Benchmarking the Efficiency

of

Australian Gas Distributors

Research Paper

INDEPENDENT PRICING AND REGULATORY TRIBUNAL
OF NEW SOUTH WALES

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FOREWORD

The Independent Pricing and Regulatory Tribunal is undertaking a review of the Access Arrangement for AGL Gas Networks Ltd (AGLGN). Section 8.37 of the National Third Party Access Code for Natural Gas Pipeline Systems (Code) requires the regulator to determine efficient non capital costs for AGLGN that are associated with accepted and good industry practice. Benchmarking, in its various forms, can help form judgments on these matters. The primary purpose of this paper is to apply a number of benchmarking approaches to the local gas distribution industry.

Roger Carrington undertook the research and wrote this report, and Eric Groom supervised the project. Dr Tim Coelli, Senior Lecturer in Econometrics at the University of New England, provided technical support and was the external referee for the paper. The views in this paper are those of the author and are not necessarily those of the Tribunal.

No benchmarking technique can provide a complete picture of performance because they all require assumptions to be made that can affect the interpretation of the results. Therefore, a sensible and prudent approach to benchmarking requires the use of several techniques. The following techniques are used in this paper to help establish local and international efficiency benchmarks for the local distributors:

- partial productivity measures
- regression analysis
- data envelopment analysis
- corrected ordinary least squares
- stochastic frontiers.

In employing the techniques, the author has had to use judgement and apply assumptions in developing the benchmarking models. Although these judgements and assumptions are in the Tribunal's view reasonable, it should be noted that alternative judgements and assumptions could have been made.

Other studies that benchmark the efficiency and productivity of local and international gas distributors can further assist the assessment of efficient non capital costs for the local distributors. Still, regulatory judgment is required to assess the performance of local distributors irrespective of the techniques chosen and to form views on these matters.

Obtaining accurate data for economic analysis is often difficult. The Tribunal sought assistance from local distributors to reconcile differences in local and overseas data. However, certain data remain imperfect and further effort is required to ensure consistent and reliable information is collected in the future. Further effort is required to determine the actual influence of the operating environment, such as climate and the age of networks, on the efficiency of gas distribution. Distributors should explain and demonstrate the influence that the operating environment has on the efficiency of gas distribution.

Regardless of the approach taken to benchmark gas distribution, better information on the sector will assist governments, managers, regulators and the broader community to gain further insights on the performance of local distributors. Such insights are an important input to setting a regulatory framework that encourages the sector to improve performance. However, world's best practice is a moving target. In a dynamic global economy, countries continue to set new standards in service delivery in response to changing patterns in demand.

The results of the study suggest that the ability of local distributors to achieve and maintain world best practice for efficient delivery of gas is mixed. Some distributors possess relatively efficient networks, but for most there is scope to improve performance. The choice of benchmarking technique did not unduly influence the results of the study in broad terms. However, the results need to be interpreted with care given the varying quality of the data used in the study.

The Tribunal welcomes comments on this research paper. The Tribunal is keen to ensure that it has a wide range of information on potential efficiency gains and that such information be available to all stakeholders for comment. This ensures that the inputs to the Tribunal's views on the potential efficiency gains are transparent and subject to testing by stakeholders. The Tribunal will consider comments on the study in assessing AGLGN's Access Arrangement, in addition to other relevant information available to it.

The Tribunal would like to thank the local distributors that participated in the benchmarking exercise. Their cooperation and assistance considerably enhanced the quality of the analysis that is presented in this paper.

Thomas G Parry
Chairman
December 1999

1 INTRODUCTION

1.1 This inquiry

The Independent Pricing and Regulatory Tribunal (IPART) is undertaking a review of the Access Arrangement for AGL Gas Networks Ltd (AGLGN). Section 8.37 of the Code requires the regulator to determine efficient non capital costs for AGLGN that are associated with accepted and good industry practice. Benchmarking can help the Tribunal to form judgments on these matters. The benchmarking techniques used in this paper contribute to the assessment of AGLGN's overall efficiency. They do not directly provide evidence on the assessment of excess non capital costs.

