# Appendix 2.2

## Relative efficiency and forecast productivity growth for Evoenergy

Economic Insights

Access arrangement information

ACT and Queanbeyan-Palerang gas network 2021–26

**Submission to the Australian Energy Regulator**

**June 2020**

evoenergy

# Relative Efficiency and Forecast Productivity Growth of Evoenergy

**Report prepared for**

**Evoenergy**

**14 April 2020**

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# EXECUTIVE SUMMARY

Evoenergy has commissioned Economic Insights Pty Ltd ('Economic Insights') to provide advice on productivity measurement and benchmarking of its gas distribution network operations in the Australian Capital Territory (ACT) and parts of New South Wales (NSW). This report examines the efficiency performance of Evoenergy over the period 1999–2019 within a group of 13 gas distribution businesses (GDBs), of which 11 are from Australia and two from New Zealand.[1] The report has been prepared for Evoenergy as an input to its forthcoming access arrangement proposal for the period July 2021 to June 2026, to be submitted for approval by the Australian Energy Regulator (AER).

## Partial Performance Indicators

In Part A, a set of partial performance indicators is presented to compare the opex and capital input efficiency of the thirteen businesses against one another. The Australian and New Zealand GDBs included in the study are: Evoenergy (in the Australian Capital Territory); AGN Albury (NSW); Australian Gas Networks (AGN) Queensland; AGN South Australia; AGN Victoria; AGN Wagga Wagga (NSW); Allgas Energy (Queensland); ATCO Gas Australia (Western Australia); AusNet Services (Victoria); JGN (NSW); Multinet (Victoria); Powerco (New Zealand); and Vector (New Zealand). The data used in this part of the study has been predominantly sourced from documents in the public domain. These data have been supplemented in some places with information provided by several major Australian GDBs in response to common detailed data surveys.

Evoenergy's operating environment characteristics can be summarised as follows:

- Evoenergy is the seventh largest GDB in the sample in terms of customer numbers; the eighth largest in terms of network length; and the 10th largest in terms of gas throughput. It is comparable in size to the two New Zealand GDBs, Powerco and Vector, and to the two Queensland GDBs, AGN Qld and Allgas.
- Evoenergy is among six GDBs in the sample that have comparatively low customer density. These are also mostly the smaller sized GDBs. Evoenergy's customer density is comparable to AGN Qld, Allgas, Powerco and AGN Wagga.
- Evoenergy's energy density per customer is the third lowest in the sample (only ATCO and AGN SA are lower). The most comparable GDBs in terms of energy density are AGN SA, AGN Qld and Jemena.
- Evoenergy has the lowest energy deliveries per km, or 'network utilisation', among all the GDBs in the sample. GDBs with comparable rates of network utilisation include ATCO, AGN Wagga, Vector and Powerco.

Partial indicators of cost efficiency are examined for two broad groups of costs, namely opex and asset costs, as well as total costs. The partial performance indicators presented are:

[1] In Part C (the econometric analysis) an additional New Zealand GDB is included in the sample. For details see Appendix A.

- Opex per customer relative to customer density
- Opex per mains km relative to customer density
- Asset cost per customer relative to customer density
- Asset cost per mains km relative to customer density
- Total cost per customer relative to customer density
- Total cost per mains km relative to customer density.

Evoenergy's comparative performance in terms of partial indicators is as follows:

- Evoenergy's average opex per customer (in $2010) over the latest five-year period was $120, which was well below the average opex per customer for the six GDBs with lowest customer density ($151). The seven GDBs with higher customer density tended to have lower opex per customer.
- Evoenergy's opex per km of mains was $3,685 over the latest five-year period, which is lower than the average of for the GDBs with comparatively low customer density ($4,449 for the latest five-years). The average opex per km for GDBs with higher customer densities was similar to the average for those with lower customer density.
- Evoenergy's capital asset cost per customer averaged $281 in the latest five-year period. This is similar to the sample average of $280. It is well below the average asset cost per customer of $369 for the group of GDBs with lower customer density. Evoenergy's capital asset cost per customer is the lowest in that group. The seven GDBs with higher customer density tended to have lower capital asset cost per customer than those with lower customer density.
- Evoenergy's average asset cost per km was $8,581 over the latest five years, which is comparatively low when compared to the average for all GDBs ($10,965) or to the average for of GDBs with lower customer density ($10,448).
- The average total cost per customer of Evoenergy in the latest five-year period was $401. This is below the average total cost per customer for the six GDBs with comparatively low customer density ($520). Evoenergy's total cost per customer is the lowest in that group. The seven GDBs with higher customer density tended to have lower total cost per customer. Nevertheless, Evoenergy's average total cost per customer is similar to the sample average of $395.
- Evoenergy's average total cost per km of mains ($12,266 in the latest five-year period) was below the average total cost per km for the GDBs with comparatively low customer density ($14,897). The average opex per km for GDBs with higher customer densities was similar to the average for those with lower customer density. Evoenergy's average total cost per km of mains was also below the sample average of $15,579.

These comparisons of partial performance indicators do not control for other drivers of opex costs that may be relevant. That is, they do not enable influences such as scale economies or different mixes of inputs to be controlled for in a rigorous fashion. An exercise in normalising opex per customer for some of the main determinants of real opex, based on the econometric analysis in Part C, supports the conclusion that Evoenergy's normalised real opex per customer is similar to the sample average.

While the partial performance indicators have the advantage of simplicity, generally speaking, because of the limited control for differences in operating environment characteristics, care is needed in interpretation, as individual partial performance indicators may give a misleading impression of overall efficiency. If a GDB is ranked poorly for most indicators then this may warrant further investigation as to whether that GDB was operating inefficiently. Conversely, if a GDB is ranked highly for most indicators then this may be taken to suggest that it is performing at levels consistent with industry best practice. If a GDB performs well on some indicators but poorly on others then the GDB's performance is harder to assess as it may be making trade–offs between different types of inputs (eg, opex and capital) and more detailed analysis may be required.

Hence, only qualified conclusions can be drawn. It is also desirable to have regard to more holistic measures of efficiency, such as total factor productivity (TFP) analysis, and other methods of measuring efficiency such as econometric cost functions which can control for differences in scale and other operating environment differences.

## Total Factor Productivity and Partial Factor Productivity

The analysis presented in Part B of this report details analysis of Evoenergy's total factor productivity (TFP) and partial factor productivity (PFP) trends, and comparison against the productivity trends of other Australian gas distribution businesses (GDBs) over time. This report also provides a comparative analysis of Evoenergy's productivity levels against other Australian GDBs using multilateral TFP.

The primary data source for this part of the study is information supplied by eight Australia GDBs, including Evoenergy. The other GDBs are Jemena Gas Networks (JGN) in NSW, Australian Gas Infrastructure Group (AGIG) in relation to the Australian Gas Networks Limited (AGN) South Australian, Victorian and Queensland gas networks, as well as Multinet Gas in Victoria, ATCO Gas Australia in Western Australia and AusNet in Victoria. The data was provided in response to common detailed data surveys, covering key output and input value, price and quantity information. For Evoenergy this data is available for 1999 to 2019 and for the other GDBs is generally available for the period from 1999 or 2000 to 2018 or 2019 (with the exception of AGN Queensland which is currently only available to 2014).

The TFP measure used includes three outputs (throughput, customer numbers and system capacity) and eight inputs (opex, lengths of transmission pipelines, high pressure pipelines, medium pressure pipelines, low pressure pipelines and services, numbers of meters, and other capital). For productivity level comparisons transmission pipelines are excluded to allow more like–with–like comparisons.

TFP indexes are used to measure the *trends* in productivity. In summary, the time series TFP results for Evoenergy are as follows:

- Evoenergy's TFP increased at an average annual rate of 0.4 per cent from 1999 to 2019. Productivity growth was stronger in the period up to 2007, and has been declining over the period since then.
- Evoenergy's Opex partial factor productivity (PFP) increased at an average annual rate of 2.5 per cent from 1999 to 2019. Capital PFP *decreased* at an average annual rate of 0.5 per cent over the same period. Opex PFP growth was strong in the period 1999 to 2007 (5.5 per cent) but growth was weaker in the periods from 2007 to 2014 (0.4 per

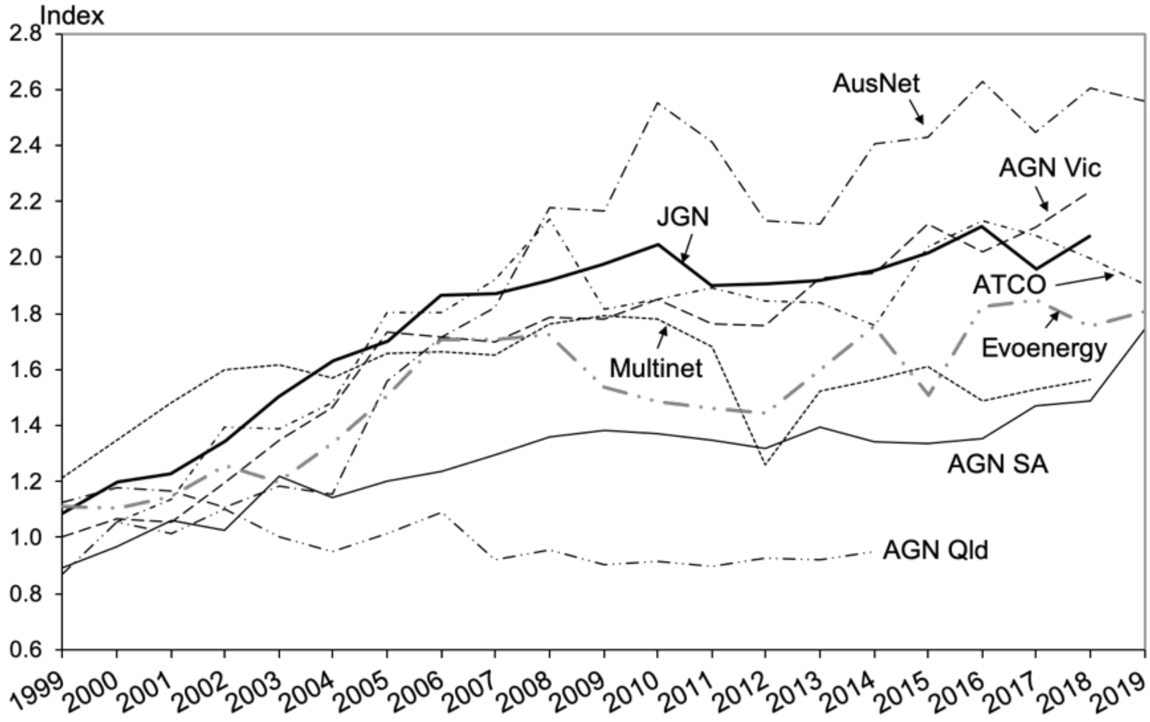
cent) and 2014 to 2019 (0.6 per cent). The decline in Evoenergy's Capital PFP mainly occurred in the periods from 2007 to 2014 (-1.3 per cent) and from 2014 to 2019 (-1.1 per cent).

- Comparing the average rates of TFP growth of GDBs, Evoenergy's TFP growth over the full sample period was below the sample average of 0.8 per cent per year, but broadly similar to JGN (0.7 per cent), Multinet (0.6 per cent) and AGN SA (0.8 per cent). ATCO, AGN Vic and AusNet had higher rates of TFP growth (1.4, 1.5 and 1.3 per cent, respectively). Most GDBs had strong rates of growth in Opex PFP, comparable to Evoenergy. However, Evoenergy's decline in Capital PFP (-0.5 per cent per year) was slightly greater than for most other GDBs.
- Over the most recent period from 2014 to 2019, Evoenergy's average annual rate of TFP growth was -0.7 per cent. Besides JGN, which had no TFP growth in this period, the other GDBs all had some productivity growth in this period. AusNet, Multinet and ATCO all had an average rate of TFP growth of 0.4 per cent per year in the 2014 to 2017 period and AGN SA and AGN Vic both had TFP growth rates of 1.4 per cent.
- Evoenergy had above-average output growth averaging 2.7 per cent per year between 1999 and 2019, compared to the average for all GDBs of 1.9 per cent over the same period. The average rate of increase in inputs for Evoenergy over the period 1999 to 2019 was 2.3 per cent per year, which was above the average for all GDBs (1.1 per cent). Over the full period from 1999 to 2019, Evoenergy's average rate of change of opex inputs was 0.2 per cent per year, compared to the average for all GDBs of –0.9 per cent per year. The average growth rate of capital inputs for Evoenergy over the period 1999 to 2019 was 3.2 per cent per year, compared to the average for all GDBs (2.1 per cent).

The multilateral total factor productivity (MTFP) index is used to measure comparative productivity *levels*. The results for comparative TFP levels are as follows:

- The MTFP results indicate that in the latest years available, Evoenergy is found to have the fifth highest TFP level in the last year of the sample—an MTFP index of 1.02 in 2019 (i.e. slightly above AGN Vic's productivity level in 1999, which is used as the index base). This TFP level is comparable to Multinet (0.98), AGN SA (1.00) and JGN (1.06). This can be compared to the following MTFP indexes for the other GDBs: AGN Vic (1.37), AusNet (1.12), and ATCO (1.09). AGN Qld has a much lower TFP level.
- Evoenergy also had the fifth highest Opex PFP level (1.80) in the last year of the sample. The Opex PFPs of the other GDBs are: AGN Vic (2.24), AusNet (2.56), JGN (2.07), ATCO (1.90), AGN SA (1.75), Multinet (1.57), and AGN Qld (0.95).
- In the latest year, Evoenergy's Capital PFP index was 0.78, which is very close to a number of other GDBs, who appear to have converged to the same Capital PFP level over the sample period. The GDBs with essentially the same level of Capital PFP as Evoenergy include; Multinet, AusNet, JGN, AGN SA and ATCO. AGN Vic had a higher level of Capital PFP (1.08) and AGN Qld a lower level (0.61).

**Figure A: GDB Opex MPFP indexes, 1999–2018**




Source: Economic Insights GDB database

## Opex Cost Function

In Part C of the report, we estimate the opex cost function for gas distribution businesses. The principal aims of the analysis are to estimate trends in technical efficiency in the industry and estimate the opex efficiency of Evoenergy relative to other GDBs. The econometric results are used to establish whether Evoenergy is efficient in its use of opex inputs, and also to estimate parameters that can be used in the 'rate of change' method of forecasting Evoenergy's opex for the period 2021 to 2026. These parameters include the average historical rate of frontier shift (or technical change) and the appropriate weights for constructing the output index.

The analysis in this part of the report is similar to those previously undertaken by Economic Insights in 2015, 2016 and 2019. This study uses additional data available since the last study was undertaken. It tests the preferred specification developed in the 2019 study and tests a simplification of that model.

The main findings of the econometric analysis are as follows:

- Evoenergy's efficiency score is 0.85, with a confidence interval of between 0.80 and 0.90. The average efficiency score of all GDBs in the sample is 0.88 and the highest efficiency score of 0.98. This suggests that Evoenergy's technical efficiency is close to average for the sample of GDBs.
- The estimated average rate of technical change or 'frontier shift' is between 0.54 and 1.35 per cent per annum; with an intermediate estimate of 0.95.[2] This estimate is slightly higher than the estimate we obtained in the previous studies for JGN in 2019 (0.74 per

[2] Frontier shift is expressed here as a rate of productivity growth and is hence a positive number.

cent) which was accepted by the AER in its draft decision on JGN's proposed access arrangement (AER 2019, 29). However, the effect of the time variable in these models is likely to include some element of catch-up to the frontier in addition to the rate of frontier shift (Economic Insights 2019a, 15–16). Further, the wide dispersion of coefficient estimates on the time variable implies considerable uncertainty about the estimated productivity trend from the models reported here. For these reasons, the estimate of 0.95 should be regarded as an upper bound, and a somewhat lower estimate may more reliably reflect the underlying opex efficiency rate of change.

- The estimated output index weights for the two outputs used in the preferred econometric model are: (i) customer numbers, 32.6 per cent; and (ii) mains length, 67.4 per cent.

# 1 INTRODUCTION

## 1.1 Terms of reference

Evoenergy commissioned Economic Insights Pty Ltd ('Economic Insights') to conduct productivity measurement and benchmarking of its gas distribution network operations in the Australian Capital Territory (ACT) and parts of New South Wales (NSW). The terms of reference are listed in Appendix D. Consequently, this report is presented in three parts as follows:

(a) *Partial Performance Indicators*: Part A of this report presents partial indicator comparisons between a set of 11 Australian and two New Zealand GDBs. These partial performance indicators are analogous to those published by the Australian Energy Regulator for electricity distribution businesses (Australian Energy Regulator (AER) 2014). This report updates similar studies carried out for AGN SA in 2015, the three Victorian GDBs (AGN Vic, AusNet and Multinet) in 2016, ATCO in 2018 and Jemena Gas Networks (JGN) in 2019 for their respective access arrangement reviews (Economic Insights 2015b; 2016a; 2018; 2019b).

(b) *Total and Partial Factor Productivity Indexes*: The analysis presented in Part B of this report details Evoenergy's total factor productivity (TFP) and partial factor productivity (PFP) trends, and comparison against the productivity trends of other Australian gas distribution businesses (GDBs) over time. This part of the study also provides a comparative analysis of Evoenergy's productivity levels against other Australian GDBs using multilateral TFP (MTFP). This entails updating and extending analysis that Economic Insights has carried out previously for JGN (Economic Insights 2015a; 2019b) and other Australian GDBs (Economic Insights 2015c; 2016b).

(c) *Econometric Analysis*: The third part of the study, presented in Part C, is to undertake econometric analysis of gas network real opex as a function of outputs, fixed capital inputs and operating environment factors, similar to studies previously carried out for JGN and Multinet (Economic Insights 2015a; 2016c; 2019b), and to use this model to:

- examine Evoenergy's opex efficiency;
- estimate the past rate of technical change; i.e. the rate of improvement in the efficient production frontier;
- estimate output index weights for use in projecting the opex rate of change over the next regulatory period; and
- examine evidence relating to the input index weights for the purposes of forecasting real opex.

## 1.2 Detailed Outline of the Report

In Part A, chapter 2 presents data on the business operating environment characteristics that influence the observed performance of GDBs. Chapter 3 provides a summary comparison of partial performance indicators relating to costs per customer.

In Part B, chapter 4 briefly explains productivity measurement and its applications in the context of the economic regulation of natural monopolies. It also discusses measurement issues, data sources and the definitions of outputs and inputs used in the study. Chapter 5 presents an analysis of TFP and PFP *trends* for Evoenergy over the period 1999 to 2019 and provides comparative information for other GDBs. Chapter 6 presents a comparative analysis of the TFP *levels* of Evoenergy and the other major Australian GDBs in other states using multilateral TFP analysis. The multilateral TFP method is explained and the results of the analysis of multilateral TFP and PFP are reported.

In Part C, chapter 7 of this report introduces the analysis of the real opex cost function of Australasian GDBs by firstly discussing the regulatory context, and the variable cost function and the variables used in the study. It documents the dataset, including the GDBs and time periods that form the data sample. It then explains the econometric methodologies, including the specification of the variable cost function, the alternative stochastic specifications, and the criteria used for model selection. Lastly, it explains how the results of the model are to be used as part of projecting opex rates of change.

Chapter 8 presents the results of the econometric analysis of the real opex cost function of Australasian GDBs. Only the preferred model is presented in that chapter. More detail relating to the models tested is shown in Appendix D. Chapter 8 also draws out the main inferences from the analysis in relation to Evoenergy's technical efficiency, the industry rate of technical change, and appropriate weights for constructing the output index.

Appendix A briefly describes the operations of the 11 Australian GDBs and two New Zealand GDBs included in this study, and Appendix B describes the databases used in the study. Appendix C documents the derivation of the output cost share weights used in the multilateral TFP analysis. Appendix D details the key models tested in deriving the preferred econometric opex cost function. The terms of reference are presented in Appendix D.

## 1.3 Economic Insights' experience

Economic Insights has been operating in Australia for over 20 years as an economic consulting firm specialising in infrastructure regulation and economic benchmarking. Economic Insights provides strategic policy advice and rigorous quantitative research to industry and government. Economic Insights' experience and expertise covers a wide range of economic and industry analysis topics including:

- infrastructure regulation;
- productivity measurement;
- benchmarking of firm and industry performance;
- infrastructure pricing issues; and
- analysis of competitive neutrality issues.

# PART A: PARTIAL PRODUCTIVITY INDICATORS

This part of the report discusses the characteristics and efficiency performance of Evoenergy over the period 1999–2019 within a group of 11 Australian and two New Zealand gas distribution businesses (GDBs). Appendix A briefly describes the operations of the 11 Australian GDBs and two New Zealand GDBs included in this part of the study, and Appendix B describes the database used.

The information presented in this section updates previous similar studies carried out by Economic Insights. These include studies carried out for AGN SA in 2015, the three Victorian GDBs (AGN Vic, AusNet and Multinet) in 2016, ATCO in 2018 and JGN in 2019 for their respective access arrangement reviews (Economic Insights 2015b; 2016a; 2018; 2019b).

Section 2 presents data on the business characteristics that influence the observed performance of GDBs. Section 3 provides a summary comparison of partial performance indicators relating to costs per customer. A set of partial performance indicators is presented to compare the opex and capital input efficiency of the thirteen businesses against one another. These indicators have the advantage of being relatively easy to construct and understand. However, care needs to be exercised in interpreting the results, as individual partial performance indicator results may give a misleading impression of overall efficiency. To gain an indication of overall relative performance, the partial indicators need to be considered together and jointly with key operating environment indicators.

# 2 OPERATING ENVIRONMENT INDICATORS

This section describes the key characteristics for the 13 GDBs included in this study, covering the years 1999 to 2019. The performance indicators discussed in this section are summarised in the Annexure at the end of this section, in Tables 2.1 to 2.4. Descriptive information on each GDB included in this study is presented in Appendix A.

The data covers the years 1999 (or 2000) to 2019 for four of the Australian GDBs, from 1999 to 2018 for a further three Australian GDBs and from 2004 to 2018 for Powerco. For the other GDBs the available data are not as up-to-date. Information on the dataset used in this analysis is included in Appendix B. Table B.1 in Appendix B shows the data sample periods for each included GDB. The data available from 1999 onwards is:

- 1999 to 2019 for AusNet, Evoenergy and AGN SA;
- 2000 to 2019 for ATCO;
- 1999 to 2018 for AGN Vic, Multinet and Jemena;
- 1999 to 2017 for AGN Albury;
- 1999 to 2016 for AGN Qld;
- 2000 to 2016 for Allgas;
- 1999 to 2015 for AGN Wagga;
- 2004 to 2018 for Powerco; and
- 2005 to 2019 for Vector.

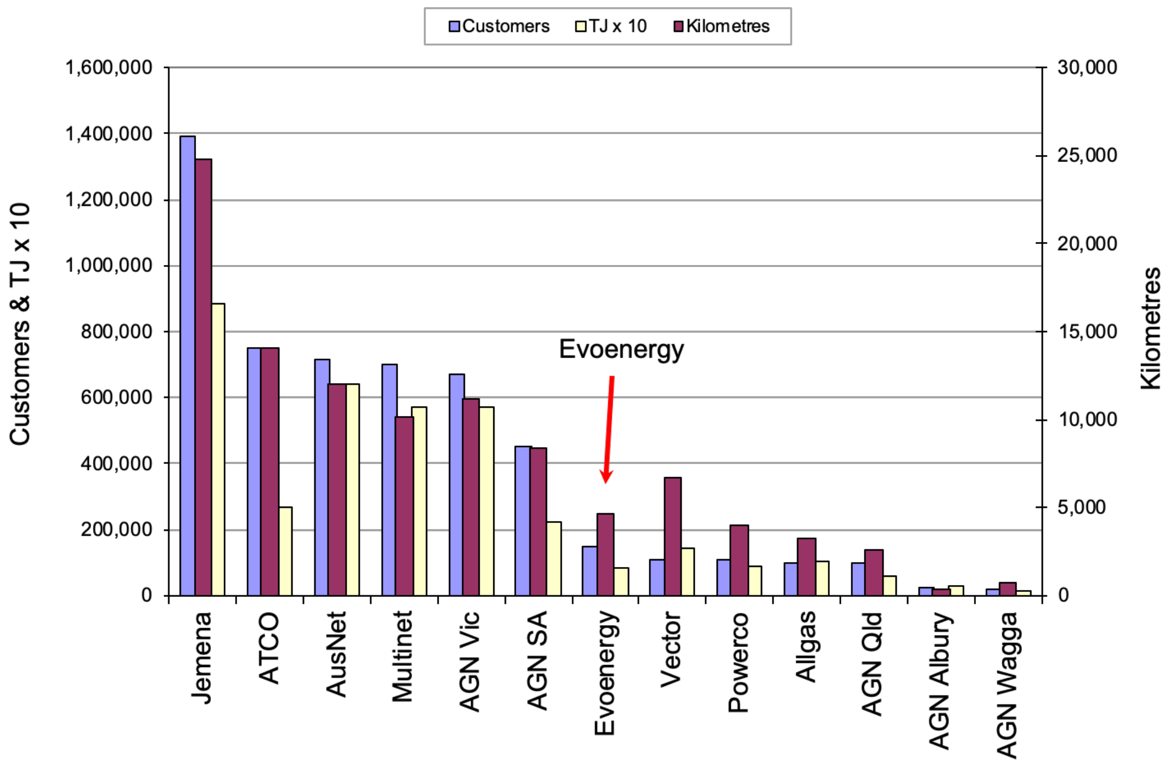
Availability of earlier data for New Zealand GDBs has been affected by merger and restructuring activity. The comparability of data for Vector from 2016 onwards, against earlier years is affected by its divestiture of gas pipelines outside Auckland in November 2015. Growth rates and averages are calculated to avoid this structural break.

The 13 Australasian distribution businesses operate in varying environments often with substantial differences in network size, amount of throughput, demand growth, number and type of customers, and the mix of rural, urban and CBD customers. The operating environment indicators presented in this section are:

- Energy delivered (TJ), number of customers and network kilometres (Figure 2.1)
- Customer density—customers per kilometre (km) of mains (Figure 2.2)
- Energy density—terajoules (TJ) per customer (Figure 2.3)
- Network utilisation—TJ per kilometre (Figure 2.4).

Figure 2.1 shows, for each GDB in the sample, customer numbers, gas throughput (TJ) and mains length (km) in 2019 (or the latest year available). GDBs are ranked in terms of number of customers and the position of Evoenergy is highlighted. Evoenergy is the seventh largest GDB in the sample in terms of customer numbers; the eighth largest in terms of network length; and the 10th largest in terms of gas throughput (only AGN Qld, AGN Albury and AGN Wagga being smaller in terms of gas throughput). Overall, Evoenergy is comparable in size to the two New Zealand businesses, Powerco and Vector, and to the two Queensland businesses, Allgas and AGN Qld. AGN Albury and AGN Wagga are smaller than these GDBs on all measures. Among the other GDBs, Jemena in NSW is by far the largest. Other GDBs that are larger than Evoenergy include the three Victorian networks, ATCO and AGN SA.

Figure 2.1: **Key features of the operating environment, 2019***




* Or latest year.

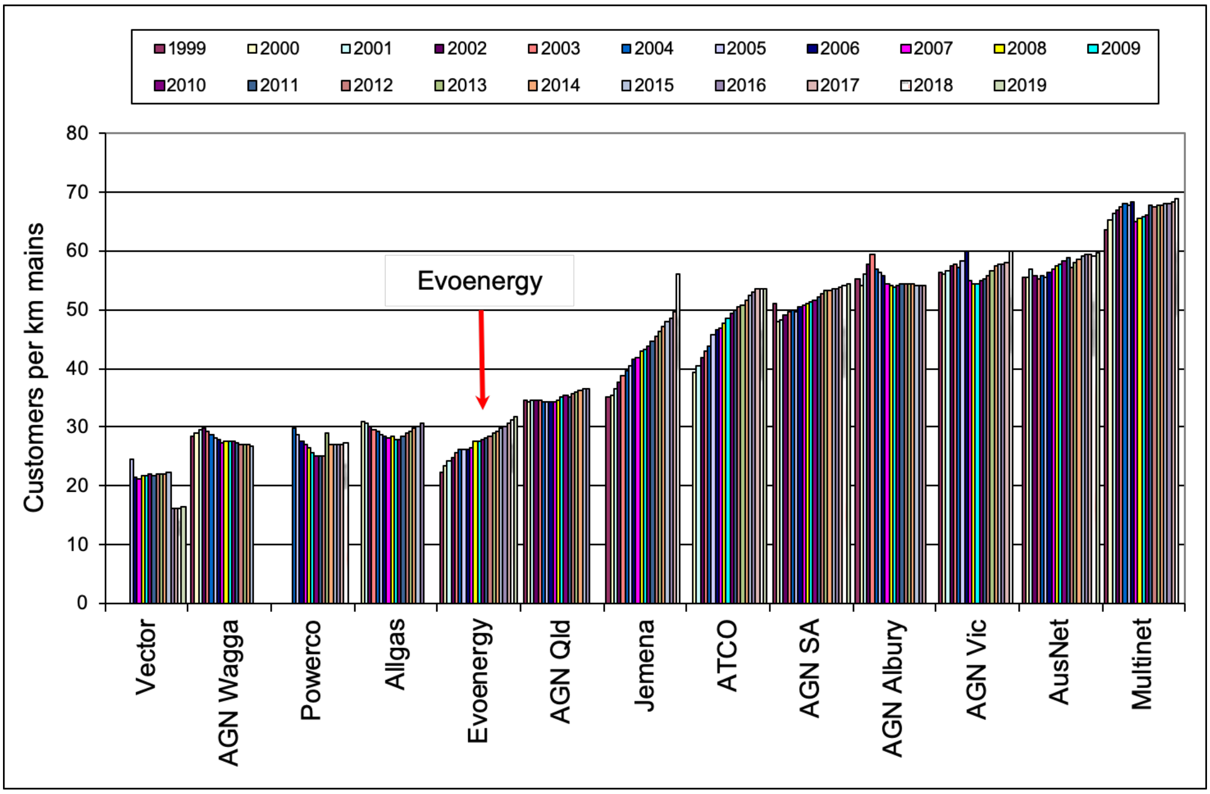
Source: Economic Insights gas utility database.

Two of the key operating environment characteristics influencing energy distribution business productivity levels and costs are customer density, measured by the number of customers per kilometre (km) of mains, and energy density measured by the energy throughput (ie, TJ) per customer. A GDB with lower customer density will require more pipeline length to reach its customers than will a GDB with higher customer density but the same consumption per customer. This would make the lower density distributor appear less efficient unless the differing densities are allowed for. Being able to deliver more energy to each customer means that a GDB will usually require less inputs to deliver a given volume of gas as it will require less pipelines than a less energy-dense GDB would need to deliver the same total volume.

These two density measures for all companies in the sample for all available years are presented in Figures 2.2 and 2.3. When the foregoing two measures are multiplied together, the result is the ratio of energy throughput per km, or 'network utilisation'. This measure is presented in Figure 2.4.

The three Victorian GDBs have the highest customer densities. In terms of the five-year average to 2019 (or latest year available) AGN Vic, AusNet and Multinet had 58.2, 59.3 and 68.2 customers per km, respectively. Other comparatively large GDBs that also have relatively high customer density are AGN SA, ATCO and Jemena (53.9, 53.2 and 49.9 customers per km, respectively over the latest five years). Evoenergy has the ninth highest (or fifth lowest) customer density in the sample (averaging 30.7 customers per km). Most of the GDBs of comparable size to Evoenergy also have comparable customer densities, including AGN Qld, Allgas and Powerco (36.1, 29.8 and 27.1 respectively), whereas Vector has a much lower customer density (17.4). Among the two very small GDBs, AGN Albury has a high customer density (54.2) and AGN Wagga has a low customer density (27.1).

Figure 2.2: **Customer density, 1999–2019**

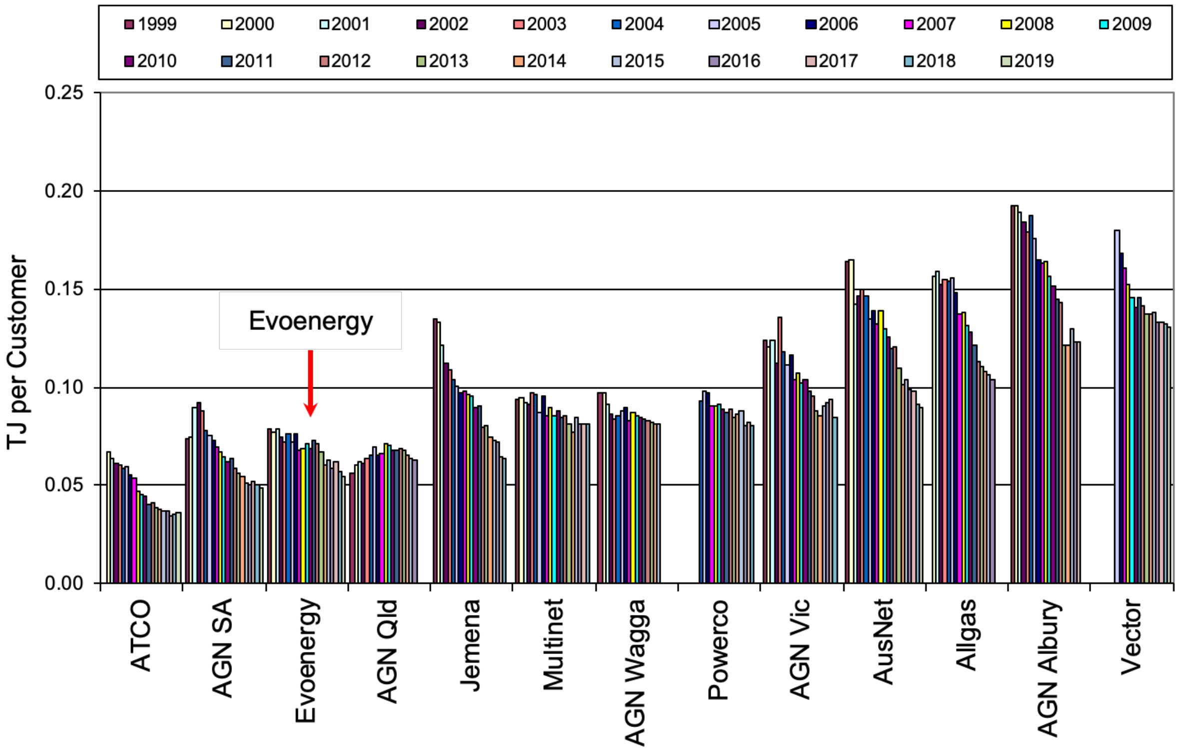



Source: Economic Insights gas utility database

Evoenergy's customer density has increased quite strongly over the sample period, much like JGN, AGN SA and ATCO. AGN Vic, AusNet and Multinet have had more moderate increases in customer density. The remaining smaller Australian GDBs and the two New Zealand businesses have either had relatively static, or even declining, network densities over the sample period.

Evoenergy had the third lowest energy density of all the GDBs in the sample, an average of 59 gigajoules (GJ) per customer over the five years to 2019. This includes all customer types.[3] By comparison, AGN Vic, AusNet and Multinet had energy densities of 89, 96 and 81 GJ per customer respectively, and Jemena had an energy density of 70 GJ per customer (all in the latest five-year period). AGN SA and ATCO are the only GDBs with lower energy density (51 and 36 GJ per customer, respectively). There is considerable diversity in the energy densities of the smaller Australian and New Zealand GDBs, reflecting wide variation in climates and the competitiveness of alternative fuels.

