australia and poses a number of challenges DNSPs have to respond to with the associated increase in the proportion of two–way electricity flows which have to be accommodated. Currently DNSP actions to accommodate this market development are not recognised as outputs in the economic benchmarking models. We plan to investigate the scope to include recognition of DNSP action to accommodate distributed generation as an additional output in the index number models. Whether this can be extended to the opex cost function models will depend on the availability of similar data for the overseas jurisdictions.

Thirdly, to measure the quantity of lines and cables inputs we collect information from each DNSP on their line and cable MVA capacities by broad voltage category as well as on their corresponding line and cable lengths. In early productivity index studies we used an MVA factor for each voltage category that was common across all DNSPs (eg Lawrence 2003). This had the advantage of consistency but took no account of variation across DNSPs. In our economic benchmarking work for the AER we have collected DNSP–specific MVA data and asked DNSPs to allow for thermal and voltage drop constraints. However, DNSPs have adopted a wide range of, in some cases, frequently changing methods to estimate the constrained MVAs and, in some cases, appear to have allowed for network constraints beyond the lines and cables in question. To introduce more consistency into this important data item, we plan to explore the scope to use 'nameplate' capacity of the installed lines and cables rather than their estimated constrained capacity. This would allow for differences across DNSPs but reduce scope for inconsistent treatment and subjectivity in the supply of

[4] The relevant revenue–at–risk for DNSPs is for the reliability component, which could be typically capped at ±4.5 per cent exclusive of the telephone response parameter under the customer service component.
[5] In anticipation of these developments we change in this report to quoting output weights relative to total revenue rather than relative to gross revenue as previously reported.

this data. To reduce the data burden on DNSPs, this information could be collected for a 'snap shot' year for each DNSP and those values applied to other years for the DNSP.

Development of the opex cost function models over the coming year is likely to concentrate on improving the monotonicity performance of the two translog models. Monotonicity (the requirement that an output cannot be increased without an increase in cost) is imposed in the Cobb–Douglass specification but not in the more flexible translog specification. Violations of the monotonicity requirement have, at times, been an issue for the SFATLG model in the full period sample and for both the SFATLG and LSETLG models in the shorter sample period from 2012 onwards. These violations have become more prevalent with the inclusion of the additional year's data for 2019. Examination of this issue will cover both model specification and database issues.

We consider that multicollinearity in the models may be affecting their monotonicity performance. There is a high degree of correlation between the customer numbers and RMD output variables. To examine this issue, we have estimated two sets of two–output models. The first of these models includes customer numbers and circuit length as the two outputs while the second includes RMD and circuit length. The monotonicity performance of these models is greatly improved. Preliminary results for these models are presented in appendix E.

Another way to address possible multicollinearity in the models is to increase the data variation in the sample. We plan to further investigate the scope to include a wider range of overseas DNSPs in the sample.

Other options will also be considered such as continuing to monitor the performance in the TLG models, particularly for the shorter period from 2012 onwards (as this is where monotonicity issues have been particularly encountered), and review the appropriate weights to apply to the efficiency scores derived from those models in forming the average score used by the AER in resets. Our current approach is to only exclude results for the DNSPs that are found to have monotonicity violations for more than half their number of observations.

In Economic Insights (2020b) we agreed there was some merit in normalising output variables in the opex cost function database by the respective means of the Australian sample rather than the means of the entire three–country sample (as suggested by FE 2019). This change would only affect the first–order output coefficients in the translog models (which reflect the mean output elasticities for the relevant sample used for normalisation). It would have no impact on either the efficiency scores of any of the models or on their statistical performance. We have decided to delay making this change until there has been sufficient opportunity to review the performance of the translog models, particularly given their monotonicity performance following the inclusion of the additional year's data for 2019 as discussed above.

1.5 Data revisions

This year a small number of revisions have been made to the Australian data.

JEN has submitted revisions to its customer numbers data for 2011 to 2019. Previously submitted data excluded de–energised NMIs. JEN has also been able to improve the treatment of unmetered customer number and billing system changes.

The AER has also been notified that JEN submitted incorrect opex data for the years 2016 to 2018 due to incorrect allocation of parent company costs to the electricity DNSP business. JEN also submitted a revision to its AUC data for 2016 and 2017. Both of these corrections have been incorporated in the data used in this report.

In line with previous practice, all Australian DNSPs' data for all years are based on the cost allocation methodologies (CAMs) that applied in 2014 rather than on more recently revised CAMs. The CAMs applying in 2014 (including ACT's revised CAM) led to opex/capex ratios being broadly consistent across DNSPs. 'Freezing' the CAMs at this point has minimised the scope for DNSPs to game the benchmarking results by reallocating costs between opex and capex and currently provides the best basis for like–with–like comparisons of overall network services opex in most cases. However, with additional CAM changes occurring over time and changing circumstances, the AER has further examined the impact of changing CAMs on economic benchmarking data requirements.

Corrections have been made to the opex data for CIT and PCR for the years 2016 and 2019. Both businesses deducted a service classification adjustment related to metering for these years in recasting their data to reflect their CAM applying in 2014. However, based on further investigation, the AER is of the view this item should not have been deducted. Similarly, opex for metering has been added back to AND's network services opex for the years 2016 to 2019.

There have also been further minor refinements to selected MVA factors for lines and cables. The most significant of these are a revision to AGD's MVA factors for its underground 11 kV cables and overhead 11 kV lines in 2019 – we have backcast these revisions to 2006, AND's MVA factor for its overhead 22 kV lines for 2006 to 2017 and END's MVA factor for underground 66 kV cables for 2006 to 2018.

Finally, as foreshadowed in Economic Insights (2020b), a minor correction has been made to the labour share used in constructing the opex price index.

1.6 Specifications used for productivity and efficiency measurement

The DNSP MTFP measures presented in this report have five outputs included:

- Energy throughput (with 8.6 per cent share of gross revenue, equivalent to 9.9 per cent of total revenue on average)
- Ratcheted maximum demand (with 33.8 per cent share of gross revenue, equivalent to 38.8 per cent of total revenue on average)
- Customer numbers (with 18.5 per cent share of gross revenue, equivalent to 21.3 per cent of total revenue on average)
- Circuit length (with 39.1 per cent share of gross revenue, equivalent to 45.0 per cent of total revenue on average), and
- (minus) Minutes off–supply (with the weight based on current AER VCRs, being –12.9 per cent of gross revenue on average and equivalent to –15.0 per cent of total revenue on average).[6]

[6] The weights of the first four outputs sum to more than 100 per cent as reliability enters as a negative output

The DNSP MTFP measures include six inputs:

- Opex (network services opex deflated by a composite labour, materials and services price index), making up 37 per cent of total costs on average
- Overhead subtransmission lines (quantity proxied by overhead subtransmission MVAkms), making up 5 per cent of total costs on average
- Overhead distribution lines (quantity proxied by overhead distribution MVAkms) , making up 15 per cent of total costs on average
- Underground subtransmission cables (quantity proxied by underground subtransmission MVAkms), making up 2 per cent of total costs on average
- Underground distribution cables (quantity proxied by underground distribution MVAkms), making up 12 per cent of total costs on average, and
- Transformers and other capital (quantity proxied by distribution transformer MVA plus the sum of single stage and the second stage of two stage zone substation level transformer MVA), making up 29 per cent of total costs on average.

In all cases, the annual user cost (AUC) of capital – the cost of using the durable input for one year – is taken to be the return on capital, the return of capital and the tax component, all calculated in a broadly similar way to that used in forming the building blocks revenue requirement.

The opex cost function econometric models include three outputs – ratcheted maximum demand, customer numbers and circuit length – along with the proportion of undergrounding and a time trend.

There are several important differences across the various models. The opex cost function models include allowance for the key network density differences and the degree of undergrounding. The opex MPFP model includes allowance for the key network density differences but not the degree of undergrounding. The opex cost function models include three outputs whereas the opex MPFP model includes five outputs (the same three as the opex cost function models plus energy delivered and reliability). The opex cost function models use parametric methods whereas the opex MPFP model uses a non–parametric method. The LSE opex cost function models use least squares (line of best fit) estimation whereas the SFA models use frontier estimation methods. The LSE opex cost function models include allowance for heteroskedasticity and autocorrelation whereas the SFA models do not. Despite all these differences in model features, the opex efficiency scores produced by the five models are broadly consistent with each other.

Growth rates in productivity indexes can be reported using either logarithmic or trend measures. Logarithmic measures track the series from endpoint to endpoint exactly. Trend measures are based on a linear regression line of best fit that may not coincide with the endpoints, particularly if they are outliers. In keeping with previous practice, all growth rates reported in the body of this report are logarithmic measures. However, we also now include tables of trend growth rates in appendix C.

and the sum of all five outputs is 100 per cent.

2 INDUSTRY–LEVEL DISTRIBUTION PRODUCTIVITY RESULTS

Distribution industry–level total output, total input and TFP indexes are presented in figure 2.1 and table 2.1. Opex and capital partial productivity indexes are also presented in table 2.1.

Figure 2.1 **Industry–level distribution output, input and total factor productivity indexes, 2006–2019**

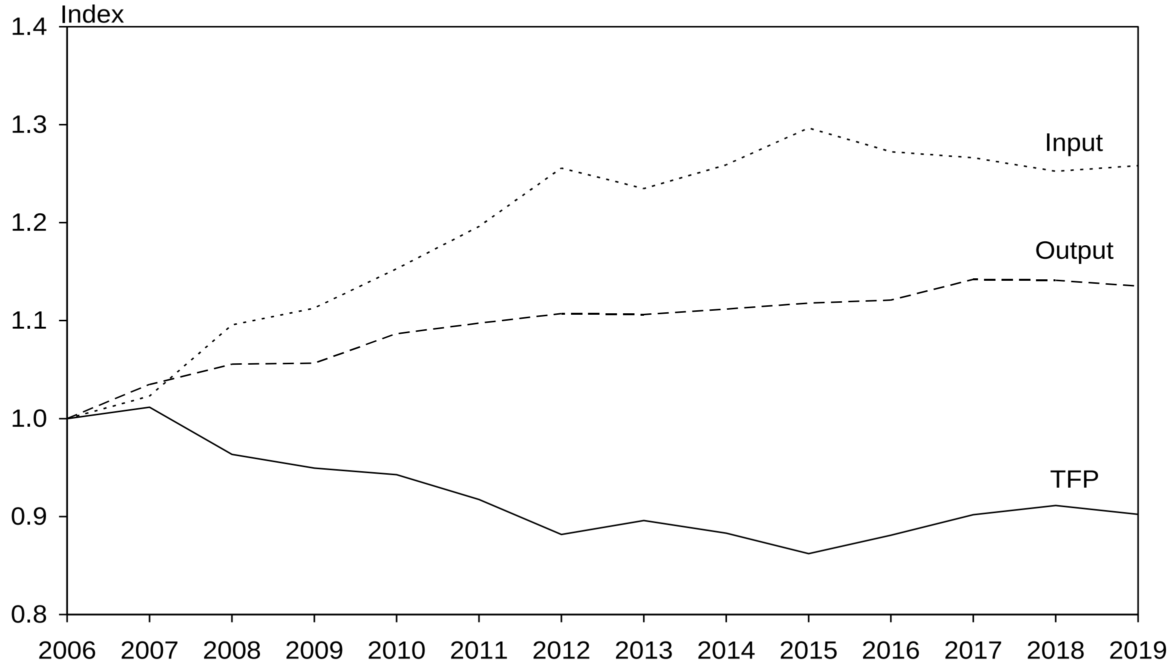


Table 2.1 **Industry–level distribution output, input and total factor productivity and partial productivity indexes, 2006–2019**

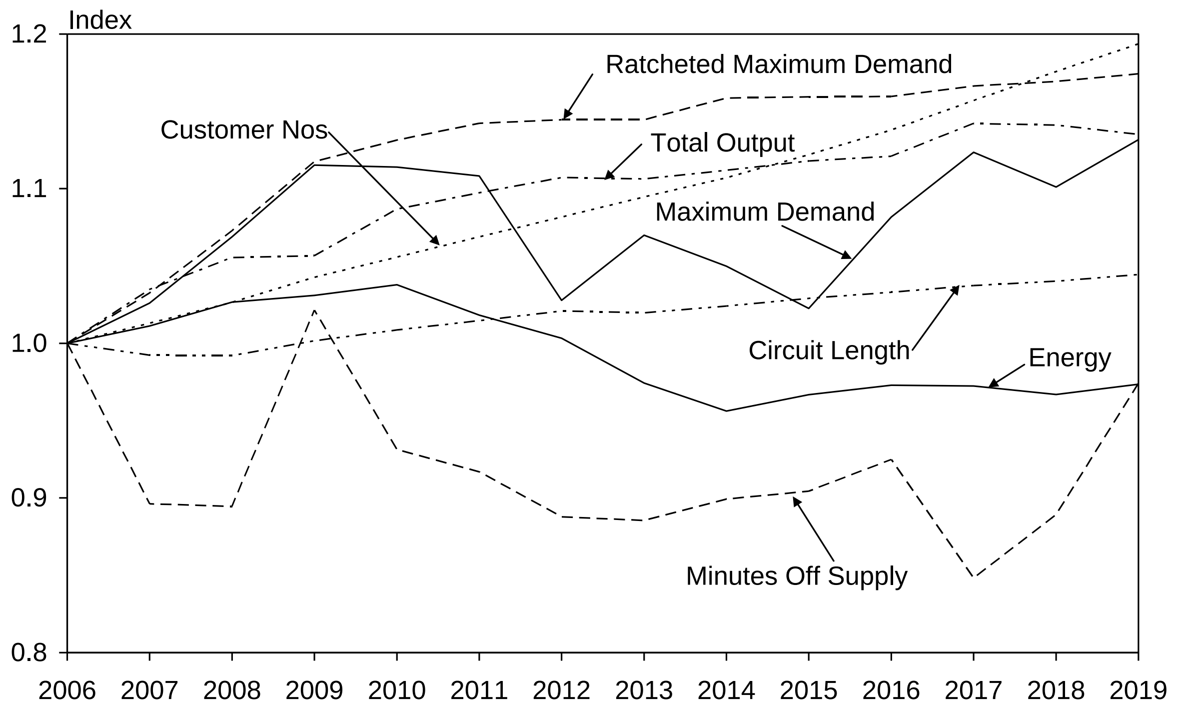
Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index Opex*	*PFP Index Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.035	1.023	1.012	1.039	0.995
2008	1.056	1.096	0.963	0.925	0.989
2009	1.057	1.113	0.950	0.938	0.957
2010	1.087	1.153	0.943	0.924	0.953
2011	1.097	1.196	0.917	0.880	0.940
2012	1.107	1.256	0.882	0.814	0.924
2013	1.106	1.235	0.896	0.882	0.904
2014	1.112	1.259	0.883	0.875	0.888
2015	1.118	1.297	0.862	0.835	0.879
2016	1.121	1.272	0.881	0.903	0.868
2017	1.142	1.266	0.902	0.949	0.877
2018	1.141	1.252	0.911	0.994	0.866
2019	1.135	1.258	0.902	0.993	0.854
Growth Rate 2006–19	0.98%	1.77%	–0.79%	–0.06%	–1.21%
Growth Rate 2006–12	1.70%	3.79%	–2.10%	–3.44%	–1.31%
Growth Rate 2012–19	0.36%	0.03%	0.33%	2.84%	–1.13%

Over the 14–year period 2006 to 2019, industry level TFP declined at an average annual rate of 0.8 per cent.[7] Although total output increased at an average annual rate of 1.0 per cent, total input use increased faster at a rate of 1.8 per cent. Since the average rate of change in TFP is the average rate of change in total output less the average rate of change in total inputs, this produced a negative average rate of productivity change. TFP change was, however, positive in five years – 2007, 2013, 2016, 2017 and 2018. In the first of these years, input use increased but at less of a rate than output increased, while in 2013, 2016, 2017 and 2018 input use decreased. TFP change in 2019 was –1.0 per cent as total output decreased by 0.5 per cent and total input increased by 0.5 per cent.

2.1 Distribution industry output and input quantity changes

To gain a more detailed understanding of what is driving these TFP changes, we need to look at the pattern of quantity change in our five distribution output components and our six distribution input components. We also need to consider the weight placed on each of these components in forming the total output and total input indexes. Later we will present results that show the contributions of each output and each input to TFP change taking account of the change in each component's quantity over time and its weight in forming the TFP index. First, however, we will look at the quantity indexes for individual outputs in figure 2.2 and for individual inputs in figure 2.3. In each case the quantities are converted to index format with a value of one in 2006 for ease of comparison.

Figure 2.2 **Industry–level distribution output quantity indexes, 2006–2019**



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

From figure 2.2 we see that the output component that receives the largest weight in forming the TFP index, circuit length, grew very modestly over the 14 years and by 2019 was only 5 per cent higher than it was in 2006. This reflects the fact that most of the increase in customer numbers over the period has been able to be accommodated by ‘in fill’ off the existing network that does not require large increases in network length. That is, the bulk of population growth is occurring on the fringes of cities and towns and as cities move from being low density to more medium to high density and so the required increases in network length are modest compared to the increase in customer numbers being serviced.

The customer numbers output increased steadily over the period and was 19 per cent higher in 2019 than it was in 2006. This steady increase is to be expected as the number of electricity customers will increase roughly in line with growth in the population. However, we see that energy throughput for distribution peaked in 2010 and fell steadily through to 2014 and has increased only marginally since then. In 2019 energy throughput was still 3 per cent less than it was in 2006.

Maximum demand has followed a broadly analogous pattern to energy throughput although it increased more rapidly between 2006 and 2009 before levelling off and then falling markedly in 2012. This fall in maximum demand and energy throughout since around 2009 partly reflects economic conditions being more subdued since the ‘global financial crisis’ but, more importantly, the increasing impact of energy conservation initiatives and more energy–efficient buildings and appliances. Distribution networks, thus, have to service a steadily increasing number of customers at a time of falling throughput and lower demand. In recognition of this, we include ratcheted maximum demand as our output measure rather than maximum demand so that DNSPs get credit for having had to provide capacity to service the earlier higher maximum demands than are now observed.

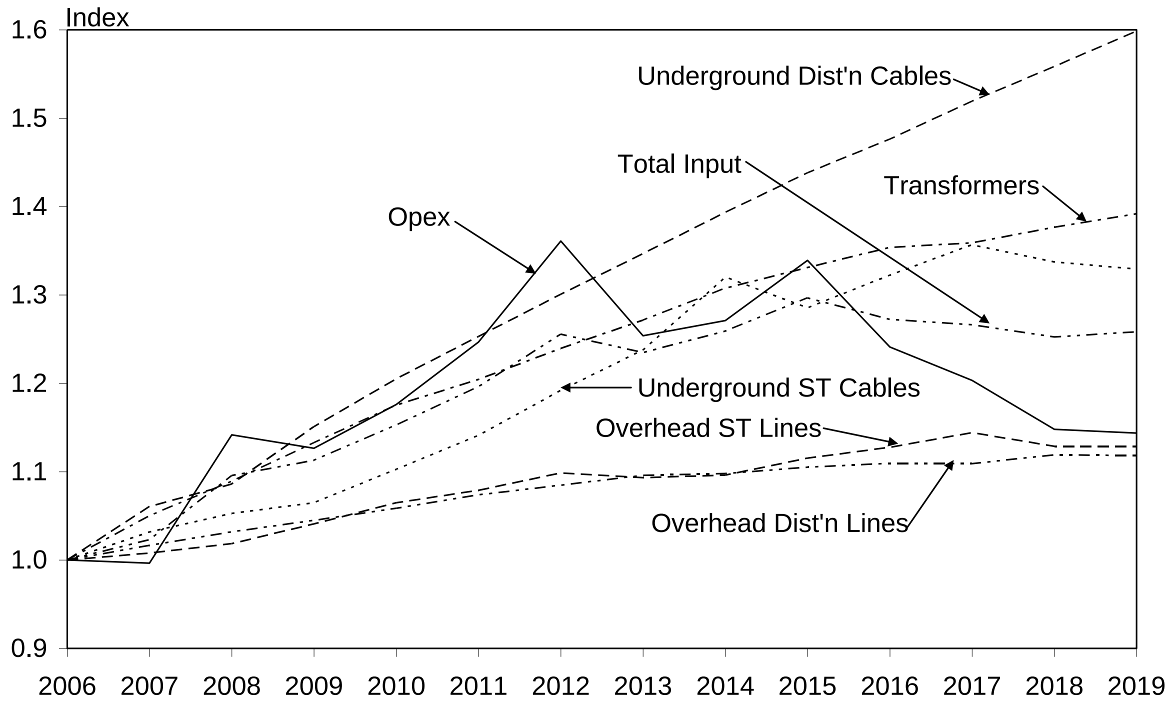
Ratcheted maximum demand, which is the output receiving the second highest weight in forming the TFP index, increased at a similar rate to maximum demand up to 2009, increased slower in 2010 and has been relatively flat since. We do observe some small increases in this output since 2009 as it is the sum of individual ratcheted maximum demands across the 13 DNSPs and maximum demand for some DNSPs increased above earlier peaks in some years even though aggregate maximum demand exceeded its 2009 peak for the first time in 2017, before temporarily reducing again in 2018. In 2019 overall ratcheted maximum demand was 17 per cent above its 2006 level.

The last output shown in figure 2.2 is total CMOS. This enters the total output index as a negative output since a reduction in CMOS represents an improvement and a higher level of service for customers. Conversely, an increase in CMOS reduces total output as customers are inconvenienced more by not having supply for a longer period. We see that, with the exception of 2009, CMOS has generally been lower and, hence, contributed more to total output than was the case in 2006. In 2019 CMOS was 3 per cent less than it was in 2006 despite having increased by 9 per cent from 2018.

Since the circuit length and ratcheted maximum demand outputs receive a weight of around 84 per cent of total revenue in forming the total output index, in figure 2.2 we see that the total output index is bounded by these two output indexes with movements influenced by the pattern of movement in the CMOS output (noting that an increase in CMOS has a negative impact on total output and is given a weight of around 15 per cent of total revenue on average). The total output index also lies close to the customer numbers output index which received the third highest weight. And throughput is given a smaller average weight of 10 per cent of total revenue in line with changes in throughput generally having relatively low marginal cost. Reductions in throughput after 2010, hence, have a more muted impact on total output. In 2019 the large increase in CMOS was enough to reduce total output despite increases in the other four outputs.

Turning to the input side, we present quantity indexes for the six input components and total input in figure 2.3. The quantity of opex (ie opex in constant 2006 prices) increased sharply between 2006 and 2012, being 36 per cent higher in 2012 than it was in 2006. It then fell in 2013 – a year that coincided with price reviews of several large DNSPs – before increasing again in 2014 and 2015 and then falling by 8 per cent in 2016, by 3 per cent in 2017, by 5 per cent in 2018 and decreasing by 0.4 per cent in 2019 at which time it was 14 per cent above its 2006 level. Opex has the largest average share in total costs at 37 per cent and so is an important driver of the total input quantity index.

Figure 2.3 **Industry–level distribution input quantity indexes, 2006–2019**



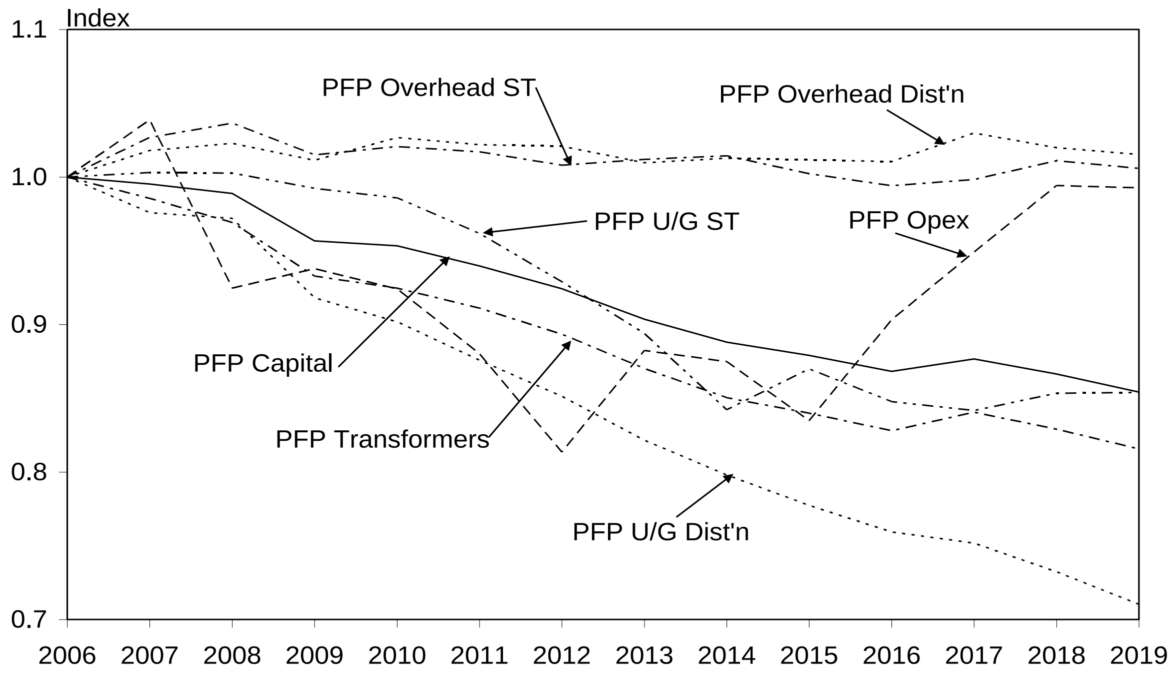
The other input component with a large average share of total cost, at 29 per cent, is transformers. The quantity of transformers has increased steadily over the period and by 2019 was 39 per cent above its 2006 level. It is by the use of more or larger transformers in zone substations and on the existing network that DNSPs can accommodate ongoing increases in customer numbers with only small increases in their overall network length.

The next key components of DNSP input are the quantities of overhead distribution and overhead subtransmission lines. These two input quantities have increased the least over the period with levels in 2019 around 12 and 13 per cent, respectively, higher than in 2006. It should be noted that overhead line input quantities take account of both the length of lines and the overall 'carrying capacity' of the lines. The fact that both overhead distribution and subtransmission quantities have increased substantially more than network length reflects the fact that the average capacity of overhead lines has increased over the period as new lines and replacement of old lines are both of higher carrying capacity than older lines. This could partly reflect the need for higher capacity lines to meet the growth in customer numbers within the overall network footprint and the need to meet higher standards but could also reflect a degree of built–in overcapacity. Overhead distribution and subtransmission lines account for around 20 per cent of total DNSP costs on average.

The fastest growing input quantity is that of underground distribution cables whose quantity was 60 per cent higher in 2019 than it was in 2006. However, this growth starts from a quite small base and so a higher growth rate is to be expected, particularly seeing that many new land developments require the use of underground distribution and there is a push in some areas to make greater use of undergrounding for aesthetic reasons. Underground distribution quantity increases somewhat faster than underground subtransmission quantity (which increased by 33 per cent over the period), again likely reflecting the increasing use of undergrounding in new subdivisions and land developments. Although the length of overhead lines is several times higher than the length of underground cables, underground cables are considerably more expensive to install per kilometre. Consequently, underground distribution and subtransmission have an average share in total costs of 14 per cent despite their relatively short length.

From figure 2.3 we see that the total input quantity index lies close to the quantity indexes for opex and transformers (which together have a weight of 66 per cent of total costs on average). The faster growing underground distribution cables quantity index generally lies above this group of quantity indexes which in turn lie above the slower growing overhead lines quantity indexes.

Figure 2.4 **Industry–level distribution partial productivity indexes, 2006–2019**

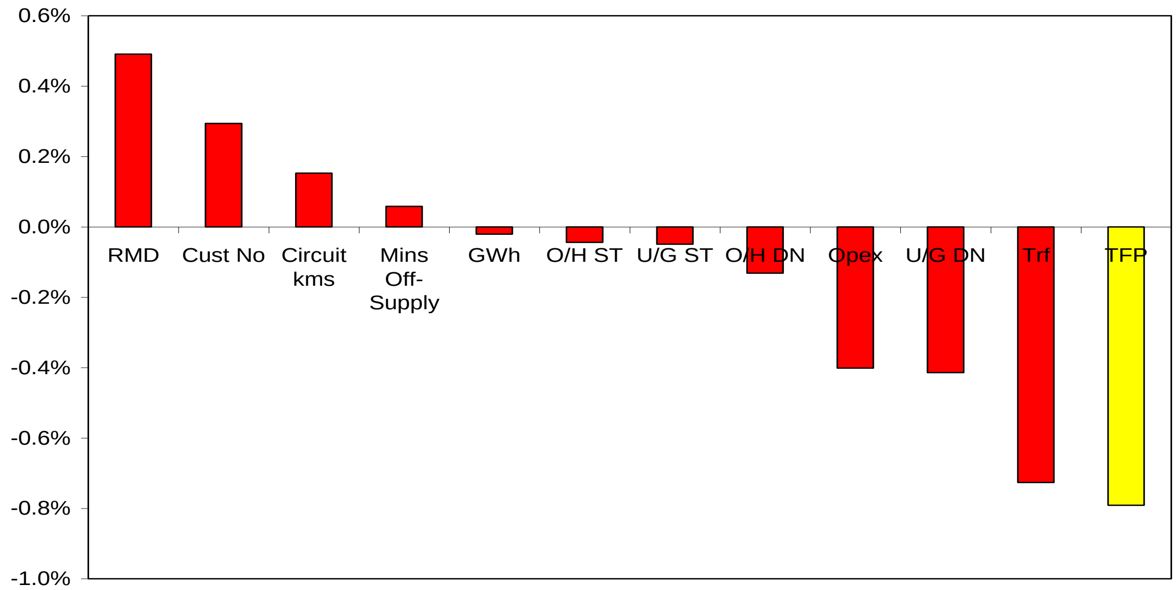


From figure 2.4 we see that movements in distribution industry–level input partial productivity indexes follow an essentially inverse pattern to input quantities (since the partial productivity index is total output quantity divided by the relevant input quantity index). Overhead lines partial productivity indexes are consequently the highest over the period, although the level of overhead distribution lines partial productivity was only 2 per cent higher in 2019 than it was in 2006. Nearly all other partial productivity indexes decline over the period which means the quantities of those inputs have increased faster than total output. Underground distribution cables partial productivity declines the most over the period, being 29 per cent lower in 2019 than in 2006. As noted above, this is because underground distribution cables have increased rapidly from a small base. Transformer partial productivity has declined by the next largest amount, being 18 per cent lower in 2019 than in 2006. Opex partial productivity declined the most through to 2012 but has generally improved since as opex use has trended down from its 2012 peak. In 2012 opex partial productivity was 19 per cent below its 2006 level but by 2019 had recovered to almost equal its 2006 level.

2.2 Distribution industry output and input contributions to TFP change

Having reviewed movements in individual output and input components in the preceding section, we now examine the contribution of each output and each input component to annual TFP change. Or, to put it another way, we want to decompose TFP change into its constituent parts. Since TFP change is the change in total output quantity less the change in total input quantity, the contribution of an individual output (input) will depend on the change in the output's (input's) quantity and the weight it receives in forming the total output (total input) quantity index. However, this calculation has to be done in a way that is consistent with the index methodology to provide a decomposition that is consistent and robust. In appendix A we present the methodology that allows us to decompose productivity change into the contributions of changes in each output and each input.

Figure 2.5 **Distribution industry output and input percentage point contributions to average annual TFP change, 2006–2019**



In figure 2.5 and table 2.2 we present the percentage point contributions of each output and each input to the average annual rate of TFP change of –0.8 per cent over the 14–year period 2006 to 2019. In figure 2.5 the red bars represent the percentage point contribution of each of the outputs and inputs to average annual TFP change which is given in the yellow bar at the far right of the graph. The contributions appear from most positive on the left to most negative on the right. If all the (red bar) positive and negative contributions in figure 2.5 are added together, the sum will equal the yellow bar of TFP change at the far right.

In figure 2.5 we see that the highest (ie most positive) contribution to TFP change over the 14–year period comes from ratcheted maximum demand which, despite flattening out after 2011, had the second highest average annual output growth rate over the period of 1.2 per cent. Combined with its average total revenue weight of around 39 per cent, this led to RMD contributing 0.5 percentage points to TFP change over the period.

The second highest contribution to TFP change comes from customer numbers which have grown steadily by over 1.4 per cent annually over the whole period as customer numbers generally increase in line with population growth. As customer numbers have the third largest weight of the output components at around 21 per cent and the highest growth rate of the output components, they contribute just under 0.3 percentage points to TFP change over the period.

Despite only increasing at an average annual rate of 0.3 per cent, circuit length receives a weight in total output of around 45 per cent of total revenue so it made the third highest contribution to TFP change at 0.2 percentage points.

The fourth highest contributor was improvements in customer minutes off–supply performance. The CMOS output receives a weight of around minus 15 per cent of total revenue in the total output index and, combined with an average annual change of –0.2 per cent (ie reduction in CMOS which increases output), contributed 0.1 percentage points to average annual TFP change.

Since energy throughput fell over the 14–year period at an average annual rate of –0.2 per cent and it only has a weight of less than 10 per cent of total revenue in total output, it made a marginal negative percentage point contribution to TFP change.

All six inputs made negative contributions to average annual TFP change. That is, the use of all six inputs increased over the 14–year period. Overhead subtransmission and distribution lines both have the lowest average annual input growth rates of around 1.0 per cent. Because they also have low weights in total input of 5 per cent and 15 per cent, respectively, they have the least negative and third least negative contributions, respectively, to TFP change at around zero and –0.1 percentage points. Despite having the third highest input average annual growth rate of 2.2 per cent, underground subtransmission cables only have a weight of 2 per cent in total inputs and so make the second least negative contribution to TFP change at –0.1 percentage points.

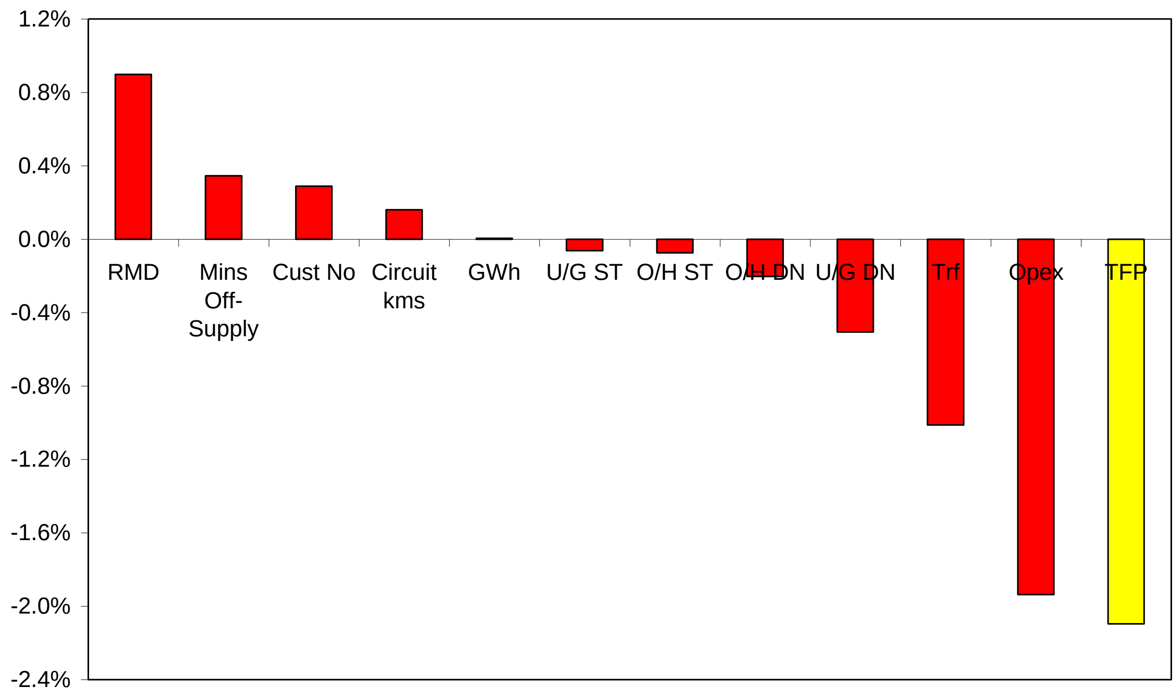
Underground distribution cables have the highest rate of average annual input growth over the period at 3.4 per cent but only get a weight of 12 per cent in the total input index. This gives them the second most negative contribution of –0.4 percentage points to TFP change.

The two inputs with the largest shares in the total input index are transformers and opex with shares of 29 per cent and 37 per cent, respectively. Since transformers have the second highest input average annual growth rate at 2.5 per cent, they make the largest negative contribution to TFP change at –0.7 percentage points. Opex has a lower average annual growth rate at 1.0 per cent but, when combined with its 37 per cent share of total inputs, it makes the third most negative contribution to TFP change at –0.4 percentage points.

Table 2.2 **Distribution industry output and input percentage point contributions to average annual TFP change: 2006–2019, 2006–2012, 2012–2019 and 2018–19**

Year	*2006 to 2019*	*2006 to 2012*	*2012 to 2019*	*2018–19*
Energy (GWh)	–0.02%	0.00%	–0.04%	0.07%
Ratcheted Max Demand	0.49%	0.90%	0.14%	0.17%
Customer Numbers	0.29%	0.29%	0.30%	0.33%
Circuit Length	0.15%	0.16%	0.15%	0.19%
CMOS	0.06%	0.35%	–0.19%	–1.29%
Opex	–0.40%	–1.94%	0.91%	0.13%
O/H Subtransmission Lines	–0.04%	–0.07%	–0.02%	0.00%
O/H Distribution Lines	–0.13%	–0.20%	–0.07%	0.01%
U/G Subtransmission	–0.05%	–0.06%	–0.04%	0.02%
U/G Distribution Cables	–0.41%	–0.51%	–0.34%	–0.29%
Transformers	–0.73%	–1.01%	–0.48%	–0.33%
TFP Change	–0.79%	–2.10%	0.33%	–0.99%

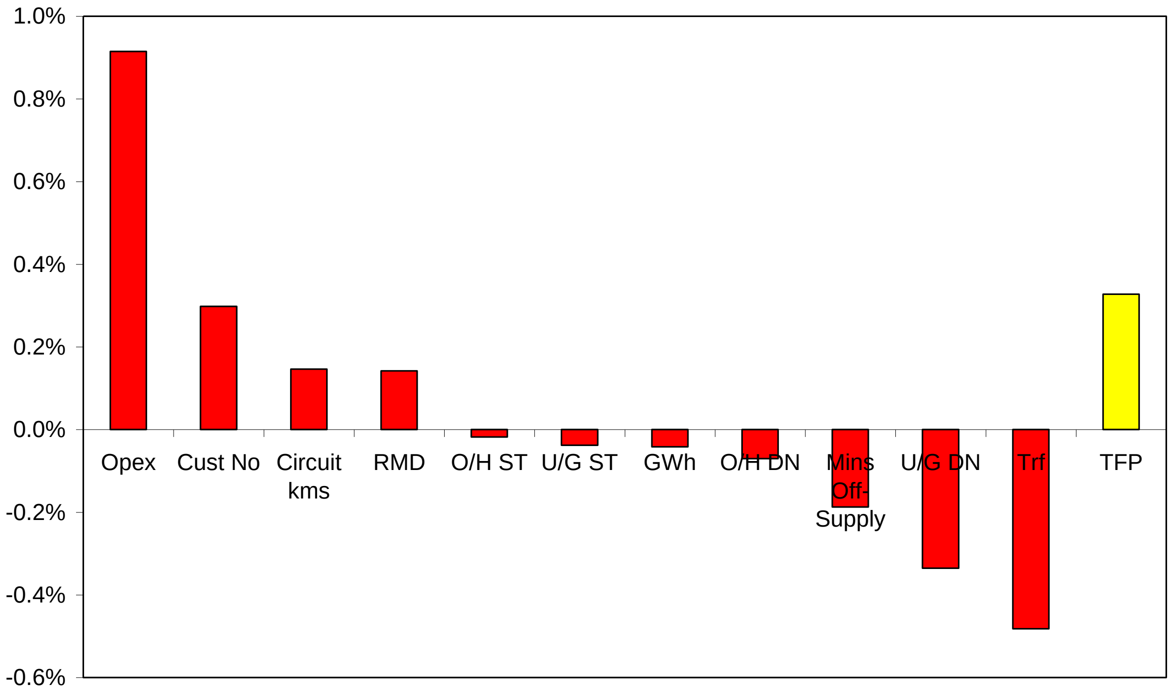
Figure 2.6 **Distribution industry output and input percentage point contributions to average annual TFP change, 2006–2012**



We next look at contributions to average annual TFP change for the period up to 2012 and then for the period after 2012. The results for the period from 2006 to 2012 are presented in figure 2.6 and table 2.2. Average annual TFP change for this period was more negative at –2.1 per cent. From figure 2.6 we can see a similar pattern of contributions to TFP change for most outputs and inputs for the period up to 2012 as for the whole period with two exceptions. The lesser of these relates to contributions from the RMD and CMOS outputs which are somewhat higher in the period up to 2012 at 0.9 percentage points and 0.4 percentage points, respectively. This coincides with the period where RMD was still increasing and CMOS was at close to its lowest point (ie most positive contribution to total output).

The most significant difference for the period up to 2012, however, relates to the contribution of opex to average annual TFP change. Opex increased rapidly from 2006 to 2012 and peaked in 2012. Its average annual growth rate over this period was a very high 5 per cent. This very high growth rate in opex likely reflects responses to meet new standards requirements, with many of those responses arguably being suboptimal, responses to changed conditions following the 2009 Victorian bushfires and lack of cost control from constraints imposed by government ownership. A detailed discussion of these issues can be found in AER (2015). This very high growth rate in the input with the highest share in total inputs made a very large negative contribution of –1.9 percentage points to average annual TFP change over this period.

Figure 2.7 **Distribution industry output and input percentage point contributions to average annual TFP change, 2012–2019**



Contributions to average annual TFP change for the period from 2012 to 2019 are presented in figure 2.7 and table 2.2. The first thing to note for this period is that average annual TFP change is now positive with a growth rate of 0.3 per cent. The most significant change relative to the earlier period is the contribution of opex to TFP change which has changed from being the most negative contributor up to 2012 to being the most positive contributor after 2012. Since 2012 opex has fallen at an average annual rate of change of –2.5 per cent. This has led to opex now making a positive contribution of 0.9 percentage points to average annual TFP change over this period. Drivers of this turnaround in opex performance include efficiency improvements in response to the AER (2015) determinations, improvements in vegetation management and preparation of some DNSPs for privatisation. The introduction of the AER's economic benchmarking program has likely also played a role.

Other contributors to improved TFP performance after 2012 are reductions in the negative contributions from transformers and underground distribution cables whose contributions to TFP change have fallen from –1.0 per cent to –0.5 percentage points and from –0.5 to –0.3 percentage points, respectively, before and after 2012. However, offsetting this have been reductions in the contributions from some outputs with RMD's contribution to average annual TFP change falling from 0.9 to 0.1 percentage points before and after 2012 and CMOS's contribution falling from 0.4 to –0.2 percentage points as RMD flattened out and reliability performance again declined somewhat. And further reductions in energy throughput turned its contribution to average annual TFP change before and after 2012 from being zero to marginally negative, respectively.

Table 2.3 **Distribution industry output and input annual changes, 2006–2019**

Year	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*
Energy	1.11%	1.52%	0.42%	0.67%	–1.92%	–1.48%	–2.92%
RMD	3.20%	3.83%	4.08%	1.24%	0.95%	0.20%	0.00%
CustomerNo	1.30%	1.32%	1.57%	1.24%	1.23%	1.19%	1.20%
Cct Length	–0.76%	–0.04%	0.97%	0.69%	0.60%	0.62%	–0.11%
CMOS	–11.0%	–0.19%	13.27%	–9.23%	–1.57%	–3.23%	–0.25%
Opex	–0.36%	13.60%	–1.33%	4.29%	5.84%	8.77%	–8.21%
O/H SubTrn	0.79%	1.04%	2.18%	2.26%	1.33%	1.80%	–0.48%
O/H Distrib	1.66%	1.50%	1.24%	1.30%	1.44%	1.00%	1.02%
U/G SubTrn	3.13%	2.01%	1.14%	3.47%	3.44%	4.36%	3.77%
U/G Distrib	5.88%	2.38%	5.79%	4.61%	3.89%	3.75%	3.47%
Transformer	4.88%	3.65%	3.93%	3.69%	2.44%	2.87%	2.55%

Year	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
Energy	–1.88%	1.10%	0.63%	–0.06%	–0.56%	0.69%
RMD	1.23%	0.06%	0.02%	0.58%	0.25%	0.43%
CustomerNo	1.13%	1.34%	1.41%	1.66%	1.61%	1.51%
Cct Length	0.42%	0.48%	0.39%	0.42%	0.27%	0.41%
CMOS	1.55%	0.56%	2.24%	–8.65%	4.71%	9.12%
Opex	1.36%	5.24%	–7.60%	–3.09%	–4.72%	–0.38%
O/H SubTrn	0.26%	1.74%	1.10%	1.44%	–1.35%	0.00%
O/H Distrib	0.19%	0.65%	0.40%	–0.04%	0.90%	–0.08%
U/G SubTrn	6.45%	–2.68%	2.85%	2.57%	–1.45%	–0.60%
U/G Distrib	3.42%	3.15%	2.62%	2.87%	2.56%	2.52%
Transformer	2.80%	1.79%	1.68%	0.38%	1.30%	1.10%

Table 2.4 **Distribution industry output and input percentage point contributions to annual TFP change, 2006–2019**

Year	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*
Energy	0.11%	0.15%	0.04%	0.06%	–0.19%	–0.15%	–0.28%
RMD	1.32%	1.53%	1.61%	0.49%	0.37%	0.07%	–0.01%
CustomerNo	0.30%	0.29%	0.33%	0.28%	0.27%	0.25%	0.25%
Cct Length	–0.34%	–0.01%	0.44%	0.32%	0.28%	0.28%	–0.05%
CMOS	2.03%	0.02%	–2.33%	1.66%	0.25%	0.45%	0.00%
Opex	0.12%	–5.19%	0.47%	–1.64%	–2.14%	–3.24%	3.07%
O/H SubTrn	–0.04%	–0.05%	–0.09%	–0.11%	–0.06%	–0.09%	0.02%
O/H Distrib	–0.25%	–0.22%	–0.18%	–0.18%	–0.22%	–0.15%	–0.16%
U/G SubTrn	–0.07%	–0.05%	–0.01%	–0.08%	–0.07%	–0.10%	–0.09%
U/G Distrib	–0.73%	–0.24%	–0.67%	–0.49%	–0.47%	–0.44%	–0.40%
Transformer	–1.31%	–1.10%	–1.06%	–1.04%	–0.72%	–0.84%	–0.77%

Year	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
Energy	–0.18%	0.11%	0.06%	0.00%	–0.06%	0.07%
RMD	0.47%	0.02%	0.02%	0.21%	0.10%	0.17%
CustomerNo	0.24%	0.28%	0.30%	0.34%	0.35%	0.33%
Cct Length	0.19%	0.21%	0.18%	0.18%	0.13%	0.19%
CMOS	–0.20%	–0.07%	–0.29%	1.14%	–0.60%	–1.29%
Opex	–0.60%	–1.95%	2.88%	1.15%	1.71%	0.13%
O/H SubTrn	–0.01%	–0.08%	–0.05%	–0.07%	0.07%	0.00%
O/H Distrib	–0.02%	–0.10%	–0.08%	0.00%	–0.14%	0.01%
U/G SubTrn	–0.14%	0.05%	–0.06%	–0.06%	0.03%	0.02%
U/G Distrib	–0.36%	–0.37%	–0.32%	–0.36%	–0.24%	–0.29%
Transformer	–0.81%	–0.48%	–0.48%	–0.17%	–0.33%	–0.33%

In tables 2.3 and 2.4, respectively, we present the annual changes in each output and each input component and their percentage point contributions to annual TFP change for each of the years 2007 to 2019. Taking 2019 as an example, the results are broadly similar to the average annual results for the period 2012 to 2019 described above, except for the contributions of opex and CMOS. Since there was a 0.4 per cent reduction in opex inputs in 2019 instead of the 2.5 per cent average annual reduction observed for the period after 2012, its percentage point contribution to TFP growth is considerably smaller at 0.1 percentage points in 2019 instead of 0.9 percentage points. CMOS, on the other hand, increased by 9.0 per cent in 2019 compared to 1.4 per cent on average for the period after 2012. This led to its contribution to TFP growth being –1.3 percentage points in 2019 compared to –0.2 on average for the period after 2012. TFP growth was itself lower in 2019 at –1.0 per cent versus an average annual rate of 0.3 per cent for the period after 2012.

3 DNSP EFFICIENCY RESULTS

In this section we present updated DNSP MTFP and MPFP results followed by an update of the econometric opex cost function models in Economic Insights (2014, 2015a,b, 2019a).

3.1 DNSP multilateral total and partial factor productivity indexes

Updated DNSP MTFP indexes are presented in figure 3.1 and table 3.1.

Figure 3.1 **DNSP multilateral total factor productivity indexes, 2006–2019**

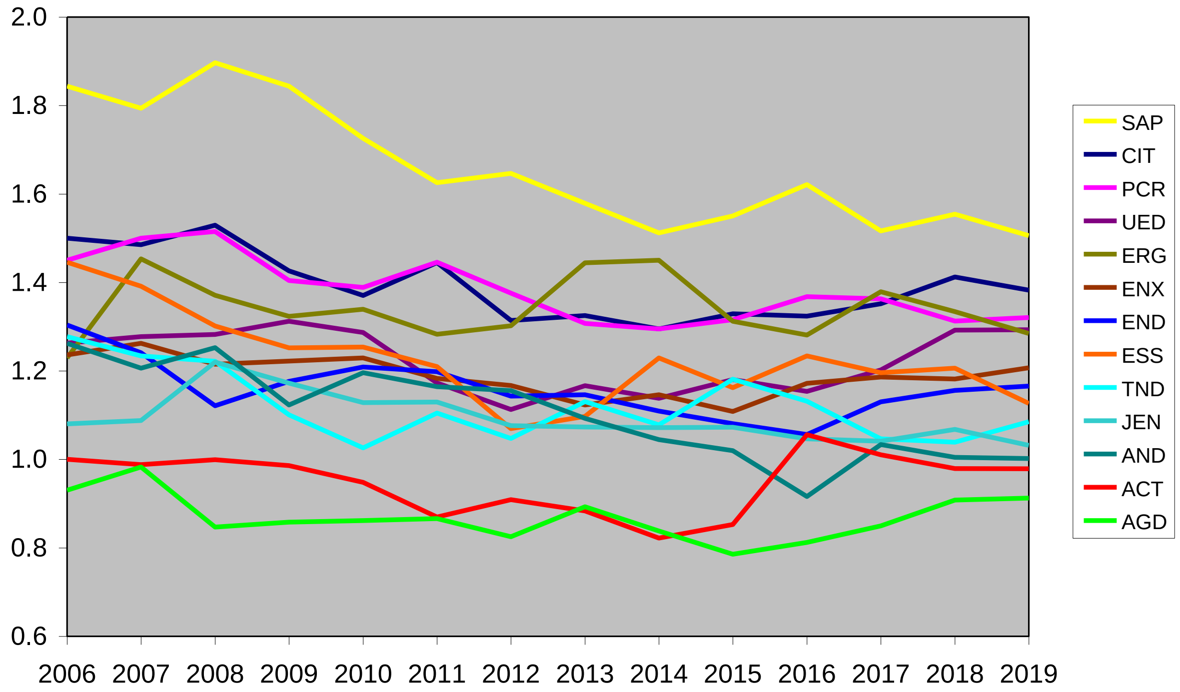


Table 3.1 **DNSP multilateral total factor productivity indexes, 2006–2019**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
ACT	1.000	0.988	0.999	0.986	0.948	0.870	0.909
AGD	0.930	0.983	0.847	0.858	0.862	0.866	0.825
AND	1.262	1.206	1.253	1.123	1.196	1.165	1.156
CIT	1.500	1.486	1.529	1.426	1.370	1.445	1.314
END	1.304	1.241	1.121	1.176	1.209	1.198	1.143
ENX	1.236	1.262	1.215	1.223	1.229	1.183	1.167
ERG	1.229	1.453	1.371	1.323	1.340	1.283	1.302
ESS	1.446	1.392	1.301	1.252	1.254	1.210	1.070
JEN	1.080	1.088	1.220	1.172	1.129	1.130	1.077
PCR	1.450	1.500	1.515	1.404	1.389	1.446	1.376
SAP	1.844	1.794	1.897	1.844	1.726	1.626	1.646
TND	1.277	1.234	1.222	1.101	1.026	1.105	1.047
UED	1.263	1.277	1.283	1.312	1.287	1.173	1.113

Table 3.1 **DNSP multilateral total factor productivity indexes, 2006–2019 (continued)**

Year	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
ACT	0.883	0.822	0.853	1.056	1.010	0.979	0.979
AGD	0.893	0.838	0.786	0.813	0.850	0.908	0.912
AND	1.093	1.045	1.020	0.916	1.034	1.005	1.002
CIT	1.325	1.295	1.329	1.324	1.352	1.412	1.383
END	1.146	1.109	1.081	1.056	1.130	1.156	1.166
ENX	1.123	1.146	1.108	1.172	1.186	1.182	1.207
ERG	1.444	1.450	1.312	1.281	1.379	1.334	1.285
ESS	1.097	1.229	1.162	1.234	1.196	1.206	1.127
JEN	1.073	1.072	1.073	1.047	1.041	1.068	1.032
PCR	1.307	1.295	1.316	1.368	1.363	1.313	1.321
SAP	1.579	1.512	1.551	1.621	1.517	1.555	1.506
TND	1.130	1.078	1.181	1.131	1.047	1.039	1.085
UED	1.167	1.138	1.181	1.154	1.202	1.292	1.293

As outlined in appendix A, MTFP and MPFP indexes allow comparisons of productivity levels as well as productivity growth to be made. For convenience, index results are presented relative to ACT in 2006 having a value of one. The results are invariant to which observation is used as the base. In figures 3.1–3.3 DNSPs are ordered in the legend according to their 2019 MTFP scores – this differs from practice in our previous reports where the legends were ordered by average scores.

In 2019 MTFP levels increased for six DNSPs and decreased for seven DNSPs. PCR, UED, ENX and END all lie in the upper half of MTFP levels and increased their productivity levels in 2019. AGD and TND also increased their MTFP levels. TND and ENX both increased their MTFP levels by more than 2 per cent in 2019. The MTFP levels of ESS, ERG, JEN and SAP all decreased by more than 3 per cent in 2019. In 2019 SAP ranked highest on MTFP levels followed by CIT, PCR, UED, ERG and ENX. In 2019 AGD ranked lowest on MTFP levels followed by ACT, AND, JEN, TND and ESS. Relative to 2018, PCR, UED, ENX, END and TND all improved their rankings by one place while the rankings of ERG and ESS both reduced by two places and JEN's ranking reduced by one place. The rankings of the other five DNSPs remained unchanged. On average, the decreases in MTFP levels in 2019 were notably larger than the increases, reflecting the TFP growth for the industry in 2019 discussed in section 2 of –1.0 per cent.

There are two main differences between the MTFP indexes presented above and those reported in Economic Insights (2019a) as a result of the revisions to the methodology made this year. The first, and much lesser, difference to note is that the reliability output plays a somewhat different role in the current MTFP scores because the AER (2019b) VCRs are somewhat larger for some DNSPs and somewhat smaller for other DNSPs than the AEMO (2014) VCRs used previously. All else equal, this will tend to decrease MTFP levels somewhat of those DNSPs whose VCR increases and who have below average reliability performance (such as ERG). Similarly, it will tend to reduce the relative MTFP levels somewhat of those DNSPs with above reliability performance whose VCRs decrease (such as ACT).

The second, and more important, difference is the use of the revised output cost weights listed in table 1.1. To understand the impact of the revised output cost weights on MTFP levels, it is useful to consider the relative output multilateral partial productivities. These are the quantity of a particular output divided by the total input quantity index. DNSPs that have a higher partial output productivity for a particular output will have a higher relative MTFP level if the revised weight for that output increases. Conversely, a DNSP’s relative MTFP level will fall if the outputs where they have the highest partial output productivities now receive less weight than previously.

Another way of thinking of the multilateral partial output productivities is that they represent the MTFP result that would apply if output were measured using only the output component in question. For example, some electricity network TFP studies have used energy throughput as the sole output measure. This may be supportable if all the networks operated in very similar operating environments and were of similar size. But, where there are a wide range of operating environments, the use of energy throughput as the output measure would tend to favour urban networks relative to rural networks. Conversely, the use of circuit length as the sole output measure would tend to favour rural networks relative to urban networks. The use of customer numbers as the sole output would tend to favour suburban networks and the use of RMD as the sole output would tend to favour networks with a high proportion of commercial and industrial customers and/or those in regions with more extreme summer (or winter) climates. It is for these reasons we use a functional output specification that includes a range of output measures and which thereby allows for differences in network density across DNSPs as part of the output specification. To look at this another way, we are effectively taking a weighted average of the five output multilateral partial productivities to form the MTFP measure where the weights are determined by our best estimates of the relative costs attributable to each of the outputs.

We present the average output multilateral partial productivities (OMPPs) for the 13 DNSPs across the five outputs in table 3.2. These output partial productivities are again based so that ACT’s 2006 output multilateral partial productivity is given a value of one. The important thing to note in table 3.2 is that a higher value for a particular output means the DNSP is an ‘intensive’ producer of that output or produces relatively more of that output per unit of total input compared to other DNSPs. There will thus be a higher relative MTFP for those DNSPs with higher OMPP values for an output if the weight on that output increases.

From table 3.2 we see that the most urbanised DNSPs (ie those with the highest numbers of customers per kilometre of line) rank the highest on both the energy and RMD OMPPs with CIT ranking top followed by UED, JEN, END and ENX and with ESS ranking lowest followed by AND, TND, ERG, PCR and SAP. From table 1.1 we see that the sums of the output weights for energy and RMD are around 40 per cent before and after correction, although the balance of weight within that total swings towards RMD and away from energy by a small amount with the correction. However, given the similarity in rankings across the energy and RMD OMPPs observed in table 3.2, this rebalancing of weight between the energy and RMD outputs is unlikely to have a major impact on MTFP rankings.

This is not the case, however, for the customer numbers and circuit length outputs for two reasons. Firstly, there is a larger rebalancing of weight of around 12 percentage points away from customer numbers and towards circuit length. And, there are substantial differences in rankings across the customer number and circuit length OMPPs. As expected, the urban and suburban DNSPs of CIT, UED, JEN and ENX rank highest on the customer numbers OMPP while the rural DNSPs of ERG and ESS rank lowest along with TND, ACT and AGD. The opposite is largely the case for the circuit length OMPP where the DNSPs with significant rural coverage such as ESS, ERG, SAP, PCR and AND rank highest and the urbanised DNSPs such as CIT, AGD, ACT, JEN and UED rank lowest. The revised output weights will thus tend to increase the relative MTFP levels of the most rural DNSPs such as ERG and ESS while reducing the relative MTFP levels of urbanised DNSPs such as CIT, ENX, JEN, and UED.