This paper assesses the efficiency of AGLGN and other local gas distributors relative to local and international best practice benchmarks for efficient gas distribution. Other studies that benchmark the efficiency and productivity of local and international gas distributors are also discussed. These have helped the Tribunal to form judgments regarding potential improvements in the performance of local distributors. The Tribunal will consider benchmarking and other analyses, which examine the cost and revenue structures of AGLGN, to help determine appropriate prices for services covered by AGLGN's proposed Access Arrangement.

Participants are encouraged to comment on the approaches used to benchmark the efficiency of local distributors, and to suggest other approaches or refinements to the analysis presented here. The Tribunal is keen to gather a broad spectrum of views on potential efficiency gains for AGLGN. These views will help the Tribunal to set the appropriate price caps for AGLGN's services. Public participation helps to ensure that the Tribunal's decisions are transparent and subject to review by participants.

1.2 The role of benchmarking

Changes in the market price of internationally traded goods and services provide benchmarks about the quality and services demanded by customers. They also provide a benchmark for local industries to meet world best practice or standards. However, this test is not available for the non-traded sector, especially for services, like gas distribution, which are not exchanged on competitive markets. Therefore, an alternative regime is required to assess improvements in the performance of the gas distributors.

Benchmarking is one way of encouraging local distributors to improve their performance. Performance indicators provide information which makes the local distributors accountable to customers and the general public. Performance indicators also promote surrogate, or yardstick, competition in gas distribution by providing information to managers and shareholders on reasons for poor performance. A distributor's performance can be assessed relative to similar organisations or to its past performance.

Assessing the performance of a distributor depends on information on **both** quality of service and efficiency. Otherwise, a distributor could improve efficiency in service delivery by sacrificing the quality of the service. This paper focuses on the efficiency of gas distribution. Indicators of quality of service are presented to place the relative efficiency of the local distributors in a broader context.

Factors that may limit the usefulness of benchmarking include:

- the assumptions that underpin the analysis
- the quality of the data
- difficulties in comparing distributors which operate in different operating environments.

To address these concerns, sensitivity analysis is used to test the sensitivity of the conclusions to of the assumptions underpinning the analysis. Analysis is undertaken to assess whether the efficiency of local distributors is influenced by external factors, such as climate, which are beyond the control of management.

Obtaining accurate data for economic analysis is often difficult. Local distributors have helped to reconcile differences in local and overseas data. However, some data remain imperfect. Further effort is required to ensure consistent and reliable information is collected in the future. In particular, information presented in the various Access Arrangement Information[1] on operating and maintenance (O&M) costs and network capacity requires greater consistency.

However, government and business officials often have to make decisions on the basis of imperfect information. Waiting for perfect data would result in excessive delays. Moreover, using existing information to measure the efficiency of local distributors provides a catalyst to improve the quality of the data. To minimise misinterpretation of the results of the benchmarking exercise, weaknesses in the data are acknowledged, and readers advised to treat the results with care.

1.3 The role of benchmarking in this inquiry

In assessing efficiency, the Tribunal is concerned to maintain a clear separation between responsibilities of the regulator, and the operational responsibilities of AGLGN. The regulatory interest is in the overall efficiency of gas distribution. On one view, the regulator should not examine the utility's operational decisions in the conduct of its business, nor identify where specific savings can be made. The benchmarking exercise undertaken provides a 'top down' view of efficiency. This form of benchmarking is in addition to, not an alternative to, the 'bottom up' approach of process benchmarking. The latter is particularly useful to management and is regularly undertaken by business.[2] Process benchmarking can also contribute the

[1] Access Arrangement Information means information provided by a service provider to the relevant regulator pursuant to the requirements of the Gas Pipelines Access Law.