Figure 2.3: **Energy density, 1999–2019**




Source: Economic Insights gas utility database.

Energy use per customer has generally declined over the period from 1999 to 2019. For example, Evoenergy's energy density declined from 79 GJ/customer in 1999 to 55 GJ/customer in 2019 (a 30 per cent decrease). For comparison, AGN SA's energy density decreased from 74 GJ per customer in 1999 to 49 GJ/customer in 2019 (a 34 per cent cumulative decrease). Jemena's energy density decreased from 135 GJ per customer in 1999, to 64 GJ/customer in 2018 (a 53 per cent cumulative decrease). ATCO's energy density decreased from 67 GJ/customer in 2000, to 36 GJ/customer in 2019 (a 47 per cent cumulative decrease), and AusNet has seen a decline from 164 GJ/customer in 1999 to 89 GJ/customer in 2019 (a 55 per cent decrease). AGN Vic's energy density decreased from 124 GJ/customer in 1999, to 85 GJ/customer in 2018 (a 31 per cent cumulative decrease); and Multinet's energy density decreased less strongly from 94 GJ/customer in 1999 to 81 GJ/customer in 2018 (a 13 per cent

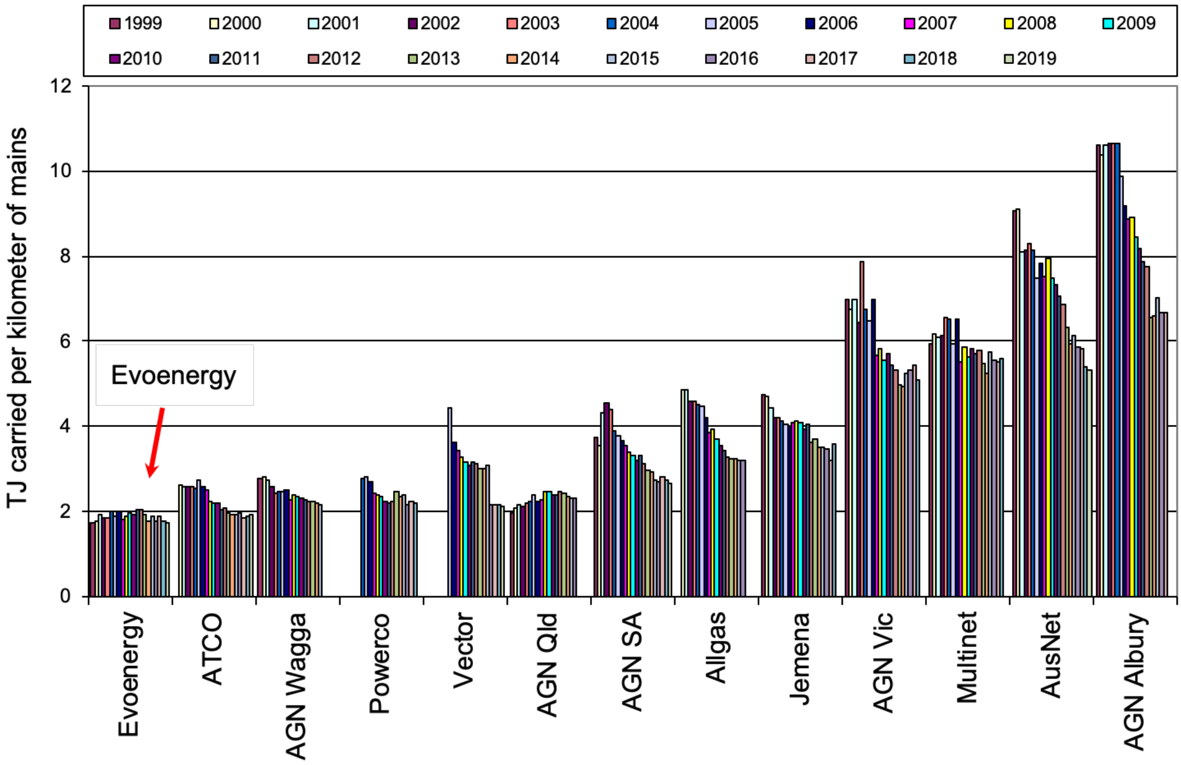
[3] A GJ is one thousandth of a TJ.

decrease).

These trends reflect a combination of decreased gas demand by energy-intensive industries, residential energy efficiency improvements, and greater competition in the domestic heating market from electric split systems (air-conditioning and heating).

The combined effect of customer density and energy density is the energy delivered per km of mains or 'network utilisation', which is shown in Figure 2.4. Evoenergy has the lowest level of network utilisation; averaging 1.8 TJ per km over the latest five-year period. ATCO has a similarly low level of network utilisation at 1.9 TJ/km. Many of the smaller GDBs in the sample also have relatively low network network utilisation: AGN Wagga (2.2 TJ/km), Powerco and Vector (both 2.3 TJ/km) and AGN Qld (2.4 TJ/km). Allgas has a somewhat higher network utilisation (3.2 TJ/km), but AGN Albury has an especially high network utilisation (6.7 TJ/km) due to the presence of several large industrial consumers. Among the remaining larger GDBs, AGN SA and JGN have average levels of network utilisation (2.7 and 3.5 TJ/km, respectively); whilst the Victorian GDBs all have comparatively high network utilisation; all above 5 TJ/km.

Figure 2.4: **Network Utilisation (Energy per kilometre), 1999–2019**




Source: Economic Insights gas utility database

Evoenergy is unlike most other GDBs in that its network utilisation has remained relatively constant over the sample period. For most GDBs, network utilisation has declined over the period, reflecting the fact that declines in energy density per customer have typically outpaced increases in customer density per km. For example, AGN SA, ATCO and JGN had cumulative decreases in network utilisation of 29, 27 and 25 per cent, respectively. AusNet had a larger decline in network utilisation over the sample period (41 per cent) and AGN Vic and Multinet had smaller declines (15 and 10 per cent, respectively).

Table 2.1 shows averages for each of the operating environment indicators presented in Figures 2.1 to 2.4, for each GDB over the five-year period to 2019 (or the latest year). It also shows a number of additional partial performance indicators including:

- Opex per customer, per TJ and per mains km
- Capex per customer, per TJ and per mains km, and
- Assets per customer, per TJ and per mains km
- Asset cost per customer, and
- Total cost per customer.

Table 2.2 shows the average growth rates of each of these partial performance indicators for each GDB over the whole sample period available for that GDB. Table 2.3 shows the average growth rates of each partial performance indicator for each GDB over the last five years of the data sample.

Table 2.1: **Operating and performance indicators, Australian and New Zealand GDBs, average***

| Company | Period | TJ | Cust. | Km | Cust/ km | TJ/ km | TJ/ cust | Opex/ TJ | Opex/ cust | Opex/ km |
|---|---|---|---|---|---|---|---|---|---|---|
| AGN Albury | 2013-2017 | 2,646 | 21,371 | 394 | 54 | 6.7 | 0.124 | 764 | 94 | 5,125 |
| AGN Vic | 2014-2018 | 56,374 | 630,330 | 10,829 | 58 | 5.2 | 0.089 | 952 | 85 | 4,946 |
| Multinet | 2014-2018 | 56,219 | 693,278 | 10,159 | 68 | 5.5 | 0.081 | 981 | 80 | 5,423 |
| AusNet | 2015-2019 | 65,691 | 682,921 | 11,513 | 59 | 5.7 | 0.096 | 705 | 68 | 4,020 |
| AGN SA | 2015-2019 | 22,334 | 442,298 | 8,210 | 54 | 2.7 | 0.051 | 2,174 | 110 | 5,920 |
| AGN Qld | 2012-2016 | 6,055 | 92,100 | 2,548 | 36 | 2.4 | 0.066 | 3,686 | 242 | 8,757 |
| Allgas Qld | 2012-2016 | 10,110 | 93,397 | 3,133 | 30 | 3.2 | 0.108 | 1,751 | 190 | 5,649 |
| AGN Wagga | 2011-2015 | 1,609 | 19,554 | 723 | 27 | 2.2 | 0.082 | 1,443 | 119 | 3,214 |
| JGN | 2014-2018 | 89,797 | 1,294,269 | 25,985 | 50 | 3.5 | 0.070 | 1,293 | 90 | 4,466 |
| Evoenergy | 2015-2019 | 8,295 | 140,516 | 4,576 | 31 | 1.8 | 0.059 | 2,032 | 120 | 3,685 |
| ATCO WA | 2015-2019 | 26,287 | 734,519 | 13,818 | 53 | 1.9 | 0.036 | 1,782 | 64 | 3,389 |
| Pwrco NZ | 2014-2018 | 8,786 | 105,071 | 3,878 | 27 | 2.3 | 0.084 | 1,622 | 136 | 3,673 |
| Vector NZ | 2016-2019 | 15,776 | 117,881 | 6,725 | 17 | 2.3 | 0.133 | 740 | 99 | 1,717 |
| **Average** | | 28,460 | 389,808 | 7,884 | 43 | 3.5 | 0.083 | 1,533 | 115 | 4,614 |

| Company | Period | Capex/ TJ | Capex/ cust | Capex/ km | Assets/ TJ | Assets/ cust | Assets/ km | Asset cost/ cust | Total cost/ cust |
|---|---|---|---|---|---|---|---|---|---|
| AGN Albury | 2013-2017 | 465 | 58 | 3,122 | 12,420 | 1,536 | 83,326 | 157 | 251 |
| AGN Vic | 2014-2018 | 1,537 | 137 | 7,970 | 22,111 | 1,976 | 115,016 | 217 | 302 |
| Multinet | 2014-2018 | 1,059 | 86 | 5,871 | 18,781 | 1,522 | 103,846 | 157 | 237 |
| AusNet | 2015-2019 | 1,234 | 119 | 7,033 | 20,456 | 1,966 | 116,600 | 180 | 248 |
| AGN SA | 2015-2019 | 3,700 | 187 | 10,055 | 61,001 | 3,078 | 165,856 | 311 | 421 |
| AGN Qld | 2012-2016 | 4,751 | 314 | 11,320 | 61,296 | 4,025 | 145,532 | 399 | 641 |
| Allgas Qld | 2012-2016 | 2,563 | 278 | 8,269 | 45,677 | 4,947 | 147,381 | 499 | 689 |
| AGN Wagga | 2011-2015 | 2,609 | 215 | 5,817 | 41,221 | 3,391 | 91,773 | 389 | 507 |
| JGN | 2014-2018 | 1,887 | 131 | 6,526 | 29,745 | 2,062 | 102,771 | 282 | 371 |
| Evoenergy | 2015-2019 | 1,824 | 109 | 3,325 | 36,537 | 2,157 | 66,181 | 281 | 401 |
| ATCO WA | 2015-2019 | 2,837 | 101 | 5,395 | 42,175 | 1,508 | 80,185 | 125 | 188 |
| Pwrco NZ | 2014-2018 | 1,365 | 114 | 3,090 | 37,223 | 3,110 | 84,260 | 312 | 447 |
| Vector NZ | 2016-2019 | 1,287 | 171 | 2,965 | 24,659 | 3,283 | 56,721 | 333 | 432 |
| **Average** | | 2,086 | 155 | 6,212 | 34,869 | 2,659 | 104,573 | 280 | 395 |

Note: * Average for period indicated. TJ is terajoules, km is kilometres, cust is customers, opex/unit is opex per unit of a comprehensive output index, assets is the regulatory value of fixed assets. All costs in 2010 Australian dollars.

Table 2.2: **Operating and performance indicators, average annual growth rate since earliest year**

| Company | Year/ Period | TJ | Cust. | Km | Cust/ km | TJ/ km | TJ/ cust | Opex/ TJ | Opex/ cust | Opex/ km |
|---|---|---|---|---|---|---|---|---|---|---|
| AGN Albury | 1999-2017 | -0.4 | 2.1 | 2.2 | -0.1 | -2.5 | -2.4 | 1.9 | -0.6 | -0.7 |
| AGN Vic | 1999-2018 | 0.6 | 2.6 | 2.3 | 0.3 | -1.6 | -2.0 | -0.8 | -2.8 | -2.5 |
| Multinet | 1999-2018 | 0.2 | 0.9 | 0.5 | 0.4 | -0.3 | -0.7 | -2.0 | -2.7 | -2.3 |
| AusNet | 1999-2019 | -0.6 | 2.5 | 2.1 | 0.4 | -2.6 | -3.0 | -0.7 | -3.6 | -3.3 |
| AGN SA | 1999-2019 | -0.3 | 1.7 | 1.4 | 0.3 | -1.7 | -2.0 | -1.2 | -3.2 | -2.9 |
| AGN Qld | 1999-2016 | 2.6 | 1.9 | 1.6 | 0.3 | 1.0 | 0.7 | -0.9 | -0.2 | 0.1 |
| Allgas Qld | 2000-2016 | 0.7 | 3.3 | 3.4 | -0.1 | -2.6 | -2.5 | 2.8 | 0.2 | 0.2 |
| AGN Wagga | 1999-2015 | 0.8 | 2.0 | 2.4 | -0.4 | -1.5 | -1.1 | -0.6 | -1.8 | -2.1 |
| JGN | 1999-2018 | -0.7 | 3.3 | 0.8 | 2.5 | -1.5 | -3.9 | -1.8 | -5.6 | -3.2 |
| Evoenergy | 1999-2019 | 1.6 | 3.4 | 1.6 | 1.8 | 0.0 | -1.8 | -1.0 | -2.8 | -1.0 |
| ATCO WA | 2000-2019 | -0.2 | 3.2 | 1.5 | 1.6 | -1.7 | -3.2 | 0.0 | -3.3 | -1.7 |
| Pwrco NZ | 2004-2018 | -0.9 | 0.1 | 0.8 | -0.6 | -1.7 | -1.0 | -1.6 | -2.6 | -3.2 |
| Vector NZ | 2005-2019* | -0.1 | 2.1 | 2.8 | -0.6 | -2.8 | -2.1 | -3.5 | -5.5 | -6.1 |
| **Average** | | 0.3 | 2.2 | 1.8 | 0.5 | -1.5 | -1.9 | -0.7 | -2.6 | -2.2 |

| Company | Year/ Period | Capex/ TJ | Capex/ cust | Capex/ km | Assets/ TJ | Assets/ cust | Assets/ km | Asset cost/ cust | Total cost/ cust |
|---|---|---|---|---|---|---|---|---|---|
| AGN Albury | 1999-2017 | 2.7 | 0.2 | 0.1 | 0.6 | -1.8 | -1.9 | -2.7 | -2.0 |
| AGN Vic | 1999-2018 | 2.5 | 0.5 | 0.9 | 1.7 | -0.3 | 0.1 | 0.2 | -0.8 |
| Multinet | 1999-2018 | 4.4 | 3.6 | 4.0 | 0.0 | -0.7 | -0.3 | -0.3 | -1.0 |
| AusNet | 1999-2019 | 4.4 | 1.3 | 1.7 | 2.7 | -0.3 | 0.1 | -1.2 | -2.1 |
| AGN SA | 1999-2019 | 5.3 | 3.1 | 3.5 | 2.8 | 0.7 | 1.0 | 1.3 | -0.1 |
| AGN Qld | 1999-2016 | 1.3 | 2.0 | 2.3 | 0.9 | 1.6 | 1.9 | 6.1 | 3.0 |
| Allgas Qld | 2000-2016 | 4.5 | 1.5 | 1.6 | 3.2 | 0.6 | 0.5 | 1.1 | 0.9 |
| AGN Wagga | 1999-2015 | 2.1 | 0.9 | 0.5 | 2.6 | 1.4 | 1.0 | 0.6 | 0.0 |
| JGN | 1999-2018 | 3.3 | -0.8 | 1.7 | 2.2 | -1.8 | 0.7 | -2.1 | -3.3 |
| Evoenergy | 1999-2019 | -1.6 | -3.3 | -1.7 | -0.5 | -2.3 | -0.5 | -3.5 | -3.3 |
| ATCO WA | 2000-2019 | 4.3 | 0.9 | 2.6 | 2.6 | -0.8 | 0.9 | -3.8 | -3.6 |
| Pwrco NZ | 2004-2018 | 4.3 | 3.1 | 4.2 | -1.3 | -2.3 | -2.9 | -2.5 | -2.5 |
| Vector NZ | 2005-2019* | 6.6 | 5.3 | 5.8 | 1.5 | -0.7 | -1.3 | -4.1 | -4.7 |
| **Average** | | 3.4 | 1.4 | 2.1 | 1.5 | -0.5 | -0.1 | -0.8 | -1.5 |

Note: TJ is terajoules, km is kilometres, cust is customers, opex/unit is opex per unit of a comprehensive output index, assets is the regulatory value of fixed assets. All costs in 2010 Australian dollars.

Table 2.3: **Average annual indicator growth rate, latest 5 years**

| Company | Year/ Period | TJ | Cust. | Km | Cust/ km | TJ/ km | TJ/ cust | Opex/ TJ | Opex/ cust | Opex/ km |
|---|---|---|---|---|---|---|---|---|---|---|
| AGN Albury | 2012-2017 | -1.3 | 1.7 | 1.7 | -0.1 | -3.0 | -2.9 | 5.3 | 2.2 | 2.2 |
| AGN Vic | 2013-2018 | 2.1 | 2.8 | 1.6 | 1.1 | 0.5 | -0.6 | -1.5 | -2.1 | -1.0 |
| Multinet | 2013-2018 | 0.7 | 0.6 | 0.3 | 0.3 | 0.4 | 0.0 | -7.5 | -7.4 | -7.1 |
| AusNet | 2014-2019 | -0.1 | 2.4 | 2.0 | 0.4 | -2.1 | -2.5 | 1.2 | -1.3 | -0.9 |
| AGN SA | 2014-2019 | -0.9 | 1.4 | 1.0 | 0.4 | -1.9 | -2.3 | -5.7 | -7.8 | -7.4 |
| AGN Qld | 2011-2016 | 1.1 | 2.5 | 1.7 | 0.8 | -0.6 | -1.4 | 3.4 | 1.9 | 2.7 |
| Allgas Qld | 2011-2016 | 0.2 | 3.4 | 1.7 | 1.7 | -1.5 | -3.1 | 3.4 | 0.3 | 1.9 |
| AGN Wagga | 2010-2015 | 0.7 | 1.5 | 2.0 | -0.5 | -1.3 | -0.8 | 0.8 | 0.0 | -0.5 |
| JGN | 2013-2018 | -1.3 | 3.4 | -0.5 | 3.9 | -0.8 | -4.5 | 0.4 | -4.2 | -0.4 |
| Evoenergy | 2014-2019 | 1.1 | 2.9 | 1.3 | 1.6 | -0.2 | -1.8 | 0.7 | -1.1 | 0.5 |
| ATCO WA | 2014-2019 | 0.7 | 1.8 | 1.0 | 0.7 | -0.3 | -1.1 | -0.7 | -1.7 | -1.0 |
| Pwrco NZ | 2013-2018 | -0.1 | 0.9 | 2.3 | -1.4 | -2.3 | -1.0 | -0.2 | -1.1 | -2.5 |
| Vector NZ | 2016-2019 | 1.7 | 2.4 | 1.7 | 0.6 | 0.0 | -0.7 | 4.0 | 3.3 | 4.0 |
| **Average** | | 0.4 | 2.1 | 1.4 | 0.7 | -1.0 | -1.7 | 0.3 | -1.5 | -0.7 |

| Company | Year/ Period | Capex/ TJ | Capex/ cust | Capex/ km | Assets/ TJ | Assets/ cust | Assets/ km | Asset cost/ cust | Total cost/ cust |
|---|---|---|---|---|---|---|---|---|---|
| AGN Albury | 2012-2017 | 17.1 | 13.7 | 13.6 | 1.2 | -1.8 | -1.8 | -6.3 | -3.3 |
| AGN Vic | 2013-2018 | -7.8 | -8.4 | -7.3 | 2.4 | 1.8 | 2.9 | 2.4 | 1.0 |
| Multinet | 2013-2018 | 11.7 | 11.8 | 12.1 | 0.1 | 0.1 | 0.4 | 3.2 | -0.2 |
| AusNet | 2014-2019 | 0.3 | -2.2 | -1.8 | 2.3 | -0.3 | 0.1 | 0.0 | -0.4 |
| AGN SA | 2014-2019 | -0.8 | -3.1 | -2.7 | 4.9 | 2.5 | 2.9 | -3.8 | -4.8 |
| AGN Qld | 2011-2016 | 9.0 | 7.5 | 8.4 | 4.2 | 2.8 | 3.6 | 7.0 | 5.1 |
| Allgas Qld | 2011-2016 | 0.8 | -2.3 | -0.7 | 3.0 | -0.2 | 1.5 | 7.2 | 5.2 |
| AGN Wagga | 2010-2015 | 3.8 | 2.9 | 2.5 | 2.3 | 1.5 | 1.0 | 5.0 | 3.7 |
| JGN | 2013-2018 | 6.5 | 1.7 | 5.7 | 3.9 | -0.8 | 3.1 | -5.2 | -4.9 |
| Evoenergy | 2014-2019 | -12.5 | -14.1 | -12.7 | 1.0 | -0.8 | 0.8 | -8.3 | -6.2 |
| ATCO WA | 2014-2019 | 0.5 | -0.5 | 0.2 | 2.9 | 1.8 | 2.5 | -11.8 | -8.0 |
| Pwrco NZ | 2013-2018 | 12.9 | 11.8 | 10.2 | 0.7 | -0.3 | -1.7 | 1.1 | 0.4 |
| Vector NZ | 2016-2019 | 6.2 | 5.5 | 6.2 | 0.8 | 0.2 | 0.8 | -10.0 | -7.0 |
| **Average** | | 3.7 | 1.9 | 2.6 | 2.3 | 0.5 | 1.2 | -1.5 | -1.5 |

Note: TJ is terajoules, km is kilometres, cust is customers, opex/unit is opex per unit of a comprehensive output index, assets is the regulatory value of fixed assets. All costs in 2010 Australian dollars.

**Table 2.4: Market decomposition, Australian and New Zealand GDBs, average***

| Company | Period | TJ Tariff V | TJ Tariff D | TJ Tariff V % | Cust. Tariff V | Cust. Tariff D |
|---|---|---|---|---|---|---|
| AGN Albury | 2013-2017 | 1,145 | 1,501 | 43.3 | 21,363 | 7 |
| AGN Vic | 2014-2018 | 37,261 | 19,113 | 66.1 | 630,071 | 259 |
| Multinet | 2014-2018 | 44,262 | 11,957 | 78.7 | 692,996 | 282 |
| AusNet | 2015-2019 | 38,268 | 27,423 | 58.3 | 682,637 | 284 |
| AGN SA | 2015-2019 | 10,631 | 11,703 | 47.6 | 442,180 | 119 |
| AGN Qld | 2012-2016 | 2,082 | 3,973 | 34.4 | 92,027 | 73 |
| Allgas Qld | 2012-2016 | 3,110 | 7,000 | 30.8 | 93,293 | 104 |
| AGN Wagga | 2011-2015 | 928 | 681 | 57.7 | 19,539 | 15 |
| JGN | 2014-2018 | 37,459 | 52,338 | 41.7 | 1,293,864 | 405 |
| Evoenergy | 2015-2019 | 7,084 | 1,210 | 85.4 | 140,477 | 40 |
| ATCO WA | 2015-2019 | 15,217 | 11,070 | 57.9 | 734,444 | 75 |
| Pwrco NZ | 2014-2018 | 4,629 | 4,157 | 52.7 | 104,843 | 228 |
| Vector NZ | 2016-2019 | 10,074 | 5,702 | 63.9 | 117,838 | 42 |
| **Average** | | 16,319 | 12,141 | 55.3 | 389,659 | 149 |

| Company | Period | TJ/km Tariff V | TJ/km Tariff D | TJ/cust Tariff V | TJ/cust Tariff D |
|---|---|---|---|---|---|
| AGN Albury | 2013-2017 | 2.91 | 3.81 | 0.054 | 208.444 |
| AGN Vic | 2014-2018 | 3.44 | 1.77 | 0.059 | 73.879 |
| Multinet | 2014-2018 | 4.36 | 1.18 | 0.064 | 42.416 |
| AusNet | 2015-2019 | 3.32 | 2.38 | 0.056 | 96.559 |
| AGN SA | 2015-2019 | 1.29 | 1.43 | 0.024 | 98.512 |
| AGN Qld | 2012-2016 | 0.82 | 1.56 | 0.023 | 54.428 |
| Allgas Qld | 2012-2016 | 0.99 | 2.23 | 0.033 | 67.308 |
| AGN Wagga | 2011-2015 | 1.28 | 0.94 | 0.048 | 45.376 |
| JGN | 2014-2018 | 1.44 | 2.01 | 0.029 | 129.102 |
| Evoenergy | 2015-2019 | 1.55 | 0.26 | 0.050 | 30.561 |
| ATCO WA | 2015-2019 | 1.10 | 0.80 | 0.021 | 147.211 |
| Pwrco NZ | 2014-2018 | 1.19 | 1.07 | 0.044 | 18.248 |
| Vector NZ | 2016-2019 | 1.50 | 0.85 | 0.085 | 134.481 |
| **Average** | | 1.9 | 1.6 | 0.045 | 88.194 |

Note: 'Tariff V' refers to volumetric customers (i.e. residential and small/medium commercial and industrial users); 'Tariff D refers to demand customers (i.e. large industrial users).

# 3 PARTIAL PERFORMANCE INDICATORS

The AER has said the following in relation to electricity distribution, which applies equally to gas distribution:

> *We consider that the most significant output of distributors is customer numbers. The number of customers on a distributor's network will drive the demand on that network. Also, the comparison of inputs per customer is an intuitive measure that reflects the relative efficiency of distributors* (Australian Energy Regulator (AER) 2014, 23).

This section presents information on the inputs per customer of GDBs compared to their network customer densities. Information on GDB inputs per mains km are also compared to their customer densities. By expressing inputs in per customer or per km values and plotting them against customer density, we seek to control for differences in the size and customer densities of GDBs.

The inputs we present information on include real opex, real asset costs, and total costs (the sum of real opex and real asset costs). All of the input, output and customer density measures presented in this section are averages over the five-year period ending 2019 (or latest year). The partial performance indicators we present are:

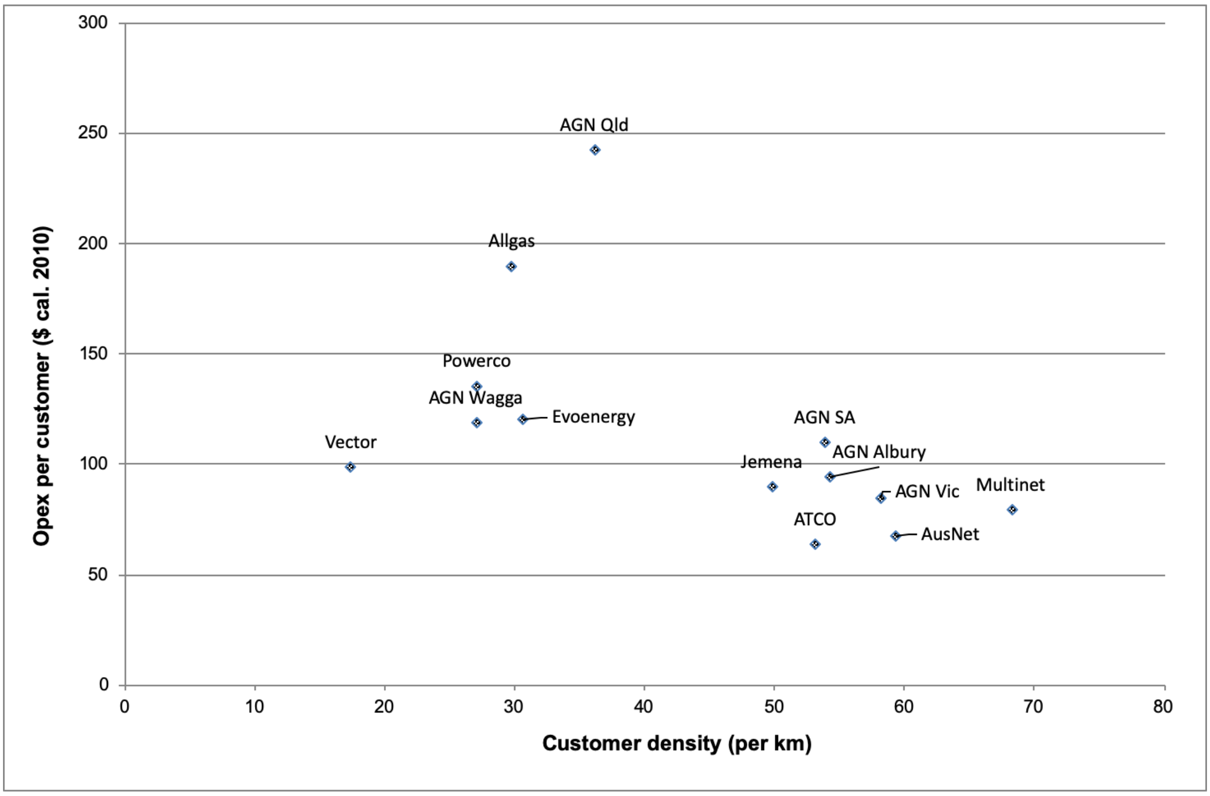
- Opex per customer relative to customer density (Figure 3.1)
- Opex per mains km relative to customer density (Figure 3.2)
- Asset cost per customer relative to customer density (Figure 3.3)
- Asset cost per mains km relative to customer density (Figure 3.4)
- Total cost per customer relative to customer density (Figure 3.5), and
- Total cost per mains km relative to customer density (Figure 3.6).

## 3.1 Opex per customer

Figure 3.1 plots real opex per customer (in $2010) against customer density. GDBs with lower customer density, such as Vector, Powerco, AGN Wagga, Allgas, Evoenergy and AGN Qld, usually have higher opex per customer, although with considerable variation. For example, opex per customer for AGN Qld and Allgas averaged $242 and $190 respectively for the latest five-year period (see Table 2.1). Opex per customer for Powerco, AGN Wagga, Evoenergy and Vector were not as high. Overall, for the six GDBs with lowest customer density, the average opex per customer was $151 for the latest five-year period. Evoenergy's opex per customer averaged $120 over the same period; which is lower than the average for lower density GDBs.

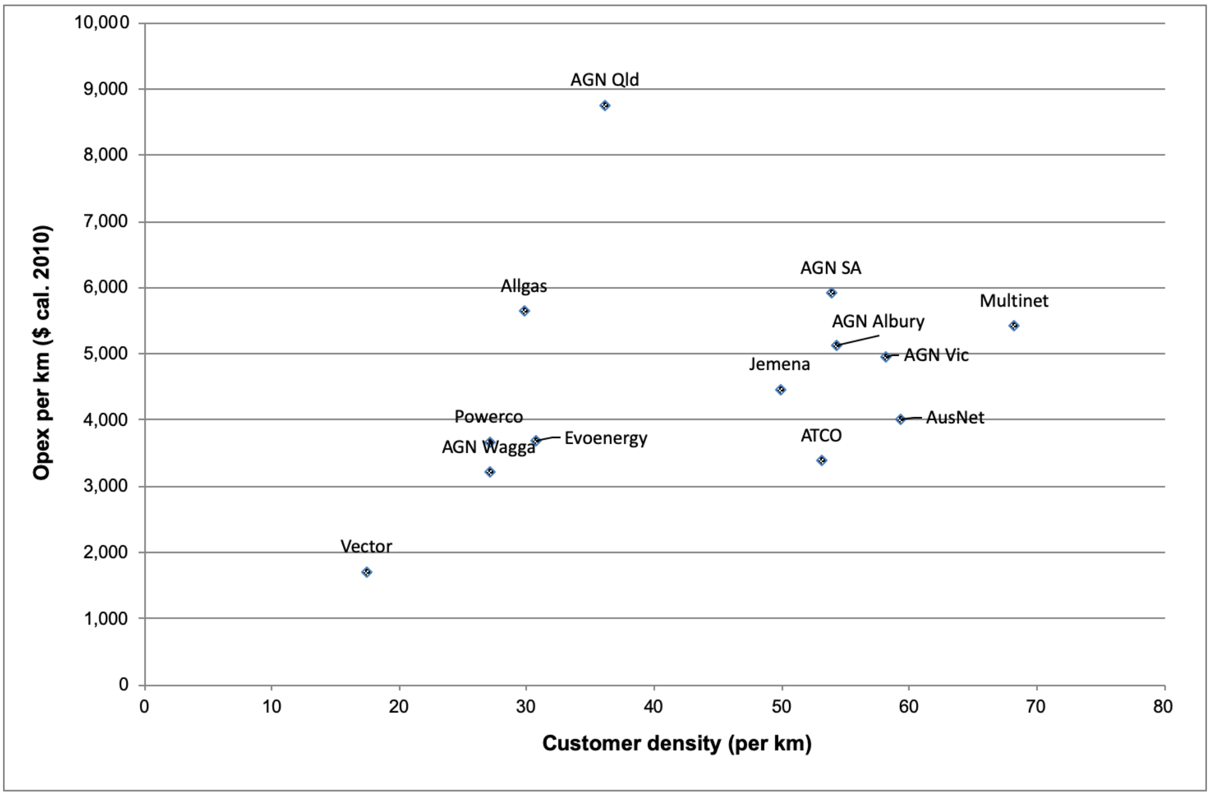
GDBs with higher customer density— such as JGN, AGN SA, ATCO, AGN Vic, AusNet, Multinet and AGN Albury—tend to have lower opex per customer. For example, the average opex per customer of AGN Vic, Multinet and AusNet over the latest five-year period was $85, $80 and $68, respectively. Average opex per customer of Jemena and AGN SA over the latest five-year period was $90 and $110, respectively. ATCO's average opex per customer ($64) was comparatively low among the GDBs with higher customer density. The average opex per customer of the seven GDBs with higher customer density was $84 over the latest five years.

Figure 3.1: **Opex per customer relative to customer density (avg. 2015–2019*)**




* Or latest 5-year period. Source: Economic Insights gas utility database.

Figure 3.2: **Opex per mains km relative to customer density (avg. 2015–2019*)**




* Or latest 5-year period. Source: Economic Insights gas utility database.

Figure 3.2 plots real opex per mains km against customer density. Among the seven GDBs with higher customer density, the average opex per km was $4,755 over the latest five years. The average opex per km for the six GDBs with relatively low customer density was $4,449 over the latest five years, which is slightly lower than for the GDBs with higher customer density. There is a very wide variation in opex per km among the GDBs with relatively low customer density. Although opex per km appears to increase with customer density, there is too much variation between the GDBs to be able to draw that conclusion firmly. Evoenergy's opex per km was $3,685 over the same period, which is below the average for the group of GDBs with lower customer density; and below the sample average of $4,613 for the latest five years.

Evoenergy's average opex per customer, and its average opex per km, are below the average for GDBs with relatively low customer density. It should be noted a comparison of this kind does not control for other drivers of opex costs that may be relevant, and only qualified conclusions can be drawn from it.

