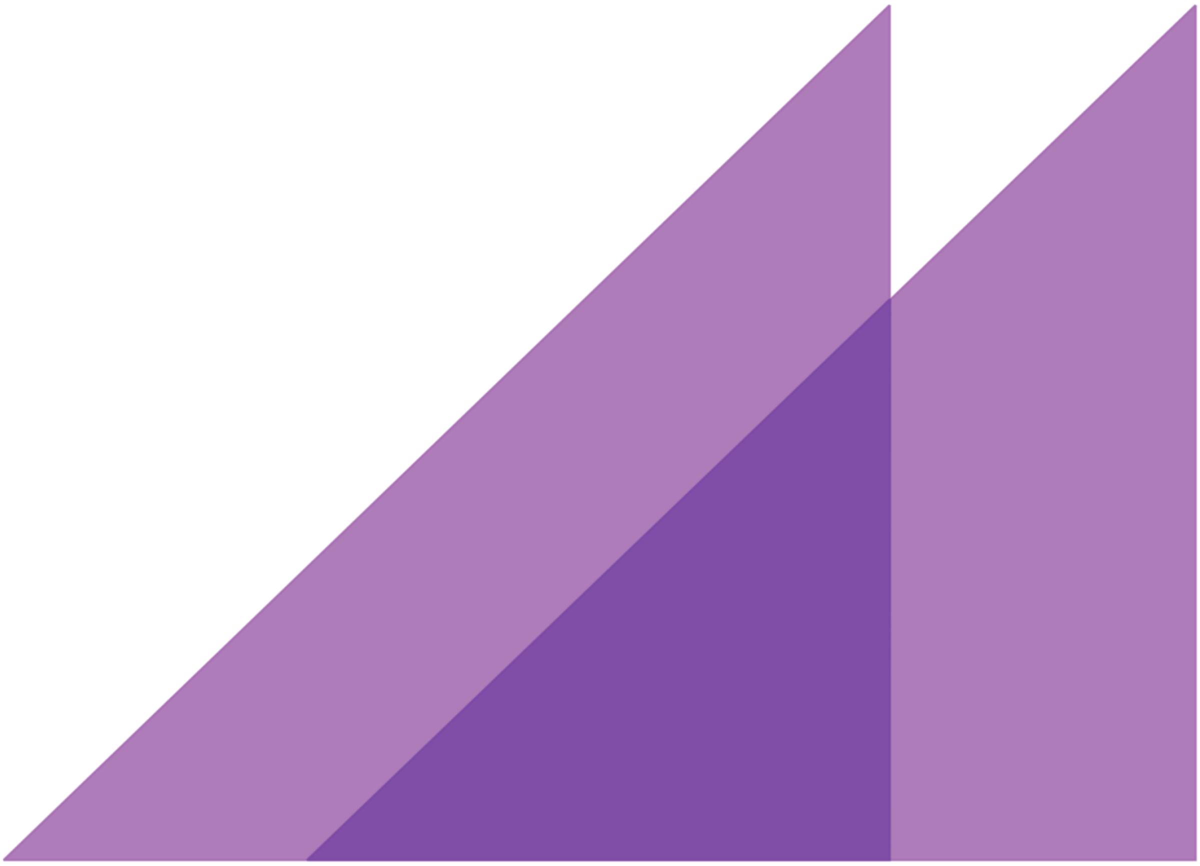
ACIL ALLEN CONSULTING

FINAL REPORT TO
JEMENA ASSET MANAGEMENT ON BEHALF OF ACTEWAGL DISTRIBUTION GAS NETWORK

29 APRIL 2015

PRODUCTIVITY STUDY

ACTEWAGL DISTRIBUTION GAS NETWORK



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Executive summary

Terms of reference

ACIL Allen Consulting (ACIL Allen) has been engaged by Jemena Asset Management Pty Ltd, (on behalf of ActewAGL Distribution Gas Network (ActewAGL)), to provide productivity analysis in support of the preparation of ActewAGL's Access Arrangement (AA) proposal for the period 1 July 2016 to 30 June 2021.

Under the Terms of Reference for the study, ACIL Allen has been asked to provide an expert report in two parts:

- *Part A:* To provide a forecast of the operating expenditure (opex) partial factor productivity growth rate that applies to the ActewAGL network for the period 1 July 2014 to 30 June 2021. Part A involves the estimation of an opex cost function which is used to estimate an opex partial productivity growth rate forecast split into three components: technology, returns to scale and operating environment.
- *Part B:* To measure ActewAGL's historical productivity growth rate using time series, unilateral Total Factor Productivity (TFP) and opex and capital expenditure (capex) Partial Factor Productivity (PFP) analysis. Part B uses index number analysis to produce historical measures of ActewAGL's TFP and opex PFP for the period to 30 June 2014. Partial productivity indicators (PPIs) are produced to assess ActewAGL's capex over the period to June 2014.

The report has been prepared in accordance with the Expert Witness Guidelines (Federal Court Practice Note CM 7) and as such, may be relied upon by both ActewAGL and the Australian Energy Regulator (AER).

Overview of benchmarking methods

Cost function analysis

In production economics, econometric cost functions provide a useful tool for determining the least cost means of production and are used by a number of regulators to explore efficient costs for energy networks. A cost function is a function that measures the minimum cost of producing a given set of outputs in a given production environment in a given time period.

By modelling the output quantities, the input prices, and the operating conditions in which the business operates, a minimum-cost function yields the periodic costs incurred by an efficient business to deliver those services in that environment.

Index number based TFP and opex PFP analysis

Index number methods, often called TFP measures, construct productivity measures directly from the data on inputs and outputs, without the need to estimate a cost or production function. Productivity is measured as the ratio of output quantity to input quantity.

Unilateral indexes can be used to measure relative performance either for a single business over time or between businesses at a single point in time. Multilateral indexes can be used to compare productivity levels and growth rates. In accordance with the Terms of Reference, this study estimates unilateral (or time series) TFP and opex PFP measures for ActewAGL over the period from 2003-04 to 2013-14.

In this study, a Fisher Index is used to estimate the TFP and opex PFP growth rates for ActewAGL. The Fisher Index is recommended as the preferred approach for time series productivity measurement in the literature given its desirable theoretical and test properties.[1]

Capex partial productivity performance indicators

In accordance with previous capex productivity benchmarking for gas distribution businesses, this study provides a range of capex PPIs that show ActewAGL's capex per unit of output.

Benchmarks are indicative not exact

It is important to recognise that, due to the limitations of data and of the benchmarking techniques, the efficiency and productivity measures produced in this study are approximate rather than exact. There are often challenges associated with accounting for differences in relevant operating environment factors, in accurately measuring inputs and outputs, and in gaining comparable, quality data over long time periods. The limitations that are specific to this study are discussed within the report.

Given that the measures are indicative, it would not be appropriate, for example, to assume that the difference between observed costs and benchmarked costs can in part or as a whole be conclusively attributed to relative inefficiency.

However, the economic analysis seeks to make the best use of benchmarking data that is available to assist ActewAGL to determine efficient cost levels and the scope for opex productivity growth over the forthcoming regulatory period. This study provides useful information which can be used as part of a suite of tools and analyses to inform ActewAGL's decisions given the uncertainties associated with forecasting expenditure over a period to 2021.

Benchmarking sample and data

The cost function analysis and capex PPIs benchmark ActewAGL against eight other Australian gas distribution businesses serving urban populations and that are subject to full economic regulation, namely:

- ATCO Gas Australia (WA)
- Australian Gas Networks South Australia (SA)
- Australian Gas Networks Victoria (VIC)
- Multinet Gas (VIC)
- AusNet Services (VIC)
- Jemena Gas Networks (NSW)
- Australian Gas Networks Queensland (QLD)
- Allgas Energy (QLD).

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[1] For example see Coelli, T. et all, 2005 and ACCC and AER, 2012 for more detail including on the index number tests.

ActewAGL

ActewAGL is one of the smaller gas distribution businesses in the sample in terms of network size and customer base, being most similar in scale to the Queensland gas distribution businesses. ActewAGL has among the lowest customer and energy density among the gas distribution businesses. ActewAGL has a customer mix that is dominated by residential and commercial customers and few larger, industrial customers.

Previous benchmarking studies of gas distribution businesses (including the Marksman Report and various reports by Economic Insights) have identified customer density (customers per kilometre of mains) and energy density (energy delivered per customer and per kilometre of mains) as material drivers of cost and hence relative efficiency.

Higher customer density means that less pipelines and associated assets need to be built and maintained per customer, resulting in relatively lower costs and a relatively higher efficiency. Similarly, greater energy density has been associated with lower inputs to deliver a given volume of gas.

To the extent that the efficiency and productivity measures that compare ActewAGL to the other gas distribution businesses do not account for differences in customer and energy density, then ActewAGL may appear relatively less efficient due to these operating environment characteristics.

Data sources

ACIL Allen has compiled a benchmarking database for the nine Australian gas distribution businesses. The benchmarking data were predominantly sourced from public reports including:

- gas distribution business Access Arrangement Information statements
- regulatory determinations by the AER and jurisdictional regulators
- AER performance reports
- annual and other reports published by the businesses
- consultant reports prepared as part of access arrangement review processes.

The database also contains confidential data provided for benchmarking analysis including data from ActewAGL, ATCO Gas and Jemena. Confidential data are not revealed within this report.

Data comparability and suitability for benchmarking

To a large extent, the benchmarking study relies on data that were reported publicly by the gas distribution businesses and, in most cases, verified by the relevant economic regulator. Where data has been provided to ACIL Allen directly, the data are reported on a basis that is consistent with the regulatory data in the Access Arrangement Information statements. In particular, the study uses the expenditure categories reported within the gas distribution businesses' Access Arrangements, including the operating expenditure and capital expenditure categories.

Within the time available for this study, and constraints on our practical ability to verify the cost data with the gas businesses, it was not possible to undertake a detailed review of the cost data items used in the study to ensure that precisely the same costs are reported in these categories by all of the nine distributors and hence to fully establish the cost data comparability between the businesses.

Notwithstanding this, the steps that ACIL Allen has undertaken to determine data comparability and hence suitability for benchmarking are as follows.

First, ACIL Allen has reviewed the numerous prior benchmarking studies of Australian gas distribution businesses to understand the appropriate sources of data and to draw on the experience of these studies in ensuring that the data used was comparable across the firms. As a result of the literature review, adjustments were made to the opex category to ensure comparability between the gas distribution businesses.

Second, ACIL Allen has undertaken its own data screening. A range of operating and capital cost ratios and operating environment ratios have been calculated for all firms and all years to identify data items that are outliers (e.g. ratios that are more than three standard deviations from the sample mean) and to identify potential areas of persistent variation between firms and across time. Where an observation has warranted further investigation, ACIL Allen has rechecked the original data source and sought any additional relevant verifying information.

Third, ACIL Allen has investigated possible differences between the Australian gas distribution businesses in terms of their allocation of costs to the operating and capital cost categories due to differences in cost allocation and capitalisation policies. This was an issue which came to light in the context of the recent electricity distribution benchmarking, with likely differences in practice observed.

The third element of analysis indicates that ActewAGL’s operating expenditures (at 50 per cent to 60 per cent of total opex and capex expenditure) consistently comprise a larger share of total expenditures compared to the majority of the other gas distribution businesses (with an opex share around 20 per cent to 30 per cent). While it has not been possible within the scope of this study to determine whether there are differences in cost allocation and capitalisation policies that mean that different costs are included within the operating and capital expenditure categories between the gas distribution businesses, this issue could be further investigated in future benchmarking analysis and would need to be considered by the AER and others in interpreting ActewAGL’s opex partial productivity measures.

Based on the screening process, ACIL Allen has not removed any observations from the benchmarking analysis. This is because we have verified the data against regulatory documents. We consider that this is reasonable given that:

- our sample size is limited and hence we wish to retain all reasonable data observations
- the key focus of this study is to estimate productivity trends, rather than on relative efficiency and productivity levels in relation to an efficient frontier.

Finally, for the opex cost function estimations, further analysis has been undertaken to test the sensitivity of the estimations to individual observations. As panel data is used (i.e. encompassing multiple gas distribution businesses and time periods), the sensitivity of the cost function estimates to the inclusion or exclusion of individual gas distribution businesses has been undertaken. This is explained in section 4 which reports on the cost function analysis.

On balance, it is our opinion that the benchmarking data used in the study is robust and appropriate for indicative benchmarking analysis, particularly as the majority of the data has been subject to scrutiny by the relevant economic regulator and in many cases also by expert consultants engaged by the economic regulators.

However, there remains uncertainty about data comparability that ACIL Allen is not able to resolve. Possible differences in the comparability of cost categories and other inevitable shortcomings in the benchmarking analysis mean that the efficiency and productivity benchmarks produced should be treated as indicative, not exact. Other potential shortcomings that limit the ability of the benchmarking models in this study to represent the gas distribution businesses' true cost and production functions include:

- the limited data available for this study e.g. a richer data set with a broader range of cost inputs, outputs and operating environment factors could be used to create model specifications that better account for the variation between the gas distribution businesses
- potential data errors that have not been identified
- the limitations of the modelling techniques in terms of their ability to accurately estimate the true efficient cost and production frontiers.

Part A: Forecast opex partial factor productivity

Part A of the analysis provides the forecast opex partial factor productivity growth rate for the period 1 July 2014 to 30 June 2021, based on cost function analysis.

Cost functions are estimated using two alternative model specifications, one with two outputs specified (energy, which is the TJs of gas throughput, and customers) and the other with a single output specified (customers).

A Cobb-Douglas functional form has been applied and five estimation methods tested to explore the sensitivity of the results to the estimation method. The five estimation methods are:

- pooled ordinary least squares (OLS)
- fixed effects
- random effects
- feasible GLS (FGLS) (with heteroscedastic panels)
- stochastic Frontier Analysis (SFA) (with time invariant inefficiency).

Cost function estimates: Two output specification

The results of the two-output model under the five estimation methods are presented in Table ES 1.

Table ES 1 **Estimated Cobb-Douglas function: Two outputs**

	Estimation technique				
Variables	Pooled OLS	Fixed effects	Random effects	FGLS	SFA
Time	-0.00436***	-0.0153	-0.00202	-0.00446***	-0.00466***
	(0.000151)	(0.0180)	(0.00542)	(0.000132)	(0.000138)
Energy	-0.259***	0.119	-0.0930	-0.164***	-0.0634
	(0.0612)	(0.0873)	(0.151)	(0.0467)	(0.0694)
Customers	0.462***	1.226**	0.524**	0.496***	0.501***
	(0.0722)	(0.401)	(0.239)	(0.0647)	(0.0689)
RAB	0.764***	0.524**	0.592***	0.645***	0.685***
	(0.0687)	(0.219)	(0.133)	(0.0612)	(0.114)
Density	-0.126	-1.024***	-0.495***	-0.228***	-0.531***
	(0.0847)	(0.281)	(0.123)	(0.0716)	(0.165)
Constant		13.38	-4.649		
		(29.64)	(10.33)		
Observations	87	87	87	87	87
R-squared	0.987	0.9432	0.9579		
Number of ID		9	9	9	9

Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
Source: ACIL Allen

A key characteristic of these models is that the energy variable (TJ of gas throughput) has a negative coefficient. Moreover it is not statistically significant at the 1 per cent level in three of the five models. These results are not surprising given that gas throughput has been declining for the majority of the distribution businesses over the period from 2005 to 2013, while operating expenditures have continued to increase.

This suggests that energy (gas throughput) is no longer a key driver of increasing operating expenses for the nine gas distribution businesses under consideration. As a result, an additional model specification is estimated excluding gas throughput.

Cost function estimates: Single output specification

Table ES 2 presents the cost function estimation results without energy throughput specified as an output.

Table ES 2 **Estimated Cobb-Douglas function: Single output**

	Estimation technique				
Variables	Pooled OLS	Fixed Effects	Random effects	FGLS	SFA
Time	-0.00423***	-0.0164	0.000323	-0.00413***	-0.00467***
	(0.000172)	(0.0174)	(0.00373)	(0.000121)	(0.000143)
Customers	0.389***	1.269***	0.555***	0.303***	0.518***
	(0.0676)	(0.377)	(0.191)	(0.0523)	(0.0670)
RAB	0.553***	0.536**	0.516***	0.676***	0.606***
	(0.0649)	(0.223)	(0.141)	(0.0516)	(0.0770)
Density	-0.281***	-1.039***	-0.685***	-0.254***	-0.615***
	(0.0728)	(0.289)	(0.173)	(0.0579)	(0.126)
Constant		16.21	-9.471		
		(28.57)	(7.330)		
Observations	87	87	87	87	87
R-squared	0.984	0.9456	0.9487		
Number of ID		9	9	9	9

Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1
Source: ACIL Allen

The results of the cost functions excluding energy throughput show that the output elasticity for customer numbers range from 0.30 in the FGLS model to 0.56 in the random effects model. This is consistent with increasing returns to scale.

The results for the random effects model are supported by statistical testing and the FGLS model corrects for the violation of the OLS assumptions.

The SFA model results and the estimated coefficients lie in between those of the FGLS and random effects model. Due to the lack of additional environmental control variables and the size of the sample, we cannot be sure that the SFA inefficiency term *u* is true managerial inefficiency, rather than a mixture of inefficiency, firm heterogeneity and bias. As such, we have reservations about using the SFA model for the purpose of assessing firm relative operational performance against the efficient frontier. We continue however, to use the estimated coefficients from the SFA model to forecast opex partial productivity for ActewAGL.

Opex partial productivity growth rate

Separate opex partial productivity forecasts were calculated for each of the random effects, FGLS and SFA cost function models. These are shown in Table ES 3 to Table ES 5 below.

Table ES 3 **Annual opex partial productivity forecasts, random effects model**

Year	Technology (A)	Returns to scale (B)	Operating environment factors (C)	PP Opex growth rate (A+B-C)
2014-15	-0.03%	1.06%	1.13%	-0.11%
2015-16	-0.03%	0.98%	1.05%	-0.10%
2016-17	-0.03%	0.94%	0.33%	0.58%
2017-18	-0.03%	1.01%	1.31%	-0.33%
2018-19	-0.03%	0.98%	0.81%	0.14%
2019-20	-0.03%	1.05%	0.49%	0.53%
2020-21	-0.03%	0.93%	-0.33%	1.23%
Average	**-0.03%**	**0.99%**	**0.68%**	**0.28%**

Source: ACIL Allen

Table ES 4 **Annual opex partial productivity forecasts, FGLS model**

Year	Technology (A)	Returns to scale (B)	Operating environment factors (C)	PP Opex growth rate (A+B-C)
2014-15	0.41%	1.66%	2.07%	0.01%
2015-16	0.41%	1.54%	1.82%	0.13%
2016-17	0.41%	1.48%	0.91%	0.98%
2017-18	0.41%	1.58%	2.16%	-0.17%
2018-19	0.41%	1.54%	1.50%	0.45%
2019-20	0.41%	1.64%	1.18%	0.88%
2020-21	0.41%	1.46%	0.07%	1.80%
Average	**0.41%**	**1.56%**	**1.39%**	**0.58%**

Source: ACIL Allen

Table ES 5 **Annual opex partial productivity forecasts, SFA model**

Year	Technology (A)	Returns to scale (B)	Operating environment factors (C)	PP Opex growth rate (A+B-C)
2014-15	0.47%	1.15%	1.50%	0.11%
2015-16	0.47%	1.07%	1.37%	0.17%
2016-17	0.47%	1.02%	0.53%	0.96%
2017-18	0.47%	1.09%	1.67%	-0.11%
2018-19	0.47%	1.06%	1.08%	0.45%
2019-20	0.47%	1.13%	0.73%	0.87%
2020-21	0.47%	1.01%	-0.24%	1.71%
Average	**0.47%**	**1.08%**	**0.95%**	**0.59%**

Source: ACIL Allen

Taking an average of the three opex partial productivity calculations provides a forecast opex partial productivity growth rate for ActewAGL of **0.5% per annum**.

Part B: Time series productivity analysis

Time series productivity analysis is used to measure the historical productivity growth rate for ActewAGL. Both total factor productivity and opex and capex partial factor productivity measures are estimated.

TFP and opex PFP indexes

The TFP and opex PFP indexes for ActewAGL are estimated using a Fisher index.

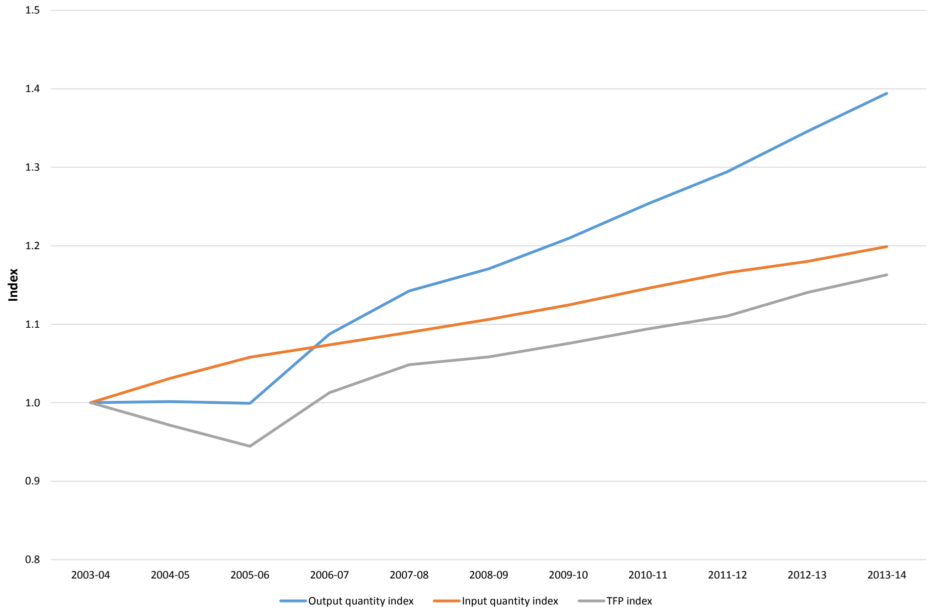
Table ES 6 below shows the TFP and opex PFP indexes estimated over the period from 2003-04 to 2013-14. Figure ES 1 shows the output, input and TFP indexes.

Table ES 6 **ActewAGL TFP and opex PFP indexes**

	Output quantity index	Input quantity index	Opex quantity index	Opex PFP index	Capital quantity index	Capital PFP index	TFP index
2003-04	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2004-05	1.001	1.031	0.881	1.137	1.032	0.971	0.971
2005-06	0.999	1.058	0.823	1.215	1.059	0.944	0.944
2006-07	1.087	1.074	0.829	1.312	1.074	1.012	1.013
2007-08	1.142	1.090	0.858	1.332	1.090	1.048	1.049
2008-09	1.171	1.106	0.971	1.206	1.106	1.058	1.058
2009-10	1.209	1.125	1.032	1.171	1.125	1.075	1.075
2010-11	1.253	1.146	1.080	1.160	1.146	1.094	1.094
2011-12	1.295	1.166	1.078	1.201	1.166	1.111	1.111
2012-13	1.346	1.180	0.985	1.367	1.180	1.140	1.140
2013-14	1.394	1.199	0.921	1.514	1.200	1.162	1.163
Average annual growth rate	3.38%	1.83%	-0.82%	4.23%	1.84%	1.52%	1.52%

Source: ACIL Allen

Figure ES 1 **ActewAGL output quantity, input quantity and TFP indexes**



Source: ACIL Allen

As ActewAGL's output has consistently grown at a faster rate than inputs, it has experienced positive TFP growth over the period from 2003-04 to 2013-14. Over the period from 2003-04 to 2013-14 ActewAGL's average annual TFP growth rate was 1.52 per cent.

Over the same period ActewAGL has had an annual average opex PFP growth rate of 4.23 per cent. ActewAGL's opex PFP average annual growth rate was higher over the modelling period than annual average TFP growth. This is due to the decline in the opex quantity on an annual average basis over the period of 0.82 per cent, while there was an annual average increase in the capital input quantity of 1.84 per cent resulting in a lower overall TFP score.

Capex partial productivity indicators

The study follows the preferred capex benchmarking approach used by regulators and within the literature of producing simpler capex ratios, also referred to as partial productivity performance indicators (PPIs).

The capex PPIs estimated are: capex per km of mains; capex per customer and capex per TJ of gas throughput.

As shown in the report, while ActewAGL's capex per km, per customer and per TJ have increased over the 2003-04 to 2013-14 period, the PPI indicators are among the lowest of the Australian gas distribution businesses in the sample.

1 Introduction

ACIL Allen Consulting (ACIL Allen) has been engaged by Jemena Asset Management Pty Ltd, (on behalf of ActewAGL Distribution Gas Network (ActewAGL)), to provide productivity analysis in support of the preparation of ActewAGL's Access Arrangement (AA) proposal for the period 1 July 2016 to 30 June 2021.

1.1 Terms of reference

This expert report on efficiency measurement and benchmarking has been prepared to assist ActewAGL develop expenditure forecasts to be included in the AA proposal. Under the Terms of Reference for the study, ACIL Allen has been asked to provide an expert report in two parts:

- *Part A:* To provide a forecast of the operating expenditure (opex) partial factor productivity growth rate that applies to the ActewAGL network for the period 1 July 2014 to 30 June 2021. Part A involves the estimation of an opex cost function which is used to estimate an opex partial productivity growth rate forecast split into three components: technology, returns to scale and operating environment.
- *Part B:* To measure ActewAGL's historical productivity growth rate using time series, unilateral Total Factor Productivity (TFP) and opex and capital expenditure (capex) Partial Factor Productivity (PFP) analysis. Part B uses index number analysis and partial productivity performance indicators to produce historical measures of TFP and PFP for the period to 30 June 2014.

A copy of the full Terms of Reference for the study is provided in Appendix A. The Terms of Reference require that ACIL Allen have regard to:

- historical and forecast cost, input and output data provided by ActewAGL
- publically available information from other gas distribution businesses, such as regulatory submissions, regulators' final decisions, and annual reports
- the Economic Insights report, Econometric Estimates of the Victorian Gas Distribution Businesses' Efficiency and Future Productivity Growth, 28 March 2012
- the Economic Insights report, Relative Opex Efficiency and Forecast Opex Productivity Growth of Jemena Gas Networks, 14 April 2014
- relevant published research literature
- relevant government decisions on energy policy and policy implementation
- factors such as the scale, topography and configuration of the ActewAGL network, that may contribute to or explain observed differences between the results obtained for ActewAGL and for other gas distribution businesses in the data set on which the analysis is based
- recent regulatory reviews for gas that have considered efficiency measures within the context of establishing cost forecasts
- such other information that, in the Expert's opinion, should be taken into account to address the scope of work.

The report has been prepared in accordance with the Expert Witness Guidelines (Federal Court Practice Note CM 7) and as such, may be relied upon by both ActewAGL and the Australian Energy Regulator (AER).