[2] For example, see UMS Group (1999), *Summary Report of 1998 Distribution Benchmarking*, IPART Research Report No 14.

regulator's assessment regarding the overall scope for improvements in efficiency. Unfortunately, AGLGN does not do regular process benchmarking.[3]

The Tribunal proposes a framework which will encourage AGLGN to continuously improve its performance. The price cap and benchmarking studies provide incentives in the short term. The real incentive for long term efficiency improvements is delivered through the form of regulation.[4] The Tribunal has recognised that regulation must be sustainable and consistent, and should seek to minimise the risk of intervention between reviews. Thus, in setting sustainable regulated revenues, it is desirable to reduce the risk of excessive profits or losses due to forecasting errors. This requires careful consideration of the scope for efficiency gains so as to base the regulatory framework on realistic assessments of efficient costs.

After considering other studies undertaken for the Tribunal (including the capital works study undertaken by Ewbank Preece (1999)) and the views expressed by AGLGN and other participants, prices for the scheduled services are determined as outlined in the Tribunal's draft decision. These prices are intended to provide AGLGN with an incentive to reduce non capital costs and to expand the market for natural gas.

1.4 Benchmarking and the natural gas code

The Tribunal is required to assess the appropriate level of non capital costs for AGLGN under section 8.37 of the Code (non capital costs). The efficiency measures developed for gas distribution, in some instances, include both non capital costs and capital costs. AGLGN suggests that benchmarking techniques (such as data envelopment analysis (DEA) and stochastic frontiers), which consider non capital and capital costs to develop measures of efficiency, may not comply with section 8.37 of the Code.[5]

Section 8.10 (initial capital gas – pipelines) and section 8.16 (new facilities investment) set the requirements for the regulator in assessing capital costs. The Code does not explicitly consider the potential for trade-offs between O&M costs and capital expenditure to achieve an optimal mix of inputs for gas distribution.

Nevertheless, in arriving at a judgment on efficient O&M costs and capital expenditure, the regulator may find that DEA and stochastic frontiers provide useful information on the optimal mix of inputs. The Code does not preclude this approach.

The UK water regulator, the Office of Water Services (Ofwat) (1998), states that a regulatory framework which focuses separately on each category of expenditure may discourage companies from perusing strategies which deliver efficient services. For example, a water company may undertake capital maintenance to reduce operating costs. Focusing entirely on the increase in capital expenditure without regard to its impact on operating costs could lead the regulator to form misleading judgments on the relative efficiency of that company.

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3 In 1995, when it was an integrated gas company, the Australian Gas Light Company (AGL) participated in a process benchmarking study conducted by the American Gas Association.

4 See IPART (1999a), *Regulation of Electricity Network Service Providers, Incentives and Principles for Regulation*, Discussion Paper 32, for a discussion of these issues.

5 Submission from AGLGN, July 16, p 1.

Ofwat states it is:

> … appropriate to assess the efficiency of operation expenditure and capital maintenance together. This approach helps to ensure companies are not unduly penalised, or rewarded, because of the way they choose to minimise expenditure, or the way in which they allocate expenditure (Ofwat 1999, p 28).

Ofwat suggests a superior way of assessing performance is to develop overall measures of efficiency using techniques such as DEA and stochastic frontiers. Water companies support the regulator's opinion that overall efficiency, or at least the interaction between capital expenditure and operating costs, be used to assess performance. The water companies share Ofwat's concern that treating capital expenditure and operating costs separately will reduce incentives to operate efficiently (Ofwat 1998).

The UK gas and electricity regulator, the Office of Gas and Electricity Marketing (Ofgem) states:

> When setting a price control it is important to give PESs [Public Electricity Suppliers] properly balanced incentives between capital and operating spending. If incentives are unbalanced, PESs may either reclassify one type of expenditure as another, or, faced with alternative capital and operating spending choices, make decisions which have higher overall cost to the customer in the long run (Ofgem 1999, p 16).