## 3.2 Capital assets cost per customer

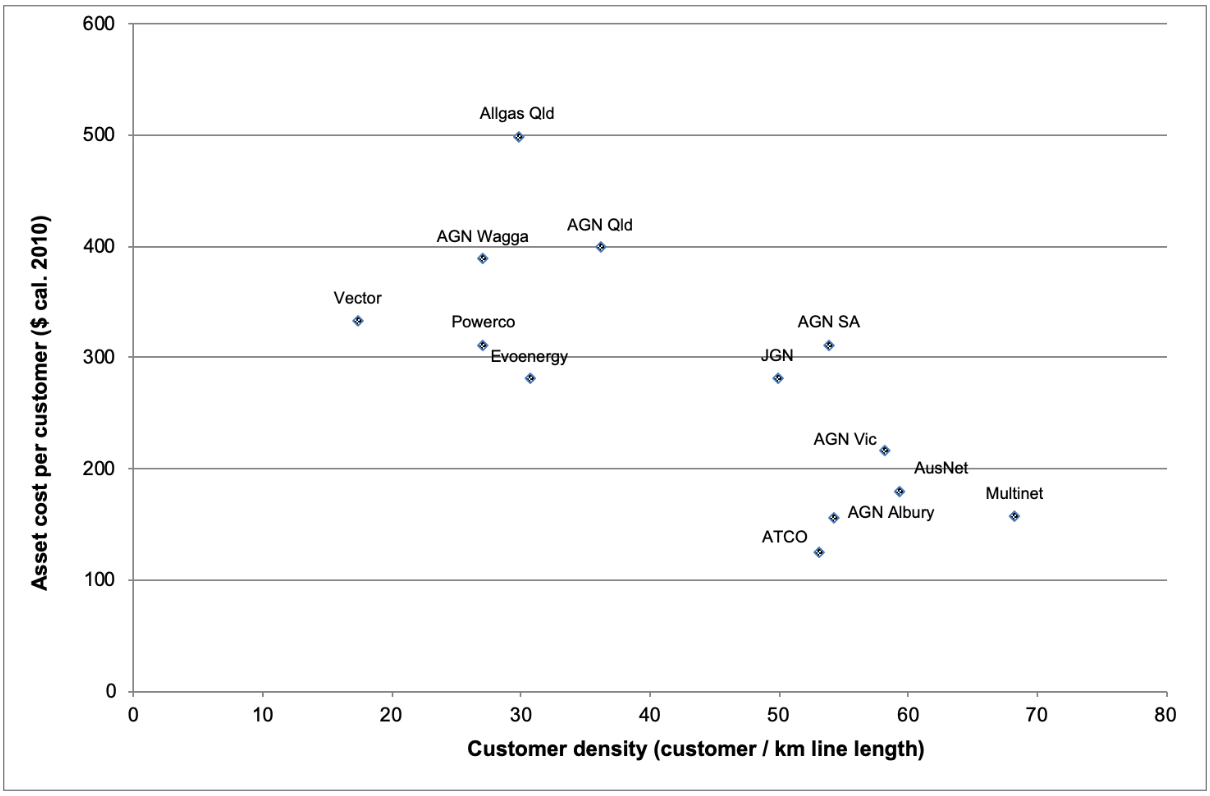
The efficiency of the use of capital inputs is indicated by asset cost per customer, which is based on actual returns to capital rather than a measure based on the opportunity cost of capital and depreciation cost, as used by the AER, because insufficient information is available from public sources to derive a measure based on the latter approach (AER, 2013).

Figure 3.3 plots the average asset cost per customer (in $2010) against average customer density in the period 2015 to 2019 (or latest five-year period available), where asset cost is measured by the actual return to and return of capital (or gross return including depreciation). The chart shows that GDBs with lower customer density tend to have higher asset cost per customer than the GDBs with higher customer density. The asset cost per customer of GDBs with lower customer density averages $369, compared to $204 for GDBs with higher customer density. Evoenergy's asset cost per customer was $281 in this period. This is below the average asset cost per customer for the six GDBs with comparatively low customer density, which was $204 over the latest five-year period. Evoenergy's asset cost per customer is close to the sample average of $280. Among the GDBs with higher customer density, ATCO's asset cost per customer of $125 is particularly low compared to the other GDBs. The asset costs per customer of the three Victorian GDBs are $157 for Multinet, $180 for AusNet and $217 for AGN Vic. Similarly, AGN Albury's asset cost per customer averaged $157. AGN SA's average asset costs per customer is $311, and Jemena's is $282.

Figure 3.4 shows average asset cost per km of mains for the latest five-year period for each GDB, plotted against customer density. There is no apparent relationship between assets cost per km and customer density. Evoenergy's average asset cost per km was $8,581 over the latest five years, which is comparatively low when compared to the average for all GDBs shown (i.e. $10,965). The average for the GDBs with lower customer density ($10,448) is broadly similar to that for the GDBs with higher customer density ($11,408).

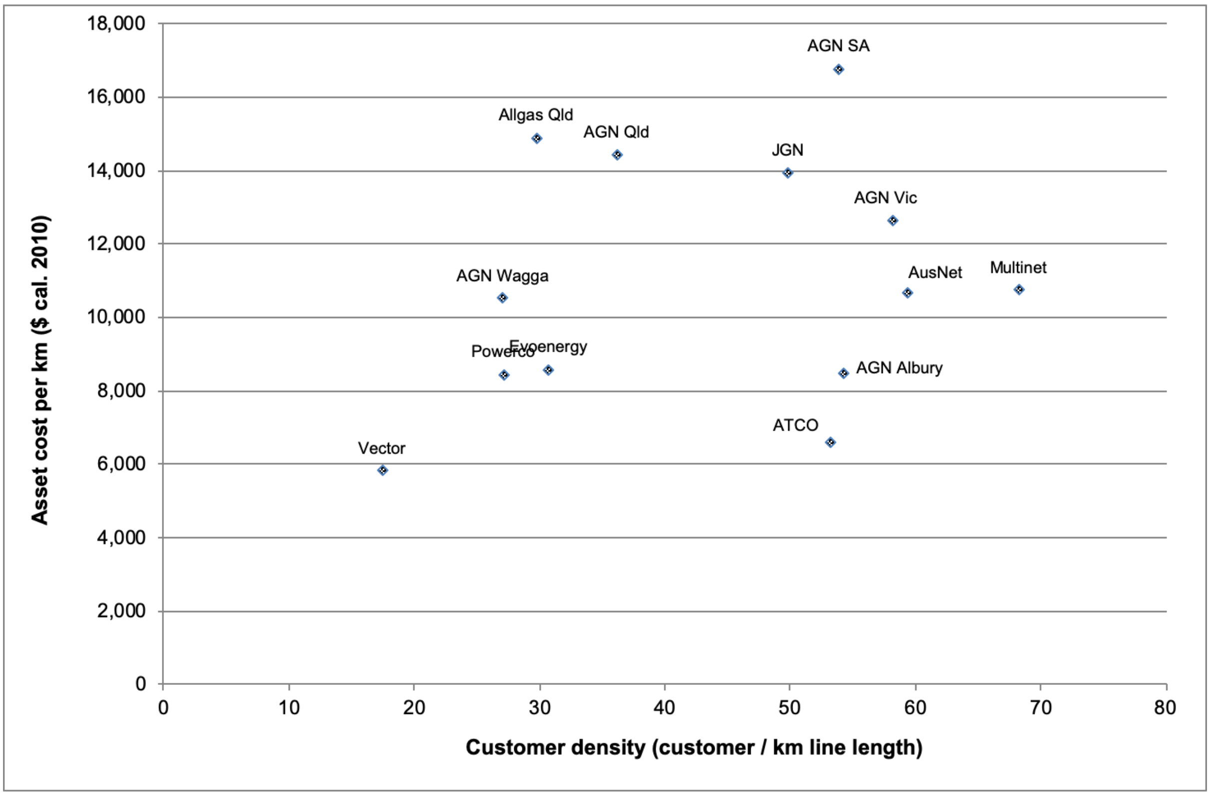
These comparisons are influenced, among other things, by asset age, original network asset valuations, and various factors not controlled-for which influence the quantity of assets per customer, and hence asset cost per customer. Thus, only qualified conclusions can be drawn from this chart. It suggests that Evoenergy has below-average asset cost per customer.

Figure 3.3: **Asset cost per customer relative to customer density (avg. 2015–2019*)**




* Or latest 5-year period. Asset cost is defined as real revenue minus real opex. Source: Economic Insights gas utility database.

Figure 3.4: **Asset cost per mains km relative to customer density (avg. 2015–2019*)**




* Or latest 5-year period. Asset cost is defined as real revenue minus real opex. Source: Economic Insights gas utility database.

## 3.3 Overall cost efficiency

Figure 3.5 plots total cost per customer against customer density, where total cost is the sum of opex and asset cost shown in Figures 3.1 and 3.3 respectively. This chart shows the very clear relationship between cost per customer and customer density. The average total cost per customer of Evoenergy in the period 2015 to 2019 was $401, which is the lowest among the GDBs with comparatively low customer density; and is most comparable to Vector ($432) and Powerco ($447). The other low customer density GDBs had considerably higher total cost per customer; AGN Wagga ($507), AGN Queensland ($641) and Allgas ($689). The total costs per customer for GDBs with lower customer density averaged $520 over the latest five years.

The GDBs with relatively high customer density typically had lower levels of total cost per customer over the latest five-year period. For example, Multinet ($237); AGN Albury ($251); AusNet ($248); AGN Vic ($302); and ATCO ($188). Evoenergy's total cost per customer is comparable to JGN ($371) and AGN SA ($421) in this group. For the seven GDBs with higher customer density, the average total cost per customer was $288. Evoenergy is close to the sample average of $395.

Figure 3.6 shows total cost per km of mains plotted against customer density. Although total cost per km appears to increase slightly with customer density, there is considerable variation among the GDBs. Several low density GDBs have relatively low total cost per km including Vector ($7,530), Powerco ($12,114), AGN Wagga ($13,734), and Evoenergy is among these with an average total cost of $12,266 per km. Some GDBs with relatively high customer density have low total cost per km, including ATCO ($10,001) and AGN Albury ($13,620). The Victorian GDBs have intermediate levels of total cost per km (AusNet, $14,691; Multinet, $16,163; and AGN Vic, $17,577). Some of the low density GDBs such as Allgas and AGN Queensland, and some of the higher density GDBs such as Jemena and AGN SA, have comparatively higher total cost per km (Allgas, $20,547; AGN Qld, $23,193; Jemena, $18,398; and AGN SA, $22,691).

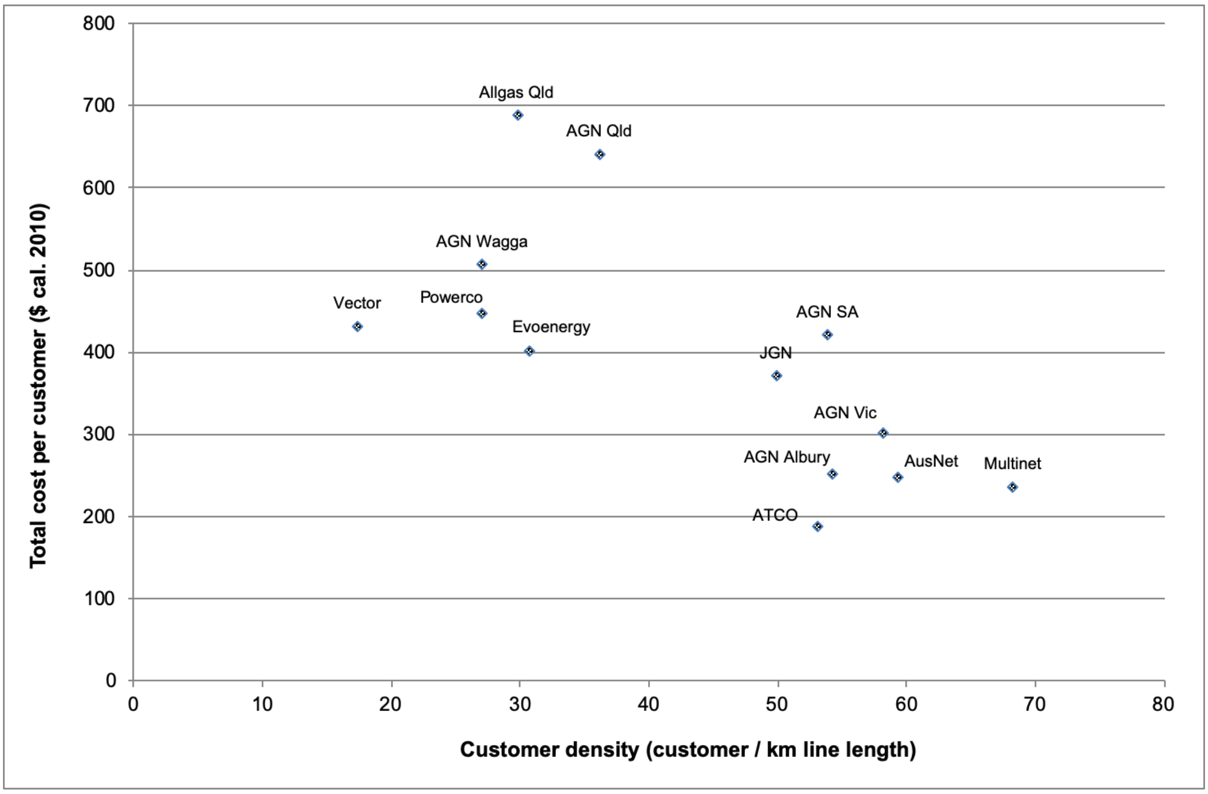
Once again, caution is needed in drawing strong conclusions for these comparisons alone. That said, the results tend to indicate that Evoenergy has below average total cost per customer among the GDBs with relatively low customer density.

## 3.4 Normalising opex per customer

Figure 3.1 shows a clear relationship between opex per customer and customer density (i.e. customers per km of mains). Figure 3.7 shows that there is also a relationship between opex per customer and scale as measured by customer numbers. Evoenergy is significantly smaller in terms of customer numbers than the six largest GDBs, and this could be another contributing factor to its higher opex cost per customer compared to the larger GDBs, shown in Figure 3.1.

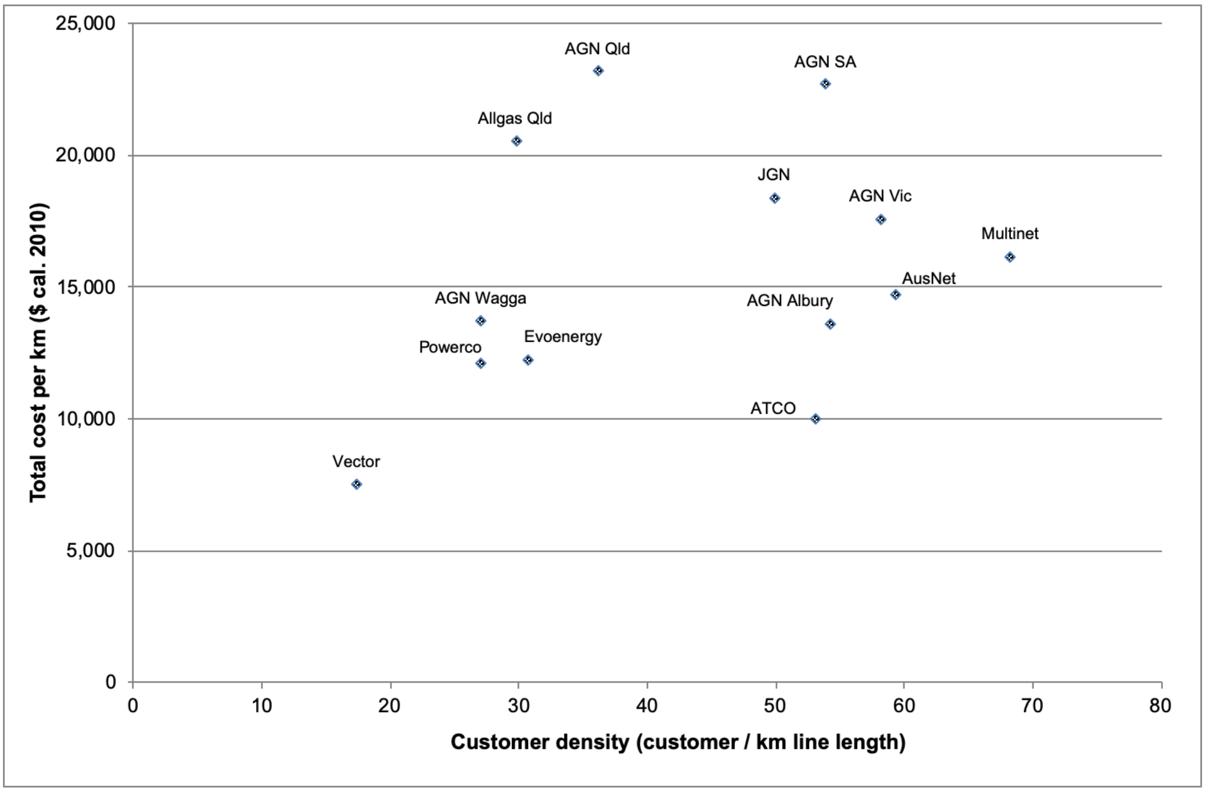
One way of adjusting for the effects of customer density and scale is to use the econometric modelling presented in Part C of this report. In the preferred model, shown in Table 8.2, log real opex is a function of several explanatory variables including log values of customer numbers, mains length, capital stock and a time variable. Normalisation is carried out in relation to the first three of these explanatory variables.

Figure 3.5: **Total cost per customer relative to customer density (avg. 2015–2019*)**



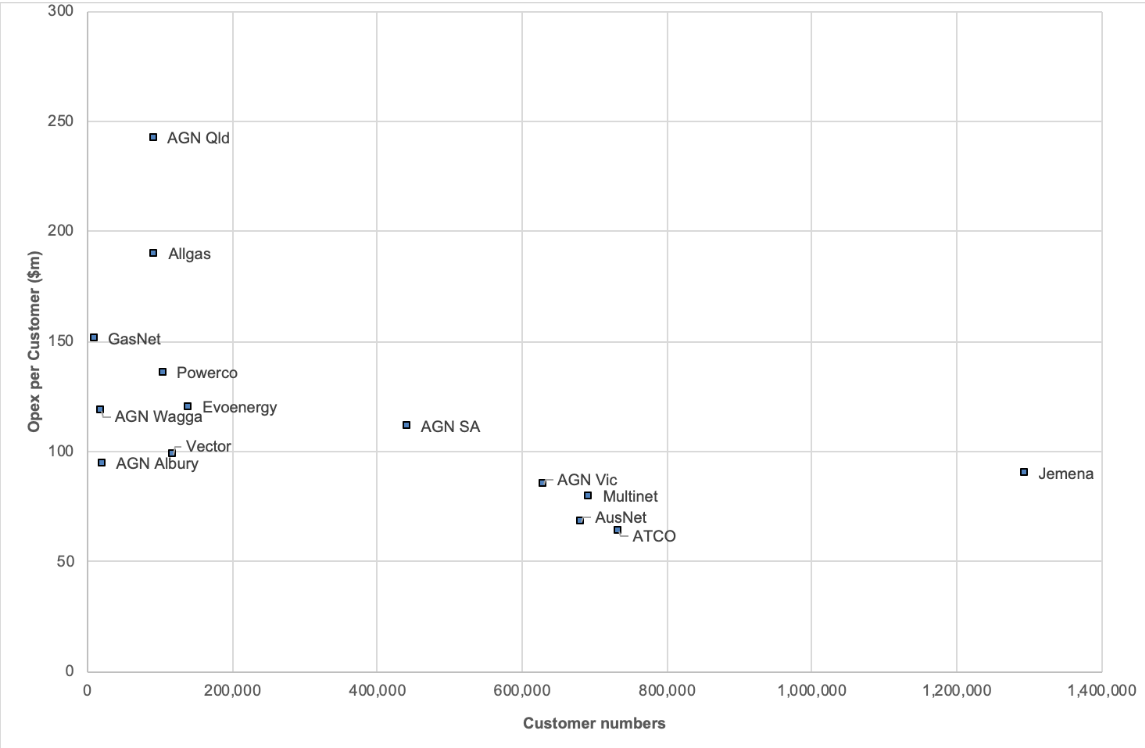

* Or latest 5-year period. Source: Economic Insights gas utility database

Figure 3.6: **Total cost per mains km relative to customer density (avg. 2015–2019*)**




* Or latest 5-year period. Source: Economic Insights gas utility database

Figure 3.7: **Opex per Customer relative to Scale (2015-2019*)**




There are two regression models shown in Table 8.2. Both generate very similar results for normalisation, and Figure 3.8 shows the average results for the two models after normalising real opex per customer for the last five years of data for each GDB. Figure 3.8 shows that Evoenergy's normalised real opex per customer is approximately equal to the sample average.[4]

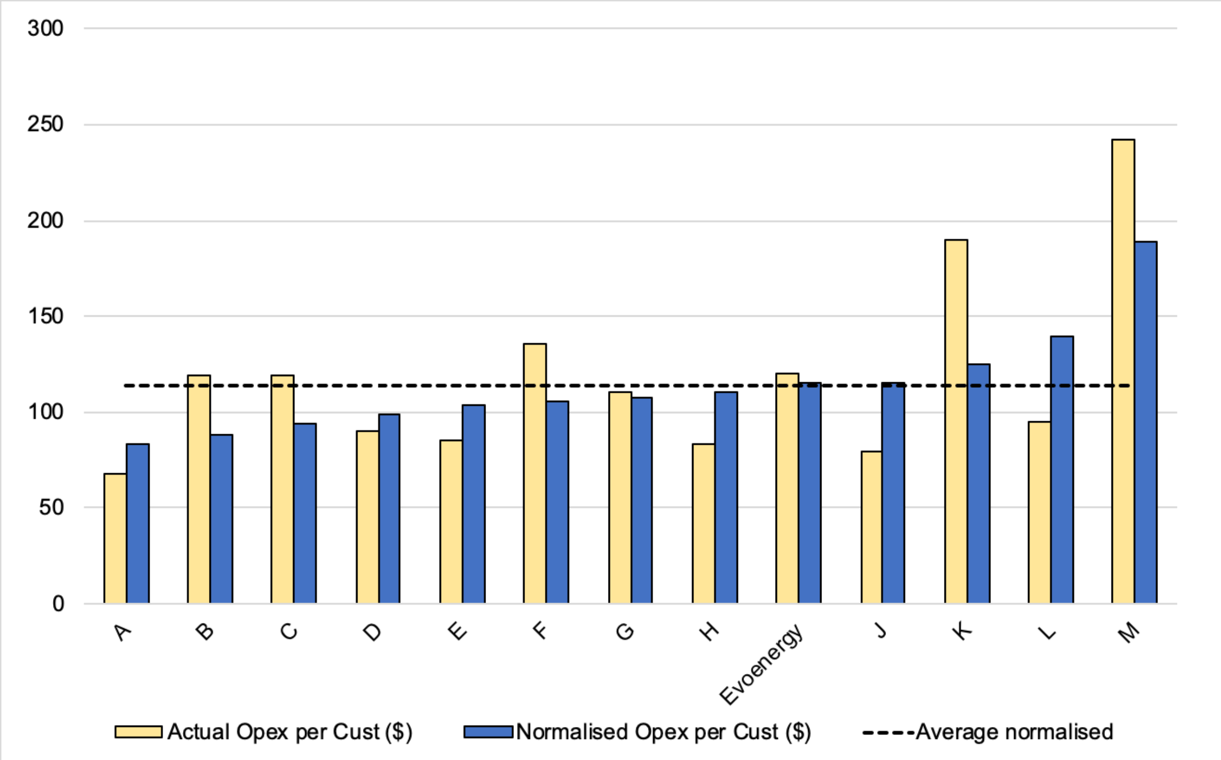
## 3.5 Summary

Evoenergy's operating environment characteristics can be summarised as follows:

- Evoenergy is the seventh largest GDB in the sample in terms of customer numbers; the eighth largest in terms of network length; and the 10th largest in terms of gas throughput. It is comparable in size to the two New Zealand GDBs, Powerco and Vector, and to the two Queensland GDBs, AGN Qld and Allgas.
- Evoenergy is among six GDBs in the sample that have comparatively low customer density. These are also mostly the smaller sized GDBs. Evoenergy's customer density is comparable to AGN Qld, Allgas, Powerco and AGN Wagga.
- Evoenergy's energy density per customer is the third lowest in the sample (only ATCO and AGN SA are lower). The most comparable GDBs in terms of energy density are AGN SA, AGN Qld and Jemena.

[4] The formula used for normalising the dependent variable is: $NRO = \exp(y^n) \,/\, \overline{cust}$, where: $y^n$ is the normalised dependent variable, obtained using: $y^n = y + \sum_k(\bar{x}_k - x_k)$, where the x variables are as discussed.

Figure 3.8: **Normalised Opex per Customer (2015-2019*)**




- Evoenergy has the lowest energy deliveries per km, or 'network utilisation', among all the GDBs in the sample. GDBs with comparable rates of network utilisation include ATCO, AGN Wagga, Vector and Powerco.

Evoenergy's comparative performance in terms of partial indicators is as follows:

- Evoenergy's average opex per customer (in $2010) over the latest five-year period was $120, which was well below the average opex per customer for the six GDBs with lowest customer density ($151). The seven GDBs with higher customer density tended to have lower opex per customer.
- Evoenergy's opex per km of mains was $3,685 over the latest five-year period, which is lower than the average of for the GDBs with comparatively low customer density ($4,449 for the latest five-years). The average opex per km for GDBs with higher customer densities was similar to the average for those with lower customer density.
- Evoenergy's capital asset cost per customer averaged $281 in the latest five-year period. This is similar to the sample average of $280. It is well below the average asset cost per customer of $369 for the group of GDBs with lower customer density. Evoenergy's capital asset cost per customer is the lowest in that group. The seven GDBs with higher customer density tended to have lower capital asset cost per customer than those with lower customer density.
- Evoenergy's average asset cost per km was $8,581 over the latest five years, which is comparatively low when compared to the average for all GDBs ($10,965) or to the average for of GDBs with lower customer density ($10,448).

- The average total cost per customer of Evoenergy in the latest five-year period was $401. This is below the average total cost per customer for the six GDBs with comparatively low customer density ($520). Evoenergy's total cost per customer is the lowest in that group. The seven GDBs with higher customer density tended to have lower total cost per customer. Nevertheless, Evoenergy's average total cost per customer is similar to the sample average of $395.
- Evoenergy's average total cost per km of mains ($12,266 in the latest five-year period) was below the average total cost per km for the GDBs with comparatively low customer density ($14,897). The average opex per km for GDBs with higher customer densities was similar to the average for those with lower customer density. Evoenergy's average total cost per km of mains was also below the sample average of $15,579.

The partial indicators analysis presented in this report do not enable influences such as scale economies or different mixes of inputs to be controlled for in a rigorous fashion. This means that care needs to be taken when drawing inferences. Based on these indicators, Evoenergy appears to have performed better than the average for GDBs with relatively low customer density, on all measures; and similar to the average for the sample as a whole. An exercise in normalising opex per customer for some of the main determinants of real opex, based on the econometric analysis in Part C, supports the conclusion that Evoenergy's normalised real opex per customer is similar to the sample average.

# PART B: PRODUCTIVITY INDEXES

This part of the study concentrates on the total and partial factor productivity performance of Evoenergy's gas distribution business for the period from 1999 to 2019. Measures of TFP and PFP are formed in this part of the report using time series and multilateral indexes. These are used to compare Evoenergy's productivity growth rates and productivity levels, respectively, with those of other GDBs in NSW, Victoria, South Australia, Western Australia and Queensland.

The primary data source for this part of the study is information supplied by Evoenergy in response to a detailed data survey, covering key output and input value, price and quantity information for financial years 1999 to 2019. Similar data was provided for this study by other GDBs; specifically, Jemena Gas Networks (JGN) in NSW; Australian Gas Infrastructure Group (AGIG) in relation to the Australian Gas Networks Limited (AGN) South Australian, Victorian and Queensland gas networks, as well as Multinet Gas in Victoria; ATCO Gas Australia in Western Australia; and AusNet in Victoria. The surveys completed by AusNet and AGN SA, cover the years 1999 to 2019, ATCO's covers the period 2000 to 2019. The surveys completed by JGN, AGN Vic and Multinet cover the years 1999 to 2018. A previously completed survey by AGN for its Queensland gas network ('AGN Qld') covers the period 1999 to 2014. Background to the measurement of total factor productivity (TFP) and partial factor productivity (PFP), as well as measurement issues, details of the variables used in productivity measurement, and descriptive information about the GDBs included in this part of the study, are presented in chapter 4.

The TFP (time series) index analysis in chapter 5 involves forming indexes of outputs and inputs using the Fisher index method. These indexes provide the best measures of the relative changes over time of aggregate inputs, aggregated outputs and TFP for each GDB. However, they cannot be used to compare productivity *levels* between GDBs. The analysis includes three outputs (throughput, customer numbers and system capacity) and eight inputs (opex, lengths of transmission pipelines, high pressure pipelines, medium pressure pipelines, low pressure pipelines, and services, meters and other capital). This specification is broadly consistent with the analogous preferred electricity distribution output and input specification presented in AER (2013). The time series TFP indexes use the first year of data (typically 1999) as the base–year for each individual GDB, and the analysis provides estimates of TFP growth over the period 1999 to 2019 (or latest year) as well as PFP growth for the GDBs. PFP is a partial measure of productivity in which the output index is divided by the quantity of one of the inputs. These measures are useful for understanding trends in TFP.

Multilateral TFP (or MTFP) analysis is presented in chapter 6. Multilateral TFP is a method of measuring the TFP levels of all the GDBs in the sample using a common base and a more complex indexing method. This indexing method allows the TFP levels of different GDBs to be compared against each other. It yields less precise measures of TFP change over time than the Fisher index method used in chapter 5, so the MTFP indexes are only used for comparing TFP levels of GDBs in this report. In this part of the analysis (in chapter 6), transmission pipelines are excluded to allow more like–with–like comparisons across GDBs.

There have been several studies undertaken previously of gas pipeline efficiency performance in Australasia. The earlier studies tended to benchmark selected Australian gas utilities against a sample of overseas gas utilities. These included Bureau of Industry Economics (BIE 1994), Independent Pricing and Regulatory Tribunal (IPART 1999), and Pacific Economics Group (PEG 2001a; 2001b; 2001c). The BIE and IPART studies used data envelopment analysis (DEA) although IPART also tested other methodologies. The IPART study concluded that the Australian GDBs were behind international best practice. The PEG studies were an econometric analysis of opex costs. They concluded that the Victorian GDBs had lower opex than predicted given their scale and operating environment conditions, implying that their opex efficiency was better than the average of the included US comparators.

The productivity index methodologies used in this study were developed in studies by Lawrence in 2004 for the New Zealand Commerce Commission (Denis Lawrence 2004a; 2004b), and in 2007 on behalf of the three Victorian GDBs (Denis Lawrence 2007). The 2004 studies involved a trend analysis of New Zealand gas businesses' TFP, and also used the multilateral TFP index method to examine productivity levels. The 2007 study developed a measure of system capacity to supplement the standard output measures of throughput and customer numbers, and included seven capital input components and presented a range of sensitivity analyses of alternative output and input specifications to assess the influence of specification changes on the results. Subsequently, PEG (2008) carried out a study of TFP trends for Victoria's GDBs on behalf of the Essential Service Commission which has also informed the methods used here.

Economic Insights has since carried out a number of productivity studies on behalf of gas distribution businesses, including for Jemena Gas Networks (JGN) (Economic Insights 2009a; 2015a; 2019b), for Envestra South Australia and Queensland (Economic Insights 2010), and AGN South Australia (Economic Insights 2015c), and several studies for the three Victorian GDBs (Economic Insights 2012b; 2016b).

# 4 PRODUCTIVITY BENCHMARKING

This chapter briefly outlines the basics of TFP and why it is of interest to regulators. It then discusses a number of key measurement issues affecting outputs, inputs and describes the data used in the study and the definitions of outputs and inputs. Finally, it provides some descriptive information relating to the comparator gas distribution businesses included in the analysis.

## 4.1 Productivity Measurement and Benchmarking

Productivity is a measure of the physical output produced from the use of a given quantity of inputs. All enterprises use a range of inputs including labour, capital, land, fuel, materials and services. If the enterprise is not using its inputs as efficiently as possible then there is scope to lower costs through productivity improvements and, hence, lower the prices charged to consumers. This may come about through the use of better quality inputs including a better trained workforce, adoption of technological advances, removal of restrictive work practices and other forms of waste, and better management through a more efficient organisational and institutional structure. When there is scope to improve productivity, this implies there is technical inefficiency. This is not the only source of economic inefficiency. For example, when a different mix of inputs can produce the same output more cheaply, given the prevailing set of inputs prices, there is allocative inefficiency.

Productivity is measured by expressing output as a ratio of inputs used. There are two types of productivity measures: total factor productivity (TFP) and partial factor productivity (PFP). TFP measures total output relative to an index of all inputs used. Output can be increased by using more inputs, making better use of the current level of inputs and by exploiting economies of scale. The TFP index measures the impact of all the factors affecting growth in output other than changes in input levels. PFP measures one or more outputs relative to one particular input (eg labour productivity is the ratio of output to labour input).

Total factor productivity is measured by the ratio of an index of all outputs (Q) to an index of all inputs (I):

(1) $$TFP = Q/I$$

The rate of change in TFP between two periods is measured by

(2) $$T\dot{F}P = \dot{Q} - \dot{I}$$

where a dot above a variable represents the rate of change of the variable.[5] In this study the partial productivity of factor *i* is defined as:

[5] This measure of the change in TFP in terms of the difference between the growth rates of outputs and inputs is known as the Hicks-Moorsteen approach. Alternative methods are based on changes in profitability with adjustment for changes in input and output prices, or on changes in measures of technical efficiency (see: Coelli et al. 2005, 64–65).

(3) $$PFP_i = Q/I_i$$

where $I_i$ is the quantity used of factor *i*. The PFP can be measured with respect to *any* single factor type. It is not a holistic measure, like TFP, but PFP measures can be useful for gaining a better understating of the trends observed in TFP.

TFP indexes have a number of advantages including:

- indexing procedures are simple and robust;
- they can be implemented when there are only a small number of observations;
- the results are readily reproducible;
- they have a rigorous grounding in economic theory;
- the procedure imposes good disciplines regarding data consistency; and
- they maximise transparency in the early stages of analysis by making data errors and inconsistencies easier to spot than using some of the alternative econometric techniques.

As noted in Lawrence (1992), by providing a means of comparing efficiency levels, TFP measurement is an ideal tool for promoting so-called 'yardstick competition' in non-competitive industries. It provides managers with useful information on how their business is performing overall and on how it is performing relative to its peers. TFP measurement, thus, provides a ready means of 'benchmarking' the business's overall performance relative to other businesses supplying similar outputs.

Forecast future productivity growth rates can play a key role in setting the annual revenue requirement used in building blocks regulation. Productivity studies provide a means of benchmarking GDB performance to assist the regulator in determining whether the GDB in question is operating at efficient cost levels. They also assist the regulator in determining possible future rates of productivity growth to build into annual revenue requirement forecasts.

## 4.2 Measurement Issues

To measure productivity performance we require data on the price and quantity of each output and input, and data on key operating environment conditions. We require quantity data because productivity is essentially a weighted average of the change in output quantities divided by a weighted average of the change in input quantities. Although the weights are complex and vary depending on the technique used, for outputs they are derived from the share of each output in total revenue or, alternatively, from output cost shares and for inputs from the share of each input in total costs. To derive the revenue and cost shares we require information on the value of each output and input, i.e. its price times its quantity. Hence, we require either the price and quantity of each output and input or, alternatively, their values and quantities, or their values and prices. To derive output cost shares we require additional information on how cost drivers link to output components. This is usually derived from estimation of econometric cost functions.