For those DNSPs that have mid–range rankings on both the customer numbers and circuit length OMPPs – such as AND and END – the reallocation of weight between the customer number and circuit length outputs will have little impact.

Since the revised output weights affect only the construction of the total output index in the productivity calculations, the same explanations as outlined above will apply to changes in relative opex MPFP and capital MPFP levels between this report and the corresponding indexes reported in Economic Insights (2019a).

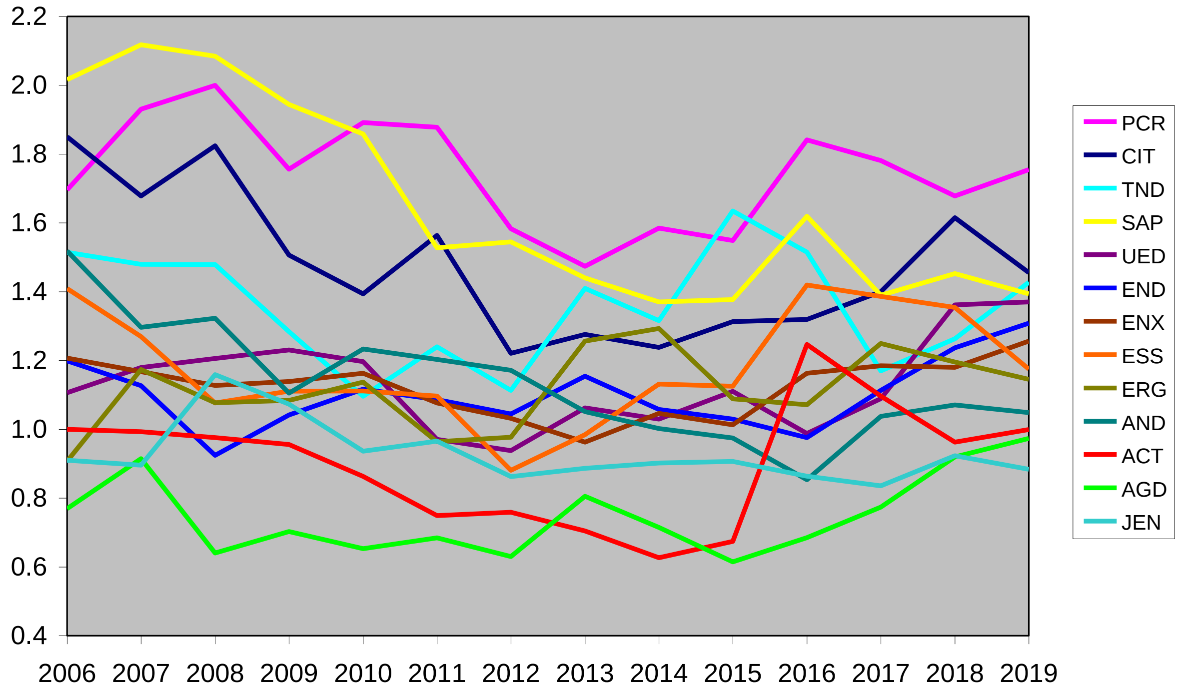
Table 3.2 **DNSP average output multilateral partial productivity indexes, 2006–2019**

Year	*Energy throughput*	*Ratcheted max. demand*	*Customer numbers*	*Circuit length*	*Customer mins off–supply*
ACT	0.911	0.942	0.988	0.954	0.952
AGD	1.002	1.004	1.040	0.856	2.419
AND	0.715	0.772	1.123	2.416	4.935
CIT	1.920	2.016	1.824	0.815	1.313
END	1.134	1.198	1.102	1.389	2.771
ENX	1.070	1.121	1.210	1.523	2.823
ERG	0.772	0.780	0.705	5.089	5.843
ESS	0.568	0.558	0.706	5.297	4.621
JEN	1.185	1.193	1.573	0.996	2.524
PCR	0.832	0.850	1.051	3.444	4.050
SAP	0.872	1.091	1.199	4.168	5.102
TND	0.769	0.887	0.866	2.314	3.978
UED	1.187	1.360	1.744	1.144	2.965

MTFP levels are an amalgam of opex MPFP and capital MPFP levels. Updated opex MTFP indexes are presented in figure 3.2 and table 3.3 while updated capital MPFP indexes are presented in figure 3.3 and table 3.4.

From figure 3.2 we see four DNSPs – TND, ENX, END, and AGD – increased their 2019 opex MPFP levels by 5 per cent or more. The first these, TND, increased its opex MPFP level by 13 per cent. And PCR and ACT increased their opex MPFP levels by more than 3 per cent while that of UED increased by less than 1 per cent. The opex MPFP levels of five DNSPs – CIT, ESS, ERG, JEN and SAP – fell by more than 4 per cent in 2019 with that of ESS falling by more than 13 per cent. AND's opex MPFP fell in 2019 by more than 2 per cent.

Figure 3.2 **DNSP multilateral opex partial productivity indexes, 2006–2019**



PCR ranked highest in terms of opex MPFP levels in 2019 followed by CIT, TND and SAP. JEN ranked lowest in terms of opex MPFP levels in 2019 followed by AGD, ACT and AND. TND improved its opex MPFP ranking by three places in 2019 to third while ENX improved its ranking by two places to seventh. ESS's opex MPFP ranking fell by three places in 2019 to eighth.

Table 3.3 **DNSP multilateral opex partial productivity indexes, 2006–2019**

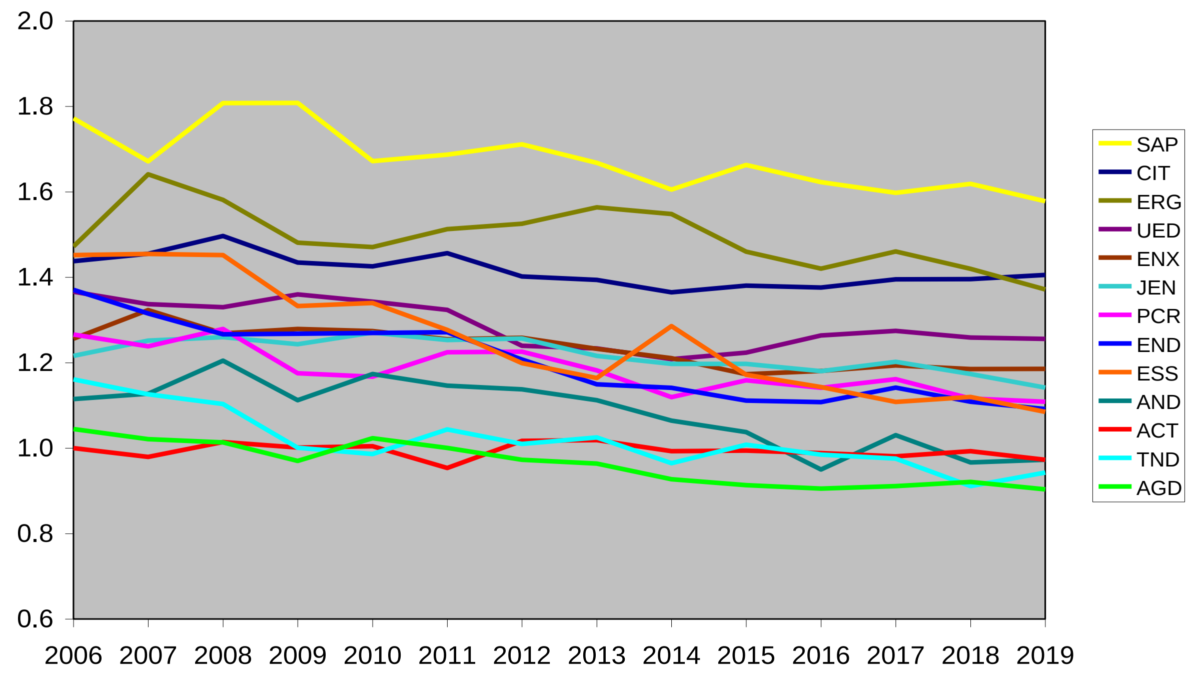
Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
ACT	1.000	0.993	0.976	0.956	0.863	0.749	0.759
AGD	0.769	0.914	0.640	0.703	0.653	0.684	0.630
AND	1.518	1.296	1.323	1.105	1.234	1.203	1.172
CIT	1.850	1.678	1.824	1.506	1.394	1.563	1.221
END	1.199	1.127	0.924	1.042	1.116	1.086	1.044
ENX	1.207	1.167	1.127	1.139	1.163	1.077	1.032
ERG	0.907	1.174	1.077	1.084	1.137	0.964	0.977
ESS	1.409	1.269	1.076	1.111	1.111	1.096	0.881
JEN	0.910	0.896	1.159	1.073	0.936	0.966	0.863
PCR	1.696	1.931	2.000	1.756	1.892	1.878	1.583
SAP	2.016	2.117	2.085	1.944	1.859	1.527	1.544
TND	1.514	1.479	1.479	1.284	1.096	1.240	1.113
UED	1.106	1.180	1.206	1.231	1.197	0.971	0.938

Table 3.3 **DNSP multilateral opex partial productivity indexes, 2006–2019 (cont'd)**

Year	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
ACT	0.705	0.627	0.674	1.247	1.097	0.962	0.999
AGD	0.805	0.715	0.615	0.685	0.774	0.920	0.974
AND	1.052	1.002	0.975	0.853	1.037	1.071	1.048
CIT	1.276	1.238	1.313	1.319	1.400	1.615	1.456
END	1.154	1.058	1.030	0.976	1.113	1.237	1.308
ENX	0.962	1.046	1.013	1.163	1.185	1.180	1.257
ERG	1.256	1.293	1.089	1.071	1.250	1.195	1.145
ESS	0.984	1.132	1.125	1.419	1.386	1.354	1.175
JEN	0.886	0.902	0.906	0.864	0.836	0.923	0.884
PCR	1.474	1.585	1.549	1.841	1.781	1.678	1.755
SAP	1.440	1.370	1.377	1.619	1.389	1.453	1.393
TND	1.410	1.316	1.635	1.515	1.170	1.263	1.428
UED	1.062	1.029	1.110	0.988	1.089	1.362	1.370

As noted in section 1, in comments on our draft report, ACT noted that its opex MPFP level in 2019 would have been higher were it not for the transfer of responsibility to it for vegetation management on unleased land in urban areas of the Territory in July 2018 and associated attendance to accumulated foliage defects affecting lines passing over that land.

Figure 3.3 **DNSP multilateral capital partial productivity indexes, 2006–2019**



From figure 3.3 and table 3.4 we can see that movements in capital MPFP levels have been much more modest, as is to be expected given the largely sunk and long–lived nature of DNSP capital assets. Four DNSPs improved their capital MPFP levels in 2019 with one of these – TND – being by more than 3 per cent. The other three had increases of less than 1 per cent. Of the nine DNSPs with reductions in capital MPFP levels in 2019, two of these – ERG and ESS – had reductions of 3 per cent or more while another three – JEN, SAP and ACT – had reductions of more than 2 per cent. SAP, CIT, ERG and UED ranked highest on capital MPFP while AGD ranked lowest followed by TND, ACT and AND. The ranking of ESS reduced two places to ninth in 2019.

Table 3.4 **DNSP multilateral capital partial productivity indexes, 2006–2019**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
ACT	1.000	0.980	1.015	1.001	1.005	0.954	1.017
AGD	1.045	1.021	1.014	0.970	1.023	1.001	0.973
AND	1.115	1.128	1.205	1.112	1.174	1.146	1.138
CIT	1.438	1.455	1.497	1.434	1.426	1.457	1.402
END	1.371	1.315	1.267	1.268	1.270	1.271	1.208
ENX	1.256	1.323	1.269	1.279	1.274	1.255	1.258
ERG	1.472	1.641	1.581	1.481	1.471	1.513	1.525
ESS	1.452	1.455	1.452	1.333	1.340	1.277	1.199
JEN	1.216	1.252	1.260	1.243	1.271	1.253	1.257
PCR	1.266	1.238	1.279	1.175	1.167	1.224	1.226
SAP	1.772	1.671	1.808	1.808	1.672	1.687	1.711
TND	1.161	1.126	1.103	1.001	0.986	1.044	1.010
UED	1.366	1.337	1.330	1.360	1.343	1.324	1.240

Year	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
ACT	1.019	0.993	0.994	0.989	0.981	0.993	0.973
AGD	0.964	0.927	0.914	0.905	0.911	0.921	0.903
AND	1.112	1.065	1.038	0.950	1.031	0.967	0.973
CIT	1.394	1.365	1.381	1.376	1.395	1.396	1.405
END	1.149	1.141	1.111	1.108	1.142	1.109	1.092
ENX	1.233	1.210	1.173	1.181	1.194	1.185	1.186
ERG	1.564	1.548	1.460	1.420	1.461	1.420	1.371
ESS	1.164	1.286	1.172	1.143	1.108	1.120	1.085
JEN	1.216	1.197	1.197	1.180	1.202	1.174	1.142
PCR	1.182	1.119	1.159	1.141	1.162	1.117	1.109
SAP	1.668	1.606	1.663	1.623	1.598	1.619	1.578
TND	1.025	0.965	1.008	0.985	0.976	0.911	0.943
UED	1.233	1.208	1.224	1.264	1.274	1.259	1.256

3.2 Econometric opex cost function efficiency scores

In this report we further update the models in Economic Insights (2019a) to include data for 2018–19 (or 2019, as relevant) for the Australian and New Zealand DNSPs and 2018 data for the Ontario DNSPs.

The econometric cost function models produce average opex efficiency scores for the period over which the models are estimated. As noted in section 1.2, four three–output opex cost function models are estimated for this report:

- a least squares econometrics model using the Cobb–Douglas functional form (LSECD)

- a least squares econometrics model using the more flexible translog functional form (LSETLG)
- a stochastic frontier analysis model using the Cobb–Douglas functional form (SFACD), and
- a stochastic frontier analysis model using the translog functional form (SFATLG).

We present the average opex efficiency scores for two periods – 2006 to 2019 and 2012 to 2019 – in this section. The corresponding regression results are presented in appendix B.

Satisfying the property of monotonicity is an important requirement for estimated cost functions. This property requires that an increase in output can only be achieved with an increase in cost. Cobb-Douglas models assume constant output elasticities and if the estimated output coefficients are greater than zero then monotonicity is satisfied. For translog models, we need to check not only the sign of the estimated first–order coefficient for each output (which is the output's elasticity at the mean of the sample used for normalisation), but also the estimated output elasticity for each observation as the models assume varying output elasticities.

In earlier modelling the SFATLG model has not performed well on this property for the period from 2006 onwards. With the current data updates, the SFATLG model still has monotonicity violations for three DNSPs for the full period. Its results are not included in the average efficiency scores for the two of these DNSPs which have violations for more than half their number of observations. No monotonicity violations are present for the LSETLG model for the full period. However, for the period from 2012 onwards, the SFATLG and LSETLG models each present monotonicity violations for five DNSPs for all their observations and their results are excluded for these DNSPs when forming an overall average efficiency score across models for the shorter period.[8]

Opex efficiency scores for each of the 13 National Electricity Market (NEM) DNSPs across the 14–year period 2006 to 2019 for the four opex cost function models and, for comparison, opex MPFP are presented in figure 3.4 and table 3.5. Average opex efficiency scores across the five economic benchmarking models are presented in figure 3.5 and table 3.5.

The opex efficiency scores in figures 3.4 and 3.5 fall into three distinct groups. Six DNSPs – PCR, CIT, SAP, UED, TND and AND – form the top performing group with average efficiency scores at or above 0.7. Another five DNSPs – ESS, ENX, ERG, END and JEN – form the middle performing group with average efficiency scores between 0.55 and 0.66. And the remaining two DNSPs – ACT and AGD – form the low performing group for the period as a whole with average opex efficiency scores between 0.4 and 0.5.

These results are broadly similar to the corresponding results presented in Economic Insights (2019, p.22) for the period up to 2018. If the averages of the same four econometric models presented for this period in Economic Insights (2019a) are compared, there have been upward movements in average performance of more than one percentage point for three DNSPs – ACT, ERG and TND.

Efficiency scores across the four econometric models are broadly similar. The SFATLG model produces slightly higher scores than the SFACD model for nine DNSPs. We note that

[8] In Economic Insights (2019) the LSETLG model had monotonicity violations for three DNSPs for the short period.

the LSETLG model produces noticeably lower efficiency scores for CIT, JEN and UED compared to the other cost function models but there are no monotonicity issues present. There are, however, monotonicity violations for the SFATLG model for two of these DNSPs and that model produces higher scores for them than the other models.

Figure 3.4 **DNSP opex cost efficiency scores, 2006–2019**

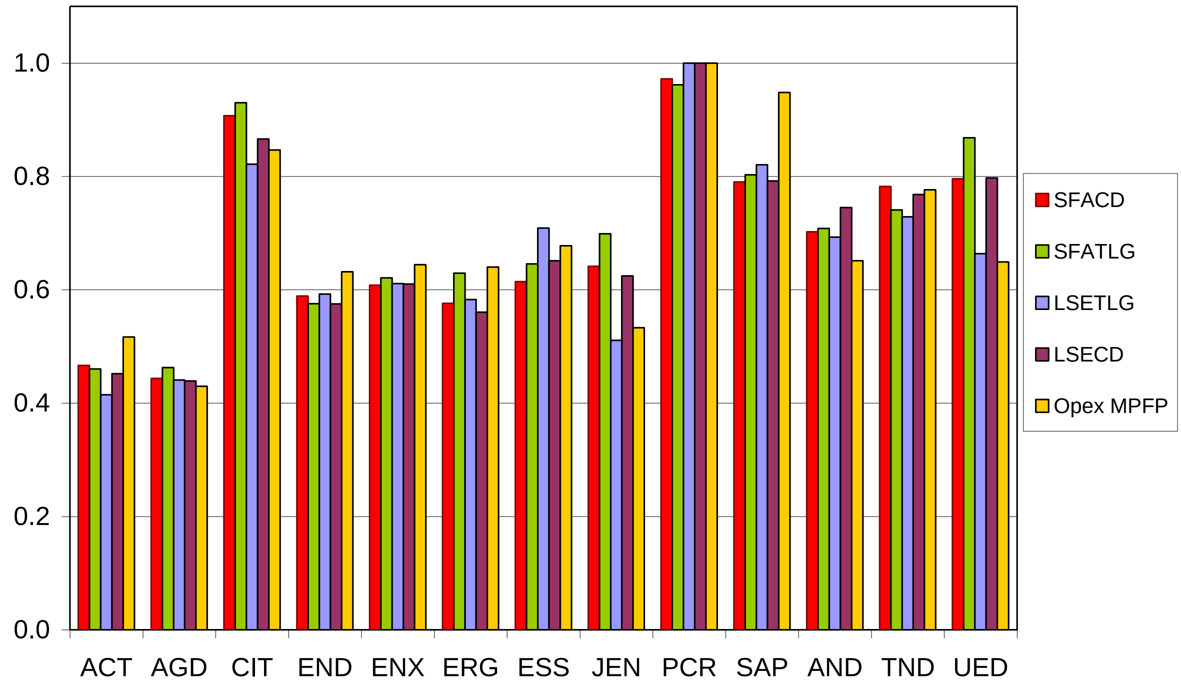
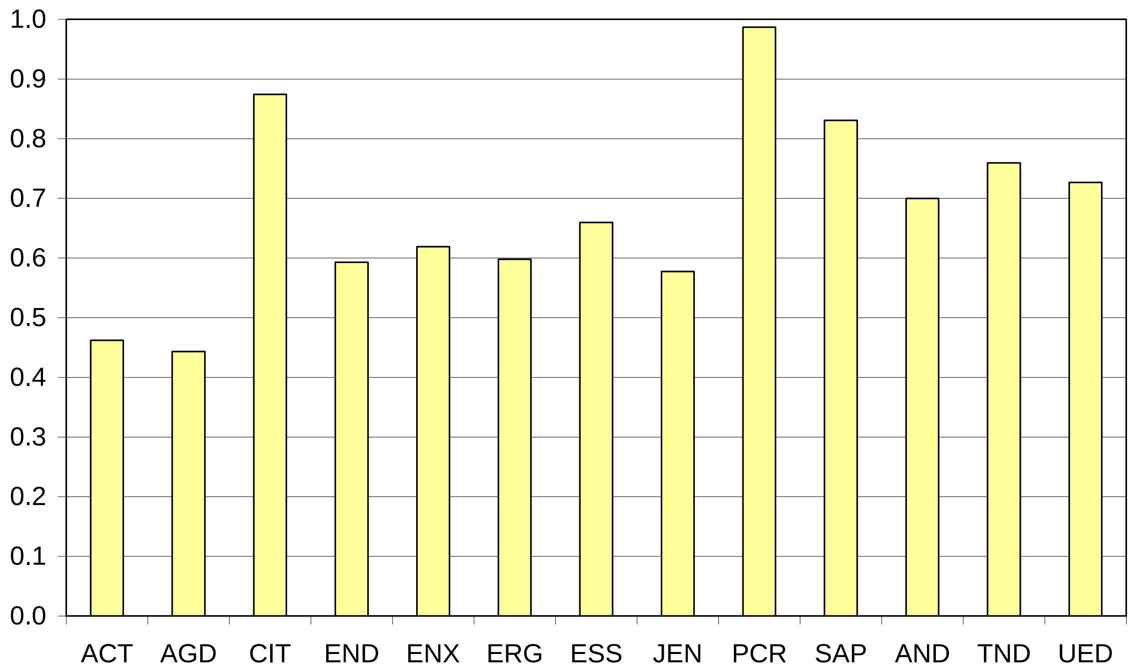


Figure 3.5 **DNSP opex cost efficiency scores, 2006–2019, average of models**



The opex MPFP efficiency scores are consistent with the range of scores for the four cost function models but are somewhat higher than the opex cost function efficiency score range for ACT, END, ENX, ERG and SAP, and somewhat below the range for AGD, AND and UED. Relative to the opex cost function models, the opex MPFP model includes an additional two outputs – energy and reliability – but excludes the impact of undergrounding.

Table 3.5 **DNSP average opex cost efficiency scores, 2006–2019**

DNSP	*SFACD*	*SFATLG*	*LSETLG*	*LSECD*	*Opex MPFP*	*Average*
ACT	0.466	0.460	0.415	0.452	0.517	0.462
AGD	0.444	0.463	0.441	0.439	0.430	0.443
CIT	0.907	0.930	0.822	0.866	0.847	0.874
END	0.589	0.575	0.592	0.575	0.632	0.593
ENX	0.608	0.621	0.611	0.610	0.644	0.619
ERG	0.576	0.629	0.583	0.560	0.640	0.598
ESS	0.614	0.646	0.709	0.651	0.678	0.659
JEN	0.642	0.699	0.511	0.624	0.533	0.577*
PCR	0.972	0.962	1.000	1.000	1.000	0.987
SAP	0.790	0.803	0.820	0.792	0.948	0.831
AND	0.702	0.708	0.693	0.745	0.651	0.700
TND	0.782	0.741	0.729	0.768	0.776	0.759
UED	0.796	0.868	0.664	0.797	0.649	0.726*

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

As noted in section 1.4, in Economic Insights (2020b) we agreed there was some merit in normalising output variables in the opex cost function database by the respective means of the Australian sample rather than the means of the entire three–country sample (as suggested by FE 2019). This change would only affect the first–order output coefficients in the translog models (which reflect the mean output elasticities for the relevant sample used for normalisation). It would have no impact on either the efficiency scores of any of the models or on their statistical performance. While we now consider it is best to delay making this change given the monotonicity performance of the updated translog models, it is instructive to examine the average output elasticities produced by the models for each of the three countries in the sample and for the sample as a whole. These average output elasticities are presented in table 3.6.

Table 3.6 **Average DNSP output elasticities by country and overall, 2006–2019**

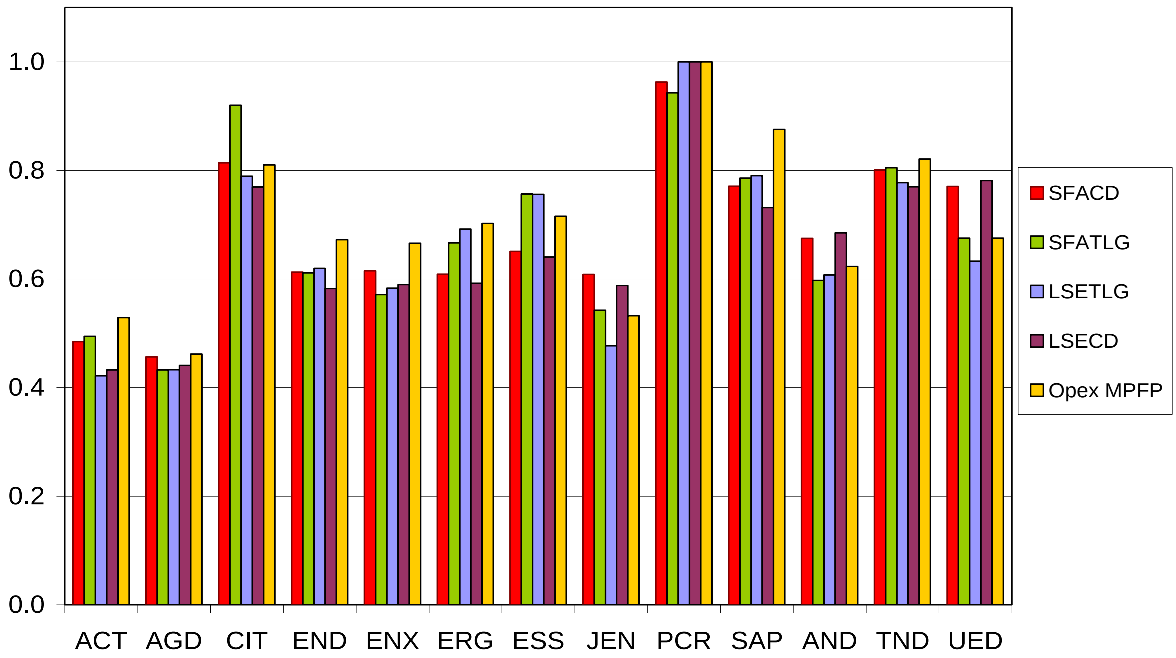
	SFATLG model			*LSETLG model*		
Sample	*Customer numbers*	*Circuit length*	*RMD*	*Customer numbers*	*Circuit length*	*RMD*
Australia	0.683	0.143	0.183	0.379	0.234	0.433
New Zealand	0.429	0.187	0.372	0.684	0.202	0.046
Ontario	0.626	0.112	0.229	0.402	0.110	0.439
Full sample	0.581	0.139	0.260	0.477	0.160	0.327

For the SFATLG model the overall sample's average customer number's output elasticity is 0.58 while it is slightly higher at 0.68 for the Australian sample. The Australian sample's average circuit length output elasticity is around the same as than for the overall sample at 0.14. And the Australian sample's average RMD output elasticity is slightly smaller than for the overall sample at 0.18 compared to 0.26.

For the LSETLG model the overall sample's average customer number's output elasticity is 0.48, somewhat lower than that for the SFATLG model, while it is somewhat lower again at 0.38 for the Australian sample. The Australian sample's average circuit length output elasticity is somewhat higher than for the overall sample at 0.23 compared to 0.16. And the Australian sample's average RMD output elasticity is also somewhat higher than for the overall sample at 0.43 compared to 0.33.

We turn now to the opex efficiency scores from the more recent period, 2012 to 2019. Opex efficiency scores for each of the 13 NEM DNSPs across the 8–year period for the four opex cost function models and opex MPFP are presented in figure 3.6 and table 3.7. Average opex efficiency scores across the five economic benchmarking models for the 8–year period are presented in figure 3.7 and table 3.7.

Figure 3.6 **DNSP opex cost efficiency scores, 2012–2019**



From figures 3.6 and 3.7 we see that there are still three reasonably distinct efficiency groups although AND has moved from the top group into the middle group. Compared to corresponding average scores across the models for the full time period, average scores improve by one percentage point or more for seven DNSPs – ERG, ESS, TND, END, UED, ACT and AGD – reflecting improved relative performance. On the other hand, compared to the full time period, corresponding average scores across the models decline by more than one percentage point for three DNSPs – AND, CIT and SAP – reflecting a relative worsening in performance.

Figure 3.7 **DNSP opex cost efficiency scores, 2012–2019, average of models**

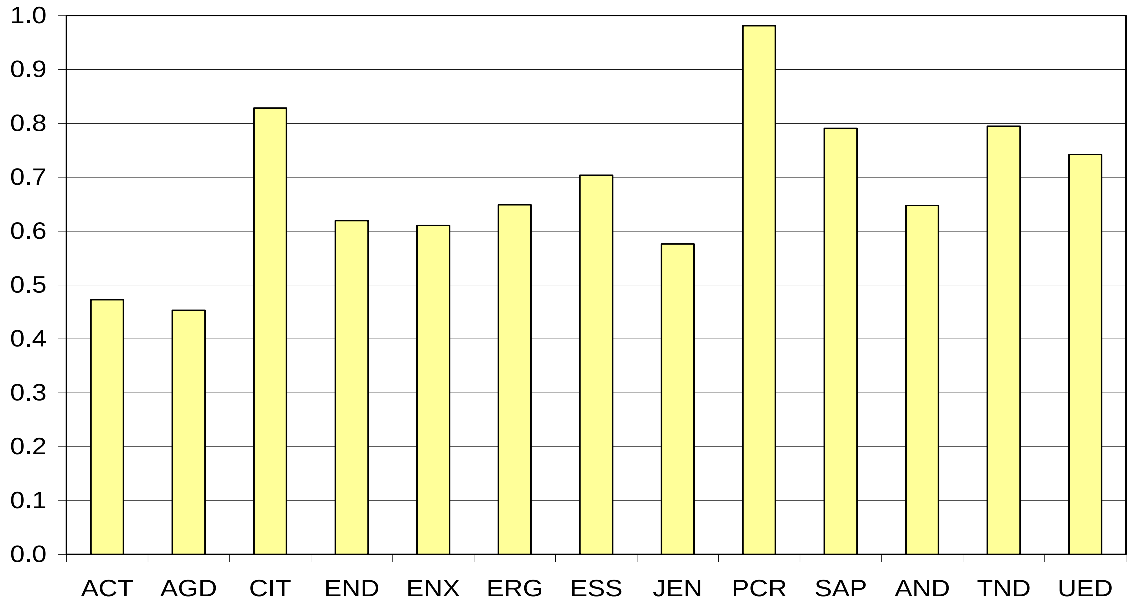


Table 3.7 **DNSP average opex cost efficiency scores, 2012–2019**

DNSP	*SFACD*	*SFATLG*	*LSETLG*	*LSECD*	*Opex MPFP*	*Average*
ACT	0.485	0.494	0.422	0.433	0.529	0.472
AGD	0.457	0.432	0.433	0.441	0.462	0.453*
CIT	0.814	0.920	0.789	0.769	0.810	0.828^
END	0.612	0.611	0.619	0.582	0.672	0.620
ENX	0.615	0.571	0.583	0.590	0.666	0.610^
ERG	0.609	0.666	0.692	0.592	0.702	0.649^
ESS	0.651	0.756	0.756	0.640	0.715	0.704
JEN	0.608	0.542	0.477	0.588	0.532	0.576*
PCR	0.963	0.943	1.000	1.000	1.000	0.981
SAP	0.771	0.786	0.790	0.732	0.875	0.791
AND	0.675	0.597	0.607	0.685	0.623	0.648^
TND	0.801	0.805	0.777	0.770	0.821	0.795
UED	0.771	0.675	0.633	0.781	0.675	0.742*

* Average exclude SFATLG and LSETLG as monotonicity requirement violated for these DNSPs using these models.

^ SFATLG excluded for ERG and AND and LSETLG excluded for CIT and ENX due to monotonicity violations.

To fully understand these movements in relative performance, it is important to recognise that they are period averages for each DNSP. It is instructive to refer back to figure 3.2 which shows the annual movements in opex MPFP over the whole period. Although the opex MPFP model has a broader inclusion of outputs and different output weights, it will still provide a good guide to interpreting the opex cost function efficiency score movements. Two patterns of movements in the annual scores are noteworthy.

Firstly, there has been a general upward movement in opex productivity since 2012. This means that although the performance of a DNSP may be improving in absolute terms since

2012, the performance of the leading DNSPs has also improved leading to little change in relative performance. Taking ENX as an example, its average efficiency score decreased marginally between the full period and the more recent period. However, its opex MPFP has grown at an average annual rate of 2.8 per cent since 2012. But offsetting this, of the two leading DNSPs, CIT's opex MPFP has grown at an average rate of 2.5 per cent and PCR's has grown at 1.4 per cent since 2012. Thus, a DNSP can be improving its opex productivity at a reasonable rate while its relative opex efficiency increases much less. In other words, a DNSP has to effectively 'run to stand still'.

The second noteworthy pattern is that the average efficiency scores of some of the leading DNSPs can fall over time despite them having strong opex productivity growth since 2012. Taking CIT as an example, its average score fell by more than 4 percentage points in the recent period compared to the full period despite having had high average annual opex productivity growth in the recent period. This is because its opex productivity levels had been higher for most of the period before 2012 compared to the period after 2012. Hence, its post 2012 average productivity level will be lower than its full period average level and its period average efficiency score will have fallen.

Another variation of this effect is AND. Despite having had relatively high productivity growth in 2017, it is yet to regain its 2012 productivity level and its 2012 productivity level was lower than for all but one of the years prior to 2012. Thus, despite impressive productivity growth in some years, its opex efficiency score has declined for the recent 8–year period compared to the full 14–year period by 5 percentage points.

And the third noteworthy effect is the converse of the second. Despite having had large productivity falls in the most recent few years, a DNSP's efficiency score can still improve for the post 2012 period compared to the full period. Taking ACT as an example, its opex productivity fell at an average annual rate of 13 per cent over 2017 and 2018. But its average opex efficiency score still increased by 1 percentage point for the post 2012 period compared to the full period. This is due to its large productivity jump in 2016 which has kept its average productivity level for the period from 2012 onwards higher than its average for the period before 2012, despite large falls in 2017 and 2018. In a regulatory context, performance changes between the average of the period and the end of the period, whether they be improvements or worsening, are allowed for in the efficient opex target roll–forward mechanism applied in Economic Insights (2014a).

Turning to the comparison of model scores, the four opex cost function models generally produce broadly similar efficiency scores for the post 2012 period although the two translog models now produce more pronounced higher opex efficiency scores for the two sparsest DNSPs – ESS and ERG – compared to the corresponding Cobb Douglas models.

Opex MPFP efficiency scores lie above the range of the cost function efficiency scores for the same five DNSPs as in the full sample – ACT, END, ENX, ERG and SAP – plus TND. They do not lie below the cost function range for any of the DNSPs. The inclusion of reliability in the opex MPFP efficiency scores will explain part of the better performance of these DNSPs. While volatile, PCR's customer minutes off supply has generally trended up over the period more than for the other DNSPs. This would tend to narrow the gap in average efficiency scores when reliability is allowed for.

4 STATE–LEVEL DISTRIBUTION PRODUCTIVITY RESULTS

In this section we present MTFP and opex MPFP results for each of the NEM jurisdictions before analysing outputs, inputs and drivers of productivity change for each jurisdiction.

4.1 State–level distribution MTFP and opex MPFP indexes

Figure 4.1 **State–level DNSP multilateral TFP indexes, 2006–2019**

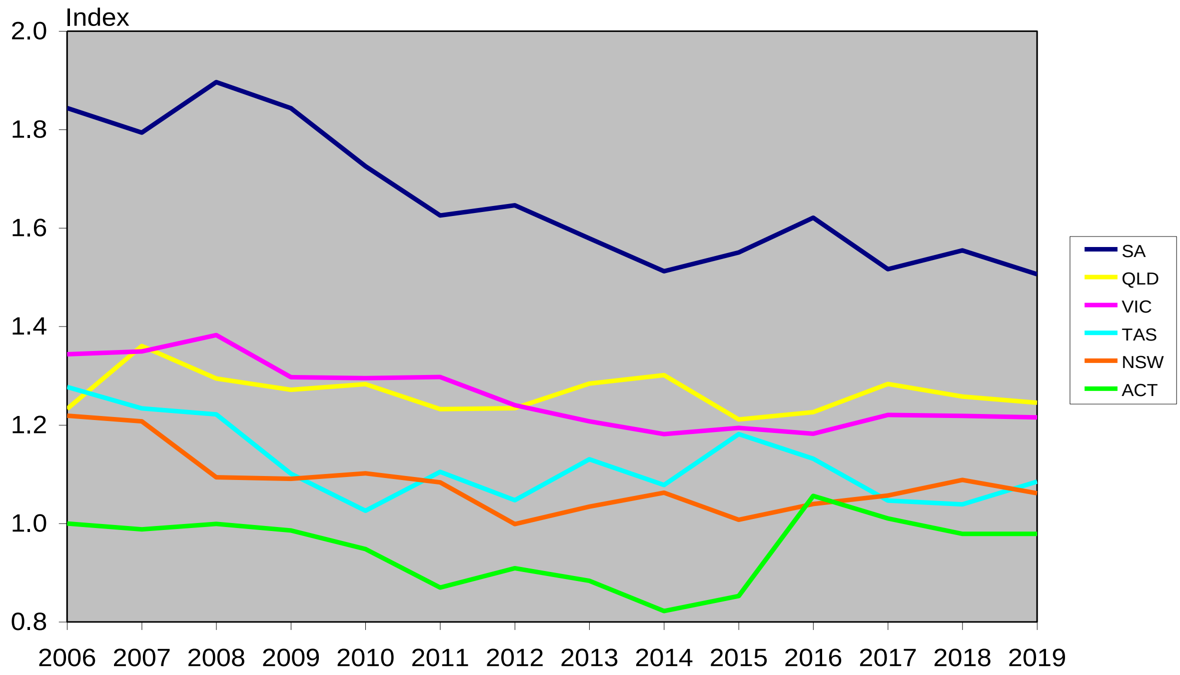
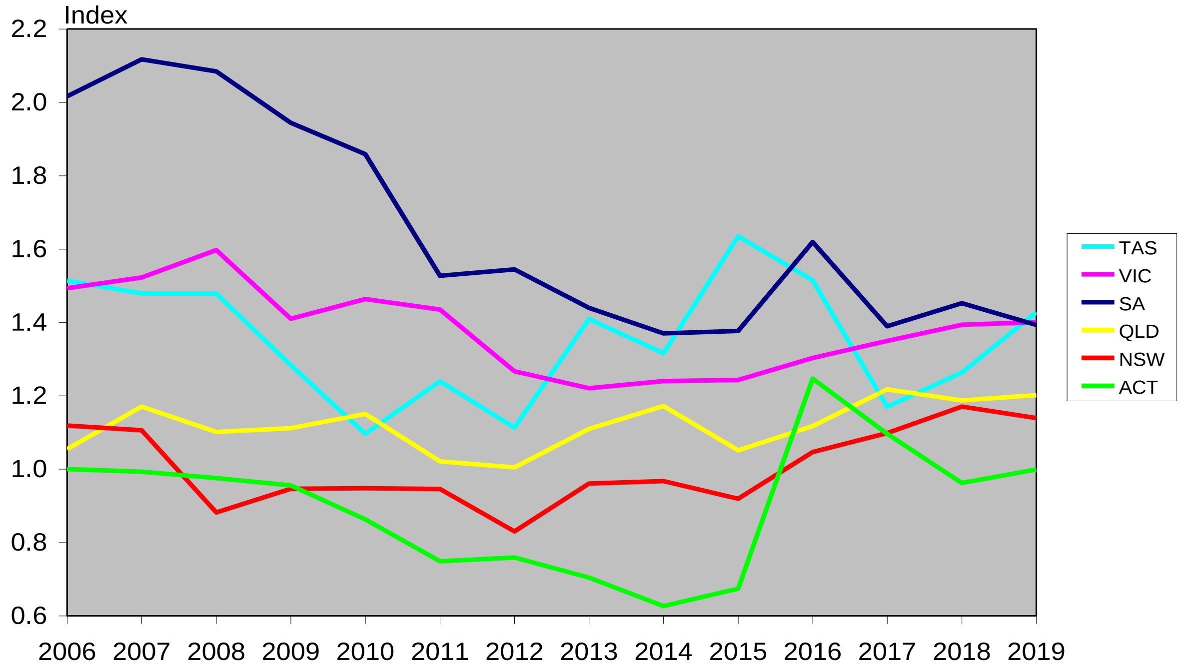


Figure 4.2 **State–level DNSP multilateral opex PFP indexes, 2006–2019**



State–level MTFP indexes are presented in figure 4.1. The revised output weights have led to Queensland's MTFP level increasing relative to Victoria given the increased weight on circuit length and reduced weight on customer numbers. Similarly, NSW's and Tasmania's MTFP levels have increased somewhat relative to the ACT. In 2019 South Australia had the highest MTFP level by a relatively wide margin followed by Queensland being in second place, marginally ahead of Victoria. Tasmania was then in fourth place, marginally ahead of NSW with the ACT having the lowest MTFP level. Tasmania's MTFP increased by 4.5 per cent in 2019 while MTFP fell by more than 1 per cent for South Australia, Queensland and NSW. MTFP remained relatively unchanged for the ACT and Victoria in 2019.

Opex MPFP levels are shown in figure 4.2. Tasmania's opex MPFP grew by a large 12.2 per cent in 2019 leading to it overtaking South Australia and Victoria for top position. South Australia's opex MPFP fell by 4.2 per cent and Victoria's opex MPFP grew by 0.5 per cent in 2019. There was then a larger gap to Queensland lying in fourth place on opex MPFP after achieving growth of 1.2 per cent. NSW was in fifth place following change in opex MPFP of –2.7 per cent in 2019. With the reweighting of outputs towards circuit length and away from customer numbers, the ACT remained in sixth position on opex MPFP despite relatively strong growth of 3.7 per cent in 2019.

4.2 State–level distribution outputs, inputs and productivity change

4.2.1 Australian Capital Territory

The Australian Capital Territory (ACT) is the smallest of the NEM jurisdictions and is served by one DNSP, Evoenergy (formerly ActewAGL). In 2019 ACT delivered 2,886 GWh to 198,432 customers over 5,435 circuit kilometres of lines and cables.

ACT productivity performance

ACT's total output, total input and TFP indexes are presented in figure 4.3 and table 4.1.

Figure 4.3 **ACT output, input and total factor productivity indexes, 2006–2019**

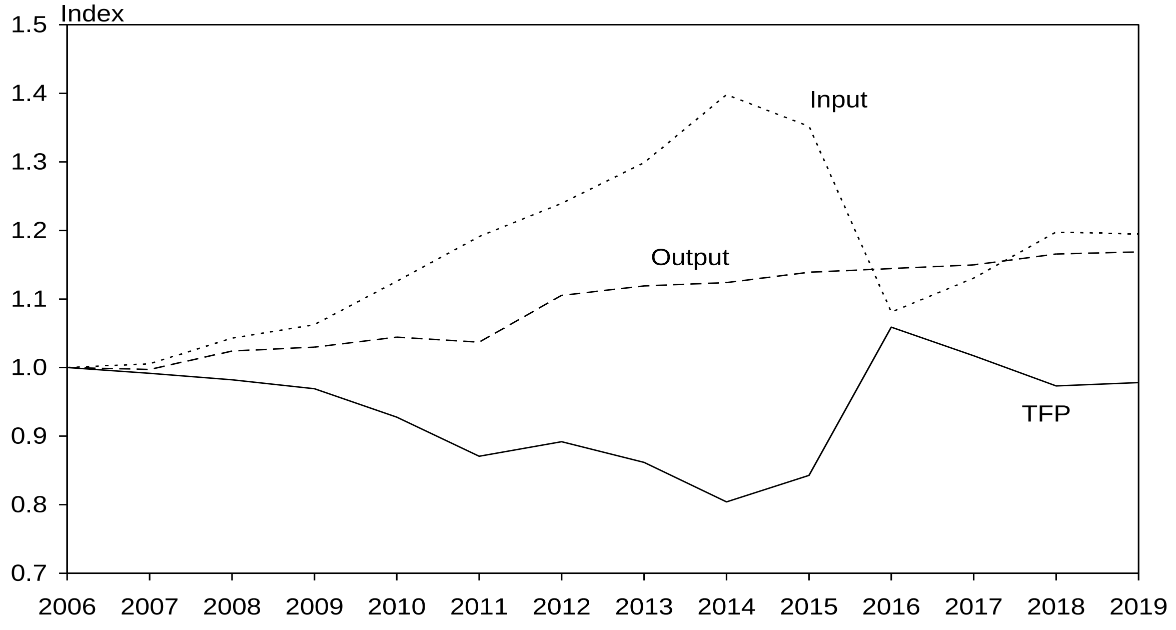


Table 4.1 **ACT output, input and total factor productivity and partial productivity indexes, 2006–2019**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index Opex*	*PFP Index Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	0.997	1.006	0.992	1.001	0.983
2008	1.024	1.043	0.982	0.965	0.993
2009	1.030	1.062	0.969	0.952	0.979
2010	1.044	1.126	0.928	0.856	0.977
2011	1.037	1.191	0.871	0.763	0.949
2012	1.105	1.239	0.892	0.760	0.992
2013	1.119	1.299	0.862	0.703	0.988
2014	1.124	1.398	0.804	0.624	0.973
2015	1.139	1.352	0.843	0.679	0.980
2016	1.144	1.081	1.059	1.258	0.975
2017	1.150	1.130	1.017	1.114	0.974
2018	1.166	1.198	0.973	0.969	0.977
2019	1.169	1.195	0.978	1.010	0.961
Growth Rate 2006–19	1.20%	1.37%	–0.17%	0.08%	–0.31%
Growth Rate 2006–12	1.67%	3.58%	–1.91%	–4.56%	–0.13%
Growth Rate 2012–19	0.80%	–0.52%	1.32%	4.05%	–0.46%

Over the 14–year period 2006 to 2019, ACT's average annual rate TFP change was –0.2 per cent. TFP levels had fallen 20 per cent between 2006 and 2014 and then increased by 23 per cent in 2016 before falling back by 4 per cent in each of 2017 and 2018 before increasing by 0.5 per cent in 2019. Total output increased steadily over the period at an average annual rate of 1.2 per cent, somewhat higher than the industry average rate seen in section 2. However, total input use increased at a much faster rate than the industry average up to 2014 before falling markedly in the following two years. It increased again in 2017 and 2018 leading to ACT's TFP level in 2019 being 2 per cent below its 2006 level. The partial productivity indexes in table 4.1 show that swings in opex usage have been the main driver of the ACT's TFP changes over the last few years.

ACT output and input quantity changes

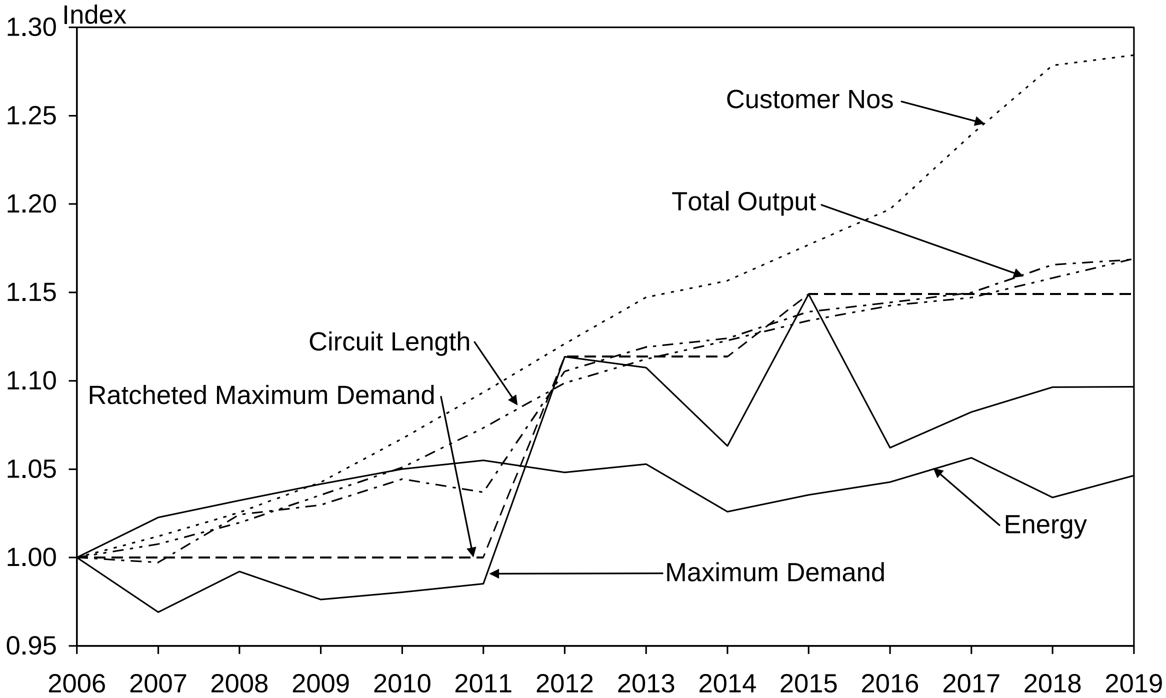
We graph the quantity indexes for ACT's five individual outputs in figure 4.4 and for its six individual inputs in figure 4.5, respectively.

From figure 4.4 we see that the output component of customer numbers increased steadily over the period and was 28 per cent higher in 2019 than it was in 2006 reflecting ACT's relatively strong output growth. Energy throughput for distribution peaked in 2011 and fell less after that than it did for the industry as a whole as seen in section 2. In 2019 energy throughput increased by 1.2 per cent to be 5 per cent above what it was in 2006.

Unlike the case for the industry as a whole, ACT's maximum demand did not exceed its 2006 level until 2012 and has been relatively volatile since then. Ratcheted maximum demand in 2019 was 15 per cent above its 2006 level – somewhat less than for the industry overall although ACT's growth in this output was concentrated between 2011 and 2015 whereas growth in demand for most other DNSPs mainly occurred in the first half of the period.

ACT's circuit length output grew much more over the 14 years than occurred for the industry overall and by 2019 was 17 per cent higher than it was in 2006 compared to an increase of only 5 per cent for the industry. This reflects the Territory's higher increase in customer numbers over the period and the ongoing expansion of the city and development of new areas on the fringes of the city as well as by 'in fill'.

Figure 4.4 **ACT output quantity indexes, 2006–2019**



We do not show ACT's total customer minutes off–supply in figure 4.4. ACT's CMOS performance is the best of the 13 DNSPs in the NEM and CMOS receives only a negative 3 per cent of total revenue weight on average in ACT's total output. Because ACT's CMOS levels are very low, fluctuations in CMOS come off a low base and so swings tend to be quite large in relative terms. Given its low levels, its inclusion in figure 4.4 would provide a misleading picture.

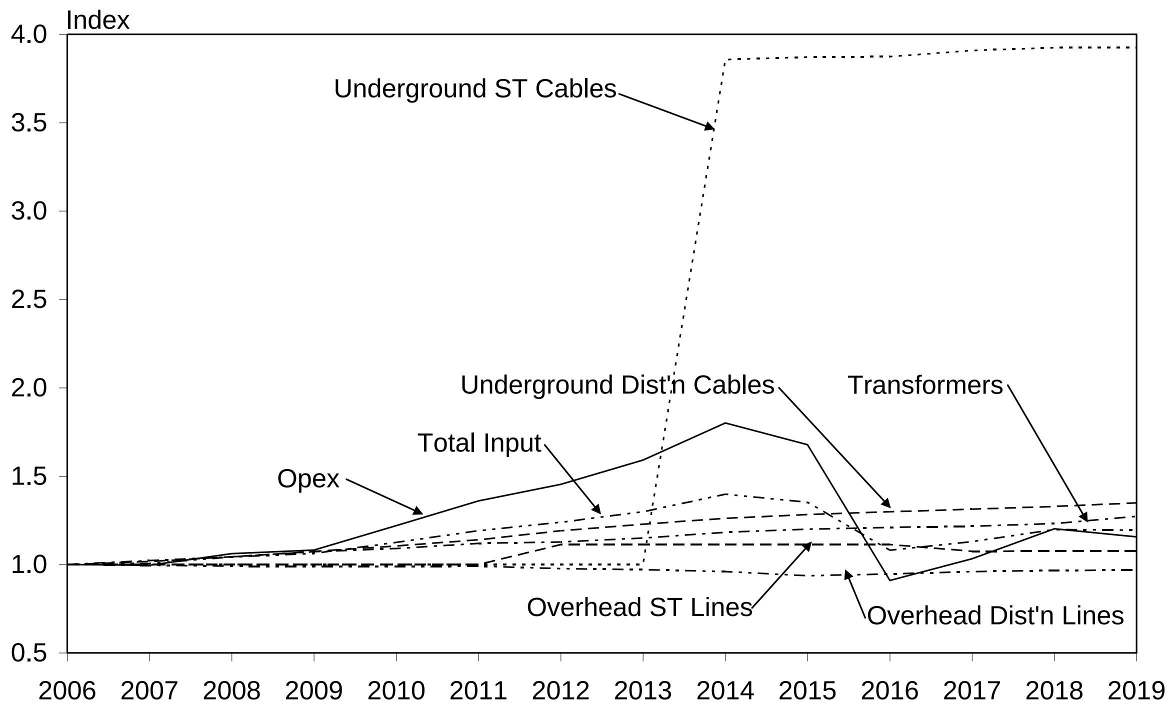
Since the ratcheted maximum demand and circuit length outputs receive an average weight of around 75 per cent of total revenue in forming the total output index for ACT, in figure 4.4 we see that the total output index tends to lie between these two output indexes and follow a similar pattern with fluctuations due to changes in CMOS.

Turning to the input side, we see from ACT's six input components and total input in figure 4.5 that the quantity of opex increased rapidly between 2009 and 2014, being 80 per cent higher in 2014 than it was in 2006. It then fell sharply in 2015 and 2016 following the AER's ACT price determination before increasing by 13 per cent in 2017 and 15 per cent in 2018 and falling by 4 per cent in 2019. In an email to the AER dated 22 August 2019, Evoenergy noted the main reasons for its increase in opex in 2018 were complying with new ring–

fencing requirements and Power of Choice reforms and preparation of its 2019–24 regulatory period proposal. In 2019 ACT's opex input quantity was 16 per cent above its 2006 level. Opex has the largest average share in ACT's total costs at 39 per cent and so is an important driver of its total input quantity index.

Except for underground subtransmission cables, ACT's other input component quantities increase at much more modest and steady rates over the period. ACT's underground subtransmission cables length doubled in 2012 and its capacity rating increased three–fold but the total length was then only 6 kilometres and this input has a negligible share in total cost. The quantity of transformer inputs, which have an average share of 26 per cent in total cost, increased by 27 per cent over the 14–year period.

Figure 4.5 **ACT input quantity indexes, 2006–2019**



From figure 4.5 we see that the total input quantity index lies between the quantity indexes for opex and transformers (which together have a weight of 66 per cent of total costs). Total input quantity fell by 22 per cent between 2014 and 2016 but increased by 5 per cent in 2017 and by 6 per cent in 2018 in line with the movements in opex usage and was flat in 2019.

ACT output and input contributions to TFP change

In table 4.2 we decompose ACT's TFP change into its constituent output and input parts for the whole 14–year period and for the periods up to and after 2012. ACT's drivers of TFP change for the whole 14–year period are broadly similar to the industry as a whole. Customer numbers and circuit length output growth both contribute more to TFP growth for ACT than for the industry given their higher rates of growth for ACT. And transformer input growth makes a less negative contribution to TFP growth for ACT than it does for the industry. Opex usage makes a somewhat more negative contribution of over 0.4 percentage points on average and is the equal second most negative contributor (after transformers) to ACT's –0.2

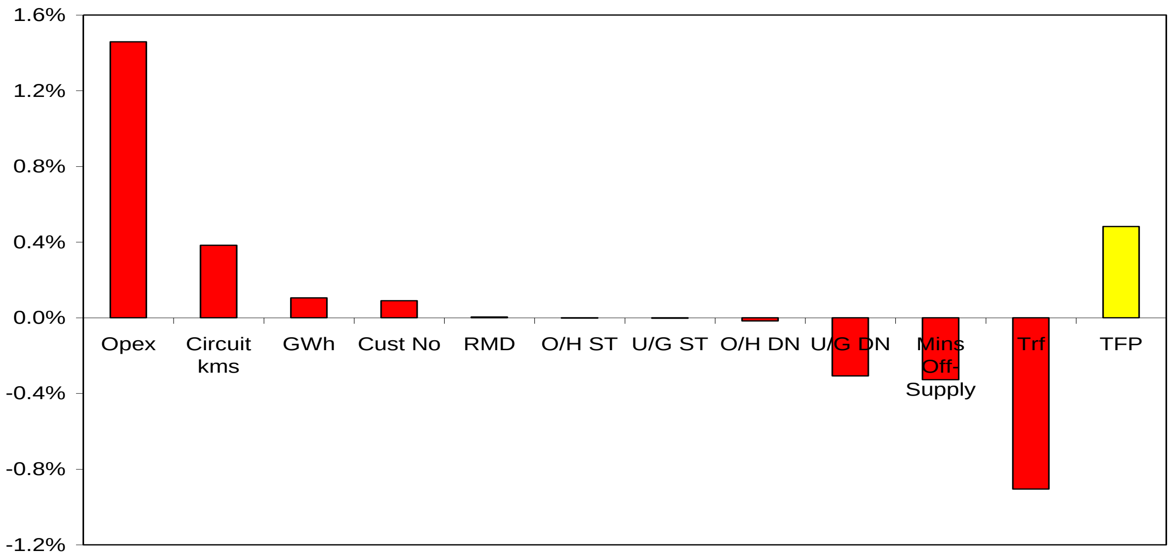
per cent average annual TFP change over the 14–year period. For the industry opex has close to the second most negative contribution of 0.4 percentage points over the whole period and this is also a major reason for the industry's negative TFP growth rate over the 14 years.

The ACT situation is, however, very much a tale of two distinct periods. For the period up to 2012, rapid opex growth made a larger negative percentage point contribution to TFP growth for ACT than for the industry, at –2.5 percentage points for ACT versus –1.9 percentage points for the industry. The large reductions made in ACT's opex in 2015 and 2016 led to opex contributing 1.3 percentage points to ACT's positive average annual TFP change of 1.3 per cent for the period after 2012, despite the sizable increases in opex in 2017 and 2018. This compares to an opex contribution of 1.0 percentage points to the industry TFP average annual change of 0.3 per cent after 2012.

Table 4.2 **ACT output and input percentage point contributions to average annual TFP change: 2006–2018, 2006–2012, 2012–2018, 2018–19**

Year	*2006 to 2019*	*2006 to 2012*	*2012 to 2019*	*2018–19*
Energy (GWh)	0.03%	0.07%	0.00%	0.11%
Ratcheted Max Demand	0.37%	0.63%	0.15%	0.00%
Customer Numbers	0.37%	0.36%	0.37%	0.09%
Circuit Length	0.49%	0.64%	0.36%	0.38%
CMOS	–0.06%	–0.03%	–0.08%	–0.33%
Opex	–0.44%	–2.48%	1.30%	1.46%
O/H Subtransmission Lines	–0.02%	–0.06%	0.02%	0.00%
O/H Distribution Lines	0.03%	0.05%	0.02%	–0.02%
U/G Subtransmission Cables	–0.01%	0.00%	–0.01%	0.00%
U/G Distribution Cables	–0.44%	–0.58%	–0.32%	–0.31%
Transformers	–0.49%	–0.50%	–0.48%	–0.91%
TFP Change	–0.17%	–1.91%	1.32%	0.48%

Figure 4.6 **ACT output and input percentage point contributions to annual TFP change, 2018–19**



The 4 per cent reduction in opex usage in 2019 contributed 1.5 percentage points to ACT's TFP change of 0.5 per cent that year as shown in figure 4.6. Circuit length growth in 2019 contributed 0.4 percentage points to TFP growth while growth in transformer capacity contributed –0.9 percentage points.