Ofgem notes that several techniques, such as partial productivity measures, regression analysis, DEA, and stochastic frontiers, can help assist the regulator to form judgments on the overall efficiency of the PESs. It uses regression analysis to help form a judgment on the overall efficiency of the PESs. Most PESs accept that this approach assists in comparing their performance.

1.5 Measuring efficiency

People usually associate improvements in efficiency with reductions in services or employment. They make this connection because business and governments often pursue these options to improve their finances. However, there are other, less publicised ways of improving efficiency. These include introducing flexible work practices and achieving economies of scale or scope. Therefore, it is possible to improve efficiency by increasing the production of goods and services with a given set of inputs. Service quality improvements can also increase efficiency provided they increase the value of the output by more than the cost of producing it. The variety of ways of improving efficiency underlines the need for a precise definition of 'efficiency' when assessing performance.

Efficiency is a relative concept. It is measured by comparing an organisation's actual ratio of outputs to inputs to the 'optimal' ratio of outputs to inputs. There are several aspects to efficiency.

Technical efficiency is a measure of an organisation's ability to convert inputs into outputs, that is, to either maximise outputs given inputs or to produce given outputs with minimal inputs. The management practices of an organisation or its size can influence technical efficiency.

Allocative efficiency is a measure of the ability of an organisation to utilise a combination of inputs to minimise the cost of production, given input prices.

Overall efficiency is the combination of technical efficiency and allocative efficiency.

Some commentators extend the concept of efficiency to include dynamic efficiency. This measures the success which organisations alter production processes over time in response to changes in consumption patterns or technology.

Increased efficiency improves the productivity of the organisation (ie an increase in the production of goods and services for a given set of inputs). The introduction of new technologies is another way that an organisation can increase productivity.

As noted above, there are several techniques that can assess the productivity or efficiency of an organisation. Moreover, some techniques, such as DEA, can assess whether productivity growth is due to technical change or improved efficiency or both. However, information on the outputs and inputs over time is required to assess growth in productivity. The information available for the gas benchmarking exercise is restricted to one year, therefore only the relative efficiency of the gas distributors is measured at a point in time. Therefore, the results of the study should be interpreted with care because a distributor could appear relatively inefficient, at a particular point in time, because it is following an optimal investment plan to achieve dynamic efficiency.

To help establish world best practices for efficient gas distribution, the study benchmarked the local distributors against US counterparts. There were several reasons for assessing only the technical efficiency of the local gas distributors.

First, some local distributors are government organisations which may have different objectives and constraints from private providers (eg community service obligations). This may restrict their ability to maximise profits or minimise costs.

Second, comparing the technical efficiency of distributors avoids the difficulties associated with obtaining information on the appropriate price of inputs eg wages and salaries or the price of capital. Difficulties in obtaining this information arise due to continuing controversy concerning the correct method of calculating the price of capital. Market characteristics for inputs vary between regions, probably distorting input prices. Whereas, the Industrial Relations Commission has a large influence on the price of labour in Australia, the market exerts a larger influence on the price of labour in the USA. Therefore, judgments on the performance of public and private providers are often made on comparisons of technical efficiency only.

No single technique can provide a complete picture of performance because each relies on assumptions which limit the veracity of the results. Therefore, a sensible and prudent approach to benchmarking requires the use of several techniques. Irrespective of the technique used, judgment is required to assess performance. The following techniques are used in this study to help establish local and international efficiency benchmarks for the local distributors:

- partial productivity measures
- regression analysis
- data envelopment analysis
- corrected ordinary least squares (COLS)
- stochastic frontiers.

These techniques are discussed in Chapter 2.

1.6 Consultation

Several workshops were held to explain the benchmarking exercise to industry and community participants and to present the initial results of the exercise. The participants' comments on the initial results helped refine the data and the analysis. A list of participants at the workshops is presented in Attachment 1. A brief information paper on DEA was prepared to help participants improve their understanding of the technique.