In a sense the quantity data are the primary drivers of productivity results while the value or price data are secondary drivers in that they are used to determine the weights for aggregation. Quantity information can be obtained either directly or indirectly. Direct quantity data are physical measures of a particular output or input, e.g. terajoules of throughput or full-time equivalent employees. Indirect quantity data are obtained by deflating the revenue or cost of a particular output or input by an average price or a price index. There are arguments in favour of both methods. Some argue that the indirect method allows greater differences in the quality of outputs or inputs to be captured and for a greater range of items to be captured within the one measure (e.g. a greater extent of automation reflected in a higher capital value). However, the indirect method places more onus on having both the value and the price data completely accurate. Since price data are generally harder to match to the specific circumstances of a particular firm, there is more scope for error with the indirect method. Hence, it is a good policy to rely on direct quantity data wherever possible and to only use indirect quantity data in those cases where the category is too diverse to be accurately represented by a single quantity (e.g. materials and services inputs).

In common with other network infrastructure industries, measuring the performance of gas pipelines presents a number of challenges. In the following section we examine a number of difficult measurement issues including how to define GDB outputs and inputs and the likely impact of operating environment conditions.

### *4.2.1 Measuring GDB outputs*

Early energy supply productivity studies simply measured output by system throughput. However, this simple measure ignores important aspects of what pipelines really do. To capture the multiple dimensions of electricity network output, Lawrence (2003) used three outputs: throughput, system line capacity and connection numbers. A similar output specification is appropriate for gas distribution given their functional similarity to electricity networks. Lawrence (2007) developed a capacity output measure for the three Victorian GDBs using detailed data on lengths, diameters and pressures of different mains types for each GDB.

To aggregate the outputs into a total output index using indexing procedures, we have to allocate a weight to each output. It is long established that the use of revenue share weights in the output index will only be consistent with measuring production efficiency growth if prices are proportionate to marginal costs, a condition of cost minimization (Denny, Fuss, and Waverman 1981; Fuss and Waverman 2002). Economic Insights (2009b) has shown that when the increasing returns to scale nature of energy networks and the role of sunk cost assets are taken into account, allocative efficiency requires that all functional outputs (of which billable outputs will be a subset) be included and the deviation of market prices from marginal costs be allowed for. One way of doing this using econometrics is to use the relative shares of cost elasticities derived from an econometric cost function. This approach is often used in industries not subject to high levels of competition because the cost elasticity shares reflect the marginal cost of providing an output and this is the approach we adopt in this study.

### *4.2.2 Measuring GDB inputs*

Previous studies of pipeline productivity have typically used two or three input categories. For instance, BIE (1994) used labour numbers, kilometres of distribution main and kilometres of transmission main. No allowance was made for materials and services inputs due to lack of data at that time. IPART (1999) used operating expenditure and kilometres of main as its two inputs. Differences in the levels of contracting out between utilities made obtaining labour data problematic either due to its unavailability or lack of comparability. PEG (2001) used a three input specification with labour, other operating expenditure and capital inputs. As labour data is not available for most Australian GDBs and the extent of contracting out makes such a measure problematic, in this study labour inputs are subsumed within operating expenditure.

There are a number of different approaches to measuring both the quantity and cost of capital inputs. The quantity of capital inputs can be measured either directly in quantity terms (eg, using pipeline length measures) or indirectly using a constant dollar measure of the value of assets. Similarly, the annual cost of using capital inputs can be measured either directly by applying the sum of an estimated depreciation rate and a rate reflecting the opportunity cost of capital to the regulatory asset base (RAB) or indirectly as the residual of revenue less operating costs.

Some analysts have argued that measuring the quantity of capital by the deflated asset value method provides a better estimate of total input as it better reflects the quality of capital and can include all capital items, not just pipelines. There are two potential problems with this approach. Firstly, it is better suited to more mature systems where the asset valuations are very consistent over time and across organisations. In Victoria and NSW there has been only one full asset valuation done in each state. In the case of Victoria, these asset values were further 'adjusted' before privatisation for political considerations and so, while the adjusted values form the basis of the current regulatory asset base, they are inappropriate for comparing capital input quantities.

The second problem with basing capital quantities on constant price asset value measures is that they usually incorporate some variant of the straight line approach to measuring depreciation. Gas pipeline assets tend to be long lived and produce a relatively constant flow of services over their lifetime. Consequently, their true depreciation profile is more likely to reflect the 'one hoss shay' or 'light bulb' assumption than that of a straight line approach. That is, they produce the same service each year of their life and until the end of their specified life rather than producing a given amount less service every year. In these circumstances it may be better to proxy the quantity of capital input by the physical quantity of the principal assets. This approach is also invariant to different depreciation profiles that may have been used by different pipeline businesses.

The direct approach to measuring capital costs involves explicitly calculating the return of and return on capital to reflect depreciation and the opportunity cost of capital. The indirect approach of allocating a residual or ex post cost to capital of the difference between revenue and operating costs has been favoured by some regulatory agencies, and is the approach used in PEG (2006). Given that the implicit rates of return in the Economic Insights GDB database are relatively stable and broadly similar in magnitude, and the focus of this study is on productivity performance, we use the indirect approach here for simplicity. We note this differs from the amortisation approach when the effect of sunk costs and financial capital maintenance are fully allowed for as in Economic Insights (2009b) but it will provide a close approximation in this case.

### *4.2.3 Normalisation for operating environment conditions*

Operating environment conditions can have a significant impact on distribution costs and productivity and in many cases are beyond the control of managers. Consequently, to ensure reasonably like-with-like comparisons it is desirable to 'normalise' for at least the most important operating environment differences. Likely candidates for normalisation include energy density (energy delivered per customer), customer density (customers per kilometre of main), customer mix, the proportion of cast iron pipes and climatic and geographic conditions.

Energy density and customer density are generally found to be the two most important operating environment variables in energy distribution normalisation studies (see: Denis Lawrence 2003) Being able to deliver more energy to each customer means that a GDB will usually require less inputs to deliver a given volume of gas, or deliver a greater volume for the same investment in pipelines. A GDB with lower customer density will require more pipeline length to reach its customers than will a GDB with higher customer density, making the lower density distributor appear less efficient unless the differing densities are allowed for.

Most energy distribution studies incorporate density variables by ensuring that the three main output components – throughput, system capacity and customers – are all explicitly included. This means that distribution businesses that have low customer density, for instance, receive credit for their longer line lengths whereas this would not be the case if output was measured by only one output such as throughput.

## 4.3 Data used

The primary data source for this study is information supplied by AGN, ATCO, AusNet, Evoenergy, JGN and Multinet in relation to each of their gas distribution networks in response to common detailed data surveys, covering key output and input value, price and quantity information for the period 1999 to 2019 (or to 2018 in some instances). Similar data was provided in previous years by AGN in relation to its Queensland gas network for the period 1999 to 2014. No forecast data are used for any of the included GDBs.

### *4.3.1 Output quantities and weights*

The outputs produced by GDBs are defined in this study as:

1) **Throughput**: The quantity of the GDB's throughput is measured by the number of terajoules of gas supplied. It is the sum of energy supplied to all customer segments: residential, commercial and large industrial customers.

2) **Customers**: Connection dependent and customer service activities are proxied by the GDB's number of customers.

3) **System capacity**: Gas distribution networks have three primary functions: delivery of gas from supply point to demand point; the interim storage of gas to make available sufficient gas during peak periods; and, the performance of these functions safely and efficiently. We include a measure of system capacity to capture the GDB's functional responsibility of making capacity available to meet the needs of customers. The measure we require is somewhat analogous to the MVA–kilometre system capacity measure used in electricity

DB TFP studies (see, for example, Lawrence 2003a) but, in this case, it needs to also capture the interim storage function of pipelines.

The system capacity measure used in this study is that developed in Lawrence (2007) which is the volume of gas held within a gas network converted to standard cubic meters using a pressure correction factor based on the average operating pressure. The volume of the distribution network is calculated based on pipeline length data for high, medium and low distribution pipelines and estimates of the average diameter of each of these pipeline types, which differ between networks. The quantity of gas contained in the system is a function of operating pressure. Thus, a conversion to an equivalent measure using a pressure correction factor is necessary to allow for networks' different operating pressures. These conversion factors also differ between networks.

From historical observations GDB engineers have forecast the approximate load on the system per month during periods of peak flow and as a result have approximated the mean pressure in the network for the twelve month period. Average network pressure is a better representation of service to the majority of customers than is fringe pressure—the minimum pressure at the fringe of the network—because it needs to be sufficient to ensure periods of peak demand can be accommodated while still meeting the minimum pressure requirement.

The system capacity measure is the addition of the individual high, medium and low pressure network capacities. As noted above, pipelines owned by GDBs operating at very high pressures (above 1050 kPa) with characteristics normally associated with transmission or sub–transmission are excluded from the calculation.

To aggregate a diverse range of outputs into an aggregate output index using indexing procedures, we have to allocate a weight to each of the three outputs. In this case we use the estimated output cost shares derived from an earlier econometric cost function, the method of which is outlined in appendix A, and was developed in Lawrence (2007) using data for the three Victorian GDBs for the period 1998 to 2006. The weights used in this study were estimated in Economic Insights (2012b) and have been used in previous Economic Insights studies, with the aim of ensuring the studies reflect actual changes in year-to-year operations. A weighted average of the output cost shares was formed using the share of each observation's estimated costs in the total estimated costs for all GDBs and all time periods following Lawrence (2003). This produced an output cost share for throughput of 13 per cent, for customers of 49 per cent and for system capacity of 38 per cent.

The total revenue of each GDB is the sum of revenue from all customer segments: residential, commercial and large industrial customers.

### *4.3.2 Input quantities and weights*

The inputs used by GDBs are defined in this study as:

1) **Opex**: The quantity of the GDB's opex is derived by deflating the value of opex by the opex price deflator originally developed by PEG (2006). As noted above, the opex values supplied by the GDBs were consistent with the GDBs' Regulatory Accounts but the focus has been on ensuring data reflects actual year–to–year operations. A number of accounting adjustments such as allowance for provisions have been excluded as they do not reflect the

actual inputs used by the businesses in a particular year which is what we need for TFP purposes. To ensure consistency in functional coverage throughout the period, for those years prior to the introduction of full retail contestability (FRC) each GDB's constant price opex is increased by the amount of expenses incurred in the early years of FRC. In these early years FRC was expected to have only affected opex (and not capital) requirements.

To ensure consistency with previous gas industry productivity studies by Economic Insights, a number of adjustments have been made to the functional coverage of opex to ensure more like-with-like comparisons between GDBs. Government levies and unaccounted for gas are excluded from opex for all GDBs. Carbon costs are excluded where separately identified.[6]

The PEG (2006) opex price deflator was developed for electricity DBs. It is made up of a 62 per cent weighting on the Electricity, gas and water sector Wages price index with the balance of the weight being spread across five Producer price indexes covering business, computing, secretarial, legal and accounting, and advertising services. Since the functions of electricity and gas distribution are broadly analogous, the PEG deflator is considered the best currently available for GDB opex as well.[7]

2) **Transmission network**: The quantity of transmission network for each GDB is proxied by its transmission pipeline length (for JGN this is defined as the sum of its 'trunk' and 'primary' mains length).

3) **High pressure network**: The quantity of each GDB's high pressure network is proxied by its high pressure pipeline length.

4) **Medium pressure network**: The quantity of each GDB's medium pressure network is proxied by its medium pressure pipeline length.

5) **Low pressure network**: The quantity of each GDB's low pressure network is proxied by its low pressure pipeline length.

6) **Services network**: The quantity of each GDB's services network is proxied by its estimated services pipeline length.

7) **Meters**: The quantity of each GDB's meter stock is proxied by its total number of meters.

8) **Other assets**: The quantity of other capital inputs is proxied by their deflated asset value. Other capital comprises city gate stations, cathodic protection, supply regulators and valve stations, SCADA and other remote control, other IT and other non–IT.

The starting point for asset values for each GDB is based on the regulatory asset base (RAB) valuation in an initial year (either 1997, 1998 to 1999) for 12 asset categories. Asset life and

[6] In the case of JGN, other items of opex have been excluded to put it on a comparable functional basis, including opex associated with trunk and primary mains, marketing and retail incentives, market operations expenses and meter reading. Network marketing expenses are also excluded for AGN Qld given its low penetration.

[7] The Australian Bureau of Statistics discontinued some of the Producer Price Indexes used in the PEG (2006) opex price deflator with its move to the latest industrial classification so it has been necessary to splice the series with the nearest proxies under the new classification.

remaining asset life estimates were provided for each GDB for each of the asset categories, as well as estimated asset lives for capex using the same asset categories. We form disaggregated constant price depreciated capital stock estimates by rolling forward the opening asset values by taking away straight line depreciation based on remaining asset life of the opening capital stock and adding in yearly constant price capital expenditure and subtracting yearly constant price depreciation on capital expenditure for each year calculated using straight line depreciation based on asset–specific asset lives.

Following PEG (2006) we use the endogenous rate of return method for forming estimates of the user cost of capital. Using this approach the value of total costs equals total revenue by definition. As noted in Lawrence (2007), when the implicit gross rate of return is relatively stable over stable over time there should be little difference in TFP estimates formed using this approach and the exogenous user cost method. The input weight given to opex is simply the ratio of opex to total revenue. The aggregate capital input weight is simply given by one minus the opex share. It is then necessary to divide this overall capital share among the 7 capital asset inputs. This is done using the share of each of the 7 asset categories' asset values in the total asset value for that year.

## 4.4 Key characteristics of the included GDBs

The key characteristics of the eight GDBs included in this study are presented in Table 4.1 for 2018 (for AGN Qld, 2014). Evoenergy is the 7$^{th}$ largest GDB in the sample (or 2$^{nd}$ smallest) in terms of throughput, customer numbers and distribution mains length. Its throughput of 8 PJ, customer numbers of 149,000 and distribution mains length of 4,600 km are much smaller than the averages for the GDBs in the sample (average throughput = 41 PJ; average customer numbers = 615,000 and average distribution mains length = 10,700 km).

Table 4.1 also shows that JGN is the largest in terms of throughput (89 PJ), customer numbers (1.4 million), and distribution mains length (24,400 km). Its network is more than five times the size of Evoenergy's, it has more than nine times as many customers and about 11 times greater throughput. The Victorian GDBs are similar to each other in size. These networks are each about two and a half times the size of Evoenergy's. Each has about five times as many customers and about seven times the throughput compared to Evoenergy. ATCO and AGN SA are also larger than Evoenergy. In terms of customer numbers and mains length, ATCO is similar in size to the Victorian GDBs, but its throughput is less than half of their average gas throughput; and more than three times that of Evoenergy. AGN SA is only slightly smaller than ATCO in terms of gas throughput, but significantly smaller in terms of customer numbers and network length. Its network is about 70 per cent larger than Evoenergy, and it has about three times as many customers. The only GDB in this sample that is smaller than Evoenergy is AGN Qld, which has throughput of 5 PJ, a customer base of 92,000, and distribution mains length of 2,500 km.

As noted previously, the two key operating environment characteristics that influence energy distribution productivity levels are energy density (throughput per customer) and customer density (customers per kilometre of mains). Together these determine the energy throughput per kilometre (km) of distribution mains. These measures are also shown in Table 4.1. Energy and customer densities shown in Table 4.1 are overall figures across domestic, commercial and industrial customers.

Evoenergy has a below-average energy density of 20 GJ per customer. The sample average energy density is 28 GJ per customer. Evoenergy's energy density is comparable to those of Jemena (19 GJ/customer) and AGN SA (17 GJ/customer). GDBs with particularly low energy densities are ATCO (14 GJ/customer) and AGN Qld (8 GJ/customer). On the other hand, the three Victorian GDBs have relatively high energy densities, ranging from 45 (AGN Vic) to 57 GJ per customer (Multinet).

Evoenergy's customer density of 32 customers per km of main is the lowest among the GDBs, and well below the sample average of 54 customers per km. The closest comparator is AGN Qld (36 customers/km). The customer densities for the Victorian GDBs are range from 60 (AusNet) to 70 customers per km (Multinet). The customer densities of JGN, ATCO and AGN SA range between 56 and 57 customers/km.

The energy per unit mains (or 'network utilisation') is the product of the energy density and the customer density. Accordingly Evoenergy has a comparatively low network utilisation because of its below-average energy density and very low customer density. Evoenergy's energy use per km of mains (1.8 TJ/km) is well below the sample average (3.6 TJ/km), and is the lowest among the GDBs shown in Table 4.1. Close comparators are ATCO (2.0 TJ/km) and AGN Qld (2.1 TJ/km). Somewhat higher are AGN SA (2.8 TJ/km) and JGN (3.6 TJ/km). The latter is similar to the sample average. The three Victorian GDBs all have similar energy demand per unit of mains, and much higher than the sample average. They range from 5.2 (AGN Vic) to 5.7 TJ per km (Multinet).

Table 4.1: **Included GDBs' key characteristics, 2018***

| GDB | Throughput | Customers | System capacity | Distribution mains length | Energy density | Customer density | Energy per unit mains |
|---|---|---|---|---|---|---|---|
| | *TJ* | *No* | *Sm³* | *kms* | *GJ/cust.* | *Cust./km* | *TJ/km* |
| AGN-Vic | 57,039 | 694,822 | 150,055 | 10,952 | 44.6 | 63.4 | 5.2 |
| Multinet | 56,921 | 702,242 | 125,889 | 10,015 | 56.9 | 70.1 | 5.7 |
| AusNet | 63,751 | 698,227 | 153,559 | 11,613 | 46.7 | 60.1 | 5.5 |
| Jemena | 88,547 | 1,390,296 | 302,196 | 24,368 | 18.6 | 57.1 | 3.6 |
| AGN-SA | 22,577 | 448,205 | 107,661 | 8,072 | 16.9 | 55.5 | 2.8 |
| AGN-Qld | 5,356 | 91,783 | 27,725 | 2,542 | 8.2 | 36.1 | 2.1 |
| ATCO | 26,449 | 746,339 | 27,725 | 13,392 | 13.8 | 56.3 | 2.0 |
| Evoenergy | 8,192 | 149,288 | 62,109 | 4,627 | 20.4 | 31.7 | 1.8 |

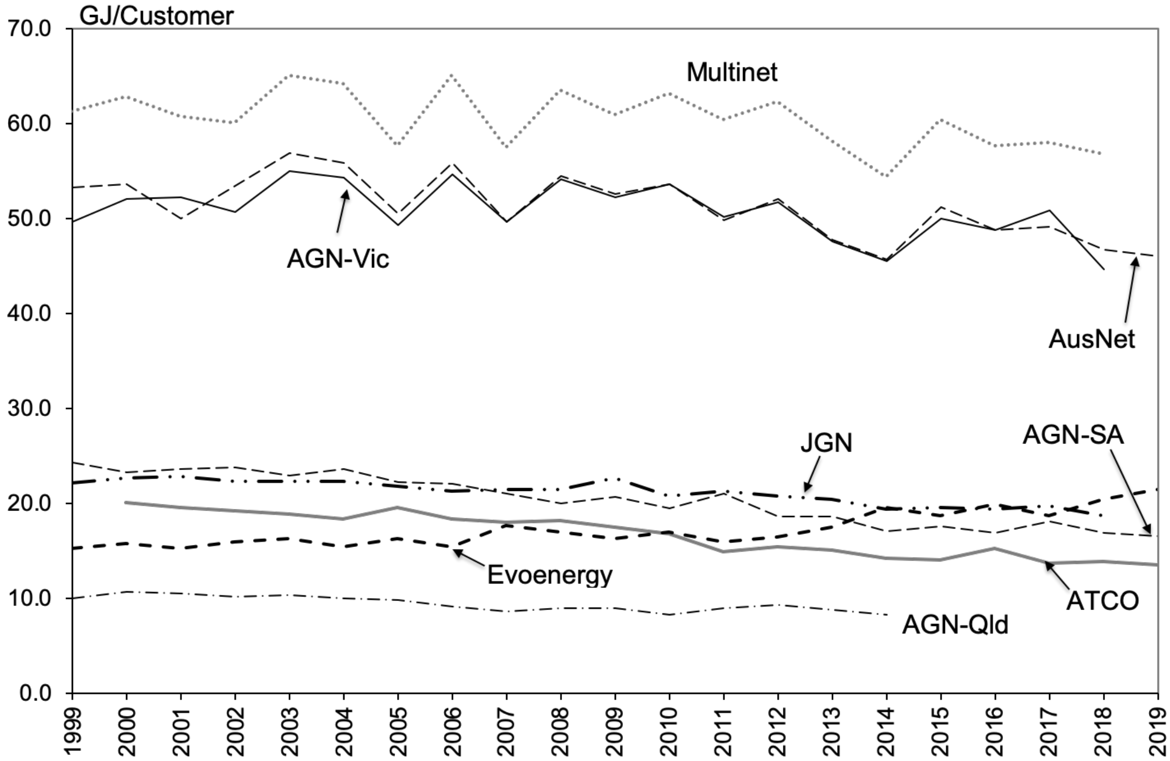
* AGN Qld (2014).

Source: Economic Insights GDB database

Domestic energy density is a key cost driver for GDBs. GDBs operating in a temperate climate will be at an obvious disadvantage relative to GDBs operating in cold climates where there is a much higher demand for gas for space heating. The domestic demand for gas for GDBs operating in temperate climates is likely to be more focused on cooking and hot water heating. The domestic energy densities of the eight included GDBs are plotted in Figure 4.1. From this figure we can see that Evoenergy has broadly similar domestic energy density to JGN, and somewhat higher than AGN SA and ATCO. For the most part this reflects broadly similar climatic conditions in reticulated areas of NSW and the ACT, and somewhat warmer climates in South Australia and Western Australia. Although the ACT does have a colder winter climate due to its higher altitude, this is not reflected in its domestic energy density. Its particularly low energy density overall is also due to the fact that there is little or no heavy industry in Evoenergy's supply area.

The three Victorian GDBs have considerably higher domestic energy densities than the non–Victorian GDBs, due to relatively higher domestic space heating demand. Greater variability of the Victorian densities is also associated with heating use, as demand is less in milder winters. The significant differences in domestic energy densities highlight the different operating conditions faced by Australian GDBs.

Figure 4.1: **Domestic energy densities, 1999–2019**

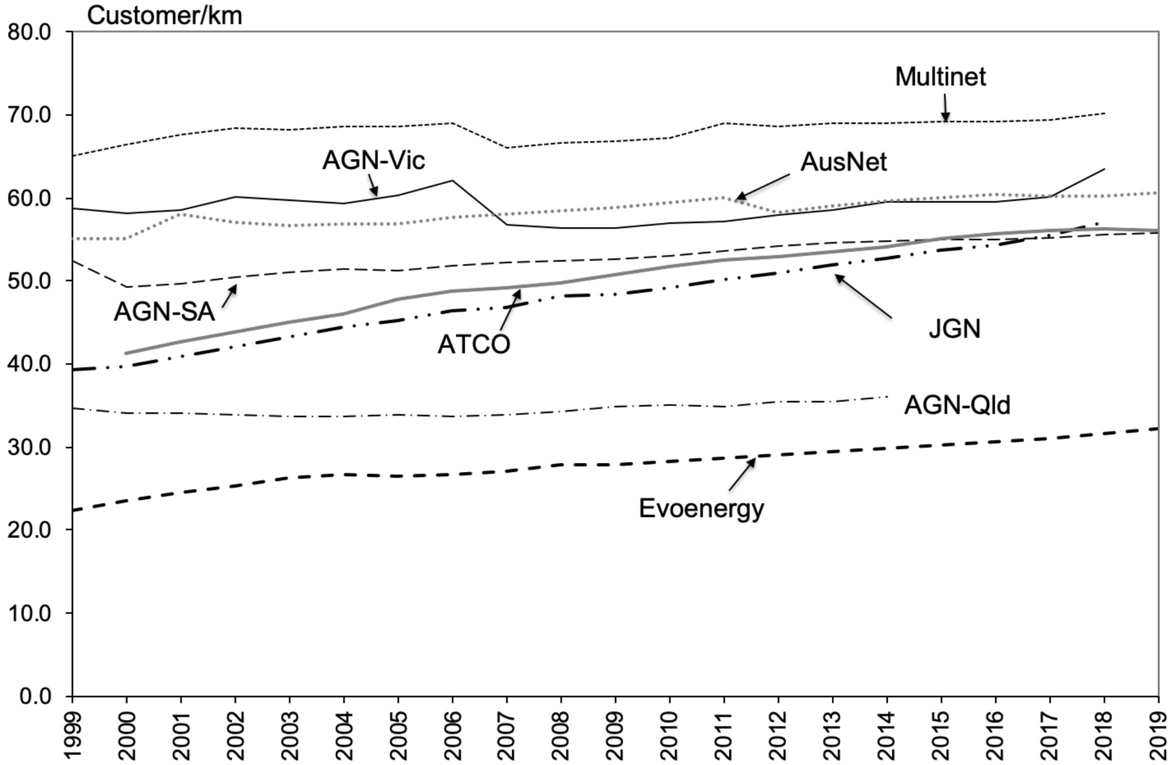



Source: Economic Insights GDB database

Such differences are further highlighted by differences in the share of domestic energy out of total energy throughput between GDBs. In 2018, domestic throughput accounted for 85 per cent of Evoenergy's throughput. In the same year (for AGN Qld, 2014), domestic demand accounted for 33 per cent of AGN SA's throughput; 38 per cent of ATCO's throughput; and 29 per cent of JGN's throughput. By contrast domestic demand accounted for only 13 per cent of AGN Qld's throughput. In the cases of AGN Vic, AusNet and Multinet, domestic demand accounted for 52 per cent, 50 per cent and 69 per cent of total throughput, respectively.

Differences in climatic conditions and the geographic characteristics of the areas served also effect customer density. Domestic customer penetration rates are typically much lower for GDBs operating in warmer climates, meaning that those GDBs have to lay relatively more length of pipeline to reach each domestic customer. Customer densities will also be lower for those GDBs whose geography dictates a relatively 'dendritic' system rather than a more compact, meshed system. A dendritic system will arise where a number of spread out pockets of consumption have to be served. Customer densities for the included GDBs are plotted in Figure 4.2. Evoenergy's customer density is the lowest of the Australian GDBs, and most comparable to AGN Qld. Multinet has the highest customer density of the included GDBs reflecting its coverage of Melbourne's densely populated inner southeast. AGN Vic and AusNet also have high customer densities. AGN SA, ATCO and JGN all have similar customer densities that are around the sample average.

Figure 4.2: **Customer densities, 1999–2017**




Source: Economic Insights GDB database

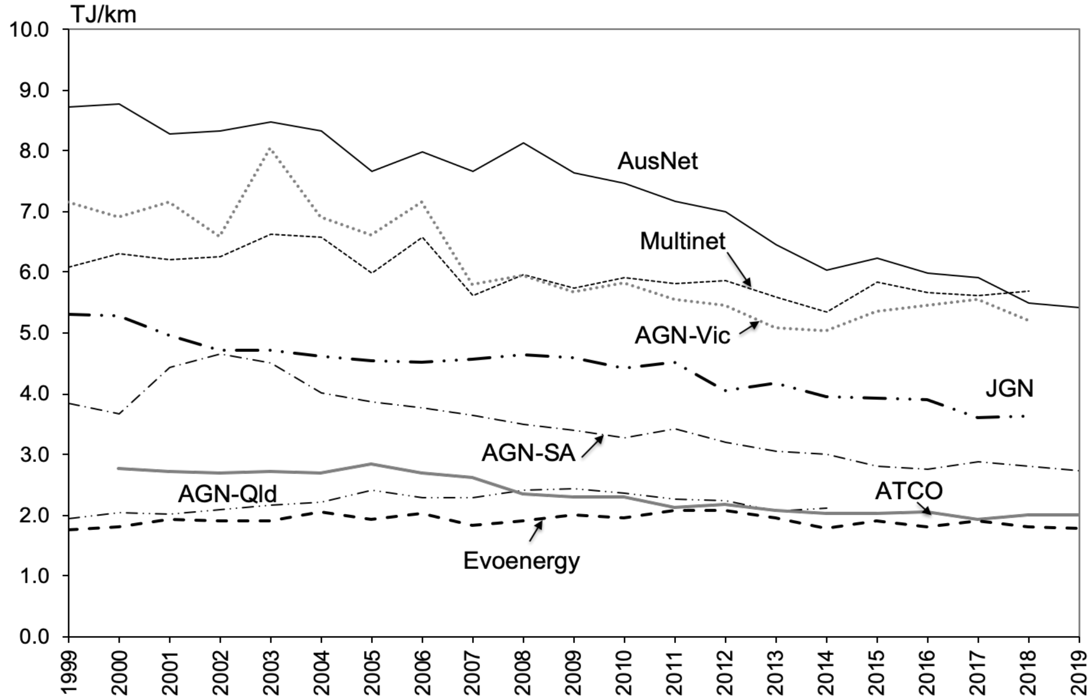
Figure 4.3 summarises the differences between the GDBs in terms of energy throughput per km of main. This is based on both domestic and non-domestic energy use. Evoenergy has a below-average level of energy deliveries per km, which reflects its below-average energy density and particularly low customer density. ATCO and AGN Qld have similar energy throughput per km of main. AGN SA has a slightly higher energy throughput per km of main. The Victorian GDBs have the highest energy throughput per km among the GDBs in the sample, which reflects a combination of the high energy densities and high customer densities previously discussed. JGN has an average level of energy throughput per km of main.

There is a general trend, across all the GDBs except Evoenergy, and perhaps AGN Qld, of declining energy throughput per km, which is quite a pronounced shift over the whole of the sample period. Over the period full sample period Evoenergy's energy throughput per km was unchanged, whereas for other GDBs the cumulative *decline* in energy throughput per km was:

AGN SA, 29 per cent; ATCO, 27 per cent; AGN Vic, 27 per cent; Multinet, 6 per cent; AusNet, 38 per cent; and JGN, 32 per cent. An important factor in these declines has been reductions in demand by major industrial ('Tariff D' or 'contract') customers. The average cumulative decline in energy throughput per km over the whole sample period, for all GDBs, was 19 per cent.

To summarise, the review of operating environment conditions has shown that Evoenergy has relatively low overall energy density, and domestic energy density. Its customer density is the lowest among the Australian GDBs. Consequently, it has a particularly low energy throughput per km of distribution mains, which is the lowest in the sample. This could be expected to give Evoenergy at least some disadvantage when comparing productivity levels against other GDBs.

Figure 4.3: **Energy throughput per km main, 1999–2017**




Source: Economic Insights GDB database

# 5 PRODUCTIVITY GROWTH RESULTS

## 5.1 TFP indexes

Index numbers are a quantitative method developed in economics for aggregating prices or quantities of products that may be measured in different units, and hence cannot be aggregated by summation or simple averages. Index numbers normally measure relativities, such as changes from one period to another or comparisons between other situations, such as comparisons between localities or groups of consumers.

To operationalise TFP measurement we need to combine changes in diverse outputs and inputs into measures of changes in total outputs and total inputs. That is, it is necessary to develop an index for all the outputs produced by a business and another for all the inputs used by the business. The four most popular index formulations are:

- the Laspeyres base period weight index;
- the Paasche current period weight index;
- the Fisher ideal index which is the square root of the product of the Paasche and Laspeyres index; and
- the Törnqvist index which has been used extensively in previous TFP studies.

Diewert (1993) reviewed alternate index number formulations to determine which index was best suited to TFP calculations. Indexing methods were tested for consistency with a number of axioms which an ideal index number should always satisfy.[8] Diewert found that only the Fisher ideal index passed all of the axiomatic tests.[9] On the basis of his analysis, Diewert recommended the Fisher ideal index be used for TFP work although he indicated that the Törnqvist index could also be used as it closely approximates Fisher's ideal index. For this study the Fisher ideal index was therefore chosen as the preferred index formulation for the TFP time series analysis. It is also increasingly the index of choice of leading national statistical agencies.

Mathematically, the Fisher ideal output index is given by:

(4) $$Q_F^t = [(\sum_{i=1}^{m} P_i^B Y_i^t / \sum_{j=1}^{m} P_j^B Y_j^B)(\sum_{i=1}^{m} P_i^t Y_i^t / \sum_{j=1}^{m} P_j^t Y_j^B)]^{0.5}$$

[8] These tests were: (a) the constant quantities test: if quantities are the same in two periods, then the output index should be the same in both periods irrespective of the price of the goods in both periods; (b) the constant basket test: this states that if prices are constant over two periods, then the level of output in period 1 compared to period 0 is equal to the value of output in period 1 divided by the value of output in period 0; (c) the proportional increase in outputs test: this states that if all outputs in period t are multiplied by a common factor, □, then the output index in period t compared to period 0 should increase by □ also; and (d) the time reversal test: this states that if the prices and quantities in period 0 and t are interchanged, then the resulting output index should be the reciprocal of the original index.

[9] The Laspeyres and Paasche index fail the time reversal test while the Törnqvist index fails the constant basket test.

where: $Q_F^t$ is the Fisher ideal output index for observation *t*;

$P_i^B$ is the price of the *i*th output for the base observation;

$Y_i^t$ is the quantity of the *i*th output for observation *t*;

$P_i^t$ is the price of the *i*th output for observation *t*; and

$Y_j^B$ is the quantity of the *j*th output for the base observation.

Similarly, the Fisher ideal input index is given by:

(5) $$I_F^t = [(\sum_{i=1}^n W_i^B X_i^t / \sum_{j=1}^n W_j^B X_j^B)(\sum_{i=1}^n W_i^t X_i^t / \sum_{j=1}^n W_j^t X_j^B)]^{0.5}$$

where: $I_F^t$ is the Fisher ideal input index for observation *t*;

$W_i^B$ is the price of the *i*th input for the base observation;

$X_i^t$ is the quantity of the *i*th input for observation *t*;

$W_i^t$ is the price of the *i*th input for observation *t*; and

$X_j^B$ is the quantity of the *j*th input for the base observation.

The Fisher ideal TFP index is then given by:

(6) $$TFP_F^t = Q_F^t / I_F^t .$$

The Fisher index can be used in either the unchained form denoted above or in the chained form used in this study where weights are more closely matched to pair–wise comparisons of observations. Denoting the Fisher output index between observations *i* and *j* by $Q_F^{i,j}$, the chained Fisher index between observations 1 and *t* is given by:

(7) $$Q_F^{1,t} = 1 \times Q_F^{1,2} \times Q_F^{2,3} \times .... \times Q_F^{t-1,t} .$$

In this section the chained Fisher ideal index number method is used to calculate output and input indexes, TFP and partial productivity measures.

## 5.2 Evoenergy's productivity growth results, 2000 to 2019

In this section we present the key productivity results for Evoenergy for the 21-year period to 2019. Results are derived using the output index specification outlined in section 2.2 (throughput, customer numbers and system capacity) and with two broad inputs (real opex and capital). The capital index is based on seven components (lengths of transmission pipelines, high pressure pipelines, medium pressure pipelines, low pressure pipelines and services, number of meters, and the real value of other capital inputs), again as described in section 2.2. Table 5.1 shows the total factor and partial factor productivity index results for Evoenergy.