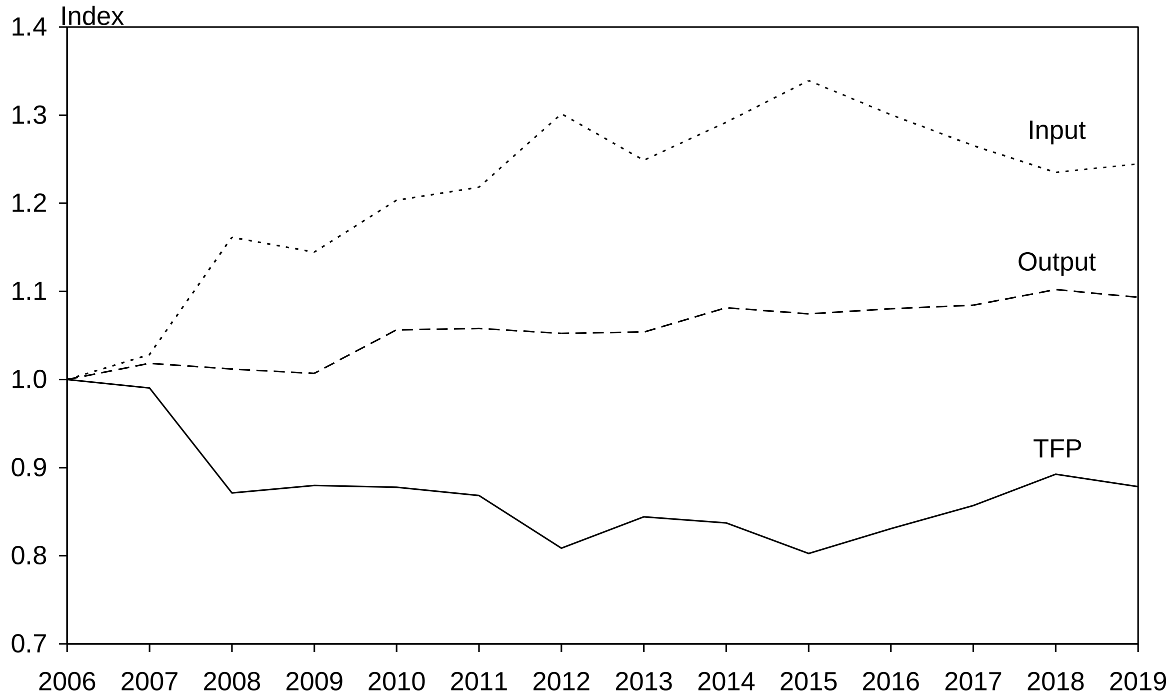
4.2.2 New South Wales

New South Wales is the largest of the NEM jurisdictions and is served by three DNSPs: Ausgrid (AGD), Endeavour Energy (END) and Essential Energy (ESS). In 2019 the three NSW DNSPs delivered 54,913 GWh to 3.69 million customers over 272,829 circuit kilometres of lines and cables.

NSW DNSP productivity performance

NSW's total output, total input and TFP indexes are presented in figure 4.7 and table 4.3. Opex and capital partial productivity indexes are also presented in table 4.3.

Figure 4.7 **NSW DNSP output, input and total factor productivity indexes, 2006–2019**



Over the 14–year period 2006 to 2019, the NSW DNSPs' TFP decreased at an average annual rate of 1.0 per cent. Although total output increased by an average annual rate of 0.7 per cent, total input use increased faster, at a rate of 1.7 per cent. NSW thus had slower output growth and slightly slower input growth compared to the industry as whole, leading to a somewhat more negative TFP growth rate. Input use increased sharply in 2008 and 2012, to be followed each time by a small reduction the following year. Input use again fell in 2016, 2017 and 2018. TFP fell markedly in 2008 and 2012 but TFP change was positive in five years – 2009, 2013, 2016, 2017 and 2018. TFP average annual change was sharply negative at –3.5 per cent for the period up to 2012 but has been positive at 1.2 per cent for the period since 2012.

Table 4.3 **NSW DNSP output, input and total factor productivity and partial productivity indexes, 2006–2019**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.018	1.028	0.990	1.022	0.969
2008	1.012	1.161	0.871	0.787	0.936
2009	1.007	1.145	0.880	0.854	0.898
2010	1.056	1.204	0.878	0.833	0.905
2011	1.058	1.218	0.868	0.844	0.882
2012	1.052	1.301	0.809	0.745	0.850
2013	1.054	1.249	0.844	0.878	0.825
2014	1.081	1.292	0.837	0.852	0.827
2015	1.075	1.339	0.802	0.786	0.812
2016	1.080	1.300	0.831	0.878	0.803
2017	1.084	1.265	0.857	0.954	0.806
2018	1.102	1.235	0.892	1.049	0.812
2019	1.093	1.245	0.878	1.036	0.797
Growth Rate 2006–19	0.69%	1.68%	–1.00%	0.27%	–1.74%
Growth Rate 2006–12	0.85%	4.39%	–3.54%	–4.91%	–2.71%
Growth Rate 2012–19	0.55%	–0.64%	1.18%	4.71%	–0.91%

The partial productivity indexes in table 4.3 show that reduced opex usage was the main driver of the improved TFP performance after 2012.

NSW DNSP output and input quantity changes

We graph the quantity indexes for the NSW DNSPs' five individual outputs in figure 4.8 and for their six individual inputs in figure 4.9.

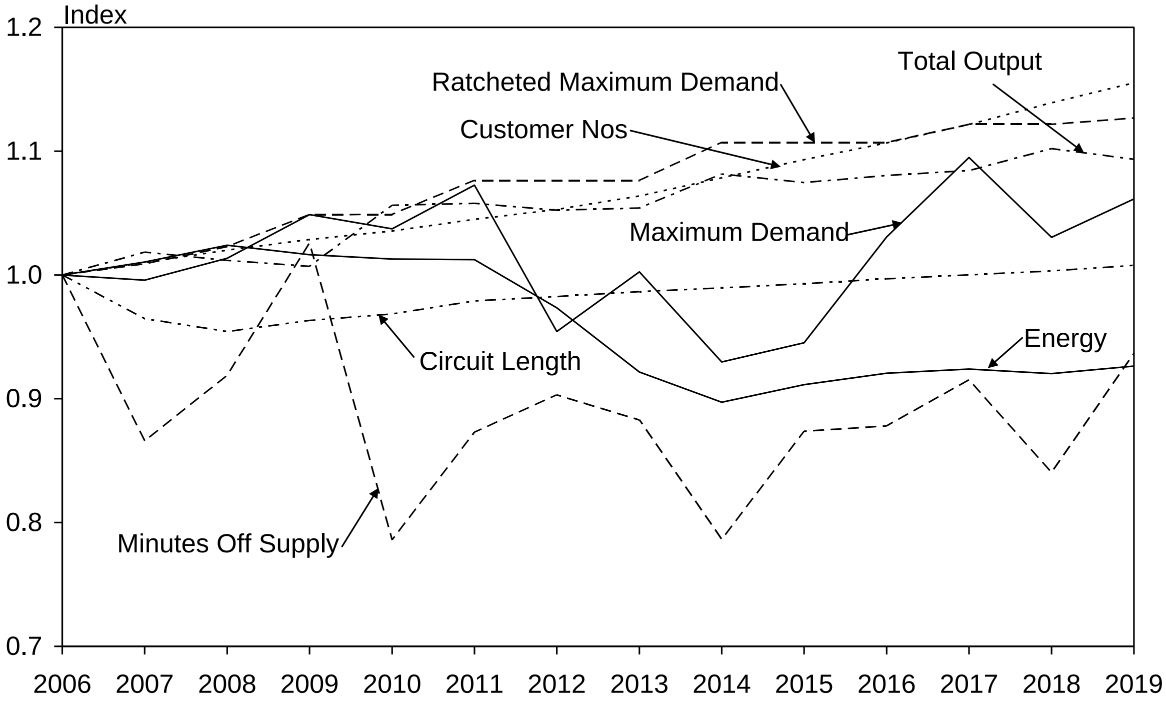
From figure 4.8 we see that NSW's output components showed a similar pattern of change to the industry as a whole except that there was much less growth in outputs for NSW between 2006 and 2009, likely reflecting the initial negative effects of the mining boom on NSW and then the impact of the global financial crisis. Customer numbers increased steadily over the period and were 16 per cent higher in 2019 than they were in 2006 reflecting NSW's relatively weak output growth. Energy throughput for distribution peaked in 2008 and has fallen since to be 7 per cent lower in 2019 than it was in 2006.

NSW's maximum demand peaked in 2011 – two to three years later than in most other states and has been relatively volatile since then. It did not exceed its 2006 level again until 2016. Ratcheted maximum demand in 2019 was 13 per cent above its 2006 level – a smaller increase than for the industry overall.

NSW's circuit length output grew less over the 14 years than occurred for the industry overall and by 2019 was less than 1 per cent higher than it was in 2006 compared to an increase of 5 per cent for the industry. NSW's circuit length actually declined somewhat between 2006 and 2008.

The last output shown in figure 4.8 is total CMOS. NSW's CMOS has generally followed a similar pattern to that of the industry although it has been more volatile in NSW. With the exception of 2009, CMOS has generally been lower and, hence, contributed more to total output than was the case in 2006. In 2019 CMOS was 6 per cent less than it was in 2006. CMOS has had an average weight of 15 per cent of total revenue over the 14–year period.

Figure 4.8 **NSW output quantity indexes, 2006–2019**



Since circuit length and ratcheted maximum demand outputs receive an average combined weight of around 84 per cent of total revenue in forming the total output index for NSW, in figure 4.8 we see that the total output index tends to lie between these two output indexes. The customer numbers index also lies close to the total output index. The CMOS index would generally lie above the other output indexes when it enters the formation of total output as a negative output (ie the reduction in CMOS over the period makes a positive contribution to total output).

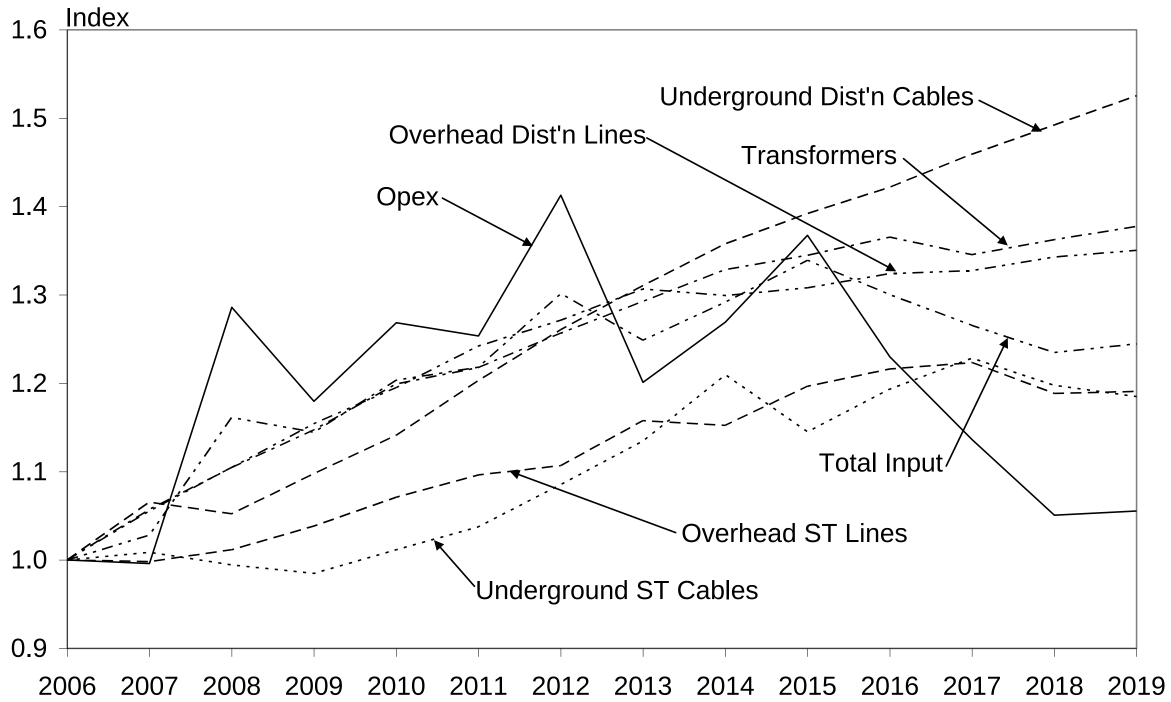
Turning to the input side, we see from NSW's six input components and total input in figure 4.9 that the quantity of NSW's opex increased more rapidly between 2006 and 2012 than the corresponding increase for the industry. For NSW, opex increased by 41 per cent up to 2012 whereas the corresponding increase for the industry was 36 per cent. NSW's opex input has also been somewhat more volatile over the whole period, with another peak in opex in 2015. However, opex again fell in 2016, 2017 and 2018 before increasing slightly in 2019 and was only 6 per cent above its 2006 level in 2019.[9] Opex has the largest average share in NSW's total costs at 38 per cent and so is an important driver of its total input quantity index.

NSW's underground distribution cables and transformers inputs increase more steadily over the period and at a similar rate to the industry as a whole. Its overhead distribution lines

[9] Note that redundancy payments are included in the opex figures presented here.

input, however, increases much more rapidly over the period with an increase of 35 per cent compared to only 12 per cent for the industry.

Figure 4.9 **NSW DNSP input quantity indexes, 2006–2019**



From figure 4.9 we see that the total input quantity index generally lies between the quantity indexes for opex and transformers (which together have a weight of 70 per cent of total costs). Total input quantity fell in 2016, 2017 and 2018 in line with the reductions in opex.

NSW output and input contributions to TFP change

In table 4.4 we decompose NSW's TFP change into its constituent output and input parts for the whole 14–year period and for the periods up to and after 2012. NSW's drivers of TFP change for the whole 14–year period are broadly similar to the industry as a whole except that the major outputs of customer numbers and RMD contribute somewhat less due to their weaker growth in NSW and opex makes a less negative contribution. Circuit length output growth contributes less to TFP growth for NSW than for the industry given circuit length's lower rate of growth for NSW. And the overhead distribution input makes a more negative contribution to TFP growth for NSW than it does for the industry.

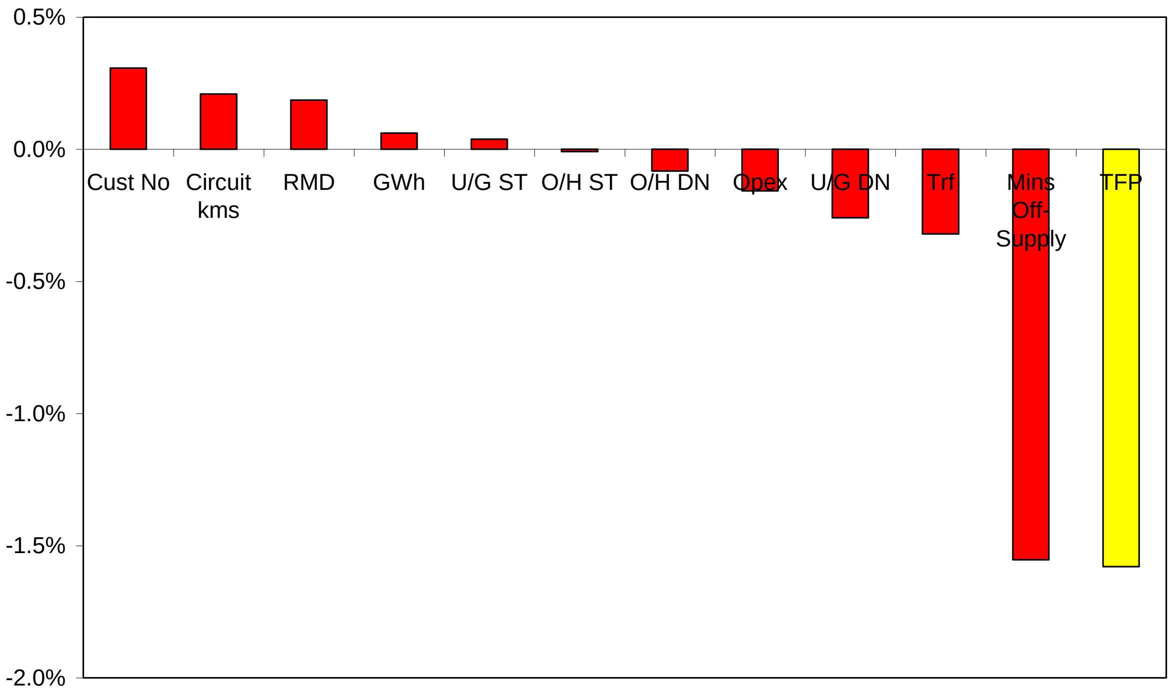
The NSW situation is again a tale of two distinct periods. For the period up to 2012, rapid opex growth made a larger negative percentage point contribution to TFP growth for NSW than for the industry, at –2.3 percentage points for NSW versus –1.9 percentage points for the industry. But the reductions made in NSW's opex after 2012 led to opex contributing 1.6 percentage points to NSW's average annual TFP change of 1.2 per cent for the period after 2012. This compares to an opex contribution of 1.0 percentage points to the industry TFP average annual change of 0.3 per cent after 2012.

The importance of the reduction in reliability in 2019 is highlighted in figure 4.10 where the –1.6 percentage point contribution of CMOS to TFP change of –1.6 per cent in the 2019 year is considerably larger than the contributions of other outputs and inputs, which also largely offset each other.

Table 4.4 **NSW output and input percentage point contributions to average annual TFP change: 2006–2019, 2006–2012, 2012–2019, 2018–19**

Year	*2006 to 2019*	*2006 to 2012*	*2012 to 2019*	*2018–19*
Energy (GWh)	–0.06%	–0.05%	–0.07%	0.06%
Ratcheted Max Demand	0.36%	0.49%	0.25%	0.19%
Customer Numbers	0.24%	0.19%	0.28%	0.31%
Circuit Length	0.02%	–0.14%	0.16%	0.21%
CMOS	0.12%	0.35%	–0.08%	–1.55%
Opex	–0.20%	–2.27%	1.57%	–0.16%
O/H Subtransmission Lines	–0.07%	–0.08%	–0.05%	–0.01%
O/H Distribution Lines	–0.25%	–0.42%	–0.11%	–0.08%
U/G Subtransmission Cables	–0.04%	–0.04%	–0.04%	0.04%
U/G Distribution Cables	–0.37%	–0.43%	–0.32%	–0.26%
Transformers	–0.75%	–1.15%	–0.40%	–0.32%
TFP Change	–1.00%	–3.54%	1.18%	–1.58%

Figure 4.10 **NSW output and input percentage point contributions to annual TFP change, 2018–19**



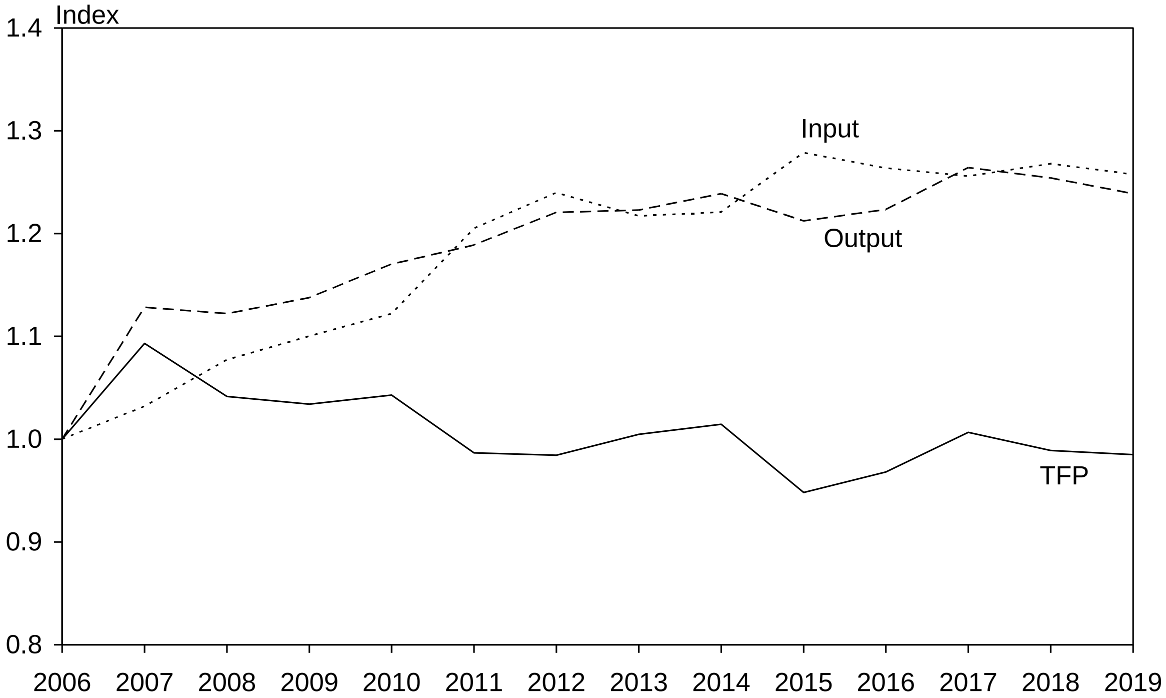
4.2.3 Queensland

Queensland (Qld) is the third largest of the NEM jurisdictions in terms of customer numbers and the second largest in terms of circuit length. It is served by two DNSPs: Energex (ENX) and Ergon Energy (ERG). In 2019 the two Queensland DNSPs delivered 34,931 GWh to 2.26 million customers over 207,056 circuit kilometres of lines and cables.

Queensland DNSP productivity performance

Queensland's total output, total input and TFP indexes are presented in figure 4.11 and table 4.5. Opex and capital partial productivity indexes are also presented in table 4.5.

Figure 4.11 **Qld DNSP output, input and total factor productivity indexes, 2006–2019**



Over the 14–year period 2006 to 2019, the Queensland DNSPs' TFP decreased at an average annual rate of 0.1 per cent. Queensland's total output increased by an average annual rate of 1.7 per cent – considerably higher than the output growth rates in ACT and NSW. Queensland's total input use increased a little faster, at a rate of 1.8 per cent – only a little higher than the rate of input growth in NSW despite Queensland's much higher output growth. Queensland has also had much higher output growth than the industry as a whole but its input growth has been very similar to the industry's input growth. Input use increased at an above average rate in 2011 and 2015. The increase in 2015 coincided with a small reduction in output that year which led to a marked fall in TFP. However, output recovered in 2016 and 2017 and, combined with a marginal reduction in input use, led to positive TFP growth in those years. Small reductions in output and a small increase followed by a small decrease in input use has led to falls in TFP in 2018 and 2019. TFP average annual change was negative for the period up to 2012 at –0.3 per cent but has been marginally positive for the period since 2012.

The partial productivity indexes in table 4.5 show that reduced opex usage was the main driver of the improved TFP performance after 2012 although this was offset somewhat by a worsening in capital partial productivity performance.

Table 4.5 **Qld DNSP output, input and total factor productivity and partial productivity indexes, 2006–2019**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.128	1.032	1.093	1.123	1.076
2008	1.122	1.077	1.042	1.056	1.034
2009	1.138	1.100	1.034	1.071	1.012
2010	1.170	1.122	1.043	1.107	1.008
2011	1.189	1.205	0.987	0.967	0.997
2012	1.221	1.240	0.984	0.950	0.999
2013	1.223	1.217	1.005	1.023	0.993
2014	1.239	1.221	1.015	1.085	0.976
2015	1.212	1.279	0.948	0.982	0.928
2016	1.223	1.264	0.968	1.048	0.925
2017	1.264	1.256	1.007	1.138	0.940
2018	1.254	1.268	0.989	1.113	0.924
2019	1.239	1.258	0.985	1.127	0.912
Growth Rate 2006–19	1.65%	1.76%	–0.12%	0.92%	–0.71%
Growth Rate 2006–12	3.32%	3.58%	–0.26%	–0.86%	–0.02%
Growth Rate 2012–19	0.21%	0.20%	0.01%	2.45%	–1.30%

Queensland DNSP output and input quantity changes

We graph the quantity indexes for the Queensland DNSPs' five individual outputs in figure 4.12 and for their six individual inputs in figure 4.13.

From figure 4.12 we see that Queensland's output components showed a generally similar pattern of change to the industry as a whole except that there was more growth in outputs for Queensland over the period. Queensland's energy and maximum demand outputs showed less of a downturn after 2010, likely reflecting the effects of the mining boom. Customer numbers increased steadily over the period and were 23 per cent higher in 2019 than they were in 2006 reflecting Queensland's relatively strong output growth. Energy throughput for distribution peaked in 2010 but was still 2 per cent higher in 2019 than it was in 2006.

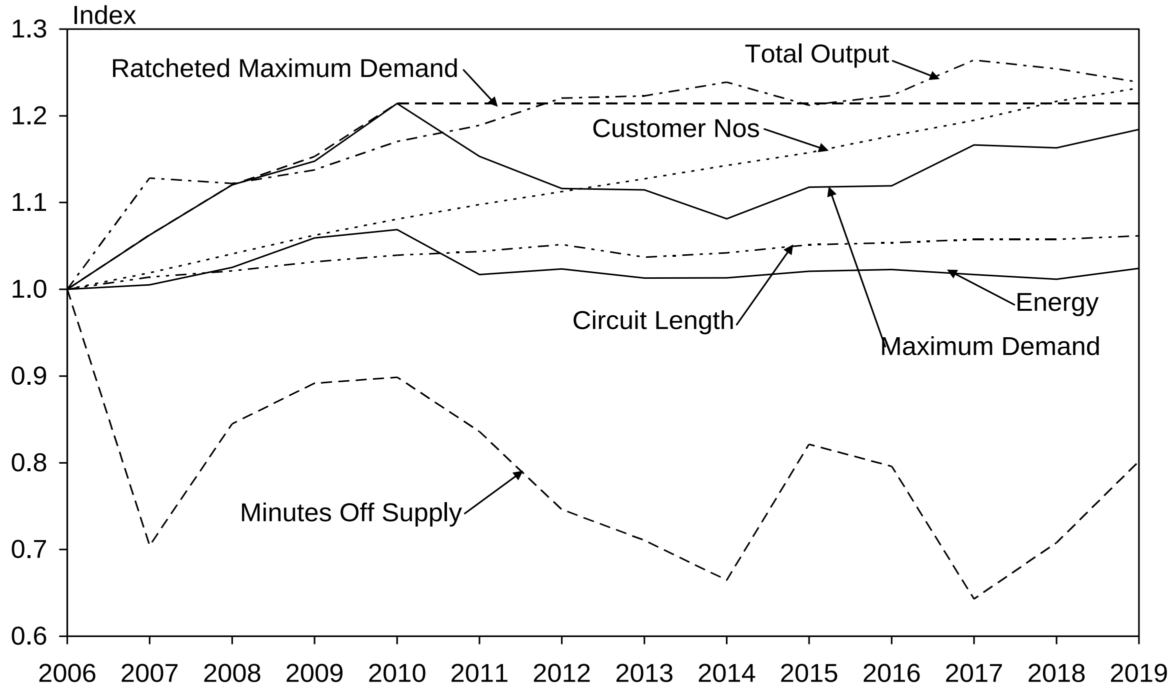
Queensland's maximum demand also peaked in 2010 and then declined through to 2014. However, unlike NSW, Queensland's maximum demand has stayed above its 2006 level for the remainder of the period. In 2019 RMD was 21 per cent above its 2006 level – a larger increase than for the industry overall.

Queensland's circuit length output also grew slightly more over the 14 years than occurred for the industry overall and by 2019 was 6 per cent above the level it was in 2006 compared to an increase of 5 per cent for the industry.

The last output shown in figure 4.12 is total CMOS. Queensland's CMOS has generally followed a similar pattern to that of the industry although it increased markedly in 2015.

CMOS has been lower and, hence, contributed more to total output for all other years than was the case in 2006. In 2019 CMOS was 20 per cent less than it was in 2006.

Figure 4.12 **Qld output quantity indexes, 2006–2019**



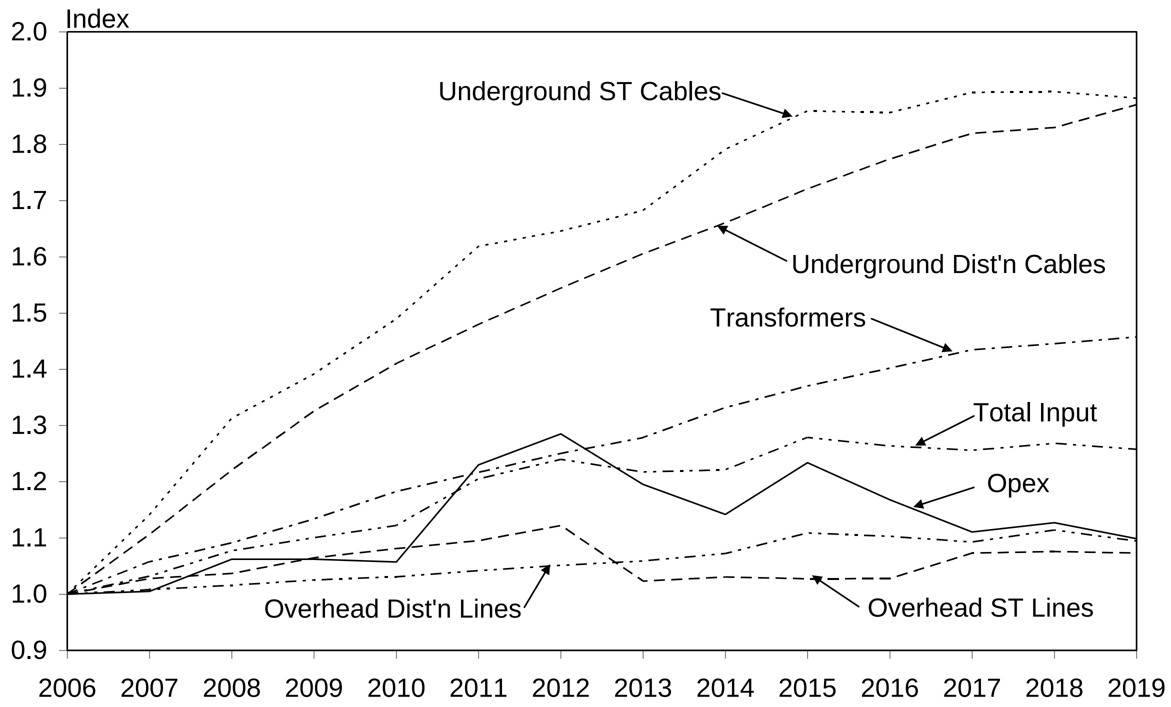
The circuit length and ratcheted maximum demand outputs receive an average weight of around 85 per cent of total revenue in forming the total output index for Queensland, but in figure 4.12 we see that the total output index often lies above these two output indexes and also above the customer numbers output index. This is due to the CMOS index which would generally lie above the other output indexes when it enters the formation of total output as a negative output (ie the reduction in CMOS over the period makes a positive contribution to total output). In Queensland CMOS receives an average weight of –17 per cent of total revenue in forming the total output index.

Turning to the input side, we see from Queensland's six input components and total input in figure 4.13 that the quantity of Queensland's underground distribution and subtransmission cables and transformers inputs have increased more than for the industry as a whole while its opex and overhead lines increased somewhat less. Again, not too much should be read into the higher increase in underground cables as this was starting from a small base and reflects Queensland's higher rate of customer numbers growth. For Queensland, opex increased by 29 per cent up to 2012 which was less than the corresponding increases for the industry of 36 per cent and for NSW of 41 per cent. After an increase in 2015, Queensland's opex again fell in 2016, 2017 and 2019 to end up 10 per cent above its 2006 level in 2019.[10] Opex has the largest average share in Queensland's total costs at 36 per cent and so is an important driver of its total input quantity index.

[10] Note that redundancy payments are included in the opex figures presented here.

From figure 4.13 we see that the total input quantity index generally lies between the quantity indexes for opex and transformers (which together have a weight of 66 per cent of total costs). Total input quantity decreased by 0.8 per cent in 2019 with decreases in four of the six input categories, including a 2.6 per cent decrease in opex usage.

Figure 4.13 **Qld DNSP input quantity indexes, 2006–2019**



Queensland output and input contributions to TFP change

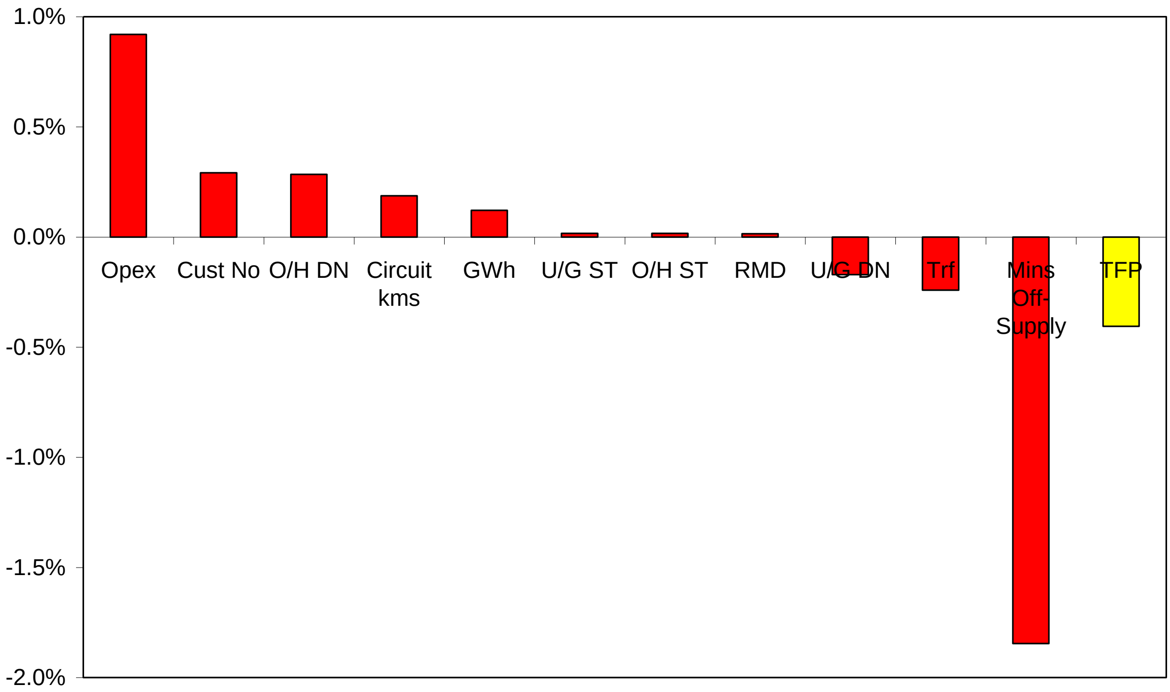
Table 4.6 **Qld output and input percentage point contributions to average annual TFP change: 2006–2019, 2006–2012, 2012–2019, 2018–19**

Year	*2006 to 2019*	*2006 to 2012*	*2012 to 2019*	*2018–19*
Energy (GWh)	0.02%	0.04%	0.00%	0.12%
Ratcheted Max Demand	0.62%	1.34%	0.00%	0.01%
Customer Numbers	0.36%	0.41%	0.31%	0.29%
Circuit Length	0.22%	0.40%	0.06%	0.19%
CMOS	0.43%	1.12%	–0.16%	–1.85%
Opex	–0.27%	–1.48%	0.76%	0.92%
O/H Subtransmission Lines	–0.04%	–0.13%	0.05%	0.02%
O/H Distribution Lines	–0.12%	–0.14%	–0.10%	0.28%
U/G Subtransmission Cables	–0.12%	–0.20%	–0.05%	0.02%
U/G Distribution Cables	–0.36%	–0.53%	–0.21%	–0.17%
Transformers	–0.86%	–1.10%	–0.66%	–0.24%
TFP Change	–0.12%	–0.26%	0.01%	–0.41%

In table 4.6 we decompose Queensland’s TFP change into its constituent output and input parts for the whole 14–year period and for the periods up to and after 2012. Queensland’s drivers of TFP change for the whole 14–year period are broadly similar to the industry as a whole except that most outputs make a larger percentage point contribution to TFP growth in Queensland and opex makes a smaller negative contribution. And the transformers input makes a somewhat more negative contribution to TFP growth for Queensland than it does for the industry. However, the stronger output growth and lower opex growth for Queensland lead to its TFP performance being considerably better than that for the industry.

The Queensland situation is also a tale of two distinct periods although the differences are less marked than for NSW and ACT. For the period up to 2012, opex growth made a smaller negative percentage point contribution to TFP growth for Queensland than for the industry, at –1.5 percentage points for Queensland versus –1.9 percentage points for the industry. The reductions made in Queensland's opex after 2012 led to opex contributing 0.8 percentage points to Queensland's average annual TFP change, somewhat less than the 1.0 percentage point contribution for the industry. After 2012, Queensland's outputs all contributed somewhat smaller amounts to TFP growth compared to the period before 2012 but its inputs generally made either positive or somewhat less negative percentage point contributions to TFP growth.

Figure 4.14 **Qld output and input percentage point contributions to annual TFP change, 2018–19**



A worsening in CMOS performance contributed –1.9 percentage points and a reduction in opex contributed 0.9 percentage points to the TFP change of –0.4 per cent in 2019 as shown in figure 4.14. Increases in transformer and underground distribution inputs were more than offset by positive contributions from customer numbers circuit length and energy throughput. A reduction in overhead distribution lines input also made a positive contribution to TFP change in 2019.

4.2.4 South Australia

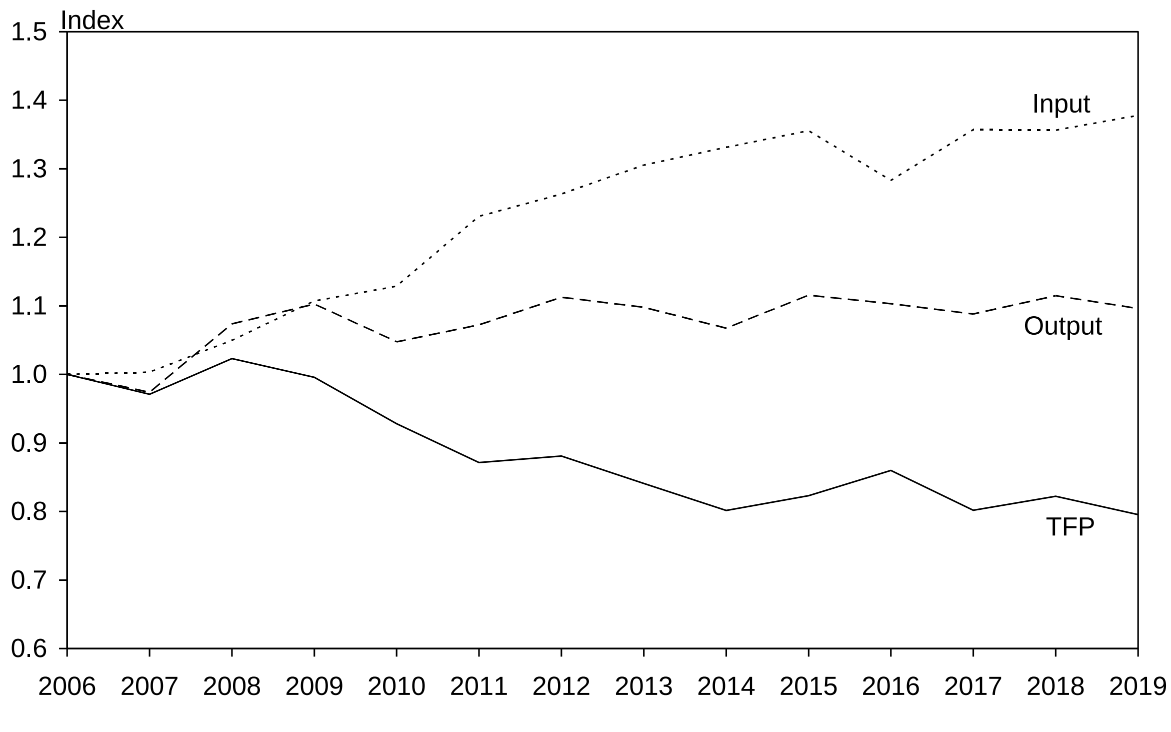
South Australia (SA) is the fourth largest of the NEM jurisdictions (by customer numbers) and is served by one DNSP, SA Power Networks (SAP). In 2019 the SA DNSP delivered 10,051 GWh to 906,198 customers over 89,298 circuit kilometres of lines and cables.

SA DNSP productivity performance

SA's total output, total input and TFP indexes are presented in figure 4.15 and table 4.7. Opex and capital partial productivity indexes are also presented in table 4.7.

Over the 14–year period 2006 to 2019, the SA DNSP's TFP decreased at an average annual rate of 1.8 per cent. Although total output increased by an average annual rate of 0.7 per cent, total input use increased faster, at a rate of 2.5 per cent. SA thus had lower output growth and considerably higher input growth and hence lower TFP growth compared to the industry as whole. Input use increased at a faster rate in 2011 but otherwise grew at a steady rate through to 2015 before falling in 2016 but then increasing again in 2017 and 2019.

Figure 4.15 **SA DNSP output, input and total factor productivity indexes, 2006–2019**



In 2018 SA's output surpassed its previous peak in 2012 but has fallen back slightly in 2019. TFP change was positive in 2008, 2012, 2015, 2016 and 2018. Compared to the whole 14–year period TFP average annual change was more negative for the period up to 2012 at –2.1 per cent compared to –1.5 per cent for the period since 2012.

The partial productivity indexes in table 4.7 show that opex productivity growth for South Australia was considerably more negative than capital productivity growth for the period up to 2012 and both have declined at 1.4 to 1.5 per cent per annum on average since 2012.

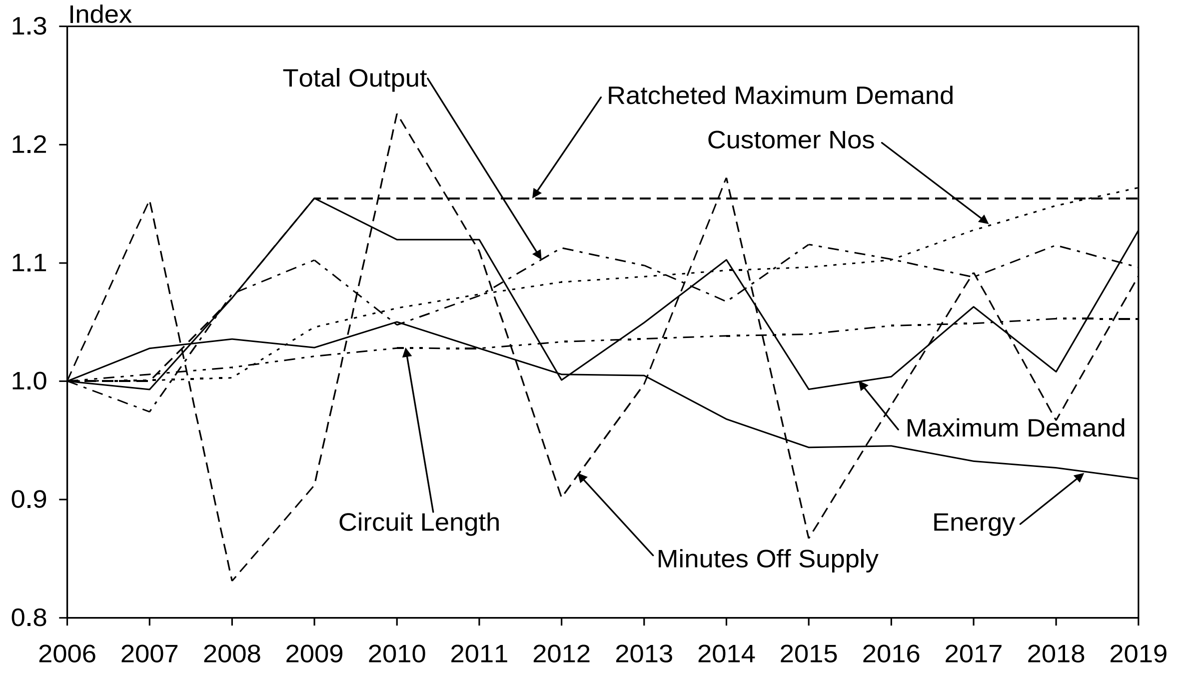
Table 4.7 **SA DNSP output, input and total factor productivity and partial productivity indexes, 2006–2019**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index Opex*	*PFP Index Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	0.974	1.003	0.971	1.051	0.940
2008	1.074	1.050	1.023	1.035	1.014
2009	1.102	1.107	0.996	0.964	1.011
2010	1.048	1.129	0.928	0.922	0.931
2011	1.072	1.231	0.871	0.756	0.935
2012	1.113	1.263	0.881	0.762	0.945
2013	1.098	1.305	0.841	0.710	0.917
2014	1.067	1.331	0.802	0.674	0.879
2015	1.116	1.355	0.823	0.679	0.908
2016	1.103	1.283	0.860	0.800	0.888
2017	1.088	1.357	0.802	0.685	0.868
2018	1.115	1.356	0.822	0.716	0.880
2019	1.096	1.378	0.795	0.686	0.857
Growth Rate 2006–19	0.71%	2.47%	–1.76%	–2.89%	–1.19%
Growth Rate 2006–12	1.78%	3.89%	–2.11%	–4.52%	–0.95%
Growth Rate 2012–19	–0.21%	1.25%	–1.46%	–1.50%	–1.40%

SA DNSP output and input quantity changes

We graph the quantity indexes for the SA DNSP's five individual outputs in figure 4.16 and for its six individual inputs in figure 4.17.

Figure 4.16 **SA output quantity indexes, 2006–2019**



From figure 4.16 we see that, with the exception of CMOS, SA's output components exhibit a similar pattern of change to the industry as a whole. Customer numbers increase steadily over the period and were 16 per cent higher in 2019 than they were in 2006 reflecting SA's somewhat weaker economic conditions, particularly since 2012. Energy throughput peaked in 2010 and has fallen since to be 8 per cent lower in 2019 than it was in 2006.

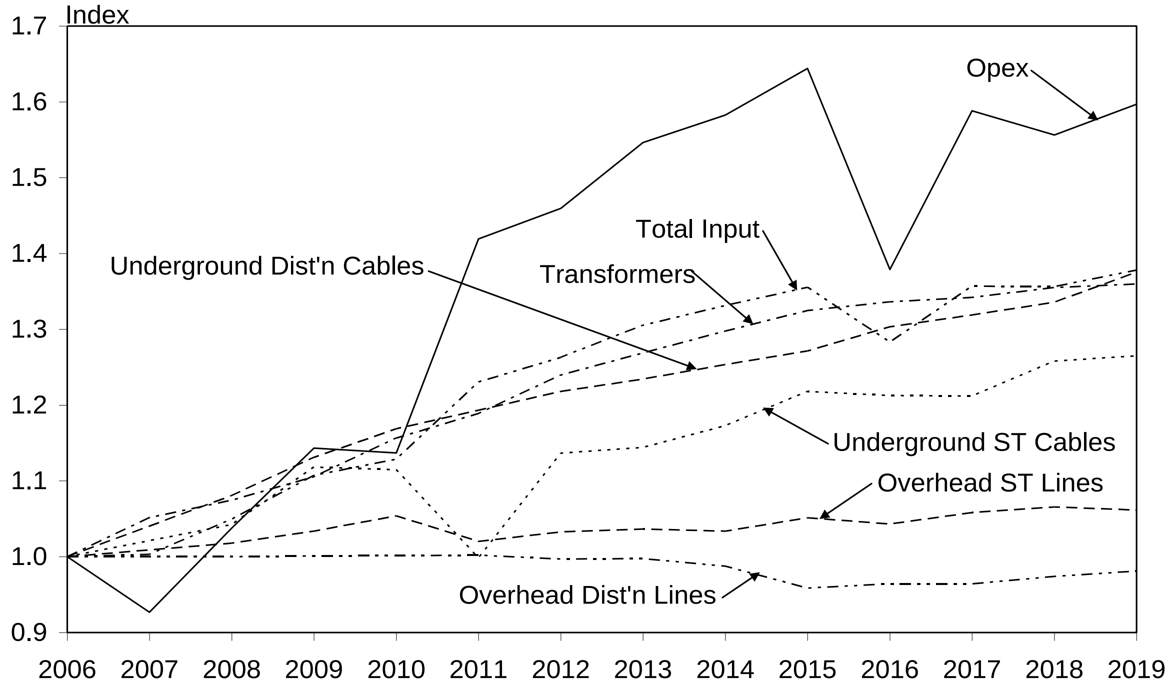
SA's maximum demand peaked in 2009 and has been relatively volatile since then. It trended down between 2009 and 2018 but increased markedly in 2019 to end up 13 per cent above its 2006 level. Ratcheted maximum demand in 2019 was 16 per cent above its 2006 level – only slightly less than for the industry overall.

SA's circuit length output grew slightly more over the 14 years than occurred for the industry overall and by 2019 was more than 5 per cent above the level it was in 2006.

The last output shown in figure 4.16 is total CMOS. SA's CMOS has been considerably more volatile than for the industry, finishing the period at 9 per cent above the level it started at. By 2008 SA's CMOS was at its lowest level for the period being 17 per cent lower than it was in 2006 but in 2010 it was at its highest being 23 per cent higher than it was in 2006. CMOS increased by 12 per cent in 2019. CMOS receives an average weight of –18 per cent of total revenue for SA.

Since the circuit length and ratcheted maximum demand outputs receive a combined average weight of around 86 per cent of total revenue in forming the total output index for SA, in figure 4.16 we see that the total output index lies between these output indexes in most years. The customer numbers output index also lies close to the total output index. Fluctuations in the total output index are mainly driven by movements in CMOS. The increase in CMOS in 2019 contributed to the decrease in the total output index in the latest year along with a further reduction in energy throughput.

Figure 4.17 **SA DNSP input quantity indexes, 2006–2019**



Turning to the input side, we see from SA's six input components and total input in figure 4.17 that the quantity of SA's opex increased more rapidly between 2006 and 2015 than the corresponding increase for the industry. For SA, opex increased by 64 per cent up to 2015 whereas the corresponding increase for the industry was 34 per cent. A major driver of this difference was an increase in SA's opex input of 22 per cent in 2011. However, opex fell sharply in 2016 but was still 38 per cent above its 2006 level compared to 23 per cent for the industry. SA's opex increased sharply in 2017 as a result of increased emergency response costs and Guaranteed Service Level payments due to severe weather events. It then fell by 2 per cent in 2018 before increasing again by 2.6 per cent in 2019. Opex has the largest average share in SA's total costs at 34 per cent and so is an important driver of its total input quantity index.

SA's transformers and underground distribution cables inputs increase more steadily over the period, both at a somewhat slower rate than for the industry as a whole. Its overhead distribution lines input decreased over the period with a fall of 2 per cent by 2019 relative to 2006 compared to a 12 per cent increase for the industry.

From figure 4.17 we see that the total input quantity index lies between the quantity indexes for opex, transformers and underground distribution cables (which together account for 87 per cent of total costs). Total input quantity increased by 1.6 per cent in 2019 with increases in all inputs other than overhead subtransmission lines.

SA output and input contributions to TFP change

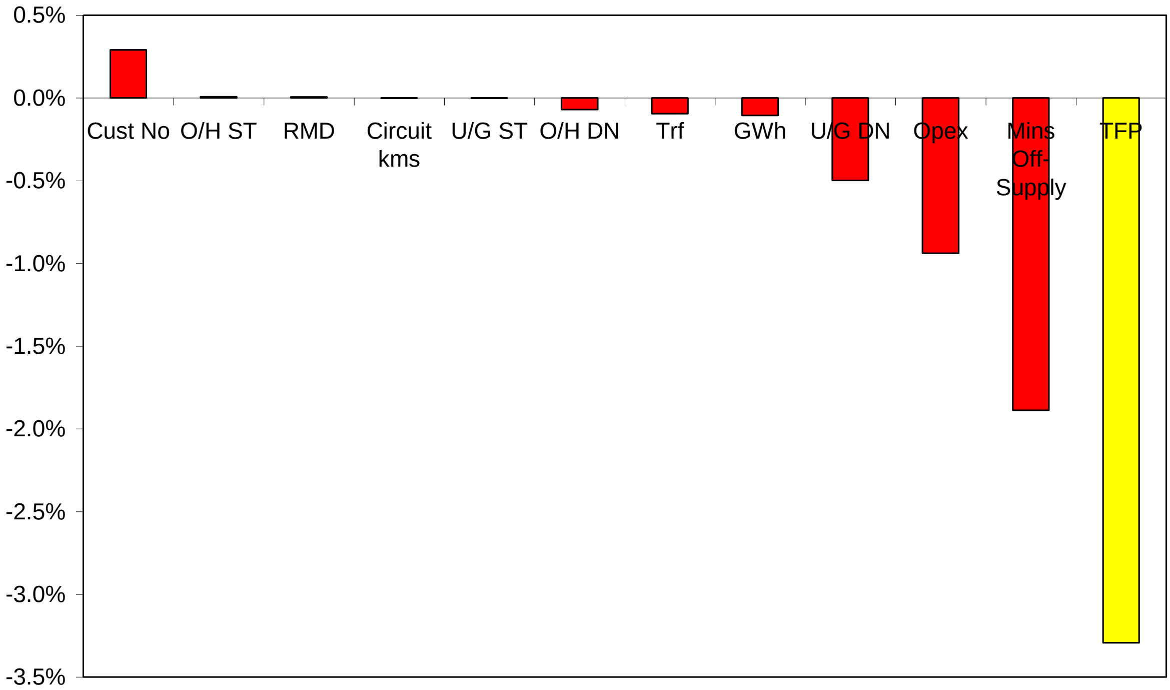
In table 4.8 we decompose SA's TFP change into its constituent output and input parts for the whole 14–year period and for the periods up to and after 2012. SA's drivers of TFP change for the whole 14–year period are broadly similar to the industry as a whole except that the CMOS output contributes somewhat less in SA and opex makes a larger negative contribution. Growth in underground distribution cables input also makes a more negative contribution for SA than for the industry.

Table 4.8 **SA output and input percentage point contributions to average annual TFP change: 2006–2019, 2006–2012, 2012–2019, 2018–19**

Year	*2006 to 2019*	*2006 to 2012*	*2012 to 2019*	*2018–19*
Energy (GWh)	–0.07%	0.01%	–0.13%	–0.11%
Ratcheted Max Demand	0.45%	0.96%	0.00%	0.01%
Customer Numbers	0.25%	0.30%	0.22%	0.29%
Circuit Length	0.18%	0.26%	0.12%	0.00%
CMOS	–0.11%	0.25%	–0.42%	–1.89%
Opex	–1.21%	–2.05%	–0.49%	–0.94%
O/H Subtransmission Lines	–0.01%	–0.01%	–0.01%	0.01%
O/H Distribution Lines	0.02%	0.01%	0.02%	–0.07%
U/G Subtransmission Cables	–0.01%	–0.01%	0.00%	0.00%
U/G Distribution Cables	–0.47%	–0.69%	–0.28%	–0.50%
Transformers	–0.79%	–1.14%	–0.48%	–0.09%
TFP Change	–1.76%	–2.11%	–1.46%	–3.29%

The SA situation is again a tale of two distinct periods. For the period up to 2012, all outputs made a positive contribution to TFP change but after 2012 this fell to near zero or negative for all outputs other than customer numbers and circuit length, whose contribution also reduced after 2012. The negative percentage point contribution of opex to TFP reduced considerably for SA after 2012, although at –0.5 percentage points it was well below the 1.0 percentage point contribution for the industry after 2012.

Figure 4.18 **SA output and input percentage point contributions to annual TFP change, 2018–19**



The importance of the increases in CMOS and opex in 2019 is highlighted in figure 4.18 where they make –1.9 and –0.9 percentage point contributions, respectively, to TFP change. This adds to contributions of 0.3 and –0.5 percentage points from increases in the customer numbers output and the underground distribution cables input, respectively. SA's TFP growth in 2019 was –3.3 per cent.

4.2.5 Tasmania

Tasmania (TAS) is the second smallest of the NEM jurisdictions (by customer numbers) and is served by one DNSP, TasNetworks Distribution (TND). In 2019 the Tasmania DNSP delivered 4,321 GWh to 290,446 customers over 22,862 circuit kilometres of lines and cables.

Tasmanian DNSP productivity performance

Tasmania's total output, total input and TFP indexes are presented in figure 4.19 and table 4.9. Opex and capital partial productivity indexes are also presented in table 4.9.