The Tribunal engaged Dr Tim Coelli, Senior Lecturer in Econometrics at the University of New England, to assist it with the benchmarking exercise. Dr Coelli provided advice on:

- the choice and use of benchmarking techniques
- use of these techniques to benchmark the gas sector
- interpreting the results of the exercise.

1.7 Structure of this discussion

The remainder of the paper is structured as follows: Chapter 2 discusses the techniques used in the benchmarking study. Chapter 3 presents productivity and efficiency trends in gas distribution. Chapter 4 discusses partial productivity measures for local and US distributors and analyses the potential cost drivers of gas distribution. Chapter 5 presents measures of efficiency for the local distributors suggested by DEA, COLS and stochastic frontiers. Chapter 6 provides some concluding remarks.

2 TECHNIQUES FOR EFFICIENCY MEASUREMENT

The techniques used in the benchmarking exercise are outlined below. Other techniques for efficiency measurement are discussed and reasons given for their exclusion from the study. The discussion below draws upon Coelli, Rao and Battese (1998), London Economics (1999), Lovell (1993) and the Steering Committee for the Review of Commonwealth/State Service Provision (1997). In particular, Coelli, Rao and Battese (1998) provide a good introduction to the economic concepts which underpin efficiency measurement.

2.1 Partial productivity measures

Partial productivity measures are usually the physical ratio of an output to an input or the recurrent cost of a unit of output. Strictly, measures of technical efficiency relate to physical partial productivity measures. For example, a physical partial productivity measure for gas distribution is throughput of gas per kilometre of main. Unit cost measures best reflect the overall efficiency of an organisation.

Because the measures are simple to calculate and are easily understood by decision-makers and the general public, partial productivity measures are widely used to assess the efficiency of organisations.

However, partial productivity measures need to be interpreted with care. By definition they are partial indicators which do not consider the relationships or the various trade-offs between outputs and inputs. This is likely to restrict their usefulness in interpreting the performance of an organisation which has multiple outputs and inputs. For example, an organisation could improve its labour productivity by replacing labour with capital.

Using a combination of several partial productivity measures may provide a broader assessment of performance. However, it is difficult to determine the overall efficiency of an organisation if the measures move in opposite directions. Furthermore, the measures for different organisations can vary for reasons other than inefficiency, eg an organisation may deliver services in a different physical environment, have a different mix of clients, or use different technology. Consequently, decision-makers, both in government and business, are increasingly using techniques that provide a broader perspective of performance to measure the efficiency of organisations. Information on the major outputs and inputs of an organisation is combined to provide a single measure of efficiency.

2.2 Regression analysis

Farrell (1957) suggested a mathematical programming technique and a parametric technique to measure the efficiency of an organisation relative to best practice. These approaches were forerunners to DEA and stochastic frontiers. Until recently, researchers persisted with traditional parametric approaches, such as ordinary least squares (OLS), to estimate a production function or cost function which produce measures of efficiency that are influenced by average practice.[6] The efficiency of an organisation is ranked by calculating the difference between observed performance and average performance (ie the residuals). The most efficient organisation has the largest positive residual when a production function is estimated. Conversely, the most efficient organisation has the largest negative residual when a cost function is estimated.

The estimation of cost functions assumes that the main objective of organisations is maximising profits or minimising costs, which are often heroic assumptions. Further, multiple outputs must be combined into an aggregate measure of output before OLS (or another estimator) can be used to estimate the production function. To measure the efficiency of water and sewerage services in the UK, Ofwat (1998, 1999) uses regression analysis to estimate cost functions. Similarly, Ofgem (1999) uses regression analysis to estimate cost functions for electricity distribution.

In this study, regression analysis is used to help assess the main cost drivers for gas distribution. The relationship between O&M costs and potential cost drivers is examined purely from a statistical viewpoint. It is not based on the economic theory that underpins the production or cost functions of gas networks because this analysis requires information on outputs and input prices (Varian 1992; Coelli, Rao and Battese 1998). Regression analysis helps to determine the emphasis that should be placed on the various partial productivity measures.