Table 5.1: **Evoenergy productivity indexes, 1999–2019**

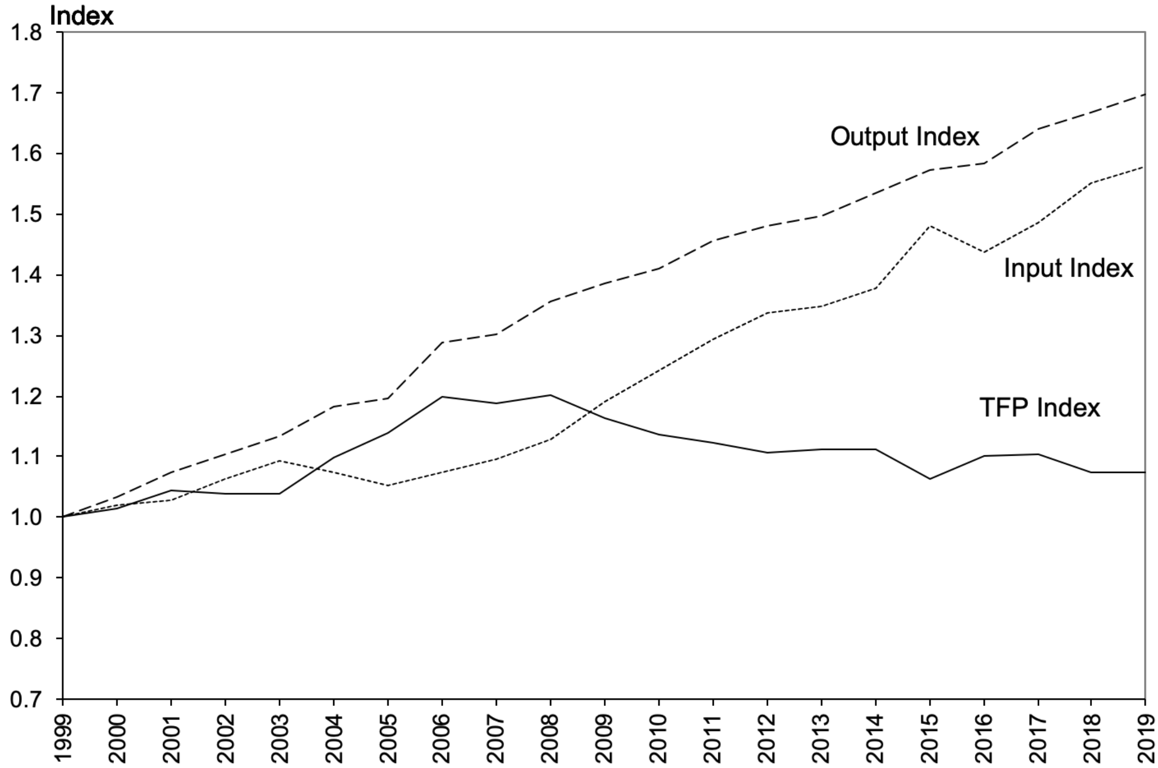
| *Year* | *Output* | *Input* | *Opex* | *Capital* | *PP Opex* | *PP Capital* | *TFP* |
|---|---|---|---|---|---|---|---|
| 1999 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2000 | 1.032 | 1.019 | 1.039 | 1.010 | 0.993 | 1.022 | 1.013 |
| 2001 | 1.074 | 1.028 | 1.043 | 1.021 | 1.029 | 1.052 | 1.045 |
| 2002 | 1.104 | 1.063 | 0.975 | 1.109 | 1.133 | 0.996 | 1.039 |
| 2003 | 1.135 | 1.093 | 1.051 | 1.113 | 1.080 | 1.020 | 1.039 |
| 2004 | 1.182 | 1.075 | 0.981 | 1.125 | 1.205 | 1.051 | 1.099 |
| 2005 | 1.197 | 1.052 | 0.883 | 1.144 | 1.357 | 1.047 | 1.138 |
| 2006 | 1.288 | 1.075 | 0.839 | 1.205 | 1.535 | 1.069 | 1.198 |
| 2007 | 1.302 | 1.096 | 0.847 | 1.235 | 1.538 | 1.054 | 1.188 |
| 2008 | 1.356 | 1.128 | 0.875 | 1.268 | 1.549 | 1.069 | 1.202 |
| 2009 | 1.387 | 1.191 | 1.002 | 1.295 | 1.384 | 1.071 | 1.164 |
| 2010 | 1.411 | 1.242 | 1.055 | 1.343 | 1.337 | 1.051 | 1.136 |
| 2011 | 1.455 | 1.295 | 1.109 | 1.395 | 1.312 | 1.043 | 1.124 |
| 2012 | 1.481 | 1.338 | 1.139 | 1.444 | 1.300 | 1.026 | 1.107 |
| 2013 | 1.498 | 1.347 | 1.042 | 1.507 | 1.438 | 0.994 | 1.113 |
| 2014 | 1.534 | 1.378 | 0.972 | 1.591 | 1.578 | 0.964 | 1.113 |
| 2015 | 1.573 | 1.480 | 1.160 | 1.644 | 1.356 | 0.957 | 1.063 |
| 2016 | 1.584 | 1.438 | 0.966 | 1.688 | 1.640 | 0.938 | 1.102 |
| 2017 | 1.640 | 1.487 | 0.987 | 1.754 | 1.662 | 0.935 | 1.103 |
| 2018 | 1.668 | 1.552 | 1.056 | 1.809 | 1.579 | 0.922 | 1.075 |
| 2019 | 1.698 | 1.579 | 1.046 | 1.865 | 1.623 | 0.910 | 1.075 |
| *Average Annual Change* | | | | | | | |
| 1999–2007 | 3.4% | 1.2% | -2.1% | 2.7% | 5.5% | 0.7% | 2.2% |
| 2007–2014 | 2.4% | 3.3% | 2.0% | 3.7% | 0.4% | -1.3% | -0.9% |
| 2014-2019 | 2.1% | 2.8% | 1.5% | 3.2% | 0.6% | -1.1% | -0.7% |
| 1999–2019 | 2.7% | 2.3% | 0.2% | 3.2% | 2.5% | -0.5% | 0.4% |

Source: Calculations using Economic Insights GDB database

Evoenergy had an average rate of growth in output over the period 1999 to 2007 of 3.4 per cent per year. Its input growth averaged 1.2 per cent per year over the same period, resulting in annual TFP growth of 2.2 per cent in that period. Output grew at a lower rate in subsequent periods. From 2007 to 2014, output growth was 2.4 per cent per year, whereas input growth increased much more strongly, at an average rate of 3.3 per year over this period, resulting in TFP growth averaging –0.9 per cent per year from 2007 to 2014. Output growth averaged 2.1 per cent per year from 2014 to 2019. During this period inputs continued to increase at the comparatively high rate of 2.8 per cent per year on average, and consequently TFP growth averaged –0.7 per cent annually in the latest period. Over the whole period from 1999 to 2019, annual output growth averaged 2.7 per cent per year and input growth averaged 2.3 per cent, with TFP averaging 0.4 per cent annually.

These trends are depicted in Figure 5.1, which plots Evoenergy's output and inputs indexes, and the TFP index, which is the ratio of the output and input indexes. The output trend has been relatively stable and movements in TFP tend to be driven by input movements. Inputs have increased slightly more strongly than outputs in the period since 2007, causing TFP to decline.

Figure 5.1: **Evoenergy output, input and TFP indexes, 1999–2019**



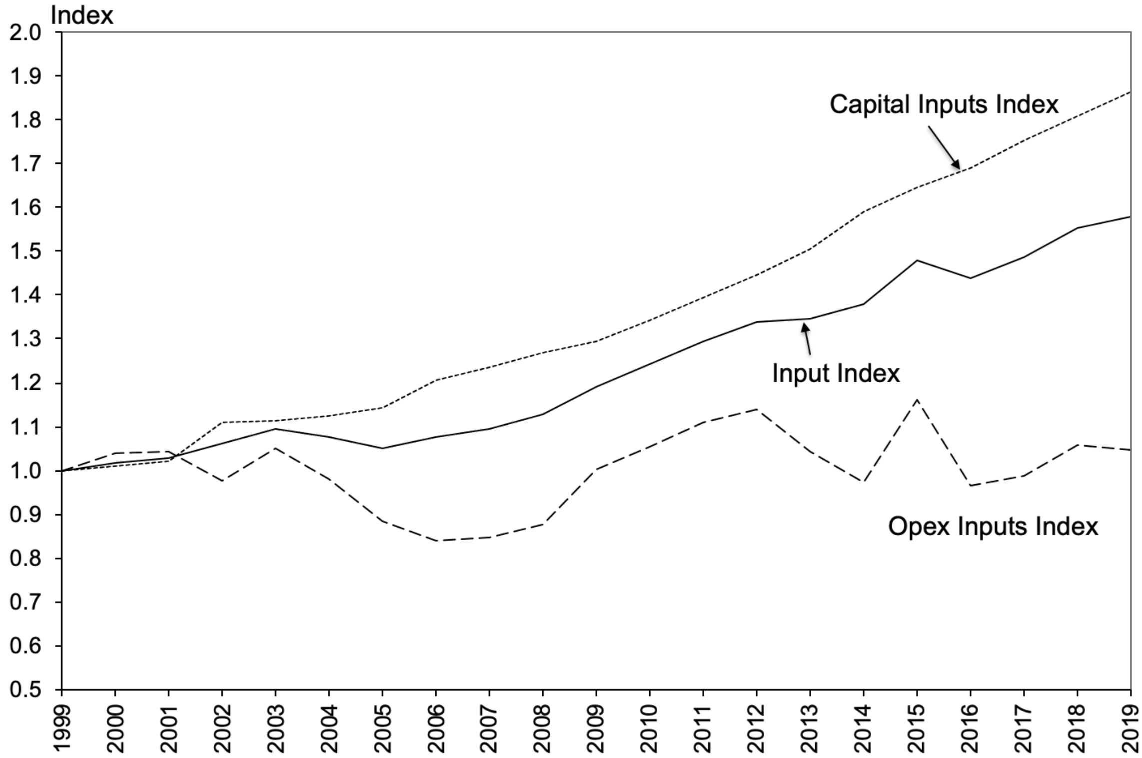

Source: Economic Insights GDB database

Figure 5.2 shows the divergent trends in the use of real opex inputs and capital inputs. On average, over the period from 1999 to 2019, opex inputs increased at an average annual rate of 0.2 per cent. There were significant reductions in opex in the period before 2007, but these were reversed in the subsequent periods. Capital inputs index increased over the whole period from 1999 to 2019, averaging an annual increase of 3.2 per cent. This was slightly higher than the rate of output growth over the same period. The movements in the input index are the aggregate effect of the increases in capital inputs, and flat real opex inputs (on a net basis for the whole period).

Figure 5.3 shows the movements in opex partial productivity and capex partial productivity indexes. These indexes represent the ratios of the output index shown in Figure 5.1, to each individual input index shown in Figure 5.2. Because of the combined effect of the growth of output and the decline in real opex inputs in the period from 1999 to 2007, opex partial productivity increased at an average annual rate of 5.5 per cent. In the period from 2007 to 2014, output growth was slower and opex inputs increased, resulting in a much weaker 0.4 per cent annual growth of opex partial productivity. From 2014 to 2019, growth of output and of real opex both continued at a slightly slower rate to the preceding period, leading to opex partial productivity increasing at an average annual rate of 0.6 per cent.

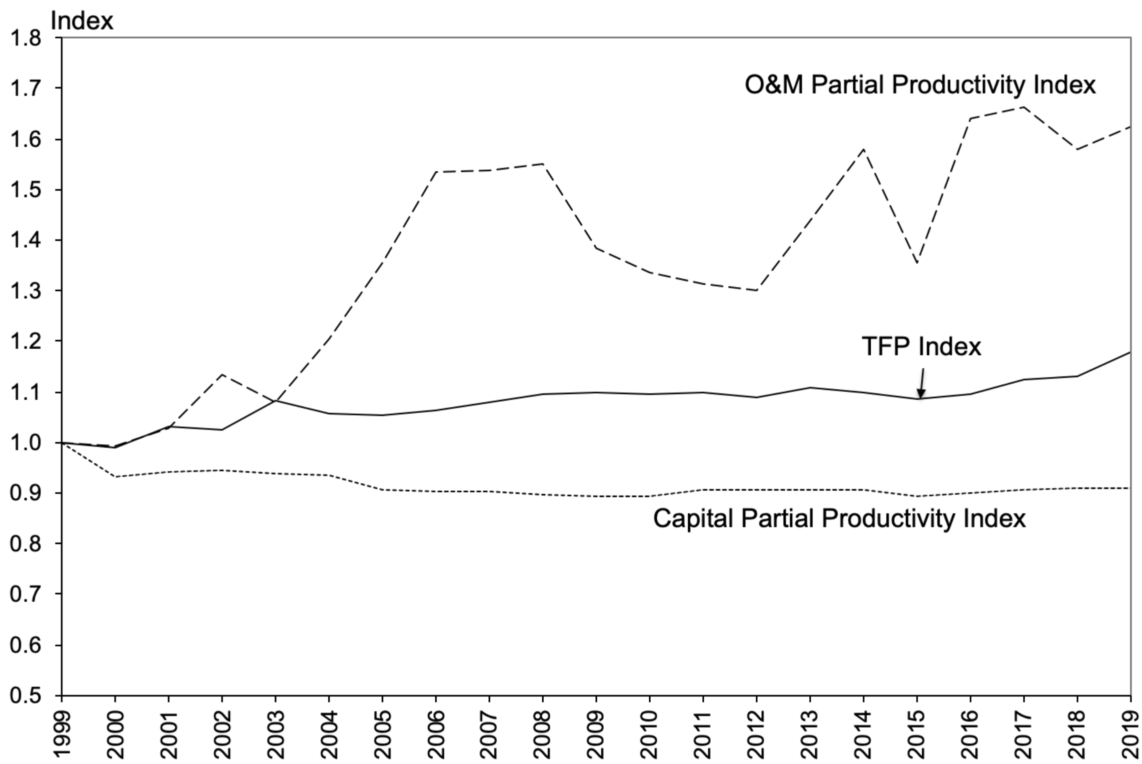
Capital partial productivity increased in the period up to 2007 and decreased by around one per cent per year thereafter; averaging a decline of 0.5 per cent per year over the whole period from 1999 to 2019. This results from similar rates of growth in output and capital inputs.

Figure 5.2: **Evoenergy inputs indexes, 1999–2019**




Source: Economic Insights GDB database

Figure 5.3: **Evoenergy partial productivity indexes, 1999–2019**




Source: Economic Insights GDB database

## 5.3 Comparison with Interstate GDB Productivity Growth

This section compares Evoenergy's productivity growth with that of the interstate GDBs. Comparative TFP, PFP, output and real opex input indexes for the eight GDBs included in the sample are presented in Figures 5.4 to 5.8. Similarly, comparative TFP, PFP, output and input indexes and growth rates are presented in Tables 5.2 to 5.8.

The TFP performance of the GDBs in the sample is plotted in Figure 5.4, and the index numbers and average growth rates are shown in Table 5.2. Three GDBs, had stronger rates of TFP growth than the other GDBs over the period 1999 to 2019, namely AGN-Vic (whose TFP growth rate of averaged 1.5 per cent per year), ATCO (1.4 per cent) and AusNet (1.3 per cent).

Evoenergy's TFP growth over the same period of 0.4 per cent per year, was below the sample average (0.8 per cent), but was broadly similar to those of JGN (with average growth of 0.7 per cent), Multinet (0.6 per cent), and AGN SA (0.8 per cent). Less data is available for AGN Qld, however the trend for the period up to 2014 suggests an ongoing decline in TFP. The time-pattern of Evoenergy's TFP index is similar to JGN and Multinet, all having stronger TFP growth in the period from 1999 to 2007, and declines in TFP in the period from 2007 to 2014. From 2014 to 2019 (or latest year), JGN's TFP did not grow, Multinet's increased slowly, and Evoenergy's continued to decrease. AGN SA's time pattern of TFP movements in different, with its strongest growth occurring in the latest period.

Figure 5.4: **Comparative TFP indexes, 1999–2019**

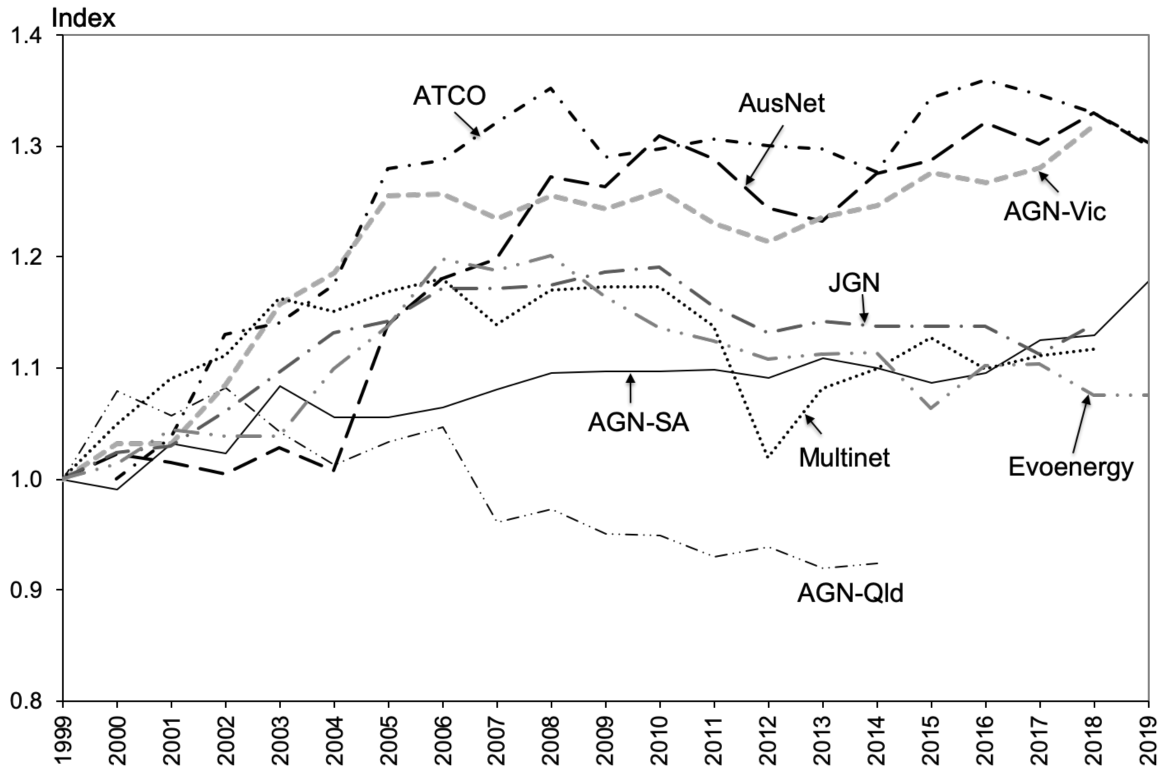


Table 5.2: **TFP indexes comparison, 2000–2019***

| *Year* | *AGN-Qld* | *AGN-SA* | *AGN-Vic* | *AusNet* | *JGN* | *Multinet* | *ATCO* | *Evoenergy* |
|---|---|---|---|---|---|---|---|---|
| 1999 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | . | 1.000 |
| 2000 | 1.079 | 0.990 | 1.032 | 1.022 | 1.024 | 1.049 | 1.000 | 1.013 |
| 2001 | 1.056 | 1.032 | 1.032 | 1.014 | 1.029 | 1.090 | 1.037 | 1.045 |
| 2002 | 1.082 | 1.023 | 1.085 | 1.004 | 1.061 | 1.111 | 1.130 | 1.039 |
| 2003 | 1.042 | 1.084 | 1.157 | 1.029 | 1.097 | 1.163 | 1.141 | 1.039 |
| 2004 | 1.013 | 1.055 | 1.186 | 1.008 | 1.131 | 1.151 | 1.175 | 1.099 |
| 2005 | 1.034 | 1.055 | 1.256 | 1.140 | 1.142 | 1.169 | 1.280 | 1.138 |
| 2006 | 1.047 | 1.065 | 1.257 | 1.181 | 1.172 | 1.181 | 1.287 | 1.198 |
| 2007 | 0.960 | 1.080 | 1.235 | 1.199 | 1.172 | 1.139 | 1.321 | 1.188 |
| 2008 | 0.973 | 1.095 | 1.255 | 1.273 | 1.175 | 1.171 | 1.353 | 1.202 |
| 2009 | 0.950 | 1.097 | 1.244 | 1.264 | 1.187 | 1.173 | 1.290 | 1.164 |
| 2010 | 0.949 | 1.097 | 1.259 | 1.309 | 1.191 | 1.173 | 1.298 | 1.136 |
| 2011 | 0.930 | 1.099 | 1.229 | 1.289 | 1.155 | 1.137 | 1.306 | 1.124 |
| 2012 | 0.938 | 1.090 | 1.213 | 1.245 | 1.132 | 1.019 | 1.300 | 1.107 |
| 2013 | 0.919 | 1.109 | 1.237 | 1.232 | 1.142 | 1.082 | 1.298 | 1.113 |
| 2014 | 0.924 | 1.099 | 1.247 | 1.275 | 1.138 | 1.099 | 1.277 | 1.113 |
| 2015 | . | 1.087 | 1.276 | 1.288 | 1.137 | 1.127 | 1.343 | 1.063 |
| 2016 | . | 1.095 | 1.267 | 1.321 | 1.137 | 1.100 | 1.360 | 1.102 |
| 2017 | . | 1.125 | 1.280 | 1.303 | 1.113 | 1.111 | 1.346 | 1.103 |
| 2018 | . | 1.130 | 1.319 | 1.330 | 1.139 | 1.118 | 1.331 | 1.075 |
| 2019 | . | 1.178 | . | 1.300 | . | . | 1.303 | 1.075 |
| *Average Annual Change* | | | | | | | | |
| 1999–2007 | -0.5% | 1.0% | 2.7% | 2.3% | 2.0% | 1.6% | 4.1% | 2.2% |
| 2007–2014 | -0.6% | 0.3% | 0.1% | 0.9% | -0.4% | -0.5% | -0.5% | -0.9% |
| 2014–2019* | . | 1.4% | 1.4% | 0.4% | 0.0% | 0.4% | 0.4% | -0.7% |
| 1999–2019* | -0.5% | 0.8% | 1.5% | 1.3% | 0.7% | 0.6% | 1.4% | 0.4% |

* Or latest year.

Source: Calculations using Economic Insights GDB database

Figure 5.5 plots the Opex PFP indexes and Table 5.3 shows the Opex PFP index numbers and the growth rates. Evoenergy's Opex PFP growth over the full period from 1999 to 2019 was 2.5 per cent per year; which was close to the average for all the GDBs (2.9 per cent). Multinet had a lower Opex PFP growth rate (1.4 per cent); whereas GDBs with higher Opex PFP growth rates over the same period included: JGN (3.5 per cent); ATCO (3.1 per cent); AGN Vic (4.3 per cent); AusNet (4.2 per cent); and AGN SA (3.4 per cent). For most GDBs, Opex PFP growth was particularly strong in the period from 1999 to 2007 (averaging 5.5 per cent per year for all GDBs), but was relatively weak in the following period from 2007 to 2014 (averaging 0.7 per cent per year for all GDBs). In the period 2014 to 2019, Opex PFP growth increased (averaging 2.0 per cent per year for all GDBs). In this period Evoenergy's Opex PFP growth was 0.6 per cent per year.

Figure 5.6 plots the Capital PFP indexes shown in Table 5.4. For most GDBs, Capital PFP indexes have had small increases, no change, or small decreases. Examples of the first are AGN Vic (0.4 per cent per year from 1999 to 2019) and ATCO (0.6 per cent). Examples of no change are Multinet (0.1 per cent per year over the same period) and AusNet (–0.1 per cent). Examples of small declines include AGN SA (–0.5 per cent per year), JGN (–0.4 per cent) and Evoenergy (–0.5 per cent).

Figure 5.5: **Comparative Opex PFP indexes, 1999 – 2019**

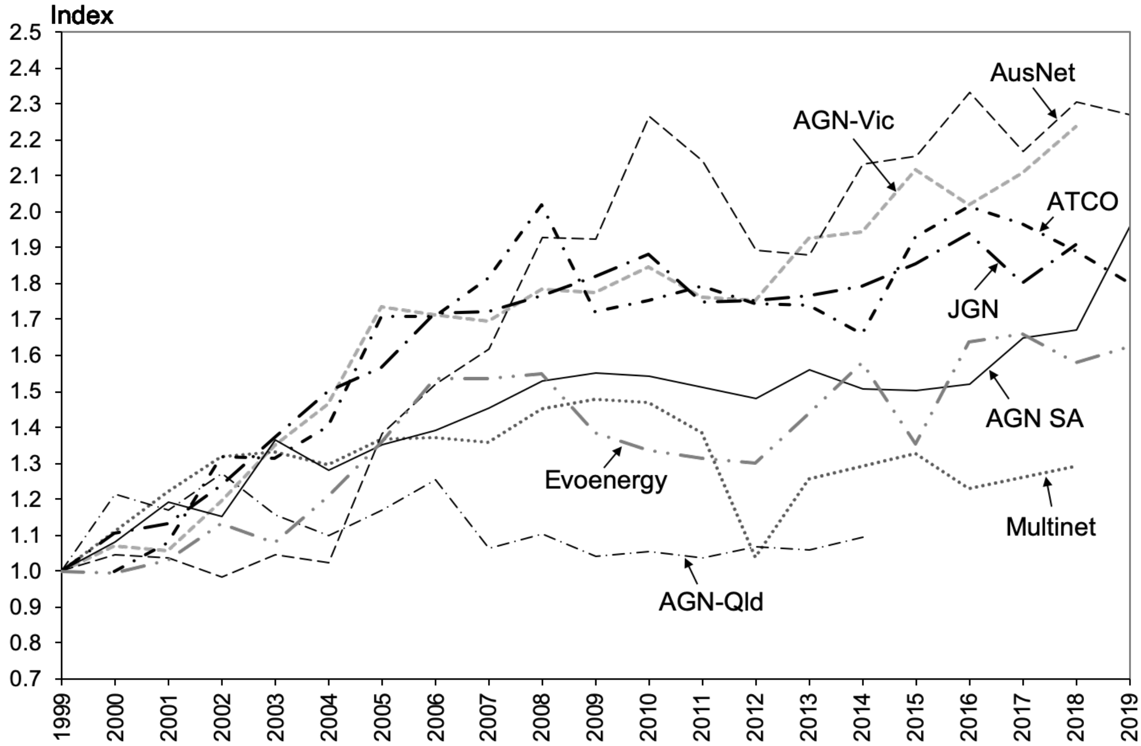



Table 5.3: **Opex PFP indexes comparison, 2000–2019***

| Year | AGN-Qld | AGN-SA | AGN-Vic | AusNet | JGN | Multinet | ATCO | Evoenergy |
|---|---|---|---|---|---|---|---|---|
| 1999 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | . | 1.000 |
| 2000 | 1.213 | 1.082 | 1.068 | 1.045 | 1.103 | 1.108 | 1.000 | 0.993 |
| 2001 | 1.169 | 1.190 | 1.058 | 1.035 | 1.132 | 1.222 | 1.077 | 1.029 |
| 2002 | 1.270 | 1.153 | 1.194 | 0.984 | 1.239 | 1.316 | 1.320 | 1.133 |
| 2003 | 1.156 | 1.367 | 1.348 | 1.047 | 1.371 | 1.333 | 1.313 | 1.080 |
| 2004 | 1.098 | 1.281 | 1.465 | 1.024 | 1.498 | 1.294 | 1.401 | 1.205 |
| 2005 | 1.168 | 1.350 | 1.733 | 1.382 | 1.565 | 1.365 | 1.708 | 1.357 |
| 2006 | 1.255 | 1.390 | 1.715 | 1.520 | 1.716 | 1.370 | 1.709 | 1.535 |
| 2007 | 1.062 | 1.452 | 1.696 | 1.617 | 1.723 | 1.359 | 1.816 | 1.538 |
| 2008 | 1.102 | 1.527 | 1.785 | 1.930 | 1.765 | 1.452 | 2.021 | 1.549 |
| 2009 | 1.039 | 1.550 | 1.777 | 1.923 | 1.820 | 1.476 | 1.720 | 1.384 |
| 2010 | 1.056 | 1.541 | 1.847 | 2.264 | 1.883 | 1.467 | 1.754 | 1.337 |
| 2011 | 1.035 | 1.511 | 1.763 | 2.140 | 1.748 | 1.385 | 1.793 | 1.312 |
| 2012 | 1.066 | 1.479 | 1.755 | 1.891 | 1.751 | 1.040 | 1.744 | 1.300 |
| 2013 | 1.060 | 1.562 | 1.925 | 1.879 | 1.765 | 1.257 | 1.741 | 1.438 |
| 2014 | 1.096 | 1.507 | 1.946 | 2.132 | 1.794 | 1.291 | 1.662 | 1.578 |
| 2015 | . | 1.502 | 2.117 | 2.153 | 1.853 | 1.328 | 1.931 | 1.356 |
| 2016 | . | 1.522 | 2.020 | 2.331 | 1.939 | 1.228 | 2.016 | 1.640 |
| 2017 | . | 1.651 | 2.108 | 2.169 | 1.802 | 1.259 | 1.967 | 1.662 |
| 2018 | . | 1.670 | 2.237 | 2.307 | 1.908 | 1.291 | 1.891 | 1.579 |
| 2019 | . | 1.958 | . | 2.268 | . | . | 1.802 | 1.623 |
| *Average Annual Change* | | | | | | | | |
| 1999–2007 | 0.7% | 4.8% | 6.8% | 6.2% | 7.0% | 3.9% | 8.9% | 5.5% |
| 2007–2014 | 0.5% | 0.5% | 2.0% | 4.0% | 0.6% | -0.7% | -1.3% | 0.4% |
| 2014–2019* | . | 5.4% | 3.6% | 1.3% | 1.6% | 0.0% | 1.6% | 0.6% |
| 1999–2019* | 0.6% | 3.4% | 4.3% | 4.2% | 3.5% | 1.4% | 3.1% | 2.5% |

* Or latest year. Source: Calculations using Economic Insights GDB database

**Figure 5.6: Comparative Capital PFP indexes, 1999–2017**

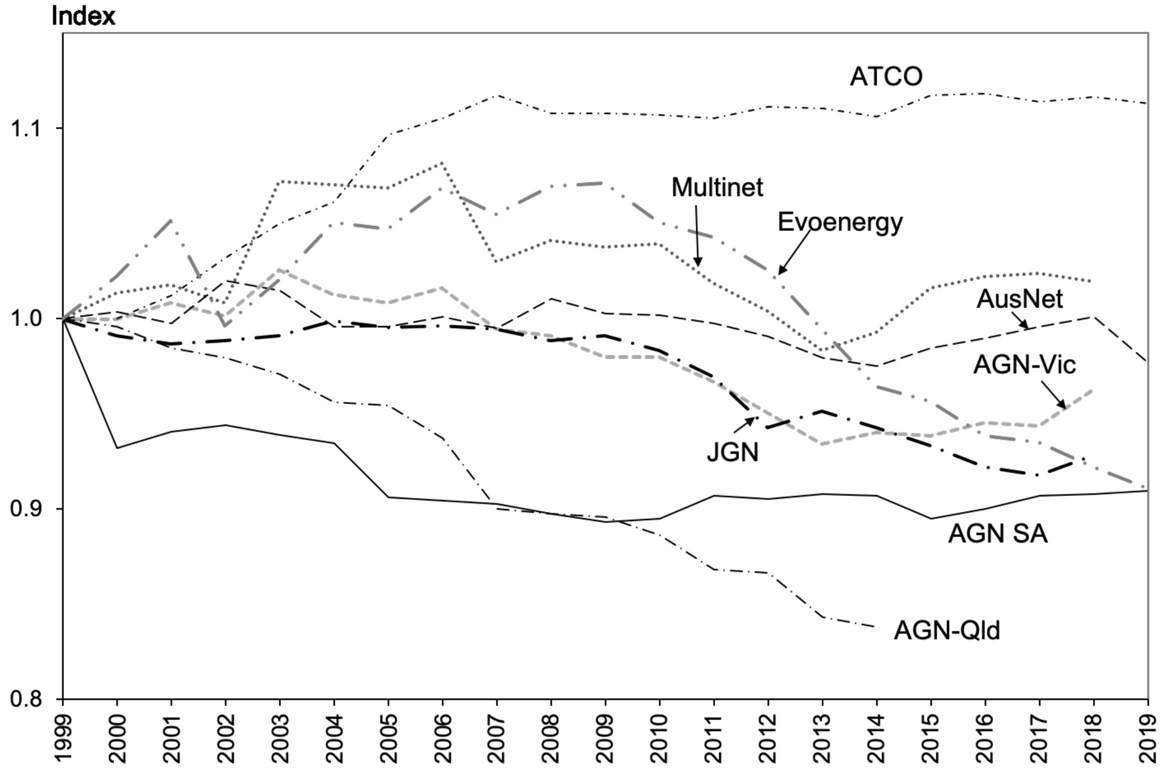



Table 5.4: **Capital PFP indexes comparison, 2000–2019***

| Year | AGN-Qld | AGN-SA | AGN-Vic | AusNet | JGN | Multinet | ATCO | Evoenergy |
|---|---|---|---|---|---|---|---|---|
| 1999 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | . | 1.000 |
| 2000 | 0.996 | 0.932 | 0.999 | 1.004 | 0.991 | 1.014 | 1.000 | 1.022 |
| 2001 | 0.984 | 0.940 | 1.008 | 0.998 | 0.986 | 1.018 | 1.012 | 1.052 |
| 2002 | 0.979 | 0.944 | 1.002 | 1.020 | 0.988 | 1.008 | 1.032 | 0.996 |
| 2003 | 0.971 | 0.939 | 1.025 | 1.014 | 0.991 | 1.072 | 1.050 | 1.020 |
| 2004 | 0.956 | 0.934 | 1.013 | 0.995 | 0.999 | 1.070 | 1.061 | 1.051 |
| 2005 | 0.954 | 0.906 | 1.009 | 0.996 | 0.995 | 1.069 | 1.097 | 1.047 |
| 2006 | 0.937 | 0.905 | 1.016 | 1.001 | 0.996 | 1.082 | 1.105 | 1.069 |
| 2007 | 0.900 | 0.903 | 0.994 | 0.995 | 0.995 | 1.030 | 1.117 | 1.054 |
| 2008 | 0.897 | 0.897 | 0.991 | 1.011 | 0.988 | 1.041 | 1.108 | 1.069 |
| 2009 | 0.896 | 0.893 | 0.980 | 1.002 | 0.991 | 1.037 | 1.108 | 1.071 |
| 2010 | 0.886 | 0.895 | 0.980 | 1.002 | 0.983 | 1.039 | 1.107 | 1.051 |
| 2011 | 0.868 | 0.906 | 0.967 | 0.997 | 0.969 | 1.019 | 1.105 | 1.043 |
| 2012 | 0.866 | 0.905 | 0.950 | 0.991 | 0.943 | 1.004 | 1.112 | 1.026 |
| 2013 | 0.843 | 0.907 | 0.934 | 0.979 | 0.952 | 0.983 | 1.110 | 0.994 |
| 2014 | 0.837 | 0.907 | 0.940 | 0.975 | 0.943 | 0.992 | 1.106 | 0.964 |
| 2015 | . | 0.895 | 0.939 | 0.984 | 0.933 | 1.016 | 1.117 | 0.957 |
| 2016 | . | 0.900 | 0.946 | 0.990 | 0.922 | 1.022 | 1.118 | 0.938 |
| 2017 | . | 0.907 | 0.944 | 0.996 | 0.917 | 1.024 | 1.114 | 0.935 |
| 2018 | . | 0.908 | 0.962 | 1.001 | 0.928 | 1.019 | 1.117 | 0.922 |
| 2019 | . | 0.909 | . | 0.977 | . | . | 1.113 | 0.910 |
| *Average Annual Change* | | | | | | | | |
| 1999–2007 | -1.3% | -1.3% | -0.1% | -0.1% | -0.1% | 0.4% | 1.6% | 0.7% |
| 2007–2014 | -1.0% | 0.1% | -0.8% | -0.3% | -0.8% | -0.5% | -0.1% | -1.3% |
| 2014–2019* | . | 0.0% | 0.6% | 0.0% | -0.4% | 0.7% | 0.1% | -1.1% |
| 1999–2019* | -1.2% | -0.5% | -0.2% | -0.1% | -0.4% | 0.1% | 0.6% | -0.5% |

* Or latest year. Source: Calculations using Economic Insights GDB database

Figure 5.7 shows the comparative output indexes, which are also presented in Table 5.5. Evoenergy had above-average output growth averaging 2.7 per cent per year between 1999 and 2019, compared to the average for all GDBs of 1.9 per cent over the same period. Other GDBs with relatively high output growth were AGN Vic and AusNet, averaging 2.4 and 2.2 per cent per annum respectively over the full sample period. Those with the lowest output growth were AGN Qld and Multinet Gas. The latter services a mature urban area which already has high rates of gas penetration.