Figure 4.19 **TAS DNSP output, input and total factor productivity indexes, 2006–2019**

Table 4.9 **TAS DNSP output, input and total factor productivity and partial productivity indexes, 2006–2019**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	0.977	1.009	0.968	0.979	0.963
2008	0.979	1.025	0.954	0.971	0.946
2009	0.952	1.080	0.882	0.846	0.903
2010	0.958	1.171	0.818	0.719	0.880
2011	1.040	1.176	0.884	0.810	0.926
2012	1.017	1.228	0.828	0.726	0.892
2013	1.043	1.144	0.912	0.918	0.910
2014	0.993	1.162	0.854	0.856	0.853
2015	1.044	1.107	0.943	1.064	0.889
2016	1.036	1.138	0.911	0.985	0.877
2017	1.052	1.261	0.834	0.761	0.879
2018	1.032	1.222	0.845	0.826	0.855
2019	1.034	1.184	0.873	0.935	0.843
Growth Rate 2006–19	0.26%	1.30%	–1.04%	–0.52%	–1.31%
Growth Rate 2006–12	0.28%	3.42%	–3.14%	–5.33%	–1.91%
Growth Rate 2012–19	0.24%	–0.52%	0.75%	3.60%	–0.80%

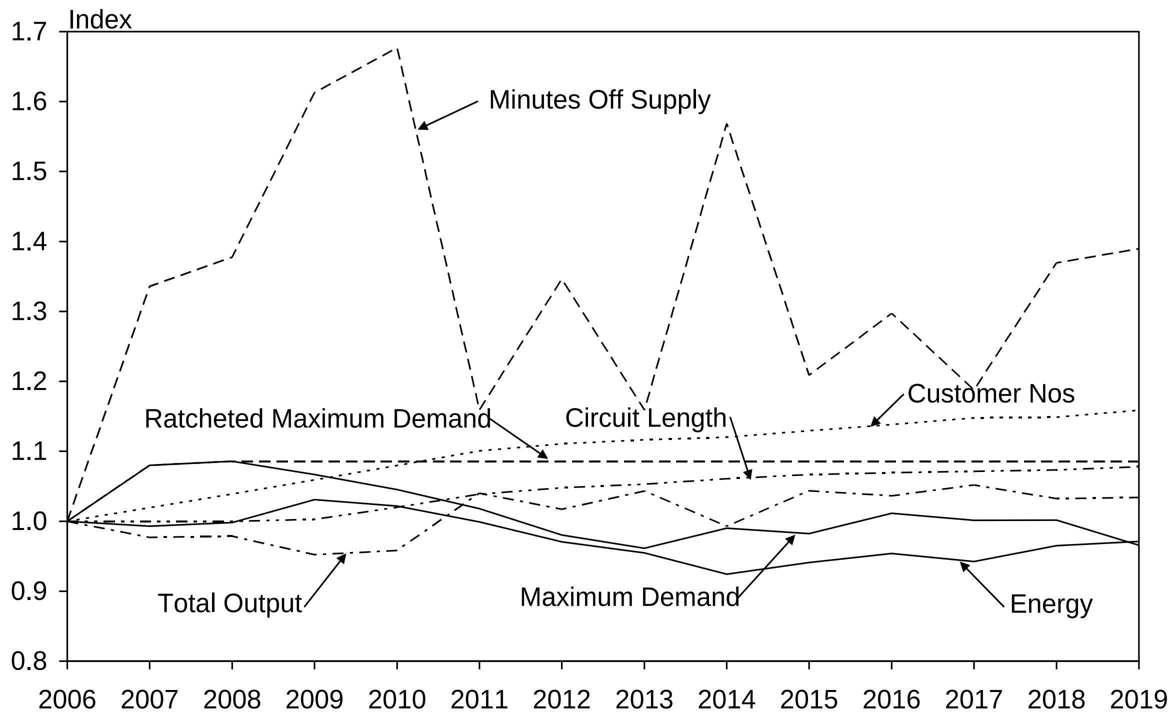
Over the 14–year period 2006 to 2019, the Tasmanian DNSP's TFP decreased at an average annual rate of 1.0 per cent. Total output has increased at only 0.3 per cent per annum on average and actually decreased by 4 per cent between 2006 and 2010. Total input use, on the other hand, has increased at an average annual rate of 1.3 per cent. Input use increased at a much faster rate between 2006 and 2012. Input use decreased in 2013 and again in 2015 but increased again in 2016 before increasing sharply in 2017 and then reducing in 2018 and again in 2019. TFP change was positive in five years: 2011, 2013, 2015, 2018 and 2019. In 2011 output grew strongly while input increase moderated. In 2013 and 2015 output grew more strongly and input use was also cut significantly while in 2018 input use was reduced while output reduced by a lesser amount and input use was again reduced in 2019. Compared to the whole 14–year period TFP average annual change was more negative for the period up to 2012 at –3.1 per cent but this reversed after 2012 to a growth rate of 0.8 per cent.

The partial productivity indexes in table 4.9 show that reduced opex usage was the main driver of the improved TFP performance after 2012 although improved capital productivity also played a role.

Tasmanian DNSP output and input quantity changes

We graph the quantity indexes for the Tasmania DNSP's five individual outputs in figure 4.20 and its six individual inputs in figure 4.21.

Figure 4.20 **TAS output quantity indexes, 2006–2019**



From figure 4.20 we see that, with the exception of CMOS, Tasmania's output components exhibit a similar pattern of change to the industry as a whole except that there has been considerably less growth in some of Tasmania's outputs. Customer numbers increased steadily over the period and were 16 per cent higher in 2019 than they were in 2006, somewhat less than the industry's increase over the 14 years. Energy throughput peaked in 2009 and decreased each year through to 2014 before recovering somewhat in the last few years. It was still 3 per cent lower in 2019 than it was in 2006.

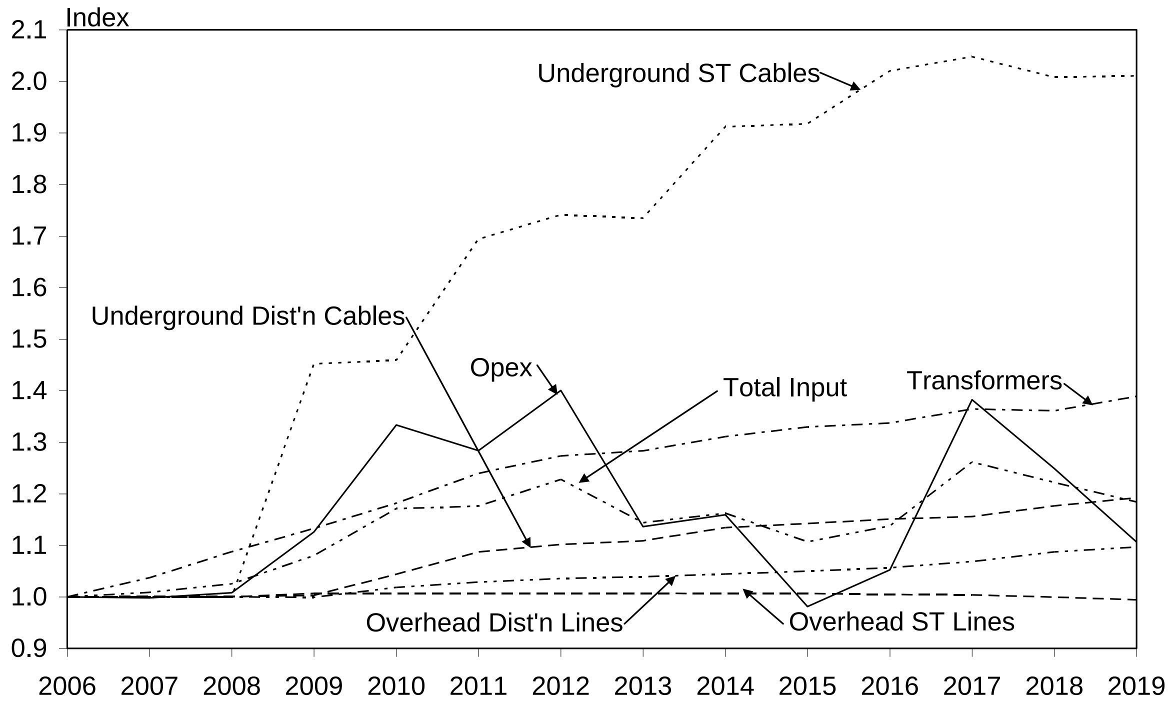
Tasmania's maximum demand reached its highest level in 2008 then declined through to 2013 before recovering somewhat subsequently. In 2019 it was around 3 per cent lower than it was in 2006. Ratcheted maximum demand in 2019 was 9 per cent above its 2006 level – a much smaller increase than the industry's 17 per cent.

Tasmania's circuit length output grew faster over the 14 years than occurred for the industry overall and by 2019 was 8 per cent above the level it was in 2006.

The last output shown in figure 4.20 is total CMOS. Tasmania's CMOS has been more volatile than for the industry and has trended upwards over the period. By 2019 Tasmania's CMOS was 39 per cent higher than it was in 2006 but this was down from 68 per cent above its 2006 level in 2010 and 57 per cent above its 2006 level in 2014. CMOS receives an average weight of –18 per cent of total revenue for Tasmania.

Although the circuit length, ratcheted maximum demand and customer numbers outputs receive most of the weight in forming the total output index, in figure 4.20 we see that the total output index lies below these three output indexes. This is because the CMOS variable enters the formation of total output as a negative output (ie the large increase in CMOS over the period makes a substantial negative contribution to total output). Movements in the total output index generally mirror movements in CMOS.

Figure 4.21 **TAS DNSP input quantity indexes, 2006–2019**



Turning to the input side, we see from Tasmania's six input components and total input in figure 4.21 that the quantity of Tasmania's opex increased somewhat more between 2006 and 2012 than the corresponding increase for the industry. For Tasmania, opex increased by 40 per cent up to 2012 whereas the corresponding increase for the industry was 36 per cent. Since then Tasmania's opex usage was reduced sharply through to 2015 but increased moderately in 2016 and then sharply in 2017 before again being reduced by over 10 per cent in both 2018 and 2019. In 2019 it was 11 per cent above its 2006 level. As noted in Economic

Insights (2018), TND indicated the 27 per cent increase in opex in 2017 was used to address bushfire and other risks that had recently been identified. Opex has the largest average share in Tasmania's total costs at 35 per cent and so is an important driver of total input quantity.

Tasmania's transformer inputs have increased at a similar annual rate to the industry's 2.5 per cent for the 14 year period as a whole. However, Tasmania's transformer input use increased somewhat more rapidly than for the industry up to 2012 but somewhat less rapidly than for the industry after 2012.

Tasmania's underground distribution cables inputs increased more modestly over the period at a lower rate than for the industry as a whole. By 2019 underground distribution cables inputs were 19 per cent higher in Tasmania than they were in 2006 compared to a corresponding increase of 55 per cent for the industry. Tasmania's overhead distribution lines input increased over the period and were 10 per cent higher in 2019 relative to 2006 compared to a corresponding 12 per cent increase for the industry.

From figure 4.21 we see the total input quantity index generally lies below the quantity indexes for opex and transformers and above the quantity index for overhead distribution lines (having a combined weight of 87 per cent of total costs). Total input quantity decreased by over 3 per cent in 2019, mainly due to the 12 per cent reduction in opex.

Tasmanian output and input contributions to TFP change

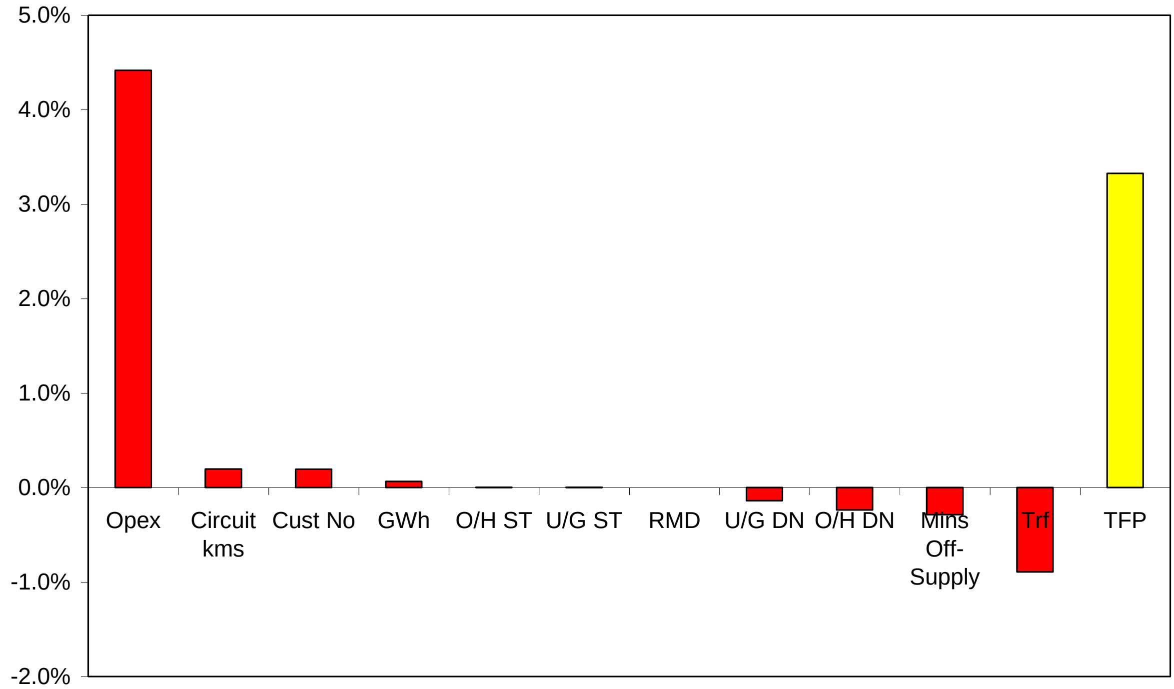
In table 4.10 we decompose Tasmania's TFP change into its constituent output and input parts for the whole 14–year period and for the periods up to and after 2012. Tasmania's drivers of TFP change for the whole 14–year period are somewhat similar to the industry as a whole except that CMOS makes a negative contribution to TFP growth for Tasmania whereas it is positive for the industry. RMD makes a smaller contribution for Tasmania and circuit length a larger contribution compared to those for the industry. Opex also makes a less negative contribution over the period for Tasmania at –0.3 per cent compared to –0.4 per cent for the industry, as does underground distribution cables input at –0.2 percentage points for Tasmania compared to –0.4 for the industry.

Table 4.10 **TAS output and input percentage point contributions to average annual TFP change: 2006–2019, 2006–2012, 2012–2019, 2018–19**

Year	*2006 to 2019*	*2006 to 2012*	*2012 to 2019*	*2018–19*
Energy (GWh)	–0.02%	–0.05%	0.00%	0.07%
Ratcheted Max Demand	0.26%	0.55%	0.00%	0.00%
Customer Numbers	0.25%	0.39%	0.13%	0.19%
Circuit Length	0.27%	0.36%	0.19%	0.20%
CMOS	–0.49%	–0.97%	–0.09%	–0.29%
Opex	–0.28%	–2.01%	1.20%	4.42%
O/H Subtransmission Lines	0.00%	0.00%	0.00%	0.00%
O/H Distribution Lines	–0.19%	–0.15%	–0.23%	–0.24%
U/G Subtransmission Cables	–0.02%	–0.03%	–0.01%	0.00%
U/G Distribution Cables	–0.16%	–0.19%	–0.13%	–0.14%
Transformers	–0.65%	–1.03%	–0.32%	–0.89%
TFP Change	–1.04%	–3.14%	0.75%	3.33%

The Tasmanian situation is again a tale of two distinct periods. With the exceptions of CMOS and energy, the contribution of outputs to TFP falls after 2012 compared to the period before 2012. And the contribution of most inputs remains relatively unchanged except for opex and transformers whose contributions improve by 3.2 percentage points and 0.7 percentage points, respectively. Opex change went from a contribution to TFP of –2.0 percentage points to a contribution of around 1.2 percentage points.

Figure 4.22 **TAS output and input percentage point contributions to annual TFP change, 2018–19**



The impact of the reduction in opex in 2019 on Tasmanian TFP performance is highlighted in figure 4.22 where opex made a 4.4 percentage point contribution to TFP change in the 2019 year. This more than offset the contributions of –0.3 and –0.9 percentage points from a worsening in CMOS and increased transformer inputs. Contributions from other outputs and inputs were all relatively small leading to Tasmanian TFP change of 3.3 per cent in 2019, well in excess of the industry TFP change of –1.0 per cent in the latest year.

4.2.6 Victoria

Victoria (VIC) is the second largest of the NEM jurisdictions (by customer numbers) and is served by five DNSPs: AusNet Services Distribution (AND), CitiPower (CIT), Jemena Electricity Networks (JEN), Powercor (PCR) and United Energy (UED). In 2019 the Victorian DNSPs delivered 36,275 GWh to 3.0 million customers over 145,903 circuit kilometres of lines and cables.

Victorian DNSP productivity performance

Victoria's total output, total input and TFP indexes are presented in figure 4.23 and table 4.11. Opex and capital partial productivity indexes are also presented in table 4.11.

Figure 4.23 **VIC DNSP output, input and total factor productivity indexes, 2006–2019**

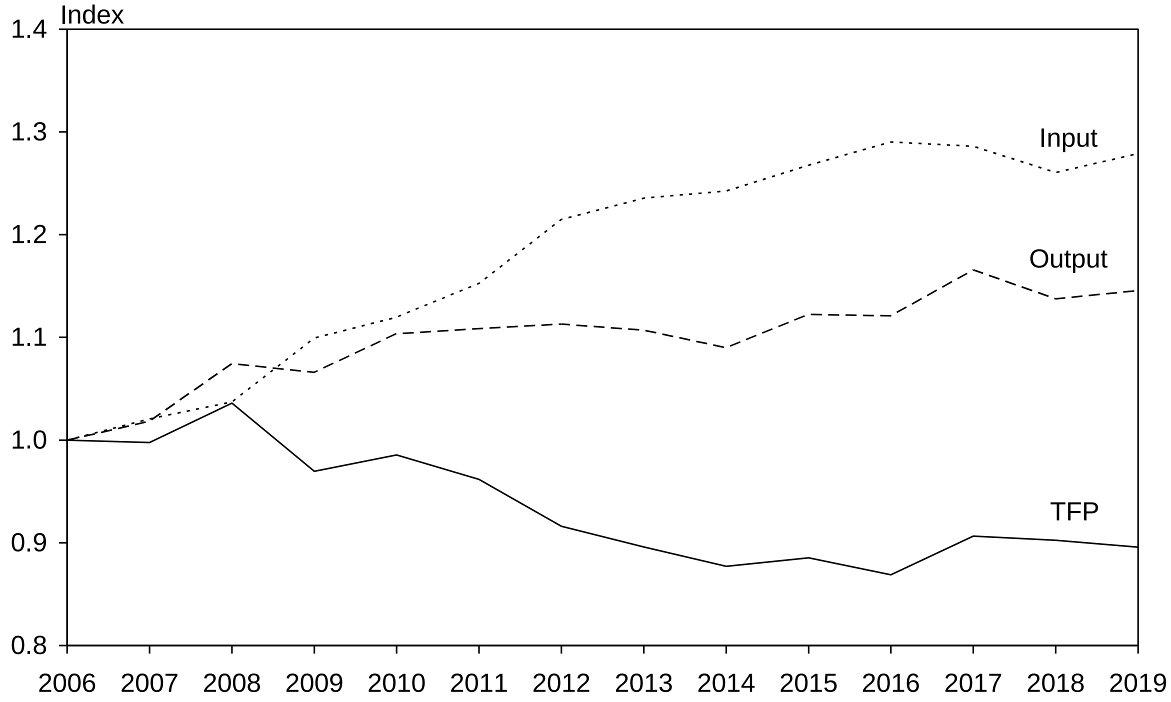


Table 4.11 **VIC DNSP output, input and total factor productivity and partial productivity indexes, 2006–2019**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index Opex*	*PFP Index Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.018	1.021	0.998	1.003	0.993
2008	1.074	1.037	1.036	1.061	1.024
2009	1.066	1.099	0.970	0.952	0.981
2010	1.104	1.120	0.986	0.973	0.995
2011	1.108	1.153	0.962	0.929	0.983
2012	1.113	1.215	0.916	0.842	0.968
2013	1.107	1.236	0.896	0.825	0.944
2014	1.090	1.243	0.877	0.824	0.913
2015	1.122	1.268	0.885	0.825	0.926
2016	1.121	1.290	0.869	0.805	0.911
2017	1.166	1.286	0.906	0.866	0.932
2018	1.138	1.260	0.903	0.920	0.893
2019	1.146	1.279	0.896	0.912	0.888
Growth Rate 2006–19	1.05%	1.89%	–0.85%	–0.71%	–0.92%
Growth Rate 2006–12	1.78%	3.24%	–1.46%	–2.86%	–0.55%
Growth Rate 2012–19	0.41%	0.73%	–0.32%	1.13%	–1.23%

Over the 14–year period 2006 to 2019, the Victorian DNSPs' TFP decreased at an average annual rate of 0.9 per cent. Although total output increased by an average annual rate of 1.0

per cent, total input use increased faster, at a rate of 1.9 per cent. Victoria thus had similar output growth but somewhat higher input growth and hence lower TFP growth compared to the industry as a whole. Input use increased at a faster rate in 2009 and 2012 but otherwise grew at a steady rate through to 2016 before levelling off in 2017, decreasing in 2018 and again increasing in 2019. Victoria's output declined in five years: 2009, 2013, 2014, 2016 and 2018. TFP change was positive in four years: 2008, 2010, 2015 and 2017. In the first three of these years there was stronger output growth and in 2017 input use levelled off at the same time there was a return to strong output growth. Compared to the whole 14–year period TFP average annual change of –0.9 per cent, TFP average annual change was more negative for the period up to 2012 at –1.5 per cent but has been –0.3 per cent for the period since 2012.

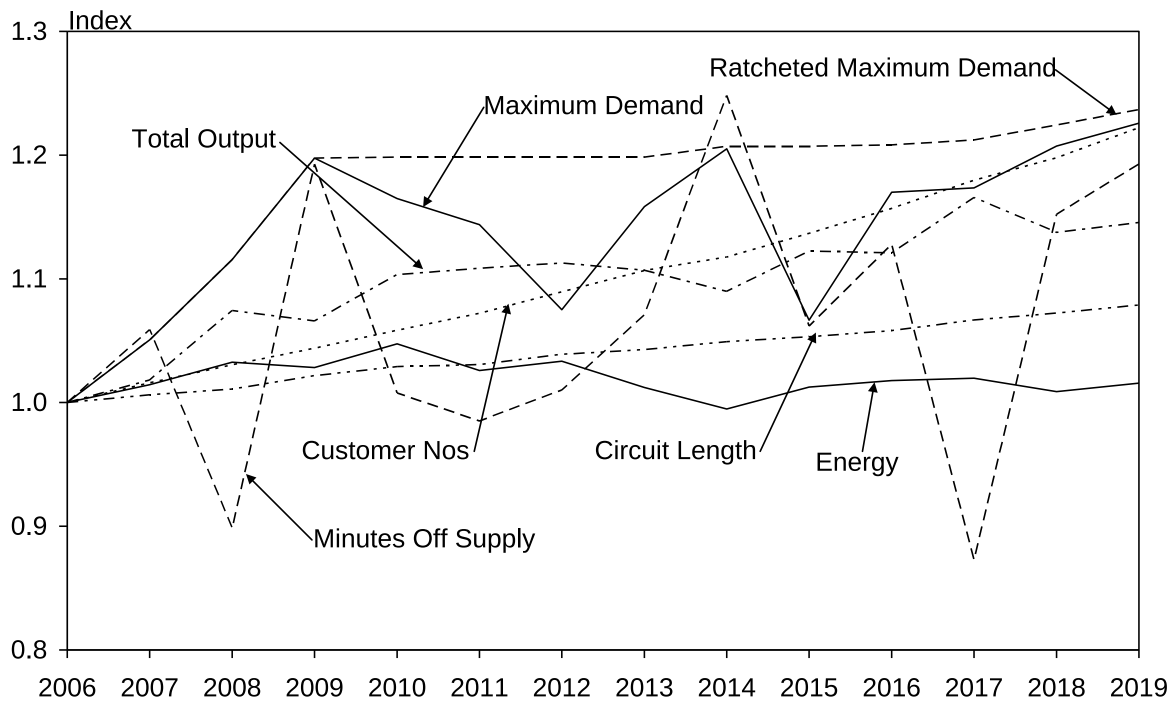
The partial productivity indexes in table 4.11 show that better opex PFP performance was the main driver of the improved TFP performance after 2012.

Victorian DNSP output and input quantity changes

We graph the quantity indexes for the Victorian DNSPs' five individual outputs in figure 4.24 and for their six individual inputs in figure 4.25.

From figure 4.24 we see that, with the exception of CMOS, Victoria's output components exhibit a similar pattern of change to the industry as a whole. Customer numbers increased steadily over the period and were 22 per cent higher in 2019 than they were in 2006, higher than the industry's increase of 19 per cent. Energy throughput for distribution peaked in 2010 and was only 2 per cent higher in 2019 than it was in 2006.

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



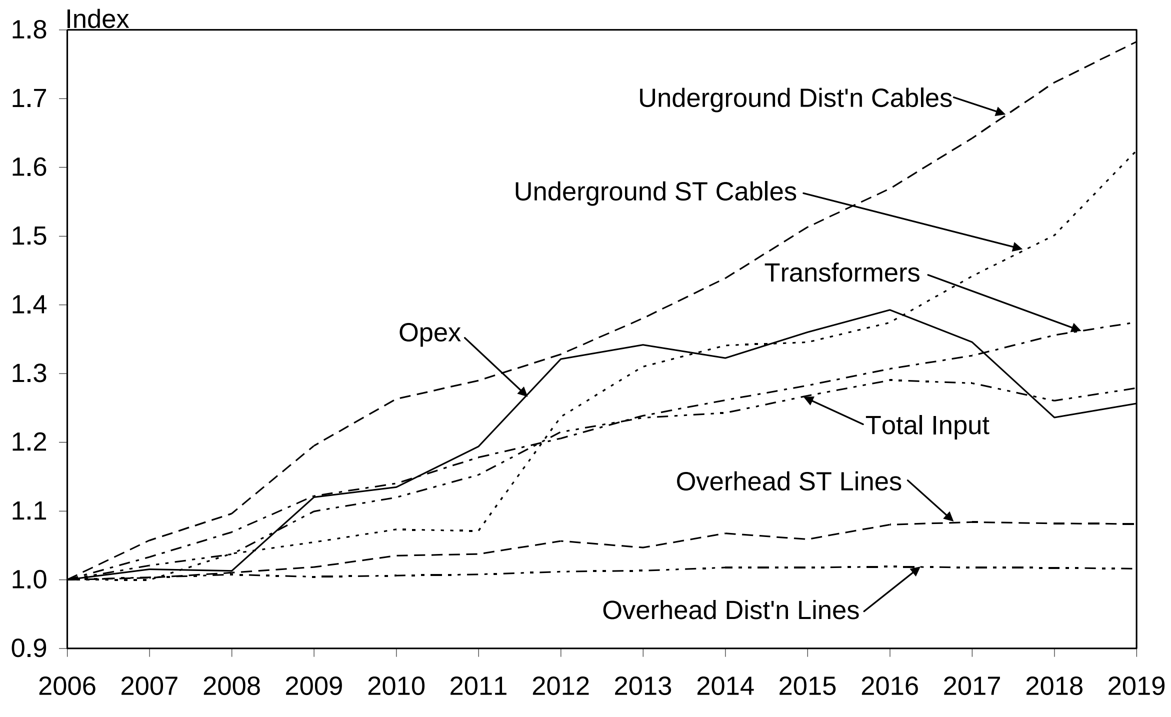
In 2018 and 2019 Victoria's maximum demand exceeded its previous highest level in 2014 but has been relatively volatile since 2009. In 2019 it was around 23 per cent above its 2006 level. Ratcheted maximum demand in 2019 was 24 per cent above its 2006 level – a larger increase than the industry's 17 per cent.

Victoria's circuit length output grew somewhat more over the 14 years than occurred for the industry overall and by 2019 was 8 per cent above the level it was in 2006 compared to an increase of 5 per cent for the industry.

The last output shown in figure 4.24 is total CMOS. Victoria's CMOS has been more volatile than for the industry and trended upwards till 2016 but then fell by 26 per cent in 2017 before again increasing by 28 per cent in 2018 and by 3.5 per cent in 2019 to be 19 per cent higher than it was in 2006. But in 2014 it had been 25 per cent above its 2006 level. CMOS receives an average weight of –14 per cent of total revenue for Victoria.

Since the circuit length and ratcheted maximum demand outputs receive a combined average weight of around 83 per cent of total revenue in forming the total output index for Victoria, in figure 4.24 we see that the total output index lies between these output indexes and is close to the customer numbers output index. The energy output index lies at a lower level and variations in the CMOS index are reflected in inverse movements in the total output index. The four non–CMOS outputs all increased in 2019, more than offset the increase in CMOS, leading to total output increasing by 0.7 per cent in the latest year.

Figure 4.25 **VIC DNSP input quantity indexes, 2006–2019**



Turning to the input side, we see from Victoria's six input components and total input in figure 4.25 that the quantity of Victoria's opex increased somewhat less rapidly between 2006 and 2012 than the corresponding increase for the industry. For Victoria, opex increased by 32 per cent up to 2012 whereas the corresponding increase for the industry was 36 per cent. Since then Victoria's opex usage was relatively flat through to 2017 before decreasing by 9 per cent in 2018 and increasing again by 2 per cent in 2019. This brought Victoria's opex reduction after 2012 to less than half that for the industry which reduced by 17 per cent.

Opex has the largest average share in Victoria’s total costs at 38 per cent and so is an important driver of its total input quantity index.

Victoria’s underground distribution cables and transformers inputs increased more steadily over the period at somewhat higher and lower rates, respectively, than for the industry as a whole. Its overhead distribution lines input increased slowly over the period with an increase of 2 per cent by 2019 relative to 2006 compared to a 12 per cent increase for the industry.

From figure 4.25 we see that the total input quantity index lies close to the quantity indexes for opex and transformers (which have a combined weight of 60 per cent of total costs). Total input quantity increased by 1.5 per cent in 2019, mainly due to increases in opex, transformer and underground distribution cables inputs.

Victorian output and input contributions to TFP change

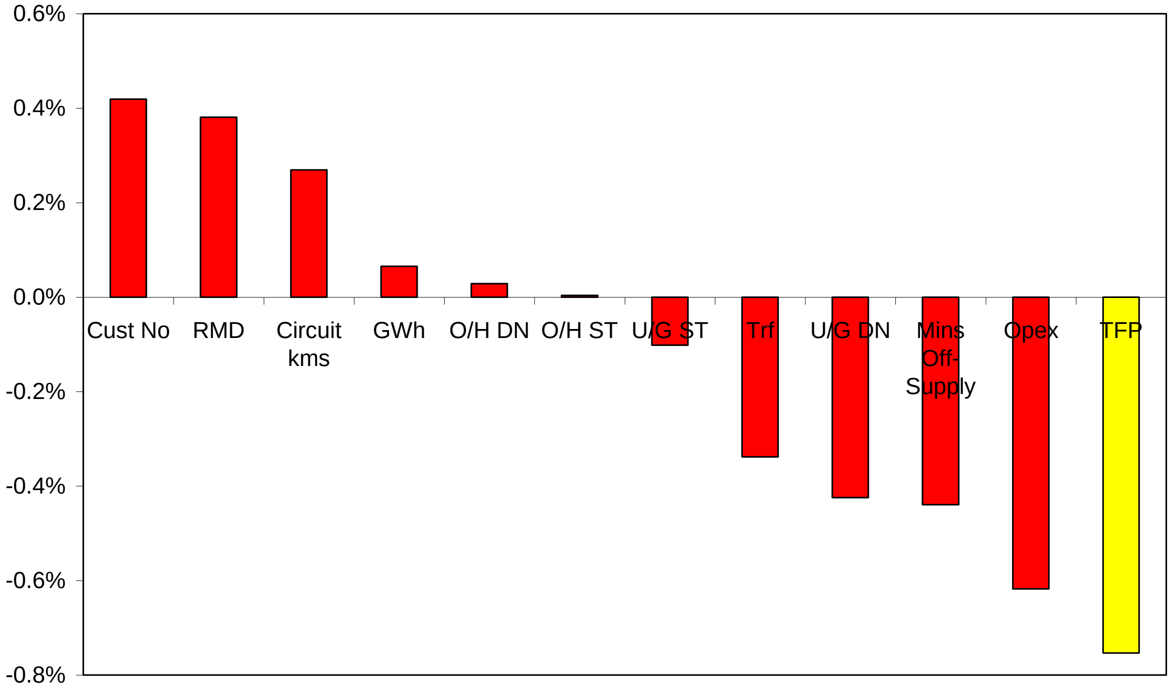
In table 4.12 we decompose Victoria’s TFP change into its constituent output and input parts for the whole 14–year period and for the periods up to and after 2012. Victoria’s drivers of TFP change for the whole 14–year period are broadly similar to the industry as a whole except that CMOS makes a negative contribution to TFP growth for Victoria as opposed to a marginal positive contribution for the industry. Opex also makes a somewhat more negative contribution over the period for Victoria at –0.7 per cent compared to –0.4 per cent for the industry. However, transformer inputs make a less negative contribution to Victoria’s TFP at –0.5 percentage points compared to –0.7 for the industry.

Table 4.12 **VIC output and input percentage point contributions to average annual TFP change: 2006–2019, 2006–2012, 2012–2019, 2018–19**

Year	*2006 to 2019*	*2006 to 2012*	*2012 to 2019*	*2018–19*
Energy (GWh)	0.01%	0.05%	–0.02%	0.07%
Ratcheted Max Demand	0.63%	1.17%	0.17%	0.38%
Customer Numbers	0.33%	0.30%	0.34%	0.42%
Circuit Length	0.26%	0.29%	0.24%	0.27%
CMOS	–0.18%	–0.03%	–0.31%	–0.44%
Opex	–0.68%	–1.83%	0.30%	–0.62%
O/H Subtransmission Lines	–0.02%	–0.03%	–0.01%	0.00%
O/H Distribution Lines	–0.03%	–0.04%	–0.01%	0.03%
U/G Subtransmission Cables	–0.05%	–0.05%	–0.05%	–0.10%
U/G Distribution Cables	–0.57%	–0.61%	–0.53%	–0.42%
Transformers	–0.54%	–0.68%	–0.42%	–0.34%
TFP Change	–0.85 %	–1.46%	–0.32%	–0.75%

The Victorian situation is again a tale of two distinct periods. The contribution of all outputs to TFP falls after 2012 compared to the period before 2012, with the exception of customer numbers. And the contribution of most inputs remains relatively unchanged except for opex and transformers whose contributions improve by 2.1 percentage points and 0.3 percentage points, respectively. Opex change went from a negative 1.8 percentage point contribution to TFP to a positive contribution of 0.3 percentage points for Victoria as opex usage reduced, although this was concentrated in 2018. This was broadly in line with changes for the industry as a whole.

Figure 4.26 **VIC output and input percentage point contributions to annual TFP change, 2019**



In figure 4.26 we see that the customer numbers, RMD and circuit length outputs contributed 0.5, 0.4 and 0.3 percentage points, respectively, to TFP change in 2019. These were more than offset by contributions from transformer and underground distribution cables inputs of around –0.4 percentage points, of –0.4 percentage points from increased CMOS and of –0.6 percentage points from opex. Victorian TFP growth in 2019 was –0.8 per cent compared to industry TFP growth of –1.0 per cent in the latest year.

5 DNSP OUTPUTS, INPUTS AND PRODUCTIVITY CHANGE

In this section we review the outputs, inputs and productivity change results for the remaining 10 NEM DNSPs – three of the NEM jurisdictions covered in the preceding section have only one DNSP so we have already covered the ACT's Evoenergy, South Australia's SA Power Networks and Tasmania's TasNetworks Distribution.

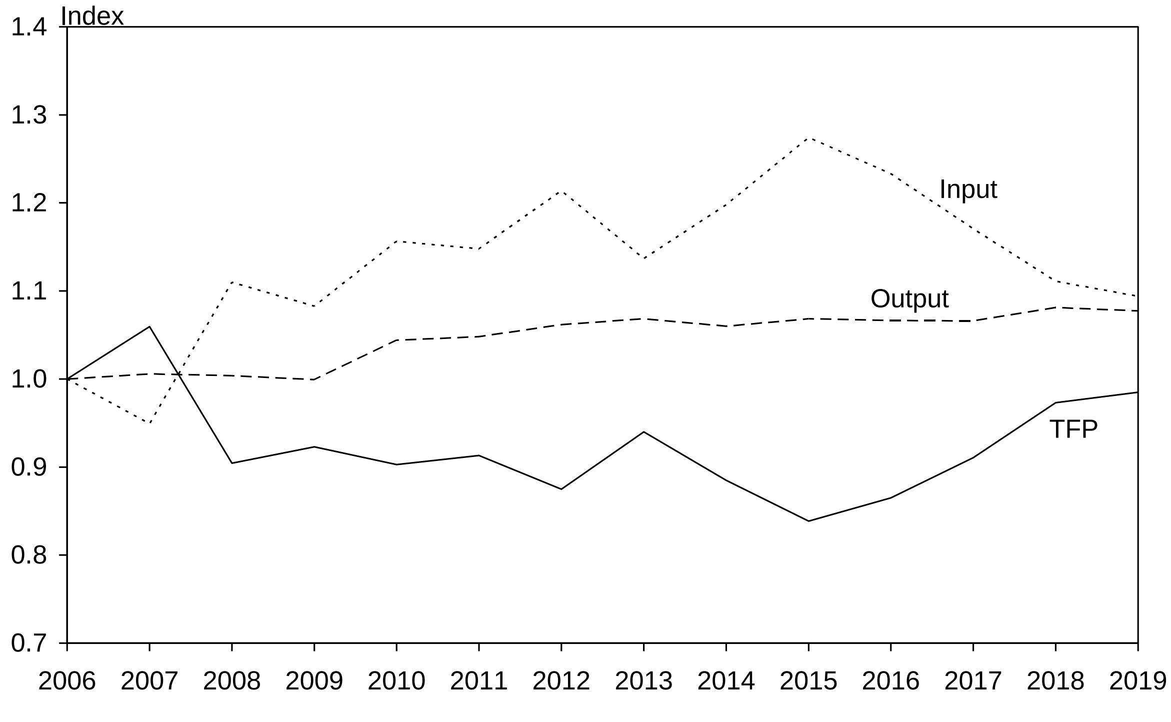
5.1 Ausgrid

In 2019 Ausgrid (AGD) delivered 25,424 GWh to 1.75 million customers over 42,007 circuit kilometres of lines and cables. AGD distributes electricity to the eastern half of Sydney (including the Sydney CBD), the NSW Central Coast and the Hunter region across an area of 22,275 square kilometres. It is the largest of the three NSW DNSPs in terms of customer numbers and energy throughput.

AGD's productivity performance

AGD's total output, total input and TFP indexes are presented in figure 5.1 and table 5.1. Opex and capital partial productivity indexes are also presented in table 5.1.

Figure 5.1 **AGD output, input and total factor productivity indexes, 2006–2018**



Over the 14–year period 2006 to 2019, AGD's TFP had an average annual change of –0.1 per cent. Although total output increased by an average annual rate of 0.6 per cent, total input use increased somewhat faster, at a rate of 0.7 per cent. AGD thus had much slower output growth than the industry as a whole. However, it has also hadslower input growth leading to AGD having marginally negative TFP growth rate compared to the industry's TFP growth rate of –0.8 per cent. Input use increased sharply in 2008, 2010 and 2012, to be followed each time by a small reduction the following year. Input use again fell each year from 2016 to

2019 after solid increases in 2014 and 2015. TFP fell markedly in 2008, 2012, 2014 and 2015 but TFP change was positive in eight years – 2007, 2009, 2011, 2013, and 2016 to 2019. TFP average annual change was sharply negative for the period up to 2012 at –2.2 per cent but has reversed for the period since 2012 with an average annual growth rate of 1.7 per cent.

Table 5.1 **AGD output, input and total factor productivity and partial productivity indexes, 2006–2019**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index Opex*	*PFP Index Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.006	0.949	1.060	1.188	0.981
2008	1.004	1.110	0.904	0.834	0.956
2009	0.999	1.083	0.923	0.917	0.926
2010	1.044	1.157	0.903	0.845	0.938
2011	1.048	1.148	0.913	0.888	0.924
2012	1.062	1.214	0.875	0.815	0.908
2013	1.069	1.137	0.940	1.038	0.890
2014	1.060	1.198	0.885	0.923	0.860
2015	1.068	1.274	0.839	0.793	0.863
2016	1.066	1.233	0.865	0.886	0.849
2017	1.066	1.171	0.911	1.002	0.862
2018	1.081	1.111	0.973	1.188	0.872
2019	1.077	1.094	0.985	1.260	0.864
Growth Rate 2006–19	0.57%	0.69%	–0.12%	1.78%	–1.12%
Growth Rate 2006–12	1.00%	3.23%	–2.23%	–3.42%	–1.61%
Growth Rate 2012–19	0.21%	–1.49%	1.70%	6.23%	–0.70%

The partial productivity indexes in table 5.1 show that reduced opex usage was the main driver of the improved TFP performance after 2012.

AGD's output and input quantity changes

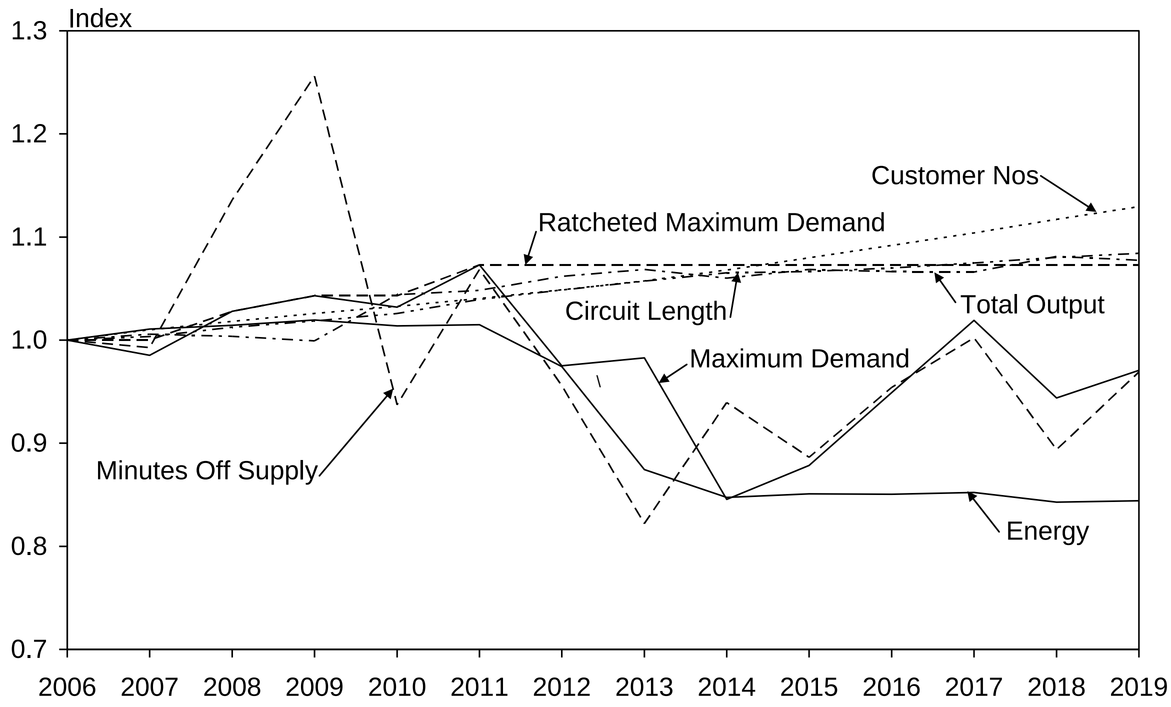
We graph the quantity indexes for AGD's five individual outputs in figure 5.2 and for its six individual inputs in figure 5.3.

From figure 5.2 we see that AGD's output components showed a similar pattern of change to the industry as a whole except that there was much less growth in outputs for AGD between 2006 and 2009, likely reflecting the initial negative effects of the mining boom on NSW and then the impact of the global financial crisis. Customer numbers increased steadily over the period and were 13 per cent higher in 2019 than they were in 2006 reflecting AGD's relatively weak output growth. Energy throughput peaked in 2009 and has fallen considerably since to be a quite large 16 per cent lower in 2019 than it was in 2006.

AGD's maximum demand peaked in 2011 – two to three years later than in most other states and then declined through to 2014 before increasing in the subsequent three years, falling again in 2018 and increasing in 2019. In 2019 it was 3 per cent below its 2006 level. Ratcheted maximum demand in 2019 was 7 per cent above its 2006 level – a considerably smaller increase than for the industry overall.

AGD's circuit length output grew more over the 12 years than occurred for the industry overall and by 2019 it was 8 per cent above its 2006 level compared to an increase of 5 per cent for the industry.

Figure 5.2 **AGD output quantity indexes, 2006–2019**



The last output shown in figure 5.2 is total CMOS. AGD's CMOS has generally followed a similar pattern to that of the industry although it has been considerably more volatile. AGD's CMOS increased by 26 per cent between 2007 and 2009 and has fluctuated since, but on a generally downward trajectory. In 2019 CMOS was 3 per cent below its 2006 level, after having increased by 8 per cent in 2019.

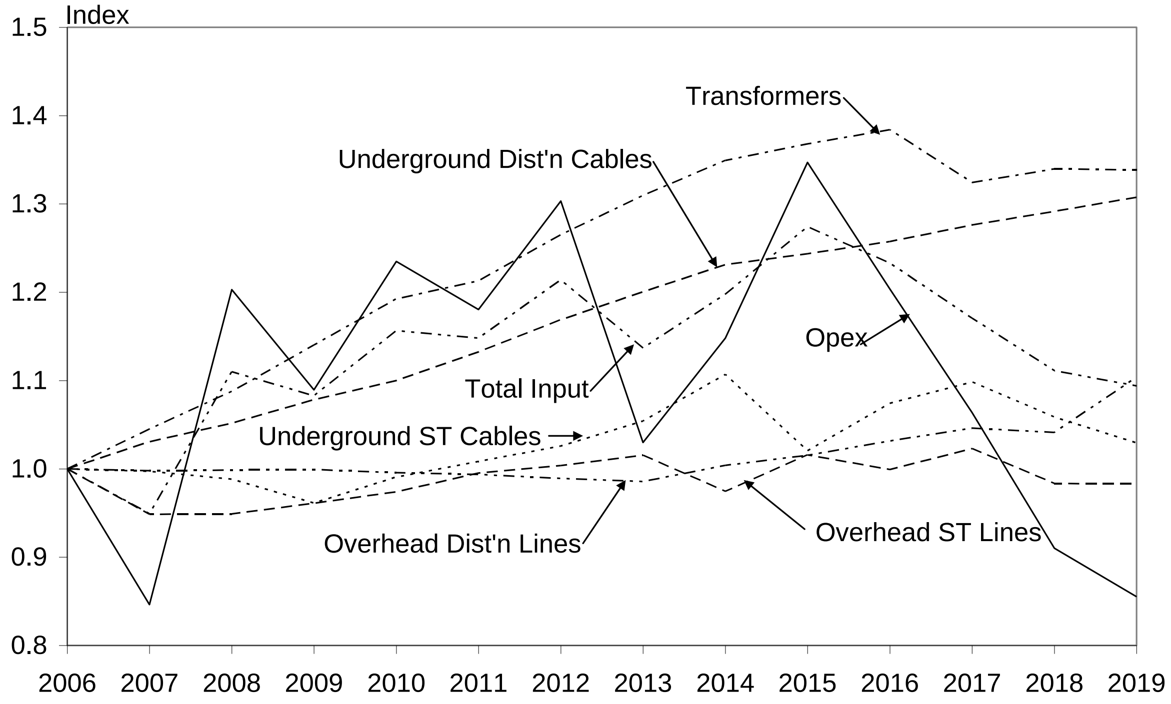
Since the circuit length and ratcheted maximum demand outputs receive the bulk of the weight in forming the total output index, in figure 5.2 we see that the total output index tends to lie very close to these two output indexes. The total output index was slightly below these two indexes between 2014 and 2017 as it is pulled down by AGD's weak throughput output and an upward movement in CMOS between 2015 and 2017.

Turning to the input side, we see from AGD's six input components and total input in figure 5.3 that the quantity of AGD's opex has been subject to wide swings over the 14–year period. AGD's opex increased by 30 per cent up to 2012 whereas the corresponding increase for the industry was 36 per cent. However, AGD's opex input has also been more volatile over the whole period, with a subsequent higher peak in opex in 2015. Opex then fell substantially each year from 2016 to 2019 to be 14 per cent below its 2006 level in 2019.[11] Opex has the largest average share in AGD's total costs at 37 per cent and so is an important driver of its total input quantity index.

[11] Note that redundancy payments are included in the opex figures presented here.

AGD's transformers and underground distribution cables inputs increased more steadily over the period, although transformer inputs were reduced in 2017. While AGD's transformer inputs increased at a broadly similar rate to the industry as a whole, its underground distribution cable inputs increased at a considerably lower rate than for the industry, probably reflecting the fact AGD operates in Australia's largest city and so undergrounding is growing from a high initial base. Similarly, AGD's overhead distribution lines input increased more slowly over the period with an increase of 8 per cent compared to 12 per cent for the industry.

Figure 5.3 **AGD input quantity indexes, 2006–2019**



From figure 5.3 we see that the total input quantity index generally lies between the quantity indexes for opex and transformers (which have a combined weight of 70 per cent of total costs). Total input quantity fell by 1.6 per cent in 2019 in line with the substantial reduction in reported opex usage that year.

AGD's output and input contributions to TFP change

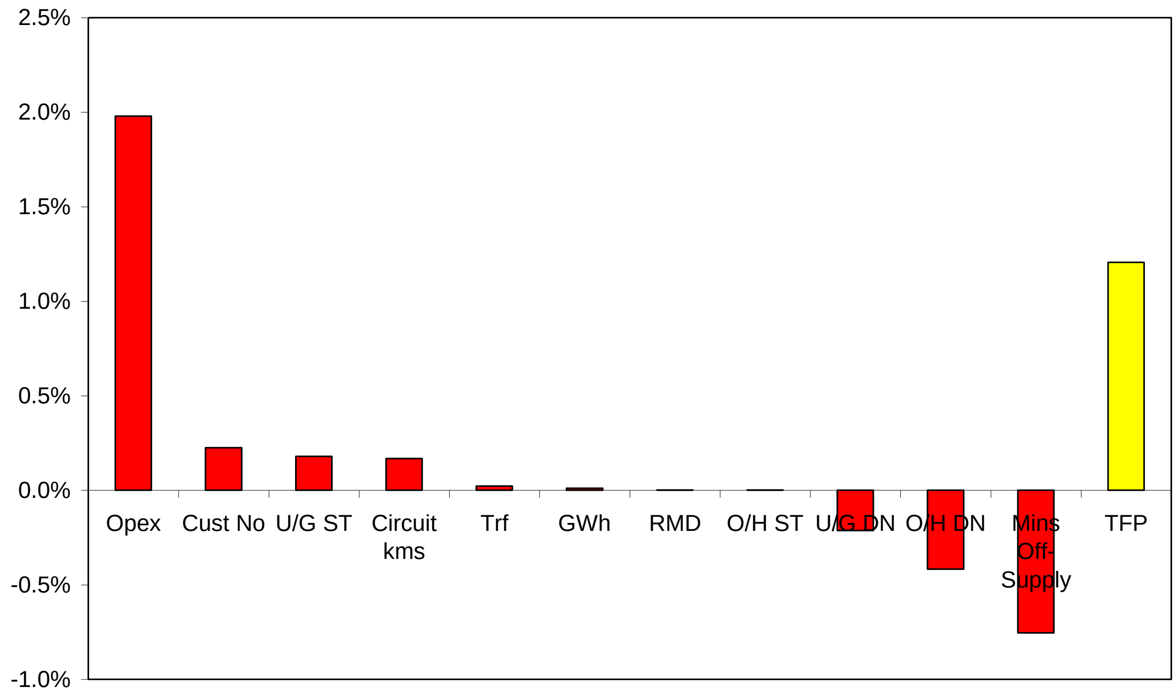
In table 5.2 we decompose AGD's TFP change into its constituent output and input parts for the whole 14–year period and for the periods up to and after 2012. AGD's drivers of TFP change for the whole 14–year period are broadly similar to the industry as a whole except that the outputs of customer numbers, RMD and energy contribute somewhat less due to their weaker growth in NSW. Circuit length output growth contributes more to TFP growth for AGD than for the industry given circuit length's higher rate of growth for AGD. Overhead distribution line inputs and underground distribution cables inputs both make less negative contributions to AGD's TFP growth relative to the industry.

AGD's situation is again a tale of two distinct periods. For the period up to 2012, opex growth made a somewhat similar negative percentage point contribution to TFP growth for AGD as it did for the industry, at around –1.7 percentage points. But the larger reductions made in AGD's opex after 2012 led to opex contributing 2.1 percentage points to AGD's average annual TFP change of 1.7 per cent for the period after 2012. This compares to an opex contribution of 0.9 percentage point to the industry's lower TFP average annual change of 0.3 per cent after 2012.

Table 5.2 **AGD output and input percentage point contributions to average annual TFP change: 2006–2019, 2006–2012, 2012–2019, 2018–19**

Year	*2006 to 2019*	*2006 to 2012*	*2012 to 2019*	*2018–19*
Energy (GWh)	–0.12%	–0.05%	–0.19%	0.01%
Ratcheted Max Demand	0.21%	0.44%	0.00%	0.00%
Customer Numbers	0.19%	0.17%	0.21%	0.23%
Circuit Length	0.27%	0.35%	0.21%	0.17%
CMOS	0.03%	0.08%	–0.02%	–0.75%
Opex	0.35%	–1.68%	2.10%	1.98%
O/H Subtransmission Lines	0.01%	0.00%	0.01%	0.00%
O/H Distribution Lines	–0.05%	0.01%	–0.11%	–0.42%
U/G Subtransmission Cables	–0.01%	–0.02%	0.00%	0.18%
U/G Distribution Cables	–0.29%	–0.34%	–0.24%	–0.21%
Transformers	–0.70%	–1.19%	–0.27%	0.02%
TFP Change	–0.12%	–2.23%	1.70%	1.21%

Figure 5.4 **AGD output and input percentage point contributions to annual TFP change, 2018–19**



The importance of the reduction in AGD's opex in 2019 is highlighted in figure 5.4 where it makes a 2.0 percentage point contribution to AGD's 1.2 per cent TFP change in the 2019 year. The worsening in CMOS makes a –0.8 percentage point contribution. The contributions of the other output and inputs are all small.

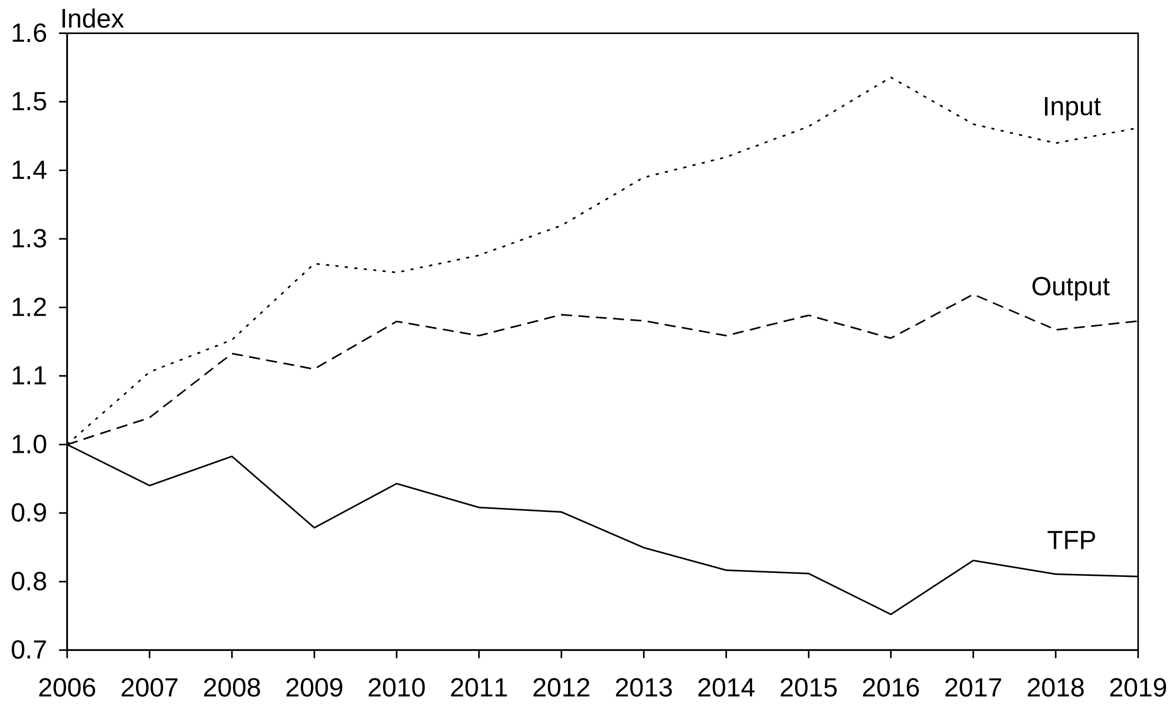
5.2 AusNet Services Distribution

In 2019 AusNet Services Distribution (AND) delivered 7,658 GWh to 762,382 customers over 45,494 circuit kilometres of lines and cables. AND distributes electricity to eastern Victoria (including Melbourne's outer northern and eastern suburbs) across an area of 80,000 square kilometres.

AND's productivity performance

AND's total output, total input and TFP indexes are presented in figure 5.5 and table 5.3. Opex and capital partial productivity indexes are also presented in table 5.3.

Figure 5.5 **AND's output, input and total factor productivity indexes, 2006–2019**



Over the 14–year period 2006 to 2019, AND's TFP decreased with an average annual change of –1.7 per cent. Although total output increased by an average annual rate of 1.3 per cent, total input use increased considerably faster, at a rate of 2.9 per cent. AND had much faster output growth than the industry as a whole up to 2012 at an average annual rate of 2.9 per cent compared to the industry's 1.7 per cent. However, since 2012 AND's output has declined marginally while the industry's output increased annually at 0.4 per cent. AND's pattern of input use has also been quite different to the industry as a whole. Whereas the industry saw rapid growth in input use up to 2012 followed by flattening out after that, AND's input use increased more rapidly than the industry up to 2012 and continued to grow strongly after 2012, albeit at a somewhat lower rate, before reducing in 2017 and 2018. AND's TFP change was positive in three years: 2008, 2010 and 2017. In the first two of these years there was strong output growth and in 2017 output growth was higher than usual while input use declined. Compared to the whole 14–year period, AND's TFP average annual change was marginally more negative for the period up to 2012 at –1.7 per cent than for the period after 2012 when it was –1.6 per cent. AND's service area was badly affected by the 2009 'Black Saturday' bushfires and this would have played a role in its pattern of input use.

Table 5.3 **AND's output, input and total factor productivity and partial productivity indexes, 2006–2019**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.039	1.105	0.940	0.849	1.000
2008	1.132	1.153	0.983	0.860	1.074
2009	1.110	1.264	0.878	0.727	0.997
2010	1.180	1.251	0.943	0.799	1.053
2011	1.159	1.276	0.908	0.779	1.008
2012	1.189	1.319	0.901	0.754	1.015
2013	1.180	1.390	0.849	0.675	0.989
2014	1.159	1.419	0.816	0.643	0.957
2015	1.188	1.464	0.812	0.623	0.971
2016	1.155	1.535	0.752	0.549	0.927
2017	1.219	1.467	0.831	0.662	0.964
2018	1.167	1.440	0.811	0.688	0.904
2019	1.180	1.462	0.807	0.674	0.910
Growth Rate 2006–19	1.27%	2.92%	–1.65%	–3.04%	–0.73%
Growth Rate 2006–12	2.89%	4.62%	–1.73%	–4.71%	0.25%
Growth Rate 2012–19	–0.11%	1.47%	–1.58%	–1.60%	–1.56%

The partial productivity indexes in table 5.3 show that opex PFP growth improved but remained negative after 2012 while capital PFP growth worsened in the more recent period.