1.2 Report structure

The report is structured as follows:

- section 2 provides an overview of the efficiency and productivity measurement approaches that have been used in the study and how they can be used to inform the development of ActewAGL's expenditure proposals to the AER
- section 3 describes ActewAGL and the other Australian gas distribution businesses included in the benchmarking sample, and the benchmarking data used in the current study
- section 4 presents the cost function analysis and the estimate of ActewAGL's opex productivity growth rate for the forecast period
- section 5 presents historical TFP and PFP measures for ActewAGL.

2 Productivity and efficiency analysis

This section of the report explains the concepts of productivity and efficiency (section 2.1), how measures of productivity and efficiency are used in the regulatory context for determining allowable costs (section 2.2) and provides an overview of the productivity and efficiency measurement approaches used in this study (section 2.3).

2.1 What is productivity and efficiency?

Different forms of productivity and efficiency analysis provide empirical measures that can be used to provide insights into efficient cost levels and the scope for productivity improvements over time. The terms productivity and efficiency are often used interchangeably. However, they are not the same. A useful explanation of the differences between these terms in the context of benchmarking can be found in Coelli, T et al (2005), pp. 2-6.

In the context of economic benchmarking, productivity means the ratio of the output(s) produced by a firm to the input(s) used. Productivity growth is the difference between output growth and input growth. Where firms produce multiple outputs and use multiple inputs (which is generally the case), the outputs and inputs must be must be aggregated in an economically sensible way. A range of economic benchmarking techniques including index number and econometric techniques are designed to do this.

Productivity is the maximum level of output attainable from inputs given the current state of technology and is represented by an efficient production frontier. Efficiency analysis compares the performance of individual companies in relation to the production frontier, that is, whether they are on or beneath the efficient frontier. Firms on the frontier are technically efficient. Firms below the frontier are not.

Variation in productivity, either across producers or through time, can be a function of:

- the efficiency of the production process which can be thought of in three dimensions:
  - technical efficiency, which is the ability to produce as much output as possible with as little inputs as possible
  - allocative efficiency, which concerns combining inputs and outputs in optimal proportions given prevailing prices
  - scale efficiency which relates to optimum size
- technological change through the creation of new technologies (known as technical change)
- the environment in which production occurs, as these environmental factors can drive costs but are outside the control of the firm. In the case of gas distribution businesses relevant operating environment factors could include:
  - characteristics of the customer base such as the size, customer mix and geographical spread which determine energy and customer density
  - differences in jurisdictional regulations
- historical or legacy factors such as the condition and age profile of assets. For gas distribution businesses the age and hence composition of pipelines in their network (i.e. the mix of older cast iron or steel relative to newer polyethylene pipelines) result in different cost profiles

— the quality of services provided.

Different approaches to benchmarking and the quality and availability of data will determine the ability to measure some or all of these contributors to overall efficiency and productivity. In the regulatory context, it is vitally important to seek to isolate the elements that are under the control of the utility managers (principally technical efficiency and quality of service) from those factors which are not (such as differences in their operating environment).

Total factor productivity (TFP) measures seek to capture the multiple inputs used and outputs produced within a single measure. Common measurement techniques include index number TFP analysis, Data Envelopment Analysis (DEA) and econometric analysis.

While providing more limited information on one dimension of costs, the use of partial measures of productivity is also common. Partial productivity assesses output relative to a single input such as labour or operating costs.

2.2 The regulatory context

The economic regulation of gas distribution networks aims to ensure that services of a desired quality are provided at efficient cost. The National Gas Rules require that capital and operating expenditure accord with expenditure incurred by a prudent service provider acting efficiently, in accordance with accepted good industry practice, to achieve the lowest sustainable cost of providing services.[2]

As part of applying the Better Regulation program and the associated expenditure forecast assessment guideline, the AER is seeking economic analysis to ensure the efficiency and prudency of the business expenditure proposals.[3] This study provides economic benchmarking analysis, to be used in conjunction with ActewAGL's other analysis and evidence, to support the development of their expenditure proposals for the 2016 to 2021 regulatory period.

2.2.1 Base step trend opex allowance

To determine allowable operating expenditure, the AER intends to apply a 'base-step-trend' approach as shown in Box 1. Using this approach, opex is based on an efficient amount of actual expenditure in a single base year, which is multiplied by a forecast rate of change for each year of the forecast period.

The base year expenditure is intended to reflect the lowest sustainable efficient cost. Where an efficiency gap is identified, the AER may seek to amend the base year expenditure. With reference to the productivity and efficiency analysis, this step is concerned with setting expenditure at a level that is technically efficient, i.e. on or close to the efficient frontier.

The rate of change allows efficient opex to be adjusted over the regulatory period to account for output growth (as providing greater levels of service will require greater expenditure), real price growth (to account for the real price growth in the range of cost inputs, which may be different to the Consumer Price Index, CPI) and productivity growth. In this context, the productivity growth is intended to reflect technical change or the shift in the efficient frontier.

Any step changes for efficient costs that are not captured by the base opex or the rate of change are also added.

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[2] See Rule 79 (capital expenditure criteria) and Rule 91(1) (operating expenditure criteria) of the National Gas Rules.

[3] AER, 2014a, p. 59.

Box 1 **AER opex base-step-trend and rate of change formulas**

The AER assess forecast opex in year t as:

$$Opex_t = \prod_{i=1}^{t} (1 + rate\ of\ change_i) \times \left(A_f^* - efficiency\ adjustment\right) \pm step\ changes_t$$

where:

- *rate of change$_i$* is the annual percentage rate of change in year *i*
- *A^*_f* is the estimated actual opex in the final year of the preceding regulatory control period (or another year chosen by the AER such as the penultimate year)
- *efficiency adjustment* is the difference between efficient opex and deemed final year opex
- *step changes$_t$* is the determined step change in year *t*

Under this assessment approach the product of the annual rates of change accounts for changes in real prices, output growth and productivity in the forecast regulatory control period. The addition of step changes accounts for any other efficient costs not captured in base opex or the rate of change.

In the above formula, the annual rate of change for year *t* will be:

$$Rate\ of\ change_t = output\ growth_t + real\ price\ growth_t + productivity\ growth_t$$

Sources: See study Terms of Reference in Appendix A; AER, 2014a, p. 61; AER 2014b, p. 7-10; AER 2013a, p. 22,23; AER 2013b, p. 61.

In accordance with the Terms of Reference for the study, cost function and index number analysis is used to produce indicative measures of opex efficiency and productivity change, which are inputs to the base-step-trend formula.

2.2.2 Capex efficiency

Under the NGR, the AER must determine that capex conforms with the capex criteria under Rule 79 if the NGR. The criteria specify that the capex must be:

- such as would be incurred by a prudent service provider acting efficiently, in accordance with good industry practice, to achieve the lowest sustainable cost of providing services
- justifiable on the following grounds:
  - have an overall economic value that is positive
  - demonstrate an expected present value of the incremental revenue that exceeds the expenditure
  - be necessary to maintain and improve the safety of services, or maintain the integrity of services, or comply with a regulatory obligation or requirement, or maintain capacity to meet levels of demand existing at the time the capex is incurred, or
  - be justifiable as a combination of the preceding two dot points.

The AER typically applies a range of approaches in order to determine that capex is conforming capex and to test the relative efficiency of the expenditure. For example, in the recent draft decision on Jemena's access arrangement for the 2015 to 2020 period, the AER examined historical capex by reviewing information on the reasoning for the capex and other supporting material including business cases.[4] For proposed capital expenditure in the 2015-20 period the AER separately assessed individual categories of capex (including

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[4] AER 2014c, p. 6-13.

growth and replacement capex) and assessed the efficiency and prudency of the expenditure by reviewing the scope, timing and cost of the proposed expenditure.

The AER does not specify a benchmarking approach in relation to capex. As noted in previous AER analysis of approaches to benchmarking opex and capex for electricity and gas distribution businesses, reliance on capex benchmarks are less common in regulatory practice which may be due to:

> significant differences across businesses in terms of asset ages, investment pattern, network capacity utilisation and other requirements[5]

These issues make the capex benchmarks less meaningful and difficult to interpret. However, the AER study does note that simpler capex benchmarking such as trend or ratio analysis has been employed. The ratio analysis refers to a ratio of capex per unit of output (such as per km of mains or per customer). For example, Economic Insights (2012a) measured the capex partial productivity of the three Victorian gas distribution businesses as input to the review of Victorian gas access arrangements for 2013 to 2017 using capex partial factor productivity indicators to assess capex partial productivity measures: The partial productivity indicators estimated included capex per TJ, capex per customer, capex per kilometre and capex per unit output (composite output measure).

The terms of reference for this study seek the estimation of capex PFP estimates. In accordance with recent regulatory and business practice, this study estimates capex partial productivity indicators.

2.3 Overview of benchmarking methods

In this study we estimate econometric cost functions and index number based total and partial factor productivity measures. These approaches are explained in the remainder of this section.

2.3.1 Cost function analysis

In production economics, econometric cost functions provide a useful tool for estimating the least cost means of production and are used by a number of regulators to explore efficient costs for energy networks. A cost function is a function that measures the minimum cost of producing a given set of outputs in a given production environment in a given time period.

By modelling the output quantities, the input prices, and the operating conditions in which the business operates, a minimum-cost function (a theoretical concept), yields an estimate of the periodic costs incurred by an efficient business to deliver those services in that environment.

Let $x = (x_1, \dots \dots, x_M)'$, $w = (w_1, \dots \dots, w_M)'$, $q = (q_1, \dots \dots, q_N)'$ and $z = (z_1, \dots \dots, z_J)'$ denote vectors of input quantities, input prices, output quantities and environmental variables respectively. Mathematically, the cost function is defined as:

$$c(w, q, z, t) = \min_{x \geq 0} \{w'x : x \; can \; produce \; q \; in \; an \; environment \; characterised \; by \; z \; in \; period \; t\}$$

Functional form

To facilitate the estimation of econometric cost functions it is necessary to assume a functional or algebraic form that can approximate the unknown, theoretical cost function.

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[5] ACCC and AER, 2012, p. 157.

The functional form imposes certain assumptions, which may be more or less strict, about the relationships between model variables (outputs, inputs prices and costs) including relating to economies of scale and elasticities of substitution and hence the shape of the underlying cost function.

The desirable features of a functional form are as follows:

- captures the underlying technology of an industry adequately
- non-decreasing in prices
  - i.e. if prices increase then costs increase
- non-decreasing in outputs
  - i.e. if outputs increase then costs increase
- homogeneity in prices
  - i.e. if you double prices, you double costs
- has a smooth function
- linearity in the parameters.

The functional forms applied most commonly in the econometric cost benchmarking literature are:

- Cobb-Douglas: a linear in logs functional form that makes relatively stricter assumptions about the functional form
- Translog: a flexible functional form that allows for linear, quadratic and interaction terms in the logarithms of the output quantity and input price variables.

In general, increased flexibility in the functional form may be desirable in terms of more closely reflecting reality and allowing for a greater range of possible estimated outcomes. However, the more flexible forms such as a Translog cost function require estimation of a large number of parameters which may introduce econometric problems (e.g. multicollinearity).

A range of practical criteria are typically used to determine the functional form used including reducing estimation problems (including multicollinearity and loss of degrees of freedom when sample size is small), ease of interpretation (some functional forms have an intrinsic and intuitive economic interpretation and in which the functional structure is clear) and computational ease.[6]

Estimation approach

Different cost function estimation approaches may also be applied. This study uses Ordinary Least Squares (OLS), Feasible Generalised Least Squares (FGLS) and Stochastic Frontier Analysis (SFA). OLS is a commonly applied regression estimation approach which compares performance relative to the sample average. SFA estimates the cost frontier representing the minimum costs rather than estimating the cost function representing the 'average' business. SFA, in its ideal form, also separates the presence of random statistical noise from the estimation of inefficiency.[7]

In accordance with the Terms of Reference for this study, opex cost functions are estimated using historical data for a sample of Australian gas distribution businesses including

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[6] Fuss, M, McFadden D. and Mundlak, Y,"A Survey of Functional Forms in the Economic Analysis of Production" in Fuss, M and McFadden D. (Eds) (1978), *Production Economics: A Dual Approach to Theory and Applications*.

[7] This 'ideal form' is predicated on the assumption that all firm heterogeneity outside of the control of management is taken into account within the model. If this is not the case, then firm heterogeneity will enter the estimated inefficiency term.

ActewAGL. The cost functions are used to forecast ActewAGL's opex partial factor productivity growth rate for the 1 July 2014 to 30 June 2021 period. This analysis, the functional form specified, and estimation approach used, is described in detail in section 4.

2.3.2 Index number based TFP and opex PFP analysis

Index number methods, often called TFP measures, construct productivity measures directly from the data on inputs and outputs, without the need to estimate a cost or production function. Productivity is measured as the ratio of output quantity to input quantity.

Different index number approaches use different means to aggregate the multiple inputs used and outputs produced by firms to obtain an input and output index. Commonly used forms include:

- Paasche Index, which uses the current period's prices as weights for the input and output quantities
- Laspeyres Index, which uses the base period's prices as weights for the input and output quantities
- Fisher Index, which is the geometric mean of the Paasche and Laspeyres indexes
- Tornqvist translog index, which weights inputs according to their share of total costs (the average share over two adjacent time periods) and weights outputs according to the share of total revenue (the average share over two adjacent time periods).

Unilateral indexes can be used to measure relative performance either for a single business over time or between businesses at a single point in time. Multilateral indexes can be used to compare productivity levels and growth rates.

In accordance with the Terms of Reference, this study estimates unilateral TFP and opex partial factor productivity measures for ActewAGL over the period from 2003-04 to 2013-14.

In this study, we use a Fisher Index to estimate total factor productivity and opex partial factor productivity growth rates for ActewAGL. The Fisher Index is recommended as the preferred approach for time series productivity measurement in the literature given its desirable theoretical and test properties.[8] Under the Terms of Reference for this study, ACIL Allen were also instructed to apply similar analysis to that reported in Economic Insights (2014). Economic Insights applied a Fisher Index to produce the time series productivity growth rates.

The unilateral TFP and opex PFP analysis is described in detail in section 5.

2.3.3 Capex partial productivity performance indicators

In accordance with previous capex productivity benchmarking for gas distribution businesses, this study provides a range of capex partial performance indicators (PPIs) that show ActewAGL's capex per unit of output.

2.3.4 Benchmarks are indicative not exact

It is important to recognise that, due to the limitations of data and of the benchmarking techniques, the efficiency and productivity measures produced in this study are approximate rather than exact. There are often challenges associated with accounting for differences in relevant operating environment factors, in accurately measuring inputs and outputs, and in

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[8] For example see Coelli, T. et all, 2005 and ACCC and AER, 2012 for more detail including on the index number tests.

gaining comparable, quality data over long time periods. The limitations that are specific to this study are discussed within the report.

Given that the measures are indicative implies that it would not be appropriate, for example, to assume that the difference between observed costs and benchmarked costs can in part or as a whole be conclusively attributed to relative inefficiency.

However, the economic analysis seeks to make the best use of benchmarking data that is available to assist ActewAGL to verify efficient cost levels and the scope for opex productivity growth over the forthcoming regulatory period. This study provides useful information which can be used as part of a suite of tools and analyses to inform ActewAGL's decisions given the uncertainties associated with forecasting expenditure over a period to 2021.

3 Benchmarking data

This section describes the sample of Australian gas distribution firms used in the benchmarking analysis.[9] Information is also provided on:

- the sources of the benchmarking data used in the study
- limitations to data that is available publicly
- qualifications regarding the extent to which ACIL Allen has been able to verify the accuracy and comparability of the data.

3.1 Sample of gas distribution businesses

The cost function analysis presented in this study benchmarks ActewAGL against eight other Australian gas distribution businesses serving urban populations and that are subject to full economic regulation, namely:

- ATCO Gas Australia (WA)
- Australian Gas Networks South Australia (SA) (previously Envestra)
- Australian Gas Networks Victoria (VIC) (previously Envestra)
- Multinet Gas (VIC)
- AusNet Services (VIC)
- Jemena Gas Networks (NSW)
- Australian Gas Networks Queensland (QLD) (previously Envestra)
- Allgas Energy (QLD).

Key characteristics of each of the nine gas distribution businesses is provided in Table 1 including their service area coverage and key outputs.

Table 1 **Benchmarked gas distribution businesses**

Gas distribution business	Key characteristics 2013-14
ACT	
ActewAGL ActewAGL Distribution operates the gas distribution network in the ACT, Queanbeyan, Palerang and Nowra. The data presented in this report excludes Nowra, as it is not covered by the access arrangement	Network length 4,395 km Customers 134,274 TJ delivered 7,629
Western Australia	
ATCO Gas Australia ATCO Gas owns, operates and maintains the reticulated gas infrastructure in Western Australia (WA) serving Geraldton, Kalgoorlie, Albany, Bunbury, Busselton, Harvey, Pinjarra, Brunswick Junction, Capel and the Perth greater metropolitan area including Mandurah	Network length 13,500 km Customers 676,287 TJ delivered 26,843

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[9] Noting that all firms are included in the cost function and capex PPI analysis, but the TFP analysis is for ActewAGL only.

Gas distribution business	Key characteristics 2013-14
South Australia	
Australian Gas Networks SA Australian Gas Networks Limited (AGN), previously Envestra Limited, is now fully owned by the Cheung Kong Consortium. It is the largest gas distribution company in Australia with natural gas distribution networks and transmission pipelines in South Australia, Victoria, Queensland, New South Wales and the Northern Territory. AGN's South Australian gas distribution network serves Adelaide, Mt Gambier, Whyalla, Pt Pirie, Barossa Valley, Murray Bridge and Berri	Network length 7,950 km Customers 425,784 TJ delivered 23,390
Victoria	
Australian Gas Networks Victoria AGN's Victorian gas distribution network serves the northern, outer eastern and southern areas of Melbourne, Mornington Peninsula, rural communities in northern, eastern and north-eastern Victoria, and south-eastern rural townships in Gippsland	Network length 10,353 km Customers 589,214 TJ delivered 54,418
Multinet Gas Multinet Gas serves customers throughout Melbourne's inner and outer east, the Yarra Ranges and South Gippsland	Network length 9,980 km Customers 682,436 TJ delivered 56,096
AusNet Services AusNet Services (previously SP AusNet) distributes gas to customers across central and western Victoria. Its service area includes metropolitan Melbourne growth corridors including Caroline Springs and Werribee.	Network length 10,206 km Customers 624,144 TJ delivered 72,400
New South Wales	
Jemena Gas Networks Jemena Gas Networks distributes natural gas to 1.1 million homes and businesses in Sydney, Newcastle, the Central Coast and Wollongong as well as to over 20 country centres including those in the Central West, Central Tablelands, South Western, Southern Tablelands, Riverina and Southern Highlands regions of New South Wales. It is the largest gas distribution business included in this study	Network length 25,693 km Customers 1,202,525 TJ delivered 89,179
Queensland	
Australian Gas Networks Queensland AGN Queensland's gas distribution network serves customers in Brisbane (north of Brisbane River), Ipswich, Rockhampton and Gladstone	Network length 2,703 km Customers 92,181 TJ delivered 6,150
Allgas Energy Allgas Energy owns and operates gas distribution pipelines in Queensland and northern New South Wales that supply natural gas to customers in Brisbane (south of the river), and in other regional centres including Toowoomba and the Gold Coast	Network length 3,272 km Customers 93,319 TJ delivered 10,107

Note: ATCO Gas data from ATCO Gas Australia, 2014.

Source: ACIL Allen

The Australian gas distribution businesses undertake the same range of regulated gas distribution activities. Hence, it is considered reasonable to include this sample of firms in the cost function and capex PPI estimations.

The gas distribution networks receive gas from the high pressure gas transmission networks and reticulate it to end users including large industrial users and households. The underground pipeline networks comprise a range of materials including cast iron, steel, polyethylene, nylon and polyvinyl chloride (PVC). Current practice is to install polyethylene pipes which can be operated at a range of pressures and are more resistant to corrosion. The older iron and steel networks are being replaced over time.

The gas distribution businesses operate their distribution networks to maintain gas pressure within technically acceptable limits. Regulating stations in the network adjust the pressure of the gas before it enters the distribution network and within the network. The main transportation pipelines are operated at high and medium pressures, while the mains connecting to customers generally operate at low pressure.

Although the gas distribution businesses undertake the same activities, the characteristics of the operating environment in which they deliver the services can vary significantly. This can in turn lead to differences in the cost to deliver the distribution services which are outside of the control of the distributors. This does not invalidate the benchmarking that compares each of the gas distribution businesses (i.e. the cost function and capex PPI analysis), but does need to be recognised and accounted for in the benchmarking analysis to the extent that is possible.

Examples of differences in the operating environment of the nine Australian gas distribution businesses include:

- the size of the businesses, including in terms of their network size, number of customers and amount of gas delivered
- customer penetration (measured in terms of the proportion of households and businesses connected to natural gas networks in a geographical area) varies across the States and hence the gas distribution businesses in the sample. Customer penetration is highest in the cooler climate areas (Victoria and South Australia have residential gas penetration of around 90 per cent and 40 per cent respectively) and lower in warmer climates (approximately 15 per cent of the residential market in Queensland).[10] These differences will be reflected in the relative size of the gas distribution businesses
- network dispersion including the distances between transmission connection points and urban centres
- customer and network densities, that is, the number of customers served for a given length of gas mains with higher densities generally reducing costs due to scale efficiencies
- energy density, which is the amount of gas delivered per customer. Over the historical study period, a trend of declining energy density is common across all of the gas distribution businesses. This is due to declining average household usage in some areas and reductions in industrial demand.

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[10] AER, *State of the Energy Market 2014,* p. 110.

3.1.2 ActewAGL

ActewAGL is one of the smaller gas distribution businesses in the sample in terms of network size and customer base, being most similar in scale to the Queensland gas businesses.

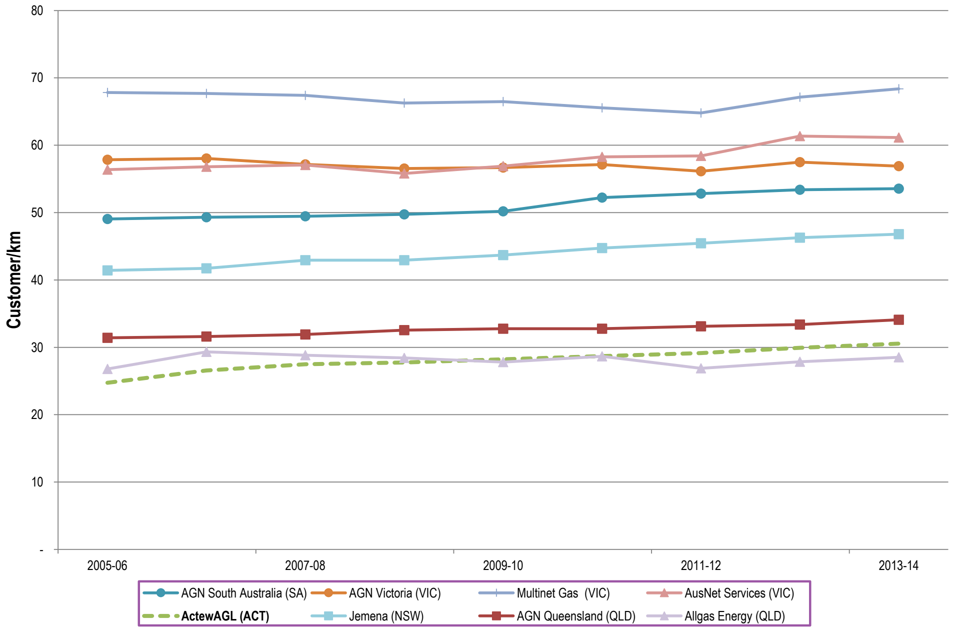
ActewAGL has among the lowest customer and energy density among the gas distribution businesses as shown in Figure 1 and Figure 2. ActewAGL has a customer mix that is dominated by residential and commercial customers and few larger, industrial customers.

Previous benchmarking studies of gas distribution businesses (including the Marksman Report and various reports by Economic Insights) have identified customer density (customers per kilometre of mains) and energy density (energy delivered per customer and per kilometre of mains) as material drivers of cost and hence relative efficiency.

Higher customer density means that less pipelines and associated assets need to be built and maintained per customer, resulting in relatively lower costs and a relatively higher efficiency. Similarly, greater energy density has been associated with lower inputs to deliver a given volume of gas.

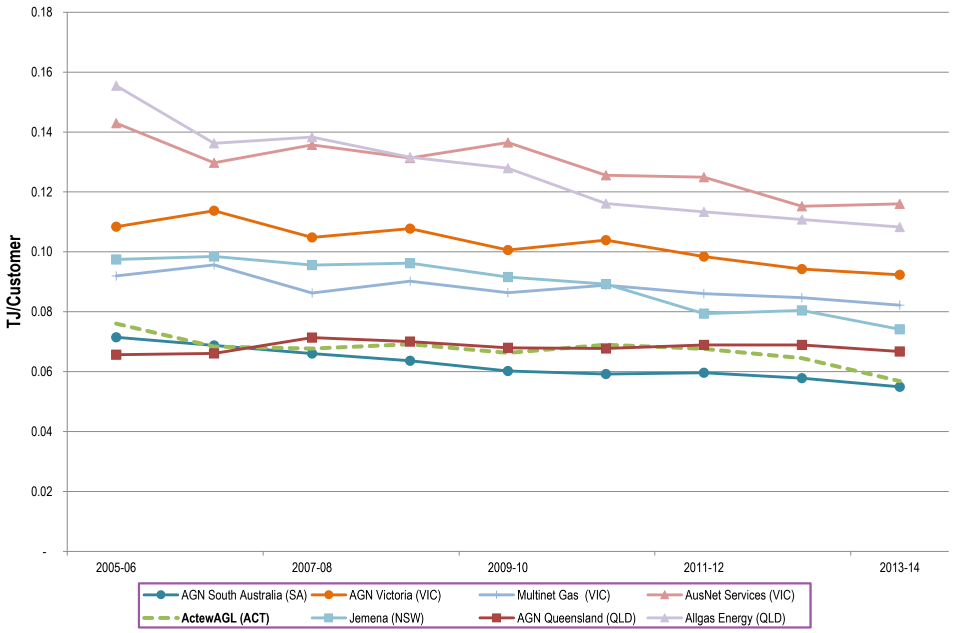
To the extent that the efficiency and productivity measures that compare ActewAGL to the other gas distribution businesses do not account for differences in customer and energy density, then ActewAGL may appear relatively less efficient due to these operating environment characteristics.

Figure 1 **Customer density (customers per km mains)**



Note: ATCO Gas is not shown, but is included in the cost function analysis.
Source: ACIL Allen

Figure 2 **Energy density (TJ per customer)**



Note: ATCO Gas is not shown, but is included in the cost function analysis.
Source: ACIL Allen

3.2 Benchmarking data

3.2.1 Data sources

ACIL Allen has compiled a benchmarking database for the nine Australian gas distribution businesses. The benchmarking data were largely sourced from public reports including:

- gas distribution business Access Arrangement Information statements
- regulatory determinations by the AER and jurisdictional regulators
- AER performance reports
- annual and other reports published by the businesses
- consultant reports prepared as part of access arrangement review processes.