Figure 5.8 and Table 5.6 show the comparative opex input indexes. There is a general time-pattern to movements in opex inputs across the sample of GDBs; and Evoenergy followed a similar pattern in the period up to 2007, but diverged from the average trend thereafter. In the period 1999 to 2007, opex inputs generally decreased substantially. Averaging across GDBs, the average rate of increase in opex was –3.1 per cent per year in that period. In the following period from 2007 to 2014, opex inputs generally increased; with an average rate of increase in opex inputs for all GDBs of 0.9 per cent per year. In the period 2014 to 2019 (or latest), the trends have been more mixed, with some GDBs reducing and others increasing opex inputs. The average rate of increase for all GDBs in that period was –0.2 per cent per year. Over the full period from 1999 to 2019, the average rate of change of opex inputs was –0.9 per cent per year.

Evoenergy's trend was broadly similar to other GDBs in the period 1999 to 2007, with its opex inputs *decreasing* at an average rate of 2.1 per cent per year. This decrease was less than the average. In the period 2007 to 2014, Evoenergy's opex inputs increased at an average rate of 2.0 per cent per year. Although opex inputs also increased from most other GDBs in this period, Evoenergy's increase was higher than the average. In the period from 2014 to 2019, Evoenergy's opex inputs increased at 1.5 per cent per year. This was a stronger increase in opex inputs compared to other GDBs.

Over the full period from 1999 to 2019, Evoenergy's average rate of change of opex inputs was 0.2 per cent per year. For most other GDBs, opex inputs decreased over the full sample period. For example: AGN SA (–1.8 per cent per year); AGN Vic (–1.9 per cent), AusNet (–1.9 per cent); JGN (–1.6 per cent); ATCO (–0.8 per cent ); and Multinet (–0.5 per cent). The main exception is AGN Qld (+1.8 per cent per year).

Tables 5.7 and 5.8 show the indexes and growth rates for capital inputs and for the combined inputs index. The average growth rate of capital inputs for Evoenergy over the period 1999 to 2019 was 3.2 per cent per year, which was significantly higher than the average for all GDBs (2.1 per cent). Most GDBs had a similar trend to the average, one exception being Multinet, which had lower growth of capital inputs.

The growth of capital inputs was generally sufficient to cause the overall index of inputs to increase, notwithstanding reductions in opex inputs. The average rate of increase in inputs for Evoenergy over the period 1999 to 2019 was 2.3 per cent per year, which was above the average for all GDBs (1.1 per cent).

Figure 5.7: **Comparative Output indexes, 1999–2019***

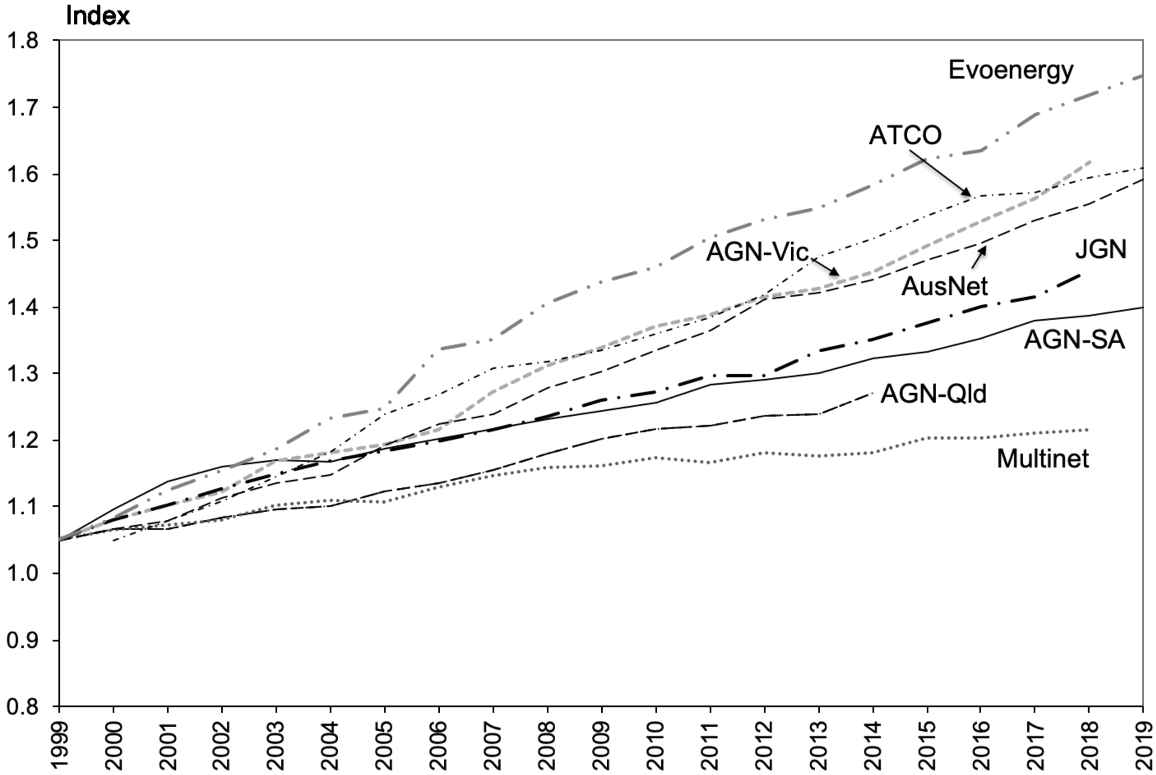



Table 5.5: **Output indexes comparison, 2000–2019***

| Year | AGN-Qld | AGN-SA | AGN-Vic | AusNet | JGN | Multinet | ATCO | Evoenergy |
|---|---|---|---|---|---|---|---|---|
| 1999 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | . | 1.000 |
| 2000 | 1.016 | 1.047 | 1.029 | 1.018 | 1.031 | 1.016 | 1.000 | 1.032 |
| 2001 | 1.016 | 1.089 | 1.051 | 1.028 | 1.052 | 1.022 | 1.028 | 1.074 |
| 2002 | 1.034 | 1.109 | 1.072 | 1.064 | 1.078 | 1.029 | 1.060 | 1.104 |
| 2003 | 1.046 | 1.120 | 1.120 | 1.086 | 1.100 | 1.052 | 1.094 | 1.135 |
| 2004 | 1.051 | 1.118 | 1.132 | 1.098 | 1.118 | 1.059 | 1.132 | 1.182 |
| 2005 | 1.073 | 1.137 | 1.144 | 1.142 | 1.135 | 1.058 | 1.188 | 1.197 |
| 2006 | 1.086 | 1.153 | 1.167 | 1.175 | 1.148 | 1.079 | 1.219 | 1.288 |
| 2007 | 1.105 | 1.167 | 1.222 | 1.188 | 1.167 | 1.096 | 1.259 | 1.302 |
| 2008 | 1.130 | 1.181 | 1.262 | 1.230 | 1.186 | 1.110 | 1.267 | 1.356 |
| 2009 | 1.153 | 1.194 | 1.288 | 1.254 | 1.210 | 1.111 | 1.285 | 1.387 |
| 2010 | 1.167 | 1.206 | 1.320 | 1.285 | 1.224 | 1.124 | 1.310 | 1.411 |
| 2011 | 1.172 | 1.234 | 1.339 | 1.314 | 1.247 | 1.116 | 1.334 | 1.455 |
| 2012 | 1.188 | 1.240 | 1.366 | 1.361 | 1.248 | 1.130 | 1.368 | 1.481 |
| 2013 | 1.190 | 1.251 | 1.378 | 1.371 | 1.285 | 1.127 | 1.425 | 1.498 |
| 2014 | 1.220 | 1.273 | 1.403 | 1.390 | 1.302 | 1.131 | 1.453 | 1.534 |
| 2015 | . | 1.284 | 1.441 | 1.421 | 1.326 | 1.152 | 1.488 | 1.573 |
| 2016 | . | 1.303 | 1.479 | 1.446 | 1.351 | 1.154 | 1.517 | 1.584 |
| 2017 | . | 1.329 | 1.513 | 1.480 | 1.366 | 1.160 | 1.523 | 1.640 |
| 2018 | . | 1.338 | 1.567 | 1.505 | 1.405 | 1.166 | 1.545 | 1.668 |
| 2019 | . | 1.351 | . | 1.541 | . | . | 1.558 | 1.698 |
| *Average Annual Change* | | | | | | | | |
| 1999–2007 | 1.3% | 1.9% | 2.5% | 2.2% | 1.9% | 1.2% | 3.3% | 3.4% |
| 2007–2014 | 1.4% | 1.3% | 2.0% | 2.3% | 1.6% | 0.4% | 2.1% | 2.4% |
| 2014–2019* | . | 1.2% | 2.8% | 2.1% | 1.9% | 0.8% | 1.4% | 2.1% |
| 1999–2019* | 1.3% | 1.5% | 2.4% | 2.2% | 1.8% | 0.8% | 2.4% | 2.7% |

* Or latest year. Source: Calculations using Economic Insights GDB database

**Figure 5.8: Comparative Opex indexes, 1999–2019***

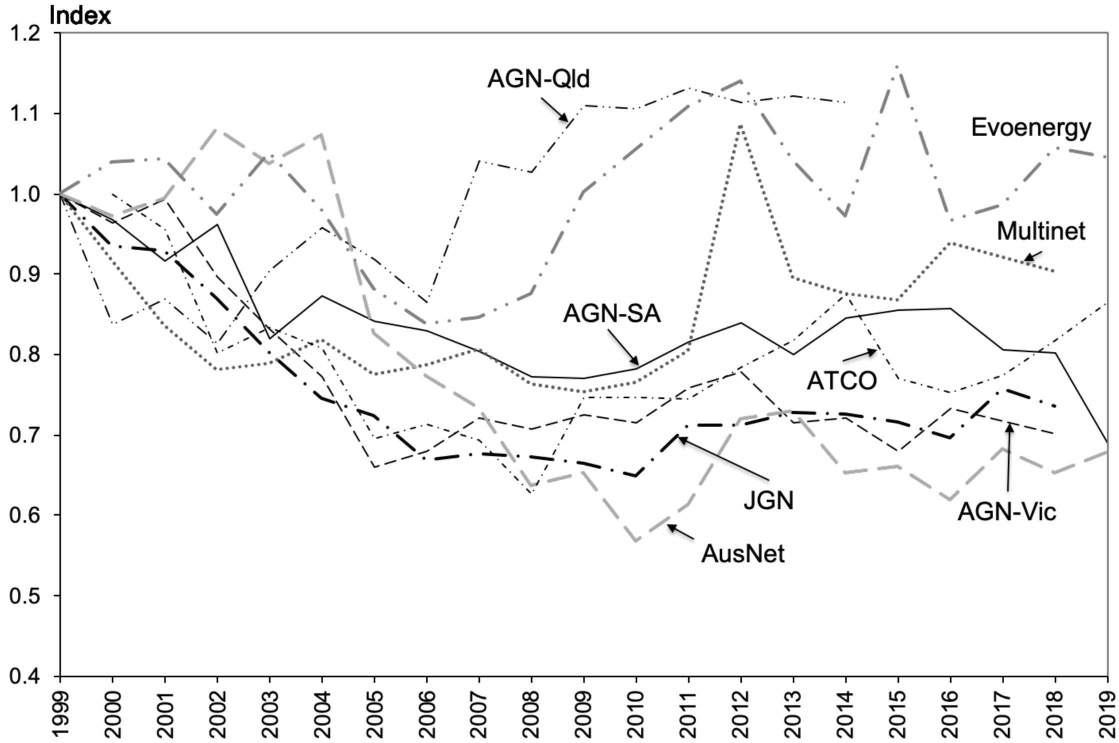



Table 5.6: **Opex input indexes comparison, 2000–2019***

| Year | AGN-Qld | AGN-SA | AGN-Vic | AusNet | JGN | Multinet | ATCO | Evoenergy |
|---|---|---|---|---|---|---|---|---|
| 1999 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | . | 1.000 |
| 2000 | 0.838 | 0.967 | 0.963 | 0.974 | 0.934 | 0.917 | 1.000 | 1.039 |
| 2001 | 0.870 | 0.915 | 0.994 | 0.994 | 0.930 | 0.837 | 0.955 | 1.043 |
| 2002 | 0.814 | 0.962 | 0.897 | 1.081 | 0.870 | 0.782 | 0.803 | 0.975 |
| 2003 | 0.905 | 0.819 | 0.831 | 1.037 | 0.802 | 0.789 | 0.833 | 1.051 |
| 2004 | 0.957 | 0.873 | 0.772 | 1.073 | 0.746 | 0.819 | 0.808 | 0.981 |
| 2005 | 0.919 | 0.842 | 0.660 | 0.826 | 0.725 | 0.775 | 0.696 | 0.883 |
| 2006 | 0.866 | 0.830 | 0.681 | 0.773 | 0.669 | 0.787 | 0.713 | 0.839 |
| 2007 | 1.041 | 0.803 | 0.721 | 0.735 | 0.677 | 0.807 | 0.693 | 0.847 |
| 2008 | 1.026 | 0.773 | 0.707 | 0.637 | 0.672 | 0.764 | 0.627 | 0.875 |
| 2009 | 1.110 | 0.771 | 0.725 | 0.652 | 0.665 | 0.753 | 0.747 | 1.002 |
| 2010 | 1.106 | 0.782 | 0.715 | 0.568 | 0.650 | 0.766 | 0.747 | 1.055 |
| 2011 | 1.132 | 0.816 | 0.759 | 0.614 | 0.713 | 0.806 | 0.744 | 1.109 |
| 2012 | 1.114 | 0.839 | 0.778 | 0.720 | 0.713 | 1.087 | 0.784 | 1.139 |
| 2013 | 1.122 | 0.801 | 0.716 | 0.729 | 0.728 | 0.896 | 0.819 | 1.042 |
| 2014 | 1.113 | 0.844 | 0.721 | 0.652 | 0.726 | 0.876 | 0.874 | 0.972 |
| 2015 | . | 0.855 | 0.681 | 0.660 | 0.716 | 0.868 | 0.771 | 1.160 |
| 2016 | . | 0.856 | 0.732 | 0.620 | 0.697 | 0.939 | 0.752 | 0.966 |
| 2017 | . | 0.805 | 0.718 | 0.682 | 0.758 | 0.921 | 0.774 | 0.987 |
| 2018 | . | 0.802 | 0.700 | 0.652 | 0.736 | 0.903 | 0.817 | 1.056 |
| 2019 | . | 0.690 | . | 0.679 | . | . | 0.865 | 1.046 |
| *Average Annual Change* | | | | | | | | |
| 1999–2007 | 0.5% | -2.7% | -4.0% | -3.8% | -4.8% | -2.6% | -5.1% | -2.1% |
| 2007–2014 | 1.0% | 0.7% | 0.0% | -1.7% | 1.0% | 1.2% | 3.4% | 2.0% |
| 2014–2019* | . | -4.0% | -0.7% | 0.8% | 0.4% | 0.8% | -0.2% | 1.5% |
| 1999–2019* | 0.7% | -1.8% | -1.9% | -1.9% | -1.6% | -0.5% | -0.8% | 0.2% |

* Or latest year. Source: Calculations using Economic Insights GDB database

Table 5.7: **Capital input indexes comparison, 2000–2019***

| Year | AGN-Qld | AGN-SA | AGN-Vic | AusNet | JGN | Multinet | ATCO | Evoenergy |
|---|---|---|---|---|---|---|---|---|
| 1999 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | . | 1.000 |
| 2000 | 1.020 | 1.123 | 1.030 | 1.014 | 1.040 | 1.002 | 1.000 | 1.010 |
| 2001 | 1.032 | 1.158 | 1.043 | 1.031 | 1.067 | 1.005 | 1.016 | 1.021 |
| 2002 | 1.056 | 1.175 | 1.070 | 1.044 | 1.090 | 1.021 | 1.027 | 1.109 |
| 2003 | 1.077 | 1.193 | 1.092 | 1.071 | 1.110 | 0.981 | 1.042 | 1.113 |
| 2004 | 1.099 | 1.196 | 1.118 | 1.103 | 1.120 | 0.990 | 1.067 | 1.125 |
| 2005 | 1.125 | 1.255 | 1.134 | 1.147 | 1.140 | 0.990 | 1.083 | 1.144 |
| 2006 | 1.159 | 1.275 | 1.149 | 1.174 | 1.153 | 0.997 | 1.103 | 1.205 |
| 2007 | 1.228 | 1.292 | 1.230 | 1.194 | 1.173 | 1.065 | 1.127 | 1.235 |
| 2008 | 1.260 | 1.316 | 1.273 | 1.217 | 1.200 | 1.066 | 1.144 | 1.268 |
| 2009 | 1.287 | 1.337 | 1.315 | 1.251 | 1.221 | 1.071 | 1.160 | 1.295 |
| 2010 | 1.317 | 1.348 | 1.348 | 1.283 | 1.245 | 1.081 | 1.183 | 1.343 |
| 2011 | 1.350 | 1.361 | 1.385 | 1.318 | 1.286 | 1.095 | 1.207 | 1.395 |
| 2012 | 1.371 | 1.370 | 1.437 | 1.374 | 1.323 | 1.125 | 1.231 | 1.444 |
| 2013 | 1.412 | 1.379 | 1.476 | 1.400 | 1.351 | 1.146 | 1.284 | 1.507 |
| 2014 | 1.457 | 1.403 | 1.493 | 1.426 | 1.381 | 1.140 | 1.314 | 1.591 |
| 2015 | . | 1.435 | 1.535 | 1.444 | 1.421 | 1.134 | 1.332 | 1.644 |
| 2016 | . | 1.448 | 1.564 | 1.460 | 1.465 | 1.128 | 1.357 | 1.688 |
| 2017 | . | 1.466 | 1.603 | 1.486 | 1.489 | 1.132 | 1.367 | 1.754 |
| 2018 | . | 1.474 | 1.628 | 1.504 | 1.514 | 1.144 | 1.383 | 1.809 |
| 2019 | . | 1.486 | . | 1.578 | . | . | 1.400 | 1.865 |
| *Average Annual Change* | | | | | | | | |
| 1999–2007 | 2.6% | 3.3% | 2.6% | 2.2% | 2.0% | 0.8% | 1.7% | 2.7% |
| 2007–2014 | 2.5% | 1.2% | 2.8% | 2.6% | 2.4% | 1.0% | 2.2% | 3.7% |
| 2014–2019* | . | 1.2% | 2.2% | 2.0% | 2.3% | 0.1% | 1.3% | 3.2% |
| 1999–2019* | 2.5% | 2.0% | 2.6% | 2.3% | 2.2% | 0.7% | 1.8% | 3.2% |

Table 5.8: **Input indexes comparison, 2000–2019***

| Year | AGN-Qld | AGN-SA | AGN-Vic | AusNet | JGN | Multinet | ATCO | Evoenergy |
|---|---|---|---|---|---|---|---|---|
| 1999 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | . | 1.000 |
| 2000 | 0.942 | 1.057 | 0.997 | 0.996 | 1.007 | 0.968 | 1.000 | 1.019 |
| 2001 | 0.962 | 1.055 | 1.019 | 1.014 | 1.022 | 0.938 | 0.991 | 1.028 |
| 2002 | 0.956 | 1.084 | 0.987 | 1.060 | 1.016 | 0.926 | 0.937 | 1.063 |
| 2003 | 1.004 | 1.034 | 0.968 | 1.055 | 1.003 | 0.904 | 0.959 | 1.093 |
| 2004 | 1.038 | 1.059 | 0.954 | 1.090 | 0.989 | 0.921 | 0.964 | 1.075 |
| 2005 | 1.038 | 1.078 | 0.911 | 1.002 | 0.994 | 0.905 | 0.929 | 1.052 |
| 2006 | 1.038 | 1.083 | 0.928 | 0.996 | 0.980 | 0.914 | 0.948 | 1.075 |
| 2007 | 1.150 | 1.080 | 0.990 | 0.991 | 0.995 | 0.963 | 0.953 | 1.096 |
| 2008 | 1.162 | 1.078 | 1.005 | 0.966 | 1.010 | 0.948 | 0.937 | 1.128 |
| 2009 | 1.214 | 1.089 | 1.036 | 0.993 | 1.019 | 0.947 | 0.996 | 1.191 |
| 2010 | 1.229 | 1.100 | 1.049 | 0.982 | 1.028 | 0.958 | 1.009 | 1.242 |
| 2011 | 1.260 | 1.123 | 1.089 | 1.020 | 1.079 | 0.981 | 1.022 | 1.295 |
| 2012 | 1.266 | 1.137 | 1.126 | 1.093 | 1.102 | 1.108 | 1.053 | 1.338 |
| 2013 | 1.294 | 1.128 | 1.115 | 1.112 | 1.125 | 1.041 | 1.098 | 1.347 |
| 2014 | 1.321 | 1.158 | 1.126 | 1.090 | 1.143 | 1.029 | 1.138 | 1.378 |
| 2015 | . | 1.181 | 1.129 | 1.104 | 1.166 | 1.022 | 1.108 | 1.480 |
| 2016 | . | 1.190 | 1.167 | 1.094 | 1.188 | 1.049 | 1.116 | 1.438 |
| 2017 | . | 1.182 | 1.182 | 1.136 | 1.227 | 1.044 | 1.131 | 1.487 |
| 2018 | . | 1.184 | 1.189 | 1.132 | 1.233 | 1.044 | 1.161 | 1.552 |
| 2019 | . | 1.146 | . | 1.185 | . | . | 1.196 | 1.579 |
| *Average Annual Change* | | | | | | | | |
| 1999–2007 | 1.8% | 1.0% | -0.1% | -0.1% | -0.1% | -0.5% | -0.7% | 1.2% |
| 2007–2014 | 2.0% | 1.0% | 1.9% | 1.4% | 2.0% | 1.0% | 2.6% | 3.3% |
| 2014–2019* | . | -0.2% | 1.4% | 1.7% | 1.9% | 0.3% | 1.0% | 2.8% |
| 1999–2019* | 1.9% | 0.7% | 0.9% | 0.9% | 1.1% | 0.2% | 0.9% | 2.3% |

# 6 PRODUCTIVITY LEVEL RESULTS

## 6.1 Multilateral TFP indexes

Traditional measures of TFP such as those discussed in section 3 have enabled comparisons to be made of rates of change of productivity between GDBs but have not enabled comparisons to be made of differences in the absolute levels of productivity in combined time series, cross section GDB 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 translog 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. Lawrence, Swan and Zeitsch (1991) and the BIE (1996) have used this index to compare the productivity levels and growth rates of the five major Australian state electricity systems and the United States investor-owned system. Lawrence (2003) and PEG (2004) also used this index to compare electricity DB TFP levels and Lawrence (2007) used it to compare TFP levels across the three Victorian GDBs. Economic Insights has used this method in a number of GDB studies.

The multilateral translog index is given by:

$$(8) \qquad \log (TFP_m/TFP_n) = \Sigma_i (R_{im}+R_i^*) (\log Y_{im} - \log Y_i^*)/2 - \Sigma_i (R_{in}+R_i^*) (\log Y_{in} - \log Y_i^*)/2 - \Sigma_j (S_{jm}+S_j^*) (\log X_{jm} - \log X_j^*)/2 + \Sigma_j (S_{jn}+S_j^*) (\log X_{jn} - \log X_j^*)/2$$

where $R_i^*$ ($S_j^*$) is the revenue (cost) share averaged over all utilities and time periods and $\log Y_i^*$ ($\log X_j^*$) is the average of the log of output *i* (input *j*). In the main application reported in the following section we have three outputs (throughput, customers and system capacity) and, hence, *i* runs from 1 to 3. In the MTFP analysis, transmission assets are not included, and consequently there are 7 inputs (opex, high pressure pipelines, medium pressure pipelines, low pressure pipelines, services pipelines, meters, and other capital) and, hence, *j* runs from 1 to 7. The $Y_i$ and $X_j$ terms are the output and input quantities, respectively. The $R_i$ and $S_j$ terms are the output and input weights, respectively.

The formula in (8) gives the proportional change in MTFP between two adjacent observations (denoted *m* and *n*). An index is formed by setting some observation (usually the first in the database) equal to one and then multiplying through by the proportional changes between all subsequent observations in the database to form a full set of indexes. The index for any observation then expresses its productivity level relative to the observation that was set equal to one. However, this is merely an expositional convenience as, given the invariant nature of the comparisons, the result of a comparison between any two observations will be independent of which observation in the database was set equal to one.

This means that when using equation (8), comparisons between any two observations *m* and *n* will be both base–distributor and base–year independent. Transitivity is satisfied since comparisons between the two GDBs for 1999 will be the same regardless of whether they are compared directly or via, say, one of the GDBs in 2002. An alternative interpretation of this index is that it compares each observation to a hypothetical average distributor with output vector $log\ Y_i*$, input vector $log\ X_j*$, revenue shares $R_i*$ and cost shares $S_j*$.

As noted, transmission assets are excluded in the MTFP analysis in order to facilitate like–for–like comparisons between GDBs, as they tend to have differing amounts of transmission mains depending on the characteristics of the territory they serve and on past decisions relating to vertical separation.

## 6.2 Productivity levels comparisons

The multilateral TFP indexes for eight GDBs are presented in table 6.1 and figure 6.1. The indexes are calculated relative to AGN Vic in 1999 having a value of one. These indexes can, of course, be influenced by a number of factors, such as economies of scale, which are mostly not controlled for in this comparison.

Table 6.1: **GDB multilateral TFP indexes, 1999–2019**

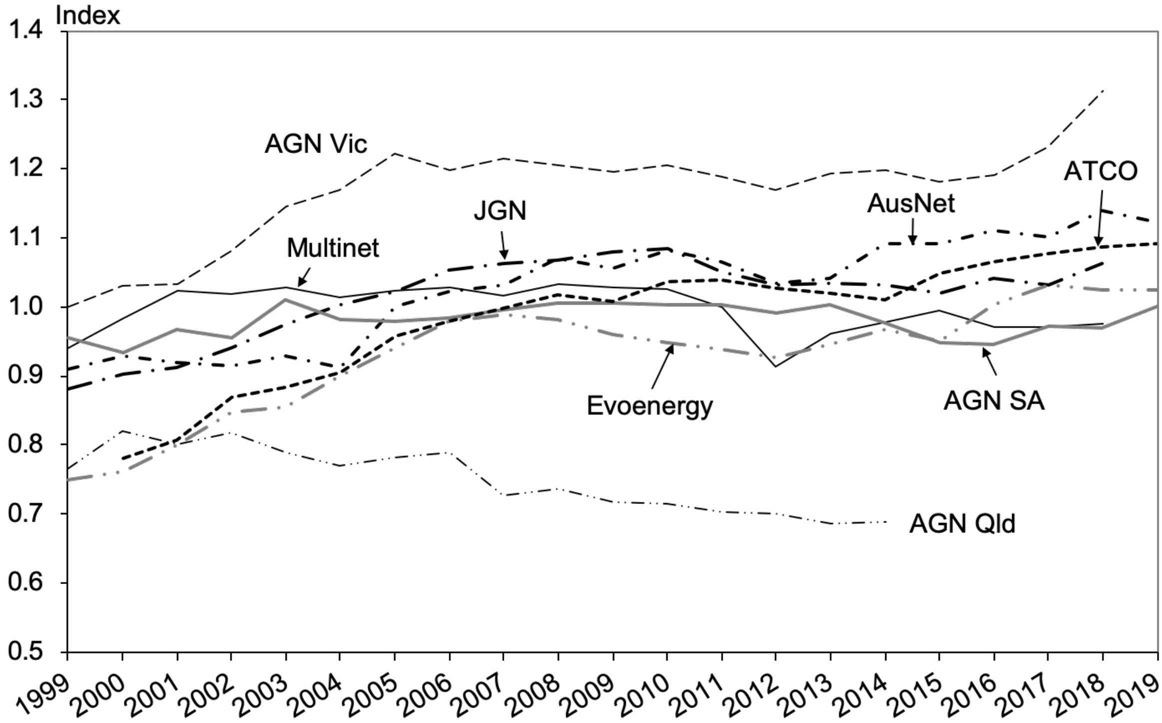
| | AGN Vic | Multinet | AusNet | JGN | AGN SA | AGN Qld | ATCO | Evoenergy |
|---|---|---|---|---|---|---|---|---|
| 1999 | 1.000 | 0.940 | 0.909 | 0.882 | 0.956 | 0.766 | . | 0.750 |
| 2000 | 1.029 | 0.983 | 0.928 | 0.903 | 0.933 | 0.820 | 0.781 | 0.760 |
| 2001 | 1.033 | 1.023 | 0.918 | 0.913 | 0.968 | 0.801 | 0.808 | 0.799 |
| 2002 | 1.081 | 1.019 | 0.916 | 0.941 | 0.955 | 0.818 | 0.869 | 0.848 |
| 2003 | 1.145 | 1.028 | 0.928 | 0.975 | 1.011 | 0.790 | 0.884 | 0.855 |
| 2004 | 1.168 | 1.013 | 0.913 | 1.004 | 0.982 | 0.769 | 0.906 | 0.900 |
| 2005 | 1.223 | 1.024 | 1.000 | 1.021 | 0.979 | 0.783 | 0.958 | 0.940 |
| 2006 | 1.197 | 1.028 | 1.022 | 1.054 | 0.984 | 0.788 | 0.978 | 0.980 |
| 2007 | 1.214 | 1.016 | 1.032 | 1.063 | 0.996 | 0.727 | 0.998 | 0.988 |
| 2008 | 1.206 | 1.033 | 1.070 | 1.068 | 1.006 | 0.735 | 1.018 | 0.981 |
| 2009 | 1.196 | 1.027 | 1.055 | 1.079 | 1.005 | 0.718 | 1.009 | 0.961 |
| 2010 | 1.205 | 1.026 | 1.081 | 1.084 | 1.004 | 0.715 | 1.037 | 0.948 |
| 2011 | 1.188 | 1.001 | 1.065 | 1.052 | 1.003 | 0.702 | 1.038 | 0.939 |
| 2012 | 1.168 | 0.912 | 1.033 | 1.031 | 0.991 | 0.701 | 1.028 | 0.926 |
| 2013 | 1.193 | 0.960 | 1.042 | 1.035 | 1.002 | 0.686 | 1.019 | 0.946 |
| 2014 | 1.197 | 0.978 | 1.091 | 1.032 | 0.976 | 0.688 | 1.010 | 0.967 |
| 2015 | 1.181 | 0.995 | 1.092 | 1.021 | 0.948 | . | 1.048 | 0.949 |
| 2016 | 1.190 | 0.970 | 1.111 | 1.041 | 0.946 | . | 1.065 | 1.002 |
| 2017 | 1.230 | 0.972 | 1.100 | 1.031 | 0.972 | . | 1.077 | 1.032 |
| 2018 | 1.313 | 0.976 | 1.140 | 1.064 | 0.969 | . | 1.086 | 1.023 |
| 2019 | . | . | 1.124 | . | 1.001 | . | 1.091 | 1.024 |

Source: Calculations using Economic Insights GDB database.

The MTFP results indicate that in the latest years available, Evoenergy is found to have the fifth highest TFP level—an MTFP index of 1.02 in 2019. The highest TFP level is AGN Vic 1.37, followed by AusNet (1.12), ATCO (1.09) and JGN (1.06). Those with TFP levels lower than (but similar to) Evoenergy include AGN SA (1.00) and Multinet (0.98), whereas AGN Qld has a much lower TFP level.

The trends in MTFP shown in Figure 6.1 suggest that Evoenergy, like ATCO, was relatively lowly ranked in terms of productivity level at the commencement of the sample period, but had a middle ranking by the end of the period. Aside from AGN Qld, which had declining productivity, the other GDBs in the sample enjoyed a significant gain in productivity over the sample period.

Figure 6.1: **GDB multilateral TFP indexes, 1999–2019**




Source: Economic Insights GDB database

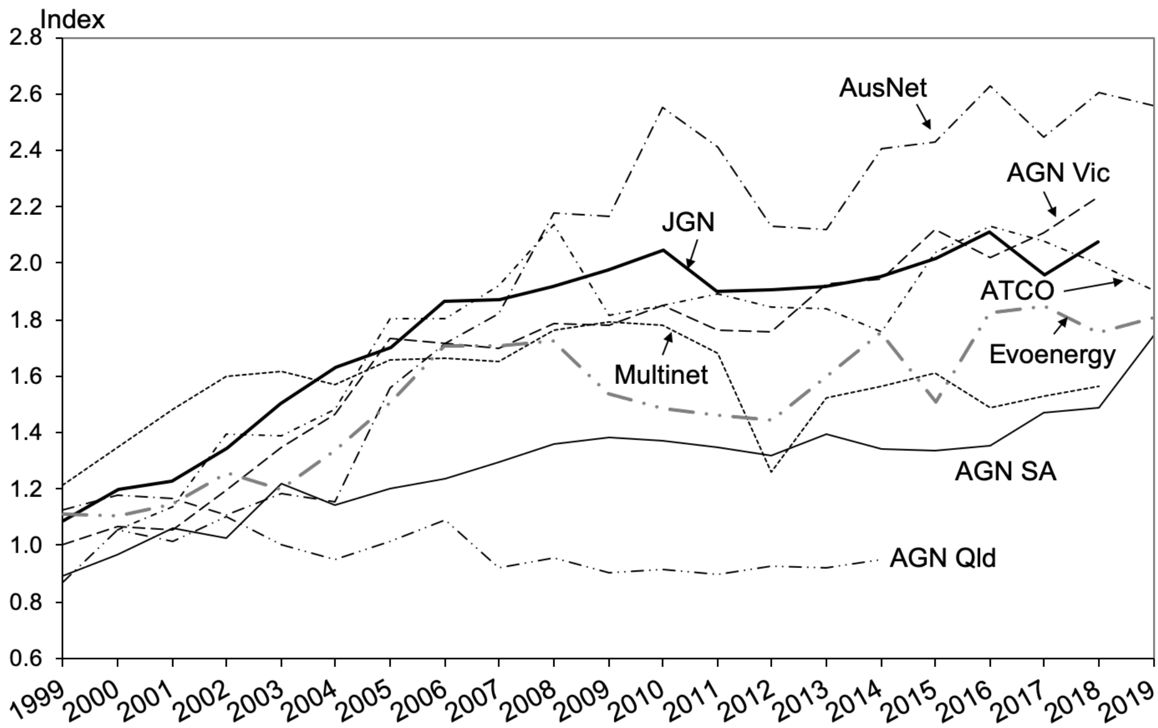
Table 6.2 and Figure 6.2 compare the levels of Opex PFP using multilateral Opex PFP indexes for the eight GDBs. In the last year available, Evoenergy had the fifth highest Opex PFP level (1.80). In comparison to Evoenergy's Opex PFP level in 1999 (1.11), it indicates a strong growth in Opex PFP over the sample period. Most of the GDBs had similarly strong growth in Opex PFP over the sample period, with the only exceptions being Multinet and AGN Qld, which had more modest gains. The GDBs with strongest growth in Opex PFP were AGN Vic and AusNet, and they also had the highest levels of Opex PFP at the end of the period (2.24 and 2.56 respectively). Evoenergy's Opex PFP level at the end of the sample period was most comparable to JGN (1.90) and AGN SA (1.75).