AND's output and input quantity changes

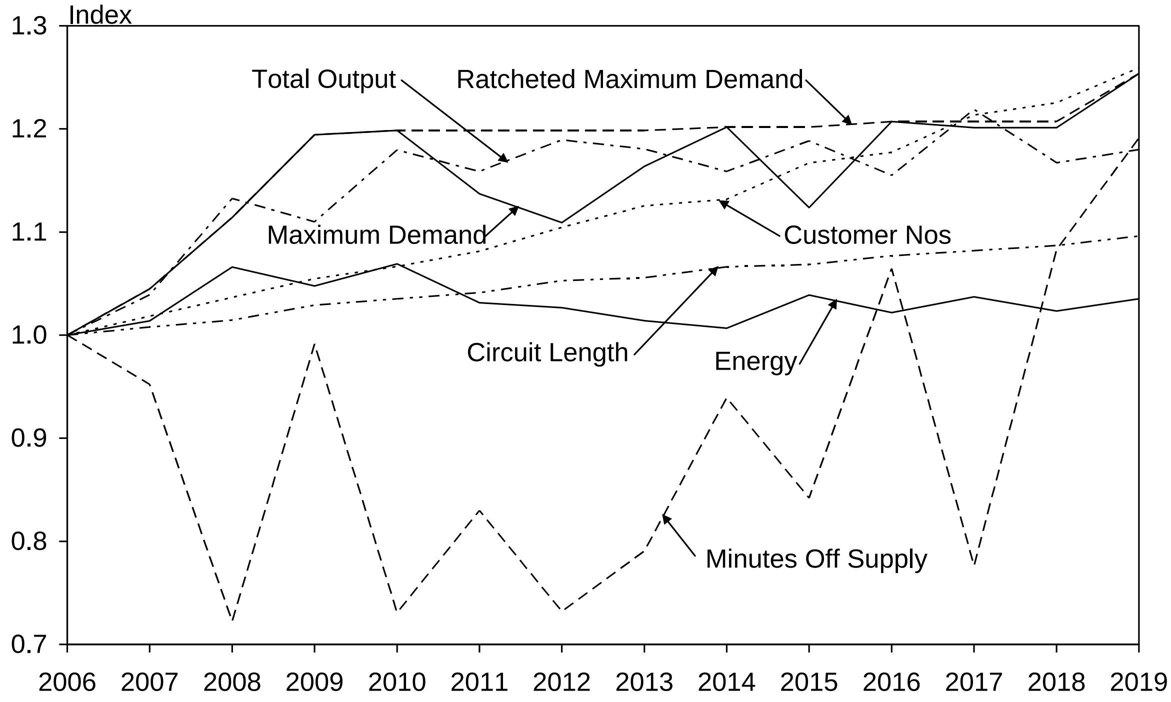
We graph the quantity indexes for AND's five individual outputs in figure 5.6 and for their six individual inputs in figure 5.7.

From figure 5.6 we see that, with the exception of CMOS, AND's output components exhibit a broadly similar pattern of change to the industry as a whole. Customer numbers increased steadily over the period and were 26 per cent higher in 2019 than they were in 2006, higher than the industry's increase of 19 per cent. Energy throughput peaked in 2010 and was 4 per cent higher in 2019 than it was in 2006.

AND's maximum demand reached its initial peak in 2010 but then marginally exceeded this level in 2014 and again in 2016 before a 4.4 per cent increase in 2019. This is a different pattern to the industry where maximum demand is still well short of its peak in 2009. In 2019 AND's maximum demand was around 25 per cent above its 2006 level. Ratcheted maximum demand in 2019 was similarly 25 per cent above its 2006 level – a larger increase than the industry's 17 per cent.

AND's circuit length output grew somewhat more over the 14 years than occurred for the industry overall and by 2019 was 10 per cent above the level it was in 2006 compared to an increase of 5 per cent for the industry.

Figure 5.6 **AND's output quantity indexes, 2006–2019**



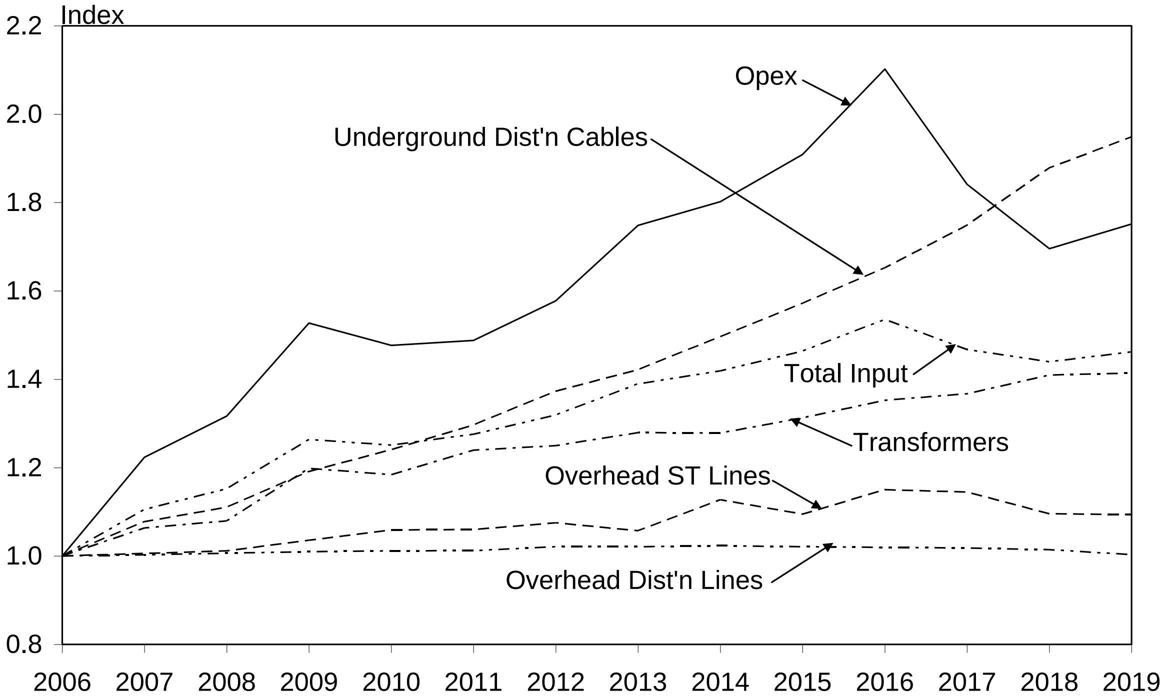
The last output shown in figure 5.6 is total CMOS. AND's CMOS has been more volatile than for the industry and, after trending downwards to 2012 (at which point it was 27 per cent below its 2006 level), it has trended upwards since. By 2019 AND's CMOS was 19 per cent higher than it was in 2006. CMOS receives an average weight of –16 per cent of total revenue for AND although this was as large as –24 per cent in 2006.

Since the circuit length and ratcheted maximum demand outputs receive a combined average weight of around 84 per cent of total revenue in forming the total output index for AND, in figure 5.6 we see that the total output index mostly lies between these two output indexes. The customer numbers output index was also between these indexes until recently. The downward trend in the CMOS index up to 2012 would generally contribute to positive growth in the output index but the steep upwards trend in CMOS since 2012 has suppressed output growth significantly over this period, particularly in 2018.

Turning to the input side, we see from AND's six input components and total input in figure 5.7 that the quantity of AND's opex has increased more rapidly than the corresponding increase for the industry. For AND, opex increased by 58 per cent up to 2012 whereas the corresponding increase for the industry was 36 per cent. Since then AND's opex usage continued to increase by another 33 per cent through to 2016 before falling by 19 per cent over the following two years and then increasing by 3 per cent in 2019. In 2019 AND's opex was still 11 per cent above its 2012 level whereas that for the industry was 16 per cent lower than its 2012 peak. Opex has the largest average share in AND's total costs at 40 per cent and so is an important driver of its total input quantity index.

AND's underground distribution cables inputs increased steadily over the period at a higher rate than for the industry as a whole while its transformers increased at a somewhat higher rate compared to the industry. Its overhead distribution lines input increased slower over the period with a 0.3 per cent increase by 2019 relative to 2006 compared to a 12 per cent increase for the industry.

Figure 5.7 **AND's input quantity indexes, 2006–2019**



From figure 5.7 we see that the total input quantity index lies between the quantity indexes for opex and transformers (which have a combined weight of 60 per cent of total costs). Total input quantity increased by 1.5 per cent in 2019 driven by the 3 per cent increase in opex usage.

AND's output and input contributions to TFP change

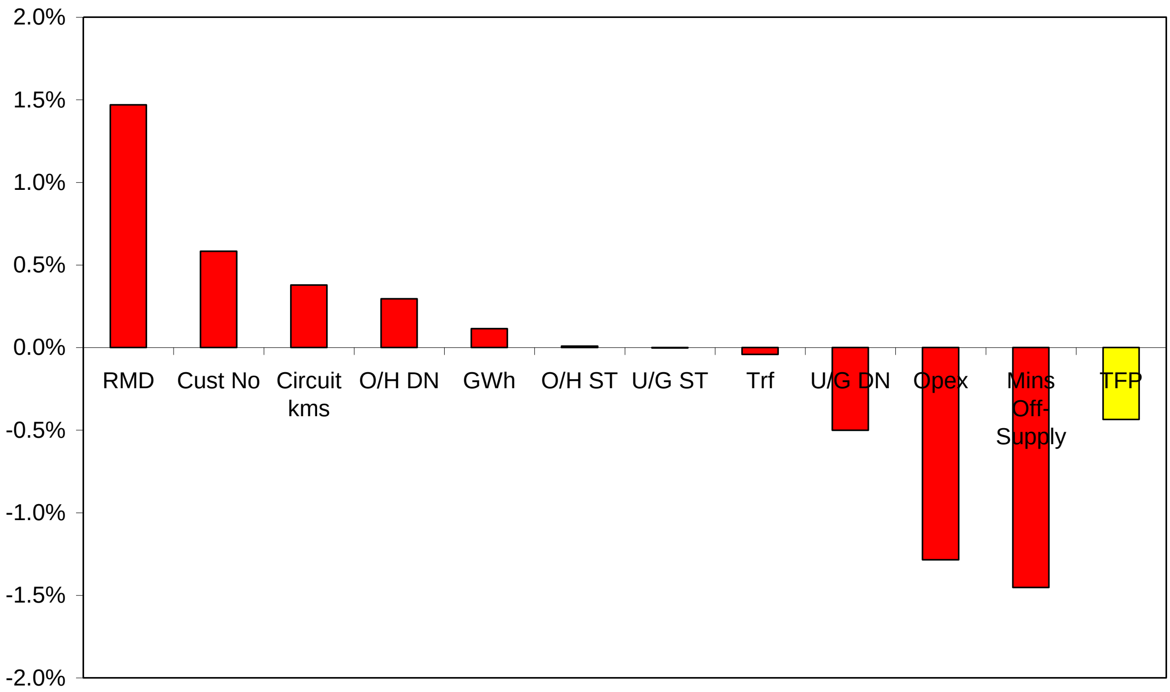
In table 5.4 we decompose AND's TFP change into its constituent output and input parts for the whole 14–year period and for the periods up to and after 2012. AND's drivers of TFP change for the whole 14–year period are broadly similar to the industry as a whole except that opex makes far and away the largest negative contribution to TFP growth for AND and relatively much larger than for the industry. Opex makes a negative contribution over the period for AND of –1.7 percentage points compared to –0.4 percentage points for the industry. Underground distribution inputs make a larger negative contribution to AND's TFP change at –0.6 percentage points than they do for the industry's at –0.4 percentage points.

AND's situation is again a tale of two distinct periods. The contribution of most outputs to TFP falls after 2012 compared to the period before 2012. And the contribution of most inputs remains relatively unchanged except for opex and transformers whose contributions improve by 2.5 percentage points and 0.4 percentage points, respectively, but still remain negative as both their quantities continued to trend upwards after 2012. This differs to the industry–wide result where opex makes a positive contribution to TFP change after 2012 as opex usage declines overall.

Table 5.4 **AND's output and input percentage point contributions to average annual TFP change: 2006–2019, 2006–2012, 2012–2019, 2019**

Year	*2006 to 2019*	*2006 to 2012*	*2012 to 2019*	*2019*
Energy (GWh)	0.03%	0.05%	0.01%	0.11%
Ratcheted Max Demand	0.70%	1.22%	0.25%	1.47%
Customer Numbers	0.39%	0.37%	0.40%	0.58%
Circuit Length	0.33%	0.40%	0.26%	0.38%
CMOS	–0.16%	0.86%	–1.03%	–1.45%
Opex	–1.71%	–3.03%	–0.58%	–1.28%
O/H Subtransmission Lines	–0.02%	–0.03%	–0.01%	0.01%
O/H Distribution Lines	0.00%	–0.08%	0.07%	0.30%
U/G Subtransmission Cables	–0.02%	–0.01%	–0.03%	0.00%
U/G Distribution Cables	–0.62%	–0.68%	–0.57%	–0.50%
Transformers	–0.54%	–0.78%	–0.34%	–0.04%
TFP Change	–1.65%	–1.73%	–1.58%	–0.44%

Figure 5.8 **AND's output and input percentage point contributions to annual TFP change, 2019**



AND's increase in RMD of 3.8 per cent in 2019 means it makes the largest positive contribution to TFP change in 2019 of 1.5 percentage points as shown in figure 5.8. The worsening in CMOS performance that year contributed –1.5 percentage points and the increase in opex contributed –1.3 percentage points. Customer numbers growth made a contribution of 0.6 percentage points while the other outputs and inputs made smaller positive and negative contributions. As a result, AND's TFP change in 2019 was –0.4 per cent compared to industry TFP change of –1.0 per cent that year.

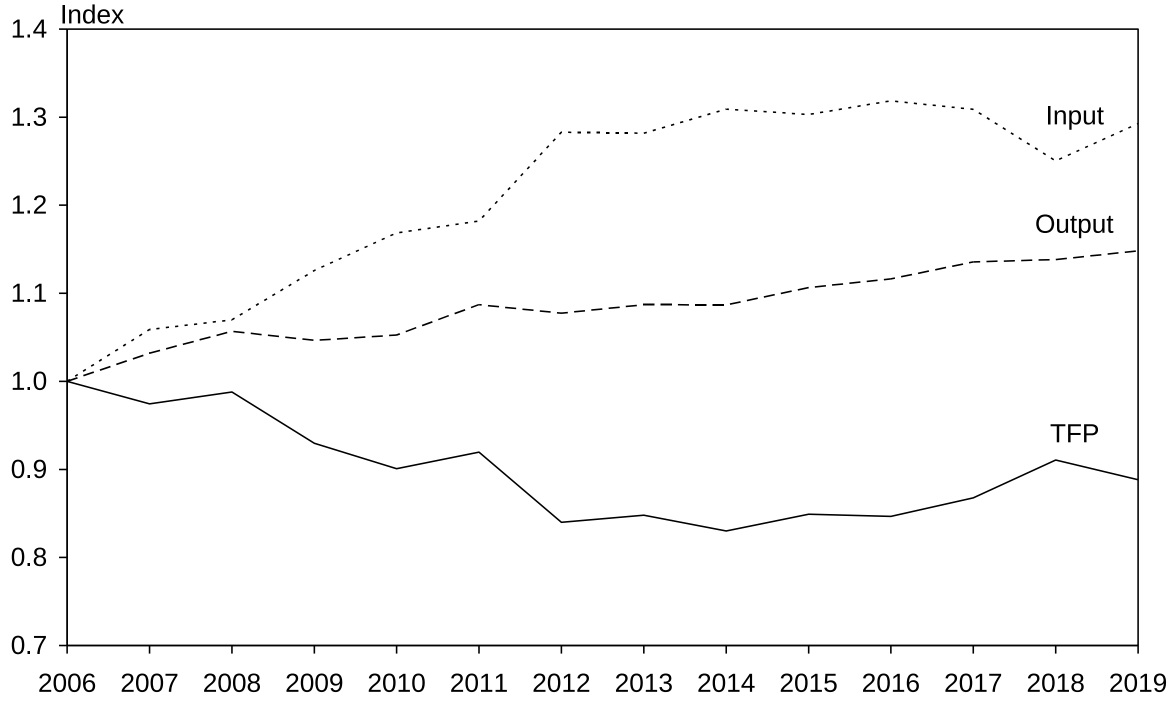
5.3 CitiPower

In 2019, CitiPower (CIT) delivered 5,813 GWh to 345,009 customers over 4,558 circuit kilometres of lines and cables. CIT is the smallest of the Victorian DNSPs (in terms of customer numbers) and covers central Melbourne, including the Melbourne CBD.

CIT's productivity performance

CIT's total output, total input and TFP indexes are presented in figure 5.9 and table 5.5. Opex and capital partial productivity indexes are also presented in table 5.5.

Figure 5.9 **CIT's output, input and total factor productivity indexes, 2006–2019**



Over the 14–year period 2006 to 2019, CIT's TFP decreased with an average annual change of –0.9 per cent. Although total output increased by an average annual rate of 1.1 per cent, total input use increased faster, at a rate of 2.0 per cent. CIT thus had higher output growth but also higher input growth and somewhat lower TFP growth compared to the industry as a whole. Input use increased at a faster rate in 2012 but has subsequently increased more slowly before declining in 2018 and increasing again in 2019. CIT's output declined in three years: 2009, 2012 and 2014. TFP change was positive in six years: 2008, 2011, 2013, 2015, 2017 and 2018. In all of these years, input change was either a smaller increase than otherwise or there was a reduction in input use. Compared to the whole 14–year period TFP average annual change was more negative for the period up to 2012 at –2.9 per cent but has been positive for the period since 2012 at 0.8 per cent as input use has levelled off, then declined and increased again recently and output has continued growing.

Table 5.5 **CIT's output, input and total factor productivity and partial productivity indexes, 2006–2019**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.032	1.059	0.975	0.903	0.997
2008	1.057	1.070	0.988	0.973	0.994
2009	1.046	1.126	0.930	0.816	0.970
2010	1.053	1.168	0.901	0.755	0.954
2011	1.087	1.182	0.920	0.840	0.947
2012	1.078	1.283	0.840	0.661	0.916
2013	1.087	1.282	0.848	0.691	0.911
2014	1.087	1.309	0.830	0.675	0.893
2015	1.106	1.303	0.849	0.713	0.901
2016	1.116	1.319	0.847	0.715	0.897
2017	1.136	1.309	0.868	0.754	0.908
2018	1.138	1.250	0.911	0.876	0.921
2019	1.148	1.293	0.888	0.786	0.924
Growth Rate 2006–19	1.06%	1.97%	–0.91%	–1.85%	–0.61%
Growth Rate 2006–12	1.24%	4.15%	–2.91%	–6.90%	–1.47%
Growth Rate 2012–19	0.91%	0.11%	0.80%	2.48%	0.13%

The partial productivity indexes in table 5.5 show that reduced opex usage was the main driver of the improved TFP performance after 2012 although capital partial productivity also made a positive contribution.

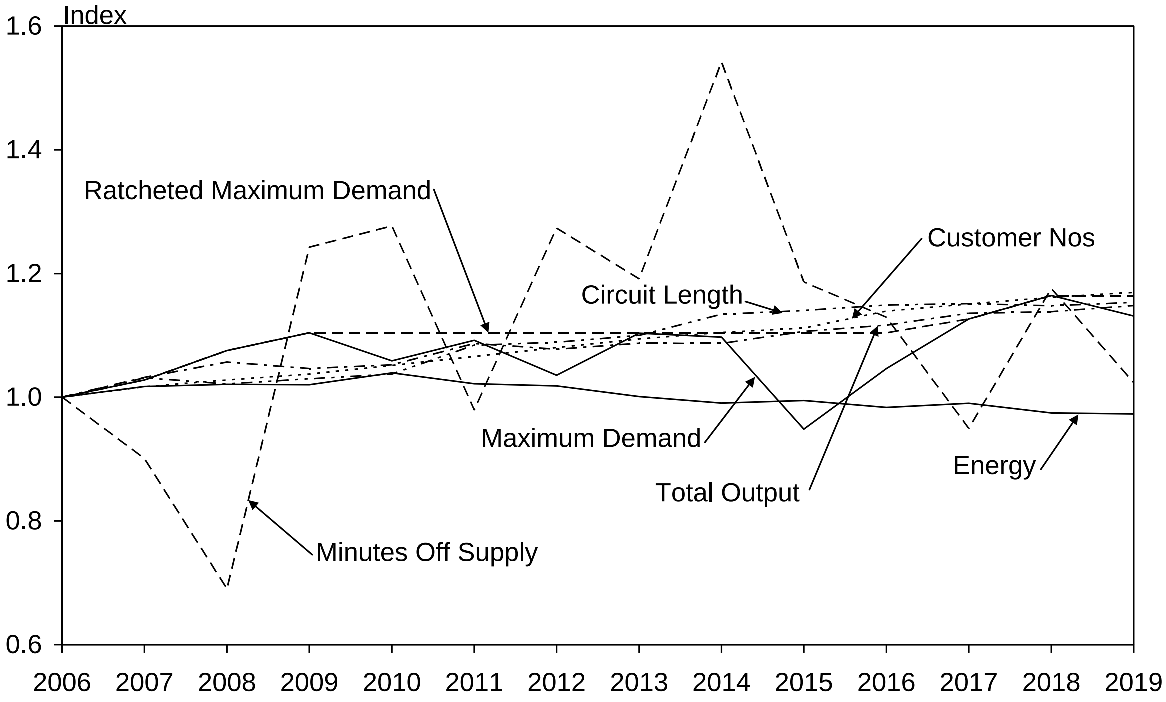
CIT's output and input quantity changes

We graph the quantity indexes for CIT's five individual outputs in figure 5.10 and for its six individual inputs in figure 5.11.

From figure 5.10 we see that, with the exception of CMOS, CIT's output components exhibit a similar pattern of change to the industry as a whole. Customer numbers increased steadily over the period and were 17 per cent higher in 2019 than they were in 2006, somewhat less than the industry's increase over this period. Energy throughput for distribution peaked in 2010 and has trended down since then to be 3 per cent lower in 2019 than it was in 2006.

CIT's maximum demand reached its initial highest level in 2009 but has been somewhat volatile since then and almost regained its 2009 peak in 2013 before surpassing it in 2017, 2018 and 2019. In 2019 it was around 13 per cent above its 2006 level. Ratcheted maximum demand in 2019 was 17 per cent above its 2006 level – a similar increase to that of the industry.

Figure 5.10 **CIT's output quantity indexes, 2006–2019**



CIT's circuit length output grew considerably more over the 14 years than occurred for the industry overall and by 2019 was 15 per cent above the level it was in 2006 compared to an increase of only 5 per cent for the industry.

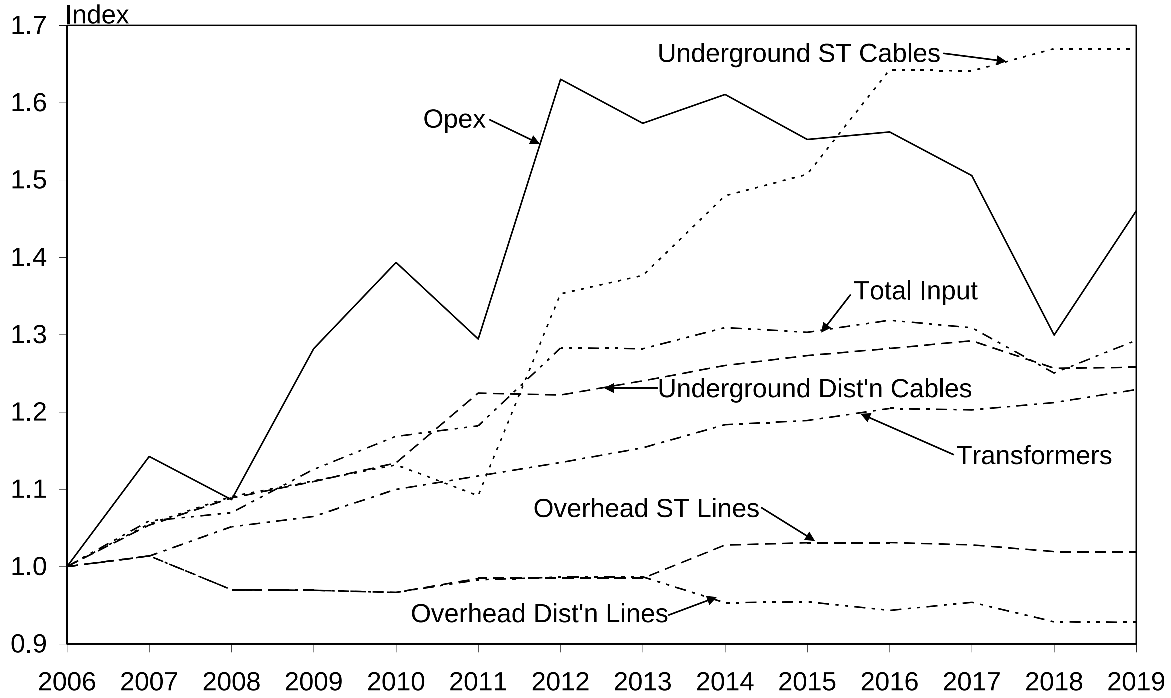
The last output shown in figure 5.10 is total CMOS. CIT's CMOS has been more volatile than for the industry and has trended upwards over the period. By 2019 CIT's CMOS was 2 per cent higher than it was in 2006 but it was 54 per cent above its 2006 level in 2014. CMOS receives an average weight of –5 per cent of total revenue for CIT.

Since the circuit length and ratcheted maximum demand outputs receive a combined weight of around 76 per cent of total revenue in forming the total output index for CIT, in figure 5.10 we see that the total output index generally lies between these two output indexes. In this case the circuit length index lies above the RMD index for most of the second half of the period. The energy output index lies at a lower level and the CMOS index would also generally lie below the other output indexes when it enters the formation of total output as a negative output (ie the increase in CMOS over the period generally makes a negative contribution to total output).

Turning to the input side, we see from CIT's six input components and total input in figure 5.11 that the quantity of CIT's opex increased more rapidly between 2006 and 2012 than the corresponding increase for the industry. For CIT, opex increased by 63 per cent up to 2012 whereas the corresponding increase for the industry was 36 per cent. Since then CIT's opex usage decreased by 20 per cent to 2018 before again increasing by 12 per cent in 2019 to finish the period 46 per cent above its 2006 level. The industry's opex, on the other hand, finished the period 14 per cent above its 2006 level. Opex has the second largest average share after underground distribution cables in CIT's total costs at 26 per cent and so is an important driver of its total input quantity index.

CIT's underground distribution cables and transformers inputs increased more steadily over the period at somewhat lower rates than for the industry as a whole. CIT's overhead distribution lines input decreased over the period and was 7 per cent lower by 2019 than it was in 2006. This compares to a 12 per cent increase for the industry.

Figure 5.11 **CIT's input quantity indexes, 2006–2019**



From figure 5.11 we see that the total input quantity index lies close to the quantity indexes for opex, underground distribution cables and transformers (which have a combined weight of 86 per cent of total costs). Total input quantity increased by 3.3 per cent in 2019 in line with the 12 per cent increase in opex usage and 1.4 per cent increase in transformer inputs.

CIT's output and input contributions to TFP change

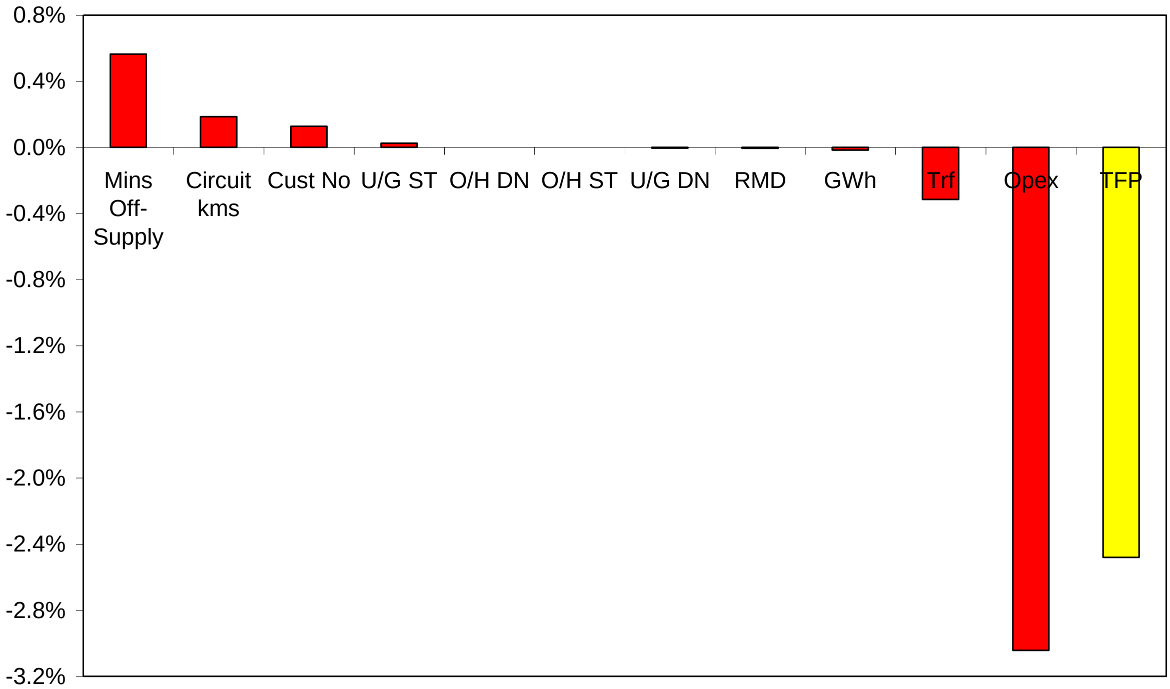
In table 5.6 we decompose CIT's TFP change into its constituent output and input parts for the whole 14–year period and for the periods up to and after 2012. CIT's drivers of TFP change for the whole 14–year period are broadly similar to the industry as a whole except that circuit length makes a larger contribution to CIT's TFP change at 0.5 percentage points compared to 0.2 percentage points for the industry, given CIT's high circuit length growth rate. Transformer inputs make a less negative contribution to CIT's TFP at –0.4 percentage points compared to –0.7 percentage points for the industry. Overhead lines make a marginally positive contribution to CIT's TFP change compared to small negative contributions for the industry. And, CIT's underground cables inputs make more negative contributions for CIT than for the industry reflecting CIT's higher proportion of undergrounding.

CIT's situation is again a tale of two distinct periods. The contribution of customer numbers growth to TFP remains strong after 2012 compared to before 2012 while the contributions of RMD and circuit length each fall by around 0.3 percentage points after 2012 and CMOS changes from making a negative contribution before 2012 to making a small positive one after 2012. The contribution of opex change went from a negative contribution to TFP of –2.1 percentage points before 2012 to a positive contribution of 0.5 percentage points after 2012 with the turnaround in opex usage. The underground distribution cable growth rate reduced markedly after 2012 which reduced underground distribution cables' contribution to TFP from –1.1 percentage points before 2012 to –0.1 percentage points after 2012.

Table 5.6 **CIT's output and input percentage point contributions to average annual TFP change: 2006–2019, 2006–2012, 2012–2019 and 2019**

Year	*2006 to 2019*	*2006 to 2012*	*2012 to 2019*	*2019*
Energy (GWh)	–0.02%	0.03%	–0.06%	–0.02%
Ratcheted Max Demand	0.41%	0.58%	0.27%	–0.01%
Customer Numbers	0.23%	0.25%	0.22%	0.13%
Circuit Length	0.45%	0.58%	0.33%	0.19%
CMOS	–0.01%	–0.20%	0.15%	0.56%
Opex	–0.73%	–2.12%	0.47%	–3.04%
O/H Subtransmission Lines	0.00%	0.00%	0.00%	0.00%
O/H Distribution Lines	0.04%	0.01%	0.06%	0.00%
U/G Subtransmission Cables	–0.26%	–0.34%	–0.20%	0.03%
U/G Distribution Cables	–0.60%	–1.13%	–0.14%	0.00%
Transformers	–0.42%	–0.58%	–0.29%	–0.32%
TFP Change	–0.91%	–2.91%	0.80%	–2.48%

Figure 5.12 **CIT's output and input percentage point contributions to annual TFP change, 2019**



CIT's opex usage increased by 12 per cent in 2019. The importance of this is highlighted in figure 5.12 where opex made a –3.0 percentage point contribution to TFP change in the 2019 year. Along with positive contributions of around 0.6, 0.2 and 0.1 percentage points from CMOS improvement, circuit length and customer numbers growth, respectively, and a contribution of –0.3 percentage points from an increase in transformer inputs, this led to CIT's TFP growth in 2019 being –2.5 per cent.

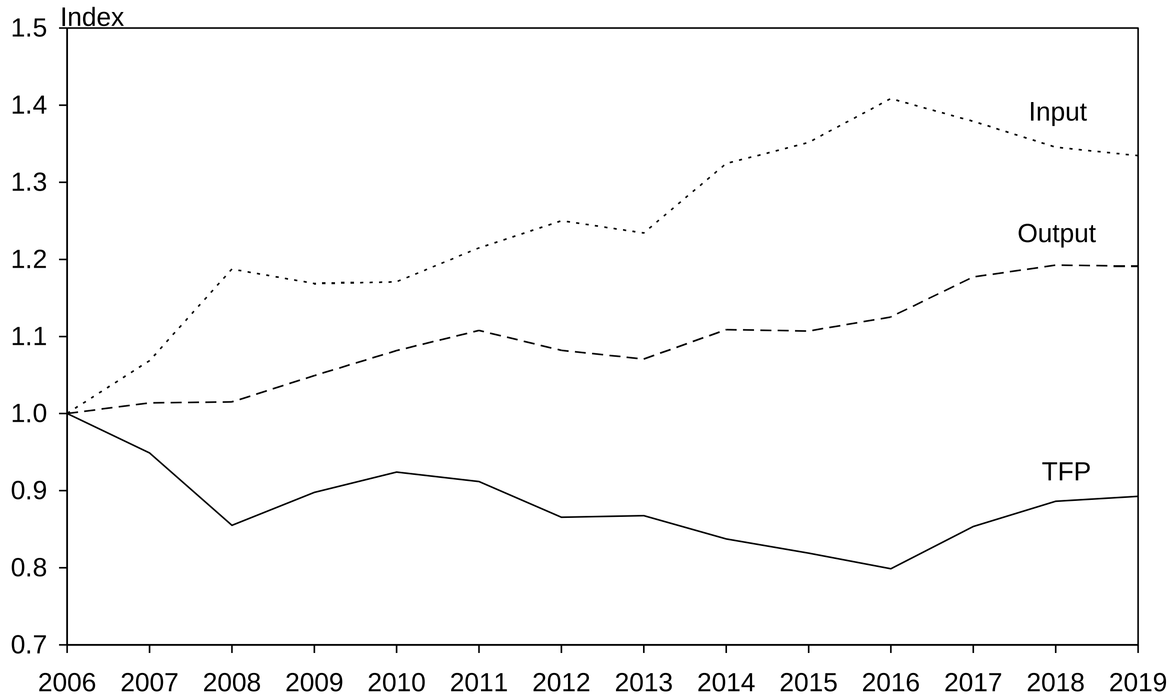
5.4 Endeavour Energy

In 2019 Endeavour Energy (END) delivered 16,759 GWh to 1.03 million customers over 38,284 circuit kilometres of lines and cables. END distributes electricity to Sydney's Greater West, the Blue Mountains, Southern Highlands, the Illawarra and the South Coast regions of NSW. It is the second largest of the three NSW DNSPs in terms of customer numbers and energy throughput.

END's productivity performance

END's total output, total input and TFP indexes are presented in figure 5.13 and table 5.7. Opex and capital partial productivity indexes are also presented in table 5.7.

Figure 5.13 **END's output, input and total factor productivity indexes, 2006–2019**



Over the 14–year period 2006 to 2019, END's TFP decreased at an average annual rate of 0.9 per cent. Although total output increased by an average annual rate of 1.4 per cent, total input use increased faster, at a rate of 2.2 per cent. END thus had faster output growth but considerably faster input growth than the industry as a whole, leading to a somewhat more negative TFP growth rate. Input use increased sharply in 2008 and 2014, to be followed by a small reduction in 2009 but continued increases in input use from 2015 to 2016. TFP fell markedly in 2008, 2012 and 2014 but TFP change was positive in six years – 2009, 2010, 2013 and 2017 to 2019. TFP average annual change was negative for the period up to 2012 at

–2.4 per cent but positive at 0.4 per cent for the period since 2012.

Table 5.7 **END's output, input and total factor productivity and partial productivity indexes, 2006–2019**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index Opex*	*PFP Index Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.014	1.068	0.949	0.940	0.957
2008	1.015	1.187	0.855	0.771	0.918
2009	1.049	1.169	0.898	0.869	0.919
2010	1.082	1.171	0.924	0.933	0.917
2011	1.108	1.215	0.912	0.908	0.913
2012	1.082	1.250	0.865	0.873	0.860
2013	1.071	1.234	0.868	0.964	0.815
2014	1.109	1.324	0.837	0.884	0.808
2015	1.107	1.352	0.819	0.860	0.793
2016	1.125	1.408	0.799	0.815	0.789
2017	1.177	1.379	0.854	0.930	0.808
2018	1.192	1.345	0.886	1.034	0.804
2019	1.191	1.334	0.893	1.093	0.787
Growth Rate 2006–19	1.35%	2.22%	–0.87%	0.68%	–1.84%
Growth Rate 2006–12	1.31%	3.72%	–2.41%	–2.27%	–2.51%
Growth Rate 2012–19	1.37%	0.93%	0.44%	3.22%	–1.26%

The partial productivity indexes in table 5.7 show that a turnaround in opex PFP growth and a less negative growth rate for capital PFP accounted for the improvement in TFP performance after 2012.

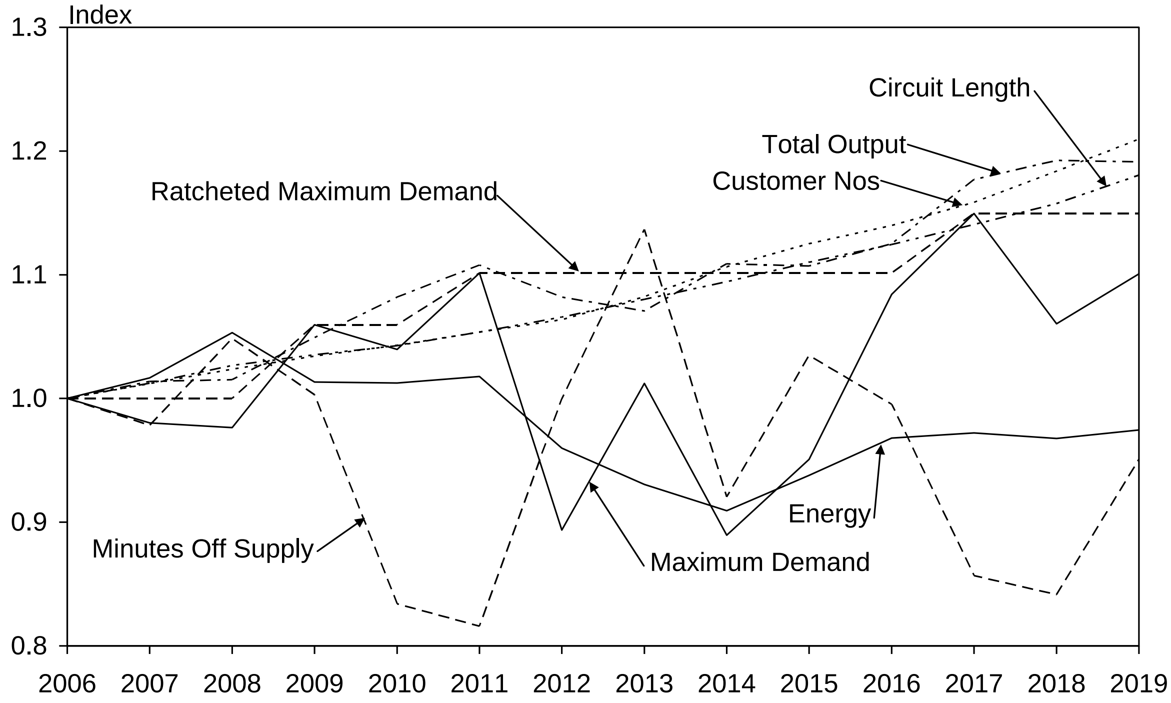
END's output and input quantity changes

We graph the quantity indexes for END's five individual outputs in figure 5.14 and for its six individual inputs in figure 5.15.

From figure 5.14 we see that END's output components showed a broadly similar pattern of change to the industry as a whole except that there was much less growth in some outputs for END between 2006 and 2009, likely reflecting the negative effects of the mining boom on NSW and the initial impact of the global financial crisis. END also has a more volatile CMOS pattern compared to the industry as a whole. Customer numbers increased steadily over the period and were 21 per cent higher in 2019 than they were in 2006, a little more growth than for the industry and more than was seen for AGD. END's energy throughput peaked in 2008 and has fallen since to be 3 per cent lower in 2019 than it was in 2006, despite a partial recovery since 2014.

END's maximum demand peaked in 2011 and has been relatively volatile since then. It then briefly exceeded its 2006 level in 2013 and again in 2016 and 2017 with the 2017 level being the highest for the period. Ratcheted maximum demand in 2019 was 15 per cent above its 2006 level – just behind the increase for the industry overall.

Figure 5.14 **END's output quantity indexes, 2006–2019**



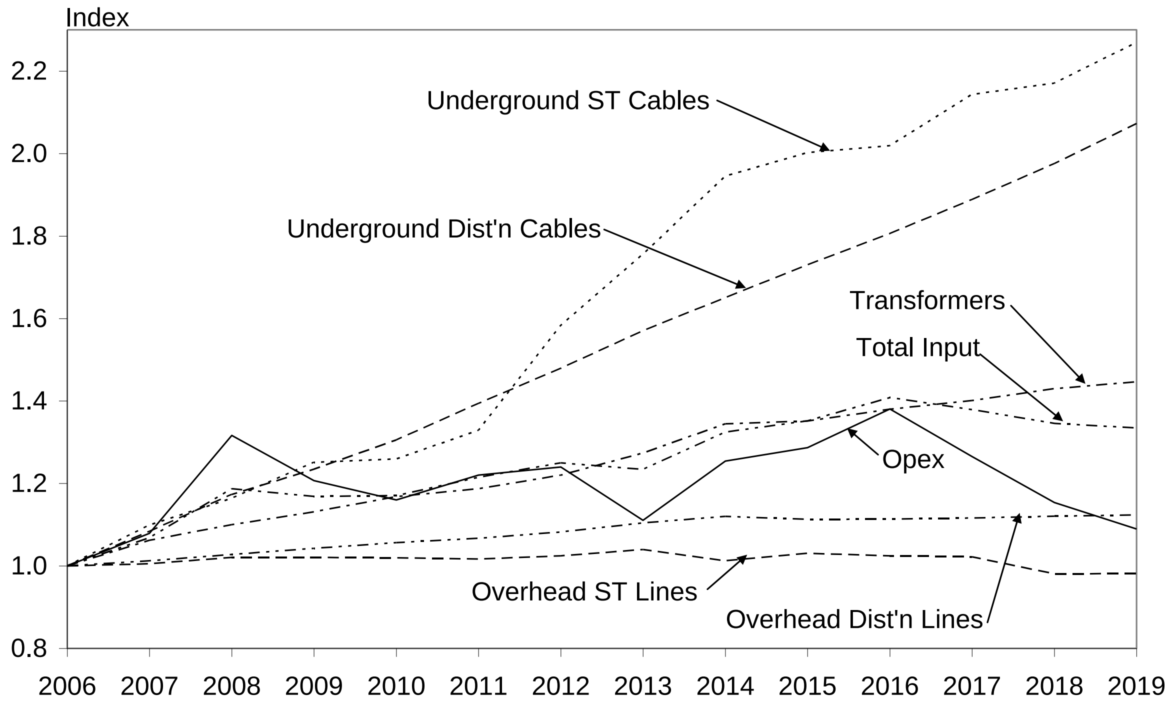
END's circuit length output grew considerably more over the 14 years than occurred for the industry overall and by 2019 was 18 per cent above the level it was in 2006 compared to an increase of only 5 per cent for the industry. This likely reflects the ongoing development of new areas to Sydney's west.

The last output shown in figure 5.14 is total CMOS. Despite a high degree of volatility, END's CMOS had a relatively flat trend through to 2016 before a substantial reduction in 2017, a further reduction in 2018 and a partial recovery in 2019. In 2019 CMOS was 5 per cent below its 2006 level. CMOS receives an average weight of –14 per cent of total revenue for END.

Since the circuit length and ratcheted maximum demand outputs receive a combined average weight of around 83 per cent of total revenue in forming the total output index, in figure 5.14 we see that the total output index tends to lie very close to these two output indexes, as well as the customer numbers index. Fluctuations of total output away from these three output indexes are driven by the large swings in CMOS.

Turning to the input side, we see from END's six input components and total input in figure 5.15 that the quantity of END's opex follows a quite different pattern to both the industry as a whole and its Sydney–based sister DNSP, AGD. END's opex increased more rapidly between 2006 and 2008 than the corresponding increase for the industry but it then declined through to 2013 before again increasing through to 2016. By 2008 END's opex was 32 per cent above its 2006 level but then fell back to within 11 per cent of its 2006 level in 2013. However, in 2016 END's opex was 38 per cent above its 2006 level before falling back to 9 per cent above its 2006 level in 2019.[12] Opex has the largest average share in END's total costs at 39 per cent and so is an important driver of its total input quantity index.

Figure 5.15 **END's input quantity indexes, 2006–2019**



END's underground distribution cables and transformers inputs increase more steadily over the period with transformers increasing at a somewhat higher rate than for the industry as a whole. However, END's underground distribution cables increased at a considerably faster rate and in 2019 were 107 per cent above their 2006 level compared to an increase of 55 per cent for the industry as a whole. END's overhead distribution lines input increased by 12 per cent over the period, similar to the increase for the industry.

From figure 5.15 we see that END's total input quantity index lies close to the quantity indexes for opex and transformers (which have a combined average weight of 69 per cent of total costs). Total input quantity fell 0.8 per cent in 2019, driven largely by a reduction in opex usage of 5.7 per cent.

END's output and input contributions to TFP change

In table 5.8 we decompose END's TFP change into its constituent output and input parts for the whole 14–year period and for the periods up to and after 2012. END's drivers of TFP change for the whole 14–year period are broadly similar to the industry as a whole except that the circuit length output makes a larger positive contribution and underground distribution cables and transformer inputs make a larger negative contribution.

END's situation is less obviously a tale of two distinct periods compared to other DNSPs. The contribution of the growth in opex usage reversed after 2012, while that of growth in underground distribution cables and transformers moderated. The contributions of customer

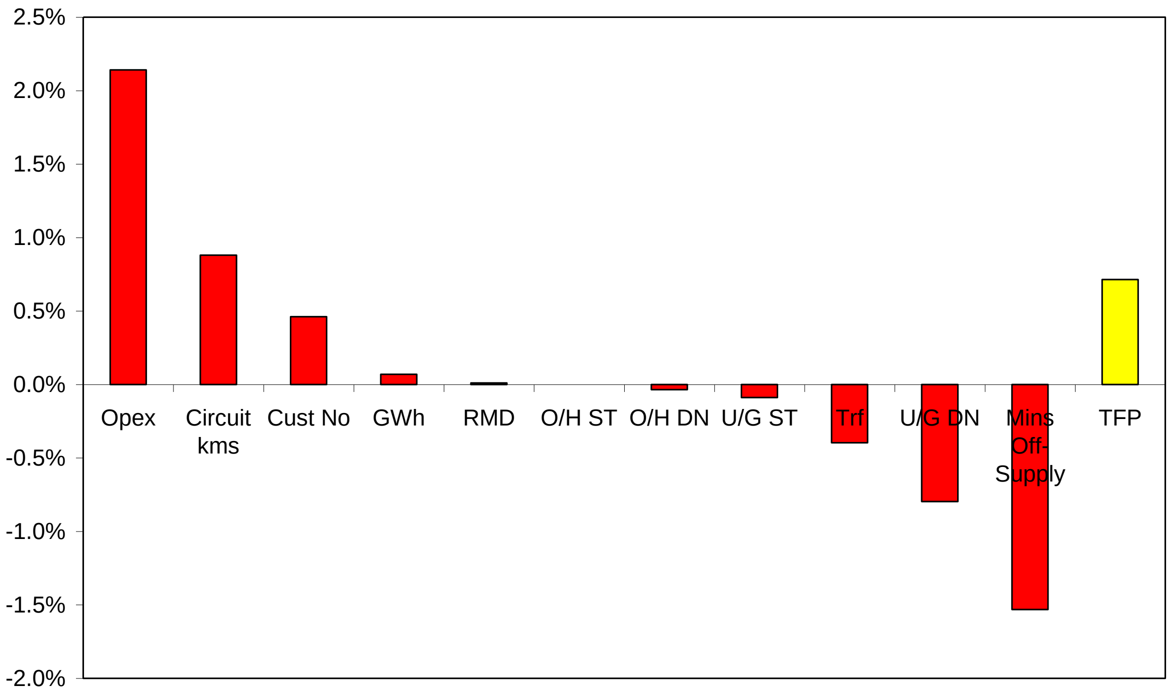
[12] Note that redundancy payments are included in the opex figures presented here.

numbers and circuit length growth increased somewhat while the contribution of RMD moderated and the contribution of the other outputs and inputs changes little between the periods before and after 2012. Increases in END's opex between 2013 and 2016 were offset by reductions in 2017, 2018 and 2019 leading to opex contributing 0.7 percentage points to END's average annual TFP change of 0.4 per cent for the period after 2012. This compares to a positive opex contribution of 1.0 percentage points to the industry TFP average annual change of 0.3 per cent after 2012.

Table 5.8 **END's output and input percentage point contributions to average annual TFP change: 2006–2019, 2006–2012, 2012–2019, 2018–19**

Year	*2006 to 2019*	*2006 to 2012*	*2012 to 2019*	*2018–19*
Energy (GWh)	–0.02%	–0.07%	0.02%	0.07%
Ratcheted Max Demand	0.42%	0.63%	0.23%	0.01%
Customer Numbers	0.31%	0.23%	0.38%	0.46%
Circuit Length	0.57%	0.49%	0.65%	0.88%
CMOS	0.06%	0.03%	0.09%	–1.53%
Opex	–0.27%	–1.40%	0.70%	2.14%
O/H Subtransmission Lines	0.01%	–0.01%	0.02%	0.00%
O/H Distribution Lines	–0.09%	–0.12%	–0.05%	–0.04%
U/G Subtransmission Cables	–0.11%	–0.13%	–0.10%	–0.09%
U/G Distribution Cables	–0.91%	–1.07%	–0.77%	–0.80%
Transformers	–0.85%	–0.99%	–0.73%	–0.40%
TFP Change	–0.87%	–2.41%	0.44%	0.71%

Figure 5.16 **END's output and input percentage point contributions to annual TFP change, 2018–19**



The importance of END's reduction in opex in 2019 is highlighted in figure 5.16. The 2.1 percentage point contribution of opex is the largest contribution to END's TFP change of 0.7 per cent in the 2019 year with the contributions of other outputs and inputs largely offsetting each other, other than the worsening in CMOS which contributed –1.5 percentage points.

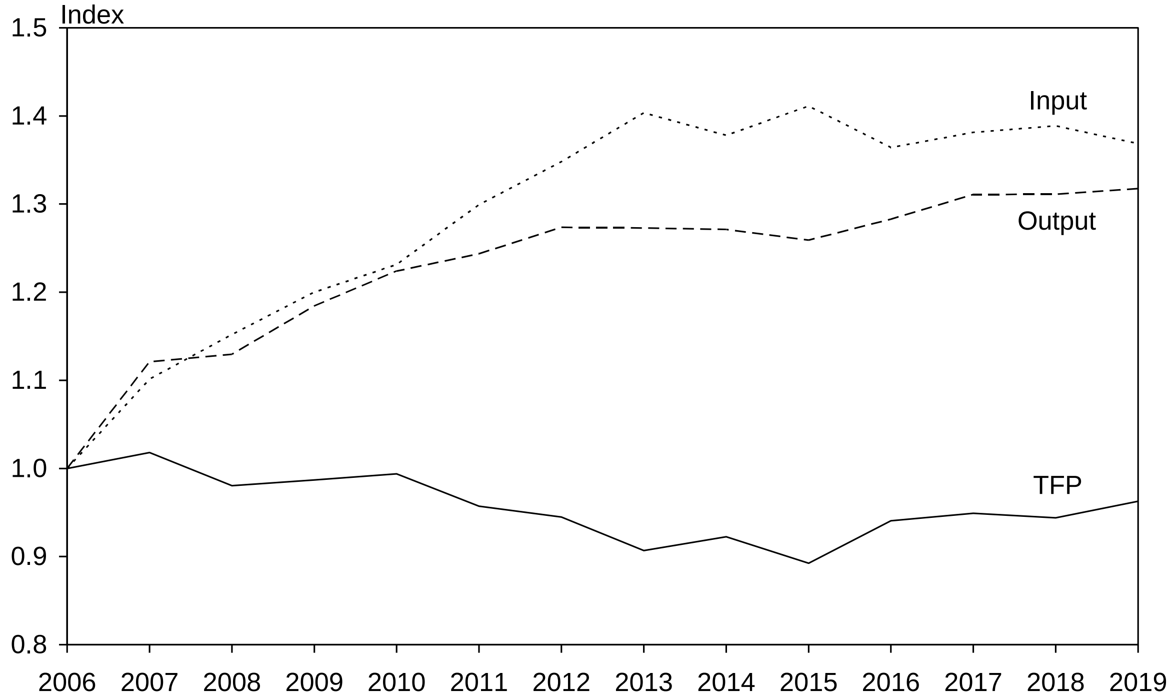
5.5 Energex

In 2019 Energex (ENX) delivered 21,427 GWh to 1.5 million customers over 54,777 circuit kilometres of lines and cables. ENX distributes electricity in South East Queensland including the major urban areas of Brisbane, Gold Coast, Sunshine Coast, Logan, Ipswich, Redlands and Moreton Bay. ENX's electricity distribution area runs from the NSW border north to Gympie and west to the base of the Great Dividing Range. It is the second largest DNSP in the NEM in terms of customer numbers and energy throughput.

ENX's productivity performance

ENX's total output, total input and TFP indexes are presented in figure 5.17 and table 5.9. Opex and capital partial productivity indexes are also presented in table 5.9.

Figure 5.17 **ENX's output, input and total factor productivity indexes, 2006–2019**



Over the 14–year period 2006 to 2019, ENX's TFP decreased with an average annual change of –0.3 per cent. ENX's total output increased by an average annual rate of 2.1 per cent – more than double the output growth rate of that the industry as a whole. ENX's total input use increased faster at a rate of 2.4 per cent. Input use increased at a steady rate through to 2013 and has fluctuated since then.

Output increased steadily from 2006 to 2012 before remaining flat for the following three years and then increasing again in 2016 and 2017 and levelling off again in 2018 and 2019.

The increase in 2016 coincided with a reduction in input that year which lead to a marked upturn in TFP. However, increases in input use led to TFP growth being relatively flat in 2017 and negative in 2018 before increasing again in 2019. TFP average annual change was more negative for the period up to 2012 at –1.0 per cent but has been positive for the period since 2012 at 0.3 per cent.

Table 5.9 **ENX's output, input and total factor productivity and partial productivity indexes, 2006–2019**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index Opex*	*PFP Index Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.121	1.101	1.018	0.964	1.050
2008	1.130	1.152	0.981	0.932	1.010
2009	1.184	1.200	0.987	0.941	1.013
2010	1.224	1.231	0.994	0.961	1.013
2011	1.244	1.299	0.957	0.889	0.997
2012	1.274	1.348	0.945	0.851	0.998
2013	1.273	1.404	0.907	0.794	0.979
2014	1.271	1.378	0.923	0.864	0.959
2015	1.259	1.411	0.892	0.839	0.923
2016	1.283	1.364	0.940	0.962	0.929
2017	1.311	1.381	0.949	0.977	0.934
2018	1.311	1.389	0.944	0.974	0.926
2019	1.318	1.369	0.963	1.038	0.923
Growth Rate 2006–19	2.12%	2.41%	–0.29%	0.28%	–0.61%
Growth Rate 2006–12	4.03%	4.98%	–0.95%	–2.69%	–0.03%
Growth Rate 2012–19	0.48%	0.22%	0.27%	2.84%	–1.12%

The partial productivity indexes in table 5.9 show that substantially improved opex PFP performance was the main driver of the improved TFP performance after 2012 although this was offset somewhat by a worsening in capital partial productivity performance.

ENX's output and input quantity changes

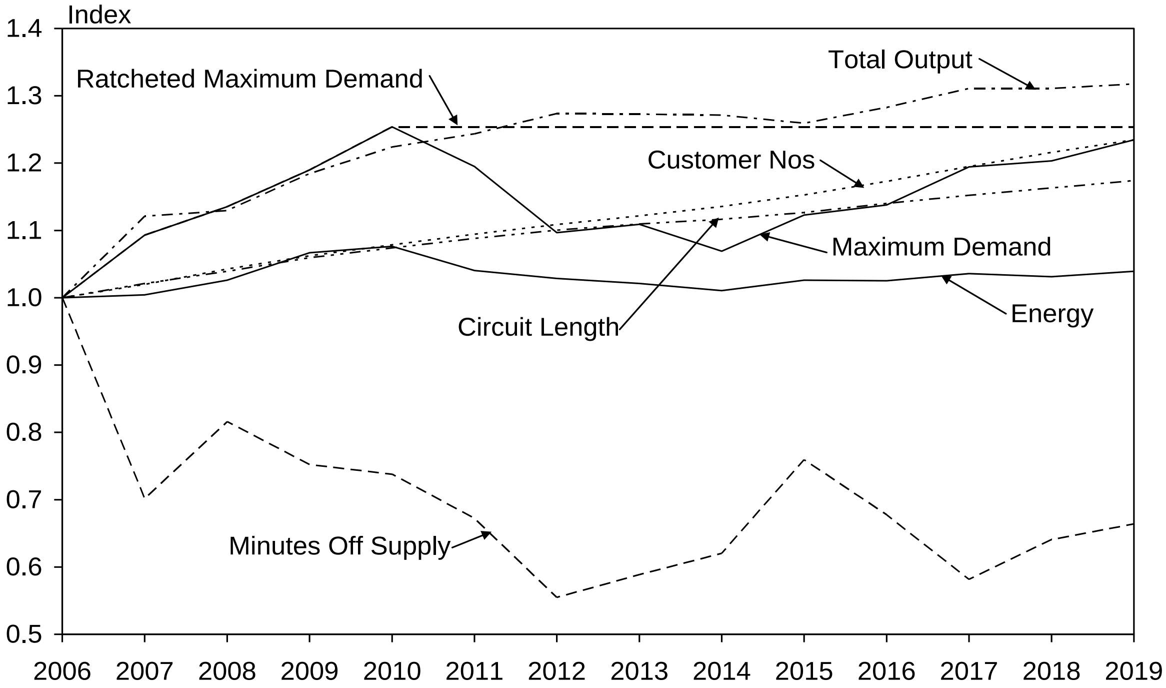
We graph the quantity indexes for ENX's five individual outputs in figure 5.18 and for its six individual inputs in figure 5.19.

From figure 5.18 we see that ENX's output components showed a generally similar pattern of change to the industry as a whole except that there was more growth in outputs for ENX over the period. ENX's energy output showed less of a downturn after 2010, likely reflecting the effects of the mining boom and continuing growth in SE Queensland. Customer numbers increased steadily over the period and were 24 per cent higher in 2019 than they were in 2006 reflecting Queensland's relatively strong output growth. Energy throughput peaked in 2010 but was still 4 per cent higher in 2019 than it was in 2006.