A reference list is provided in Appendix E.

ACIL Allen's database also contains confidential data from ActewAGL, ATCO Gas and Jemena provided for benchmarking analysis. Confidential data are not revealed within this report.

ACIL Allen has sourced benchmarking data for the historical period from 2003-04 to 2013-14. Data for all gas distribution businesses is available from 2004-05. Data is available for a subset of the businesses in 2003-04. Over the historical period the benchmarking study relies to the greatest extent possible on data from reported actual costs and outputs, rather than on forecasts. Where it has been necessary to use forecasts, the data reflect final forecasts agreed with the regulator (and amended by appeal where relevant).

3.2.2 Estimation of missing data items

In two instances, ACIL Allen has estimated observations that were unavailable in the public data. These instances are explained in Table 2.

Table 2 **Estimation of unavailable data items**

Gas distribution business	Missing data item	Estimation
AGN South Australia	UAFG 2005-06	Assumed to be the same amount as 2006-07 in real dollar terms. Given the consistency of the UAFG amount for AGN SA, this assumption is considered reasonable.
Allgas Energy	Mains km 2007-08	Estimated as the average of the reported 2006-07 and 2008-09 mains km. Given the relatively small changes in the network length, this was considered to be a reasonable estimate.

3.2.3 Data comparability and suitability for benchmarking

To a large extent, the benchmarking study relies on data that were reported publicly by the gas distribution businesses and, in most cases, verified by the relevant economic regulator. Where data has been provided to ACIL Allen directly, the data are reported on a basis that is consistent with the regulatory data in the Access Arrangement Information statements. In particular, the study uses the expenditure categories reported within the gas distribution businesses' Access Arrangements, including the operating expenditure and capital expenditure categories.

Within the time available for this study, and constraints on our practical ability to verify the cost data with the gas businesses, it was not possible to undertake a detailed review of the cost data items used in the study to ensure that precisely the same costs are reported in these categories by all of the nine distributors and hence to fully establish the cost data comparability between the businesses.

Notwithstanding this, the steps that ACIL Allen has undertaken to determine data comparability and hence suitability for benchmarking are as follows.

First, ACIL Allen has reviewed the numerous prior benchmarking studies of Australian gas distribution businesses to understand the appropriate sources of data and to draw on the experience of these studies in ensuring that the data used was comparable across the firms. The previous reports were submitted as part of regulatory processes and include Economic Insights (2014), Economic Insights (2012a), Economic Insights (2012b), Marchment Hill Consulting (2012), Economic Insights (2010), Marksman Consulting Services (2010), ActewAGL (2009a), WorleyParsons (2007) and Meyrick and Associates (2004). The lessons from those studies in terms of ensuring data comparability have been applied in ACIL Allen's updated analysis. This has resulted in adjustments to the operating expenditure data which are explained in section 0 below.

Second, ACIL Allen has undertaken its own data screening. A range of operating and capital cost ratios and operating environment ratios have been calculated for all firms and all years to identify data items that are outliers (e.g. ratios that are more than three standard deviations from the sample mean) and to identify potential areas of persistent variation between firms and across time. The ratios are provided in Appendix B. Where an observation has warranted further investigation, ACIL Allen has rechecked the original data source and sought any additional relevant verifying information.

Third, ACIL Allen has investigated possible differences between the Australian gas distribution businesses in terms of their allocation of costs to the operating and capital cost categories due to differences in cost allocation and capitalisation policies. This was an issue which came to light in the context of the recent electricity distribution benchmarking, with likely differences in practice observed. Figure 14 in Appendix B shows the ratio of operating expenses to total operating and capital expenditure for each of the nine Australian gas distribution businesses between 2005 and 2013.

The third element of analysis indicates that ActewAGL's operating expenditures (at 50 per cent to 60 per cent of total opex and capex expenditure) consistently comprise a larger share of total expenditures compared to the majority of the other gas distribution businesses (with an opex share around 20 per cent to 30 per cent). While it has not been possible within the scope of this study to determine whether there are differences in cost allocation and capitalisation policies that mean that different costs are included within the operating and capital expenditure categories between the gas distribution businesses, this issue could be further investigated in future benchmarking analysis and would need to be considered by the AER and others in interpreting ActewAGL's opex partial productivity measures.

Based on the screening process, ACIL Allen has not removed any observations from the benchmarking analysis. This is because we have verified the data against regulatory documents. We consider that this is reasonable given that:

- our sample size is limited and hence we wish to retain all reasonable data observations
- the key focus of this study is to estimate productivity trends, rather than on relative efficiency and productivity levels in relation to an efficient frontier.

Finally, for the opex cost function estimations, further analysis has been undertaken to test the sensitivity of the estimations to individual observations. As panel data is used (i.e. encompassing multiple gas distribution businesses and time periods), the sensitivity of the cost function estimates to the inclusion or exclusion of individual gas distribution businesses has been undertaken. This is explained in section 4 which reports on the cost function analysis.

On balance, it is our opinion that the benchmarking data used in the study is robust and appropriate for indicative benchmarking analysis, particularly as the majority of the data has been subject to scrutiny by the relevant economic regulator and in many cases also by expert consultants engaged by the economic regulators.

However, there remains uncertainty about data comparability that ACIL Allen is not able to resolve. Possible differences in the comparability of cost categories and other inevitable shortcomings in the benchmarking analysis mean that the efficiency and productivity benchmarks produced should be treated as indicative, not exact. Other potential shortcomings that limit the ability of the benchmarking models in this study to represent the gas distribution businesses' true cost and production functions include:

- the limited data available for this study e.g. a richer data set with a broader range of cost inputs, outputs and operating environment factors could be used to create model specifications that better account for the variation between the gas distribution businesses
- potential data errors that have not been identified
- the limitations of the modelling techniques in terms of their ability to accurately estimate the true efficient cost and production frontiers.

3.3 Data definitions

The following describes the data items used in the analysis.

Operating expenditure

The operating expenditure amounts used in this benchmarking study reflect the costs classified as operating expenditure within each businesses' Access Arrangement. This typically includes a range of operating costs (including network operations, regulatory costs and billing cost), maintenance costs (including for pipelines, meters and network control) and other management and administration costs.

As had been identified in previous benchmarking reports, unaccounted for gas (UAFG) is treated differently between the jurisdictions. As a result, it has been excluded from operating costs for this study. Debt raising costs have also been removed where included in reported operating expenditure. This has also been done to account for differences in the treatment of these costs over time and between the businesses. Other operating expenditure items removed to aid comparability and to remove costs that are outside the control of the gas distribution businesses are carbon costs and government levies.

The operating expenditure data sourced for the benchmarking study were reported in a range of nominal and constant dollar values within the source documents. All dollar amounts have been placed on a common basis using the Australian Bureau of Statistics All Groups, Weighted average of eight capital cities, CPI (Series ID: A2325846C).

Capital expenditure

The capital expenditure amounts used in this benchmarking study reflect the costs classified as capital expenditure within each businesses' Access Arrangement. Capex is incurred to purchase new capital assets to meet business expansion needs and to renew and replace long lived capital assets. The capex used in the analysis is net capex, i.e., capex excluding customer contributions.

As with the opex data, all dollar amounts have been placed on a common basis using the Australian Bureau of Statistics All Groups, Weighted average of eight capital cities, CPI (Series ID: A2325846C).

Regulatory asset base (RAB)

The measure of RAB is the closing value for each year.

Network length

The network length for the gas distribution businesses includes the mains that the businesses classify as low, medium and high pressure distribution mains and transmission pressure mains operated above 1,050kPa.

Customers

The customer number measure is the total number of customers including residential and non-residential volume customers and contract customers.

Gas delivered

The gas delivered measure is the total gas delivered to the above customers measured in Terajoules (TJ).

Further data requirements associated with the individual modelling approaches are discussed within the relevant sections of the report.

Part A

Estimation of the opex cost function and forecast opex partial productivity growth rate for ActewAGL.

4 Opex cost function and productivity growth rate

In this section we specify and estimate a set of operating cost functions that characterise the operating cost structure of the nine gas distribution businesses in our sample. The estimated coefficients from the cost function models are then used in conjunction with forecasts of opex cost drivers from ActewAGL to forecast operating cost productivity growth over the regulatory period from 2014-15 to 2020-21.

4.1 Econometric approach

An econometric approach is adopted in estimating the opex cost functions. The econometric approach is a parametric approach that aims to establish a statistical relationship between operating costs and the individual cost drivers. In benchmarking, estimated or predicted costs are compared to a business's actual costs, with any differences attributed to inefficiency.

The main advantages of the econometric approach are that it allows for:

- statistical testing to choose between competing models
- differences in operating environment such as scale and density to be controlled for across firms, something which is not possible within many non-parametric methods.

The main disadvantages are:

- the conventional econometric method does not separate statistical noise from inefficiency
  - this is where Stochastic Frontier Analysis (SFA) deviates from the conventional econometric approach by attempting to split one from the other through the introduction of a composite error term
- the econometric method is reliant on the functional form of the model to be chosen so as to reflect the appropriate production technology of the firms in question
- it is subject to a number of data limitations and statistical problems which may bias the results.

There are a number of steps required to estimate an econometric cost function for benchmarking purposes.

First, it is necessary to identify and select the variables that will be used in the estimation process, in particular the number of outputs produced by the gas distribution businesses, the input price of opex and the choice of environmental or operating condition variables that affect operating costs. The data and variables used are discussed in section 4.2.

It is then necessary to choose a functional form for the cost function. The two functional forms considered in this study are the Cobb-Douglas and Translog functional form. These are discussed in greater detail in section 4.3.

Once the functional form of the cost function is selected, an estimation technique must be applied to produce estimates of the relevant parameters of the model. A large range of possible estimation techniques is possible. In this study we consider pooled OLS, Fixed and random effects models, Feasible GLS and SFA. These are discussed in greater detail in section 4.4.

In section 4.5 we discuss some of the data limitations that are present in this study. Section 4.6 discusses model validation and testing. Section 4.7 presents the estimated opex cost functions and section 4.8 compares ActewAGL's cost efficiency performance against its peers. Finally, section 4.9 presents opex partial productivity forecasts for ActewAGL.

4.2 Data and choice of variables

The estimated models use data for nine gas distribution businesses covering the period from 2003 to 2013. The data comprises an unbalanced panel of 87 observations for the nine gas distribution businesses. While the time series component of the data ends at 2013-14, the starting point of the series differs between businesses, with the earliest observations commencing from 2003-04 for ActewAGL and Jemena.

ACIL Allen has decided to make minimal use of future year forecasts in the dataset and exclude future year forecasts which have not been approved by the regulatory process (e.g. that are at draft determination stage).

The possible output, input and operating environment variables that may be specified from the data available in the benchmarking database are shown below.

Outputs

- energy throughput (TJ)
- customer numbers

Inputs

- capital services (constant price Regulatory Asset Base (RAB))
- opex price index (weighted price index described below)

Environmental variables

- network density (customers per km of network length)

Constant price RAB is used as a proxy for capital instead of mains length mainly to avoid significant multicollinearity issues that arise from the presence of mains length in the denominator of the network density variable.

An alternative specification was tested with line length as an input instead of the constant price RAB, and excluding the network density variable. This was found to have lower sample goodness of fit and a tendency for the elasticity on customer numbers to be statistically insignificant. The alternative specification was therefore not considered as an option.

The opex price index is the index recommended by the AER for network service providers.[11] This is a weighted opex price index formed using the following Australian Bureau of Statistics (ABS) indexes and weights:

- electricity, gas, water and waste services (EGWWS) wage price index (WPI) — 62 per cent
- intermediate inputs: domestic producer price index (PPI) —19.5 per cent

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[11] See AER, 2013a, p. 154-155.

- data processing, web hosting and electronic information storage PPI —8.2 per cent
- other administrative services PPI —6.3 per cent
- legal and accounting PPI —3 per cent
- market research and statistical services PPI —1 per cent.

ACIL Allen sourced these indexes from the ABS and calculated the weighted index.

Since the data set used has only one environmental control variable, the likelihood of correct model specification is limited. However, this does not invalidate the results, but rather suggests that the results need to be cautiously interpreted.

4.3 Model functional form

The two functional forms under consideration in this analysis are the Cobb-Douglas and the more flexible Translog functional form.

Cobb-Douglas function

The Cobb-Douglas function assumes a log-linear functional form where the natural logarithm of opex is linear in the logarithm of the output quantities and the input price.

For a Cobb-Douglas function with:

- two output variables:
  - energy throughput (E)
  - customer numbers (C)
- two input variables:
  - capital services proxied by the constant price RAB (R)
  - opex price (P)
- a single operating environment variable, customer density (CD)
- a time trend capturing technological changes

the function takes the form:

$$\ln(Opex) = a + b_1 Time + b_2 \ln(E) + b_3 \ln(C) + b_4 \ln(P) + b_5 \ln(R) + b_6 \ln(CD)$$

To ensure homogeneity in prices, the coefficient on the opex price variable (P), b_4 is restricted to equal 1. This is dealt with in the estimation process by subtracting ln(P) from both sides of the equation so that the dependent variable in the regression becomes ln(Opex) minus ln(P) and the price variable disappears from the right hand side of the equation.

The Cobb-Douglas function imposes a constant elasticity of opex to each of the outputs regardless of the scale of the business. From the above specification, this implies that a 1 per cent increase in customer numbers (C) will result in a b_3 per cent increase in opex, regardless of whether the firm is large or small.

The sum of the coefficients of the output variables gives an indication of the type of returns to scale present in the sample. If the coefficients b_2 and b_3 sum to less than 1, operating costs increase at a slower rate than the outputs, implying increasing returns to scale. We would expect this to be the case for gas distribution businesses.

The Cobb-Douglas functional form is useful to the extent that it reflects the underlying production technology of the gas distribution business. This functional form has been applied in a number of previous studies of gas distribution businesses.

Translog functional form

The Translog functional form allows for linear, quadratic and interaction terms between the output and input variables.

The Translog is an example of a flexible functional form which is considerably less restrictive than the Cobb-Douglas. It allows for linear, quadratic and interaction terms in the natural logarithms of output and input prices. Its main advantage over the Cobb-Douglas is that it allows the degree of returns to scale to vary with firm size, something that the Cobb-Douglas does not allow.

Extending the two output, two input and single environmental variable Cobb-Douglas function above to the more flexible Translog function, we get:

$$
\begin{aligned}
&\ln(Opex) = a + b_1 Time + b_2 \ln(E) + b_3 \ln(C) + b_4 \ln(P) + b_5 \ln(R) + \\
&b_6 \ln(CD) + 0.5 b_{22} \ln(E)^2 + b_{23} \ln(E)\ln(C) + 0.5 b_{33} \ln(C)^2 + 0.5 b_{44} \ln(P)^2 + \\
&0.5 b_{55} \ln(R)^2 + 0.5 b_{66} \ln(CD)^2 + b_{24} \ln(E)\ln(P) + b_{25} \ln(E)\ln(R) + b_{26} \ln(E)\ln(CD) + \\
&b_{34} \ln(C)\ln(P) + b_{35} \ln(C)\ln(R) + b_{36} \ln(C)\ln(CD) + b_{45} \ln(P)\ln(R) + b_{46} \ln(P)\ln(CD) + \\
&b_{56} \ln(R)\ln(CD)
\end{aligned}
$$

In this instance the Translog function requires twenty-one explanatory variables, compared to six for the Cobb-Douglas.

Under certain restrictions, the Translog function reduces to a Cobb Douglas function. This will be the case when the coefficients on all the quadratic and interaction terms are zero.

While the Translog is more suitable due to its flexible form, it becomes unsuitable in the face of a limited sample size. Small samples will have insufficient degrees of freedom to reliably estimate the parameters of the model. Furthermore, there is likely to be strong multicollinearity between the explanatory variables due to numerous terms involving transformations of the same variables and interaction among variables. This problem is exacerbated when the sample size is small.

Choice of functional form

As part of this study we initially considered both the Cobb Douglas and Translog functional forms as potential options.

While the Translog offers extra flexibility, this is achieved at additional cost. One of the requirements of the Translog specification is a sample size that is large enough to provide sufficient degrees of freedom to reliably estimate the cost function and also to overcome the problem of multicollinearity between the explanatory variables.

For the sample of 87 observations available for this study, the addition of quadratic and interaction terms into a translog specification resulted in significant instability in the parameter estimates.

It is our opinion that the analysis is limited in this respect and that it should remain focussed on the simpler but more restrictive Cobb-Douglas form, where the parameter estimates can be readily interpreted and are reasonably robust to changes in the estimation technique applied. Because of this necessary assumption, good statistical practice means that any results need to be further tempered.

4.4 Estimation techniques

The study tested the following cost function estimation techniques.

4.4.1 Pooled OLS

The standard econometric technique to estimate a cost function is ordinary least squares (OLS). OLS fits a linear relationship between the dependent variable and a set of explanatory variables, in our case a set of outputs, inputs and operating environment variables. The line of best fit is chosen so as to minimise the sum of squared errors of the model.

The OLS estimator is considered BLUE (the best linear unbiased estimator) under a set of restrictive assumptions:

- the dependent variable is a linear function of a set of independent variables plus a disturbance term
- the expected value of the disturbance term is zero (unbiasedness)
- disturbances have uniform variance and are uncorrelated (homoscedastic, no serial correlation)
- observations on the independent variables are fixed in repeated samples
- there are no exact linear relationships between independent variables (no perfect multicollinearity).

Pooled OLS treats the entire sample as if it is a single cross section. It does not recognise that the data has two dimensions, both across time and firms. This approach therefore does not recognise the panel structure of the data. This is not an issue if there is no heterogeneity across firms or if the heterogeneity can be captured entirely by existing explanatory variables in the model. However, in this and similar analyses, this is difficult due to the lack of environmental variables and the uncertainty about the comparability of the data.

4.4.2 Fixed and random effects models

The panel nature of our dataset has a number of attractive features which can be captured through the application of fixed or random effects models. These are:

- panel data can be used to deal with heterogeneity across firms. There are a large number of unmeasured explanatory variables that will affect the behaviour of each firm. Failure to account for these can lead to bias in estimation.
- by combining both cross section and time series, panel data provides more variation in data which can help to alleviate multicollinearity problems and lead to more efficient estimates.

In the standard fixed effects specification, the unobserved variables that drive the heterogeneity across firms is accounted for by different intercepts for each firm in the estimation. The main drawback of the fixed effects model is the loss of significant degrees of freedom through the implicit inclusion of dummy variables to account for the different intercepts across firms. This leads to less efficient estimates of the common slopes.

The random effects model adopts an alternative way of allowing for different intercepts across firms, which aims to overcome the loss of efficiency that arises in the fixed effect specification.

The random effects model views the different intercepts across firms as having been drawn from a random pool of possible intercepts. The random effects model therefore has a single overall intercept, a set of explanatory variables and a composite error term. The composite error term has two components:

- the random intercept term which measures the extent to which the individual firms intercept differs from the overall intercept

- the conventional error term, which indicates the random disturbance for a given firm in each time period.

The random intercept term is the same for each firm across all time periods.

The random effects estimator saves on degrees of freedom and consequently produces more efficient estimates of the slope coefficients than the fixed effects model. This suggests that the random effects estimator is superior to the fixed effects model. Unfortunately, this is only true if the individual firms' intercepts are not correlated with any of the explanatory variables. If they are, then the estimated slope coefficients will be biased. This is not a problem with the fixed effects estimator because the different intercepts are recognised explicitly.

4.4.3 Feasible GLS (FGLS)

An alternative estimation method to that of OLS is Feasible Generalised Least Squares (FGLS).

OLS estimates are only efficient under the assumption of homoscedasticity and no serial correlation in the residuals. When these assumptions are violated, the OLS estimates are inefficient, although they remain unbiased. By inefficient we mean that the estimator no longer has the minimum variance among the class of linear unbiased estimators.

In this circumstance, the usual formula of the variance-covariance matrix is incorrect and the estimated variance-covariance matrix will be biased. In this context, interval estimation and hypothesis testing can no longer be trusted.

To address these problems, two solutions have been developed.

The first is a set of heteroscedasticity and autocorrelation consistent variance-covariance matrix estimators for the OLS estimator, which eliminate the bias in the variance-covariance matrix (albeit only asymptotically). These then allow OLS and other estimators to be employed with more confidence.

These heteroscedasticity and autocorrelation consistent variance-covariance estimators are sometimes referred to as robust variance estimates. Wherever possible in this study, we present t statistics based on heteroscedasticity and autocorrelation consistent variance-covariance estimators.

Alternatively, another estimator which explicitly recognises the heteroscedasticity and autocorrelation of the disturbances is FGLS, which can produce a linear unbiased estimator with smaller variances than OLS. This is done by using additional information such as that large disturbances are likely to be large because their variances are larger, or that large and positive error values in one period are likely to be followed by large and positive error values in the following period.

While OLS estimation minimises the sum of squared residuals, FGLS minimises an appropriately weighted sum of squared residuals, which gives lower weights to those residuals that are expected to be large because their variance is large or those residuals that are expected to be large because other residuals are large.

This approach results in a more efficient estimator than that obtained through OLS regression under heteroscedasticity or serial correlation. Under the classical OLS assumptions of spherical disturbances, the OLS estimator is the most efficient.

4.4.4 Stochastic Frontier Analysis (SFA)

The standard econometric approach is typically interpreted as all deviations from the predicted values of the model are due to inefficiency. This interpretation is an assumption, whereas in truth, the error term (i.e. 'deviation') is due to three causes: measurement error and other statistical noise, firm heterogeneity outside of management control, and managerial inefficiency.

Just like the standard econometric approach, SFA aims to model the relationship between operating costs, outputs and environmental variables. However, SFA separates the error term into two components:

- an inefficiency term, and
- a random error component.

This split attempts to remove the influence of random noise from the estimate of firm inefficiency. However, these two terms can only be interpreted as such if all firm heterogeneity outside of management control is accounted for within the model. If such factors are not taken into account within the model, then this firm heterogeneity will enter, most likely, both terms as well as affect estimates of the other parameters.

SFA uses maximum likelihood estimation to model the relationship between opex and its drivers. The model takes the form:

$$\ln(C_{it}) = \beta_0 + \sum \beta_j \ln(x_{jit}) + v_{it} + u_{it}$$

where, in the ideal case:

- C_{it} is the opex for firm i at time t
- x_{jit} refers to all output and environmental drivers of opex j for firm i at time t
- v_{it} captures the effect of random factors such as unusual weather conditions for firm i at time t
- u_{it} captures the inefficiency for firm i at time t.

The statistical noise term is assumed to follow a normal distribution with mean zero and variance σ^2:

$$v_{it} \sim N(0, \sigma_v^2)$$

The inefficiency term is assumed to follow a one-sided non-negative truncated normal distribution with mean μ and variance equal to σ^2:

$$u_{it} = N^+(\mu, \sigma_u^2)$$

It is logical for the inefficiency term to remain positive because a business cannot reduce costs below the minimum possible level for a given set of outputs at a given set of input prices.

Just as in the standard econometric approach, SFA requires additional assumptions about the functional form of the cost function. If the underlying production technology of the industry is not reflected in the choice of cost function, there is a risk that this mis-specification could lead to biased estimates.

Because of the separation of the error term into two separate components, estimation of SFA cost models are more computationally demanding than conventional econometric methods. Moreover, separating the random and inefficiency components of the error term requires a large number of data points. This is a significant drawback in our case, where we have data on only nine firms and a panel with 87 observations.

4.5 Data limitations and issues

4.5.1 Small number of firms

A key limitation of this study is that the sample includes only nine firms. As a result, the results may be sensitive to the removal or addition of a single firm, and it may be difficult to accurately determine the location of the efficient frontier.

While other studies have tried to rectify this situation by significantly expanding the sample size to include firms from international jurisdictions, this is likely to exacerbate other problems such as the failure to account for operating differences between jurisdictions. In any case, expanding the number of firms in the sample is outside the scope of this study.

4.5.2 Multicollinearity between explanatory variables

An issue arises in the specification of econometric models when there is a high degree of multicollinearity between the explanatory variables in a regression. Multicollinearity is a phenomenon in which the predictor variables in a regression are highly correlated with each other. When this happens, it becomes difficult to measure the impact of any specific variable in the model, despite the model performing reasonably well as a whole.

A model with collinear explanatory variables will tend to be characterised by:

- imprecise coefficient estimates leading to high standard errors and statistical insignificance
- erratic shifts in the coefficients in response to small changes in the model
- the presence of theoretically inconsistent coefficients.

The presence of multicollinearity is problematic because we are attempting to estimate separate elasticities for each variable within a cost function. If these variables do not exhibit sufficient independent variation then it will not be possible to reliably disentangle the separate effects of each variable.

Table 3 below shows the correlation matrix between the main output, input and environmental variables in the regression. The matrix shows that that there is a high degree of correlation between customer numbers, line length, energy and the constant price RAB, with most correlation coefficients exceeding 0.9 for these variables. Lower levels of correlation were found to exist between customer density and the other variables comprising the matrix.

Table 3 **Correlation matrix between key output, input and environmental variables**

	Customers	Line length	Energy	RAB	Customer density
Customers	1.000	0.955	0.917	0.937	0.614
Line length		1.000	0.860	0.961	0.362
Energy			1.000	0.906	0.614
RAB				1.000	0.415
Customer density					1.000

Source: ACIL Allen

The multicollinearity problems expands exponentially when estimating the Translog cost function, which contains quadratic and interaction terms for each output, input and operating environment term.

We found that the estimated coefficients in the Translog specification were of magnitudes outside the bounds of expectation, often with signs that were inconsistent with theory and hence difficult to interpret. For this reason, it is our opinion that the high degree of multicollinearity between explanatory variables and the small sample size make it impossible to reliably estimate a Translog cost function in this instance. We have therefore limited ourselves to the Cobb-Douglas specification.

4.5.3 Different accounting treatment of opex

When benchmarking opex, different accounting practices for capitalising costs can potentially disadvantage those businesses that capitalise a smaller percentage of their expenditure. These businesses will show higher levels of opex compared to those businesses that capitalise a larger percentage of their expenditure onto their balance sheets. More details are provided in Appendix B.

4.5.4 Missing environmental variables and model mis-specification

Data limitations are such that we are only able to control for a small number of operating environment variables. Failure to control for important environmental or operational differences can potentially lead to biased results. The key operating environment variable specified in the cost functions is customer density. In previous benchmarking studies of gas distribution businesses this has been shown to be a significant explanator of differences in operating and capital costs.

Economic Insights (2014) included additional operating environment variables related to network age (proxied by the proportion of mains length not made of cast iron or unprotected steel) and service area dispersion (proxied by the number of city gates). ACIL Allen do not have the data necessary to include these additional operating environment variables. The exclusion of these, and potentially other significant operating environment variables could reduce the accuracy of the inefficiency measure that can be attributed to actions of the gas distribution businesses. However, this is not in itself a reason to discount the cost function analysis in this report. Good statistical practice requires that these limitations be considered in interpreting the results of the models.