Table 6.2: **GDB multilateral Opex PFP indexes, 1999–2019**

| | AGN Vic | Multinet | AusNet | JGN | AGN SA | AGN Qld | ATCO | Evoenergy |
|---|---|---|---|---|---|---|---|---|
| 1999 | 1.000 | 1.213 | 1.127 | 1.087 | 0.891 | 0.868 | . | 1.111 |
| 2000 | 1.068 | 1.344 | 1.178 | 1.199 | 0.965 | 1.052 | 1.056 | 1.104 |
| 2001 | 1.058 | 1.482 | 1.167 | 1.230 | 1.060 | 1.014 | 1.137 | 1.144 |
| 2002 | 1.194 | 1.596 | 1.110 | 1.346 | 1.028 | 1.101 | 1.394 | 1.259 |
| 2003 | 1.348 | 1.616 | 1.181 | 1.500 | 1.218 | 1.003 | 1.387 | 1.201 |
| 2004 | 1.465 | 1.569 | 1.154 | 1.629 | 1.141 | 0.952 | 1.480 | 1.340 |
| 2005 | 1.733 | 1.656 | 1.558 | 1.701 | 1.203 | 1.013 | 1.803 | 1.508 |
| 2006 | 1.715 | 1.662 | 1.713 | 1.866 | 1.238 | 1.088 | 1.805 | 1.706 |
| 2007 | 1.695 | 1.649 | 1.823 | 1.873 | 1.294 | 0.921 | 1.918 | 1.709 |
| 2008 | 1.785 | 1.761 | 2.175 | 1.919 | 1.360 | 0.956 | 2.135 | 1.722 |
| 2009 | 1.777 | 1.790 | 2.168 | 1.979 | 1.381 | 0.901 | 1.817 | 1.538 |
| 2010 | 1.847 | 1.780 | 2.553 | 2.047 | 1.373 | 0.916 | 1.852 | 1.486 |
| 2011 | 1.763 | 1.680 | 2.412 | 1.900 | 1.346 | 0.898 | 1.894 | 1.458 |
| 2012 | 1.755 | 1.261 | 2.132 | 1.904 | 1.318 | 0.924 | 1.842 | 1.445 |
| 2013 | 1.925 | 1.525 | 2.119 | 1.918 | 1.392 | 0.920 | 1.838 | 1.598 |
| 2014 | 1.946 | 1.566 | 2.403 | 1.950 | 1.343 | 0.951 | 1.755 | 1.754 |
| 2015 | 2.117 | 1.610 | 2.427 | 2.014 | 1.338 | . | 2.039 | 1.507 |
| 2016 | 2.020 | 1.489 | 2.629 | 2.108 | 1.356 | . | 2.129 | 1.823 |
| 2017 | 2.108 | 1.527 | 2.445 | 1.959 | 1.471 | . | 2.077 | 1.847 |
| 2018 | 2.237 | 1.566 | 2.601 | 2.074 | 1.488 | . | 1.997 | 1.755 |
| 2019 | . | . | 2.557 | . | 1.745 | . | 1.903 | 1.804 |

Source: Calculations using Economic Insights GDB database.

Figure 6.2: **GDB multilateral Opex PFP indexes, 1999–2019**




Source: Economic Insights GDB database.

Table 6.3 and Figure 6.3 compare Capital PFP levels using multilateral Capital PFP indexes. In the latest year, Evoenergy's Capital PFP index was 0.78, which is very close to a number of other GDBs, who appear to have converged to the same Capital PFP level over the sample period. The GDBs with essentially the same level of Capital PFP as Evoenergy include; Multinet, AusNet, JGN, AGN SA, ATCO and AGN SA. AGN Vic had a higher level of Capital PFP (1.08) and AGN Qld a lower level (0.61).

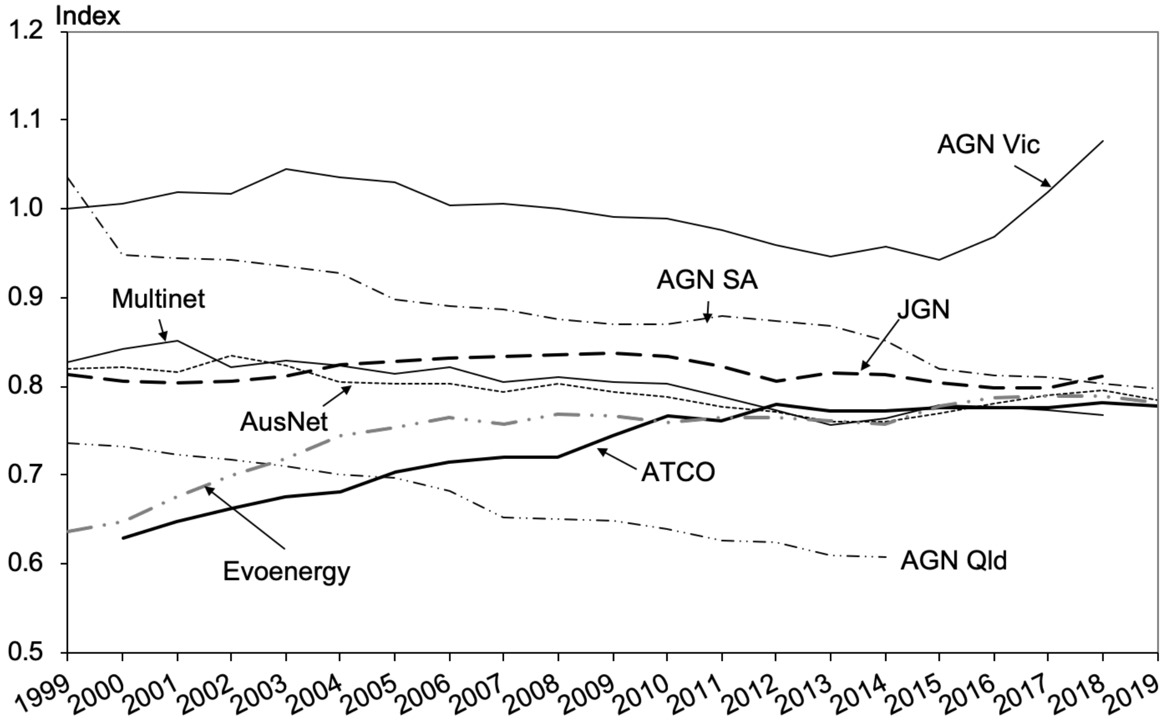
In terms of the trend, there was little change in the Multilateral Capital PFP indexes between the beginning and end of the sample period for the three Victorian GDBs and for Jemena. For Evoenergy and ATCO there was a substantial improvement, in the order of 20 per cent. Only AGN SA and AGN Qld showed deterioration in Capital PFP over the sample period, both in the order of 20 per cent decrease.

Table 6.3: **GDB multilateral Capital PFP indexes, 1999–2019**

| | AGN Vic | Multinet | AusNet | JGN | AGN SA | AGN Qld | ATCO | Evoenergy |
|---|---|---|---|---|---|---|---|---|
| 1999 | 1.000 | 0.827 | 0.819 | 0.812 | 1.036 | 0.736 | . | 0.636 |
| 2000 | 1.005 | 0.841 | 0.822 | 0.806 | 0.948 | 0.733 | 0.629 | 0.647 |
| 2001 | 1.019 | 0.851 | 0.816 | 0.803 | 0.944 | 0.722 | 0.647 | 0.676 |
| 2002 | 1.016 | 0.821 | 0.834 | 0.806 | 0.943 | 0.716 | 0.662 | 0.700 |
| 2003 | 1.044 | 0.829 | 0.824 | 0.812 | 0.935 | 0.710 | 0.675 | 0.717 |
| 2004 | 1.036 | 0.823 | 0.806 | 0.824 | 0.927 | 0.700 | 0.681 | 0.745 |
| 2005 | 1.030 | 0.815 | 0.803 | 0.828 | 0.897 | 0.697 | 0.704 | 0.754 |
| 2006 | 1.003 | 0.821 | 0.804 | 0.831 | 0.890 | 0.682 | 0.714 | 0.764 |
| 2007 | 1.005 | 0.805 | 0.794 | 0.833 | 0.886 | 0.651 | 0.720 | 0.758 |
| 2008 | 1.000 | 0.810 | 0.802 | 0.835 | 0.876 | 0.651 | 0.721 | 0.769 |
| 2009 | 0.992 | 0.804 | 0.793 | 0.838 | 0.869 | 0.648 | 0.745 | 0.767 |
| 2010 | 0.989 | 0.802 | 0.788 | 0.833 | 0.869 | 0.638 | 0.767 | 0.760 |
| 2011 | 0.975 | 0.788 | 0.778 | 0.823 | 0.878 | 0.627 | 0.762 | 0.765 |
| 2012 | 0.959 | 0.773 | 0.771 | 0.806 | 0.873 | 0.623 | 0.779 | 0.764 |
| 2013 | 0.947 | 0.757 | 0.761 | 0.816 | 0.869 | 0.609 | 0.772 | 0.762 |
| 2014 | 0.957 | 0.764 | 0.760 | 0.813 | 0.852 | 0.607 | 0.772 | 0.758 |
| 2015 | 0.942 | 0.779 | 0.769 | 0.804 | 0.820 | . | 0.776 | 0.777 |
| 2016 | 0.968 | 0.778 | 0.781 | 0.798 | 0.813 | . | 0.776 | 0.786 |
| 2017 | 1.018 | 0.773 | 0.790 | 0.799 | 0.810 | . | 0.776 | 0.790 |
| 2018 | 1.076 | 0.767 | 0.796 | 0.812 | 0.803 | . | 0.781 | 0.789 |
| 2019 | . | . | 0.785 | . | 0.797 | . | 0.778 | 0.781 |

Source: Calculations using Economic Insights GDB database

Figure 6.3: **GDB multilateral Capital PFP indexes, 1999–2019**




Source: Economic Insights GDB database

## 6.3 Summary

Fisher indexes are used to measure TFP trends. The time series TFP results for Evoenergy are as follows:

1. Evoenergy's TFP increased at an average annual rate of 0.4 per cent from 1999 to 2019. Productivity growth was stronger in the period up to 2007, and has been declining over the period since then.
2. Evoenergy's Opex partial factor productivity (PFP) increased at an average annual rate of 2.5 per cent from 1999 to 2019. Capital PFP *decreased* at an average annual rate of 0.5 per cent over the same period. Opex PFP growth was strong in the period 1999 to 2007 (5.5 per cent) but growth was weaker in the periods from 2007 to 2014 (0.4 per cent) and 2014 to 2019 (0.6 per cent). The decline in Evoenergy's Capital PFP mainly occurred in the periods from 2007 to 2014 (-1.3 per cent) and from 2014 to 2019 (-1.1 per cent).
3. Comparing the average rates of TFP growth of GDBs, Evoenergy's TFP growth over the full sample period was below the sample average of 0.8 per cent per year, but broadly similar to JGN (0.7 per cent), Multinet (0.6 per cent) and AGN SA (0.8 per cent). ATCO, AGN Vic and AusNet had higher rates of TFP growth (1.4, 1.5 and 1.3 per cent respectively). Most GDBs had strong rates of growth in Opex PFP, comparable to Evoenergy. However, Evoenergy's decline in Capital PFP (-0.5 per cent per year) was slightly greater than for most other GDBs.
4. Over the most recent period from 2014 to 2019, Evoenergy's average annual rate of TFP growth was -0.7 per cent. Besides JGN, which had no TFP growth in this period,

the other GDBs all had some productivity growth in this period. AusNet, Multinet and ATCO all had an average rate of TFP growth of 0.4 per cent per year in the 2014 to 2017 period and AGN SA and AGN Vic both had TFP growth rates of 1.4 per cent.

5. Evoenergy had above-average output growth averaging 2.7 per cent per year between 1999 and 2019, compared to the average for all GDBs of 1.9 per cent over the same period. The average rate of increase in inputs for Evoenergy over the period 1999 to 2019 was 2.3 per cent per year, which was above the average for all GDBs (1.1 per cent). Over the full period from 1999 to 2019, Evoenergy's average rate of change of opex inputs was 0.2 per cent per year, compared to the average for all GDBs of –0.9 per cent per year. The average growth rate of capital inputs for AGN SA over the period 1999 to 2019 was 3.2 per cent per year, compared to the average for all GDBs (2.1 per cent).

The multilateral total factor productivity (MTFP) index is used to measure comparative productivity *levels*. The results for comparative TFP levels are as follows:

1. The MTFP results indicate that in the latest years available, Evoenergy is found to have the fifth highest TFP level in the last year of the sample—an MTFP index of 1.02 in 2019 (i.e. slightly above AGN Vic's productivity level in 1999, which is used as the index base). This TFP level is comparable to Multinet (0.98), AGN SA (1.00) and JGN (1.06). This can be compared to the following MTFP indexes for the other GDBs: AGN Vic (1.37), AusNet (1.12), and ATCO (1.09). AGN Qld has a much lower TFP level.
2. Evoenergy also had the fifth highest Opex PFP level (1.80) in the last year of the sample. The Opex PFPs of the other GDBs are: AGN Vic (2.24), AusNet (2.56), JGN (2.07), ATCO (1.90), AGN SA (1.75), Multinet (1.57), and AGN Qld (0.95).
3. In the latest year, Evoenergy's Capital PFP index was 0.78, which is very close to a number of other GDBs, who appear to have converged to the same Capital PFP level over the sample period. The GDBs with essentially the same level of Capital PFP as Evoenergy include; Multinet, AusNet, JGN, AGN SA and ATCO. AGN Vic had a higher level of Capital PFP (1.08) and AGN Qld a lower level (0.61).

# PART C: ECONOMETRIC COST FUNCTION ANALYSIS

In this part of the report, we estimate the opex cost function for gas distribution businesses. The principal aims of the analysis are to estimate trends in technical efficiency in the industry and estimate the opex efficiency of Evoenergy relative to other GDBs. The econometric results are used to establish whether Evoenergy is efficient in its use of opex inputs, and also to estimate parameters that can be used when forecasting Evoenergy's opex rate of change (which is equal to the rate of opex price growth plus the rate of output growth minus the opex partial productivity growth rate) for the period 2021-22 to 2025-26. These parameters include the average historical rate of frontier shift (or technical change) and the appropriate weights for constructing the output index.

Cost function analysis of gas network businesses has a long history. In the United States, Barcella (1992) estimated the cost function of gas distribution businesses based on a sample of 50 companies over the period 1969-1988. In the context of Australia and New Zealand, Pacific Economics Group (2001a; 2001b; 2001c) evaluated the opex performance of the three Victorian GDBs relative to that of US gas distribution utilities by estimating an econometric cost function model that explained the effect on a company's gas distribution cost of some measurable 'business conditions'. The parameters of the model were estimated using data from a large sample of American investor–owned gas distribution utilities. The model was used to predict opex for the Australian utilities given the values for the (included) business conditions that the utilities faced. The business condition variables included input prices, the amount of outputs supplied and certain characteristics of the customer base and service territory. The model therefore controlled, among other things, for differences in realised scale economies. Cost performance was evaluated by comparing the Australian utilities' actual opex with those predicted by the model for an average US utility facing similar business conditions.

Economic Insights (2012a) used econometric analyses of the total and opex cost functions for gas distribution businesses to assess the comparative efficiency of SP AusNet. This analysis was based on a sample of 9 Australian GDBs and 2 New Zealand GDBs using data sourced from the public domain to the maximum extent possible. Total cost function analysis takes into account opex and capital input trade–offs, price effects and controls for certain operating environment factors in the analysis of comparative cost efficiency. The study also developed econometric estimates of the variable or operating cost function and the parameters of this function were combined with forecasts of output and capital input levels to forecast SP AusNet's future GDB opex partial productivity growth rates. Such forecasts are used in the 'rate of change' formula for rolling forward opex allowances often used in the application of building blocks regulation.

Economic Insights (2015a) estimated an econometric variable cost function for Australian and New Zealand gas networks on behalf of Jemena Gas Networks. The econometric analysis utilised both stochastic frontier and feasible generalized least squares methods, and the models were used for both efficiency benchmarking and forecasting opex partial productivity. The two outputs used in that study were customer numbers and gas throughput. Customer density was also an important explanatory variable, measured by customer numbers per kilometre (km) of mains. Real opex was found to be negatively related to customer density, which implies a positive relationship between network length and real opex.

In a subsequent econometric study for Multinet Gas, Economic Insights (2016c) estimated the relationship between gas network real operating costs ('opex') and outputs, fixed capital inputs and operating environment factors. The aim of that study was to ascertain the most significant output measures as determinants of opex and to quantify the elasticities of real opex with respect to each of the outputs. The study used a database that included 11 Australian and 3 New Zealand gas distribution businesses (GDBs). The study used stochastic frontier (SF) and random effects (RE) methods. The study concluded that gas throughput is not a statistically significant determinant of real opex; whereas customer numbers and network length were both found to be statistically significant determinants of real opex. A similar modelling exercise was undertaken for JGN in 2019 for the purpose of ascertaining JGN's relative technical efficiency compared to an estimated efficiency frontier and for forecasting productivity trends.

The analysis in this part of the report is similar to those previously undertaken by Economic Insights in 2015, 2016 and 2019, and uses additional data available since those studies was undertaken. The analysis carried out here re-estimates the same model specifications developed in the 2019 study undertaken for JGN with the latest data, and also estimates a simplified model specification.

To ensure comparability with earlier studies and to ensure that the sample is as large and broad as possible, this econometric study uses a database that includes 11 Australian and 3 New Zealand gas distribution businesses (GDBs). The data has two main sources. For 5 Australian GDBs the data was provided by the businesses in response to surveys prepared by Economic Insights. These GDBs include Australian Gas Networks (AGN) South Australia (SA), AGN Victoria, Multinet, ATCO, AusNet Services, Evoenergy and JGN. Data for the other GDBs in the sample was sourced from documents in the public domain. The sample periods differ between utilities, but in most cases includes historical data for the period from 1999 to 2018 or 2019. In a relatively small number of cases, forecast data from final regulatory determinations are also included, primarily because several of the smaller GDBs in the sample are no longer subject to price regulation, and up-to-date statistical information is no longer available for them. The data includes revenue, throughput, customer numbers, distribution pipeline length, opex, capex and regulatory asset value. In some cases missing observations were estimated based on growth rates for the variable or a related variable before and after the missing year. The database includes a total of 261 observations. This sample is larger than those available for previous econometric studies of the gas industry undertaken by Economic Insights.

# 7 CONTEXT, DATA & METHODOLOGY

Section 7.1 discusses the context relevant to the applications of the study. In section 7.2 the variable or opex cost function is introduced and the considerations relating to choosing the initial set of variables to be used in the analysis is discussed. The data used in the study is described in section 7.3. The approaches used to develop the functional form and the stochastic specifications are discussed in section 7.4, and section 7.5 discusses the method of employing the model in opex cost function analysis.

## 7.1 Regulatory Context

This study is directed to informing some of the requirements of Evoenergy and the procedures of the Australian Energy Regulator (AER) under the gas industry regulatory framework. The AER has described its approach to forecasting opex in electricity network regulation in its *Expenditure Forecast Assessment Guideline 2013* and *Forecasting Productivity Growth 2019* (Australian Energy Regulator (AER) 2013; AER 2019). The same principles are assumed to apply in gas distribution network regulation. The AER uses a 'base-step-trend' method for assessing businesses' opex proposals and forming its own view of the efficient future opex allowance for regulated energy distribution network service providers (DNSPs). This method involves estimating the efficient opex for a base year, at the end of the previous regulatory period, and projecting it forward for each year of the forthcoming regulatory period using forecasts for the rates of change in opex input prices, outputs and a relevant measure of opex productivity. Further adjustments, termed 'step changes', may be made to reflect any changes in DNSP responsibilities during the forthcoming regulatory period.

Productivity is taken into account in two different ways in the base-step-trend method. Firstly, the AER takes any *material inefficiency* of a DNSP into account when determining the base-year efficient opex. "When assessing a distributor's opex proposal we compare the distributor's productivity performance against that of the frontier to determine the distributor's efficiency in operating its network business" (AER 2018, 5). This adjustment reflects an allowance for 'catch up' to the efficiency frontier. It may only be a partial adjustment to remove inefficiency because the incentive features of the regulatory framework (including carry-over of efficiencies to later periods) may be relied on to ensure any remaining inefficiencies are removed over the prospective regulatory period.

Secondly, forecast *productivity growth* is one component of the calculation of the rate of change formula. In calculating the rate of change, productivity growth is measured as "the shift in the productivity frontier. It is not intended to include any 'catch up' to the frontier for a distributor that is materially inefficient." (AER 2018, 5) This productivity growth forecast is to be based on that which can be achieved by the best performing (ie, 'frontier') businesses. The AER's expectation is that "an efficient and prudent distributor should achieve the same level of productivity growth as the frontier distributors." (AER 2018, 5)

This study provides information directly relevant to both of these productivity-related questions. That is, whether Evoenergy is estimated to have any material inefficiency in the latest periods for which data is available, and the historical rate of productivity growth associated with shift in the productivity frontier. The AER has noted that an estimate of the average rate of technological change over a past period need not be representative of future trends, and other information may need to be taken into account to reach an overall assessment.

The rate of change formula used for projecting opex forward over the next regulatory period also relies on estimates of the rates of change of an index of the relevant outputs and of an index of relevant input prices. Constructing an output index involves defining the relevant outputs and deriving appropriate weights for each output. Forecasts of the individual outputs are part of the set of forecasts developed by the DNSP for the purposes of its access arrangement (AA). From among these are chosen the most relevant output measures, and the weights are used to aggregate the relevant forecasts into an output index projected over the forthcoming regulatory period. The procedure for constructing the opex input price index relies heavily on estimating the split between labour and non-labour components of opex. These weights are used to construct the opex input price index from forecasts of labour and non-labour price movements. This study addresses three questions relating to the forecast of the rates of change of outputs and input prices:

- The choice of outputs to be used in the output index;
- The weights to be used in the output index; and
- The weights to be used in the input price index.

## 7.2 Variable Cost Function and Choice of Variables

The variable cost function is the variable cost part of the short-run cost function (i.e. excluding fixed costs), and the short run cost function is the minimum cost of producing a given set of outputs subject to the constraint that in the short-run some input or set of inputs is fixed. The variable cost function is a function in which a GDB's variable cost is dependent on the quantities of the outputs produced, the input prices of the variable inputs, and the quantities of the fixed inputs. The functional relationship between these explanatory variables and variable cost reflects the technology available and used in the industry. Differences in the operating environment characteristics of the distinct localities in which the utilities operate can influence the technology — i.e. the ability of an efficient firm to translate inputs into outputs.

Developing a model for a variable cost function involves:

- Deciding on the outputs and inputs, including those that are fixed and those that are variable, and identifying the operating environment variables, and determining how these quantities and input prices are to be measured.
- Specifying the functional form of the variable cost function and the stochastic specification of the model, which is essential to the inferences drawn from the model.

Our general approach to choosing the variables is to begin with those variables used in the recent econometric study of gas DNSP opex costs that Economic Insights carried out in 2019. The strategy is then to consider variations, and determine those that improve the modelling, given the current dataset. The variables considered are generally consistent with other benchmarking studies of energy networks.

In the 2019 study, the dependent variable used throughout the analysis was constant price opex (in 2010$). In the preferred model there were two outputs; customer numbers and the network length in km (both in log form). A measure of capital inputs was included — the constant price asset value. The annual rate of technological change was measured by the coefficient on a variable that measures time in years. Operating environment variables used or tested in the studies included: (i) the proportion of the network not made of cast iron or unprotected steel (a proxy for network age); (ii) the number of city gates (a proxy for service area dispersion); and (iii) tariff class customer share of total gas throughput (all in log form; and (iv) the load factor (i.e. the ratio of the maximum day quantity (MDQ) to the average daily quantity delivered). In the preferred model only the first three of these operating environment variables were included.

Data for the outputs and inputs are reasonably complete in the dataset, although in some instances missing observations were estimated based on growth rates for the variable or a related variable before and after the missing year. In a number of cases adjustments were made to ensure the data related to comparable activities and measures (eg, unaccounted for gas allowances for non–Victorian GDBs have been excluded to put those GDBs on a comparable basis with Victorian reporting). Data coverage of some of the business environment variables is less complete — especially with regard to load factors for Victorian GDBs. Interpolation or extrapolation are used where necessary. While every effort has been made to make the publicly available data used in this study as consistent as possible, the limitations of currently available public domain data need to be recognised. For some of the small GDBs that are no longer regulated, the latest available regulatory forecasts are used due to lack of reported data in recent years. There may be somewhat different coverage of activities and definitions of variables reported between GDBs or over time where regulators have changed reporting requirements.

## 7.3 Data

The analysis makes use of the Economic Insights dataset for Australian and New Zealand gas distribution businesses, which includes the following gas distribution businesses (GDBs):

- in Australia: AGN Albury, AGN Vic, Multinet, AusNet, AGN SA, AGN Qld, Allgas, AGN Wagga, Jemena, Evoenergy, ATCO; and
- in New Zealand: Powerco, Vector and GasNet.

All of these GDBs are included in the sample in this part of the study.[10] Details of the sample are shown in Table B.1 in Appendix B. The data represents yearly observations, and GDBs differ in whether their reporting years end in June or December, or in one case, September. Some have changed their reporting years during the period studied. Overall, there are 264 observations, or approximately 19 observations per GDB on average. Data for most of the Australian GDBs in the study are available for the period from 1999 or 2000 to 2018 or 2019. However, there are fewer consistent observations available for the New Zealand GDBs, reflecting the impact of mergers, asset sales and industry restructuring. Some of the smallest Australian GDBs are no longer subject to price regulation, and the data for these GDBs are supplemented by regulator forecasts.

The data for AGN Vic, AusNet, AGN SA, Jemena, Multinet Gas, ATCO and Evoenergy are drawn from confidential survey data provided by those businesses for the purposes of productivity analysis. Two years of survey data is used for AGN Qld also. All of the remaining data has been sourced from public documents such as regulator final decisions, Assess Arrangement Information, asset management plans, statutory information disclosure and/or company Annual Reports. The public domain data source used for the New Zealand GDBs is the Information Disclosure Data filings required by the Gas (Information Disclosure)

[10] In Part A, GasNet was excluded due to its small size.

Regulations 1997. For Australian GDBs, we have used the final approval information, where possible, as we consider that it is the most consistent and objective source of information available. In some cases the data represents official forecasts made by regulators. As detailed in Table B.1 (Appendix B), they represent only a small proportion of the observations.

The data used for the Australian GDBs covers only their regulated activities. Data relating to large industrial users whose supply is not regulated are not included. Inclusion of this data would require access to information not generally in the public domain and has been beyond the scope and timeframe of this study.

All cost data were first converted to nominal terms (where necessary) using the All Groups Consumer Price Index in Australia and the equivalent in New Zealand. The nominal series were then converted to real series in (calendar year) 2010 dollars using the same price indexes. The New Zealand data were then converted to Australian dollars using the OECD (2014) purchasing power parity for 2010. Purchasing power parities are the rates of currency conversion that eliminate differences in international price levels and are commonly used to make comparisons of real variables between countries.

## 7.4 Model specification

The functional specifications of the models tested in this study are discussed in section 7.4.1. The stochastic specifications are discussed in section 7.4.2.

### *7.4.1 Functional specification*

The functional specification used here is generally based on the Cobb-Douglas variable cost function, in which the exogenous variables enter the model directly in log form. In the 2019 study for JGN, more flexible functional forms were tested, but were found to offer no improvement over the simpler Cobb-Douglas specification in this application. The model includes variables that represent different operating environment characteristics of utilities, which also enter into the model in log-linear fashion.

It is assumed there are only two inputs: capital inputs, which are fixed in the short-run cost function; and noncapital inputs, which are variable. Hence there is only one variable input price. Since the short-run variable cost function is linearly homogenous in the variable input prices, when there is only one variable input, this implies that variable cost (*VC*) is proportionate to the noncapital input price (*W*). The Cobb-Douglas variable cost (*VC*) function in this case has the following form:

(7.1) $$\ln VC = a_0 + \ln W + c_1 \ln K + \sum_j \theta_j \ln Y_j + \sum_h a_h \ln Z_h + a_t t + \varpi$$

where:

- $Y_j$ is the quantity of output *j*; where *j,k* = 1, 2, … *J*;
- *K* is a service flow measure of fixed capital;[11]

[11] This refers to the annual capital input quantity. Due to its durable nature, capital has two distinct economic

- $Z_h$ are operating environment factors $h$; where $h = 1, 2, \ldots H$;
- $t$ is a measure of time and reflects the principle that, all else unchanged, costs decrease marginally each year due to technical change; and
- $\varpi$ is a stochastic term that reflects the combined influence of all other influences on variable cost, including inefficiency.

The main model specifications tested in this study involve different sets of $Z$ variables. In all models there are two outputs ($Y$ variables): customer numbers and the length of mains (km). The measure of capital input ($K$) is the real asset value. The dependent variable is the log of real operating costs: $\ln VC - \ln W$.

The operating environment variables ($Z$s) tested here are those used in the 2019 study:

- Proportion of total mains length not made of cast iron or unprotected steel (proxy for network age);
- Number of city gates (proxy for service area dispersion);
- Tariff customer-class gas volumes / total gas volumes.

### 7.4.2 Stochastic specifications

The stochastic specification is another important aspect of the theoretical model underlying the econometric specification. Two of the issues to consider are the possibility that some businesses are not fully efficient, and also the possibility of 'unobserved heterogeneity' among the businesses in the sample.

*Inefficiency:* A cost function represents the minimum cost that a business can achieve with given technology, input prices and the levels of outputs. In theory the minimum cost is an ideal or frontier, which may not be realised by all businesses, and businesses may differ in the degree to which they minimise cost. That is, they may differ in their degrees of efficiency, and the measurement of their differing degrees of efficiency is one objective of the analysis.

*Unobserved heterogeneity:* Although the explanatory variables of the model ideally represent all of the important determinants of variable cost, there will always be a range of lesser determinants that affect technology (i.e. the ability of a best-practice GDB to transform inputs into outputs), some of which cannot be explicitly taken into account (eg, because they are not readily measurable or data is not available). Influences of this kind can give rise to "unobserved heterogeneity' between the businesses in the sample, and can affect measures of inefficiency.

The stochastic specifications discussed in this section differ in terms of which of these effects they seek to measure and how they do so. The approaches used in this study are stochastic frontier (SF) analysis and feasible generalized least squares (FGLS). Stochastic frontier models seek to identify an efficient frontier, based on best practice among the firms in the sample, and each firm may be closer or further from the frontier, hence there is a firm-specific inefficiency.

characteristics, as a source of capital services in production and as a store of wealth. Measures of these characteristics will often be different, and the appropriate measure depends on the analytical context. Wealth measures of capital are more commonly available, and in some circumstances may be used as a proxy measure of capital services (as is the case in this study).

The FGLS model does not separate firm-specific inefficiency from other sources of stochastic error, although it does permit standard errors to vary between GDBs. It is a useful comparator to the SF results. These two estimation methodologies were used in the study undertaken for JGN in 2015 and 2019 and other earlier studies.

In what is perhaps the most standard stochastic frontier (SF) model, the stochastic specification is:

(7.2) $$\varpi_{it} = u_{it} + \varepsilon_{it}$$

$$u_{it} = u_i G(t)$$

$$u_i \sim N^+(\mu, \sigma_v^2)$$

$$\varepsilon_{it} \sim N(0, \sigma_\varepsilon^2)$$

where: $\varepsilon_{it}$ is a normally distributed random variable which has a unique value for each observation; $u_{it}$ is interpreted as a measure of the inefficiency of GDB *i* relative to the efficient frontier (ie, best practice) in period *t*; $u_i$ is a strictly positive random variable which, as shown, has a truncated normal distribution with mean $\mu$, and has a unique value for each GDB; and $G(t)$ is some function of time, which represents a time pattern of inefficiency common to all GDBs. In the time invariant inefficiency model: $G(t) = 1$, and when the inefficiency effects are assumed to have a half-normal distribution: $\mu = 0$. Absent very large datasets, restrictions of this kind are often desirable to keep the models computationally tractable and to gain better precision on the effects of interest. The assumptions of time-invariant and half-normally distributed inefficiency are used throughout this analysis.

A number of more flexible and more complicated SF specifications are available, most of which involve either: (i) different distributions adopted for $u_i$; (ii) allowing the parameters $\mu, \sigma_v^2$ and $\sigma_\varepsilon^2$ to be functions of the same or other exogenous factors; or (iii) various alternative functional forms for $G(t)$ (Kumbhakar, Wang, and Horncastle 2015). Beyond the simpler of these extensions, and absent large datasets, extensions of this kind can be difficult to implement satisfactorily. Hence, the reliance on a simple formulation of the SF model in this study.

The FGLS estimator allows for heteroscedastic panels, but does not provide estimates of the comparative efficiency of the GDBs. Here:

(7.3) $$\varpi_{it} = \varepsilon_{it}$$

$$\varepsilon_{it} \sim N(0, \sigma_{\varepsilon i}^2)$$

The random error term has zero mean across the whole sample, and $\sigma_{\varepsilon i}^2$ is a different variance for each panel of the dataset, meaning the variance matrix of the disturbance terms has the form:

(7.4) $$\mathrm{E}[\boldsymbol{\varepsilon} \cdot \boldsymbol{\varepsilon}'] = \begin{bmatrix} \sigma_1^2 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \sigma_n^2 \end{bmatrix}$$

for panels 1 to *n*. This assumption is appropriate in this context because there is wide variation in the sizes of the GDBs in the sample, so the dependent variables, and some of the explanators, are of different orders of magnitude for some GDBs compared to others. So it is reasonable to expect the scale of the variances may also differ.

We report, and combine, the results from both the FGLS and SFA methods because each has different assumptions regarding the nature of the stochastic disturbance term assumed when estimating the model. Each has particular advantages that are appropriate to this application. The elasticities used from the models are simple averages of the elasticity estimates from each model. The SFA model is used to provide estimates of the technical efficiency of each GDB in the sample.