ENX's maximum demand also peaked in 2010 and then declined through to 2014. However, unlike many DNSPs, ENX's maximum demand has stayed above its 2006 level for the remainder of the period. In 2019 RMD was 25 per cent above its 2006 level – a larger increase than for the industry overall.

Queensland's circuit length output also grew more over the 14 years than occurred for the industry overall and by 2019 was 17 per cent above the level it was in 2006 compared to an increase of only 5 per cent for the industry.

Figure 5.18 **ENX's output quantity indexes, 2006–2019**

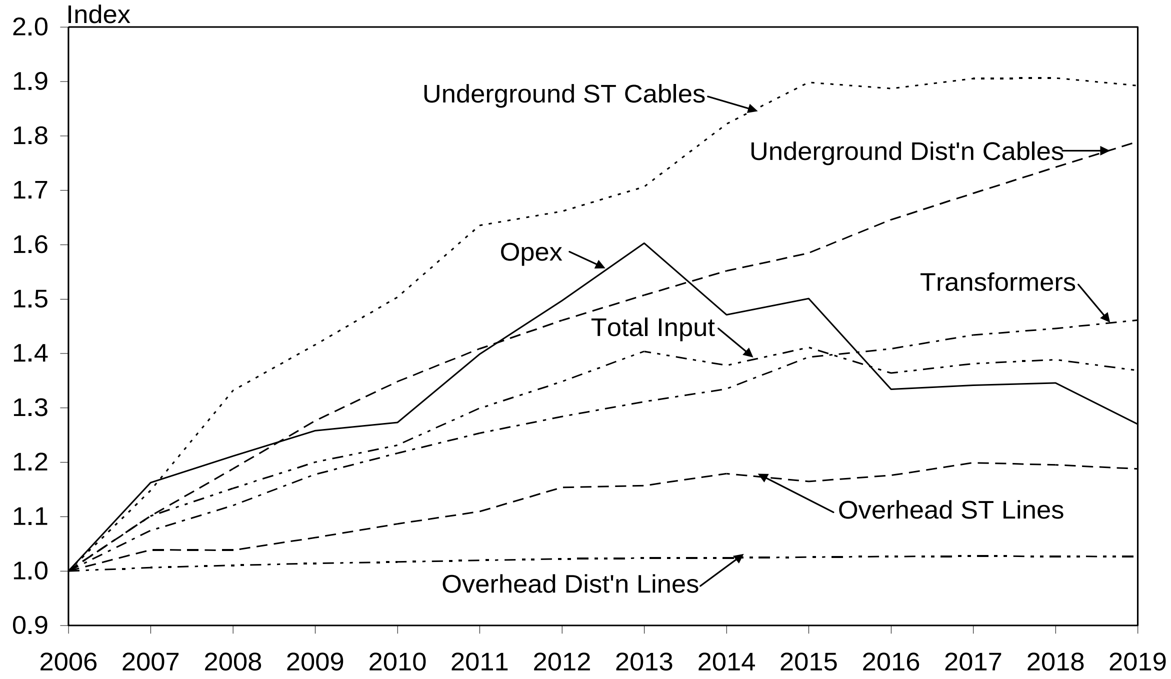


The last output shown in figure 5.18 is total CMOS. ENX's CMOS has generally followed a similar pattern to that of the industry and has trended downwards although it increased from 2012 to 2015 and again in 2018 and 2019. CMOS has been lower and, hence, contributed more to total output for all other years than was the case in 2006. In 2019 CMOS was 34 per cent less than it was in 2006. CMOS receives an average weight of –11 per cent of total revenue for ENX.

Since the circuit length and ratcheted maximum demand outputs receive a combined weight of around 81 per cent of total revenue in forming the total output index, in figure 5.18 we see that the total output index tends to lie close to these two output indexes. In ENX's case the customer numbers output index also lies close to the circuit length index. The total output index lies above the RMD and circuit length output indexes from 2012 onwards as the reduction in CMOS makes an additional positive contribution to output growth.

Turning to the input side, we see from ENX's six input components and total input in figure 5.19 that the quantity of ENX's underground distribution and subtransmission cables and opex inputs have increased more than for the industry as a whole while its transformers input increased somewhat more than for the industry but its overhead distribution lines increased considerably less. Again, not too much should be read into the higher increase in underground cables as this was starting from a smaller base and reflects ENX's higher rate of customer numbers growth. For ENX, opex increased by 60 per cent up to 2013 which was more than the corresponding increase for the industry of 36 per cent (up to 2012). However, ENX's opex has trended down since 2013 and was 27 per cent above its 2006 level in 2019 (with redundancy payments included). Opex has the largest average share in ENX's total costs at 36 per cent and so is an important driver of its total input quantity index.

Figure 5.19 **ENX's input quantity indexes, 2006–2019**



From figure 5.19 we see that the total input quantity index generally lies between the quantity indexes for opex and transformers (which have a combined weight of 68 per cent of total costs). Total input quantity decreased by 1.5 per cent in 2019 driven by a decrease in opex usage of 5.8 per cent.

ENX's output and input contributions to TFP change

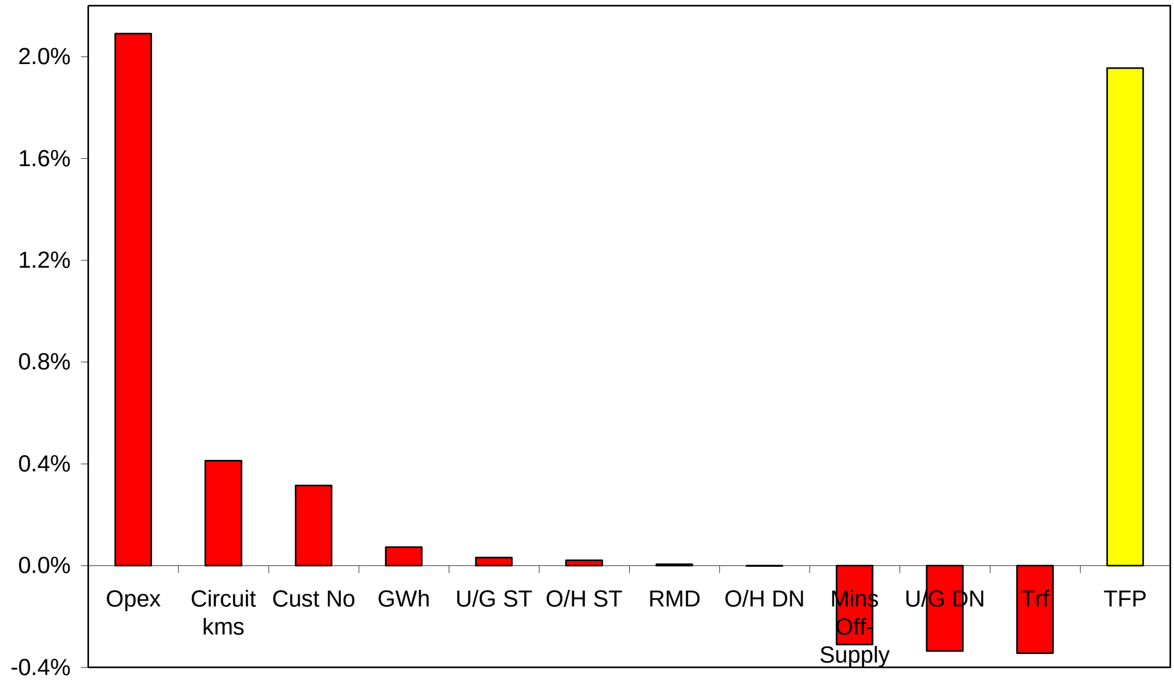
In table 5.10 we decompose ENX's TFP change into its constituent output and input parts for the whole 14–year period and for the periods up to and after 2012. ENX's drivers of TFP change for the whole 14–year period are broadly similar to the industry as a whole except that all five outputs make a larger percentage point contribution to TFP growth for ENX and opex and transformers make a somewhat more negative contribution. However, the stronger output growth for ENX, particularly from improvements in CMOS, lead to its TFP performance being better than that for the industry.

The Queensland situation is also a tale of two distinct periods. For the period up to 2012, all five outputs made a larger positive contribution to TFP change but all six inputs, and particularly opex, made a more negative percentage point contribution to TFP growth compared to the period after 2012. Up to 2012 ENX's average annual TFP change was –1.0 per cent compared to –2.1 per cent for the industry. The reductions made in ENX's opex after 2012 led to opex contributing 0.8 percentage points to ENX's average annual TFP change of 0.3 percentage points compared to 0.9 percentage points contribution from opex for the industry.

Table 5.10 **ENX's output and input percentage point contributions to average annual TFP change: 2006–2019, 2006–2012, 2012–2019, 2018–19**

Year	*2006 to 2019*	*2006 to 2012*	*2012 to 2019*	*2018–19*
Energy (GWh)	0.03%	0.05%	0.01%	0.07%
Ratcheted Max Demand	0.68%	1.48%	0.00%	0.01%
Customer Numbers	0.34%	0.37%	0.31%	0.31%
Circuit Length	0.55%	0.73%	0.40%	0.41%
CMOS	0.52%	1.40%	–0.24%	–0.31%
Opex	–0.66%	–2.38%	0.81%	2.09%
O/H Subtransmission Lines	–0.05%	–0.08%	–0.01%	0.02%
O/H Distribution Lines	–0.03%	–0.05%	–0.01%	0.00%
U/G Subtransmission Cables	–0.23%	–0.39%	–0.09%	0.03%
U/G Distribution Cables	–0.53%	–0.75%	–0.35%	–0.34%
Transformers	–0.92%	–1.33%	–0.57%	–0.34%
TFP Change	–0.29%	–0.95%	0.27%	1.96%

Figure 5.20 **ENX's output and input percentage point contributions to annual TFP change, 2018–19**



The importance of the decrease in opex in 2019 is highlighted in figure 5.20 where it makes a 2.1 percentage point contribution to TFP change in the 2019 year. Growth in circuit length and customer numbers make positive contributions of 0.4 and 0.3 percentage points, respectively, while growth in CMOS, underground distribution and transformers each make contributions of around –0.3 percentage points. These changes combine to produce a TFP change of 2.0 per cent in 2019.

5.6 Ergon Energy

In 2019 Ergon Energy (ERG) delivered 13,504 GWh to 765,924 customers over 152,279 circuit kilometres of lines and cables. ERG distributes electricity throughout regional Queensland, excluding South East Queensland. ERG is around the seventh largest DNSP in the NEM in terms of customer numbers but is the second largest in terms of network length.

ERG's productivity performance

ERG's total output, total input and TFP indexes are presented in figure 5.21 and table 5.11. Opex and capital partial productivity indexes are also presented in table 5.11.

Figure 5.21 **ERG's output, input and total factor productivity indexes, 2006–2019**

Over the 14–year period 2006 to 2019, ERG's TFP increased at an average annual rate of 0.2 per cent. ERG's total output increased by an average annual rate of 1.4 per cent – considerably higher than for most other DNSPs. ERG's total input use increased at a rate of 1.1 per cent – considerably slower than for the industry as a whole. The combination of higher output growth and slower input growth has led to ERG having better TFP growth performance than the industry over the 14–year period. Input use increased at an above average rate in 2011 but fell in 2007, 2013 and 2017. The input use decrease in 2007 coincided with a sizable increase in output that year which lead to a marked increase in TFP. Similarly, the reduction in input use in 2013 was accompanied by output growth leading to a jump in TFP. However, a reduction in output in 2015 combined with strong input growth that year led to a fall in TFP. ERG's TFP average annual change was 0.6 per cent for the period up to 2012 but fell to –0.1 per cent for the period since 2012.

Negative output growth in 2019 more than offset a small decrease in input use leading to negative TFP growth in the latest year.

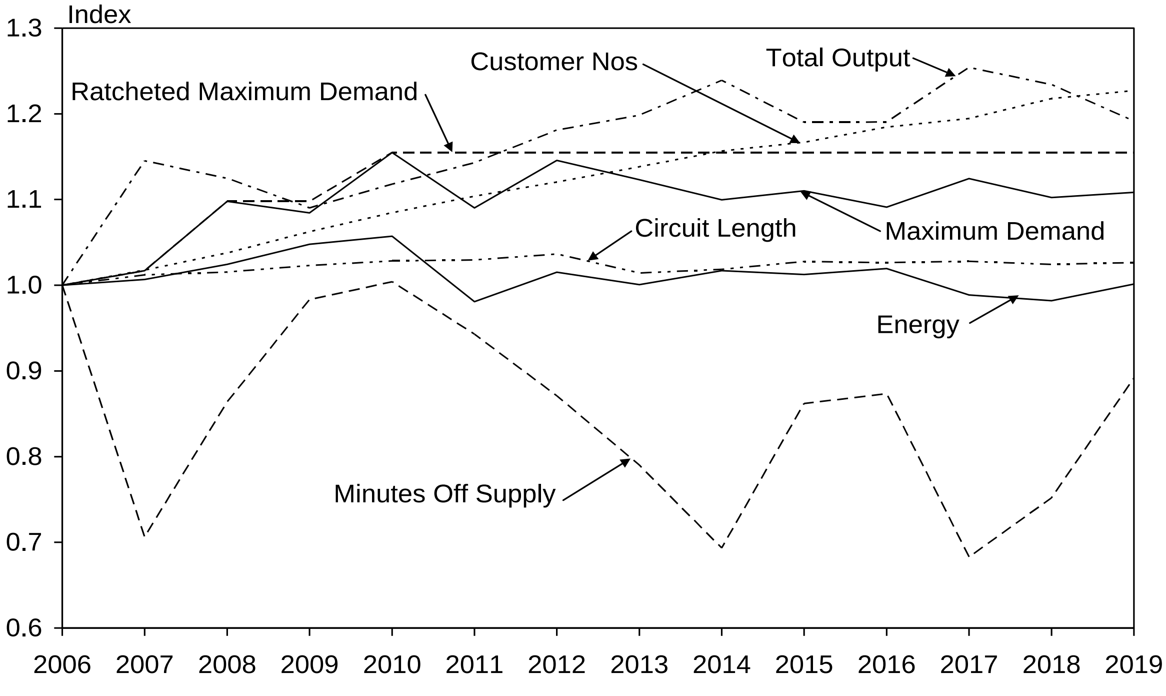
Table 5.11 **ERG's output, input and total factor productivity and partial productivity indexes, 2006–2019**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index Opex*	*PFP Index Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.145	0.971	1.179	1.287	1.117
2008	1.125	1.008	1.116	1.179	1.079
2009	1.090	1.007	1.083	1.185	1.023
2010	1.118	1.023	1.093	1.242	1.013
2011	1.143	1.116	1.024	1.033	1.014
2012	1.181	1.139	1.037	1.045	1.022
2013	1.198	1.050	1.142	1.334	1.043
2014	1.239	1.083	1.144	1.373	1.028
2015	1.190	1.154	1.031	1.145	0.968
2016	1.191	1.171	1.017	1.137	0.950
2017	1.254	1.145	1.095	1.330	0.980
2018	1.234	1.162	1.062	1.275	0.953
2019	1.192	1.160	1.027	1.223	0.926
Growth Rate 2006–19	1.35%	1.14%	0.21%	1.55%	–0.59%
Growth Rate 2006–12	2.77%	2.17%	0.60%	0.73%	0.36%
Growth Rate 2012–19	0.13%	0.26%	–0.13%	2.25%	–1.40%

The partial productivity indexes in table 5.11 show that improvements in opex PFP after 2012 have been more than offset by a worsening in capital PFP leading to reduced TFP growth.

ERG's output and input quantity changes

Figure 5.22 **ERG's output quantity indexes, 2006–2019**



We graph the quantity indexes for ERG's five individual outputs in figure 5.22 and for its six individual inputs in figure 5.23.

From figure 5.22 we see that ERG's output components showed a generally similar pattern of change to the industry as a whole except that there was more growth in outputs for ERG over the period. ERG's energy throughput and maximum demand outputs showed less of a downturn after 2010, likely reflecting the effects of the mining boom. Customer numbers increased steadily over the period and were 23 per cent higher in 2019 than they were in 2006 reflecting regional Queensland's relatively strong growth. Energy throughput peaked in 2010 and its 2019 level was the same as it was in 2006.

ERG's maximum demand also peaked in 2010 before recovering in 2012 and then declining through to 2016 before increasing in 2017 and falling again in 2018. However, unlike many DNSPs in the NEM, ERG's maximum demand has stayed above its 2006 level for the remainder of the period. In 2019 RMD was 16 per cent above its 2006 level – a similar increase to the industry overall.

ERG's circuit length output grew at a somewhat slower rate than for the industry over the 14 years and by 2019 was 3 per cent above the level it was in 2006.

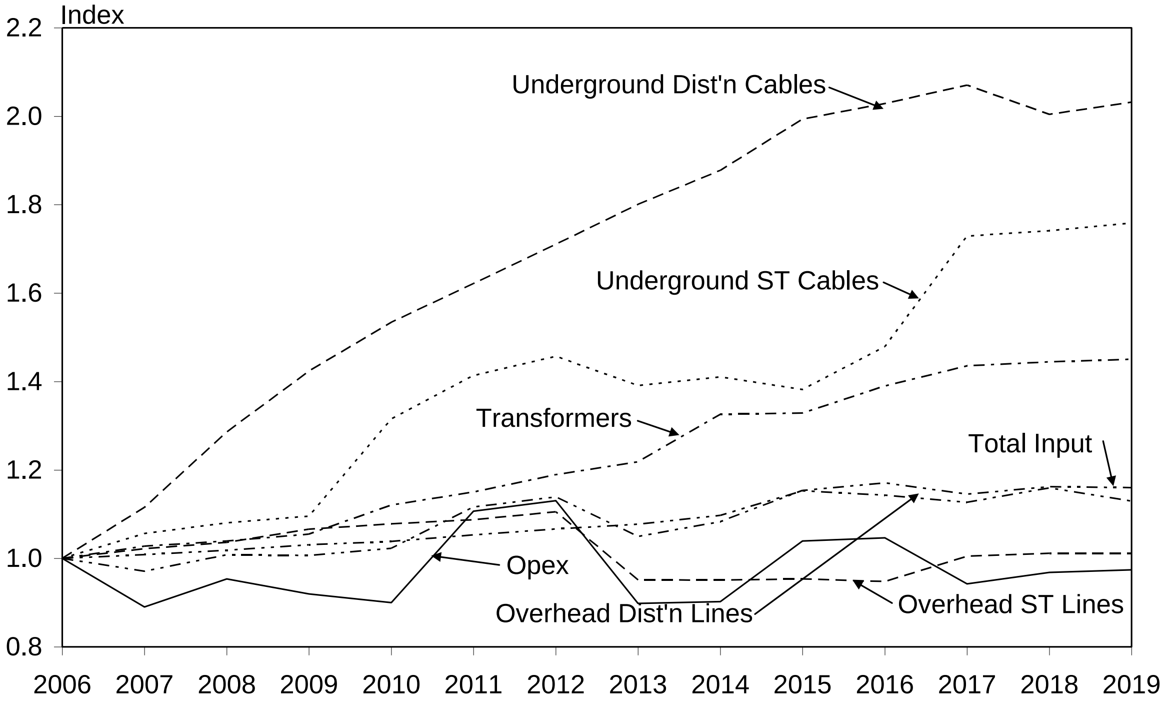
The last output shown in figure 5.22 is total CMOS. ERG's CMOS has generally followed a similar pattern to that of the industry although it increased markedly in 2015. With the exception of 2010, CMOS has been lower and, hence, contributed more to total output for all other years than was the case in 2006. In 2019 CMOS was 11 per cent less than it was in 2006 after having increased by 17 per cent in 2019.

Since the circuit length and ratcheted maximum demand outputs receive a combined weight of around 92 per cent of total revenue in forming the total output index for ERG, in figure 5.22 we see that the total output index tends to lie close to but often above these two output indexes. The total output index lies above the RMD and circuit length output indexes from 2012 onwards as the reduction in CMOS makes an additional positive contribution to output growth. CMOS receives a quite high average weight of 27 per cent of total revenue for ERG as, being a remote regional DNSP and having a low network density, it has a higher level of CMOS. The customer numbers output index also lies close to the total output index.

Turning to the input side, we see from ERG's six input components and total input in figure 5.23 that the quantity of ERG's underground distribution and subtransmission cables inputs have increased more than for the industry as a whole, its transformers and overhead distribution lines inputs have increased somewhat more than for the industry while its opex has fallen while the industry's has increased. Again, not too much should be read into the higher increase in underground cables as this was starting from a very small base and reflects Queensland's higher rate of customer numbers growth. For ERG, opex increased by 13 per cent up to 2012 which was much less than the corresponding increase for the industry of 36 per cent. After a substantial fall in 2013, ERG's opex subsequently increased through to 2016 before falling in 2017 and increasing somewhat in 2018 and 2019. In 2019 it was 3 per cent below its 2006 level.[13] Opex has the largest average share in ERG's total costs at 36 per cent and so is an important driver of its total input quantity index.

[13] Note that redundancy payments are included in the opex figures presented here.

Figure 5.23 **ERG's input quantity indexes, 2006–2019**



From figure 5.23 we see that the total input quantity index generally lies between the quantity indexes for opex and transformers (which have a combined weight of 65 per cent of total costs). Total input quantity decreased by 0.2 per cent in 2019 driven by small decrease in overhead distribution lines input.

ERG's output and input contributions to TFP change

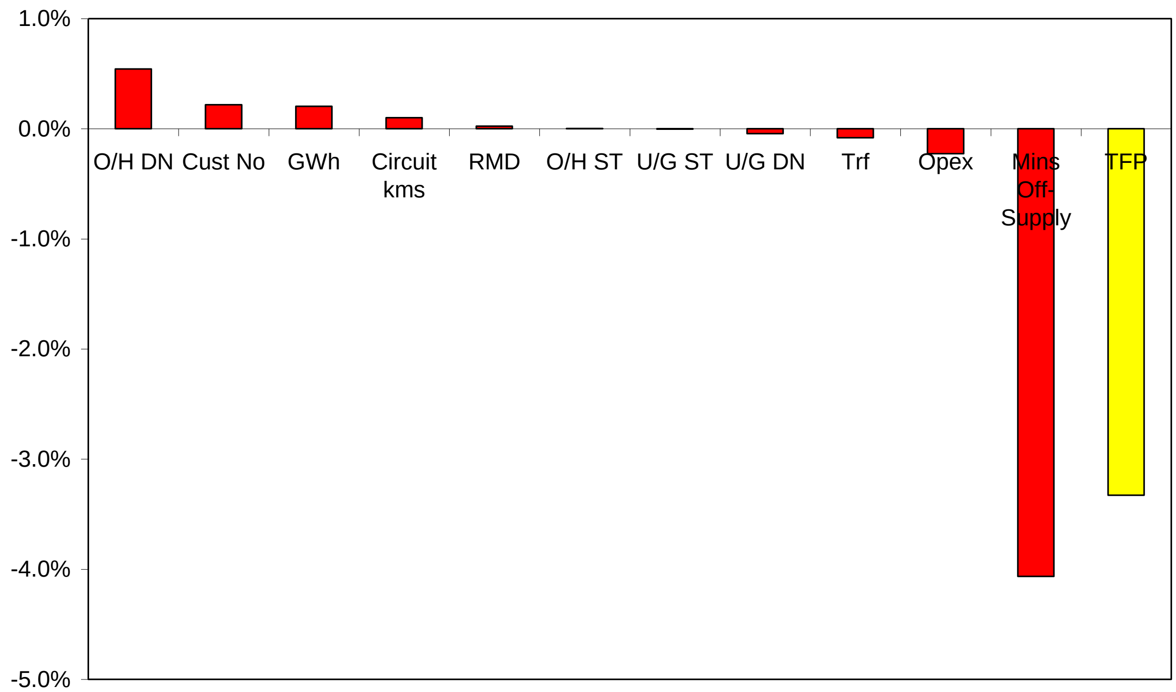
In table 5.12 we decompose ERG's TFP change into its constituent output and input parts for the whole 14–year period and for the periods up to and after 2012. ERG's drivers of TFP change for the whole 14–year period are broadly similar to the industry as a whole except that the customer numbers and CMOS outputs make a larger percentage point contribution to TFP growth in regional Queensland and opex makes a small positive contribution rather than a negative contribution. And the transformers input makes a somewhat more negative contribution to TFP growth for ERG than it does for the industry. However, the stronger output growth and reduced opex usage for ERG lead to its TFP performance being considerably better than that for the industry.

ERG's situation is also a tale of two distinct periods. For the period up to 2012, opex growth made a smaller negative percentage point contribution to TFP growth for ERG than for the industry, at –0.7 percentage points for ERG versus –1.9 percentage points for the industry. The reductions made in ERG's opex after 2012 led to opex making a somewhat smaller positive percentage point contribution to ERG's average annual TFP change than that for the industry. After 2012, ERG's outputs all contributed less to TFP growth compared to the period before 2012, particularly RMD and circuit length, but its inputs, with the exception of transformers, made either positive or somewhat less negative percentage point contributions to TFP growth.

Table 5.12 **ERG's output and input percentage point contributions to average annual TFP change: 2006–2019, 2006–2012, 2012–2019, 2018–19**

Year	*2006 to 2019*	*2006 to 2012*	*2012 to 2019*	*2018–19*
Energy (GWh)	0.00%	0.03%	–0.02%	0.20%
Ratcheted Max Demand	0.50%	1.08%	0.00%	0.02%
Customer Numbers	0.38%	0.48%	0.30%	0.22%
Circuit Length	0.11%	0.31%	–0.07%	0.10%
CMOS	0.36%	0.87%	–0.09%	–4.06%
Opex	0.08%	–0.67%	0.72%	–0.23%
O/H Subtransmission Lines	–0.01%	–0.17%	0.13%	0.00%
O/H Distribution Lines	–0.20%	–0.22%	–0.18%	0.54%
U/G Subtransmission Cables	–0.02%	–0.03%	–0.01%	0.00%
U/G Distribution Cables	–0.17%	–0.28%	–0.08%	–0.04%
Transformers	–0.82%	–0.79%	–0.83%	–0.08%
TFP Change	0.21%	0.60%	–0.13%	–3.33%

Figure 5.24 **ERG's output and input percentage point contributions to annual TFP change, 2018–19**



The importance of the worsening in CMOS in 2019 is highlighted in figure 5.24 where it makes a very large negative contribution of 4.1 percentage point to TFP change of –3.3 per cent in the 2019 year.

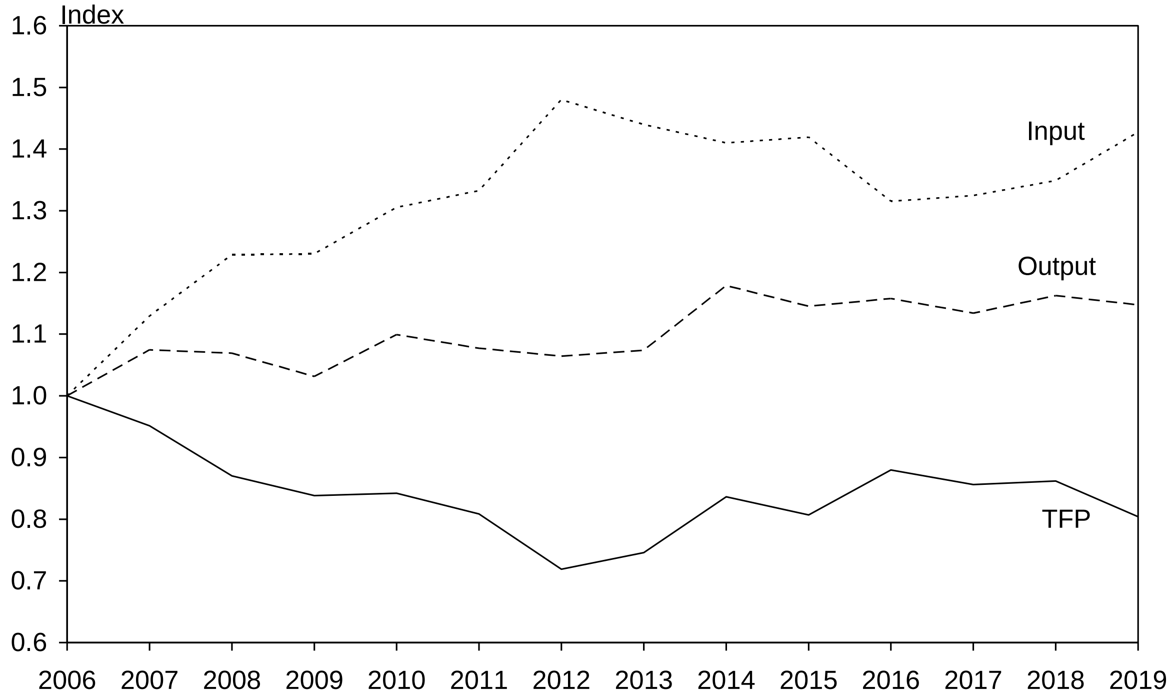
5.7 Essential Energy

In 2019 Essential Energy (ESS) delivered 12,730 GWh to 916,471 customers over 192,538 circuit kilometres of lines and cables. ESS distributes electricity throughout 95 per cent of New South Wales' land mass and parts of southern Queensland. ESS is the fourth largest NEM DNSP in terms of customer numbers but by far the largest in terms of network length.

ESS's productivity performance

ESS's total output, total input and TFP indexes are presented in figure 5.25 and table 5.13. Opex and capital partial productivity indexes are also presented in table 5.13.

Figure 5.25 **ESS's output, input and total factor productivity indexes, 2006–2019**



Over the 14–year period 2006 to 2019, ESS's TFP decreased at an average annual rate of 1.7 per cent. Although total output increased by an average annual rate of 1.1 per cent, total input use increased faster, at a rate of 2.7 per cent. ESS thus had a slightly higher output growth but considerably higher input growth than the industry, leading to a lower TFP growth rate than that for the industry. Input use increased sharply in 2007, 2008, 2012 and 2019. Input use flattened out in 2009 before increasing through to 2012 and then falling in subsequent years. Input use then fell markedly in 2016 before increasing marginally in 2017 and somewhat more in 2018. Apart from a small increase in 2010, TFP fell each year through to 2012 but, except for 2015, TFP change was positive each year from 2013 to 2016. TFP fell by 2.8 per cent in 2017 before increasing by 0.7 per cent in 2018 and then falling by 7 per cent in 2019. TFP average annual change was sharply negative for the period up to 2012 but has been positive at 1.6 per cent for the period since 2012.

Table 5.13 **ESS's output, input and total factor productivity and partial productivity indexes, 2006–2019**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index Opex*	*PFP Index Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.074	1.129	0.952	0.895	0.995
2008	1.069	1.229	0.870	0.757	0.962
2009	1.031	1.230	0.838	0.781	0.881
2010	1.099	1.305	0.842	0.777	0.887
2011	1.077	1.333	0.808	0.763	0.840
2012	1.064	1.480	0.719	0.609	0.808
2013	1.074	1.440	0.746	0.679	0.793
2014	1.179	1.410	0.836	0.786	0.871
2015	1.145	1.419	0.807	0.780	0.826
2016	1.158	1.316	0.880	1.000	0.819
2017	1.134	1.325	0.856	0.973	0.798
2018	1.163	1.349	0.862	0.950	0.812
2019	1.147	1.427	0.804	0.826	0.790
Growth Rate 2006–19	1.06%	2.74%	–1.68%	–1.47%	–1.81%
Growth Rate 2006–12	1.04%	6.54%	–5.50%	–8.26%	–3.55%
Growth Rate 2012–19	1.07%	–0.52%	1.59%	4.34%	–0.33%

The partial productivity indexes in table 5.13 show that reduced opex usage was the main driver of the improved TFP performance after 2012 although capital partial productivity also improved.

ESS's output and input quantity changes

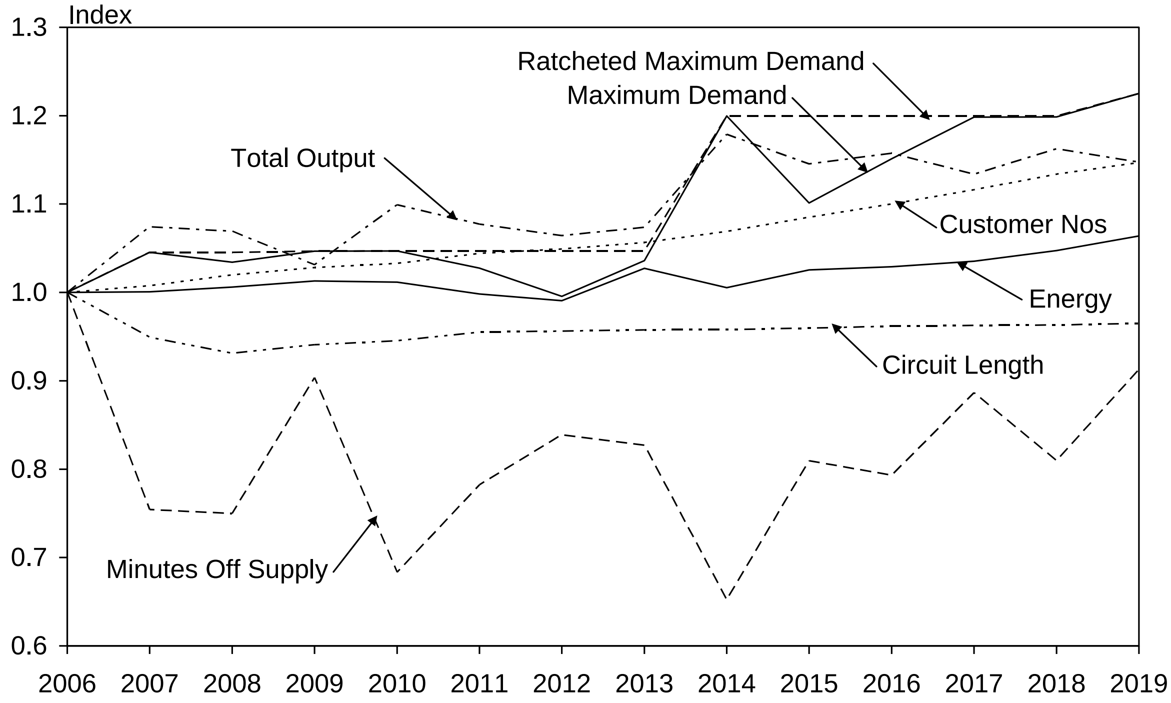
We graph the quantity indexes for ESS's five individual outputs in figure 5.26 and for its six individual inputs in figure 5.27.

From figure 5.26 we see that ESS's output components show a quite different pattern of change to the industry with energy and demand outputs effectively being flat through to 2012 but increasing subsequently. This likely reflects the negative impact of the global financial crisis and then progressively positive economic effects of the mining boom on regional NSW. Customer numbers increased more steadily over the period and were 15 per cent higher in 2019, a lower increase than that for the industry. Energy throughput for distribution peaked in 2009 and again in 2013 but has increased each year since 2014 to be 6 per cent higher in 2019 than it was in 2006.

ESS's maximum demand initially peaked in 2014 – several years later than for most other DNSPs. This peak was exceeded in 2019 and ratcheted maximum demand in 2019 was 23 per cent above its 2006 level – a larger increase than for the industry overall.

ESS's circuit length output declined in 2007 and 2008 and has increased gradually since then. By 2019 it was still 3 per cent lower than it was in 2006 compared to an increase of 5 per cent for the industry.

Figure 5.26 **ESS's output quantity indexes, 2006–2019**



The last output shown in figure 5.26 is total CMOS. ESS's CMOS has generally followed a similar pattern to that of the industry although it has been somewhat more volatile. CMOS has generally trended downwards over the period and, hence, contributed more to total output than was the case in 2006. But CMOS increased by 12 per cent in 2019 and was then 9 per cent less than it was in 2006.

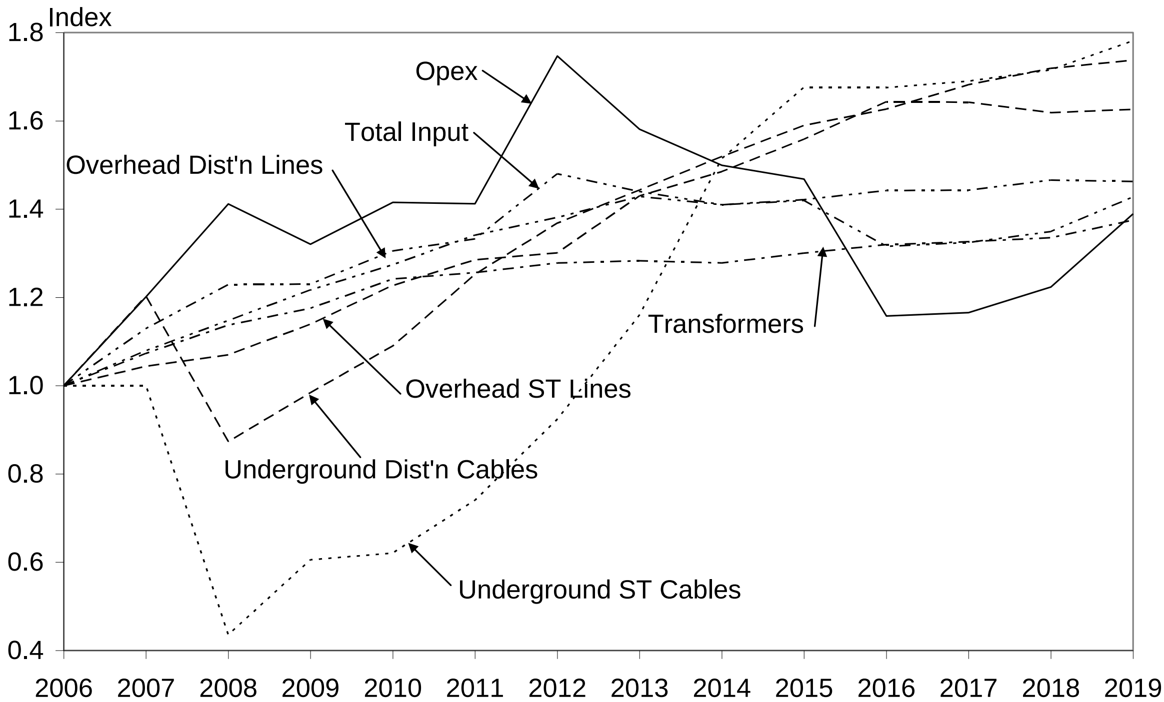
Since the circuit length and ratcheted maximum demand outputs receive a combined average weight of around 88 per cent of total revenue in forming the total output index for ESS, in figure 5.26 we see that the total output index tends to lie close to but often above these two output indexes. The customer numbers and energy indexes generally lie between the RMD and circuit length indexes. But the CMOS index would generally lie above the other output indexes when it enters the formation of total output as a negative output (ie the reduction in CMOS over the period makes a positive contribution to total output). CMOS receives a larger weight for ESS at an average of –21 per cent of total revenue as, being a remote regional DNSP and having a low network density like ERG, ESS also has a higher level of CMOS. ESS's CMOS weight in 2006 was a very large –35 per cent of total revenue.

Turning to the input side, we see from ESS's six input components and total input in figure 5.27 that the quantity of ESS's opex increased considerably more rapidly between 2006 and 2012 than the corresponding increase for the industry. For ESS, opex increased by 75 per cent up to 2012 whereas the corresponding increase for the industry was 36 per cent. However, ESS's opex then fell significantly through to 2016 before increasing again from 2017 and 2019 at which point it was 39 per cent above its 2006 level.[14] This compares to the industry's 2019 opex usage being 14 per cent above its 2006 level. Opex has the largest

[14] Note that redundancy payments are included in the opex figures presented here.

average share in ESS's total costs at 40 per cent and so is an important driver of its total input quantity index.

Figure 5.27 **ESS's input quantity indexes, 2006–2019**



ESS's underground distribution cables and transformers inputs increase more steadily over the period and at rates somewhat higher and lower, respectively, than for the industry as a whole. Its overhead distribution lines input, however, increases much more rapidly over the period with an increase of 46 per cent compared to only 12 per cent for the industry.

From figure 5.27 we see that the total input quantity index generally lies between the quantity indexes for opex and transformers (which have an average combined weight of 69 per cent of total costs). Total input quantity increased by 5.7 per cent in 2019 driven by an increase of 12.7 per cent in opex usage and an increase of 3.0 per cent in transformer inputs.

ESS's output and input contributions to TFP change

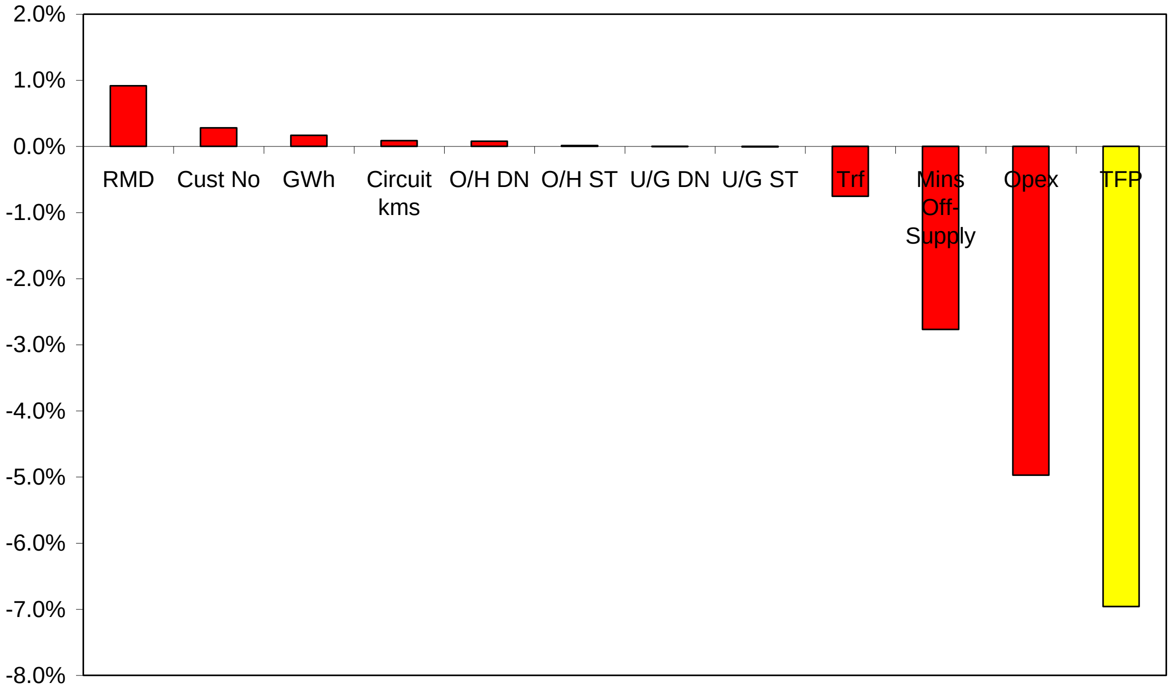
In table 5.14 we decompose ESS's TFP change into its constituent output and input parts for the whole 14–year period and for the periods up to and after 2012. ESS's drivers of TFP change for the whole 14–year period are broadly similar to the industry as a whole except that the RMD output makes a larger positive contribution for ESS while the circuit length output makes a negative contribution to TFP growth for ESS in contrast to the positive contribution of circuit length output for the industry. Opex usage contributes –1.0 percentage points to ESS's TFP growth compared to –0.4 percentage points for the industry.

ESS's situation is again a tale of two distinct periods but with the opposite relativities compared to most other DNSPs. For the period up to 2012, output growth (except for the CMOS output) made less of a contribution to TFP growth than it did after 2012. ESS's rapid opex growth up to 2012 made a larger negative percentage point contribution to TFP growth than it did for the industry, at –3.8 percentage points for ESS versus –1.9 percentage points for the industry. But the reductions made in ESS's opex after 2012 led to opex contributing 1.4 percentage points to ESS's average annual TFP change of 1.6 per cent for the period after 2012. This compares to an opex contribution of 1.0 percentage points to the industry TFP average annual change of 0.3 per cent after 2012.

Table 5.14 **ESS's output and input percentage point contributions to average annual TFP change: 2006–2019, 2006–2012 and 2012–2019**

Year	*2006 to 2019*	*2006 to 2012*	*2012 to 2019*	*2018–19*
Energy (GWh)	0.05%	–0.01%	0.11%	0.17%
Ratcheted Max Demand	0.66%	0.36%	0.92%	0.92%
Customer Numbers	0.24%	0.19%	0.29%	0.28%
Circuit Length	–0.14%	–0.37%	0.06%	0.09%
CMOS	0.24%	0.87%	–0.30%	–2.77%
Opex	–1.03%	–3.82%	1.36%	–4.97%
O/H Subtransmission Lines	–0.27%	–0.33%	–0.22%	0.01%
O/H Distribution Lines	–0.55%	–0.97%	–0.20%	0.08%
U/G Subtransmission Cables	–0.01%	0.00%	–0.02%	–0.01%
U/G Distribution Cables	–0.16%	–0.20%	–0.13%	0.00%
Transformers	–0.71%	–1.22%	–0.28%	–0.75%
TFP Change	–1.68%	–5.50%	1.59%	–6.96%

Figure 5.28 **ESS's output and input percentage point contributions to annual TFP change, 2018–19**



The importance of the increases in opex and in CMOS in 2019 is highlighted in figure 5.28 where the 12.7 per cent increase in opex contributes –5.0 percentage points and the 12 per cent in CMOS –2.8 percentage points. The increase in RMD contributes 0.9 percentage points to produce TFP change of –7.0 per cent in 2019.

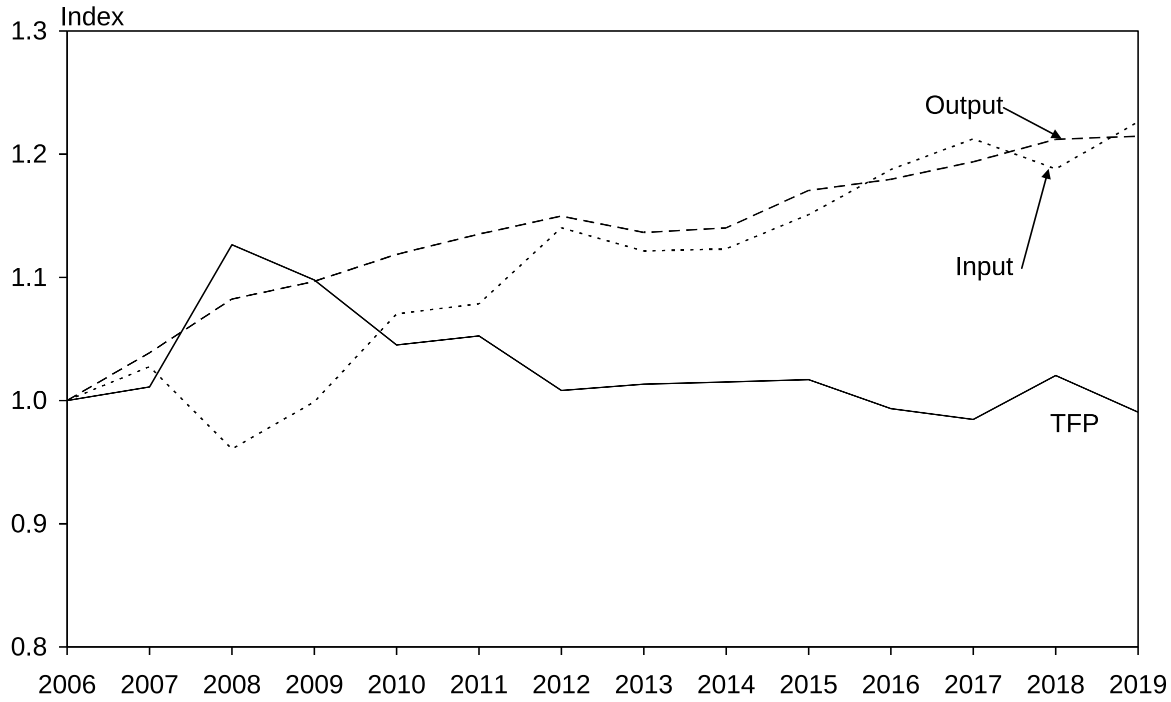
5.8 Jemena Electricity Networks

In 2019 Jemena Electricity Networks (JEN) delivered 4,229 GWh to 354,452 customers over 6,628 circuit kilometres of lines and cables. JEN distributes electricity across 950 square kilometres of north–west greater Melbourne. JEN's network footprint incorporates a mix of major industrial areas, residential growth areas, established inner suburbs and Melbourne International Airport.

JEN's productivity performance

JEN's total output, total input and TFP indexes are presented in figure 5.29 and table 5.15. Opex and capital partial productivity indexes are also presented in table 5.15.

Figure 5.29 **JEN's output, input and total factor productivity indexes, 2006–2019**



Over the 14–year period 2006 to 2019, JEN's TFP decreased at an average annual rate of 0.1 per cent. Although total output increased by an average annual rate of 1.5 per cent, total input use increased slightly faster, at a rate of 1.6 per cent. JEN thus had a higher output growth rate compared to the industry and it had a considerably lower input growth rate than the industry leading to a small downward trend in TFP growth overall for JEN compared to a decline in TFP at the rate of –0.8 per cent per annum for the industry as a whole. JEN's input use decreased in 2008 before then increasing at a higher rate through to 2012 and flattening off through to 2014 before again increasing. TFP change was positive in 2007, 2008, 2011 and 2018, negative in 2009, 2010, 2012, 2016, 2017 and 2019 and relatively flat in the other years. In 2008 output growth was strong while input usage fell markedly leading to a TFP increase of 11 per cent. In 2019 output growth was lower while there was higher growth in input leading to a TFP change of –3.0 per cent. Compared to the whole 14–year period TFP average annual change was positive for the period up to 2012 at 0.1 per cent but has been somewhat negative at –0.3 per cent for the period since 2012.

Table 5.15 **JEN's output, input and total factor productivity and partial productivity indexes, 2006–2019**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.039	1.027	1.011	0.984	1.034
2008	1.082	0.961	1.127	1.270	1.044
2009	1.097	0.999	1.098	1.179	1.039
2010	1.119	1.070	1.045	1.025	1.061
2011	1.135	1.079	1.052	1.055	1.052
2012	1.150	1.140	1.008	0.940	1.066
2013	1.136	1.121	1.013	0.971	1.047
2014	1.140	1.123	1.015	0.988	1.036
2015	1.170	1.151	1.017	0.988	1.040
2016	1.180	1.187	0.994	0.942	1.034
2017	1.194	1.212	0.985	0.910	1.045
2018	1.212	1.188	1.020	1.005	1.033
2019	1.215	1.226	0.991	0.965	1.011
Growth Rate 2006–19	1.50%	1.57%	–0.07%	–0.28%	0.09%
Growth Rate 2006–12	2.32%	2.19%	0.14%	–1.02%	1.06%
Growth Rate 2012–19	0.79%	1.04%	–0.25%	0.37%	–0.75%

The partial productivity indexes in table 5.15 show that while opex PFP growth improved after 2012, this was more than offset by a worsening in capital PFP growth.

JEN's output and input quantity changes

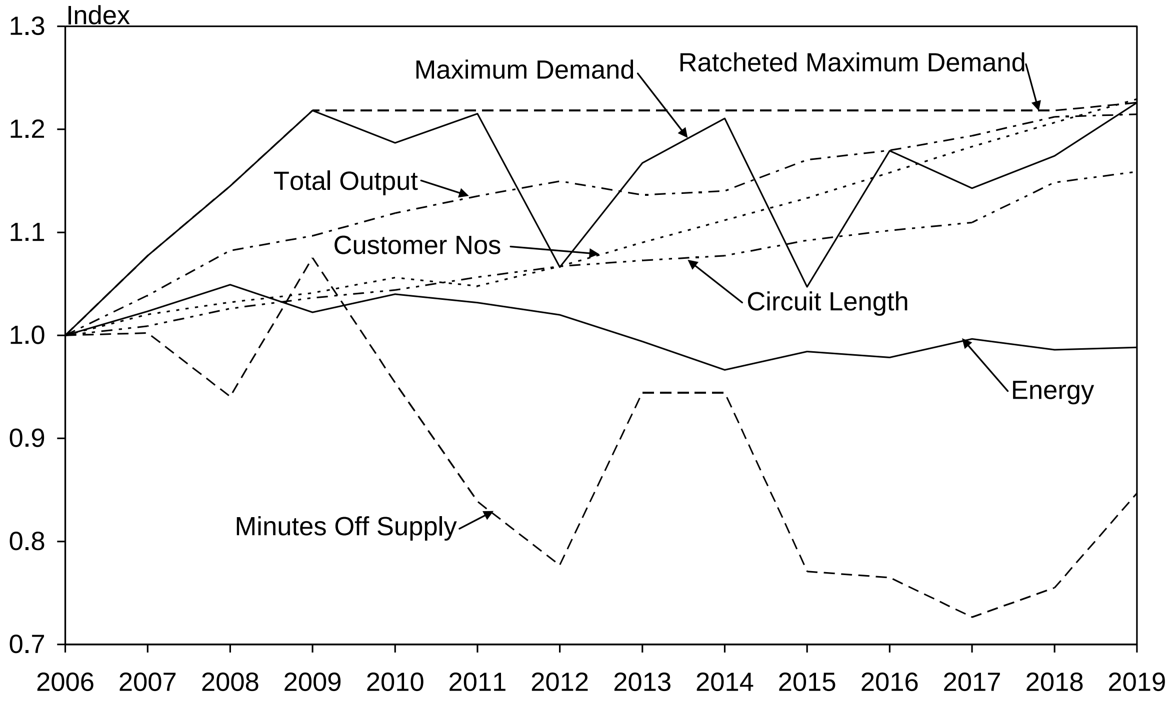
We graph the quantity indexes for the JEN's five individual outputs in figure 5.30 and for its six individual inputs in figure 5.31.

From figure 5.30 we see that JEN's output components exhibit a similar pattern of change to the industry as a whole. Customer numbers increased steadily over the period and were 23 per cent higher in 2019 than they were in 2006, somewhat higher than for the industry. Energy throughput for distribution peaked in 2008 – a year or two earlier than for most DNSPs – and was 1 per cent lower in 2019 than it was in 2006.

JEN's maximum demand reached its initial peak level in 2009 but has been relatively volatile since then. It almost regained its 2009 level in 2011 and again in 2014 and did exceed it in 2019. In 2019 it was around 23 per cent above its 2006 level, as was ratcheted maximum demand – a larger increase than the industry's 17 per cent.

JEN's circuit length output grew more over the 14 years than occurred for the industry overall and by 2019 was 16 per cent above the level it was in 2006 compared to an increase of only 5 per cent for the industry.

Figure 5.30 **JEN's output quantity indexes, 2006–2019**

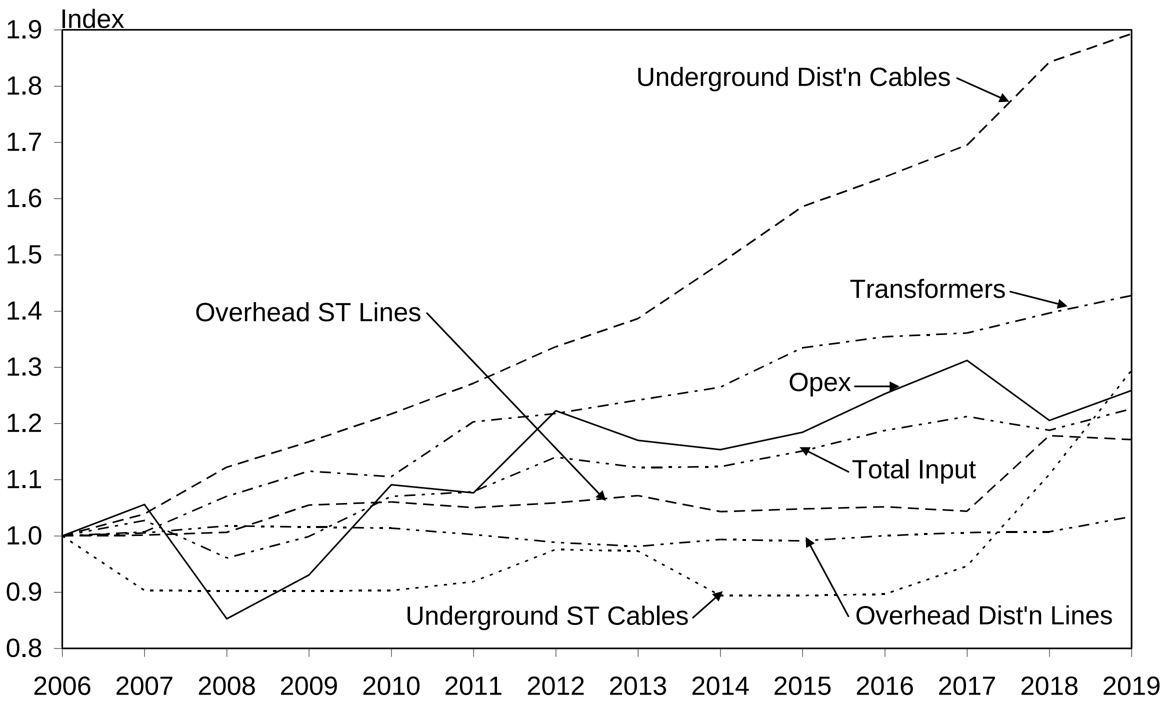


The last output shown in figure 5.30 is total CMOS. JEN's CMOS has been more volatile than for the industry but has similarly trended downwards over the period. By 2019 JEN's CMOS was 15 per cent lower than it was in 2006, after increasing by 12 per cent in 2019, but it had been only 6 per cent below its 2006 level in 2013. CMOS receives an average weight of –8 per cent of total revenue for JEN.

Since the circuit length and ratcheted maximum demand outputs receive a combined average weight of around 79 per cent of total revenue in forming the total output index for JEN, in figure 5.30 we see that the total output index lies between these two output indexes. The customer numbers output index also lies close to the circuit length index while the energy output index lies at a lower level. The CMOS index would lie above the other output indexes in most years when it enters the formation of total output as a negative output (ie the decrease in CMOS over the period makes a positive contribution to total output). The CMOS increase in 2013 is the main reason for the dip in total output in that year.

Turning to the input side, we see from JEN's six input components and total input in figure 5.31 that the quantity of JEN's opex decreased sharply in 2008 and was the driver of the fall in total inputs in that year. Opex usage then increased again through to 2012. However, for JEN, opex increased by 22 per cent up to 2012 whereas the corresponding increase for the industry was 36 per cent. Since then JEN's opex usage initially decreased but then increased to be 31 per cent above its 2006 level in 2017 before falling by over 8 per cent in 2018 and increasing by over 4 per cent in 2019 to finish up 26 per cent above its 2006 level. This compares to opex usage for the industry being 14 per cent above its 2006 level in 2019. Opex has the largest average share in JEN's total costs at 43 per cent and so is an important driver of its total input quantity index.

Figure 5.31 **JEN's DNSP input quantity indexes, 2006–2019**



JEN's underground distribution cables and transformers inputs increased more steadily over the period at somewhat higher and similar rates, respectively, compared to the industry as a whole. Its overhead distribution lines input remained virtually unchanged over most of the period but finished 4 per cent above its 2006 level in 2019 compared to a 12 per cent increase for the industry.