4.6 Model validation and testing

In order to assess the suitability of the various estimated opex cost functions a number of assessment criteria are applied. These are:

- theoretical coherence
- statistical testing and performance
- robustness to changes in estimation technique and sample businesses.

4.6.1 Theoretical coherence

In assessing the suitability of any model, it is important that the selected model is consistent with economic theory. This means that the model should contain the theoretical drivers of operating costs as well as variables that control for operating conditions between firms.

The estimated coefficients on each of the explanatory variables must have a theoretically correct sign. That is, increases in drivers such as energy throughput or customers must lead to increases in predicted operating costs from the model. If they do not, then the model is not consistent with economic theory and can be considered suspect.

Similarly, the customer density of the gas network is expected to have a negative relationship to operating expenses. As the network grows denser, a given level of outputs is able to be produced at a lower cost compared to a network with lower customer density.

The magnitude of the coefficients should also be consistent with our expectations of the production technology of the industry. We would expect there to be economies of scale with regard to opex in the gas distribution business. This is both logical and supported by a significant number of empirical studies of both gas and electricity distribution businesses.

Increasing returns to scale with respect to opex implies that the sum of output coefficients is less than one.

4.6.2 Statistical testing

Statistical significance of estimated coefficients

An important step in assessing the suitability of any explanatory variable is its statistical significance. Not only should the variable be of a sign and magnitude that is consistent with economic theory, but standard hypothesis testing should indicate that the variable is statistically significant, ideally at the 1 per cent significance level.

A statistically significant result is one which is unlikely to have occurred by chance. Each estimated coefficient in the regression models has an associated t-statistic or p value. If the estimated p value is less than 0.01 then that coefficient is statistically significant at the 1 per cent significance level. A p-value that is less than 0.05 is significant at the 5 per cent level of significance. The lower the observed p value on a coefficient the greater the probability that a statistically significant relationship exists between the dependent variable and the explanatory variable concerned.

One of the key issues concerning statistical significance that is generally poorly understood is that a statistically significant result does not necessarily imply that the inclusion of a particular variable will have a sizeable impact on the model outcomes. Often in large sample sizes, statistically significant results are identified which are of little or no economic consequence.

A statistically significant result also has some chance of being wrong. At the 1 per cent significance level, 1 in 100 significant results will in fact be insignificant.

Goodness of fit

The most commonly used measure of the goodness of fit of a linear regression model to the observed data is the coefficient of determination, also known as R^2. It represents the proportion of the variation in the dependent variable that is explained by variation in the independent variables. In assessing a model's suitability and fitness for purpose, we would prefer the within sample fit to be strong.

However, in the model validation process, the R^2 is just one of a wide suite of tools available. While it is important to emphasize that goodness of fit is a desirable feature of any model, there are factors other than in sample fit that need to be taken into account. For example, a high R^2 is no guarantee that a model will have any predictive ability.

Testing for fixed and random effects

To choose between pooled OLS, random and fixed effects a number of statistical tests are available.

To test between OLS and a random effects model, we apply the Breusch-Pagan[12] Lagrange multiplier test. This tests the null hypothesis that variance across firms is zero and that there is no significant difference across firms. In other words, there is no panel effect. Failure to reject the null hypothesis results in the conclusion that there are no significant differences across firms and that pooled OLS can be justified.

If the null hypothesis is rejected, then the random effects model is preferred to simple OLS.

The Hausman test[13] is applied to test if the random effects estimator is unbiased. The Hausman test allows you to decide between a fixed or random effects model, where the null hypothesis supports the random effects model. The test works by testing whether the error terms are correlated with the explanatory variables, a key requirement under the random effects model. If the null hypothesis is not rejected then the random effects model is preferred over the fixed effects model.

Tests for heterogeneity and serial correlation

Additional statistical tests are carried out to assess the presence of heteroscedasticity and autocorrelation in the model residuals. To test for heteroscedasticity, we apply a Modified Wald test for groupwise heteroscedasticity[14]. Serial correlation is tested for via the Wooldridge Lagrange Multiplier (LM)[15] test for autocorrelation in panel data.

4.6.3 Robustness of coefficients

The robustness of an estimated cost function to changes in the sample or estimation technique will give us some confidence in the conclusions drawn from it.

To test the robustness of our opex cost functions, they have been estimated using five separate estimation techniques. The preferred cost functions are estimated eight times, by removing a single business from the sample on each occasion. We do this for all businesses other than ActewAGL.

While this is a good way of assessing the sensitivity of the model estimates to particular businesses, it is important to stress that our sample size is already small, and making it smaller by omitting data is likely to exacerbate the estimation problems associated with small sample size.

4.7 Cost function estimates

Five separate estimation methods were applied to our Cobb-Douglas operating cost function. These are:

- pooled ordinary least squares (OLS)
- fixed effects
- random effects
- feasible GLS (FGLS) (with heteroscedastic panels)
- Stochastic Frontier Analysis (SFA) (with time invariant inefficiency).

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[12] Breusch, T and A. Pagan (1980)

[13] Hausman, J. A. (1978)

[14] See Greene (2000)

[15] Wooldridge, J.M (2002)

The results of all five methods are presented below. The results presented in section 4.7.1 are for a model specification including two outputs (energy, which is measured as TJ of gas throughput and customers) and in section 4.7.2 for a model specification with a single output (customers).

4.7.1 Two output specification

Table 4 shows the results of the estimated Cobb-Douglas cost functions with two outputs, energy (TJ of gas throughput) and customer numbers.

Table 4 **Estimated Cobb-Douglas function: Two outputs**

	Estimation technique				
Variables	Pooled OLS	Fixed effects	Random effects	FGLS	SFA
Time	-0.00436***	-0.0153	-0.00202	-0.00446***	-0.00466***
	(0.000151)	(0.0180)	(0.00542)	(0.000132)	(0.000138)
Energy	-0.259***	0.119	-0.0930	-0.164***	-0.0634
	(0.0612)	(0.0873)	(0.151)	(0.0467)	(0.0694)
Customers	0.462***	1.226**	0.524**	0.496***	0.501***
	(0.0722)	(0.401)	(0.239)	(0.0647)	(0.0689)
RAB	0.764***	0.524**	0.592***	0.645***	0.685***
	(0.0687)	(0.219)	(0.133)	(0.0612)	(0.114)
Density	-0.126	-1.024***	-0.495***	-0.228***	-0.531***
	(0.0847)	(0.281)	(0.123)	(0.0716)	(0.165)
Constant		13.38	-4.649		
		(29.64)	(10.33)		
Observations	87	87	87	87	87
R-squared	0.987	0.9432	0.9579		
Number of ID		9	9	9	9

Note: Robust standard errors in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$

A key characteristic of these models is that the energy throughput variable has a negative coefficient. Moreover it is not statistically significant at the 1 per cent level in three of the five models. These results are not surprising given that gas throughput has been declining for the majority of the distribution businesses over the period from 2005 to 2013, while operating expenditures have continued to increase.

This suggests that energy (gas throughput) is no longer a key driver of increasing operating expenses for the nine gas distribution businesses under consideration. As a result, an additional model specification is estimated excluding gas throughput.

4.7.2 Single output specification

Table 5 shows the estimated Cobb-Douglas functions with only a single output variable, customer numbers.

Table 5 **Estimated Cobb-Douglas function: Single output**

	Estimation technique				
Variables	Pooled OLS	Fixed Effects	Random effects	FGLS	SFA
Time	-0.00423***	-0.0164	0.000323	-0.00413***	-0.00467***
	(0.000172)	(0.0174)	(0.00373)	(0.000121)	(0.000143)
Customers	0.389***	1.269***	0.555***	0.303***	0.518***
	(0.0676)	(0.377)	(0.191)	(0.0523)	(0.0670)
RAB	0.553***	0.536**	0.516***	0.676***	0.606***
	(0.0649)	(0.223)	(0.141)	(0.0516)	(0.0770)
Density	-0.281***	-1.039***	-0.685***	-0.254***	-0.615***
	(0.0728)	(0.289)	(0.173)	(0.0579)	(0.126)
Constant		16.21	-9.471		
		(28.57)	(7.330)		
Observations	87	87	87	87	87
R-squared	0.984	0.9456	0.9487		
Number of ID		9	9	9	9

Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

The results show that the output elasticity for customer numbers range from 0.30 in the FGLS model to 0.56 in the random effects model. This is consistent with increasing returns to scale.

The Breusch-Pagan LM test of random effects versus pooled OLS supports the random effects model, with a null hypothesis of no panel effects rejected at the 1 per cent significance level. The Hausman test of fixed versus random effects also fails to reject the null hypothesis of a random effects model at the 1 per cent significance level. Together, these results suggest that the businesses intercepts are different and that the random effects model is the appropriate choice.

Moreover, the coefficient size on the customer numbers elasticity from the fixed effects model appears to lie outside the bounds of plausibility, suggesting decreasing returns to scale with respect to operating expenses.

Additional testing for group-wise heteroscedasticity rejected the null hypothesis of no heteroscedasticity at the 1 per cent significance level. The Wooldridge test of serial autocorrelation in panel data failed to reject the null hypothesis of no autocorrelation. These results provide evidence in support of group wise heteroscedasticity in the panel, but not of autocorrelation.

The FGLS model estimates a variance-covariance matrix with group-wise heteroscedasticity. For this reason, we prefer this model over the pooled OLS model which imposes an assumption of homoscedasticity on the disturbances.

In subsequent sections of this report, we do not present results for the pooled OLS model or the fixed effects models, but continue to show results for the random effects model, which is supported by statistical testing, and the FGLS model, which corrects for the violation of the OLS assumptions.

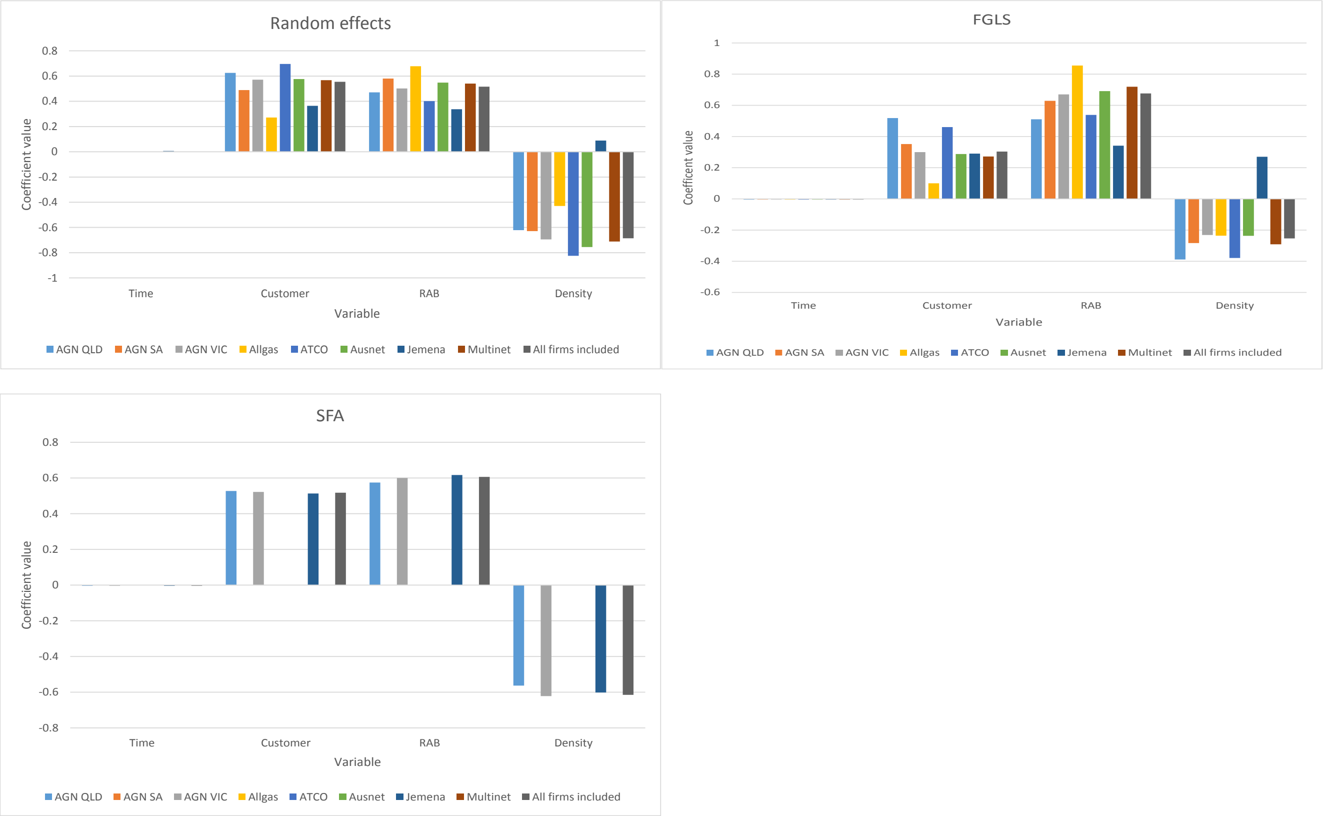
The SFA model results are also shown, and the estimated coefficients lie in between those of the FGLS and random effects model.

Due to the lack of additional environmental control variables and the size of the sample, we cannot be sure that the SFA inefficiency term *u* is true managerial inefficiency, rather than a mixture of inefficiency, firm heterogeneity and bias. As such, we have reservations about using the SFA model for the purpose of assessing firm relative operational performance against the efficient frontier. We continue however, to use the estimated coefficients from the SFA model to forecast opex partial productivity for ActewAGL.

Sensitivity of estimated parameters to sample choice

Figure 3 shows the parameter estimates for the Cobb-Douglas function for each of the three selected estimation methods, with a single business omitted on each occasion.

Figure 3 **Parameter estimates from each estimation method with single business omitted on each occasion**



Note: The identified gas distribution business is the firm omitted from the model.

Source: ACIL Allen

Figure 3 shows, for example, that under the random effects model, the estimated coefficients for customer numbers range between around 0.3 to 0.7, with individual gas distribution businesses removed. The coefficient is just under 0.6 with all of the gas distribution businesses included.

Figure 3 indicates that the parameter estimates do exhibit some variation when individual businesses are omitted from the sample. The coefficients maintain their theoretically correct signs throughout, although the estimated model when Jemena was omitted produced theoretically inconsistent values for the customer density variable in the random effects and FGLS models.

The computational difficulty of estimating an SFA cost model is clearly evident here, with only four of the nine estimated models able to converge to a solution. These were the samples that excluded AGN Qld, AGN Vic, Jemena and also the full sample containing all firms.

While some of the estimated models showed considerable shifts in the estimates, it is our opinion that this is a problem that arises from having a small sample size rather than anything else. Nevertheless, the sensitivity in the coefficient estimates suggests that there is a need for caution when interpreting the model results.

In our opinion, there is little reason to exclude any of the businesses from the estimated sample given the source data is from credible sources and as the sample of nine businesses is already sufficiently small to present considerable difficulties in estimation.

4.8 Comparative firm performance

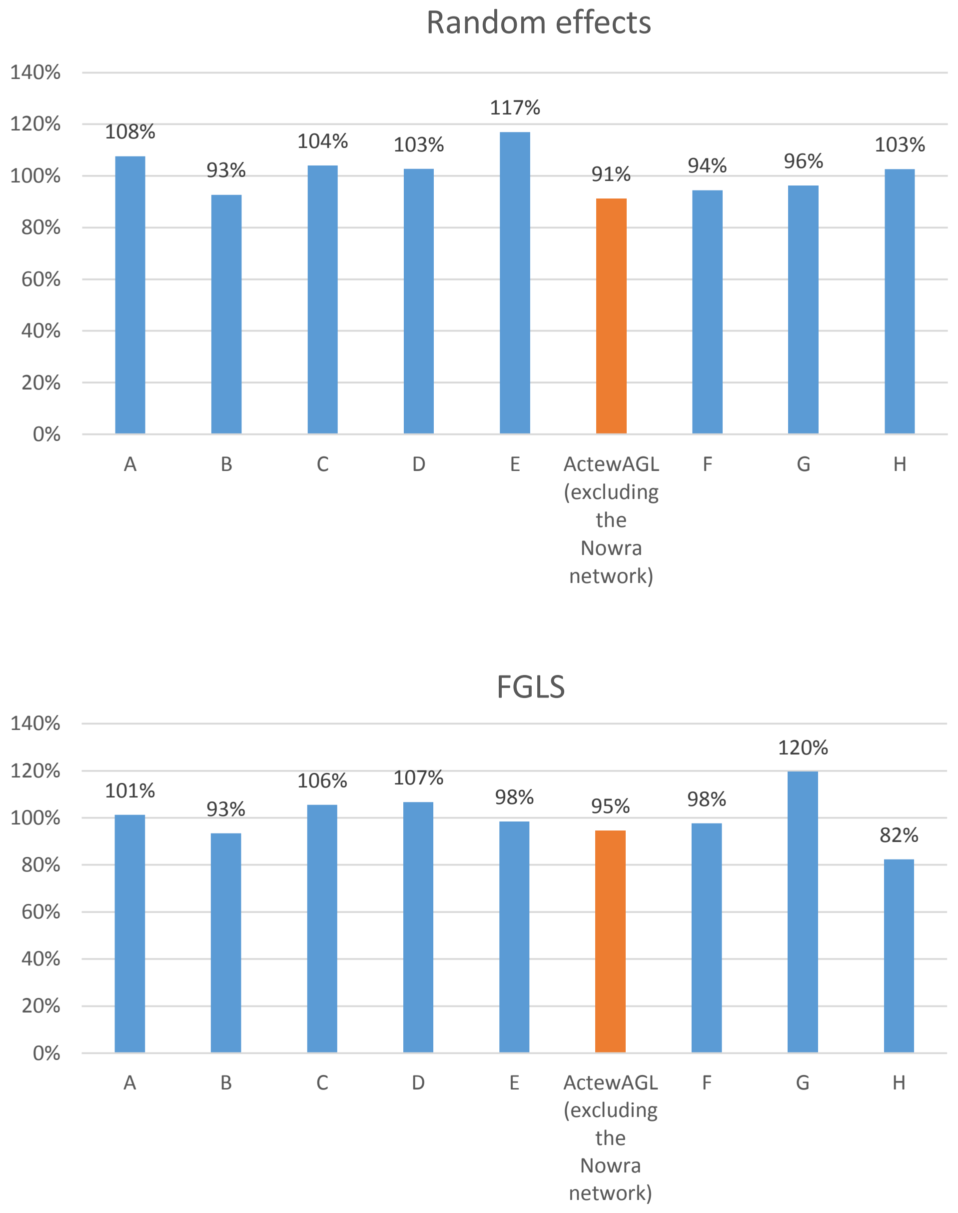
In this section we present the comparative cost performance of each business against the predicted values from the econometric models.

First we present the businesses' actual 2013 opex against the model predicted opex for the random effects and FGLS model. This is shown in Figure 4 below.

Under the random effects model, ActewAGL's 2013 opex was 91 per cent of its predicted opex, suggesting that ActewAGL is more efficient than the average of its peers after controlling for size and network density. ActewAGL was also ranked the most efficient firm under the random effects model.

Under the separate FGLS model, the results did not change significantly, with ActewAGL's actual 2013 opex being 95 per cent of the model's predicted opex. This ranks it third among its peers.

Figure 4 **Actual opex as share of model predicted opex, 2013**



Source: ACIL Allen

While the random effects and FGLS econometric models can provide a good indication of the relative performance between businesses in the sample, they do not provide a measure of the distance of each firm from the efficient frontier.

To get an indication of this, we use the estimates of technical efficiency from the SFA cost model.

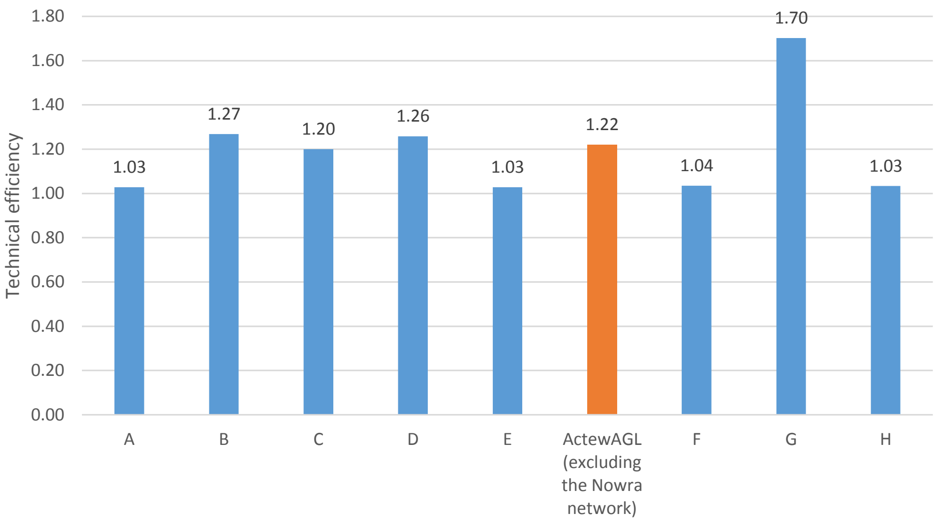
These are shown in Figure 5 below. In this figure a value of 1 represents the efficient frontier, with higher values representing opex inefficiency.

Under the SFA cost model with time invariant inefficiency, ActewAGL is estimated to have opex that lies 22 per cent above the efficient frontier.

Under the SFA cost specification, ActewAGL ranked sixth against its peers. However, the SFA model estimates time invariant efficiency which means that the firms' rankings cannot be directly compared with the econometric models in Figure 4 which show the rankings for 2013 only.

The technical efficiency measures from the SFA model are based on the entire sample up to 2013.

Figure 5 **Comparative firm cost inefficiency**



Source: ACIL Allen

As already stated previously, we do not consider our data set suitable for the purposes of accurately estimating an efficient frontier using the SFA technique.

4.8.1 Sensitivity of rank to sample size

In this section we assess the change in ActewAGL's relative rank against its peers in terms of opex efficiency when individual businesses are omitted from the estimation sample. Figure 6 below shows that the position of ActewAGL is relatively stable for all three estimation techniques when individual businesses are excluded from the sample.

For the random effects model, ActewAGL is ranked first in eight out of the nine samples.[16] Under FGLS, ActewAGL ranks first on one occasion, and second or third in the remaining samples. In the four instances where SFA was able to converge to a solution, ActewAGL ranked fifth on two occasions and sixth on the other two occasions.

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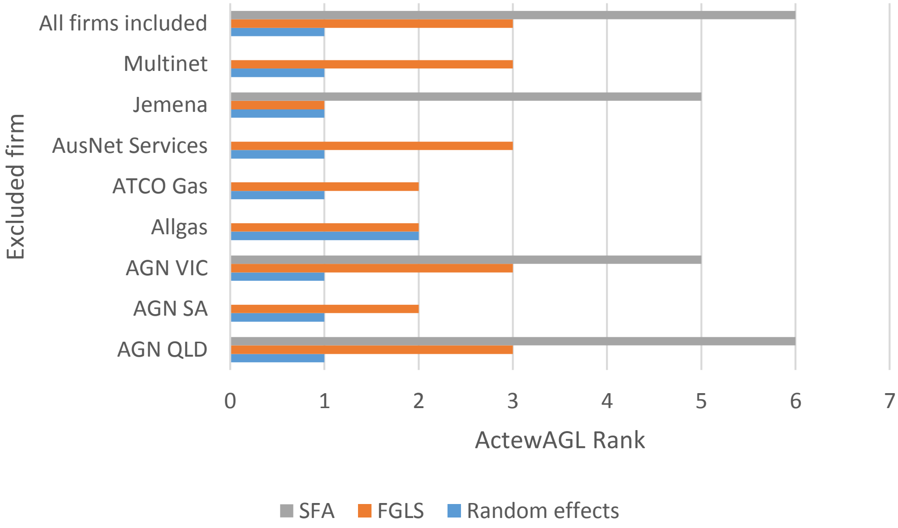
[16] Noting that the nine samples include one sample with all of the nine gas distribution businesses included and eight samples with one of the individual gas distribution businesses (other than ActewAGL) excluded.

Figure 6 **Rank of ActewAGL against its peers with single business omitted on each occasion**



Source: ACIL Allen

The stability of the results (between the estimation approaches and samples), provides some reassurance in the conclusions drawn from the comparative firm performance analysis.

4.9 Opex productivity growth forecasts

In this section we take the parameter estimates from the preferred cost function models (i.e. the random effects, FGLS and SFA cost models) and combine them with ActewAGL's forecasts of customer numbers, RAB, and pipeline length over the next regulatory control period to obtain forecasts of ActewAGL's opex partial productivity.

4.9.1 Inputs to calculating opex partial productivity

The parameter estimates from the models are shown in Table 6 below.

Table 6 **Single output opex cost function regression estimate**

	Estimation technique		
Coefficients	Random effects	FGLS	SFA
Time	0.000323	-0.00413	-0.00467
Customers	0.555	0.303	0.518
RAB	0.516	0.676	0.606
Customer density	-0.685	-0.254	-0.615

Source: ACIL Allen

Table 7 shows ActewAGL's forecasts of the growth drivers of opex over the period from 2014-15 to 2020-21. The growth in customer density is derived from forecast customer numbers and line length.

Over the next regulatory period average customer number growth is expected to be 2.2 per cent per annum, while the RAB and customer density are projected to grow at an annual average rate of 2.3 per cent and 0.8 per cent respectively.

Table 7 **Forecast changes in growth drivers**

Year	Customers	Energy	RAB	Customer density
2014-15	2.38%	0.41%	3.40%	0.91%
2015-16	2.21%	-1.37%	2.95%	0.69%
2016-17	2.12%	-1.02%	1.62%	0.73%
2017-18	2.27%	-1.35%	3.46%	0.70%
2018-19	2.21%	-0.39%	2.47%	0.69%
2019-20	2.35%	-0.41%	2.06%	0.83%
2020-21	2.09%	-0.13%	0.40%	0.78%
Average	**2.23%**	**-0.61%**	**2.34%**	**0.76%**

Source: ActewAGL

4.9.2 Calculating opex partial productivity

Following Economic Insights (2014), ACIL Allen calculate the partial opex partial productivity growth rate and its three components, namely:

- technical change
- returns to scale
- changes in operating environment.

Technical change is represented by the time trend in the regression. It has a negative coefficient and represents the percentage decrease in opex every year as a result of technological change. This may be due to actual technology, but also encompasses improvements in work practices and methods that lead to lower opex over time.