## 7.5 Using the econometric opex function

This section discusses how the econometric analysis can be applied within the 'base-step-trend' regulatory framework for projecting rates of change in productivity. In our 2015 report prepared for JGN, (Economic Insights 2015a, ch. 5) the short-run or opex cost function (combining equations (5.2) and (5.3) of that report) was expressed generically as:

(7.5) $$C^{OM} = g(Y, W, K, Z, T).\eta$$

where: $C^{OM}$ is real opex; $Y$ represents the set of outputs; $W$ is an index of the real opex input prices; $K$ is fixed capital inputs; $Z$ is a set of operating environment variables; $T$ is time; and $\eta$ is an inefficiency factor specific to each business ($\eta = 1$ for an efficient business, and $\eta > 1$ for an inefficient business). Efficiency benchmarking of the businesses in the sample, used to inform base-year efficiency adjustments, is based on the estimated values of the cost inefficiency, $\eta$, for each business.

The rate of change of opex requires a decomposition of the sources of changes in opex. The components of the rate of change in costs is shown in equation (5.6) of the 2015 report; reproduced below as equation (7.6) (except here only including a single capital input). This shows how the growth rate of real opex is related to the independent variables.

(7.6) $$\dot{C}^{OM} = \sum_i \varepsilon_{Yi}\dot{Y}_i + \dot{W} + \varepsilon_K \dot{K} + \sum_n \varepsilon_{Zn}\dot{Z}_n + \dot{g} + \dot{\eta}$$

where the dot over a variable represents the variable's growth rate, and the $\varepsilon$ coefficients are elasticities of opex cost with respect to the variable. If equation (5) is estimated using a log-log form, then these elasticities are the partial derivatives of the dependent variable with respect to the relevant exogenous variable. In (7.6): $\dot{g}$ is the shift in the cost frontier over time (ie, technical change); and $\dot{\eta}$ is the growth rate of the inefficiency factor (ie, catch-up to the frontier). Equation (7.6) is a method for decomposing the sources of change in opex using the econometrically estimated parameters (the $\varepsilon$'s, $\dot{g}$, and $\dot{\eta}$). For the purpose of forecasting technical change, $\dot{g}$ is the relevant measure of frontier shift over the sample period. The other main drivers of opex growth are: the growth rate of real input prices ($\dot{W}$); and the growth rates of outputs ($\dot{Y}_i$) and capital inputs ($\dot{K}$). The rate of change in opex is also influenced by the interaction between output growth and economies-of-scale,[12] and by the combined effect of changes in the operating environment variables. These effects are generally small.

Forecasting opex requires forecasts of the growth rates of outputs and fixed capital inputs,

[12] In equation (2), if $\sum_i \varepsilon_{Yi} < 1$, then there are economies of scale.

defined consistently with the model. These forecasts will, of course, be the same as the demand and customer forecasts, and the capital inputs forecasts, used by JGN in its proposed access arrangement. The definitions of outputs and capital inputs used for opex forecasting need to be the same as those used in the econometric model if the productivity forecast is to be consistent.(Australian Energy Regulator (AER) 2013, 23)

Formula (7.6) can be related to the AER's rate of change formula:

(7.7) $$\delta_t = \dot{Y}_t + \dot{W}_t - \dot{\rho}_t$$

where $\delta_t$ is the rate of change applied to opex in year *t* of the regulatory period; $\dot{Y}_t$ is the growth rate of output in the same year; $\dot{W}_t$ is the rate of change in real input prices; and $\dot{\rho}_t$ is the rate of change in a relevant measure of productivity. The type of productivity measure used by the AER is discussed below.

In our 2015 report for JGN we rearranged (7.6) as:

(7.8) $$\dot{C}_t^{OM} = \dot{Y}_t + \dot{W}_t - P\dot{F}P_t^{OM}$$

where: $$\dot{Y} = \left(\sum\nolimits_i \varepsilon_{Yi}\dot{Y}_i\right) \Big/ \left(\sum\nolimits_i \varepsilon_{Yi}\right)$$

and: $$P\dot{F}P^{OM} = \left(1 - \sum\nolimits_i \varepsilon_{Yi}\right)\dot{Y} - \varepsilon_K \dot{K} - \sum\nolimits_n \varepsilon_{Zn}\dot{Z}_n - \dot{g} - \dot{\eta}$$

Hence the rate of change in opex PFP depends on the effects of: economies or diseconomies of scale; changes in the capital stock; changes in the business environment variables; frontier shift (ie, technical change); and catch-up to the frontier.

However, this is *not* the relevant measure of productivity used by the AER in calculating the rate of change in its recent guidance and decisions relevant to gas distribution access arrangements. Firstly, the AER expressly does not include any effect of catch-up to the frontier ($\dot{\eta}$): "Since we consider the scope for catch-up productivity as part of our assessment of an individual distributor's base opex, the productivity growth factor that we use in trending forward base opex should only capture the productivity growth that would be achieved by a distributor on the efficiency frontier."(AER 2019, 8) In addition to addressing any material inefficiencies via an adjustment to the base year opex, there is a reliance on the incentive features of the regulatory framework to ensure any remaining inefficiencies are removed over the prospective regulatory period(s). Secondly, the AER has emphasised that its primary focus is on the shift in the cost frontier over time ($\dot{g}$): "Our forecast of productivity growth represents our best estimate of the shift in the industry 'efficiency frontier'" (AER 2017, 7–13). Consistent with this statement, the method used in the Multinet decision was to use the estimated rate of technical change over time as the relevant measure of productivity (AER 2017, 7–21). The AER has also said that "for opex, we rely on the efficiency incentives created by both revenue or price-cap regulation and the efficiency carryover mechanism" (AER 2017, 7–9).

The foregoing AER decisions and guidance statements tend to suggest that, for the purpose of making opex rate of change projections, the productivity component of those projections which the AER proposes to rely on are focused on the rate of technical change as the relevant measure of productivity in the rate of change calculations. Hence, for the purposes of this part of the study it has been assumed that this is the method that the AER will again adopt.

# 8 MODELLING AND RESULTS

This section presents the results of testing two alternative specifications, in each case using both the stochastic frontier and FGLS estimators. The first specification is that derived in the 2019 study for JGN. The second specification excludes the operating environment variables.

## 8.1 Econometric Results

Tables 8.1 and 8.2 compare the two alternative specifications. In the model is shown in Table 8.1: *Cust* refers to the number of customers; *Mains* refers to the length of mains; *RAV* refers to real asset value (based on the RAB); *NCI* is the proportion of mains not cast iron or unprotected steel; *CG* is city gates; *VSHR* refers to the share of tariff V customers in total sales; and *t* is a time variable.

The model in Table 8.1 generally satisfies the following requirements:

- the elasticities of variable cost with respect to each of the outputs (*Cust* and *Mains*) are positive and significant;
- the elasticity of variable cost with respect to the capital stock (*RAV*) is positive and significant;
- the elasticities of variable cost with respect to the operating environment factors (*NCI*, *CG* and *VSHR*), in most cases, have the expected sign and are significant in at least one of the SF or FGLS models. The elasticity of variable cost with respect to the proportion of mains *not* made of cast iron or unprotected steel (*NCI*) should be negative because older mains require higher maintenance. The elasticity with respect to the number of city gates should be positive because more inputs may be needed to maintain a more geographically dispersed network. A negative coefficient on the share of tariff V customers in total throughput suggests, broadly, that the average variable cost per tariff V customer is lower than for the average variable cost per tariff D customer. That is, because the coefficient on the *Cust* variable reflects the partial effect of customer numbers on real operating cost, and if a large customer imposes a higher cost than a small customer, then the coefficient on *VSHR* would be negative.

In regard to this last criterion, the performance of the model in Table 8.1 is not entirely satisfactory because none of the estimated coefficients on the operating environment factors were statistically significant in the stochastic frontier model (although all were statistically significant in the FGLS model), and because the FGLS model has an unexpected sign on *VSHR*. Since the stochastic frontier model is used to calculate technical efficiencies, the inadequacy of the operating environment variables in the stochastic frontier model is of concern, especially for that purpose.

In light of these limitations, Table 8.2 shows a model which excludes all of the operating environment variables.

Table 8.1: **Log real opex (Cobb-Douglas form previously used)**

| | *SF model** | | *FGLS model*** | |
|---|---|---|---|---|
| | *coeff* | *t-stat* | *coeff* | *t-stat* |
| Const | -5.2165 | (-12.13) | -4.7745 | (-23.45) |
| ln*Cust* | 0.2037 | (2.45) | 0.2000 | (7.33) |
| ln*Mains* | 0.3486 | (3.25) | 0.3753 | (8.65) |
| ln*RAV* | 0.4457 | (5.19) | 0.3658 | (9.31) |
| ln*NCI* | -0.2438 | (-1.36) | -0.6631 | (-7.18) |
| ln*CG* | 0.0235 | (0.85) | 0.0460 | (4.31) |
| ln*VSHR* | -0.1114 | (-1.33) | 0.1295 | (3.48) |
| *t* | -0.0090 | (-4.24) | -0.0017 | (-1.08) |
| D-H test (p-value)(1) | 0. 7577 | | 0.0015 | |
| *BIC*(2) | -180.6245 | | -221.2937 | |
| *RMSE*(3) | 0.1530 | | 0.1859 | |
| *N* (sample size) | 261 | | 261 | |

* Inefficiencies are time invariant and with a half-normal distribution.

** Feasible generalised least squares with allowance for heteroscedastic errors between panel groups.

(1) Doornik-Hansen test for normality of residuals; p > 0.05 suggests residuals are normally distributed.

(2) Bayesian Information Criterion (BIC) — a goodness-of-fit measure in lower values indicate a better fit.

(3) Root-mean-square error of stochastic disturbance (not including estimated inefficiency effects).

Table 8.2: **Log real opex (removing operating environment variables)**

| | *SF model** | | *FGLS model*** | |
|---|---|---|---|---|
| | *coeff* | *t-stat* | *coeff* | *t-stat* |
| Const | -4.8969 | (-15.91) | -5.4509 | (-35.56) |
| ln*Cust* | 0.1289 | (1.55) | 0.2590 | (10.21) |
| ln*Mains* | 0.3861 | (3.63) | 0.3842 | (11.01) |
| ln*RAV* | 0.5226 | (7.46) | 0.3805 | (11.37) |
| *t* | -0.0126 | (-7.54) | -0.0144 | (-10.42) |
| D-H test (p-value)(1) | 0.4174 | | 0.0079 | |
| *BIC*(2) | -189.96 | | -211.62 | |
| *RMSE*(3) | 0.1443 | | 0.1936 | |
| *N* (sample size) | 264 | | 264 | |

See notes to Table 8.1.

## 8.2 Inference

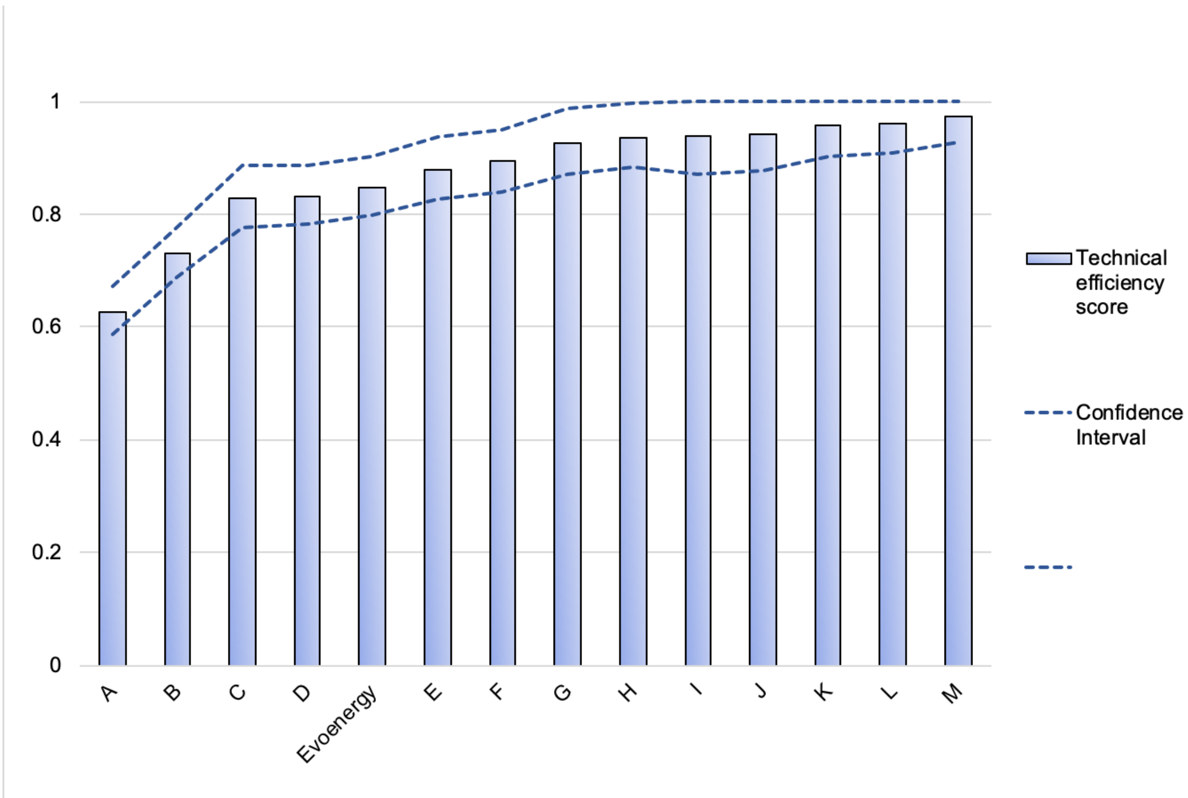
### *8.2.1 Industry Rate of Frontier Shift*

The estimated coefficient on the time variable measures the estimated average rate of technical change or 'frontier shift' relevant to opex inputs. This represents the average reduction in real opex requirements per year associated from frontier shift. The estimates obtained in Table 8.1 are -0.90 per cent and -0.17 per cent per annum (with an average of -0.54 per cent). The estimates obtained in Table 8.2 are -1.26 per cent and -1.44 per cent per annum (with an average of -1.35 per cent). These two estimates indicate a reasonable range of estimates based on the data sample available. The average of the two sets of estimates is -0.95, which is slightly higher that the estimate we obtained in our previous study for JGN in 2019 (-0.74 per cent) which was accepted by the in its draft decision on JGN's proposed access arrangement (AER 2019, 29). However, the effect of the time variable in these models is likely to include some element of catch-up to the frontier in addition to the rate of frontier shift (Economic Insights 2019a, 15–16). Further, the wide dispersion of coefficient estimates on the time variable implies considerable uncertainty about the estimated productivity trend from the models reported here. For these reasons, the estimate of 0.95 should be regarded as an upper bound, and a somewhat lower estimate may more reliably reflect the underlying opex efficiency rate of change.

### *8.2.2 Evoenergy's Technical Efficiency*

A chart showing the pattern of efficiency scores across the GDBs in the sample is presented in Figure 8.1. It is based on the model in Table 8.2. Evoenergy's efficiency score in this model is 0.85, with a confidence interval of between 0.80 and 0.90. The average efficiency score of all GDBs in the sample is 0.88 and the highest efficiency score of 0.98. This suggests that Evoenergy's technical efficiency is close to average for the sample of GDBs.

Figure 8.1: **Comparative Technical Efficiency Scores (with confidence interval)***




* Value labels relate to the central estimates of the efficiency scores indicated by the height of the bars.

### 8.2.3 Output Index Weights

The output index weights are derived as shown in equation (7.8) and presented in Table 8.3, based on the model shown in Table 8.2. Each estimated output elasticity is divided by the sum of the output elasticities to obtain weights which sum to one.

**Table 8.3 Output index weights (%)**

| *Output* | *SF model* | *FGLS model* | *Avg* |
|---|---|---|---|
| Customer numbers | 25.0 | 40.3 | 32.6 |
| Mains length | 75.0 | 59.7 | 67.4 |
| Total | 100.0 | 100.0 | 100.0 |

## 8.3 Summary Conclusions

The main findings of the econometric analysis are as follows:

- Evoenergy's efficiency score is 0.85, with a confidence interval of between 0.80 and 0.90. The average efficiency score of all GDBs in the sample is 0.88 and the highest efficiency score of 0.98. This suggests that Evoenergy's technical efficiency is close to average for the sample of GDBs.
- The estimated average rate of technical change or 'frontier shift' is between 0.54 and 1.35 per cent per annum; with an intermediate estimate of 0.95.[13] This estimate is slightly higher than the estimate we obtained in the previous studies for JGN in 2019 (0.74 per cent) which was accepted by the AER in its draft decision on JGN's proposed access arrangement (AER 2019, 29). However, the effect of the time variable in these models is likely to include some element of catch-up to the frontier in addition to the rate of frontier shift (Economic Insights 2019a, 15–16). Further, the wide dispersion of coefficient estimates on the time variable implies considerable uncertainty about the estimated productivity trend from the models reported here. For these reasons, the estimate of 0.95 should be regarded as an an upper bound, and a somewhat lower estimate may more reliably reflect the underlying opex efficiency rate of change.
- The estimated output index weights for the two outputs used in the preferred econometric model are: (i) customer numbers, 32.6 per cent; and (ii) mains length, 67.4 per cent.

[13] Frontier shift is expressed here as a rate of productivity growth and is hence a positive number.

# APPENDIX A: GAS DISTRIBUTION BUSINESSES INCLUDED IN THE STUDY

The database formed for the study includes 11 Australian GDBs and three New Zealand GDBs (although GasNet is not used in Part A - it is only used in Part C). Part B uses a subset of Australian GDBs which have completed detailed survey questionnaires. A brief summary of the operations of the included GDBs follows.

## *Australian GDBs*

### Evoenergy, Australian Capital Territory

Evoenergy (the energy networks part of Evoenergy[14]) is the distribution business supplying gas and electricity in the Australian Capital Territory (ACT). The total population of the ACT in 2017 was 413,000. Gas is distributed to a predominantly residential customer base with Canberra the largest market. Outside the ACT, Evoenergy supplies gas to Queanbeyan, Bungendore and Nowra in NSW. There are relatively few major industrial users in its supply area. Canberra covers a large geographical area and the majority of urban development is low density. Moreover, gas distribution in residential areas utilises a dual mains configuration with mains on both sides of a street, rather than a single sided system with longer across-road service connection. For these reasons, it is a low-density distribution network when measured in terms of customers per kilometre of main. In 2017 Evoenergy supplied 140,200 customers with 7,600 TJ of gas from a distribution network of around 4,700 kilometres of mains.

### Allgas Energy Pty Ltd (Allgas), Queensland

Allgas is owned by Marubeni Corporation, SAS Trustee Corporation and the APA Group. It supplies gas to consumers in several areas in and around Brisbane and to several Queensland regional areas. The Allgas distribution system is separated into three operating regions. About 59 per cent of the network is located in Brisbane (south of the Brisbane river to the Albert River), 19 per cent in the Western region (including Toowoomba and Oakey) and the remaining 22 per cent on the South Coast (including the Gold Coast, and Tweed Heads in NSW).

Queensland's mild to hot climate means that residential and commercial heating demand is low. Residential demand for gas is mainly for hot water systems and cooking. In 2016 southeast Queensland's population was around 3.3 million. Approximately 70 per cent of Allgas' gas demand is from around 100 large demand class customers. In 2016 Allgas supplied approximately 99,600 customers with 10,300 TJ of gas from a distribution network of 3,200 kilometres of mains. From 2015-16, Allgas is no longer required to have an approved access arrangement, and instead the AER arbitrates any access disputes.

### AGN Albury, NSW

Australian Gas Networks Limited (AGN) is, since 2017, part of the Australian Gas Infrastructure Group, owned by a consortium led by CK Infrastructure Holdings.

[14] Evoenergy includes an energy retailing partnership and an energy distribution partnership. The latter is called Evoenergy, and is owned jointly by Icon Water and Jemena Networks (ACT) Pty Ltd.

AGN Albury operates in the large regional centre on the border of NSW and Victoria often referred to as Albury–Wodonga. It operates on the North side of the Murray River in Albury and Ettamogah which in 2016 had a population of approximately 51,000. There is a small number of large industrial customers which represent over half of its gas deliveries. In 2017 AGN Albury supplied its 22,100 customers with around 2,200 TJ of gas from a distribution network of 400 kilometres of mains. Prior to 2017, AGN had separate approved access arrangements for AGN Albury and AGN Victoria, but these are now consolidated into a single approved access arrangement.

#### AGN Queensland, Queensland

AGN Queensland is an operating division of AGN, with a distribution network that supplies a Brisbane region (including Ipswich and suburbs north of the Brisbane river); and a Northern region (serving Rockhampton, Gladstone and Bundaberg). The network comprises approximately 2,600 kilometres of low, medium, high and transmission pressure mains. Assets used to service the Brisbane region comprise 88 per cent of the network with the balance of 12 per cent attributable to the Northern region.

AGN Queensland is subject to similar climatic influences on residential gas demand as Allgas. Customer numbers are similar to those for Allgas but gas volumes for customers included in this study are smaller. However, AGN has a number of industrial customers with very large volumes that are not reflected in the data used in this study. In 2016 there were approximately 96,600 customers consuming 6,100 TJ of gas. From 2015, AGN Queensland is no longer required to have an approved access arrangement, and instead the AER arbitrates any access disputes.

#### AGN SA, South Australia

AGN SA's distribution network services: greater Adelaide; to the north-east of Adelaide, the Barossa Valley, Riverland and Mildura in Victoria; to the north, Peterborough, Port Pirie and Whyalla; and in the east and south-east regions, Murray Bridge and Mt Gambier. Adelaide's population in 2016 was approximately 1.3 million. As with Melbourne, Adelaide's winter climate is conducive to relatively high residential gas demand for heating.

In 2017, AGN SA supplied 442,300 customers with 23,000 TJ of gas from a distribution network of 8,200 kilometres of mains. The Adelaide network makes up 93 per cent of the total network length.

#### AGN Victoria, Victoria

AGN Victoria serves parts of the greater Melbourne metropolitan area (population of 4.85 million in 2016) including the northern suburbs, the Mornington Peninsula and Pakenham/Cranbourne. AGN Victoria also supplies the north central Victorian area (including Seymour, Wodonga, Wangaratta, Shepparton-Mooropna and Echuca among others). It also supplies rural townships and cities in the Gippsland region (including Bunyip, Drouin, Warragul, Traralgon, Morwell and Sale among others), and a number of outlying towns in East Gippsland such as Bairnsdale and Paynesville (which are in the new Eastern Zone). The Distribution System is divided into four Zones – North, Central, Murray Valley and Eastern.

Melbourne's gas market is well established and cool to mild climatic conditions result in high residential gas consumption for heating, cooking and hot water systems. A relatively high concentration of industry also supports industrial gas demand provided that prices are competitive with other sources of energy supply. In 2017 there were 640,900 customers using 54,100 TJ of gas, supplied from a distribution network of 10,800 kilometres of mains.

**AGN Wagga Wagga, NSW**

AGN (formerly Envestra) took over gas supply from the NSW Government's Country Energy from October 2010. It supplies gas to the city of Wagga Wagga (estimated population of 48,300 in 2016) in southern regional NSW.

In 2015 there were approximately 20,100 customers. AGN supplied these customers with 1,600 TJ of gas from a distribution network of 750 kilometres of mains. In April 2014 the NSW Energy Minister, the Honourable Anthony Roberts, determined that coverage of the Wagga Wagga gas distribution network be revoked, and economic regulation of the network by the AER ceased at that time.

**ATCO Gas Australia, Western Australia**

ATCO acquired the network previously operated by WA Gas Networks (WAGN) in July 2011. ATCO Gas Australia is the principal GDB for Western Australian businesses and households. It operates the gas distribution system in the mid-west and south-west of Western Australia, including the greater Perth Metropolitan region (with a population of approximately 1.9 million in 2016), Busselton and Bunbury (together a population of 96,000), Geraldton, Kalgoorlie and the Albany region (each with a population of approximately 30,000). Each of these urban areas has a separate gas distribution network (Albany is supplied with reticulated LPG). In 2017, ATCO supplied approximately 738,100 customers with 25,300 TJ of gas from a distribution network of 13,800 kilometres of mains.

**AusNet Services, Victoria**

AusNet's Victorian gas distribution business was formerly TXU networks, which was formerly Westar (Assets) Pty Ltd, and is now part of AusNet Services, an ASX-listed business. The AusNet gas distribution business delivers gas to a number of urban centres across a geographically diverse region spanning the western half of Victoria, including the Western part of Melbourne, from the Hume highway in metropolitan Melbourne west to the South Australian border and from the southern coast to Horsham and just north of Bendigo. Its supply area includes the major Victorian regional centres of Geelong, Ballarat and Bendigo, and many other cities and towns in western Victoria. In 2017, AusNet supplied its 677,800 customers with 71,800 TJ of gas from a distribution network of 11,300 kilometres of mains.

**Jemena Gas Network, NSW**

JGN was formed from the sale of Alinta Ltd in 2007, Alinta itself having acquired the gas assets of AGL Gas Networks (AGLGN) in 2006. It is now co-owned by State Grid Corporation of China and Singapore Power. The JGN network provides gas to customers in Sydney, Newcastle, Wollongong and the Central Coast, and over 20 country centres including those within the Central Tablelands, Central West, Southern Tablelands and Riverina regions of NSW. JGN has the largest distribution network and customer base of the Australian GDBs. In 2017 it supplied 1,330,800 customers with 86,200 TJ of gas from a distribution network of 26,800 kilometres of mains.

#### Multinet Gas, Victoria

Multinet Gas is, since 2017, part of the Australian Gas Infrastructure Group, owned by a consortium led by CK Infrastructure Holdings, following that consortium's acquisition of the DUET Group. The Multinet gas distribution system covers the eastern and south–eastern suburbs of Melbourne extending over an area of approximately 1,600 square kilometres as well as comparatively recent extensions of supply to townships in the Yarra Valley and South Gippsland. In 2017, Multinet supplied 697,300 customers with 54,800 TJ of gas from a distribution network of 10,100 kilometres of mains.

### *New Zealand GDBs*

The New Zealand gas distribution industry is generally less mature than Victoria's with penetration rates still increasing relatively quickly, but comparatively low customer density at present.

#### Powerco Limited

Powerco is based in New Plymouth (population 56,000 in 2015) and distributes gas in the central and lower North Island regions. It is a dual gas and electricity network business. Powerco's gas networks in the central North Island region include the Taranaki (including New Plymouth), Manawatu and Horowhenua (including Palmerston North, population 83,500 in 2015), and Hawkes Bay networks (including Napier-Hastings, population 130,000 in 2015). In the lower North Island it supplies Wellington City (population of 203,000 in 2015), Hutt Valley (estimated population 141,000 in 2015) and Porirua (district population of 54,000 in 2015). Powerco acquired part of UnitedNetworks' gas operations in 2002 comprising the Hawkes Bay, Wellington, Horowhenua and Manawatu networks. In 2017, Powerco supplied 106,000 customers with 8,700 TJ of gas from a distribution network of 3,900 kilometres of mains.

#### Vector Ltd

Vector Ltd operates the gas distribution network in Auckland (estimated population of 1,418,000 including North Shore City, and the urban parts of Waitakere and Manukau cities). It is listed on the NZ Stock Exchange and is about 75 per cent owned by the Auckland Energy Consumer Trust. Vector acquired the remaining part of UnitedNetworks' gas operations in 2002 comprising its Auckland gas network and the National Gas Corporation's gas distribution business in 2004 and 2005. The Vector data from 2006 represent the combined operations of Vector and the former NGC Distribution. In November 2015 it sold its regional gas pipelines business via which it supplied a number of regional towns and cities in the North Island. In 2015, Vector supplied 105,900 gas distribution customers with 14,100 TJ of gas from a distribution network of 6,500 kilometres of mains.

#### GasNet

GasNet is a New Zealand GDB which is owned by the Whanganui District Council and operates five gas networks in the Whanganui, Rangitikei and South Taranaki regions in the North Island of New Zealand. It was formed 2008 after amalgamating with Whanganui Gas Limited. In 2017, GasNet had 9,900 customers and supplied 1,250 TJ, and its networks were approximately 400 km in length. In terms of customer numbers it is approximately half the size of AGN Albury and AGN Wagga. In terms of mains length it is smaller than AGN Wagga, but similar is size of AGN Albury.

# APPENDIX B: DATABASES USED IN THE STUDY

The analysis in Parts A and C of this report uses a dataset that includes 13 GDBs, including 11 Australian and two New Zealand GDBs. The analysis in Part B uses data for six major Australian GDBs (AusNet, AGN Vic, Multinet, AGN SA, ATCO and JGN). Data for these six GDBs used in Part B was sourced from survey data obtained for this study. In most cases this survey data extends from 1999 to 2017, and for JGN and ATCO it extends to 2018. In Parts A and C of the report, the survey data is supplemented by data for another seven GDBs, which has been sourced from documents in the public domain and relates to the period 1999 to 2018, or a shorter period.

**Table B.1: Summary of data sample**

| *GDB* | *Data period* | *Years ending* | *# obs* |
|---|---|---|---|
| AGN Albury | 1999–2017 | Dec | 19 |
| AGN Qld# | 1999–2016(1) | Jun | 18 |
| AGN SA | 1999–2019 | Jun | 21 |
| AGN Vic | 1998–2018 | Dec | 21 |
| AGN Wagga | 1999–2015(2) | Jun | 17 |
| Allgas | 2000–2016(1) | Jun | 17 |
| ATCO | 2000–2019 | Dec | 20 |
| AusNet | 1998–2019 | Dec | 22 |
| Evoenergy | 1999–2019 | Jun | 21 |
| Jemena | 1999–2018 | Jun | 20 |
| Multinet | 1998–2018 | Dec | 21 |
| Powerco (NZ) | 2004–2018(3) | Sep | 15 |
| Vector (NZ) | 2005–2019(4) | Jun | 15 |
| GasNet (NZ)* | 1999–2019 | Jun | 20 |

Notes: # For AGN Qld, public domain data is used in Parts A and C; and survey data is used in Part B which is available for the period 1999-2014.

* GasNet is included in Part C but not included in Part A analysis.

(1) Regulatory forecasts used for the period 2012 to 2016

(2) Regulatory forecasts used for the period 2011 to 2015.

(3) Capex available only for 2011–2018.

(4) Capex available only for 2007–2019. Vector divested some major networks in November 2015. In Part C, the periods after 2015 are excluded.

The detailed data surveys carried out for the major Australian GDBs followed a common format, covering key output and input value, price and quantity information over the period from 1998 or 1999 to the latest year available (either 2017 or 2018). The GDBs for which data from public sources data is used in Parts A and C include: (i) in Australia, Evoenergy, AGN Albury, AGN Qld, AGN Wagga, and Allgas; and (ii) in New Zealand, Powerco, Vector and GasNet (the last in part C only).

The public domain data sources used for Australian GDBs include:

- Access Arrangement Information (AAI) filings as proposed and as amended by a regulator's decision

- Regulators' final decisions, sometimes with amendment following appeal, and
- Annual Reports from the GDB or its parent firm.

The public domain data source used for the NZ GDBs is the Information Disclosure Data filings required by the Gas (Information Disclosure) Regulations 1997. There are fewer consistent observations publicly available for the New Zealand GDBs, reflecting the impact of mergers, asset sales and industry restructuring.

Data used includes throughput, customer numbers, distribution pipeline length, opex, capex and regulatory asset value. While every effort has been made to make the publicly available data used in this study as consistent as possible, the limitations of currently available public domain data need to be recognised. In a few cases missing observations were estimated based on growth rates for the variable or a related variable before and after the missing year. In a number of cases adjustments were made to ensure the data related to comparable activities and measures (eg unaccounted for gas allowances for non-Victorian GDBs have been excluded to put those GDBs on a comparable basis with Victorian reporting). The data used for the Australian GDBs cover only the regulated (or previously regulated) activities. Data relating to large industrial users whose supply is not regulated are not included. Inclusion of this data would require access to information not generally in the public domain and has been beyond the scope and timeframe of this study.

The data derived from public sources relate to the time periods normally reported by each GDB, and some GDBs use calendar year reporting while others use financial year reporting, and sources varied in reporting data in nominal and real terms. All cost data were first converted to nominal terms (where necessary) using the All Groups Consumer Price Index in Australia and the equivalent in New Zealand. The nominal series were then converted to real series in 2010 dollars using the same price indexes. The New Zealand data were then converted to Australian dollars using the OECD (2014) purchasing power parity for 2010. Purchasing power parities are the rates of currency conversion that eliminate differences in international price levels and are commonly used to make comparisons of real variables between countries.

The measure of opex covers regulated distribution activities only and excludes all capital costs. It includes all non–capital costs allowed by the regulatory authorities, including directly employed labour costs, contracted services, materials and consumables, administration costs and overheads associated with operating and maintaining the distribution service. It excludes unaccounted for gas for all the GDBs as this is treated differently in Victoria compared to the other Australian States and excluding this item provides the best basis for like–with–like comparisons. In line with earlier studies, full retail contestability (FRC) costs are included as reported. All of the cost data are expressed in $A 2010 prices. The estimates of capital assets are based on depreciated asset values for regulatory purposes or those calculated using the same approach as used in regulatory accounts in $A 2010.

# APPENDIX C: DERIVING OUTPUT COST SHARE WEIGHTS

The index analysis in Part B of this study uses output cost share weights derived by estimating a multi–output Leontief cost function using a method applied in Lawrence (2007). The weights used in this study were developed in Economic Insights (2012b). These weights are then used as the revenue shares in forming the multilateral output index outlined in appendix A. This multi–output Leontief functional form essentially assumes that GDBs use inputs in fixed proportions for each output and is given by:

(C1) $$C(y^t, w^t, t) = \sum_{i=1}^{M} w_i^t \, [\sum_{j=1}^{N} (a_{ij})^2 \, y_j^t \, (1 + b_i t)]$$

where there are $M$ inputs and $N$ outputs, $w_i$ is an input price, $y_j$ is an output and $t$ is a time trend representing technological change. 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 three outputs was imposed but this can be either positive or negative.

The estimating equations were the $M$ input demand equations:

(C2) $$x_i^t = \sum_{j=1}^{N} (a_{ij})^2 \, y_j^t \, (1 + b_i t)$$

where the $i$'s represent the $M$ inputs, the $j$'s the $N$ outputs and $t$ is a time trend representing the nine years, 1998 to 2006.

The input demand equations were estimated separately for each of the three GDBs using the non–linear regression facility in Shazam (White 1997) and data for the years 1998 to 2006. Given the limited number of observations and the absence of cross equation restrictions, each input demand equation is estimated separately.

Lawrence (2007) then derived the output cost shares for each output and each observation as follows:

(C3) $$h_j^t = \{\sum_{i=1}^{M} w_i^t \, [(a_{ij})^2 \, y_j^t \, (1 + b_i t)]\} / \{\sum_{i=1}^{M} w_i^t \, [\sum_{j=1}^{N} (a_{ij})^2 \, y_j^t \, (1 + b_i t)]\} .$$

Lawrence (2007) then formed a weighted average of the estimated output cost shares for each observation to form an overall estimated output cost share where the weight for each observation, $b$, is given by:

(C4) $$s_b^t = C(b, y_b^t, w_b^t, t) / \sum_{b,t} C(b, y_b^t, w_b^t, t) .$$

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