From figure 5.31 we see that JEN's total input quantity index lies close to the quantity indexes for opex and overhead distribution lines (with the latter receiving a higher weight for JEN than for most DNSPs). Total input quantity increased by 3.2 per cent in 2019, driven by increases in all inputs other than overhead subtransmission lines.

JEN's output and input contributions to TFP change

In table 5.16 we decompose JEN's TFP change into its constituent output and input parts for the whole 14–year period and for the periods up to and after 2012. JEN's drivers of TFP change for the whole 14–year period are broadly similar to the industry as a whole except that circuit length makes a larger positive contribution to TFP growth for JEN, opex makes a larger negative contribution and the underground distribution cables and transformers inputs make a smaller negative contribution. Opex makes a considerably more negative contribution over the period for JEN at –0.8 per cent compared to –0.4 per cent for the industry.

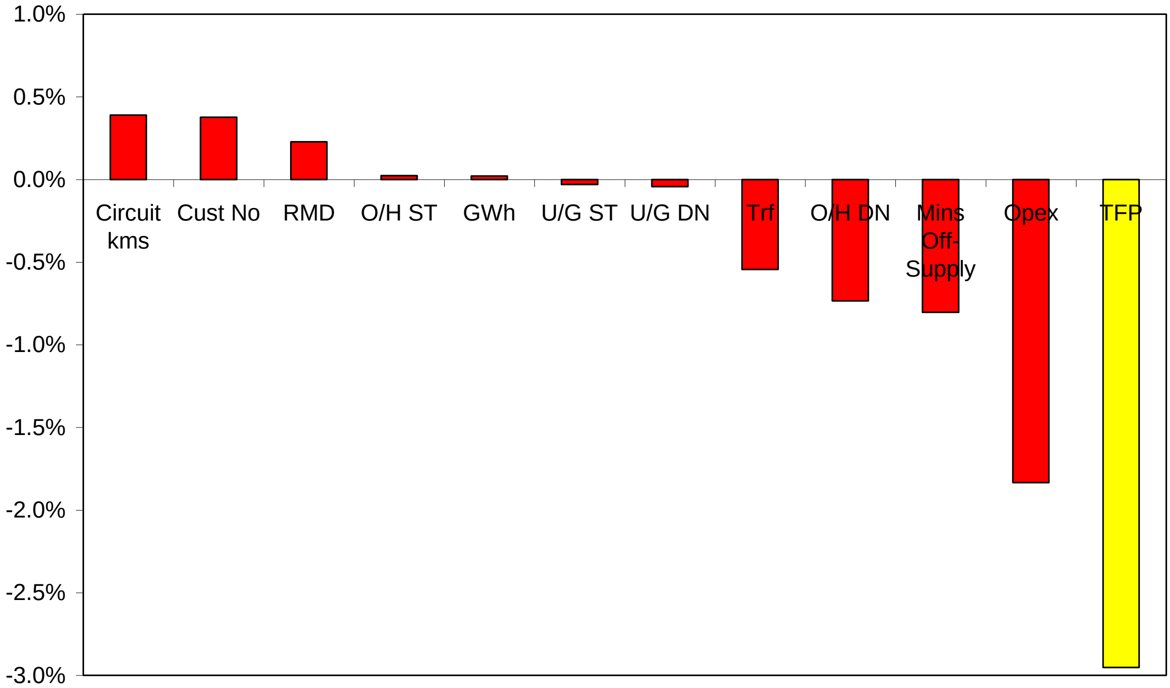
JEN's situation is again a tale of two distinct periods. Except for circuit length and customer numbers, the contribution of outputs to TFP falls after 2012 compared to the period before 2012. And the contribution of most inputs remains relatively unchanged except for opex whose contribution improves by 1.3 percentage points. Opex change went from –1.5

percentage points contribution to TFP before 2012 to –0.2 percentage points contribution for JEN after 2012. This differs to the industry–wide result where opex makes a positive contribution to TFP change of 0.9 percentage points after 2012 as opex usage declines overall.

Table 5.16 **JEN's output and input percentage point contributions to average annual TFP change: 2006–2019, 2006–2012, 2012–2019 and 2019**

Year	*2006 to 2019*	*2006 to 2012*	*2012 to 2019*	*2019*
Energy (GWh)	–0.01%	0.03%	–0.04%	0.02%
Ratcheted Max Demand	0.58%	1.22%	0.03%	0.23%
Customer Numbers	0.32%	0.22%	0.40%	0.38%
Circuit Length	0.48%	0.47%	0.50%	0.39%
CMOS	0.12%	0.38%	–0.10%	–0.80%
Opex	–0.77%	–1.49%	–0.15%	–1.83%
O/H Subtransmission Lines	–0.06%	–0.04%	–0.07%	0.02%
O/H Distribution Lines	–0.07%	0.05%	–0.18%	–0.74%
U/G Subtransmission Cables	0.00%	0.00%	–0.01%	–0.03%
U/G Distribution Cables	–0.10%	–0.11%	–0.10%	–0.04%
Transformers	–0.56%	–0.61%	–0.53%	–0.54%
TFP Change	–0.07%	0.14%	–0.25%	–2.95%

Figure 5.32 **JEN's output and input percentage point contributions to annual TFP change, 2019**



The importance of JEN's increase in opex usage, its worsening reliability and increased inputs of overhead distribution lines and transformers in 2019 is highlighted in figure 5.32 with –1.8, –0.8, –0.7 and –0.5 percentage point contributions to TFP change, respectively.

These more than offset contributions from increases in customer numbers, circuit length and RMD. JEN's 2019 TFP growth was –3.0 per cent compared to industry TFP growth of –1.0 per cent that year.

5.9 Powercor

In 2019 Powercor (PCR) delivered 10,882 GWh to 853,771 customers over 75,815 circuit kilometres of lines and cables. PCR distributes electricity to the western half of Victoria, including the western suburbs of Melbourne and stretching west to the border of South Australia and north to New South Wales.

PCR's productivity performance

PCR's total output, total input and TFP indexes are presented in figure 5.33 and table 5.17. Opex and capital partial productivity indexes are also presented in table 5.17.

Figure 5.33 **PCR's output, input and total factor productivity indexes, 2006–2019**

Over the 14–year period 2006 to 2019, PCR's TFP grew at an average annual rate of –0.6 per cent. Total output increased by an average annual rate of 1.0 per cent while total input use increased at a rate of 1.6 per cent. PCR thus had a similar output growth rate compared to the industry but it also had a lower input growth rate than the industry leading to a somewhat less negative TFP growth for PCR compared to the TFP growth rate of –0.8 per cent per annum for the industry as a whole. PCR's input use decreased in 2007 before then increasing at a higher rate through to 2013 and flattening off through to 2015 before decreasing significantly in 2016 and then increasing again in 2017 and 2018 and increasing marginally in 2019. TFP change was positive in 2007, 2008, 2010, 2011, 2015, 2016 and 2019, negative in 2009, 2012, 2013 and 2018, and relatively flat in 2014 and 2017.

In 2008, 2010 and 2011 output growth was strong while input usage moderated. In 2016 input use decreased by 5.6 per cent while output growth continued albeit at a moderated rate leading to a TFP change of 6.4 per cent. A return to strong output growth in 2017 was accompanied by an increase in input use of 4.3 per cent leading to TFP growth of 0.4 per cent. In 2018 total output fell substantially while input use continued to increase, albeit at a reduced rate, to produce TFP change of –6.1 per cent. In 2019 modest output growth was accompanied by little change in input use to produce TFP growth of 1.3 per cent. TFP average annual change was –1.0 per cent for the period up to 2012 and –0.4 per cent for the period after 2012.

Table 5.17 **PCR's output, input and total factor productivity and partial productivity indexes, 2006–2019**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	0.996	0.958	1.040	1.136	0.974
2008	1.058	0.978	1.082	1.181	1.017
2009	1.019	1.053	0.968	1.031	0.924
2010	1.056	1.058	0.998	1.114	0.927
2011	1.093	1.070	1.022	1.108	0.965
2012	1.092	1.155	0.945	0.933	0.953
2013	1.076	1.202	0.895	0.865	0.916
2014	1.046	1.168	0.896	0.927	0.873
2015	1.100	1.216	0.904	0.908	0.900
2016	1.109	1.150	0.964	1.080	0.892
2017	1.163	1.201	0.968	1.050	0.914
2018	1.116	1.226	0.911	0.983	0.862
2019	1.131	1.226	0.922	1.028	0.855
Growth Rate 2006–19	0.95%	1.57%	–0.62%	0.22%	–1.20%
Growth Rate 2006–12	1.46%	2.41%	–0.95%	–1.16%	–0.81%
Growth Rate 2012–19	0.50%	0.85%	–0.35%	1.40%	–1.54%

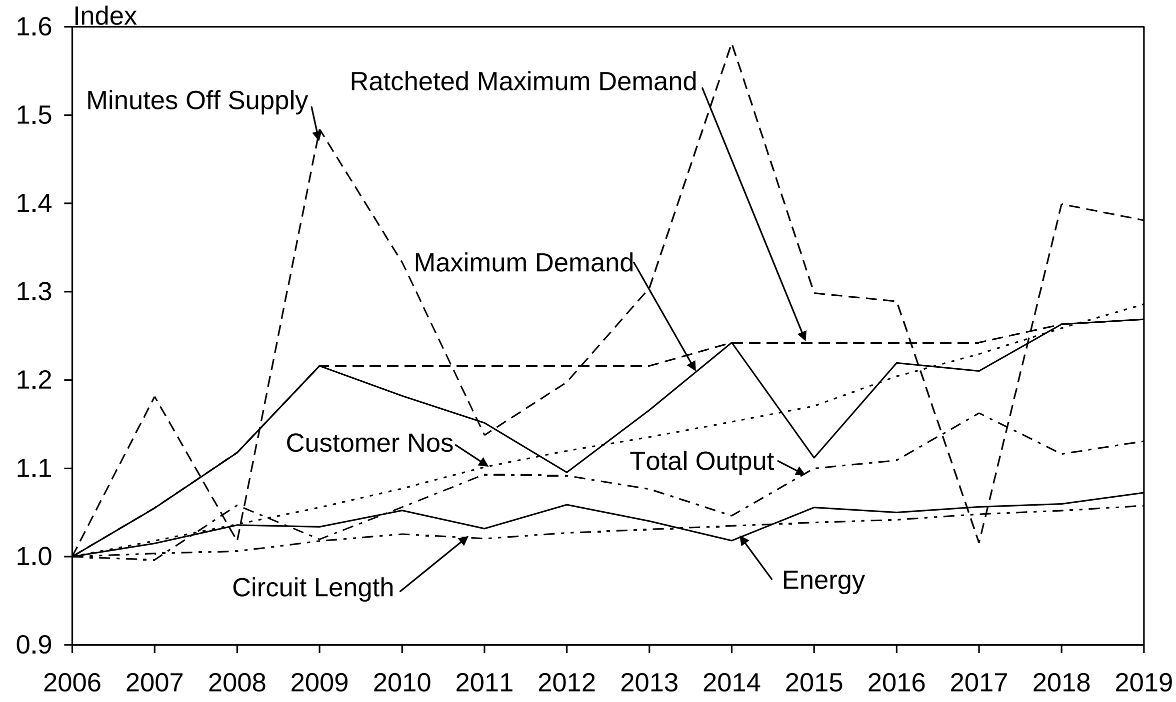
The partial productivity indexes in table 5.17 show that opex PFP growth improved after 2012 but this was partly offset by a worsening in capital PFP change after 2012.

PCR's output and input quantity changes

We graph the quantity indexes for PCR's five individual outputs in figure 5.34 and for its six individual inputs in figure 5.35.

From figure 5.34 we see that PCR's output components exhibit a similar pattern of change to the industry as a whole, except that CMOS is more volatile and exhibits an upward rather than a downward trend over the period as a whole. Customer numbers increased steadily over the period and were 29 per cent higher in 2019 than they were in 2006, a larger increase than the industry's increase of 19 per cent. Energy throughput for distribution peaked in 2012 – a little later than for most DNSPs – and was 7 per cent higher in 2019 than it was in 2006.

Figure 5.34 **PCR's output quantity indexes, 2006–2019**



PCR's maximum demand reached its highest level in 2019 – later than for most DNSPs – but has been relatively volatile since lower peaks in 2009 and 2014. In 2019 it was around 27 per cent above its 2006 level. Ratcheted maximum demand in 2019 was also 27 per cent above its 2006 level – a larger increase than the industry's 17 per cent.

PCR's circuit length output grew slightly more over the 14 years than occurred for the industry overall and by 2019 was 6 per cent above the level it was in 2006 compared to an increase of 5 per cent for the industry.

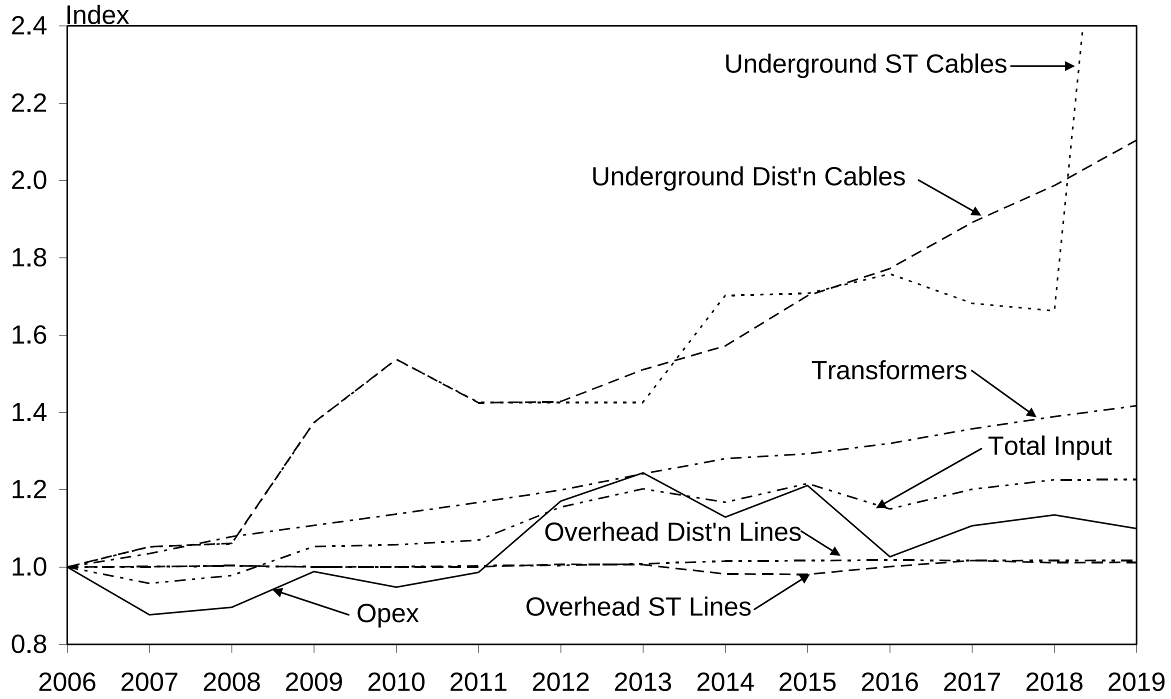
The last output shown in figure 5.34 is total CMOS. PCR's CMOS has been more volatile than for the industry and has trended upwards instead of trending downwards as it has for the industry. In 2019 PCR's CMOS was 38 per cent higher than it was in 2006 but it had been 58 per cent higher than its 2006 level in 2014. CMOS receives an average weight of –20 per cent of total revenue for PCR.

Since the circuit length and ratcheted maximum demand outputs receive a combined weight of around 87 per cent of total revenue in forming the total output index for PCR, in figure 5.34 we see that the total output index lies between these two output indexes. The total output index also lies below the customer numbers output index and above the energy output index. In this case, the CMOS index would lie well below the other output indexes in most years when it enters the formation of total output as a negative output (ie the increase in CMOS over the period makes a negative contribution to total output). The large CMOS increases in 2009, 2014 and 2018 are the main reason for dips in total output in those years.

Turning to the input side, we see from PCR's six input components and total input in figure 5.35 that the quantity of PCR's opex decreased sharply in 2014 and again in 2016. It was the driver of the fall in total inputs in those years. For PCR, opex increased by 24 per cent up to

2013 whereas the corresponding increase for the industry was 36 per cent up to 2012. Since 2013 PCR's opex usage decreased sharply in 2016 but has increased again in 2017 and 2018 before decreasing in 2019 to be 10 per cent above its 2006 level in the latest year. By comparison, the industry's opex usage in 2019 was 14 per cent above its 2006 level. Opex has the largest average share in PCR's total costs at 40 per cent and so is an important driver of its total input quantity index.

Figure 5.35 **PCR's DNSP input quantity indexes, 2006–2019**



PCR's underground distribution cables and transformers inputs increased more steadily over the period at somewhat higher and similar rates, respectively, compared to the industry as a whole. PCR's underground subtransmission inputs more than doubled in 2019 but the length involved was quite short. Its overhead distribution lines input only increased a little over the period to be 2 per cent above its 2006 level in 2019 compared to a 12 per cent increase for the industry.

From figure 5.35 we see that PCR's total input quantity index generally lies between the quantity indexes for opex and transformers. Total input quantity was relatively flat in 2019 with the reduction in opex being offset by increases in underground distribution and transformer inputs.

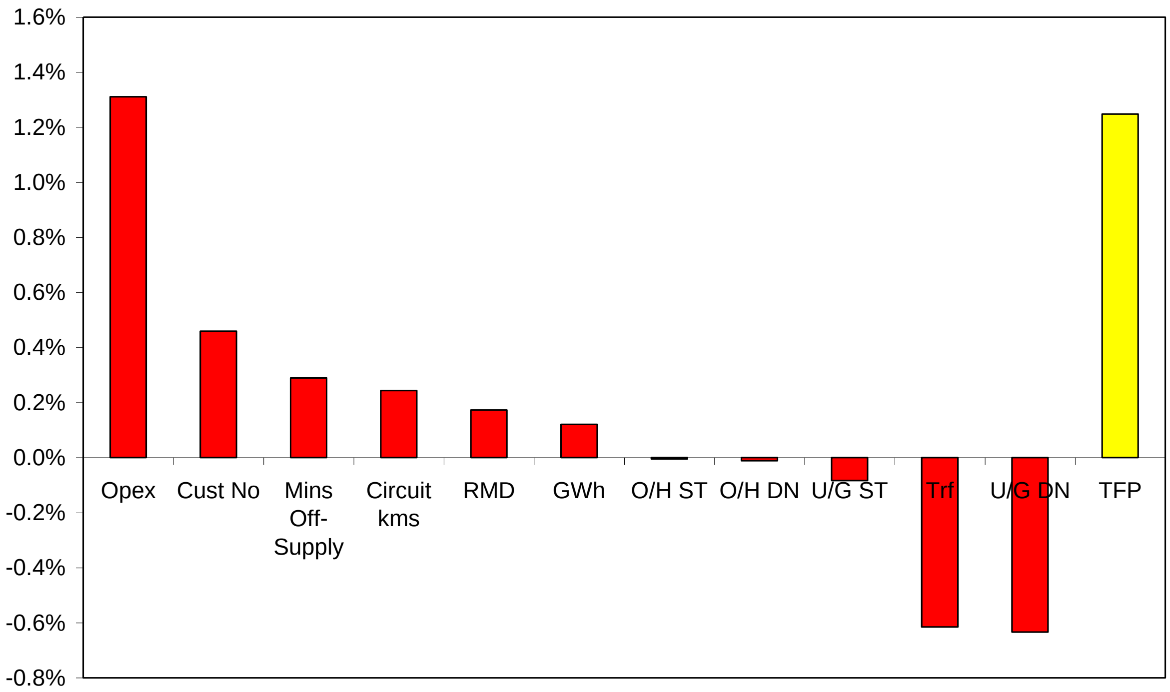
PCR's output and input contributions to TFP change

In table 5.18 we decompose PCR's TFP change into its constituent output and input parts for the whole 14–year period and for the periods up to and after 2012. PCR's drivers of TFP change for the whole 14–year period differ from those for the industry as a whole in a number of ways. The RMD and customer numbers outputs make a larger positive contribution for PCR. Transformers input makes a smaller negative contribution for PCR but CMOS makes a negative contribution for PCR instead of the marginal positive one it makes for the industry. Opex makes a contribution over the period for PCR of –0.3 per cent compared to –0.4 per cent for the industry.

Table 5.18 PCR's output and input percentage point contributions to average annual TFP change: 2006–2019, 2006–2012, 2012–2019 and 2019

Year	*2006 to 2019*	*2006 to 2012*	*2012 to 2019*	*2019*
Energy (GWh)	0.05%	0.10%	0.02%	0.12%
Ratcheted Max Demand	0.74%	1.31%	0.24%	0.17%
Customer Numbers	0.43%	0.42%	0.43%	0.46%
Circuit Length	0.20%	0.21%	0.20%	0.24%
CMOS	-0.47%	–0.57%	-0.39%	0.29%
Opex	-0.30%	–1.11%	0.39%	1.31%
O/H Subtransmission Lines	0.00%	0.00%	0.00%	0.00%
O/H Distribution Lines	-0.03%	–0.02%	-0.04%	-0.01%
U/G Subtransmission Cables	-0.01%	–0.01%	-0.01%	-0.08%
U/G Distribution Cables	-0.65%	–0.68%	-0.62%	-0.63%
Transformers	-0.58%	–0.60%	-0.56%	-0.61%
TFP Change	–0.62%	–0.95%	–0.35%	1.25%

Figure 5.36 PCR's output and input percentage point contributions to annual TFP change, 2019



PCR's situation is also a tale of two distinct periods. With the exception of CMOS and customer numbers, the contribution of outputs to TFP falls after 2012 compared to the period before 2012. And the contribution of most inputs remains relatively unchanged except for opex whose contribution improves by 1.5 percentage points. Opex change went from a –1.1

percentage point contribution to TFP to 0.4 percentage points for PCR before and after 2012 as opex usage trended downwards after its 2013 peak.

The importance of PCR’s 3.2 per cent decrease in opex in 2019 is highlighted in figure 5.36 where opex made a 1.3 percentage point contribution to TFP change in the 2019 year. There was also a total of 1.3 percentage points in contributions from the five outputs that year, all of which were positive. These were slightly more than offset by a total of –1.4 percentage points in contributions from the other five inputs, most coming from increases in underground distribution and transformer input quantities, leading to PCR’s TFP change in 2019 being 1.3 per cent compared to industry 2019 TFP change of –1.0 per cent.

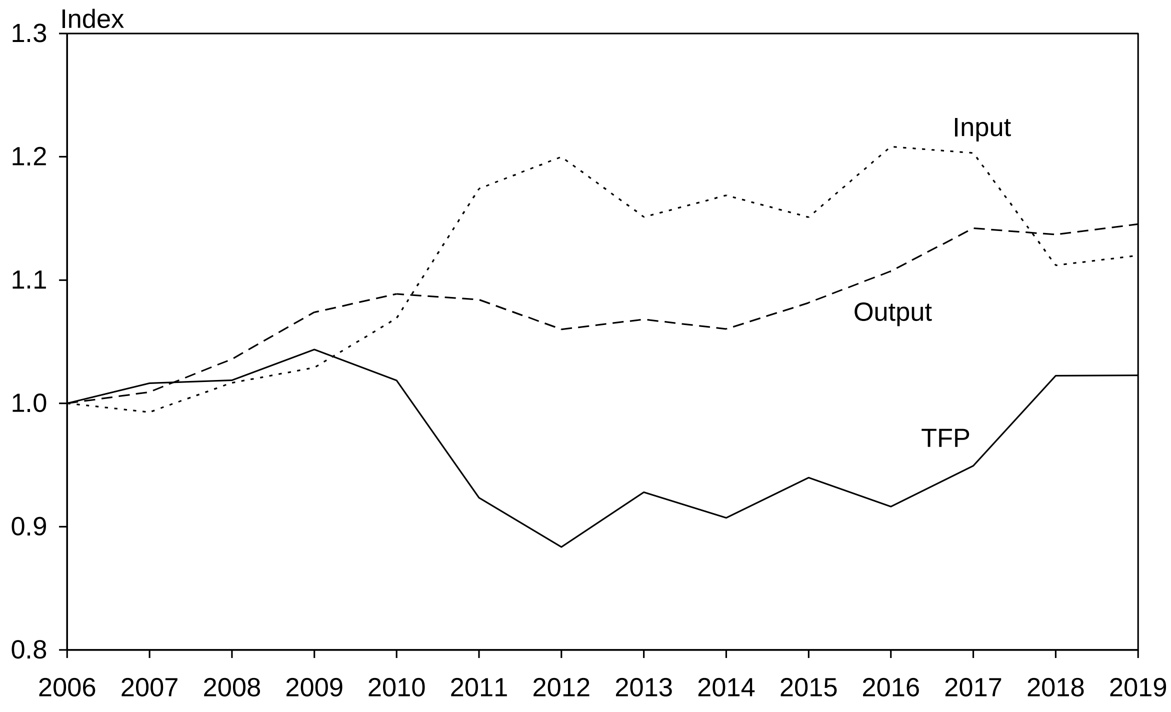
5.10 United Energy

In 2019 United Energy (UED) delivered 7,693 GWh to 697,594 customers over 13,407 circuit kilometres of lines and cables. UED distributes electricity across east and south–east Melbourne and the Mornington Peninsula.

UED’s productivity performance

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

Figure 5.37 **UED’s output, input and total factor productivity indexes, 2006–2019**



Over the 14–year period 2006 to 2018, UED’s TFP increased with an average annual change of 0.2 per cent. Total output increased by an average annual rate of 1.0 per cent while total input use increased at a rate of 0.9 per cent. UED thus had similar output growth, considerably slower input growth and positive instead of negative TFP growth compared to the industry as a whole. Input use increased at a faster rate in 2011 and 2016. It decreased in 2013 and then levelled off for two years. It decreased again in 2017 and 2018 and increased a little in 2019. UED's output declined in four years: 2011, 2012, 2014 and 2018. TFP change was positive in six years: 2007, 2009, 2013, 2015, 2017 and 2018. In all but the second of these years there were input decreases and in the second there was stronger output growth. TFP was relatively flat in 2008 and 2019. In 2019 there was slow growth in total output but a somewhat slower growth in input use leading to marginally positive TFP growth. Compared to the whole 14–year period TFP average annual change was much more negative for the period up to 2012 at –2.1 per cent but has been positive at 2.1 per cent for the period since 2012.

Table 5.19 **UED's output, input and total factor productivity and partial productivity indexes, 2006–2019**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.009	0.993	1.016	1.070	0.983
2008	1.036	1.017	1.019	1.094	0.974
2009	1.074	1.029	1.044	1.116	0.999
2010	1.089	1.069	1.019	1.083	0.980
2011	1.084	1.174	0.923	0.880	0.957
2012	1.060	1.200	0.883	0.855	0.906
2013	1.068	1.151	0.928	0.967	0.903
2014	1.060	1.169	0.907	0.939	0.887
2015	1.082	1.151	0.940	1.009	0.898
2016	1.107	1.208	0.916	0.894	0.928
2017	1.142	1.203	0.949	0.980	0.929
2018	1.137	1.112	1.022	1.228	0.918
2019	1.145	1.120	1.023	1.234	0.915
Growth Rate 2006–19	1.04%	0.87%	0.17%	1.62%	–0.68%
Growth Rate 2006–12	0.97%	3.04%	–2.06%	–2.61%	–1.65%
Growth Rate 2012–19	1.11%	–0.99%	2.09%	5.24%	0.15%

The partial productivity indexes in table 5.19 show that improvements in both opex PFP and capital PFP have played a role in the improved TFP performance after 2012.

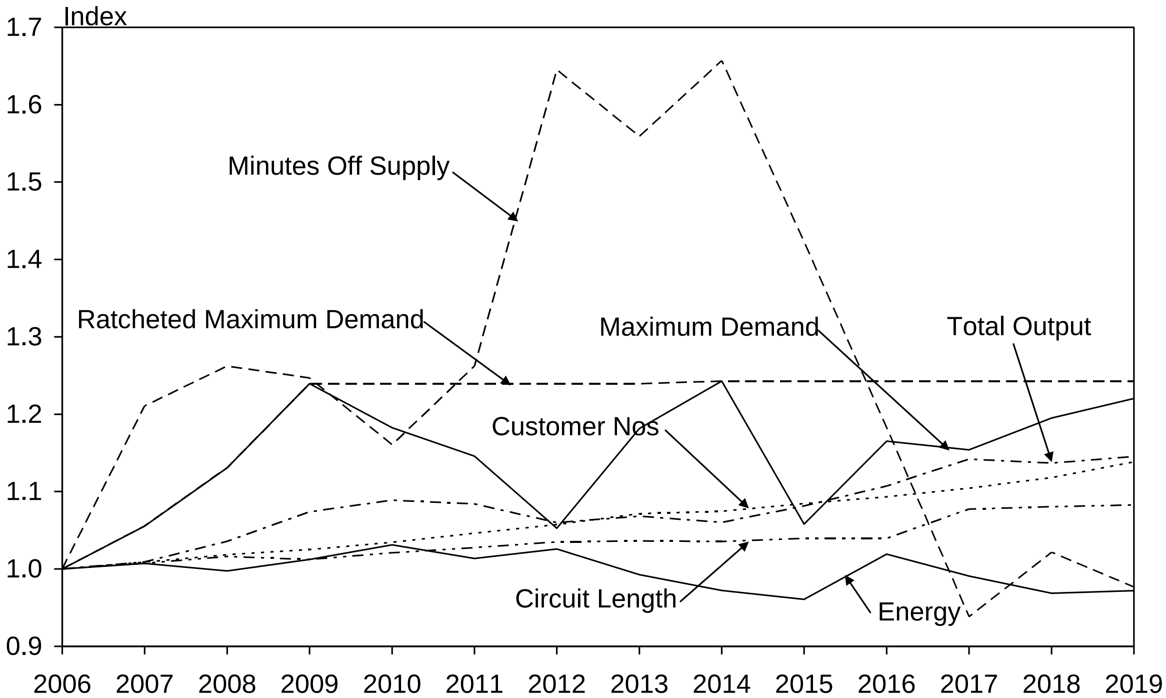
UED's output and input quantity changes

We graph the quantity indexes for UED's five individual outputs in figure 5.38 and for their six individual inputs in figure 5.39.

From figure 5.38 we see that, with the exception of CMOS, UED's output components exhibit a similar pattern of change to the industry as a whole. Customer numbers increased steadily over the period and were 14 per cent higher in 2019 than they were in 2006, a noticeably smaller increase than the industry's increase of 19 per cent. Energy throughput for distribution peaked in 2012 and was 3 per cent lower in 2019 than it was in 2006.

UED's maximum demand reached its highest level in 2014 but has been relatively volatile since a slightly lower peak in 2009. In 2019 it was around 22 per cent above its 2006 level. Ratcheted maximum demand in 2019 was 24 per cent above its 2006 level – a larger increase than the industry's 17 per cent.

Figure 5.38 **UED's output quantity indexes, 2006–2019**



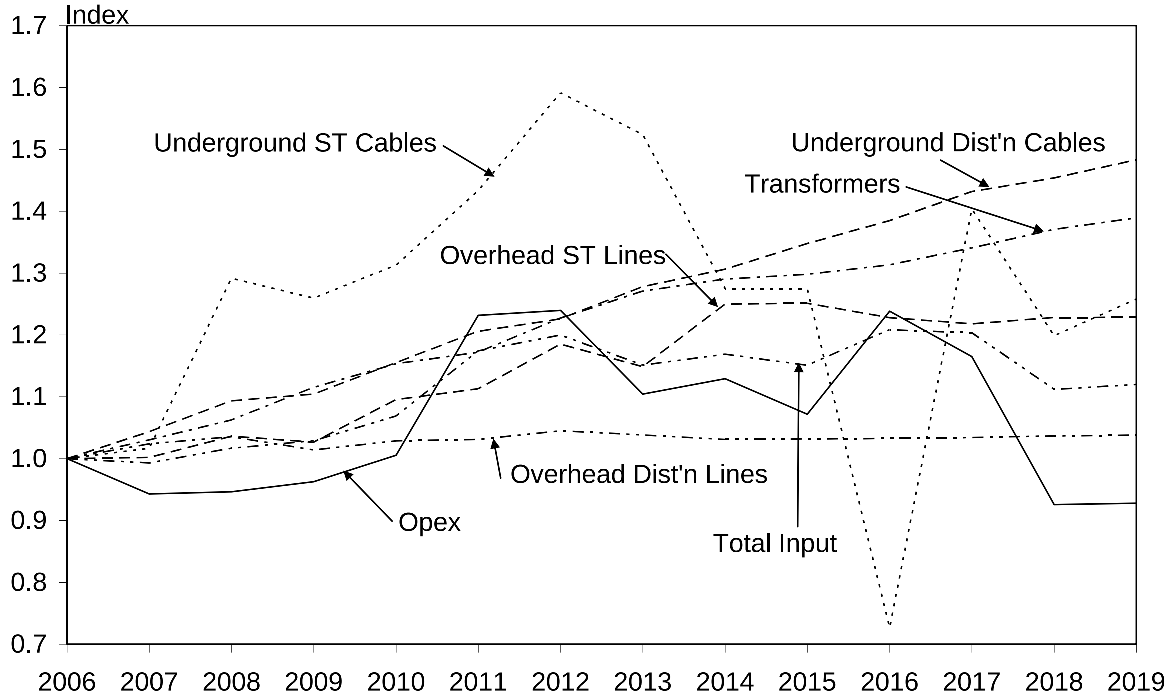
UED's circuit length output grew more over the 14 years than occurred for the industry overall and by 2019 was 8 per cent above the level it was in 2006 compared to an increase of 5 per cent for the industry.

The last output shown in figure 5.38 is total CMOS. UED's CMOS has been considerably more volatile than for the industry but has had a flat trend over the period as a whole. It trended upwards strongly from 2006 to 2014 but declined substantially through to 2017 before again increasing somewhat. In 2019 UED's CMOS was 2 per cent lower than it was in 2006 but it had been 66 per cent above its 2006 level in 2014. CMOS receives an average weight of –9 per cent of total revenue for UED.

Since the circuit length and ratcheted maximum demand outputs receive a weight of around 79 per cent of total revenue in forming the total output index for UED, in figure 5.38 we see that the total output index lies between these two output indexes. The customer numbers index also lies close to the total output index, the energy output index lies at a lower level and the CMOS index would generally lie well below the other output indexes when it enters the formation of total output as a negative output (ie the increase in CMOS over the period makes a negative contribution to total output for most years other than the most recent three years). The CMOS decrease in 2019 combined with growth in customer numbers to supplement weak growth in the other outputs to produce total output growth of 0.8 per cent in the latest year.

Turning to the input side, we see from UED's six input components and total input in figure 5.39 that the quantity of UED's opex was relatively flat through to 2010 but then increased sharply in 2011. For UED, opex increased by 24 per cent up to 2012 – considerably less than the corresponding increase for the industry of 36 per cent. Since then UED's opex initially decreased but then returned to its 2012 level in 2016 and then decreased again in 2017 and 2018 before remaining flat in 2019. This took UED's opex change between 2006 and 2019 to be considerably better than for the industry, with UED's 2019 opex being 7 per cent below its 2006 level compared to 14 per cent higher for the industry. Opex has the largest average share in UED's total costs at 38 per cent and so is an important driver of its total input quantity index.

Figure 5.39 **UED's input quantity indexes, 2006–2019**



UED's underground distribution cables and transformers inputs increased more steadily over the period but at somewhat lower and similar rates, respectively, than for the industry as a whole. Its overhead distribution lines input increased over the period with an increase of 4 per cent by 2019 relative to 2006, substantially less than the increase for the industry of 12 per cent.

From figure 5.39 we see that the total input quantity index lies close to the quantity indexes for opex and transformers (which have a total share of 60 per cent of total costs). Total input quantity increased by 0.7 per cent in 2019 with relatively small increases in all inputs.

UED's output and input contributions to TFP change

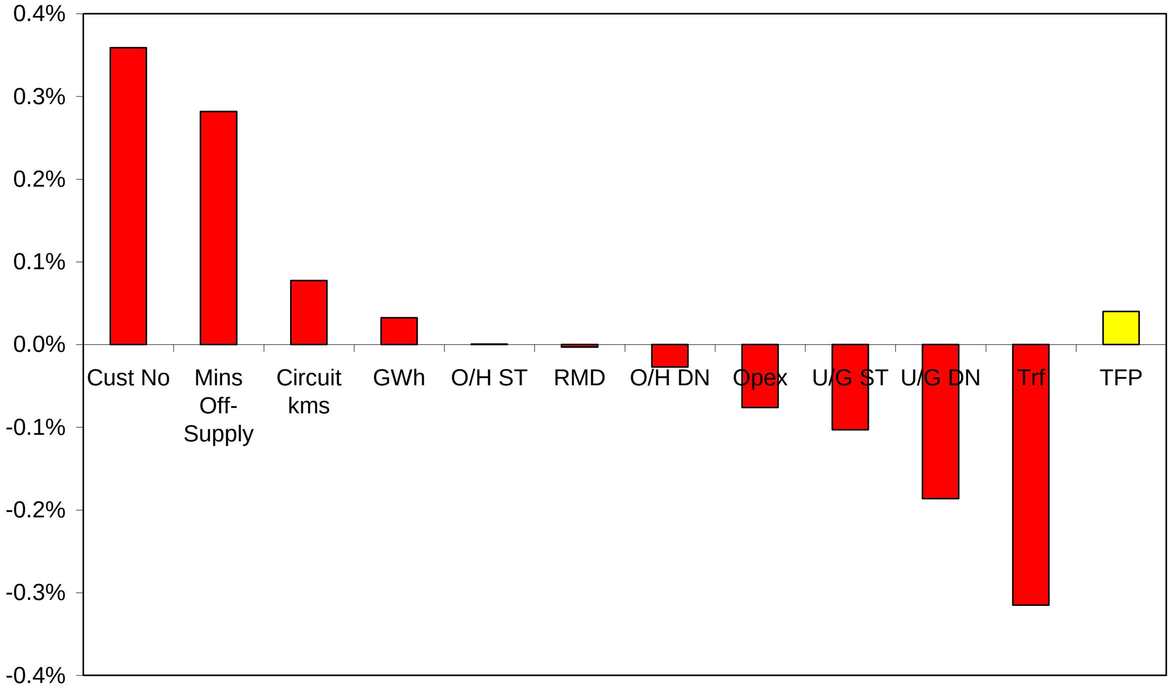
In table 5.20 we decompose UED's TFP change into its constituent output and input parts for the whole 14–year period and for the periods up to and after 2012. UED's drivers of TFP change for the whole 14–year period are broadly similar to the industry as a whole except that opex makes a positive contribution over the period for UED at 0.2 percentage points compared to –0.4 for the industry. Transformer inputs make a less negative contribution to UED's TFP at –0.6 percentage points compared to the industry's –0.7.

The UED situation is again a tale of two distinct periods. The contribution of the energy throughput and RMD outputs to TFP falls after 2012 compared to the period before 2012. And the contribution of all inputs becomes either positive or less negative. Opex change went from a negative percentage point contribution to TFP of –1.5 percentage points to a positive contribution of 1.6 percentage points, a turnaround of 3.1 percentage points.

Table 5.20 **UED's output and input percentage point contributions to average annual TFP change: 2006–2018, 2006–2012, 2012–2019 and 2019**

Year	*2006 to 2019*	*2006 to 2012*	*2012 to 2019*	*2019*
Energy (GWh)	–0.02%	0.04%	–0.07%	0.03%
Ratcheted Max Demand	0.61%	1.31%	0.01%	0.00%
Customer Numbers	0.20%	0.19%	0.21%	0.36%
Circuit Length	0.26%	0.24%	0.27%	0.08%
CMOS	0.00%	–0.81%	0.69%	0.28%
Opex	0.20%	–1.45%	1.61%	–0.08%
O/H Subtransmission Lines	–0.11%	–0.18%	–0.04%	0.00%
O/H Distribution Lines	–0.06%	–0.15%	0.02%	–0.03%
U/G Subtransmission Cables	–0.03%	–0.14%	0.07%	–0.10%
U/G Distribution Cables	–0.28%	–0.30%	–0.27%	–0.19%
Transformers	–0.59%	–0.82%	–0.40%	–0.32%
TFP Change	0.17%	–2.06%	2.09%	0.04%

Figure 5.40 **UED's output and input percentage point contributions to annual TFP change, 2019**



In figure 5.40 we see that customer numbers and CMOS outputs made the main positive contribution to TFP change in 2019, at 0.4 and 0.3 percentage points, respectively. The main negative contributions came from growth in transformers and underground distribution inputs at –0.3 and –0.2 percentage points, respectively. UED's TFP change in the 2019 year was marginally positive compared to industry TFP growth of –1.0 per cent that year.

APPENDIX A METHODOLOGY

A1 Time–series TFP

Productivity is a measure of the quantity of output produced from the use of a given quantity of inputs. Productivity is measured by constructing a ratio of output produced to inputs used. Productivity index number methods provide a ready way of aggregating output quantities into a measure of total output quantity and aggregating input quantities into a measure of total input quantity. For time–series analysis, the TFP index is the change in the ratio of total output quantity to total input quantity over time. The PFP index is the change in the ratio of total output quantity to the quantity of the relevant input over time.

To form the total output and total input measures we need a price and quantity for each output and each input, respectively. The quantities enter the calculation directly as it is changes in output and input quantities that we are aggregating. The relevant output and input prices are used to weight together changes in output quantities and input quantities into measures of total output quantity and total input quantity. Or, to put this another way, the TFP index is the ratio of the change in a weighted average of output quantities to the change in a weighted average of input quantities.

Different index number methods perform the aggregation and weighting in different ways. In previous DNSP benchmarking reports we have used the Fisher and Törnqvist indexes for time–series TFP analysis. These indexes are members of a family of index number methods that have desirable properties such as providing second–order approximations to underlying technologies (see Economic Insights 2014). However, while these indexes satisfy a number of desirable properties for index numbers to be used in time–series analyses, they do not satisfy the property of transitivity – the property that the results of comparison of two observations should be the same regardless of whether the comparison is done directly or indirectly through other observations, as discussed further below. This is not normally an issue in time–series analysis where output and input quantities change in a non–erratic manner over time. However, in our accompanying economic benchmarking report on transmission (Economic Insights 2020), the TNSP energy not supplied (ENS) output has continued to exhibit very large annual percentage changes as first seen in 2009 and 2010 for Victoria with its large one–off outage, but now also includes some TNSPs achieving close to or actually achieving perfect reliability in some years. The standard time–series indexes are less able to accurately capture the impact of these large percentage changes because they do not satisfy the transitivity property.

To provide improved accuracy in the face of these large ENS percentage changes (albeit generally from small bases) we are changing to using the multilateral Törnqvist index method used in our panel data comparisons for our TNSP productivity growth and contributions to growth analyses at both the industry and individual TNSP levels as well. This index does satisfy the transitivity property and is not subject to drifting following reliability variable spikes. For consistency, and in anticipation of possible future changes to the treatment of the CMOS reliability output for DNSPs, we make the same change for DNSP analysis in this report.

Changes to the treatment of the DNSP reliability may be necessary because it currently receives a weight of up to 45 per cent of total revenue for some rural DNSPs in some years. Such high VCR–based output weights allocated to reliability have the potential to distort TFP results both for individual DNSPs over time and for levels comparisons across DNSPs. This has likely been exacerbated by the AER (2019b) VCRs being up to 9 per cent higher on average for some rural DNSPs compared to the AEMO (2014) VCRs.

This index number change means we now use the one index method throughout the distribution and transmission reports. For the productivity growth and contributions analyses the multilateral Törnqvist index is applied to the 14 annual time–series observations sample for the relevant DNSP or the industry as a whole whereas for the panel data comparisons the index is applied across the full sample of 182 observations.

A2 Multilateral TFP comparisons

Traditional measures of TFP, such as the Fisher ideal index and the Törnqvist index, have enabled comparisons to be made of *rates of change* of productivity between firms but have not enabled comparisons to be made of differences in the *absolute levels* of productivity in combined time series, cross section firm data. This is due to the failure of conventional TFP measures to satisfy the important technical property of transitivity. This property states that direct comparisons between observations *m* and *n* should be the same as indirect comparisons of *m* and *n* via any intermediate observation *k*.

Caves, Christensen and Diewert (1982) developed the multilateral Törnqvist TFP (MTFP) index measure to allow comparisons of the absolute levels as well as growth rates of productivity. It satisfies the technical properties of transitivity and characteristicity which are required to accurately compare TFP levels within panel data. 'Characteristicity' says that when comparing two observations, the index should use sufficient information relating to those two observations. The multilateral Törnqvist index satisfies these properties for the whole sample by making comparisons through the sample mean (rather than directly between pairs of observations as done by traditional time–series index number methods).

The Caves, Christensen and Diewert (CCD) multilateral Törnqvist index is given by:

$$
\begin{aligned}
\ln (TFP_m/TFP_n) = \; & \textstyle\sum_i (r_{im}+R_i^*) (\ln y_{im} - \ln Y_i^*)/2 - \\
& \textstyle\sum_i (r_{in}+R_i^*) (\ln y_{in} - \ln Y_i^*)/2 - \\
& \textstyle\sum_j (s_{jm}+S_j^*) (\ln x_{jm} - \ln X_j^*)/2 + \\
& \textstyle\sum_j (s_{jn}+S_j^*) (\ln x_{jn} - \ln X_j^*)/2
\end{aligned} \qquad (1)
$$

where *t* and *t*–1 are adjoining time periods, there are *N* output quantities, y_i, r_i is the revenue weight given to output *i*, there are *M* input quantities, x_j, s_j is the share of input *j* in total cost, R_i^* (S_j^*) is the revenue (cost) share of the *i*–th output (*j*–th input) averaged over all utilities and time periods, ln is the natural logarithm operator and ln Y_i^* (ln X_j^*) is the average of the natural logarithms of output *i* (input *j*). Transitivity is satisfied since comparisons between, say, two NSPs for 2009 will be the same regardless of whether they are compared directly or via, say, one of the NSPs in 2015. An alternative interpretation of this index is that it compares each observation to a hypothetical sample–average NSP with output vector Y_i*, input vector X_j*, revenue shares R_i* and cost shares S_j*.

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

A3 Output and input contributions to TFP change

The next task is to decompose TFP change into its constituent parts. Since TFP change is the change in total output quantity less the change in total input quantity, the contribution of an individual output (input) will depend on the change in the output's (input's) quantity and the weight it receives in forming the total output (total input) quantity index. However, this calculation has to be done in a way that is consistent with the index methodology to provide a decomposition that is consistent and robust. The multilateral Törnqvist index methodology allows us to readily decompose productivity change into the contributions of changes in each output and each input. The percentage point contribution of output i to productivity change between years t and $t–1$ is given by the following equation:

$$(2)\ \textit{Contribution of output } i = (r_{i,t}+R_i^*)\,(\ln y_{i,t} - \ln Y_i^*)/2 - (r_{i,t-1}+R_i^*)\,(\ln y_{i,t-1} - \ln Y_i^*)/2$$

And, the contribution of input j to productivity change between years t and t–1 is given by the following equation:

$$(3)\ \textit{Contribution of input } j = -(s_{j,t}+S_j^*)\,(\ln x_{j,t} - \ln X_j^*)/2 + (s_{j,t-1}+S_j^*)\,(\ln x_{j,t-1} - \ln X_j^*)/2$$

where all variables in equations (2) and (3) have the same definition as those in equation (1).

Using these consistent equations ensures the sum of the percentage point contributions of all outputs and all inputs equals the rate of TFP change obtained in equation (1).

A4 Output weights

This study uses multi–output Leontief cost functions to estimate the output cost shares used in the index number methodology, using a similar procedure to that used in Lawrence (2003). Updated estimates for these output cost shares are provided in appendix B. This functional form essentially assumes that DNSPs use inputs in fixed proportions for each output and is given by:

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

where there are M inputs and N outputs, w_i is an input price, y_j is an output, t is a time trend representing technological change and there are k observations. The input/output coefficients a_{ij} are squared to ensure the non–negativity requirement is satisfied, ie increasing the quantity of any output cannot be achieved by reducing an input quantity. This requires the use of non–linear regression methods. To conserve degrees of freedom a common rate of technological change for each input across the four outputs was imposed but this can be either positive or negative.

The estimating equations were the M input demand equations:

(5) $x_i^k = \sum_{j=1}^{N} (a_{ij})^2 y_j^k (1+b_i t)$

where the i's represent the M inputs, the j's the N outputs and t is a time trend representing the 13 years, 2006 to 2018.

The input demand equations were estimated separately for each of the 13 DNSPs using the non–linear regression facility in Shazam (Northwest Econometrics 2007) and data for the years 2006 to 2018. Given the absence of cross equation restrictions, each input demand equation is estimated separately.

We then derive the estimated output cost shares, s_j^k, for each output j and each observation k from the 5 firm–specific cost functions as follows:

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

where f=1,..,13.

We then form a weighted average of the estimated output cost shares across all observations to form an overall estimated output cost share where the weight in the weighted average, g^k, for each observation, k, is given by that observation's estimated total cost divided by the overall sum of estimated total costs across all observations:

(7) $g^k = C_f(b, y^k, w^k, t) / \sum_k C_f(b, y^k, w^k, t)$.

A5 Opex cost function methodologies

While the opex MPFP analysis presented in the preceding sections has the advantage of producing robust results even with small datasets, it is a deterministic method that does not facilitate the calculation of confidence intervals. We thus also include econometric operating cost functions, which do facilitate this and which potentially allow the direct inclusion of adjustment for a wider range of operating environment factors.

To outline our methods we begin by defining the following notation:

C = nominal opex;

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

$K = (K_1, K_2, ..., K_H)$ = an H×1 vector of capital quantities;

$Z = (Z_1, Z_2, ..., Z_R)$ = an R×1 vector of operating environment factors; and

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

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

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

We use lower case notation to define the natural logarithms of variables. For example, $x_1 = \log(X_1)$.

A5.1 Least squares opex cost function methods

The two most commonly used functional forms in econometric estimation of cost functions are the Cobb–Douglas and translog functional forms. These functions are linear in logs and quadratic in logs, respectively.

The Cobb–Douglas cost function may be written as:

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

while the translog cost frontier may be specified as:

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

where subscripts i and t denote DNSP and year, respectively. Furthermore, the regressor variable 't' is a time trend variable used to capture the effects of year to year technical change (and other factors not modelled that have changed over time such as increasing regulatory obligations), v_{it} is a random disturbance term and the Greek letters denote the unknown parameters that are to be estimated.

One can then include a set of N–1 dummy variables into this model to capture efficiency differences across the N firms in the sample (see Pitt and Lee 1981 and Kumbhakar and Lovell 2000). These dummy variables are defined as:

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

Including these dummy variables into models (8) and (9) we obtain

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

and

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

respectively.

In this study, the models in equations (11) and (12) are estimated using a variant of *ordinary least squares* (OLS) regression, where OLS is applied to data that has been transformed to correct for serial correlation (assuming a common autoregressive parameter across the DNSPs). We have also chosen to report *panel–corrected standard errors*, where the standard errors have been corrected for cross–sectional heteroskedasticity. The estimation methods used follow those described in Beck and Katz (1995) and Greene (2000, Ch15) and have been calculated using the *xtpcse* command in *Stata Release 13* (StataCorp 2013).

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

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

where $\delta_1 = 0$ by definition because it is arbitrarily chosen as the base firm.

These cost efficiency scores vary between zero and one with a value of one indicating full cost efficiency, while a value of 0.8 (for example) would imply that the inefficient firm could reduce its opex by 20 per cent and still produce the same level of output.

A5.2 Stochastic frontier analysis opex cost function methods

The above least squares dummy variables approach to estimating cost functions and predicting firm–level cost efficiencies requires access to panel data and an assumption that cost inefficiencies are invariant over time. An alternative approach (that can also be applied to cross–sectional data) is the stochastic frontier analysis (SFA) method proposed by Aigner, Lovell and Schmidt (1977), which we outline below. Following Pitt and Lee (1981), Battese and Coelli (1988) and Kumbhakar and Lovell (2000), we add a one–sided, time–invariant inefficiency disturbance term to the cost function models in (8) and (9) to obtain a Cobb–Douglas stochastic cost frontier:

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

and a translog stochastic cost frontier:

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

where it is assumed that the random disturbance term v_{it} is normally distributed $N(0, \sigma_v^2)$ and independent of the one–sided inefficiency disturbance term u_i, which is assumed to have a truncated normal distribution $\left| N(\mu, \sigma_u^2) \right|$.

Given these distributional assumptions, the unknown parameters in models (16) and (17) can be estimated using Maximum Likelihood Estimation (MLE) methods. In this study we do this using the *xtfrontier* command in *Stata Release 13*.

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

(16) $CE_n = \exp[u_n]$, (n = 1, 2,...,N).

However, given that u_n is unobservable, *Stata* makes use of the results in Battese and Coelli (1988) to predict the cost efficiency scores using the conditional expectation:

(17) $CE_n = E[\exp(u_n) | (v_n + u_n)]$, ($n$ = 1, 2,...,N),

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

Confidence intervals for these predictions can be obtained using the formula presented in Horrace and Schmidt (1996). We have calculated these using the *frontier_teci* Stata ado code written by Merryman (2010).

APPENDIX B CORRECTED LEONTIEF REGRESSION RESULTS

The input demand equation (equation (5) in appendix A4 above) estimation results are presented in tables B1 to B13 for each of the four inputs for each of the 13 DNSPs.