The productivity gains associated with technical change (A) is estimated as:

$$Technology\ (A) = -Time\ coeffcient$$

Returns to scale are productivity gains that arise as a result of increasing business size over time. The productivity gains from returns to scale (B) are calculated as:

$$Returns\ to\ scale\ (B) = (1 - Customer\ elasticity) \times (Percentage\ \ change\ in\ customers)$$

Operating environment partial productivity is calculated as the RAB and customer density coefficients multiplied by each of their respective changes in each year. The total operating environment contribution to opex partial productivity is the negative of the sum of the RAB and customer density contributions.

$$Operating\ environment\ factors\ (C) = (RAB\ elasticity \times \%\Delta\ in\ RAB) + (Customer\ density\ elasticity \times \%\Delta\ in\ Customer\ density)$$

The opex partial factor productivity growth rate is estimated from these three elements, using the formula:

$$Opex\ partial\ productivity\ growth\ rate = A\ (Technology) + B\ (Returns\ to\ scale) - C\ (Operating\ environment\ factors)$$

Table 8 shows the annual opex partial productivity forecasts for the period from 2014-15 to 2020-21 from the random effects model. This model predicts average partial productivity growth of 0.3 per cent per annum over the forecast period.

Table 8 **Annual opex partial productivity forecasts, random effects model**

Year	Technology (A)	Returns to scale (B)	Operating environment factors (C)	PP Opex growth rate (A+B-C)
2014-15	-0.03%	1.06%	1.13%	-0.11%
2015-16	-0.03%	0.98%	1.05%	-0.10%
2016-17	-0.03%	0.94%	0.33%	0.58%
2017-18	-0.03%	1.01%	1.31%	-0.33%
2018-19	-0.03%	0.98%	0.81%	0.14%
2019-20	-0.03%	1.05%	0.49%	0.53%
2020-21	-0.03%	0.93%	-0.33%	1.23%
Average	**-0.03%**	**0.99%**	**0.68%**	**0.28%**

Source: ACIL Allen

As shown in Table 9, the FGLS model predicts a higher average rate of partial productivity growth of 0.6 per cent per annum over the period 2014-15 to 2020-21.

Table 9 **Annual opex partial productivity forecasts, FGLS model**

Year	Technology (A)	Returns to scale (B)	Operating environment factors (C)	PP Opex growth rate (A+B-C)
2014-15	0.41%	1.66%	2.07%	0.01%
2015-16	0.41%	1.54%	1.82%	0.13%
2016-17	0.41%	1.48%	0.91%	0.98%
2017-18	0.41%	1.58%	2.16%	-0.17%
2018-19	0.41%	1.54%	1.50%	0.45%
2019-20	0.41%	1.64%	1.18%	0.88%
2020-21	0.41%	1.46%	0.07%	1.80%
Average	**0.41%**	**1.56%**	**1.39%**	**0.58%**

Source: ACIL Allen

Table 10 shows that the SFA cost model also projects average partial productivity growth over the period 2014-15 to 2020-21 of 0.6 per cent per annum.

Table 10 **Annual opex partial productivity forecasts, SFA model**

Year	Technology (A)	Returns to scale (B)	Operating environment factors (C)	PP Opex growth rate (A+B-C)
2014-15	0.47%	1.15%	1.50%	0.11%
2015-16	0.47%	1.07%	1.37%	0.17%
2016-17	0.47%	1.02%	0.53%	0.96%
2017-18	0.47%	1.09%	1.67%	-0.11%
2018-19	0.47%	1.06%	1.08%	0.45%
2019-20	0.47%	1.13%	0.73%	0.87%
2020-21	0.47%	1.01%	-0.24%	1.71%
Average	**0.47%**	**1.08%**	**0.95%**	**0.59%**

Source: ACIL Allen

This raises the difficulty of choosing between the alternative estimates from the three separate specifications. There is a body of empirical evidence which suggests that combining forecasts derived from methods that differ substantially can improve forecast accuracy[17].

Armstrong (2001) suggests equal weights as a starting point where there is no additional knowledge about which method is the most accurate. If we follow this advice, then a simple average of the three separate average partial productivity measures should be considered. This would result in an average forecast opex partial productivity growth rate of **0.5 per cent per annum.**

The opex partial productivity growth rate (noting that this is an indicative rather than an exact estimate) may be used as the productivity growth component of the rate of change formula shown in Box 1.

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[17] See Armstrong J. S (2001), p. 417-439.

Part B

Historical time series Total Factor Productivity and Partial Factor Productivity estimates for ActewAGL.

5 Time series productivity analysis

This section of the report presents the time series productivity analysis to measure the historical productivity growth rate for ActewAGL. Both total factor productivity and opex and capex partial factor productivity measures are estimated.

5.1 TFP and opex PFP indexes

5.1.1 Fisher index

As discussed in section 2, productivity is defined as the ratio of output(s) that a distribution business produces to the input(s) that it consumes. This is easily calculated if a gas distribution business produces only one output and use only one input. However, this is not the case as multiple inputs are used to produce multiple outputs. The index number technique used in this study, the Fisher Index, provides a sound means of aggregating the multiple outputs and inputs used into a single index.

The Fisher quantity index is the geometric mean of a Laspeyres and Paasche quantity indexes:

- the Laspeyres index uses the base period's prices as weights for the input and output quantities
- the Paasche index uses the current period's prices as weights for the input and output quantities.

The Fisher TFP index between two time periods *s* and *t* is given by:[18]

$$TFP_{st} = \frac{Output\ index_{st}\ (Fisher)}{Input\ index_{st}\ (Fisher)}$$

The output and input quantity indexes are estimated as follows:

$$Q_{st}^{L} = \frac{\sum_{m=1}^{M} p_{ms}\, q_{mt}}{\sum_{m=1}^{M} p_{ms}\, q_{ms}}$$

$$Q_{st}^{P} = \frac{\sum_{m=1}^{M} p_{mt}\, q_{mt}}{\sum_{m=1}^{M} p_{mt}\, q_{ms}}$$

$$Q_{st}^{F} = \sqrt{Q_{st}^{L} \times Q_{st}^{P}}$$

Where:

- Q_{st}^{L} is the Laspeyres quantity index
- Q_{st}^{P} is the Paasche quantity index

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[18] See Coelli, T. et al, 2005, p.91.

- Q_{st}^{F} is the Fisher quantity index
- there are 1 to *M* outputs and 1 to *M* inputs
- *s* and *t* represent consecutive time periods.

A chained Fisher index is estimated for this study, following the approach of Economic Insights (2014). For productivity measurement, the aim is to compare productivity change from year to year and then to combine annual changes to measure productivity change over a given time period. The chain based comparisons are most appropriate in this context.

The chained Fisher index from year 1 to year *t* is calculated as:[19]

$$Q_F^{1,t} \ = 1 \times Q_F^{1,2} \times Q_F^{2,3} \times \ldots . \times Q_F^{t-1,t}$$

5.1.2 Model specification and period of analysis

The model specification describes the output and inputs specified in the Fisher index analysis and the quantities and prices specified for each. By necessity, ACIL Allen has used a more simplified model specification for the index number estimations relative to that specified in Economic Insights (2014). This is due to constraints on the data available for this study. However, key outputs and inputs are included within the model specification and are summarised in Table 11.

Table 11 **Specification of Fisher index models**

	Outputs		Inputs	
	Quantity	**Price**	**Quantity**	**Price**
TFP model				
	Throughput – TJ of gas supplied	Econometrically estimated output cost share 14 per cent	Opex quantity – nominal dollar value deflated by price index	Opex/total revenue
	Customers – total number of customers	Econometrically estimated output cost share 86 per cent	Mains km	1-opex share
Opex PFP model	As per TFP model		Opex quantity – nominal dollar value deflated by price index	-

Further detail is provided below.

Output prices

Following the approach of Economic Insights (2014) and as recommended by the AER, ‘functional’ prices or weights are used which represent the share of costs associated with each output or service delivered.[20]

ACIL Allen has sourced weights that are appropriate for the two output (throughput and customers) specification shown above.

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[19] See Economic Insights, 2014, p. 14.

[20] AER, 2013a, p.148-149 outlines the AER’s recommendation regarding output weights and states that *“a functional outputs specification, rather than a billed outputs specification, is more appropriate for measuring NSPs’ outputs”* and *“We prefer to estimate an econometric cost function using the available data if appropriate, to determine output weights”*.

ACIL Allen has used weights previously estimated for gas distribution benchmarking which are referenced in Meyrick and Associates (Dr Denis Lawrence) (2004), p.18. The cost shares were originally estimated for US gas distribution businesses using a translog cost function. The throughput share is 14 per cent and the customer number share is 86 per cent. In accordance with previous studies, these shares are applied to all time periods.

Opex quantity

The opex quantity is derived by deflating the value of opex (in nominal dollars) by the opex price index recommended by the AER for network service providers, which was also applied in the cost function analysis.[21] This is a weighted opex index formed using the following Australian Bureau of Statistics (ABS) indexes and weights:

- electricity, gas, water and waste services (EGWWS) wage price index (WPI) — 62 per cent
- intermediate inputs: domestic producer price index (PPI) —19.5 per cent
- data processing, web hosting and electronic information storage PPI —8.2 per cent
- other administrative services PPI —6.3 per cent
- legal and accounting PPI —3 per cent
- market research and statistical services PPI —1 per cent.

ACIL Allen sourced these indexes from the ABS and calculated the weighted index.

Input prices

Following the endogenous rate-of-return approach in Economic Insights (2014), the input weight specified for opex is the ratio of opex to total revenue. The capital input (mains km) weight is equal to one minus the opex share.

Period of analysis

The Fisher TFP index and the opex PFP index are estimated over the period 2003-04 to 2013-14.

5.1.3 Productivity measures

The productivity estimates calculated using the Fisher index measure the growth in ActewAGL's productivity over the study period. The total factor productivity (TFP) index measures productivity growth over time incorporating key outputs produced and inputs used. The opex partial factor productivity (PFP) index measures the productivity of opex usage alone in producing the range of outputs.

The TFP and opex PFP indexes are presented in turn in the following sections.

TFP results

Table 12 provides the TFP and component indexes for ActewAGL for each year of the modelling period. The table also shows the average annual growth rate for each index over the modelling period.

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[21] See AER, 2013a, p. 154-155.

Table 12 **ActewAGL TFP and opex PFP indexes**

	Output quantity index	Input quantity index	Opex quantity index	Opex PFP index	Capital quantity index	Capital PFP index	TFP index
2003-04	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2004-05	1.001	1.031	0.881	1.137	1.032	0.971	0.971
2005-06	0.999	1.058	0.823	1.215	1.059	0.944	0.944
2006-07	1.087	1.074	0.829	1.312	1.074	1.012	1.013
2007-08	1.142	1.090	0.858	1.332	1.090	1.048	1.049
2008-09	1.171	1.106	0.971	1.206	1.106	1.058	1.058
2009-10	1.209	1.125	1.032	1.171	1.125	1.075	1.075
2010-11	1.253	1.146	1.080	1.160	1.146	1.094	1.094
2011-12	1.295	1.166	1.078	1.201	1.166	1.111	1.111
2012-13	1.346	1.180	0.985	1.367	1.180	1.140	1.140
2013-14	1.394	1.199	0.921	1.514	1.200	1.162	1.163
Average annual growth rate	3.38%	1.83%	-0.82%	4.23%	1.84%	1.52%	1.52%

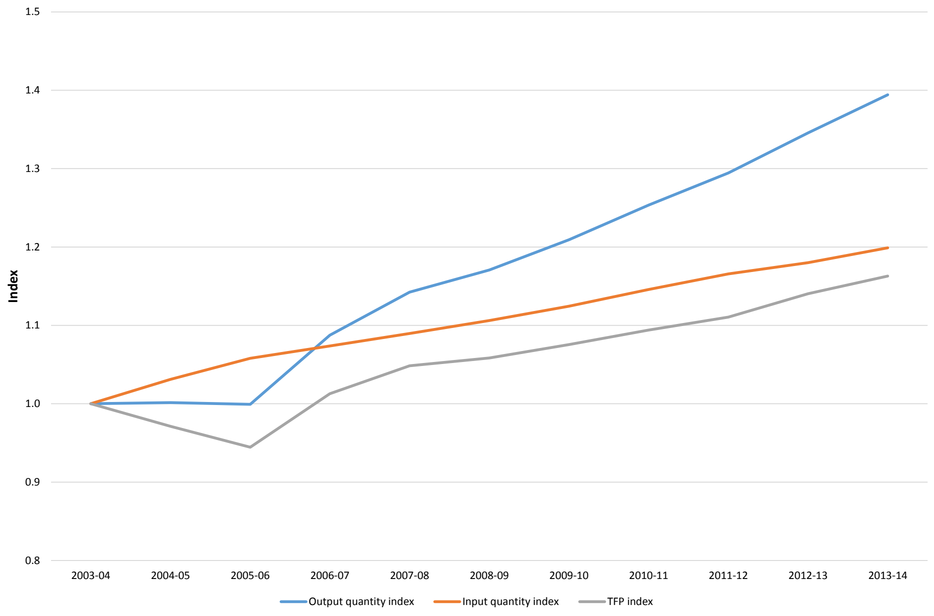
Source: ACIL Allen

Figure 7 shows the output quantity index, the input quantity index and the TFP index. This shows that as ActewAGL's output has consistently grown at a faster rate than inputs, it has experienced positive TFP growth over the period from 2003-04 to 2013-14.

ActewAGL's average annual output growth rate over the period from 2003-04 to 2013-14 was 3.38 per cent, reflecting the growth in ActewAGL's gas throughput and customer numbers. The output quantity index was relatively flat between 2003-04 and 2005-06 reflecting a small decline in customer numbers of 0.2 per cent over this period. After 2005-06, the output quantity index rose consistently. While gas throughput grew at a lower level than customer numbers over the period from 2003-04 to 2013-14 and declined in some years, the higher weighting on customer numbers and consistent increase in customer numbers after 2005-06 resulted in an increasing output quantity index.

The average annual input growth rate over the period from 2003-04 to 2013-14 was lower at 1.83 per cent. Hence, over the period from 2003-04 to 2013-14 this resulted in an average annual TFP growth rate of 1.52 per cent.

Figure 7 **ActewAGL output quantity, input quantity and TFP indexes**



Source: ACIL Allen

Opex PFP results

The opex PFP index is estimated as the ratio of the Fisher output quantity index (calculated in the TFP analysis above which incorporates two outputs, throughput and customer numbers) and the opex quantity index. The opex PFP provides a measure of the efficiency with which opex inputs are used to produce outputs.

As shown in Table 12, over the period from 2003-04 to 2013-14 ActewAGL's annual average opex PFP growth rate was 4.23 per cent. ActewAGL's opex PFP average annual growth rate was higher over the modelling period than annual average TFP growth. This is due to the decline in the opex quantity on an annual average basis over the period of 0.82 per cent, while there was an annual average increase in the capital input quantity of 1.84 per cent resulting in a lower overall TFP score.

5.2 Capex PPIs

As discussed in section 2, this study follows the preferred capex benchmarking approach used by regulators and within the literature of producing simpler capex ratios or partial productivity performance indicators.

The capex PPIs estimated are:

- capex per km of mains
- capex per customer
- capex per TJ of gas throughput.

5.2.1 Data and period of analysis

As explained in section 3, the capital expenditure measures for the gas distribution businesses is the costs classified as capital expenditure within each businesses' Access Arrangement.

The capex PPIs must be estimated using real dollar amounts. The nominal dollar amounts have been converted to September 2014 dollars using the Australian Bureau of Statistics All Groups, Weighted average of eight capital cities, CPI (Series ID: A2325846C).

The capex PPIs are calculated for the period from 2003-04 to 2013-14.

5.2.2 Productivity measures

ActewAGL's capex PPIs are shown in Table 13.

Table 13 **ActewAGL capex PPIs**

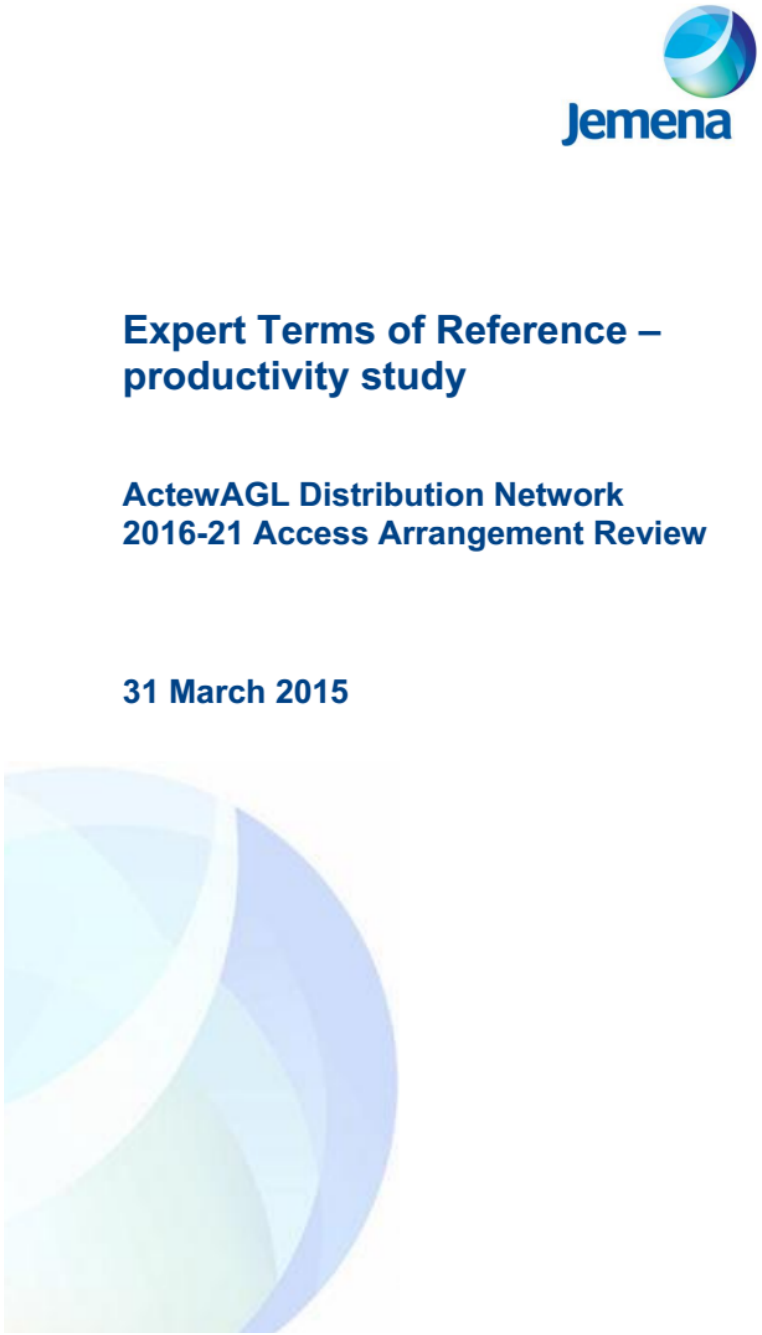
	Capex ($2014) per km	Capex ($2014) per customer	Capex ($2014) per TJ
2003-04	2,734	104	1,509
2004-05	2,719	107	1,528
2005-06	2,301	93	1,223
2006-07	3,425	129	1,886
2007-08	2,215	81	1,190
2008-09	2,191	79	1,141
2009-10	2,585	92	1,382
2010-11	2,926	102	1,477
2011-12	3,533	121	1,793
2012-13	4,293	143	2,222
2013-14	4,073	133	2,346

Source: ACIL Allen

While capex per km, per customer and per TJ have increased over the 2003-04 to 2013-14 period, the PPI indicators are among the lowest of the Australian gas distribution businesses in the sample (as shown in Figure 11 to Figure 13 in Appendix B).

This indicates that ActewAGL's capex is at an efficient level. While not tested within the scope of this study, this conclusion is likely to hold even if there are some differences in the allocation of costs to the operating and capital expenditure categories between the gas distribution businesses in the sample.

Appendix A Terms of reference



Jemena

Expert Terms of Reference – productivity study

ActewAGL Distribution Network
2016-21 Access Arrangement Review

31 March 2015

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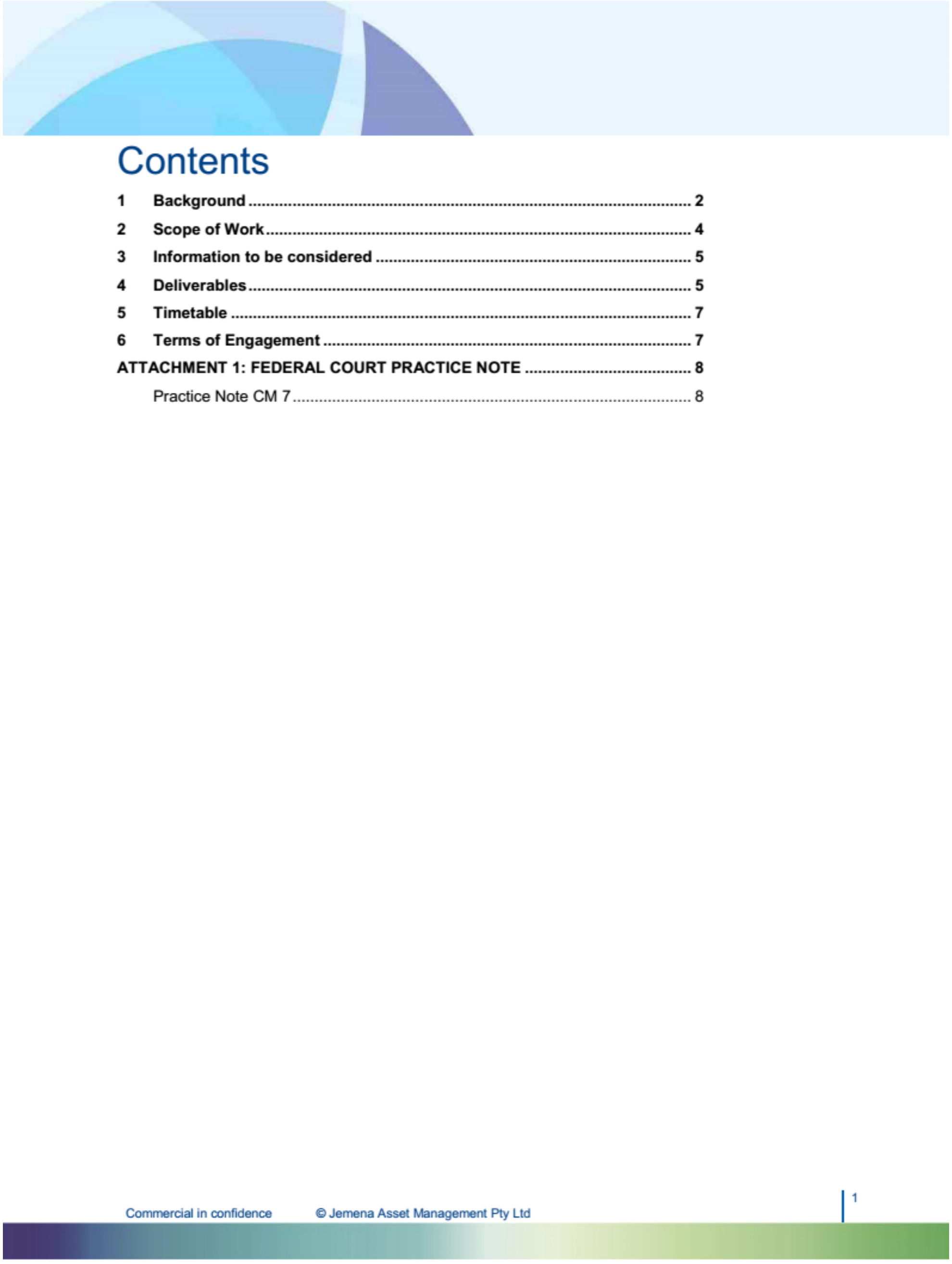

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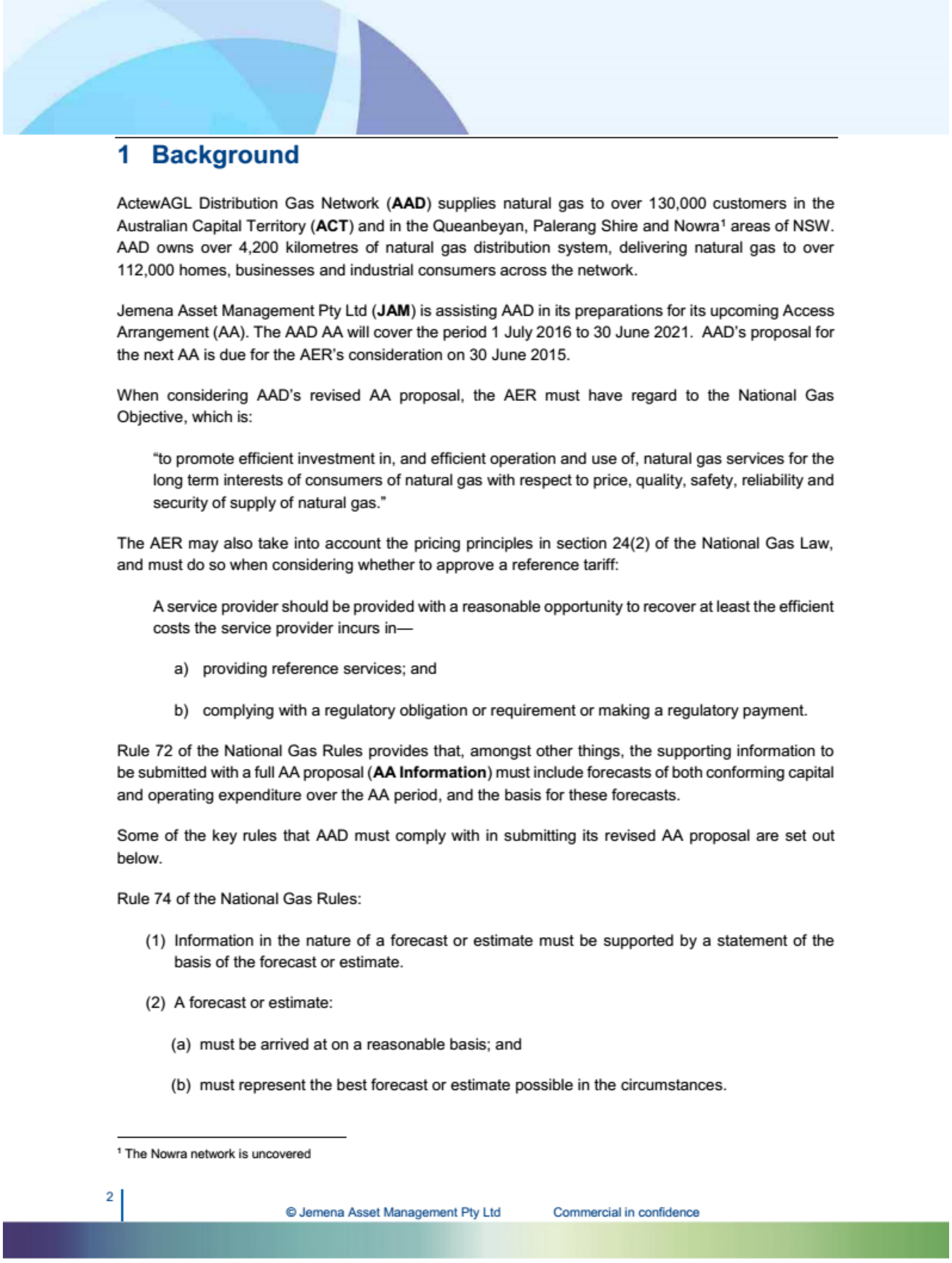

1 Background

ActewAGL Distribution Gas Network (**AAD**) supplies natural gas to over 130,000 customers in the Australian Capital Territory (**ACT**) and in the Queanbeyan, Palerang Shire and Nowra[1] areas of NSW. AAD owns over 4,200 kilometres of natural gas distribution system, delivering natural gas to over 112,000 homes, businesses and industrial consumers across the network.