Table B1: **ACT Leontief cost function regression results**

Variable	*OpEx*		*O/H Lines*		*U/G Cables*		*Transformers*	
	Coef	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*
Energy	0.000	0.000	0.000	0.000	0.000	0.000	0.475	3.039
RMD	2.125	0.052	9.356	12.466	2.226	3.873	0.000	0.000
Customer No	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Circuit Length	2.728	0.640	1.630	2.869	1.078	6.855	0.722	11.470
Time	0.002	0.136	-0.006	-7.409	0.021	10.879	0.007	3.973

Table B2: **AGD Leontief cost function regression results**

Variable	*OpEx*		*O/H Lines*		*U/G Cables*		*Transformers*	
	Coef	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*
Energy	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
RMD	7.928	32.146	0.000	0.000	0.000	0.000	2.028	120.950
Customer No	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Circuit Length	0.000	0.000	–3.036	–214.71	–2.026	–201.78	0.000	0.000
Time	–0.001	–0.175	–0.003	–2.630	0.007	4.754	0.022	8.492

Table B3: **CIT Leontief cost function regression results**

Variable	*OpEx*		*O/H Lines*		*U/G Cables*		*Transformers*	
	Coef	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*
Energy	2.193	31.760	0.000	0.000	–0.438	–1.129	–0.721	–3.024
RMD	0.000	0.000	0.000	0.000	0.000	0.000	0.393	0.326
Customer No	0.000	0.000	0.082	1.528	0.000	0.000	0.000	0.000
Circuit Length	0.000	0.000	1.355	5.628	–1.358	–6.982	–0.810	–4.999
Time	0.038	3.390	–0.010	–12.956	0.020	4.074	0.013	2.346

Table B4: **END Leontief cost function regression results**

Variable	*OpEx*		*O/H Lines*		*U/G Cables*		*Transformers*	
	Coef	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*
Energy	3.013	2.800	0.000	0.000	0.000	0.000	0.000	0.000
RMD	0.000	0.000	5.275	2.922	0.000	0.000	0.606	0.624
Customer No	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Circuit Length	–0.719	–0.291	2.842	7.292	0.945	85.793	0.642	5.971
Time	0.018	1.023	–0.010	–11.282	0.073	15.329	0.019	12.926

Table B5: **ENX Leontief cost function regression results**

Variable	*OpEx*		*O/H Lines*		*U/G Cables*		*Transformers*	
	Coef	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*
Energy	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
RMD	6.921	50.423	1.556	1.299	3.243	157.980	1.283	12.402
Customer No	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Circuit Length	0.000	0.000	2.351	29.857	0.000	0.000	0.520	20.395
Time	0.006	1.063	0.000	–0.035	0.040	18.448	0.018	25.680

Table B6: **ERG Leontief cost function regression results**

Variable	*OpEx*		*O/H Lines*		*U/G Cables*		*Transformers*	
	Coef	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*
Energy	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
RMD	2.786	0.017	6.503	3.435	–1.913	–98.335	0.000	0.000
Customer No	0.000	0.000	0.000	0.000	0.000	0.000	0.130	156.710
Circuit Length	1.225	0.166	1.624	10.818	0.000	0.000	0.000	0.000
Time	0.001	0.008	–0.004	–1.838	0.055	14.440	0.020	10.598

Table B7: **ESS Leontief cost function regression results**

Variable	*OpEx*		*O/H Lines*		*U/G Cables*		*Transformers*	
	Coef	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*
Energy	0.000	0.000	3.171	2.261	0.000	0.000	0.000	0.000
RMD	0.000	0.000	0.000	0.000	1.578	1.833	0.000	0.000
Customer No	0.577	23.090	0.000	0.000	0.000	0.000	0.141	92.992
Circuit Length	0.000	0.000	1.423	7.218	0.150	1.315	0.000	0.000
Time	–0.007	–0.559	0.048	15.524	0.072	3.006	0.010	3.354

Table B8: **JEN Leontief cost function regression results**

Variable	*OpEx*		*O/H Lines*		*U/G Cables*		*Transformers*	
	Coef	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*
Energy	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
RMD	0.000	0.000	–1.212	–0.847	0.000	0.000	–0.844	–3.219
Customer No	0.383	56.578	0.209	0.685	0.000	0.000	0.000	0.000
Circuit Length	0.000	0.000	2.352	1.663	–1.140	–179.26	0.680	12.600
Time	0.017	3.148	–0.005	–4.133	0.041	20.992	0.021	12.992

Table B9: **PCR Leontief cost function regression results**

Variable	*OpEx*		*O/H Lines*		*U/G Cables*		*Transformers*	
	Coef	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*
Energy	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
RMD	2.220	0.213	0.000	0.000	1.841	5.504	–0.518	–3.235
Customer No	0.000	0.000	0.622	6.746	0.040	0.762	0.000	0.000
Circuit Length	–1.153	–1.837	1.561	4.577	0.000	0.000	0.321	39.425
Time	0.015	1.058	–0.011	–5.019	0.050	7.200	0.025	29.647

Table B10: **SAP Leontief cost function regression results**

Variable	*OpEx*		*O/H Lines*		*U/G Cables*		*Transformers*	
	Coef	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*
Energy	0.000	0.000	1.457	3.555	0.000	0.000	–0.535	–2.052
RMD	–6.193	–37.134	0.000	0.000	1.495	7.644	–0.602	–1.109
Customer No	0.000	0.000	0.207	2.526	0.000	0.000	0.000	0.000
Circuit Length	0.000	0.000	1.298	10.892	0.439	19.175	0.281	5.437
Time	0.043	4.519	–0.003	–1.816	0.017	19.169	0.029	4.489

Table B11: **AND Leontief cost function regression results**

Variable	*OpEx*		*O/H Lines*		*U/G Cables*		*Transformers*	
	Coef	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*
Energy	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
RMD	7.378	36.997	1.176	2.577	0.000	0.000	1.526	9.918
Customer No	0.000	0.000	0.000	0.000	0.152	228.370	0.059	1.373
Circuit Length	0.000	0.000	2.151	160.690	0.000	0.000	0.138	0.443
Time	0.035	3.848	–0.001	–1.436	0.044	28.822	0.014	2.489

Table B12: **TND Leontief cost function regression results**

Variable	*OpEx*		*O/H Lines*		*U/G Cables*		*Transformers*	
	Coef	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*
Energy	3.398	30.554	–2.069	–4.809	0.000	0.000	0.000	0.000
RMD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Customer No	0.000	0.000	0.000	0.000	0.109	1.791	0.115	208.880
Circuit Length	0.000	0.000	1.908	19.120	–0.558	–3.892	0.000	0.000
Time	0.022	2.069	0.002	1.737	0.014	7.056	0.016	10.822

Table B13: **UED Leontief cost function regression results**

Variable	*OpEx*		*O/H Lines*		*U/G Cables*		*Transformers*	
	Coef	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*	*Coef*	*t–stat*
Energy	3.080	3.844	0.000	0.000	0.000	0.000	0.000	0.000
RMD	1.564	0.235	2.353	2.266	0.877	5.681	0.965	7.896
Customer No	0.000	0.000	0.355	16.486	0.077	2.445	0.086	19.985
Circuit Length	0.000	0.000	0.000	0.000	–0.581	–2.891	0.000	0.000
Time	0.015	1.194	0.003	2.132	0.025	15.738	0.018	16.541

APPENDIX C REGRESSION–BASED TREND GROWTH RATES

Table C1 **Distribution output, input, total factor productivity and partial productivity index trend annual growth rates, 2006–2019**

DNSP	*Output*	*Input*	*TFP*	*PFP Index*	
Period	*Index*	*Index*	*Index*	*Opex*	*Capital*
Industry					
Growth Rate 2006–19	0.89%	1.80%	–0.91%	–0.23%	–1.30%
Growth Rate 2006–12	1.61%	3.74%	–2.12%	–3.40%	–1.38%
Growth Rate 2012–19	0.49%	0.10%	0.39%	2.75%	–0.97%
ACT					
Growth Rate 2006–19	1.37%	1.43%	–0.07%	0.26%	–0.15%
Growth Rate 2006–12	1.42%	3.78%	–2.36%	–5.31%	–0.39%
Growth Rate 2012–19	0.79%	–1.81%	2.61%	7.08%	–0.34%
AGD					
Growth Rate 2006–19	0.64%	1.06%	–0.42%	0.98%	–1.18%
Growth Rate 2006–12	1.08%	3.58%	–2.50%	–4.23%	–1.53%
Growth Rate 2012–19	0.21%	–1.12%	1.33%	4.86%	–0.54%
AND					
Growth Rate 2006–19	0.97%	2.75%	–1.79%	–3.01%	–0.97%
Growth Rate 2006–12	2.78%	4.29%	–1.51%	–3.91%	0.15%
Growth Rate 2012–19	0.01%	1.24%	–1.23%	–0.86%	–1.48%
CIT					
Growth Rate 2006–19	0.93%	1.96%	–1.03%	–1.67%	–0.82%
Growth Rate 2006–12	1.16%	3.77%	–2.61%	–5.86%	–1.46%
Growth Rate 2012–19	0.97%	–0.07%	1.05%	3.26%	0.20%
END					
Growth Rate 2006–19	1.32%	2.18%	–0.86%	0.67%	–1.84%
Growth Rate 2006–12	1.70%	3.26%	–1.55%	–1.03%	–1.96%
Growth Rate 2012–19	1.67%	1.25%	0.42%	2.41%	–0.83%
ENX					
Growth Rate 2006–19	1.63%	2.21%	–0.58%	0.07%	–0.95%
Growth Rate 2006–12	3.62%	4.62%	–1.00%	–2.20%	–0.37%
Growth Rate 2012–19	0.59%	0.03%	0.56%	3.47%	–1.07%
ERG					
Growth Rate 2006–19	1.16%	1.44%	–0.28%	0.88%	–0.94%
Growth Rate 2006–12	1.75%	2.44%	–0.70%	–0.92%	–0.69%
Growth Rate 2012–19	0.29%	0.98%	–0.68%	0.92%	–1.55%

Table C1 **Distribution output, input, total factor productivity and partial productivity index trend annual growth rates, 2006–2019 (cont'd)**

DNSP	*Output*	*Input*	*TFP*	*PFP Index*	
Period	*Index*	*Index*	*Index*	*Opex*	*Capital*
ESS					
Growth Rate 2006–19	0.98%	1.82%	–0.84%	0.52%	–1.71%
Growth Rate 2006–12	0.79%	5.60%	–4.82%	–6.35%	–3.78%
Growth Rate 2012–19	0.97%	–1.00%	1.98%	5.59%	–0.37%
JEN					
Growth Rate 2006–19	1.28%	1.76%	–0.48%	–1.13%	–0.01%
Growth Rate 2006–12	2.25%	2.14%	0.11%	–0.93%	0.87%
Growth Rate 2012–19	1.02%	1.26%	–0.24%	0.07%	–0.49%
PCR					
Growth Rate 2006–19	0.96%	1.94%	–0.98%	–0.79%	–1.12%
Growth Rate 2006–12	1.59%	2.62%	–1.02%	–1.14%	–0.92%
Growth Rate 2012–19	0.90%	0.64%	0.25%	2.23%	–1.11%
SAP					
Growth Rate 2006–19	0.68%	2.64%	–1.96%	–3.53%	–1.18%
Growth Rate 2006–12	1.74%	4.22%	–2.48%	–5.68%	–0.95%
Growth Rate 2012–19	0.02%	0.96%	–0.93%	–0.57%	–1.13%
TND					
Growth Rate 2006–19	0.57%	1.35%	–0.78%	–0.33%	–1.00%
Growth Rate 2006–12	0.55%	3.77%	–3.22%	–5.85%	–1.76%
Growth Rate 2012–19	0.27%	0.42%	–0.14%	0.96%	–0.74%
UED					
Growth Rate 2006–19	0.90%	1.25%	–0.35%	0.37%	–0.77%
Growth Rate 2006–12	1.31%	3.33%	–2.01%	–3.11%	–1.23%
Growth Rate 2012–19	1.31%	–0.62%	1.93%	4.49%	0.39%

APPENDIX D IMPACT OF METHODOLOGY UPDATES

In this appendix we present information on the impact of the methodology updates contained in this report. Industry level productivity index and panel data multilateral MTFP, opex MPFP and capital MPFP results for 2006 to 2019 are presented for a number of cases:

- tables D1.1 to D1.4 use the methodology in Economic Insights (2019a)
- tables D2.1 to D2.4 use the Economic Insights (2019a) methodology but with the revised output weights included
- tables D3.1 to D3.4 use the Economic Insights (2019a) methodology but with the AER (2019b) VCRs included, and
- table D4 uses the Economic Insights (2019a) methodology but with the revised index number method included.

Each of the methodology updates are added to the methodology used in Economic Insights (2019a) separately, rather than added in sequentially, to maximise clarity and the scope for like–with–like comparisons.

Table D1.1 **Industry–level distribution output, input and total factor productivity and partial productivity indexes, 2006–2019, using the Economic Insights (2019a) methodology**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.038	1.023	1.016	1.042	0.999
2008	1.060	1.097	0.966	0.928	0.992
2009	1.057	1.114	0.949	0.938	0.957
2010	1.088	1.154	0.943	0.925	0.954
2011	1.098	1.197	0.917	0.881	0.940
2012	1.108	1.257	0.882	0.814	0.925
2013	1.108	1.237	0.896	0.884	0.905
2014	1.113	1.261	0.883	0.876	0.889
2015	1.121	1.299	0.863	0.837	0.881
2016	1.126	1.276	0.883	0.908	0.871
2017	1.148	1.269	0.905	0.954	0.880
2018	1.149	1.257	0.914	1.001	0.871
2019	1.146	1.263	0.907	1.002	0.861
Growth Rate 2006–19	1.05%	1.79%	–0.75%	0.01%	–1.15%
Growth Rate 2006–12	1.71%	3.81%	–2.09%	–3.42%	–1.31%
Growth Rate 2012–19	0.47%	0.07%	0.41%	2.96%	–1.02%

Table D1.2 **DNSP multilateral total factor productivity indexes, 2006–2019, using the Economic Insights (2019a) methodology**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
ACT	1.000	0.990	1.001	0.989	0.952	0.875	0.908
AGD	0.958	1.013	0.872	0.883	0.885	0.887	0.843
AND	1.157	1.105	1.150	1.023	1.094	1.065	1.059
CIT	1.639	1.620	1.666	1.555	1.497	1.571	1.432
END	1.272	1.212	1.097	1.144	1.174	1.161	1.106
ENX	1.216	1.232	1.186	1.191	1.195	1.148	1.132
ERG	0.966	1.142	1.075	1.043	1.054	1.011	1.031
ESS	1.128	1.099	1.033	0.993	0.999	0.964	0.855
JEN	1.152	1.157	1.293	1.237	1.192	1.189	1.133
PCR	1.264	1.306	1.318	1.215	1.205	1.259	1.201
SAP	1.586	1.544	1.625	1.579	1.480	1.396	1.417
TND	1.126	1.074	1.064	0.961	0.897	0.978	0.924
UED	1.332	1.345	1.345	1.371	1.346	1.227	1.166

Table D1.2 **DNSP multilateral total factor productivity indexes, 2006–2019, using the Economic Insights (2019a) methodology (continued)**

Year	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
ACT	0.884	0.822	0.852	1.057	1.016	0.986	0.986
AGD	0.907	0.851	0.799	0.828	0.867	0.927	0.932
AND	1.003	0.957	0.940	0.843	0.956	0.928	0.926
CIT	1.442	1.406	1.442	1.439	1.469	1.534	1.501
END	1.109	1.072	1.047	1.025	1.094	1.120	1.131
ENX	1.089	1.113	1.078	1.140	1.156	1.153	1.179
ERG	1.150	1.159	1.050	1.025	1.104	1.069	1.031
ESS	0.880	0.978	0.926	0.980	0.952	0.963	0.900
JEN	1.131	1.131	1.133	1.106	1.104	1.130	1.093
PCR	1.143	1.131	1.154	1.204	1.203	1.160	1.170
SAP	1.359	1.300	1.333	1.391	1.305	1.341	1.301
TND	1.001	0.945	1.045	1.001	0.928	0.917	0.959
UED	1.222	1.192	1.235	1.211	1.256	1.350	1.354

Table D1.3 **DNSP multilateral opex partial factor productivity indexes, 2006–2019, using the Economic Insights (2019a) methodology**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
ACT	1.000	0.995	0.978	0.958	0.866	0.753	0.758
AGD	0.792	0.943	0.659	0.723	0.670	0.701	0.644
AND	1.392	1.187	1.214	1.007	1.129	1.100	1.074
CIT	2.022	1.829	1.987	1.642	1.522	1.700	1.330
END	1.170	1.100	0.904	1.013	1.084	1.053	1.010
ENX	1.187	1.140	1.100	1.110	1.130	1.045	1.001
ERG	0.712	0.923	0.844	0.854	0.894	0.760	0.773
ESS	1.099	1.002	0.854	0.881	0.886	0.874	0.704
JEN	0.970	0.953	1.228	1.132	0.989	1.016	0.908
PCR	1.478	1.681	1.740	1.519	1.642	1.635	1.382
SAP	1.734	1.822	1.786	1.665	1.594	1.312	1.329
TND	1.335	1.288	1.288	1.121	0.958	1.098	0.982
UED	1.167	1.242	1.264	1.285	1.252	1.015	0.983

Table D1.3 **DNSP multilateral opex partial factor productivity indexes, 2006–2019, using the Economic Insights (2019a) methodology (cont'd)**

Year	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
ACT	0.705	0.626	0.674	1.247	1.102	0.969	1.006
AGD	0.818	0.726	0.625	0.698	0.790	0.938	0.995
AND	0.965	0.918	0.899	0.785	0.960	0.989	0.969
CIT	1.389	1.344	1.424	1.434	1.521	1.754	1.580
END	1.116	1.023	0.998	0.947	1.078	1.198	1.269
ENX	0.933	1.015	0.985	1.132	1.154	1.151	1.228
ERG	1.000	1.033	0.871	0.857	1.000	0.958	0.919
ESS	0.789	0.901	0.897	1.127	1.104	1.082	0.939
JEN	0.934	0.951	0.957	0.913	0.886	0.977	0.937
PCR	1.288	1.385	1.359	1.620	1.572	1.483	1.555
SAP	1.240	1.178	1.184	1.389	1.195	1.253	1.203
TND	1.248	1.154	1.446	1.341	1.037	1.115	1.261
UED	1.112	1.078	1.161	1.037	1.138	1.423	1.435

Table D1.4 **DNSP multilateral capital partial factor productivity indexes, 2006–2019, using the Economic Insights (2019a) methodology**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
ACT	1.000	0.981	1.017	1.004	1.009	0.959	1.016
AGD	1.076	1.053	1.043	0.999	1.051	1.025	0.994
AND	1.022	1.033	1.106	1.013	1.074	1.048	1.043
CIT	1.571	1.586	1.631	1.564	1.557	1.584	1.527
END	1.337	1.284	1.239	1.233	1.233	1.232	1.168
ENX	1.236	1.292	1.238	1.247	1.238	1.218	1.220
ERG	1.156	1.290	1.239	1.167	1.157	1.192	1.208
ESS	1.132	1.149	1.152	1.057	1.068	1.017	0.958
JEN	1.296	1.332	1.335	1.312	1.342	1.319	1.323
PCR	1.103	1.078	1.113	1.017	1.013	1.066	1.071
SAP	1.524	1.438	1.549	1.549	1.433	1.449	1.473
TND	1.024	0.981	0.961	0.874	0.863	0.924	0.891
UED	1.441	1.407	1.394	1.421	1.404	1.384	1.299

Table D1.4 **DNSP multilateral capital partial factor productivity indexes, 2006–2019, using the Economic Insights (2019a) methodology (cont'd)**

Year	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
ACT	1.019	0.992	0.993	0.989	0.986	1.000	0.980
AGD	0.980	0.942	0.929	0.923	0.930	0.940	0.923
AND	1.021	0.976	0.957	0.874	0.954	0.893	0.900
CIT	1.517	1.483	1.498	1.496	1.516	1.515	1.526
END	1.112	1.103	1.077	1.075	1.105	1.074	1.059
ENX	1.196	1.175	1.141	1.149	1.163	1.156	1.158
ERG	1.245	1.237	1.168	1.136	1.169	1.138	1.100
ESS	0.933	1.023	0.934	0.908	0.882	0.895	0.867
JEN	1.282	1.263	1.264	1.248	1.274	1.242	1.210
PCR	1.034	0.978	1.017	1.004	1.025	0.987	0.983
SAP	1.436	1.381	1.430	1.393	1.375	1.396	1.363
TND	0.907	0.846	0.892	0.872	0.865	0.804	0.833
UED	1.292	1.265	1.280	1.327	1.331	1.315	1.315

Table D2.1 **Industry–level distribution output, input and total factor productivity and partial productivity indexes, 2006–2019, using the Economic Insights (2019a) methodology with revised output weights included**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.037	1.023	1.014	1.041	0.997
2008	1.058	1.097	0.965	0.927	0.991
2009	1.057	1.114	0.949	0.938	0.957
2010	1.088	1.154	0.942	0.925	0.954
2011	1.099	1.197	0.918	0.881	0.940
2012	1.108	1.257	0.882	0.814	0.925
2013	1.108	1.237	0.895	0.884	0.904
2014	1.114	1.261	0.883	0.876	0.889
2015	1.120	1.299	0.862	0.836	0.880
2016	1.123	1.276	0.880	0.905	0.869
2017	1.143	1.269	0.901	0.950	0.876
2018	1.142	1.257	0.909	0.995	0.866
2019	1.137	1.263	0.901	0.995	0.855
Growth Rate 2006–19	0.99%	1.79%	–0.80%	–0.04%	–1.21%
Growth Rate 2006–12	1.72%	3.81%	–2.09%	–3.42%	–1.30%
Growth Rate 2012–19	0.37%	0.07%	0.30%	2.85%	–1.13%

Table D2.2 **DNSP multilateral total factor productivity indexes, 2006–2019, using the Economic Insights (2019a) methodology with revised output weights included**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
ACT	1.000	0.988	0.999	0.986	0.948	0.870	0.909
AGD	0.929	0.982	0.846	0.857	0.861	0.865	0.824
AND	1.258	1.203	1.250	1.118	1.194	1.162	1.154
CIT	1.499	1.484	1.528	1.426	1.370	1.444	1.314
END	1.303	1.240	1.121	1.175	1.207	1.196	1.142
ENX	1.236	1.261	1.214	1.221	1.228	1.182	1.165
ERG	1.246	1.459	1.380	1.337	1.352	1.289	1.308
ESS	1.445	1.391	1.301	1.253	1.253	1.210	1.070
JEN	1.080	1.087	1.219	1.171	1.127	1.128	1.075
PCR	1.449	1.500	1.513	1.404	1.389	1.444	1.375
SAP	1.844	1.797	1.895	1.842	1.726	1.625	1.645
TND	1.274	1.220	1.204	1.085	1.011	1.100	1.041
UED	1.262	1.276	1.281	1.311	1.286	1.172	1.111

Table D2.2 **DNSP multilateral total factor productivity indexes, 2006–2019, using the Economic Insights (2019a) methodology with revised output weights included (continued)**

Year	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
ACT	0.883	0.822	0.852	1.055	1.010	0.979	0.978
AGD	0.892	0.837	0.785	0.812	0.849	0.907	0.911
AND	1.090	1.042	1.018	0.914	1.032	1.002	0.999
CIT	1.324	1.294	1.328	1.323	1.351	1.411	1.381
END	1.146	1.108	1.080	1.055	1.128	1.154	1.164
ENX	1.121	1.145	1.107	1.170	1.184	1.180	1.206
ERG	1.447	1.451	1.316	1.286	1.380	1.336	1.290
ESS	1.098	1.228	1.163	1.235	1.198	1.207	1.129
JEN	1.072	1.071	1.072	1.045	1.040	1.067	1.030
PCR	1.307	1.295	1.315	1.367	1.361	1.312	1.320
SAP	1.578	1.513	1.549	1.620	1.516	1.553	1.506
TND	1.127	1.068	1.177	1.127	1.043	1.032	1.078
UED	1.165	1.137	1.179	1.152	1.201	1.291	1.292

Table D2.3 **DNSP multilateral opex partial productivity indexes, 2006–2019, using the Economic Insights (2019a) methodology with revised output weights included**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
ACT	1.000	0.993	0.976	0.955	0.863	0.749	0.759
AGD	0.768	0.913	0.639	0.701	0.652	0.684	0.629
AND	1.514	1.292	1.320	1.101	1.231	1.200	1.170
CIT	1.849	1.677	1.822	1.506	1.393	1.563	1.220
END	1.198	1.126	0.924	1.041	1.115	1.084	1.043
ENX	1.207	1.166	1.126	1.138	1.162	1.075	1.030
ERG	0.919	1.179	1.084	1.095	1.147	0.969	0.981
ESS	1.409	1.269	1.076	1.112	1.111	1.096	0.881
JEN	0.909	0.895	1.158	1.072	0.935	0.964	0.861
PCR	1.694	1.930	1.998	1.756	1.892	1.876	1.582
SAP	2.016	2.120	2.082	1.942	1.859	1.527	1.543
TND	1.510	1.463	1.457	1.264	1.080	1.235	1.106
UED	1.105	1.178	1.205	1.229	1.196	0.970	0.937

Table D2.3 **DNSP multilateral opex partial productivity indexes, 2006–2019, using the Economic Insights (2019a) methodology with revised output weights included (cont'd)**

Year	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
ACT	0.704	0.626	0.674	1.246	1.096	0.962	0.998
AGD	0.804	0.714	0.614	0.684	0.773	0.919	0.973
AND	1.049	1.000	0.973	0.851	1.036	1.068	1.045
CIT	1.275	1.237	1.312	1.318	1.399	1.614	1.454
END	1.153	1.056	1.029	0.975	1.111	1.235	1.306
ENX	0.961	1.045	1.012	1.162	1.183	1.178	1.255
ERG	1.259	1.293	1.091	1.075	1.250	1.197	1.150
ESS	0.984	1.131	1.125	1.421	1.388	1.355	1.178
JEN	0.885	0.901	0.905	0.863	0.835	0.922	0.883
PCR	1.473	1.585	1.548	1.840	1.779	1.677	1.754
SAP	1.439	1.370	1.375	1.618	1.389	1.452	1.393
TND	1.405	1.304	1.629	1.508	1.166	1.255	1.418
UED	1.061	1.028	1.109	0.987	1.088	1.361	1.369

Table D2.4 **DNSP multilateral capital partial productivity indexes, 2006–2019, using the Economic Insights (2019a) methodology with revised output weights included**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
ACT	1.000	0.979	1.014	1.001	1.004	0.953	1.017
AGD	1.043	1.020	1.012	0.969	1.022	0.999	0.972
AND	1.111	1.124	1.203	1.108	1.171	1.144	1.136
CIT	1.437	1.454	1.496	1.434	1.425	1.456	1.401
END	1.370	1.314	1.266	1.267	1.267	1.269	1.206
ENX	1.256	1.322	1.268	1.278	1.273	1.253	1.256
ERG	1.492	1.648	1.592	1.496	1.484	1.520	1.532
ESS	1.451	1.454	1.451	1.334	1.339	1.276	1.199
JEN	1.215	1.251	1.259	1.242	1.269	1.252	1.255
PCR	1.265	1.238	1.278	1.176	1.167	1.223	1.225
SAP	1.772	1.674	1.806	1.807	1.672	1.687	1.710
TND	1.157	1.114	1.088	0.986	0.972	1.040	1.004
UED	1.365	1.335	1.329	1.359	1.341	1.322	1.238

Table D2.4 **DNSP multilateral capital partial productivity indexes, 2006–2019, using the Economic Insights (2019a) methodology with revised output weights included (cont'd)**

Year	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
ACT	1.018	0.993	0.994	0.988	0.980	0.993	0.972
AGD	0.963	0.926	0.913	0.904	0.910	0.920	0.902
AND	1.110	1.062	1.036	0.948	1.029	0.964	0.970
CIT	1.393	1.364	1.380	1.375	1.394	1.394	1.404
END	1.149	1.140	1.110	1.106	1.140	1.107	1.090
ENX	1.231	1.209	1.172	1.179	1.192	1.183	1.184
ERG	1.567	1.549	1.464	1.425	1.461	1.422	1.377
ESS	1.165	1.285	1.172	1.144	1.110	1.121	1.087
JEN	1.215	1.196	1.196	1.179	1.200	1.172	1.141
PCR	1.182	1.120	1.158	1.141	1.160	1.116	1.108
SAP	1.667	1.606	1.661	1.622	1.597	1.618	1.578
TND	1.022	0.956	1.004	0.981	0.972	0.905	0.936
UED	1.231	1.207	1.222	1.263	1.273	1.258	1.254

Table D3.1 **Industry–level distribution output, input and total factor productivity and partial productivity indexes, 2006–2019, using the Economic Insights (2019a) methodology with AER VCRs included**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index Opex*	*PFP Index Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.039	1.023	1.016	1.043	0.999
2008	1.060	1.097	0.967	0.929	0.993
2009	1.057	1.114	0.949	0.938	0.957
2010	1.089	1.154	0.943	0.926	0.955
2011	1.099	1.197	0.918	0.881	0.941
2012	1.109	1.257	0.883	0.815	0.925
2013	1.109	1.237	0.896	0.884	0.905
2014	1.114	1.261	0.883	0.877	0.889
2015	1.122	1.299	0.864	0.838	0.881
2016	1.127	1.276	0.884	0.908	0.872
2017	1.149	1.269	0.905	0.955	0.881
2018	1.150	1.257	0.915	1.002	0.872
2019	1.146	1.263	0.908	1.002	0.861
Growth Rate 2006–19	1.05%	1.79%	–0.74%	0.02%	–1.15%
Growth Rate 2006–12	1.72%	3.81%	–2.08%	–3.41%	–1.30%
Growth Rate 2012–19	0.47%	0.07%	0.40%	2.96%	–1.02%

Table D3.2 **DNSP multilateral total factor productivity indexes, 2006–2019, using the Economic Insights (2019a) methodology with AER VCRs included**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
ACT	1.000	0.990	1.001	0.989	0.952	0.875	0.909
AGD	0.959	1.014	0.874	0.885	0.886	0.889	0.844
AND	1.161	1.109	1.152	1.027	1.097	1.067	1.061
CIT	1.641	1.621	1.668	1.556	1.498	1.572	1.432
END	1.273	1.213	1.097	1.145	1.176	1.163	1.107
ENX	1.216	1.234	1.187	1.193	1.196	1.150	1.134
ERG	0.950	1.135	1.065	1.029	1.042	1.004	1.025
ESS	1.128	1.099	1.033	0.991	1.000	0.964	0.854
JEN	1.153	1.159	1.295	1.238	1.194	1.191	1.135
PCR	1.265	1.306	1.320	1.215	1.205	1.260	1.202
SAP	1.585	1.541	1.627	1.580	1.479	1.397	1.418
TND	1.131	1.088	1.082	0.977	0.912	0.983	0.931
UED	1.333	1.346	1.346	1.372	1.347	1.228	1.168

Table D3.2 **DNSP multilateral total factor productivity indexes, 2006–2019, using the Economic Insights (2019a) methodology with AER VCRs included (continued)**

Year	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
ACT	0.884	0.822	0.853	1.058	1.017	0.987	0.987
AGD	0.908	0.852	0.800	0.829	0.868	0.928	0.933
AND	1.005	0.960	0.942	0.845	0.958	0.931	0.929
CIT	1.443	1.407	1.443	1.440	1.470	1.535	1.503
END	1.110	1.074	1.048	1.027	1.096	1.122	1.133
ENX	1.091	1.114	1.079	1.142	1.158	1.155	1.181
ERG	1.146	1.157	1.046	1.020	1.103	1.067	1.025
ESS	0.879	0.979	0.925	0.978	0.950	0.962	0.897
JEN	1.133	1.132	1.134	1.108	1.105	1.132	1.095
PCR	1.144	1.131	1.155	1.205	1.205	1.160	1.171
SAP	1.360	1.300	1.334	1.392	1.305	1.341	1.301
TND	1.005	0.956	1.050	1.006	0.932	0.924	0.966
UED	1.224	1.194	1.236	1.212	1.257	1.352	1.355

Table D3.3 **DNSP multilateral opex partial productivity indexes, 2006–2019, using the Economic Insights (2019a) methodology with AER VCRs included**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
ACT	1.000	0.995	0.978	0.958	0.867	0.753	0.758
AGD	0.793	0.944	0.660	0.724	0.671	0.702	0.644
AND	1.396	1.191	1.216	1.011	1.131	1.102	1.076
CIT	2.024	1.831	1.989	1.643	1.523	1.701	1.331
END	1.171	1.101	0.904	1.014	1.086	1.055	1.011
ENX	1.187	1.141	1.101	1.111	1.132	1.046	1.003
ERG	0.701	0.917	0.837	0.843	0.884	0.755	0.769
ESS	1.099	1.002	0.854	0.880	0.886	0.874	0.703
JEN	0.971	0.954	1.230	1.133	0.990	1.018	0.909
PCR	1.479	1.681	1.742	1.519	1.642	1.636	1.383
SAP	1.733	1.819	1.788	1.666	1.593	1.312	1.330
TND	1.341	1.305	1.309	1.140	0.974	1.103	0.989
UED	1.168	1.243	1.266	1.287	1.253	1.016	0.984

Table D3.3 **DNSP multilateral opex partial productivity indexes, 2006–2019, using the Economic Insights (2019a) methodology with AER VCRs included (cont'd)**

Year	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
ACT	0.705	0.627	0.674	1.248	1.103	0.970	1.007
AGD	0.819	0.727	0.626	0.699	0.791	0.940	0.996
AND	0.967	0.921	0.901	0.787	0.962	0.992	0.972
CIT	1.389	1.345	1.426	1.435	1.523	1.756	1.582
END	1.117	1.024	0.999	0.949	1.080	1.201	1.272
ENX	0.935	1.017	0.986	1.133	1.156	1.153	1.229
ERG	0.997	1.031	0.868	0.853	0.999	0.956	0.914
ESS	0.789	0.901	0.896	1.125	1.101	1.080	0.936
JEN	0.936	0.953	0.958	0.915	0.887	0.979	0.938
PCR	1.289	1.384	1.360	1.621	1.574	1.483	1.555
SAP	1.240	1.177	1.185	1.390	1.196	1.254	1.203
TND	1.253	1.167	1.452	1.348	1.041	1.124	1.271
UED	1.114	1.079	1.162	1.038	1.139	1.424	1.436

Table D3.4 **DNSP multilateral capital partial productivity indexes, 2006–2019, using the Economic Insights (2019a) methodology with AER VCRs included**

Year	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
ACT	1.000	0.981	1.017	1.004	1.009	0.959	1.017
AGD	1.077	1.054	1.045	1.000	1.052	1.026	0.995
AND	1.025	1.037	1.108	1.018	1.076	1.051	1.045
CIT	1.573	1.588	1.632	1.565	1.558	1.585	1.528
END	1.338	1.285	1.240	1.234	1.235	1.235	1.170
ENX	1.236	1.293	1.239	1.248	1.240	1.219	1.222
ERG	1.138	1.281	1.228	1.152	1.144	1.184	1.201
ESS	1.133	1.149	1.152	1.055	1.068	1.017	0.957
JEN	1.298	1.333	1.337	1.313	1.344	1.321	1.325
PCR	1.104	1.078	1.114	1.017	1.013	1.067	1.071
SAP	1.523	1.436	1.551	1.550	1.433	1.450	1.474
TND	1.028	0.993	0.977	0.889	0.877	0.929	0.898
UED	1.443	1.409	1.396	1.422	1.405	1.386	1.301

Table D3.4 **DNSP multilateral capital partial productivity indexes, 2006–2019, using the Economic Insights (2019a) methodology with AER VCRs included (cont'd)**

Year	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
ACT	1.020	0.993	0.994	0.990	0.987	1.001	0.981
AGD	0.981	0.943	0.930	0.924	0.931	0.941	0.924
AND	1.023	0.978	0.958	0.877	0.955	0.896	0.902
CIT	1.518	1.483	1.499	1.497	1.518	1.517	1.527
END	1.113	1.105	1.078	1.077	1.108	1.076	1.061
ENX	1.198	1.176	1.142	1.150	1.165	1.158	1.160
ERG	1.241	1.235	1.164	1.131	1.168	1.135	1.094
ESS	0.933	1.023	0.933	0.906	0.880	0.893	0.864
JEN	1.284	1.264	1.265	1.250	1.276	1.244	1.212
PCR	1.034	0.978	1.017	1.005	1.026	0.987	0.983
SAP	1.436	1.380	1.431	1.393	1.375	1.397	1.363
TND	0.911	0.855	0.896	0.876	0.868	0.811	0.840
UED	1.293	1.267	1.282	1.328	1.333	1.317	1.316

Table D4 **Industry–level transmission output, input and total factor productivity and partial productivity indexes, 2006–2019, using the Economic Insights (2019a) methodology with revised index number method included**

Year	*Output Index*	*Input Index*	*TFP Index*	*PFP Index*	
				Opex	*Capital*
2006	1.000	1.000	1.000	1.000	1.000
2007	1.036	1.023	1.012	1.039	0.996
2008	1.056	1.096	0.964	0.925	0.990
2009	1.056	1.113	0.949	0.938	0.956
2010	1.087	1.153	0.943	0.924	0.953
2011	1.097	1.196	0.917	0.880	0.939
2012	1.107	1.256	0.881	0.813	0.924
2013	1.106	1.235	0.896	0.882	0.903
2014	1.111	1.259	0.882	0.874	0.887
2015	1.119	1.297	0.863	0.836	0.880
2016	1.124	1.272	0.883	0.906	0.871
2017	1.146	1.266	0.905	0.953	0.880
2018	1.147	1.252	0.916	0.999	0.871
2019	1.143	1.258	0.909	1.000	0.860
Growth Rate 2006–19	1.03%	1.77%	–0.74%	0.00%	–1.16%
Growth Rate 2006–12	1.69%	3.79%	–2.11%	–3.45%	–1.32%
Growth Rate 2012–19	0.47%	0.03%	0.44%	2.95%	–1.02%

APPENDIX E OPEX COST FUNCTION REGRESSION RESULTS

E1 Three–output model estimation results

Table E1 **SFA Cobb–Douglas cost frontier estimates using 2006–2019 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.497	0.080	6.190
ln(CircLen)	0.146	0.047	3.090
ln(RMDemand)	0.334	0.071	4.680
ln(ShareUGC)	–0.150	0.033	–4.580
Year	0.016	0.001	14.920
Country dummy variables:			
New Zealand	0.147	0.102	1.450
Ontario	0.247	0.090	2.750
Constant	–22.130	2.126	–10.410
Variance parameters:			
Mu	0.349	0.084	4.170
SigmaU squared	0.039	0.011	3.431
SigmaV squared	0.012	0.001	20.943
LLF			635.298

Table E2 **SFA translog cost function estimates using 2006–2019 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.581	0.084	6.900
ln(CircLen)=x2	0.139	0.048	2.870
ln(RMDemand)=x3	0.260	0.075	3.470
x1*x1/2	0.894	0.471	1.900
x1*x2	–0.313	0.118	–2.640
x1*x3	–0.524	0.383	–1.370
x2*x2/2	0.120	0.061	1.960
x2*x3	0.193	0.099	1.950
x3*x3/2	0.284	0.319	0.890
ln(ShareUGC)	–0.118	0.036	–3.240
Year	0.015	0.001	12.510
Country dummy variables:			
New Zealand	0.149	0.116	1.290
Ontario	0.284	0.087	3.280
Constant	–19.899	2.357	–8.440
Variance parameters:			
Mu	0.350	0.071	4.910
SigmaU squared	0.043	0.012	3.441
SigmaV squared	0.012	0.001	20.688
LLF			639.600

Table E3 **LSE Cobb–Douglas cost function estimates using 2006–2019 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.623	0.064	9.680
ln(CircLen)	0.161	0.028	5.690
ln(RMDemand)	0.200	0.060	3.310
ln(ShareUGC)	–0.155	0.021	–7.220
Year	0.015	0.002	8.550
Country dummy variables:			
New Zealand	–0.283	0.130	–2.170
Ontario	–0.084	0.130	–0.640
DNSP dummy variables:			
AGD	0.029	0.171	0.170
CIT	–0.650	0.147	–4.430
END	–0.241	0.145	–1.670
ENX	–0.300	0.138	–2.170
ERG	–0.215	0.153	–1.400
ESS	–0.365	0.162	–2.260
JEN	–0.323	0.142	–2.270
PCR	–0.794	0.146	–5.430
SAP	–0.561	0.145	–3.860
AND	–0.500	0.146	–3.430
TND	–0.530	0.155	–3.410
UED	–0.568	0.151	–3.760
Constant	–20.786	3.622	–5.740
R–Square			0.992

Table E4 **LSE translog cost function estimates using 2006–2019 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.477	0.068	7.040
ln(CircLen)=x2	0.160	0.028	5.620
ln(RMDemand)=x3	0.327	0.057	5.760
x1*x1/2	–0.534	0.472	–1.130
x1*x2	0.259	0.114	2.280
x1*x3	0.203	0.362	0.560
x2*x2/2	–0.009	0.039	–0.240
x2*x3	–0.225	0.092	–2.450
x3*x3/2	0.118	0.278	0.420
ln(ShareUGC)	–0.144	0.025	–5.860
Year	0.017	0.002	9.420
Country dummy variables:			
New Zealand	–0.364	0.124	–2.940
Ontario	–0.203	0.123	–1.650
DNSP dummy variables:			
AGD	–0.061	0.173	–0.350
CIT	–0.684	0.140	–4.890
END	–0.356	0.140	–2.540
ENX	–0.387	0.139	–2.790
ERG	–0.340	0.164	–2.070
ESS	–0.536	0.172	–3.120
JEN	–0.208	0.146	–1.420
PCR	–0.880	0.143	–6.170
SAP	–0.682	0.143	–4.760
AND	–0.513	0.144	–3.550
TND	–0.564	0.148	–3.820
UED	–0.470	0.158	–2.980
Constant	–23.258	3.555	–6.540
R–Square			0.993

Table E5 **SFA Cobb–Douglas cost frontier estimates using 2012–2019 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.524	0.110	4.780
ln(CircLen)	0.229	0.052	4.400
ln(RMDemand)	0.220	0.098	2.240
ln(ShareUGC)	–0.086	0.044	–1.970
Year	0.009	0.002	4.680
Country dummy variables:			
New Zealand	0.050	0.098	0.510
Ontario	0.289	0.091	3.170
Constant	–8.841	3.937	–2.250
Variance parameters:			
Mu	0.377	0.069	5.490
SigmaU squared	0.033	0.008	4.356
SigmaV squared	0.009	0.001	15.309
LLF			403.555

Table E6 **SFA translog cost function estimates using 2012–2019 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.541	0.118	4.580
ln(CircLen)=x2	0.218	0.051	4.310
ln(RMDemand)=x3	0.212	0.106	1.990
x1*x1/2	–1.429	0.677	–2.110
x1*x2	0.196	0.168	1.170
x1*x3	1.083	0.539	2.010
x2*x2/2	0.131	0.077	1.710
x2*x3	–0.326	0.129	–2.520
x3*x3/2	–0.622	0.440	–1.410
ln(ShareUGC)	–0.057	0.049	–1.180
Year	0.009	0.002	4.420
Country dummy variables:			
New Zealand	–0.098	0.106	–0.920
Ontario	0.193	0.089	2.180
Constant	–9.018	4.220	–2.140
Variance parameters:			
Mu	0.408	0.074	5.500
SigmaU squared	0.030	0.007	4.210
SigmaV squared	0.008	0.001	14.919
LLF			414.981

Table E7 **LSE Cobb–Douglas cost function estimates using 2012–2019 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.607	0.074	8.200
ln(CircLen)	0.184	0.031	5.890
ln(RMDemand)	0.199	0.074	2.700
ln(ShareUGC)	–0.161	0.025	–6.340
Year	0.010	0.003	3.240
Country dummy variables:			
New Zealand	–0.295	0.179	–1.650
Ontario	–0.085	0.178	–0.480
DNSP dummy variables:			
AGD	–0.019	0.213	–0.090
CIT	–0.575	0.189	–3.040
END	–0.297	0.190	–1.560
ENX	–0.310	0.188	–1.650
ERG	–0.314	0.198	–1.590
ESS	–0.392	0.207	–1.900
JEN	–0.307	0.181	–1.700
PCR	–0.838	0.191	–4.400
SAP	–0.525	0.187	–2.820
AND	–0.459	0.188	–2.450
TND	–0.576	0.208	–2.770
UED	–0.591	0.200	–2.950
Constant	–10.710	6.453	–1.660
R–Square			0.995

Table E8 **LSE translog cost function estimates using 2012–2019 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.410	0.073	5.610
ln(CircLen)=x2	0.199	0.028	7.110
ln(RMDemand)=x3	0.358	0.062	5.780
x1*x1/2	–0.924	0.558	–1.660
x1*x2	0.266	0.129	2.070
x1*x3	0.501	0.422	1.190
x2*x2/2	0.041	0.042	0.990
x2*x3	–0.280	0.101	–2.760
x3*x3/2	–0.059	0.319	–0.180
ln(ShareUGC)	–0.130	0.024	–5.450
Year	0.012	0.003	4.120
Country dummy variables:			
New Zealand	–0.407	0.150	–2.720
Ontario	–0.208	0.149	–1.390
DNSP dummy variables:			
AGD	–0.026	0.191	–0.140
CIT	–0.627	0.160	–3.920
END	–0.385	0.162	–2.370
ENX	–0.324	0.166	–1.960
ERG	–0.495	0.186	–2.660
ESS	–0.584	0.197	–2.960
JEN	–0.123	0.164	–0.750
PCR	–0.864	0.167	–5.170
SAP	–0.628	0.164	–3.840
AND	–0.365	0.171	–2.140
TND	–0.612	0.175	–3.490
UED	–0.406	0.182	–2.230
Constant	–14.480	6.018	–2.410
R–Square			0.995

E2 Two–output model estimation results

As discussed in sections 1.2 and 3.2, monotonicity violations have, at times, occurred in our three–output models. We have undertaken some preliminary investigations about the role multicollinearity may be playing in this, given we have found that the customer numbers and RMD outputs are highly correlated. As part of this investigation, we have estimated two sets of two–output models: one with customer numbers and circuit length as the outputs and one with RMD and circuit length as the two outputs. Initial results for these models are presented in the following sections.

E2.1 Customer number and circuit length opex cost function models

Models with customer numbers and circuit length as the two outputs were estimated for the 2006–2019 and 2012–2019 time periods. No monotonicity violations were found for any DNSP in the overall sample for either the SFATLG or LSETLG models for the 2006–2019 sample. For the shorter 2012–2019 period one Australian DNSP (CIT) has monotonicity violations for each of the SFATLG and LSETLG models.

Regression results for the 2006–2019 period are presented in tables E9–E12. Average efficiency scores for the same period are presented in table E13.

Regression results for the 2012–2019 period are presented in tables E14–E17. Average efficiency scores for the same period are presented in table E18.

Table E9 **SFA Cobb–Douglas cost frontier estimates using 2006–2019 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.792	0.050	15.970
ln(CircLen)	0.187	0.044	4.290
ln(ShareUGC)	–0.109	0.032	–3.400
Year	0.015	0.001	14.140
Country dummy variables:			
New Zealand	0.040	0.095	0.430
Ontario	0.347	0.086	4.040
Constant	–19.884	2.094	–9.490
Variance parameters:			
Mu	0.426	0.078	5.490
SigmaU squared	0.035	0.008	4.663
SigmaV squared	0.012	0.001	20.944
LLF			624.211

Table E10 **SFA translog cost function estimates using 2006–2019 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.797	0.050	16.060
ln(CircLen)=x2	0.178	0.045	3.960
x1*x1/2	0.148	0.081	1.830
x1*x2	–0.127	0.067	–1.900
x2*x2/2	0.119	0.065	1.840
ln(ShareUGC)	–0.087	0.035	–2.490
Year	0.014	0.001	13.580
Country dummy variables:			
New Zealand	0.026	0.103	0.250
Ontario	0.344	0.085	4.040
Constant	–19.236	2.126	–9.050
Variance parameters:			
Mu	0.398	0.069	5.790
SigmaU squared	0.034	0.008	4.507
SigmaV squared	0.012	0.001	20.881
LLF			626.076

Table E11 **LSE Cobb–Douglas cost function estimates using 2006–2019 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.818	0.032	25.680
ln(CircLen)	0.170	0.029	5.910
ln(ShareUGC)	–0.137	0.021	–6.560
Year	0.015	0.002	8.080
Country dummy variables:			
New Zealand	–0.312	0.135	–2.300
Ontario	–0.012	0.133	–0.090
DNSP dummy variables:			
AGD	0.030	0.178	0.170
CIT	–0.614	0.152	–4.040
END	–0.216	0.150	–1.440
ENX	–0.310	0.145	–2.140
ERG	–0.164	0.158	–1.040
ESS	–0.380	0.167	–2.270
JEN	–0.357	0.147	–2.430
PCR	–0.807	0.152	–5.320
SAP	–0.570	0.151	–3.780
AND	–0.554	0.151	–3.670
TND	–0.497	0.161	–3.090
UED	–0.596	0.157	–3.810
Constant	–19.458	3.668	–5.310
R–Square			0.992

Table E12 **LSE translog cost function estimates using 2006–2019 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.823	0.033	24.680
ln(CircLen)=x2	0.150	0.030	4.930
x1*x1/2	0.177	0.047	3.760
x1*x2	–0.110	0.039	–2.830
x2*x2/2	0.095	0.041	2.340
ln(ShareUGC)	–0.102	0.026	–3.920
Year	0.014	0.002	7.580
Country dummy variables:			
New Zealand	–0.343	0.142	–2.420
Ontario	–0.047	0.140	–0.330
DNSP dummy variables:			
AGD	–0.155	0.198	–0.780
CIT	–0.713	0.161	–4.430
END	–0.292	0.161	–1.820
ENX	–0.428	0.160	–2.690
ERG	–0.194	0.182	–1.060
ESS	–0.423	0.192	–2.200
JEN	–0.392	0.155	–2.530
PCR	–0.797	0.161	–4.940
SAP	–0.607	0.164	–3.700
AND	–0.551	0.158	–3.480
TND	–0.439	0.169	–2.590
UED	–0.675	0.167	–4.050
Constant	–18.040	3.723	–4.850
R–Square			0.992

Table E13 **DNSP opex cost efficiency scores, customer numbers and circuit length as outputs, 2006–2019**

DNSP	*SFACD*	*SFATLG*	*LSETLG*	*LSECD*
ACT	0.447	0.449	0.451	0.446
AGD	0.417	0.441	0.526	0.433
CIT	0.800	0.870	0.920	0.824
END	0.539	0.545	0.604	0.553
ENX	0.585	0.598	0.692	0.608
ERG	0.520	0.570	0.547	0.526
ESS	0.614	0.675	0.688	0.652
JEN	0.635	0.653	0.667	0.638
PCR	0.961	0.959	1.000	1.000
SAP	0.779	0.800	0.827	0.789
AND	0.732	0.720	0.782	0.776
TND	0.715	0.702	0.699	0.733
UED	0.774	0.802	0.885	0.809

Table E14 **SFA Cobb–Douglas cost frontier estimates using 2012–2019 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.731	0.060	12.100
ln(CircLen)	0.246	0.052	4.700
ln(ShareUGC)	–0.068	0.045	–1.490
Year	0.008	0.002	4.140
Country dummy variables:			
New Zealand	0.012	0.098	0.120
Ontario	0.363	0.086	4.220
Constant	–5.746	3.701	–1.550
Variance parameters:			
Mu	0.420	0.075	5.600
SigmaU squared	0.034	0.007	4.702
SigmaV squared	0.009	0.001	15.306
LLF			401.055

Table E15 **SFA translog cost function estimates using 2012–2019 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.755	0.061	12.270
ln(CircLen)=x2	0.234	0.054	4.340
x1*x1/2	0.238	0.089	2.670
x1*x2	–0.258	0.075	–3.420
x2*x2/2	0.251	0.075	3.350
ln(ShareUGC)	–0.029	0.050	–0.570
Year	0.007	0.002	3.520
Country dummy variables:			
New Zealand	–0.043	0.109	–0.390
Ontario	0.334	0.090	3.700
Constant	–3.593	3.736	–0.960
Variance parameters:			
Mu	0.413	0.074	5.540
SigmaU squared	0.035	0.009	4.035
SigmaV squared	0.008	0.001	14.854
LLF			407.481

Table E16 LSE Cobb–Douglas cost function estimates using 2012–2019 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)	0.805	0.037	22.030
ln(CircLen)	0.190	0.032	6.000
ln(ShareUGC)	–0.147	0.024	–6.090
Year	0.009	0.003	2.780
Country dummy variables:			
New Zealand	–0.317	0.191	–1.650
Ontario	–0.019	0.190	–0.100
DNSP dummy variables:			
AGD	–0.022	0.229	–0.090
CIT	–0.542	0.201	–2.690
END	–0.275	0.203	–1.350
ENX	–0.320	0.202	–1.590
ERG	–0.271	0.211	–1.280
ESS	–0.406	0.219	–1.850
JEN	–0.344	0.194	–1.770
PCR	–0.858	0.204	–4.200
SAP	–0.535	0.200	–2.670
AND	–0.519	0.200	–2.590
TND	–0.549	0.223	–2.460
UED	–0.620	0.215	–2.880
Constant	–7.677	6.447	–1.190
R–Square			0.995

Table E17 **LSE translog cost function estimates using 2012–2019 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(Custnum)=x1	0.816	0.035	23.240
ln(CircLen)=x2	0.167	0.032	5.190
x1*x1/2	0.249	0.050	4.970
x1*x2	–0.186	0.042	–4.410
x2*x2/2	0.165	0.043	3.820
ln(ShareUGC)	–0.099	0.027	–3.710
Year	0.008	0.003	2.470
Country dummy variables:			
New Zealand	–0.364	0.179	–2.030
Ontario	–0.056	0.177	–0.320
DNSP dummy variables:			
AGD	–0.177	0.227	–0.780
CIT	–0.679	0.191	–3.560
END	–0.321	0.194	–1.660
ENX	–0.402	0.197	–2.040
ERG	–0.332	0.216	–1.540
ESS	–0.474	0.226	–2.100
JEN	–0.391	0.183	–2.140
PCR	–0.821	0.194	–4.220
SAP	–0.554	0.193	–2.870
AND	–0.481	0.188	–2.550
TND	–0.476	0.209	–2.270
UED	–0.696	0.205	–3.400
Constant	–5.294	6.274	–0.840
R–Square			0.995

Table E18 **DNSP opex cost efficiency scores, customer numbers and circuit length as outputs, 2012–2019**

DNSP	*SFACD*	*SFATLG*	*LSETLG*	*LSECD*
ACT	0.466	0.474	0.440	0.424
AGD	0.438	0.417	0.526	0.433
CIT	0.751	0.870	0.868	0.729
END	0.575	0.542	0.607	0.558
ENX	0.598	0.551	0.658	0.584
ERG	0.568	0.681	0.613	0.556
ESS	0.644	0.774	0.707	0.636
JEN	0.606	0.636	0.651	0.598
PCR	0.955	0.928	1.000	1.000
SAP	0.755	0.764	0.766	0.724
AND	0.693	0.648	0.712	0.712
TND	0.754	0.742	0.708	0.734
UED	0.758	0.769	0.882	0.787

E2.2 Ratcheted maximum demand and circuit length opex cost function models

Models with RMD and circuit length as the two outputs were estimated for the 2006–2019 and 2012–2019 time periods. No monotonicity violations were found for any DNSP in the overall sample for either the SFATLG or LSETLG models for the 2006–2019 sample. For the shorter 2012–2019 period there are no monotonicity violations for Australian DNSPs for either the SFATLG or LSETLG models. The LSETLG model has no monotonicity violations in the overall sample and the SFATLG model only has monotonicity violations for two Ontario DNSPs.

Regression results for the 2006–2019 period are presented in tables E19–E22. Average efficiency scores are presented in table E23.

Regression results for the 2012–2019 period are presented in tables E24–E27. Average efficiency scores for the same period are presented in table E28.

Table E19 **SFA Cobb–Douglas cost frontier estimates using 2006–2019 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(RMDemand)	0.662	0.044	15.140
ln(CircLen)	0.272	0.043	6.280
ln(ShareUGC)	–0.117	0.030	–3.860
Year	0.017	0.001	15.960
Country dummy variables:			
New Zealand	–0.055	0.087	–0.630
Ontario	0.092	0.098	0.940
Constant	–23.899	2.125	–11.250
Variance parameters:			
Mu	0.430	0.079	5.470
SigmaU squared	0.048	0.011	4.375
SigmaV squared	0.012	0.001	20.897
LLF			615.062

Table E20 **SFA translog cost function estimates using 2006–2019 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(RMDemand)=x1	0.668	0.049	13.760
ln(CircLen)=x2	0.274	0.046	5.910
x1*x1/2	0.028	0.057	0.490
x1*x2	–0.050	0.049	–1.010
x2*x2/2	0.052	0.051	1.030
ln(ShareUGC)	–0.104	0.040	–2.610
Year	0.017	0.001	15.040
Country dummy variables:			
New Zealand	–0.081	0.113	–0.720
Ontario	0.079	0.102	0.780
Constant	–23.951	2.294	–10.440
Variance parameters:			
Mu	0.451	0.122	3.710
SigmaU squared	0.049	0.014	3.523
SigmaV squared	0.012	0.001	20.644
LLF			616.796

Table E21 **LSE Cobb–Douglas cost function estimates using 2006–2019 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(RMDemand)	0.667	0.035	19.280
ln(CircLen)	0.286	0.032	8.920
ln(ShareUGC)	–0.115	0.027	–4.340
Year	0.016	0.002	8.520
Country dummy variables:			
New Zealand	–0.330	0.135	–2.450
Ontario	–0.198	0.133	–1.480
DNSP dummy variables:			
AGD	0.130	0.175	0.740
CIT	–0.599	0.152	–3.930
END	–0.263	0.150	–1.760
ENX	–0.228	0.141	–1.610
ERG	–0.392	0.159	–2.460
ESS	–0.381	0.171	–2.230
JEN	–0.108	0.147	–0.740
PCR	–0.736	0.153	–4.810
SAP	–0.603	0.150	–4.010
AND	–0.343	0.148	–2.320
TND	–0.611	0.161	–3.790
UED	–0.340	0.156	–2.180
Constant	–22.576	3.860	–5.850
R–Square			0.992

Table E22 LSE translog cost function estimates using 2006–2019 data

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(RMDemand)=x1	0.665	0.031	21.300
ln(CircLen)=x2	0.260	0.030	8.780
x1*x1/2	0.157	0.029	5.470
x1*x2	–0.083	0.030	–2.740
x2*x2/2	0.108	0.034	3.210
ln(ShareUGC)	–0.060	0.029	–2.080
Year	0.016	0.002	8.390
Country dummy variables:			
New Zealand	–0.401	0.138	–2.920
Ontario	–0.297	0.135	–2.200
DNSP dummy variables:			
AGD	–0.144	0.183	–0.790
CIT	–0.696	0.154	–4.510
END	–0.437	0.156	–2.810
ENX	–0.449	0.148	–3.030
ERG	–0.600	0.175	–3.440
ESS	–0.635	0.196	–3.240
JEN	–0.091	0.150	–0.610
PCR	–0.832	0.159	–5.240
SAP	–0.791	0.159	–4.970
AND	–0.394	0.151	–2.610
TND	–0.572	0.164	–3.500
UED	–0.375	0.159	–2.350
Constant	–21.603	3.807	–5.670
R–Square			0.992

Table E23 DNSP opex cost efficiency scores, RMD and circuit length as outputs, 2006–2019

DNSP	*SFACD*	*SFATLG*	*LSETLG*	*LSECD*
ACT	0.463	0.460	0.435	0.479
AGD	0.391	0.365	0.502	0.421
CIT	0.837	0.847	0.873	0.872
END	0.581	0.552	0.674	0.623
ENX	0.560	0.528	0.682	0.602
ERG	0.673	0.685	0.793	0.709
ESS	0.637	0.674	0.821	0.701
JEN	0.536	0.528	0.476	0.534
PCR	0.952	0.944	1.000	1.000
SAP	0.823	0.817	0.960	0.876
AND	0.626	0.619	0.645	0.675
TND	0.840	0.828	0.771	0.882
UED	0.650	0.630	0.633	0.673

Table E24 **SFA Cobb–Douglas cost frontier estimates using 2012–2019 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(RMDemand)	0.621	0.091	6.820
ln(CircLen)	0.322	0.078	4.140
ln(ShareUGC)	–0.057	0.067	–0.850
Year	0.012	0.002	5.930
Country dummy variables:			
New Zealand	–0.061	0.134	–0.460
Ontario	0.115	0.102	1.130
Constant	–14.456	4.041	–3.580
Variance parameters:			
Mu	0.485	0.193	2.510
SigmaU squared	0.040	0.009	4.632
SigmaV squared	0.009	0.001	15.202
LLF			391.751

Table E25 **SFA translog cost function estimates using 2012–2019 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(RMDemand)=x1	0.624	0.049	12.850
ln(CircLen)=x2	0.315	0.051	6.140
x1*x1/2	0.216	0.060	3.610
x1*x2	–0.205	0.054	–3.830
x2*x2/2	0.193	0.056	3.460
ln(ShareUGC)	–0.004	0.043	–0.100
Year	0.012	0.002	6.350
Country dummy variables:			
New Zealand	–0.172	0.112	–1.540
Ontario	0.071	0.099	0.710
Constant	–13.895	3.728	–3.730
Variance parameters:			
Mu	0.451	0.079	5.710
SigmaU squared	0.040	0.010	4.101
SigmaV squared	0.008	0.001	14.846
LLF			400.013

Table E26 **LSE Cobb–Douglas cost function estimates using 2012–2019 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(RMDemand)	0.657	0.044	14.800
ln(CircLen)	0.302	0.040	7.620
ln(ShareUGC)	–0.113	0.034	–3.320
Year	0.014	0.003	4.080
Country dummy variables:			
New Zealand	–0.347	0.159	–2.180
Ontario	–0.192	0.159	–1.210
DNSP dummy variables:			
AGD	0.082	0.192	0.430
CIT	–0.531	0.172	–3.100
END	–0.317	0.170	–1.860
ENX	–0.241	0.168	–1.440
ERG	–0.462	0.179	–2.580
ESS	–0.393	0.195	–2.020
JEN	–0.103	0.161	–0.640
PCR	–0.763	0.172	–4.420
SAP	–0.556	0.168	–3.320
AND	–0.290	0.168	–1.730
TND	–0.634	0.187	–3.400
UED	–0.378	0.180	–2.100
Constant	–17.534	6.833	–2.570
R–Square			0.994

Table E27 **LSE translog cost function estimates using 2012–2019 data**

Variable	*Coefficient*	*Standard error*	*t–ratio*
ln(RMDemand)=x1	0.654	0.036	17.950
ln(CircLen)=x2	0.276	0.034	8.060
x1*x1/2	0.204	0.031	6.600
x1*x2	–0.120	0.032	–3.750
x2*x2/2	0.130	0.035	3.690
ln(ShareUGC)	–0.050	0.035	–1.450
Year	0.013	0.003	4.070
Country dummy variables:			
New Zealand	–0.439	0.167	–2.630
Ontario	–0.292	0.166	–1.760
DNSP dummy variables:			
AGD	–0.181	0.204	–0.890
CIT	–0.654	0.178	–3.680
END	–0.476	0.181	–2.640
ENX	–0.442	0.180	–2.460
ERG	–0.620	0.202	–3.070
ESS	–0.592	0.227	–2.610
JEN	–0.087	0.167	–0.520
PCR	–0.817	0.185	–4.420
SAP	–0.700	0.184	–3.810
AND	–0.313	0.177	–1.760
TND	–0.570	0.196	–2.910
UED	–0.413	0.187	–2.210
Constant	–15.893	6.453	–2.460
R–Square			0.995

Table E28 **DNSP opex cost efficiency scores, RMD and circuit length as outputs, 2012–2019**

DNSP	*SFACD*	*SFATLG*	*LSETLG*	*LSECD*
ACT	0.464	0.477	0.442	0.466
AGD	0.402	0.407	0.529	0.430
CIT	0.756	0.880	0.849	0.793
END	0.596	0.589	0.711	0.640
ENX	0.555	0.543	0.687	0.593
ERG	0.662	0.724	0.821	0.741
ESS	0.626	0.753	0.798	0.691
JEN	0.494	0.498	0.481	0.517
PCR	0.883	0.884	1.000	1.000
SAP	0.756	0.783	0.889	0.814
AND	0.563	0.560	0.604	0.623
TND	0.810	0.788	0.781	0.879
UED	0.624	0.621	0.667	0.681

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