Jemena Asset Management Pty Ltd (**JAM**) is assisting AAD in its preparations for its upcoming Access Arrangement (AA). The AAD AA will cover the period 1 July 2016 to 30 June 2021. AAD's proposal for the next AA is due for the AER's consideration on 30 June 2015.

When considering AAD's revised AA proposal, the AER must have regard to the National Gas Objective, which is:

> "to promote efficient investment in, and efficient operation and use of, natural gas services for the long term interests of consumers of natural gas with respect to price, quality, safety, reliability and security of supply of natural gas."

The AER may also take into account the pricing principles in section 24(2) of the National Gas Law, and must do so when considering whether to approve a reference tariff:

> A service provider should be provided with a reasonable opportunity to recover at least the efficient costs the service provider incurs in—
>
> a) providing reference services; and
>
> b) complying with a regulatory obligation or requirement or making a regulatory payment.

Rule 72 of the National Gas Rules provides that, amongst other things, the supporting information to be submitted with a full AA proposal (**AA Information**) must include forecasts of both conforming capital and operating expenditure over the AA period, and the basis for these forecasts.

Some of the key rules that AAD must comply with in submitting its revised AA proposal are set out below.

Rule 74 of the National Gas Rules:

> (1) Information in the nature of a forecast or estimate must be supported by a statement of the basis of the forecast or estimate.
>
> (2) A forecast or estimate:
>
> (a) must be arrived at on a reasonable basis; and
>
> (b) must represent the best forecast or estimate possible in the circumstances.

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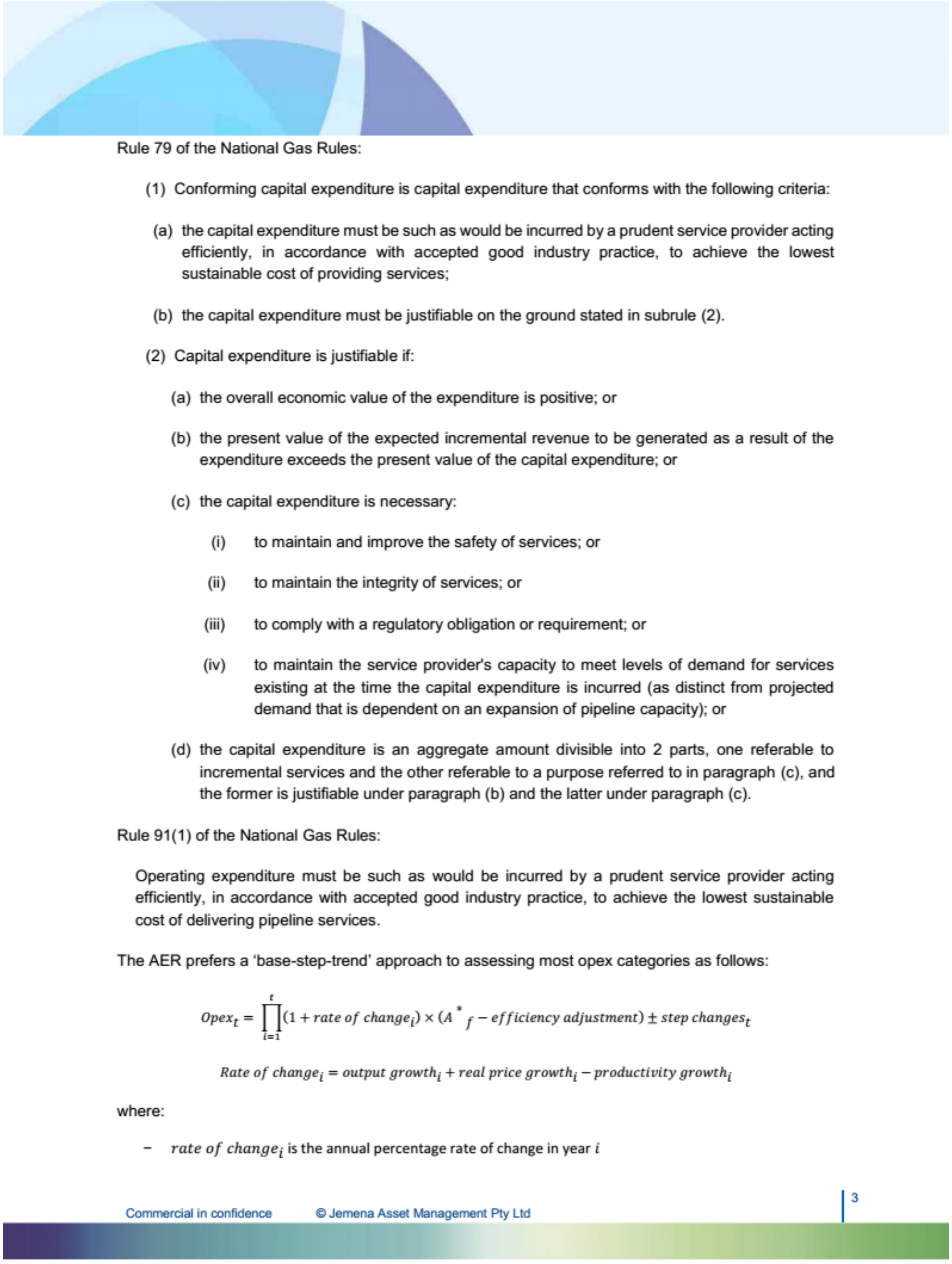
[1] The Nowra network is uncovered



Rule 79 of the National Gas Rules:

(1) Conforming capital expenditure is capital expenditure that conforms with the following criteria:

(a) the capital expenditure must be such as would be incurred by a prudent service provider acting efficiently, in accordance with accepted good industry practice, to achieve the lowest sustainable cost of providing services;

(b) the capital expenditure must be justifiable on the ground stated in subrule (2).

(2) Capital expenditure is justifiable if:

(a) the overall economic value of the expenditure is positive; or

(b) the present value of the expected incremental revenue to be generated as a result of the expenditure exceeds the present value of the capital expenditure; or

(c) the capital expenditure is necessary:

(i) to maintain and improve the safety of services; or

(ii) to maintain the integrity of services; or

(iii) to comply with a regulatory obligation or requirement; or

(iv) to maintain the service provider's capacity to meet levels of demand for services existing at the time the capital expenditure is incurred (as distinct from projected demand that is dependent on an expansion of pipeline capacity); or

(d) the capital expenditure is an aggregate amount divisible into 2 parts, one referable to incremental services and the other referable to a purpose referred to in paragraph (c), and the former is justifiable under paragraph (b) and the latter under paragraph (c).

Rule 91(1) of the National Gas Rules:

> Operating expenditure must be such as would be incurred by a prudent service provider acting efficiently, in accordance with accepted good industry practice, to achieve the lowest sustainable cost of delivering pipeline services.

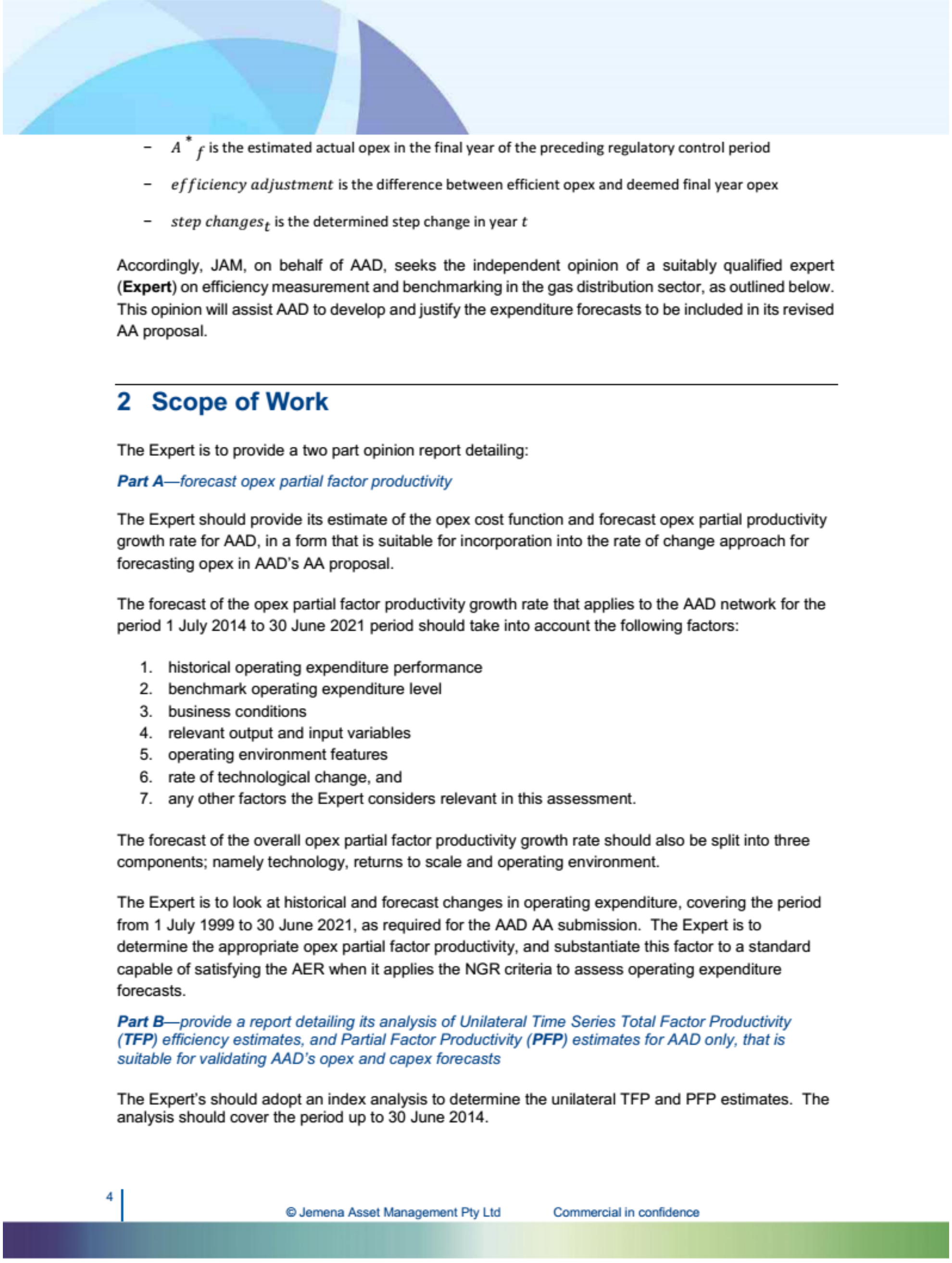
The AER prefers a 'base-step-trend' approach to assessing most opex categories as follows:

$$Opex_t = \prod_{i=1}^{t}(1 + rate\ of\ change_i) \times (A^{*}{}_{f} - efficiency\ adjustment) \pm step\ changes_t$$

$$Rate\ of\ change_i = output\ growth_i + real\ price\ growth_i - productivity\ growth_i$$

where:

- $rate\ of\ change_i$ is the annual percentage rate of change in year i



- A^{*}_{f} is the estimated actual opex in the final year of the preceding regulatory control period
- $efficiency\ adjustment$ is the difference between efficient opex and deemed final year opex
- $step\ changes_{t}$ is the determined step change in year t

Accordingly, JAM, on behalf of AAD, seeks the independent opinion of a suitably qualified expert (**Expert**) on efficiency measurement and benchmarking in the gas distribution sector, as outlined below. This opinion will assist AAD to develop and justify the expenditure forecasts to be included in its revised AA proposal.

2 Scope of Work

The Expert is to provide a two part opinion report detailing:

***Part A**—forecast opex partial factor productivity*

The Expert should provide its estimate of the opex cost function and forecast opex partial productivity growth rate for AAD, in a form that is suitable for incorporation into the rate of change approach for forecasting opex in AAD's AA proposal.

The forecast of the opex partial factor productivity growth rate that applies to the AAD network for the period 1 July 2014 to 30 June 2021 period should take into account the following factors:

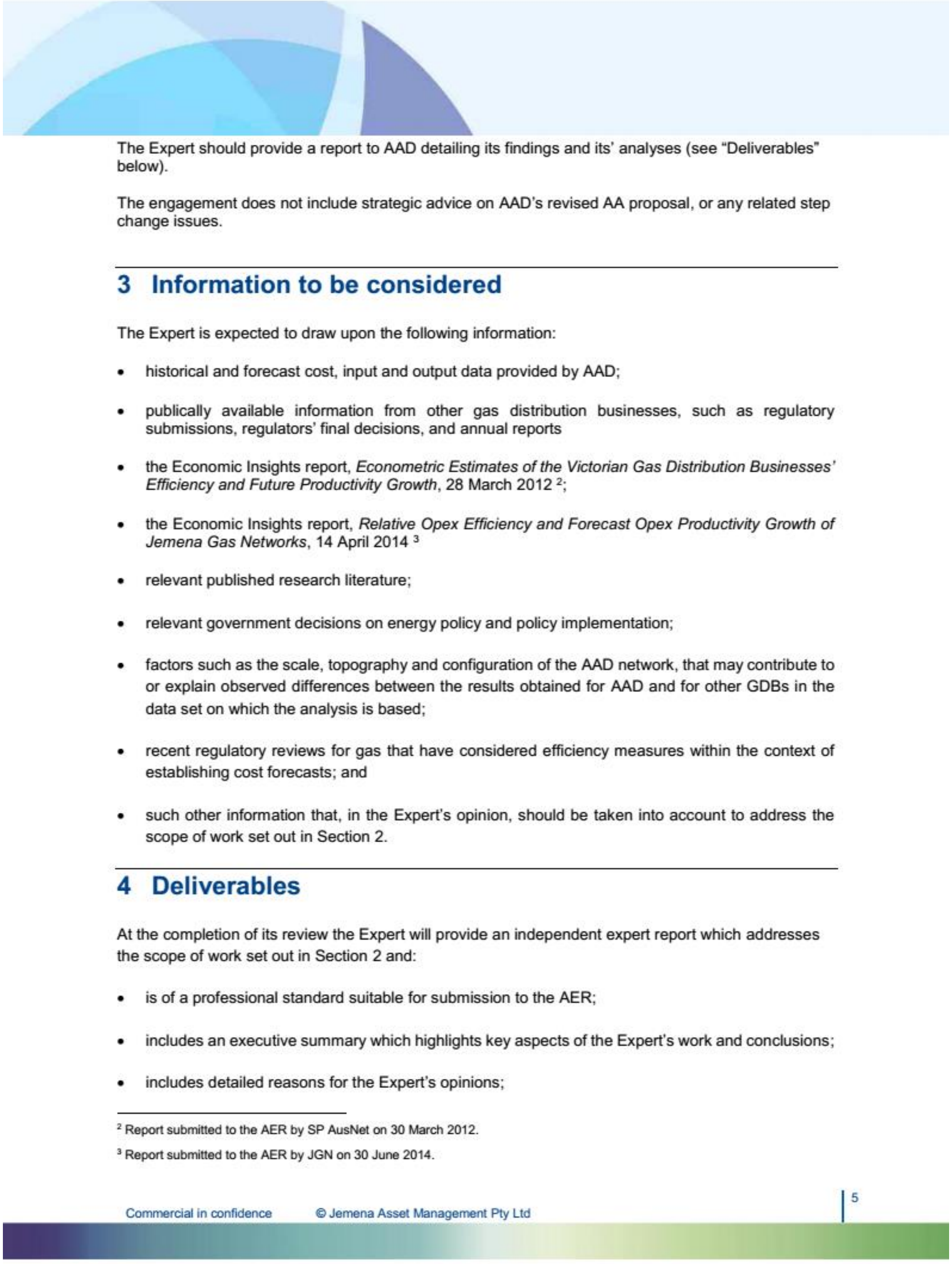
1. historical operating expenditure performance
2. benchmark operating expenditure level
3. business conditions
4. relevant output and input variables
5. operating environment features
6. rate of technological change, and
7. any other factors the Expert considers relevant in this assessment.

The forecast of the overall opex partial factor productivity growth rate should also be split into three components; namely technology, returns to scale and operating environment.

The Expert is to look at historical and forecast changes in operating expenditure, covering the period from 1 July 1999 to 30 June 2021, as required for the AAD AA submission. The Expert is to determine the appropriate opex partial factor productivity, and substantiate this factor to a standard capable of satisfying the AER when it applies the NGR criteria to assess operating expenditure forecasts.

***Part B**—provide a report detailing its analysis of Unilateral Time Series Total Factor Productivity (**TFP**) efficiency estimates, and Partial Factor Productivity (**PFP**) estimates for AAD only, that is suitable for validating AAD's opex and capex forecasts*

The Expert's should adopt an index analysis to determine the unilateral TFP and PFP estimates. The analysis should cover the period up to 30 June 2014.



The Expert should provide a report to AAD detailing its findings and its' analyses (see "Deliverables" below).

The engagement does not include strategic advice on AAD's revised AA proposal, or any related step change issues.

3 Information to be considered

The Expert is expected to draw upon the following information:

- historical and forecast cost, input and output data provided by AAD;
- publically available information from other gas distribution businesses, such as regulatory submissions, regulators' final decisions, and annual reports
- the Economic Insights report, *Econometric Estimates of the Victorian Gas Distribution Businesses' Efficiency and Future Productivity Growth*, 28 March 2012 [2];
- the Economic Insights report, *Relative Opex Efficiency and Forecast Opex Productivity Growth of Jemena Gas Networks*, 14 April 2014 [3]
- relevant published research literature;
- relevant government decisions on energy policy and policy implementation;
- factors such as the scale, topography and configuration of the AAD network, that may contribute to or explain observed differences between the results obtained for AAD and for other GDBs in the data set on which the analysis is based;
- recent regulatory reviews for gas that have considered efficiency measures within the context of establishing cost forecasts; and
- such other information that, in the Expert's opinion, should be taken into account to address the scope of work set out in Section 2.

4 Deliverables

At the completion of its review the Expert will provide an independent expert report which addresses the scope of work set out in Section 2 and:

- is of a professional standard suitable for submission to the AER;
- includes an executive summary which highlights key aspects of the Expert's work and conclusions;
- includes detailed reasons for the Expert's opinions;

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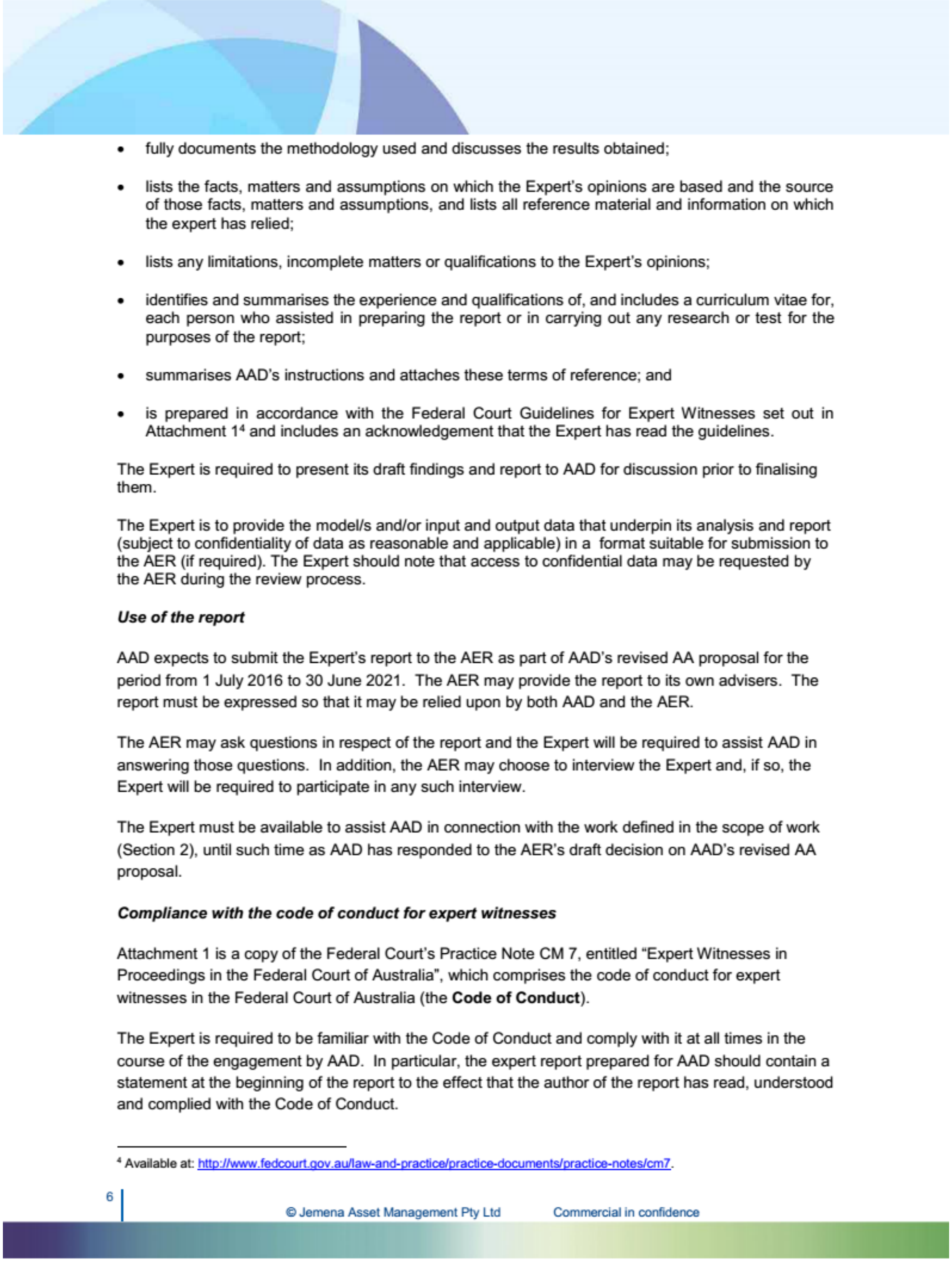
[2] Report submitted to the AER by SP AusNet on 30 March 2012.

[3] Report submitted to the AER by JGN on 30 June 2014.



- fully documents the methodology used and discusses the results obtained;
- lists the facts, matters and assumptions on which the Expert's opinions are based and the source of those facts, matters and assumptions, and lists all reference material and information on which the expert has relied;
- lists any limitations, incomplete matters or qualifications to the Expert's opinions;
- identifies and summarises the experience and qualifications of, and includes a curriculum vitae for, each person who assisted in preparing the report or in carrying out any research or test for the purposes of the report;
- summarises AAD's instructions and attaches these terms of reference; and
- is prepared in accordance with the Federal Court Guidelines for Expert Witnesses set out in Attachment 1[4] and includes an acknowledgement that the Expert has read the guidelines.

The Expert is required to present its draft findings and report to AAD for discussion prior to finalising them.

The Expert is to provide the model/s and/or input and output data that underpin its analysis and report (subject to confidentiality of data as reasonable and applicable) in a format suitable for submission to the AER (if required). The Expert should note that access to confidential data may be requested by the AER during the review process.

Use of the report

AAD expects to submit the Expert's report to the AER as part of AAD's revised AA proposal for the period from 1 July 2016 to 30 June 2021. The AER may provide the report to its own advisers. The report must be expressed so that it may be relied upon by both AAD and the AER.

The AER may ask questions in respect of the report and the Expert will be required to assist AAD in answering those questions. In addition, the AER may choose to interview the Expert and, if so, the Expert will be required to participate in any such interview.

The Expert must be available to assist AAD in connection with the work defined in the scope of work (Section 2), until such time as AAD has responded to the AER's draft decision on AAD's revised AA proposal.

Compliance with the code of conduct for expert witnesses

Attachment 1 is a copy of the Federal Court's Practice Note CM 7, entitled "Expert Witnesses in Proceedings in the Federal Court of Australia", which comprises the code of conduct for expert witnesses in the Federal Court of Australia (the **Code of Conduct**).

The Expert is required to be familiar with the Code of Conduct and comply with it at all times in the course of the engagement by AAD. In particular, the expert report prepared for AAD should contain a statement at the beginning of the report to the effect that the author of the report has read, understood and complied with the Code of Conduct.

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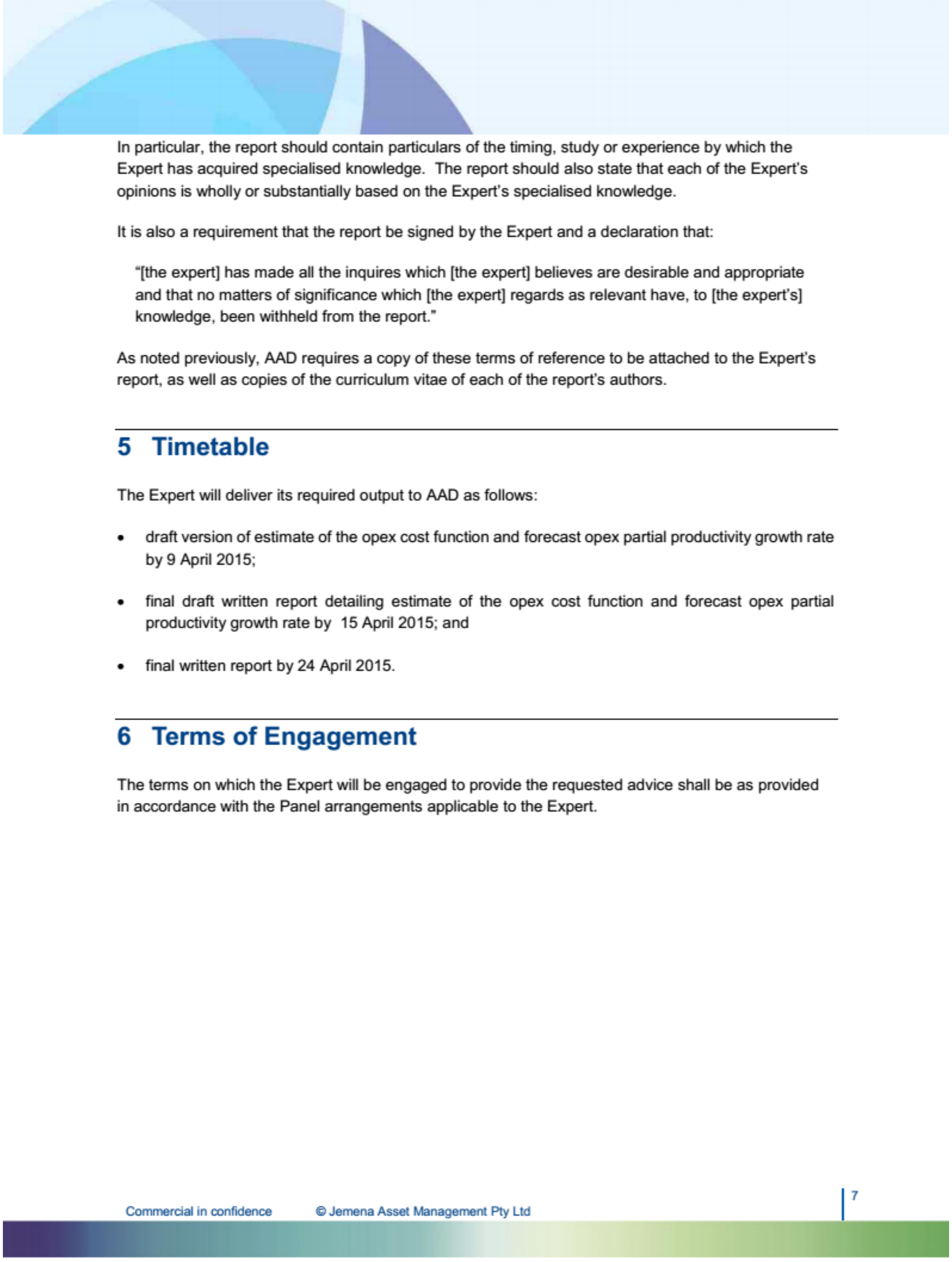
[4] Available at: http://www.fedcourt.gov.au/law-and-practice/practice-documents/practice-notes/cm7.



In particular, the report should contain particulars of the timing, study or experience by which the Expert has acquired specialised knowledge. The report should also state that each of the Expert's opinions is wholly or substantially based on the Expert's specialised knowledge.

It is also a requirement that the report be signed by the Expert and a declaration that:

> "[the expert] has made all the inquires which [the expert] believes are desirable and appropriate and that no matters of significance which [the expert] regards as relevant have, to [the expert's] knowledge, been withheld from the report."

As noted previously, AAD requires a copy of these terms of reference to be attached to the Expert's report, as well as copies of the curriculum vitae of each of the report's authors.

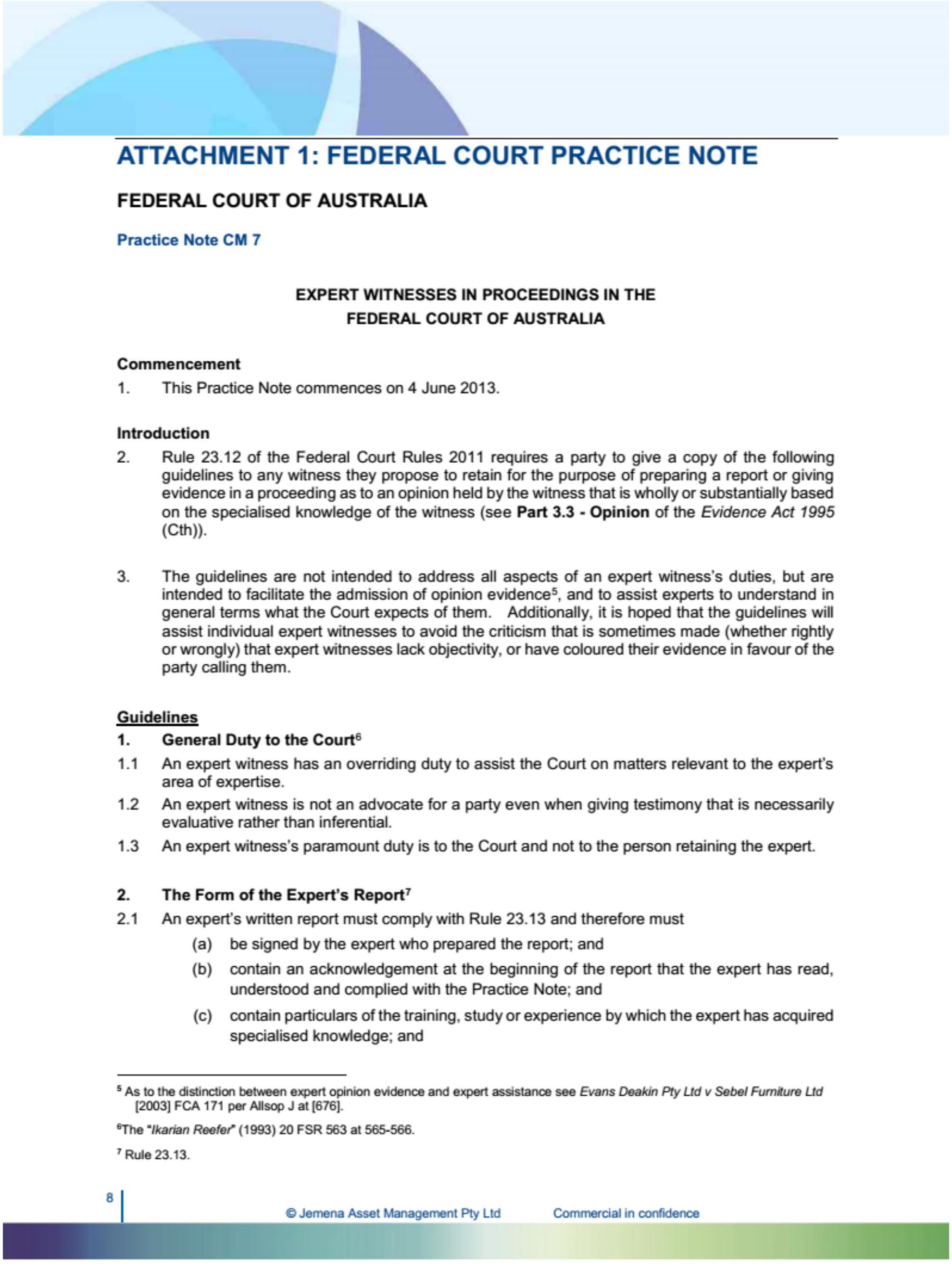
5 Timetable

The Expert will deliver its required output to AAD as follows:

- draft version of estimate of the opex cost function and forecast opex partial productivity growth rate by 9 April 2015;
- final draft written report detailing estimate of the opex cost function and forecast opex partial productivity growth rate by 15 April 2015; and
- final written report by 24 April 2015.

6 Terms of Engagement

The terms on which the Expert will be engaged to provide the requested advice shall be as provided in accordance with the Panel arrangements applicable to the Expert.



ATTACHMENT 1: FEDERAL COURT PRACTICE NOTE

FEDERAL COURT OF AUSTRALIA

Practice Note CM 7

EXPERT WITNESSES IN PROCEEDINGS IN THE FEDERAL COURT OF AUSTRALIA

Commencement

1. This Practice Note commences on 4 June 2013.

Introduction

2. Rule 23.12 of the Federal Court Rules 2011 requires a party to give a copy of the following guidelines to any witness they propose to retain for the purpose of preparing a report or giving evidence in a proceeding as to an opinion held by the witness that is wholly or substantially based on the specialised knowledge of the witness (see **Part 3.3 - Opinion** of the *Evidence Act 1995* (Cth)).

3. The guidelines are not intended to address all aspects of an expert witness's duties, but are intended to facilitate the admission of opinion evidence[5], and to assist experts to understand in general terms what the Court expects of them. Additionally, it is hoped that the guidelines will assist individual expert witnesses to avoid the criticism that is sometimes made (whether rightly or wrongly) that expert witnesses lack objectivity, or have coloured their evidence in favour of the party calling them.

Guidelines

1. General Duty to the Court[6]

1.1 An expert witness has an overriding duty to assist the Court on matters relevant to the expert's area of expertise.

1.2 An expert witness is not an advocate for a party even when giving testimony that is necessarily evaluative rather than inferential.

1.3 An expert witness's paramount duty is to the Court and not to the person retaining the expert.

2. The Form of the Expert's Report[7]

2.1 An expert's written report must comply with Rule 23.13 and therefore must

- (a) be signed by the expert who prepared the report; and
- (b) contain an acknowledgement at the beginning of the report that the expert has read, understood and complied with the Practice Note; and
- (c) contain particulars of the training, study or experience by which the expert has acquired specialised knowledge; and

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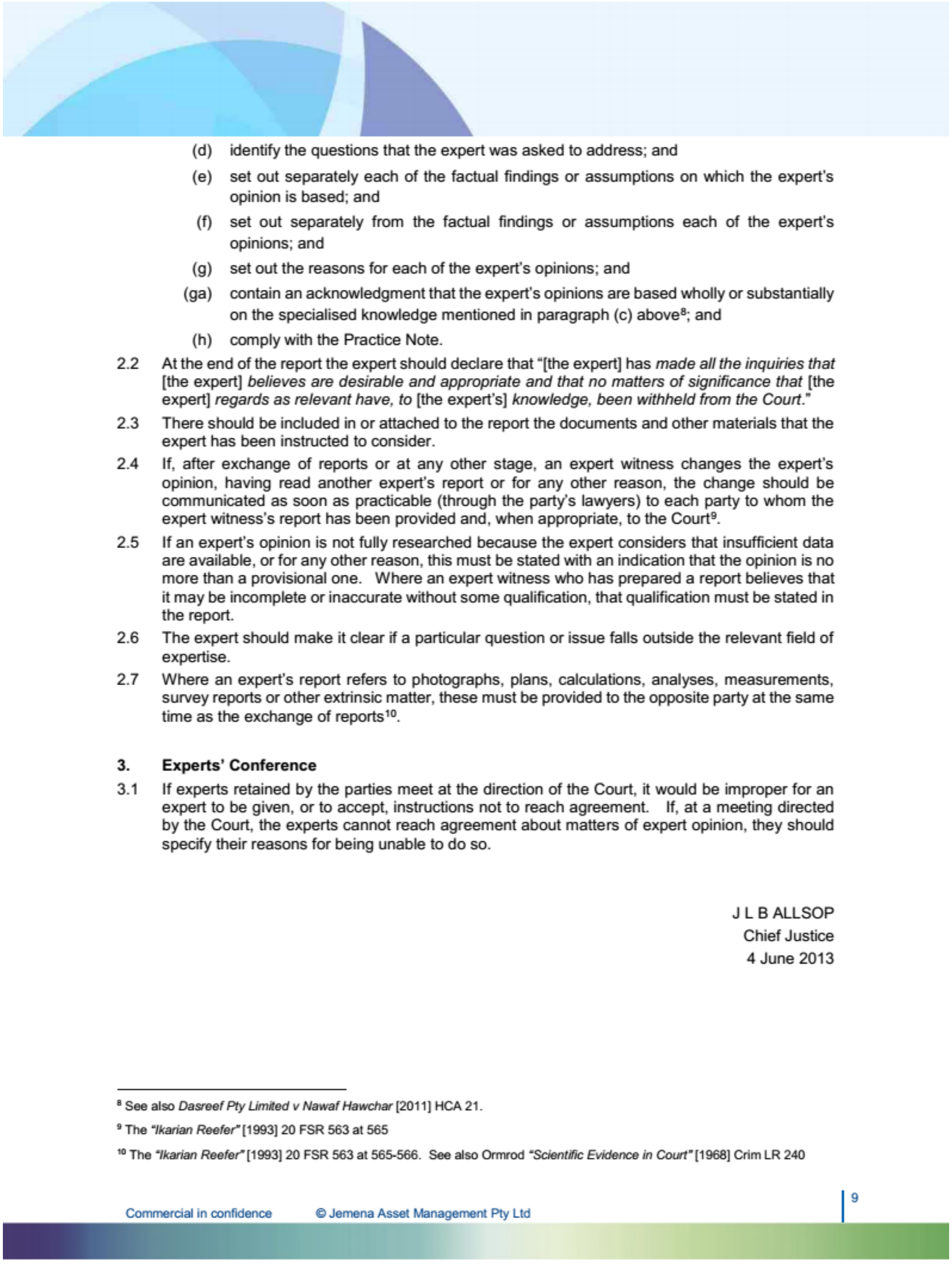
[5] As to the distinction between expert opinion evidence and expert assistance see *Evans Deakin Pty Ltd v Sebel Furniture Ltd* [2003] FCA 171 per Allsop J at [676].

[6] The "*Ikarian Reefer*" (1993) 20 FSR 563 at 565-566.

[7] Rule 23.13.



(d) identify the questions that the expert was asked to address; and

(e) set out separately each of the factual findings or assumptions on which the expert's opinion is based; and

(f) set out separately from the factual findings or assumptions each of the expert's opinions; and

(g) set out the reasons for each of the expert's opinions; and

(ga) contain an acknowledgment that the expert's opinions are based wholly or substantially on the specialised knowledge mentioned in paragraph (c) above[8]; and

(h) comply with the Practice Note.

2.2 At the end of the report the expert should declare that "[the expert] has *made all the inquiries that* [the expert] *believes are desirable and appropriate and that no matters of significance that* [the expert] *regards as relevant have, to* [the expert's] *knowledge, been withheld from the Court*."

2.3 There should be included in or attached to the report the documents and other materials that the expert has been instructed to consider.

2.4 If, after exchange of reports or at any other stage, an expert witness changes the expert's opinion, having read another expert's report or for any other reason, the change should be communicated as soon as practicable (through the party's lawyers) to each party to whom the expert witness's report has been provided and, when appropriate, to the Court[9].

2.5 If an expert's opinion is not fully researched because the expert considers that insufficient data are available, or for any other reason, this must be stated with an indication that the opinion is no more than a provisional one. Where an expert witness who has prepared a report believes that it may be incomplete or inaccurate without some qualification, that qualification must be stated in the report.

2.6 The expert should make it clear if a particular question or issue falls outside the relevant field of expertise.

2.7 Where an expert's report refers to photographs, plans, calculations, analyses, measurements, survey reports or other extrinsic matter, these must be provided to the opposite party at the same time as the exchange of reports[10].

3. Experts' Conference

3.1 If experts retained by the parties meet at the direction of the Court, it would be improper for an expert to be given, or to accept, instructions not to reach agreement. If, at a meeting directed by the Court, the experts cannot reach agreement about matters of expert opinion, they should specify their reasons for being unable to do so.

J L B ALLSOP
Chief Justice
4 June 2013

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[8] See also *Dasreef Pty Limited v Nawaf Hawchar* [2011] HCA 21.

[9] The *"Ikarian Reefer"* [1993] 20 FSR 563 at 565

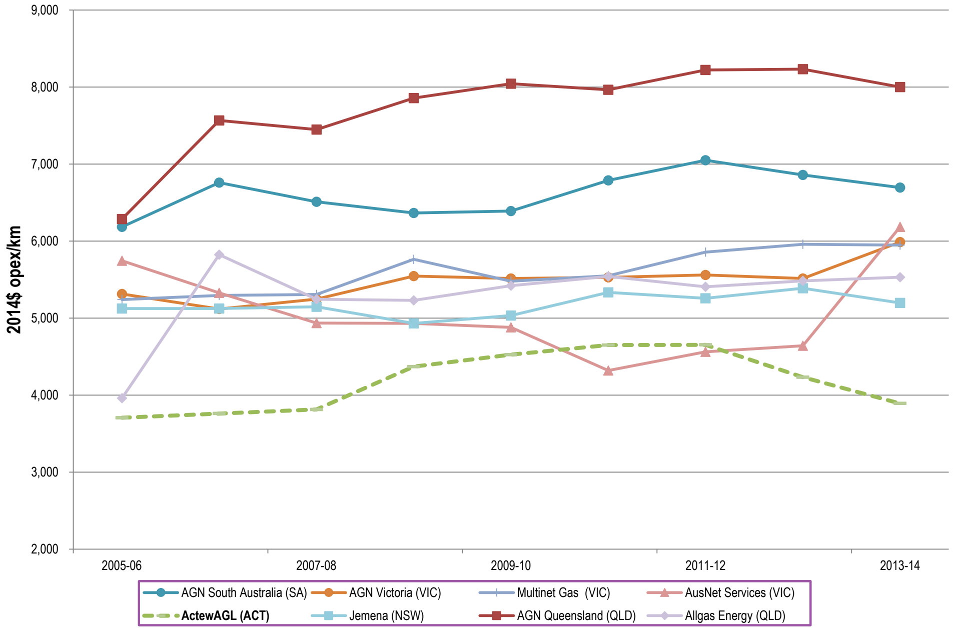
[10] The *"Ikarian Reefer"* [1993] 20 FSR 563 at 565-566. See also Ormrod *"Scientific Evidence in Court"* [1968] Crim LR 240

Appendix B Data analysis and partial indicators

The following figures show the ratios examined by ACIL Allen as part of the data screening process.

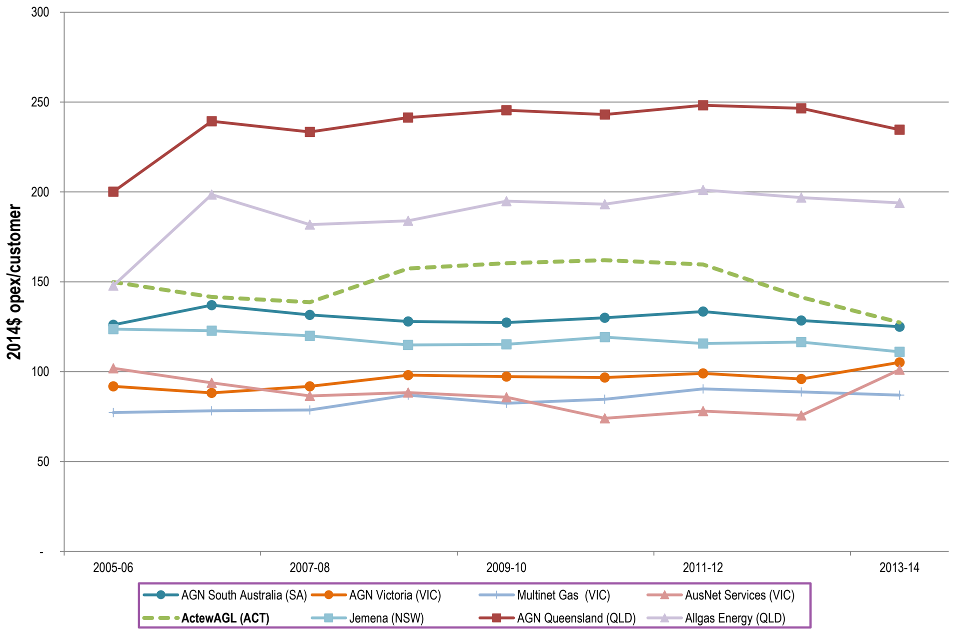
Opex ratios

Figure 8 **Opex per km**



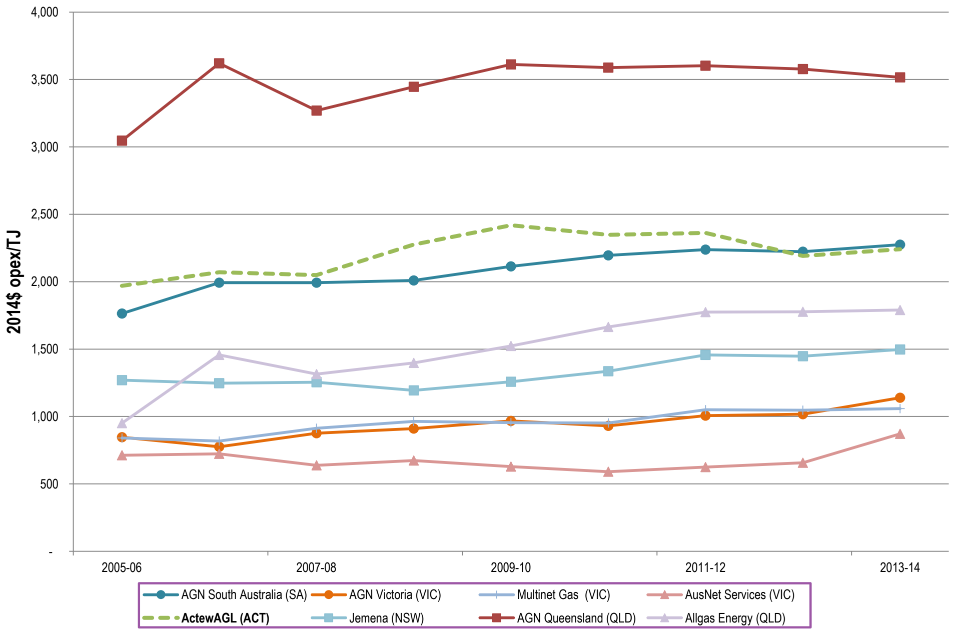
Note: ATCO Gas is not shown, but is included in the analysis.
Source: ACIL Allen

Figure 9 **Opex per customer**



Note: ATCO Gas is not shown, but is included in the analysis.
Source: ACIL Allen

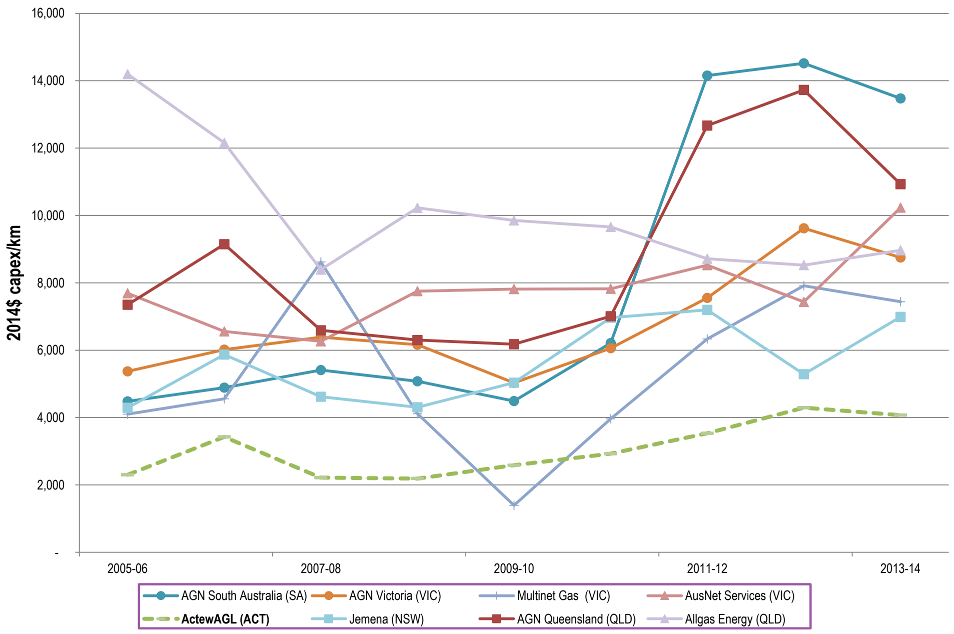
Figure 10 **Opex per TJ**



Note: ATCO Gas is not shown, but is included in the analysis.
Source: ACIL Allen

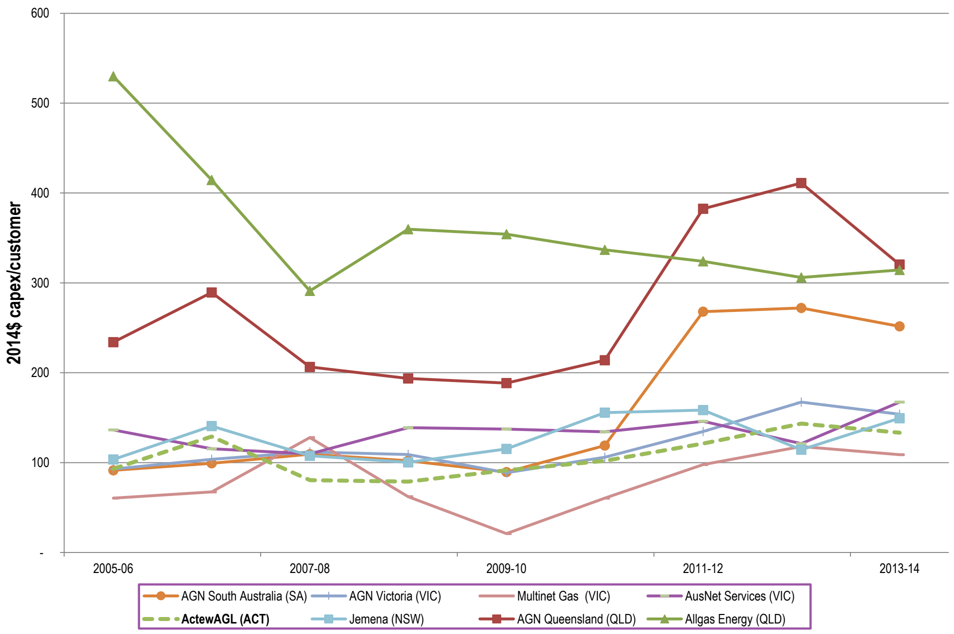
Capex ratios

Figure 11 **Capex per km**



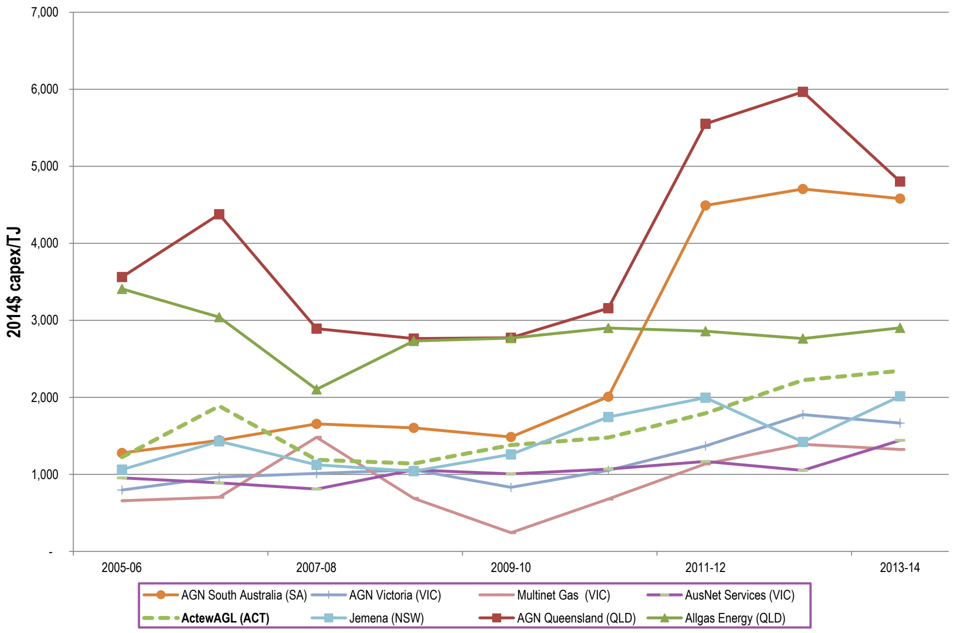
Note: ATCO Gas is not shown, but is included in the analysis.
Source: ACIL Allen

Figure 12 **Capex per customer**



Note: ATCO Gas is not shown, but is included in the analysis.
Source: ACIL Allen

Figure 13 **Capex per TJ**



Note: ATCO Gas is not shown, but is included in the analysis.
Source: ACIL Allen

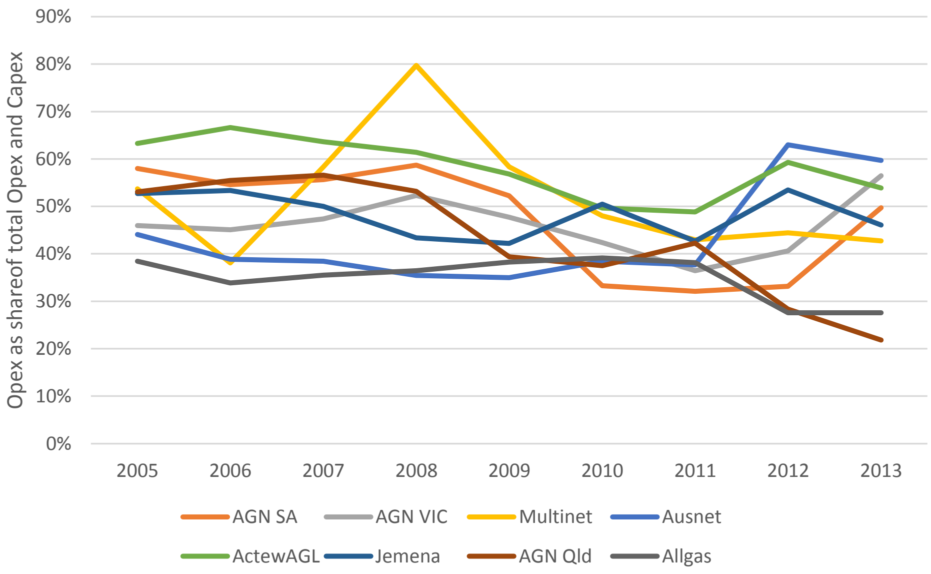
Different accounting treatment of opex

Different accounting practices can mean that there are differences in how the Australian gas distribution businesses allocate costs to the opex and capex cost categories. A particular issue where there may be differences is in relation to capitalisation policies. To the extent that there are differences in these practices, comparisons of the individual (opex and capex) cost categories would not be on a consistent basis. Businesses that capitalise a small proportion of their operating expenses would appear to have higher levels of opex (and hence appear inefficient) compared to those businesses that capitalise are larger percentage of their expenditures.

Figure 14 below shows, for each of the nine gas distribution businesses in our sample, the share that operating expenses comprise of total operating and capital expenditure.

Operating expenditures have consistently made up a larger share of total expenditures for ActewAGL compared to other gas distribution businesses. Opex as a share of total expenditures has generally maintained a level between 20 per cent and 30 per cent for most of the distributors. In the case of ActewAGL the share of operating expenses has been considerably larger, generally around the 50 per cent to 60 per cent mark between 2005 and 2013.

Figure 14 **Opex as share of total opex and capex, 2005 to 2013**



Note: ATCO Gas is not shown, but is included in the analysis.
Source: ACIL Allen

Appendix C Declaration

Compliance with the Code of Conduct for Expert Witnesses

We are Principals of ACIL Allen Consulting.

We have read, understood and complied with the Expert Witness Guidelines (Federal Court Practice Note CM 7, entitled "*Expert Witnesses in Proceedings in the Federal Court of Australia*") in preparing this report.

We have made all inquiries that we believe are desirable and appropriate and no matters of significance that we regard as relevant have, to our knowledge, been withheld from the report.

Necessary limitations to the scope and depth of the analysis undertaken, and the resulting findings that can be made based on the analysis, are outlined in the report.

Deirdre Rose.

Deirdre Rose
Principal

Jim Diamantopoulos
Principal

Appendix D Curriculum vitae

Deirdre Rose

Deirdre is a Principal at ACIL Allen in Melbourne with over 16 years of economic consulting experience at leading consulting firms including her own practice Ilex Consulting, Ernst & Young, Frontier Economics and London Economics.

Deirdre has undertaken productivity and efficiency benchmarking of a range of industries and government services over a period of close to 20 years, including benchmarking of electricity distribution businesses and water supply businesses. Deirdre was initially trained while a research economist at NSW Treasury by leading international academics in economic performance benchmarking techniques (including Total Factor Productivity (index number) and Data Envelopment Analysis).

Deirdre has also provided wide-ranging analytical and advisory support to regulated firms across a range of industries. This has been in the context of regulatory determinations advising on elements of the building blocks and broader support relevant to the operations and investments of the regulated firms. Deirdre has also advised governments and regulators on economic regulatory frameworks.

Deirdre has a degree in administration and economics from Griffith University.

Relevant to this assignment, Deirdre has significant economic benchmarking experience including:

- *ATCO Gas:* Preparation of two expert witness report providing partial productivity measures of ATCO Gas against a sample of Australian gas distribution businesses. (2014)
- *Victorian and South Australian DNSPs:* Project to estimate econometric cost functions and to advise on how this analysis may be used to produce output weights for multilateral Total Factor Productivity Analysis as proposed by the Australian Energy Regulator. (2013-14)
- *Victorian diary sector:* While the Chief Economist of the Victorian Department of Primary Industries, oversighted a study by to measure the productivity and efficiency of the Victorian dairy industry. (2012)
- *Victorian water business:* Led a TFP study for a large metropolitan Victorian water business to assess their productivity over time using index number techniques. (2008)
- *Review of ERIG analysis of electricity network performance:* Provided an electricity network business with a critique of the productivity measures included in the ERIG discussion papers on energy market reforms released in November 2006. (2006)
- *Sydney Water:* Assisted in undertaking a TFP study for Sydney Water to assess their productivity over time using index number techniques. This was done in the context of their periodic price review process with IPART. We presented this analysis to IPART on behalf of Sydney Water and were able to turn around the regulator's negative view of the businesses' productivity performance to a more positive stance, with an understanding that significant investments had increased costs but had commensurately significantly improved their required quality of service particularly in terms of wastewater quality. (2005)

- *Victorian distribution pricing review:* Regulatory advice to TXU Networks during the 2001 Victorian electricity distribution pricing review on benchmarking analysis. (2000)
- *NSW electricity distribution:* Led the team (including Professor Tim Coelli) that undertook a detailed benchmarking study for the Independent Pricing and Regulatory Tribunal (IPART). The study used a range of economic benchmarking techniques including partial indicators, Data Envelopment Analysis, Stochastic Frontier Analysis and index number techniques. The results of the study were used to help determine the regulated price paths of the NSW electricity distributors for the five-year period from July 1999. (1998, 1999)
- *Queensland electricity supply industry:* Supervised and undertook benchmarking studies of the generation, retail and network businesses in Queensland. The network sector studies were used to establish appropriate X factors as part of the revenue caps for the transmission and distribution businesses in Queensland. The retail sector study was used in setting allowed revenues in relation to non-contestable customers. (1998)
- *West Australia electricity supply industry:* Benchmarked the economic performance of the West Australian firms in the generation, transmission and distribution sector against international firms using DEA. This was done as part of a broader study of options for reforming the electricity supply industry in Western Australia. (1998)
- *Water and Sewerage Companies, England and Wales:* Member of advisory teams to water companies subject to take over bids which were referred to the Monopolies and Mergers Commission (MMC) during 1996. Worked on projects to assess the relative efficiency of firms in the UK water sector (using DEA and Total Factor Productivity (TFP) analysis), to examine the structure of the water sector, and to provide general advice on likely economic and regulatory consequences of further mergers in the UK water sector. Appeared before hearings of the MMC to report on the results of the efficiency studies. (1996)
- *Government owned businesses and budget sector agencies:* At NSW Treasury, applied efficiency measurement tools to measure and assess the performance of government owned businesses and budget sector agencies (including electricity distributors, correctional centres, rail and ferry services). Deirdre developed considerable expertise in using TFP or index number techniques and Data Envelopment Analysis (DEA) to measure and benchmark public sector performance. At this time, Deirdre received training in the use of economic benchmarking techniques from leading academics including Knox Lovell, Hal Fried, Tim Coelli and Suthathip Yaisawarng. (1994, 1995)

Jim Diamantopoulos

Jim Diamantopoulos is a Principal in ACIL Allen's Melbourne office.

He has a strong background in the application of economic, financial and econometric modelling techniques in the analysis of economic problems and issues. Since joining ACIL Allen, Jim has worked on a range of modelling projects across a number of sectors, with a strong emphasis on demand forecasting in the energy sector.

Jim has recently undertaken a project to estimate econometric cost functions for three Australian distribution firms.

Jim has recently worked with AEMO to develop a new maximum demand and energy forecasting methodology at the connection point level. The assignment involved all aspects of the forecasting process from model specification, development and estimation to weather normalisation.

Jim's relevant project experience includes:

- Project to estimate econometric cost functions and to advise on how this analysis may be used to produce output weights for multilateral Total Factor Productivity Analysis as proposed by the Australian Energy Regulator.
- Development of a sophisticated connection point and zone substation load demand forecasting model for Aurora Energy. The model incorporated weather correction as well as adjustments for permanent transfers, major block loads, embedded generation and demand side management initiatives.
- A review of the Independent Market Operator's (IMO) energy and maximum demand forecasting methodologies for the SWIS in Western Australia.
- A review of Ergon Energy's spatial maximum demand forecasting methodology
- Comprehensive reviews of Ergon Energy's and Energex's system demand forecasting methodologies, identifying deficiencies and weaknesses in the existing methodologies and developing methodological improvements consistent with best practice.
- Advising Aurora Energy on their energy consumption and load demand forecasting methodology as part of their pricing submission to the AER.
- Development of energy consumption forecasts for six customer classes, constructing an econometric model that incorporated the key drivers, including economic, demographic and weather variables for Aurora Energy
- Development of a comprehensive model of water demand for SA Water. The model is econometrically driven and generates water demand forecasts by sector for South Australia after estimating suitable relationships between water use and its key drivers.
- A project for the Australian Energy Regulator reviewing the electricity demand, energy sales and customer numbers forecasts of the five Victorian electricity distribution businesses submitted as part of the latest regulatory pricing review. He critically assessed the forecast input assumptions, the soundness of the forecasting methodologies employed and the reasonableness of the forecast outputs.
- Development of a simulation model of electricity peak demand and energy for the South East Queensland region for Energex. The model allows for the analysis of the impact of changes in carbon emissions policies, MRET, electricity prices, trends in appliance energy efficiency and market penetration of various appliances to estimate the impact on both peak summer and winter load and annual energy sales. The model also considers the impact of demand side management initiatives and assesses the likely impact of changes in building efficiency standards, photovoltaic cells and solar hot water systems.

- Creation of a suite of Excel based simulation models that enable the user to analyse the economics of a range of gas network reticulation options for the WA Office of Energy. Options analysed included the development of Greenfield/Brownfield LNG and LPG reticulation options, and the extension of a natural gas pipeline. Capital and operating costs for each of the reticulation options were constructed based on a range of assumptions and the models were solved for a customer per unit gas price that generated a predetermined rate of return to the service provider.
- Provision of advice to Powerlink in Queensland on their load forecasting methodology with a particular focus on their approach to weather normalisation.
- Econometric analysis and modelling of residential electricity demand for the Australian Greenhouse Office
- An economic model benchmarking the returns and costs of racing animal ownership in Western Australia (2007)
- An econometric model of the determinants of Australian house prices on behalf of the Housing Industry Association of Australia (2006)
- An econometric analysis of the effects of mass media anti-smoking advertising expenditure and other relevant factors on smoking prevalence and tobacco consumption (2007)

Jim holds a Master of Economics degree from Monash University, specialising in econometrics, a Bachelor of Economics degree with Honours, and a Graduate Diploma of Applied Finance and Investment.

Appendix E References

ACCC and AER, 2012, *Benchmarking Opex and Capex in Energy Networks*, Working Paper no.6, May

ACIL Tasman, 2012a, *Review of Demand Forecasts for Envestra Victoria, Victorian Gas Access Arrangement Review for the period 2013 – 2017, Final Report*, Prepared for the Australian Energy Regulator, August

— 2012b, *Review of Demand Forecasts for SP AusNet, Victorian Gas Access Arrangement Review for the period 2013 – 2017, Final Report*, Prepared for the Australian Energy Regulator, August

ActewAGL, *Annual Report 2012-13*

— *Annual Report 2011-12*

— *Annual Report 2010-11*

— 2010, *Access Arrangement Information for the ACT, Queanbeyan and Palerang Gas Distribution Network, 1 July 2010 – 30 June 2015, Amended by Order of the Australian Competition Tribunal made on 23 September 2010,* April

— 2009a, *ActewAGL Gas Network Performance Benchmark Study, FY2000 – FY2008*, Prepared by Darrall Cutting, May

— 2009b, *Access Arrangement Information for the ACT, Queanbeyan and Palerang Gas Distribution Network*, June

— 2004, *Access Arrangement Information for ActewAGL Gas Distribution System in ACT and Greater Queanbeyan*, November

— 2003, *Access Arrangement Information for ActewAGL Distribution System in ACT, Queanbeyan and Yarrowlumla*, December

AER, 2014a, *Overview, Draft decision: Jemena Gas Networks (NSW) Ltd Access Arrangement 2015-20*, November

— 2014b, *Draft decision: Jemena Gas Networks (NSW) Ltd Access Arrangement 2015-20, Attachment 7 – Operating Expenditure*, November

— 2014c, *Draft decision: Jemena Gas Networks (NSW) Ltd Access Arrangement 2015-20, Attachment 6 – Capital Expenditure*, November

— 2014d, *Victorian Gas Distribution Business Comparative Performance Report 2012*, February

— 2013a*, Better Regulation, Expenditure Forecast Assessment Guideline for Electricity Distribution*, November

— 2013b*, Better Regulation, Explanatory Statement, Expenditure Forecast Assessment Guideline*, November

— 2013c, *Victorian Gas Distribution Business Comparative Performance Report 2009–2011*, March

— 2013d, *Access arrangement final decision, Envestra Ltd 2013–17, Part 2: Attachments*, March

— 2013e, *Multinet Gas (DB No. 1) Pty Ltd, Multinet Gas (DB No. 2) Pty Ltd, 2013–17 Access arrangement, Opening capital base, Decision, Pursuant to Orders of the*

Australian Competition Tribunal in Application by Multinet Gas (DB No. 1) Pty Ltd (No 2) [2013] ACompT 6, October

— 2013f, *Access arrangement final decision, Multinet Gas (DB No. 1) Pty Ltd Multinet Gas (DB No. 2) Pty Ltd 2013–17, Part 2: Attachments*, March

— 2013g, *Access arrangement final decision, SPI Networks (Gas) Pty Ltd 2013–17, Part 2: Attachments*, March

— 2012a, *Access Arrangement draft decision Multinet Gas (DB No.1) Pty Ltd Multinet Gas (DB No.2) Pty Ltd 2013–17 Part 2 Attachments*, September

— 2012b, *Access Arrangement draft decision* SPI Networks (Gas) Pty Ltd *2013–17 Part 2 Attachments*, September

— 2011a, *Envestra Ltd Access arrangement proposal for the Qld gas network 1 July 2011 – 30 June 2016, Final Decision*, June

— 2011b, APT Allgas *Access arrangement proposal for the Qld gas network 1 July 2011 – 30 June 2016, Final Decision*, June

— 2011c, *Envestra Ltd Access arrangement proposal for the SA gas network 1 July 2011 – 30 June 2016, Final Decision*, June

— 2011d, *Envestra Ltd Access arrangement proposal for the Qld gas network, 1 July 2011 – 30 June 2016, Draft Decision*, February

— 2010a, *Victorian Gas Distribution Business Comparative Performance Report 2008*, May

— 2010b, *Access arrangement proposal ACT, Queanbeyan and Palerang gas distribution Network 1 July 2010–30 June 2015*, Final decision–Public, March

AGL Gas Networks, 2005, *Access Arrangement for NSW Network*, June

AlintaGas Networks, 2005, *Access Arrangement Information For the Mid-West and South-West Gas Distribution Systems*, Amended AAI dated 29 July 2005

APA Group, *Annual Review 2010*

— *Annual Report 2009*

APT Allgas Energy, 2011, *Access Arrangement Information, Effective 01 July 2011 – 30 June 2016, Amended by order of the Australian Competition Tribunal, 10 February 2012*, June

— 2010a, *Load Forecast, Effective 01 July 2011 – 30 June 2016*, 1 November

— 2010b, *Access Arrangement Information, Effective 01 July 2011 – 30 June 2016*, September

— *Access Arrangement Submission, Effective 01 July 2011 – 30 June 2016*

— 2006, *Access Arrangement Information for the Queensland Network*, 7 June

— 2001, *Access Arrangement Information for the Queensland Network*, 12 November

Armstrong J. S, 2001, *Principals of forecasting: A Handbook for Researchers and Practitioners*, Kluver Academic Publishing

ATCO Gas Australia, 2014, *Access Arrangement Information 1 July 2014 – 31 December 2019 (AA4)*, Submitted to the Economic Regulation Authority, March

— 2012, *Access Arrangement Information for the Mid-West and South-West Gas Distribution Systems*, 28 June

Breusch, T and A. Pagan, 1980, *The LM Test and Its Application to Model specification in Econometrics*, Review of Economic Studies, 47 p 239-254

Centre for International Economics, 2012, *Gas demand forecasting, SPAusNet, 2013-17*, January

Coelli, T, D.S Prasada Rao, C.J. O'Donnell, G. E. Battese, 2005, *An Introduction to Efficiency and Productivity Analysis, Second Edition*, Springer, New York

Coelli,T., A. Estache, S. Perelman, L. Turjillo, 2003, *A Primer on Efficiency Measurement for Utilities and Transport Regulators*, The World Bank, Washington

Coelli, T, D.S. Prasada Rao, G. E. Battese, 1998, *An Introduction to Efficiency and Productivity Analysis,* Kluwer Academic Publishers, Massachusetts

Core Energy Group, 2012, *Demand, Energy and Customer Forecasts*, Envestra Limited – Gas Access Arrangement Review, Victoria and Albury Networks (2013 to 2017), March

Diversified Utility and Energy Trusts (DUET) Group, 2008, *Multinet Gas Access Arrangement Review, Final ESC Decision*, Presentation, 7 March

— *Annual Report 2007*

— *Annual Report 2006*

— *Annual Report 2005*

— *Annual Report 2004*

Economic Insights, 2014, *Relative Opex Efficiency and Forecast Opex Productivity Growth of Jemena Gas Networks*, Report prepared for Jemena Gas Networks, 14 April

— 2012a, *Benchmarking the Victorian Gas Distribution Businesses' Operating and Capital Costs Using Partial Productivity Indicators*, Report prepared for Envestra Victoria, Multinet and SP AusNet, 26 March

— 2012b, *The Total Factor Productivity Performance of Victoria's Gas Distribution Industry*, Report prepared for Envestra Victoria, Multinet and SP AusNet, 26 March

— 2010, *The Productivity Performance of Envestra's South Australian and Queensland Gas Distribution Systems*, Report prepared for Envestra Ltd, 30 September

— 2009, *The Productivity Performance of Jemena Gas Networks' NSW Gas Distribution System*, Report prepared for Jemena Gas Networks (NSW) Ltd, 18 August

Economic Regulation Authority Western Australia, 2011, *Final decision on WA Gas Networks Pty Ltd proposed revised access arrangement for the Mid-West and South-West Gas Distribution Systems*, 28 February

Economics and Industry Standing Committee, 2011, *Inquiry into Domestic Gas Prices*, Report No. 6, 24 March

Energy Consulting Group, 2006, *Envestra Limited Capital and Operating Expenditure Review For Essential Services Commission of South Australia*, 26 March

— 2004, *Review of AGLGN Gas Access Arrangement For Independent Pricing and Regulatory Tribunal*, 30 August

Envestra, 2013, *Victorian Access Arrangement Information*, *Envestra's Victorian Gas Distribution Network, 1 January 2013 – 31 December 2017*, April

— 2012, *Victorian Access Arrangement Information*, 30 March

— 2012b, *Access Arrangement Information, Envestra's Queensland Gas Distribution Network, 1 July 2011 – 30 June 2016,* Amended by order of the Australian Competition Tribunal, 10 February

— 2011a, *Access Arrangement Information Envestra's South Australian Gas Distribution Network, 8 July 2011 – 30 June 2016*, July

— 2011b, *Queensland Access Arrangement Information, Public Version*, As revised on 23 March

— 2011c, *South Australian Access Arrangement Information, Public Version*, As revised on 23 March

— 2010a, *Queensland Access Arrangement Information, Public Version*, 1 October

— 2010b, *South Australian Access Arrangement Information, Public Version*, 1 October

— 2009, *Access Arrangement for Victorian Distribution System, Part A – Principal Arrangements, With revisions drafted and approved by the Essential Services Commission of Victoria under section 2.42 of the National Third Party Access Code for Natural Gas Pipeline Systems for the Access Arrangement Period commencing 2 June 2008 and varied by order of the Essential Services Commission Appeal Panel under sections 38 and 39 of the Gas Pipelines Access (Victoria) Law dated 11 November 2008*, March

— 2006, *Amended Access Arrangement Information for Envestra's South Australian Network*, 24 July

— 2005, *Access Arrangement Information for Envestra's South Australian Network*, September

ESC, 2008a, *Gas Access Arrangement Review 2008-2012, Final Decision – Public Version*, 7 March

— 2008b, *Gas Access Arrangements 2008-2012, Further Final Decision and Approval of Commission's Amended Revisions to Access Arrangement, Multinet,* 19 May

— 2008c, *Gas Access Arrangements 2008-2012, Further Final Decision and Approval of Commission's Amended Revisions to Access Arrangement, SP AusNet,* 19 May

ESCOSA, 2006a, *Proposed Revisions to the Access Arrangement for the South Australian Gas Distribution System, Further Final Decision*, October

— 2006b, *Proposed Revisions to the Access Arrangement for the South Australian Gas Distribution System, Final Decision*, June

— 2006c, *Proposed Revisions to the Access Arrangement for the South Australian Gas Distribution System, Draft Decision*, March

Fuss, M and L. Waverman, "Econometric Cost Functions", Chapter 5 in Cave, M., S. Majumdar and I. Vogelsang (eds), 2002, *Handbook of Telecommunications Economics, Volume 1, Structure, Regulation and Competition*, Elsevier, Oxford

Fuss, M. and D. McFadden (eds), 1978, *Production Economics: A Dual Approach to Theory and Applications, Volume 1, The Theory of Production*, North-Holland Publishing Company, Amsterdam

Greene, 2000, *Econometric Analysis*, Upper Saddle River, NJ: Prentice-Hall

Hausman, J. A., 1978, *Specification tests in econometrics*, Econometrics 46: 1251-1271

Independent Competition and Regulatory Commission, 2004a, *Access arrangement for ActewAGL gas distribution system in the ACT and Greater Queanbeyan, Final Approval*, November

— 2004b, *Review of access arrangement for ActewAGL natural gas system in ACT, Queanbeyan and Yarrowlumla*, July

Independent Pricing and Regulatory Tribunal, 2005, *Revised Access Arrangement for AGL Gas Networks, Final Decision*, April

— 2004, *Revised Access Arrangement for AGL Gas Networks, Draft Decision*, December

Jemena Gas Networks, 2014, *2015-20 Access Arrangement Information*, 30 June

Jemena Gas Networks (NSW) Ltd, 2009, *Access Arrangement Information*, 25 August

Marchment Hill Consulting, 2012, *Multinet Gas International Gas Benchmarking*, Final Results, January

Marksman Consulting Services, 2010, *Gas Distributor Benchmarking Report Envestra South Australia and Queensland*, 28 September

Meyrick and Associates, 2004, *Comparative Benchmarking of Gas Networks in Australia and New Zealand, Public Version*, Report prepared for Commerce Commission, 14 May

Multinet Gas, 2013, *Access Arrangement Information, Multinet Gas (DB No 1) and Multinet Gas (DB No 2) Gas Distribution Network, 1 January 2013 – 31 December 2017, Amended to take account of orders from the Australian Competition Tribunal*, October

— 2012a, *Gas Access Arrangement Review January 2013-December 2017 Revised Proposal and Response to Draft Decision*, 9 November

— 2012b, *Gas Access Arrangement Review January 2013-December 2017 Access Arrangement Information,* 30 March

National Institute of Economic and Industry Research, 2011, *Natural gas forecasts and customer number forecasts for the Multinet distribution region to 2021*, A report for Multinet, December

— 2010a, *Natural gas forecasts for the Queensland Envestra distribution regions to 2020*, A report for Envestra, September

— 2010b, *Natural gas forecasts for the Envestra South Australian distribution region to 2019-20*, A report for Envestra, September

NSW Department of Water and Energy, 2009, *NSW Gas Networks Performance report 2007-08*

NSW Trade & Investment, *New South Wales 2011-2012 Gas Networks Performance Report*

Parsons Brinckerhoff, 2010, *Allgas CAPEX and OPEX Review*, October

— 2003, *Review of AGL Gas Networks Capital and Operating Expenditure*, December

Queensland Competition Authority, 2006a, *Revised Access Arrangement for Gas Distribution Networks: Envestra, Final Decision*, May

— 2006b, *Revised Access Arrangement for Gas Distribution Networks: Allgas Energy, Final Decision*, May

SP AusNet, 2014, *Business Review 2014*

— SP AusNet, 2014b, *2013/14 Full Year Results Release and Investor Presentation*, 15 May

- — 2013, *Business Review 2013*
- — SP AusNet, 2012, *2013-2017 Gas Access Arrangement Review, Access Arrangement Information*, 30 March
- — 2010, *SP AusNet 2009/10 Full-Year Results Release and Investor Presentation, ASX & SGX-ST Release*, 12 May
- — 2009, *Business Review 2009*, June
- — *Annual Report 2007*
- — 2006, *SP AusNet 2009/10 Full-Year Results for Period Ended 31 March 2006, ASX Release*, 5 June
- — *Annual Report 2006*

The Brattle Group, 2008, *Use of Total Factor Productivity Analysis in Network Regulation, Case Studies of Regulatory Practice*, October, Belgium

WIK-Consult, 2011, *Cost Benchmarking in Energy Regulation in European Countries, Final Report*, Study for the Australian Energy Regulator, December, Bad Honnef

Wilson Cook & Co, 2010, *Review of Expenditure of Queensland & South Australian Gas Distributors: Envestra Ltd (Queensland)*, December

Wooldridge, J.M, 2002, *Econometric Analysis of Cross Section and Panel Data*. Cambridge, MA: MIT Press

WorleyParsons, 2007, *Review of Envestra Gas Access Arrangement for Victoria*, March

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