2.3 Data envelopment analysis

A mathematical programming technique, DEA combines outputs and inputs to produce a single measure of efficiency. The technique does not require information on prices to measure the technical efficiency of an organisation. DEA identifies best performing organisations by their ability to produce the greatest outputs with a given level of inputs or to produce certain outputs with minimum inputs. Best practice organisations form the efficiency frontier. The efficiency of other organisations is determined by measuring their performance relative to best performers (or peers) which have a similar mix of outputs and inputs. This means, the relative efficiency of a small regional gas distributor is influenced by similar best practice organisations and not by efficient large metropolitan distributors. In this exercise, the efficiency of the distributors is assessed by their potential to reduce inputs, given certain outputs. The relationship between the inputs and the outputs is described by an input distance function.

An input distance function describes multiple output and multiple input technology without recourse to specific behavioural assumptions such as profit maximisation or cost minimisation. Assuming outputs are fixed, the input distance function seeks to proportionately reduce the vector of inputs by the largest margin. Further information on distance functions is presented in Coelli, Rao and Battese (1998) and Färe and Grosskopf (1996).

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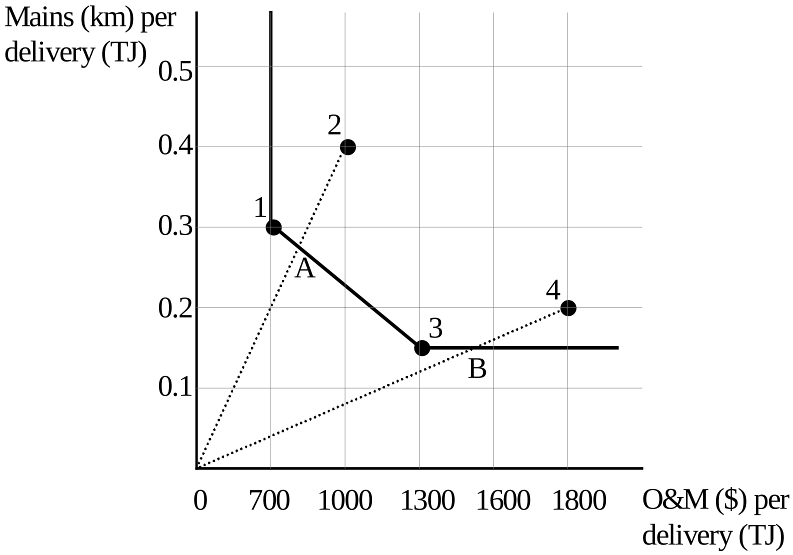
6 A 'production function' is a technical relationship which depicts the maximum output for a given level of inputs. A 'cost function' describes the minimum cost of producing certain outputs. In the literature on productivity measurement a production function is referred to as a 'production frontier'. Similarly, a cost function is known as a 'cost frontier'.

Figure 2.1 illustrates the application of DEA where the objective of the gas distributors is to minimise inputs, given outputs. Furthermore, it is assumed that the distributors have constant returns to scale. In this simple example, the output of gas distribution is deliveries of gas and the inputs are length of mains and O&M costs.

Figure 2.1 Hypothetical example of the efficiency of gas distribution



Here, the distributors closest to the origin require the least mains and O&M costs to deliver gas. Therefore, they are deemed efficient. The line joining Distributor 1 and Distributor 3 is the efficient frontier. The frontier runs parallel to the vertical and horizontal axis because DEA envelops all the points. Distributors 2 and 4 are less efficient than the other distributors because they lie above the frontier. The technical efficiency score for Distributor 2 is determined by the ratio 0A/02, which is about 0.67.[7] Distributor 2 could potentially reduce all its inputs by about 33 per cent to produce the same output. The technical efficiency of Distributor 4 is the ratio 0B/04, which is 0.75. Therefore, Distributor 4 could potentially reduce all inputs by 25 per cent to produce the same output.[8]

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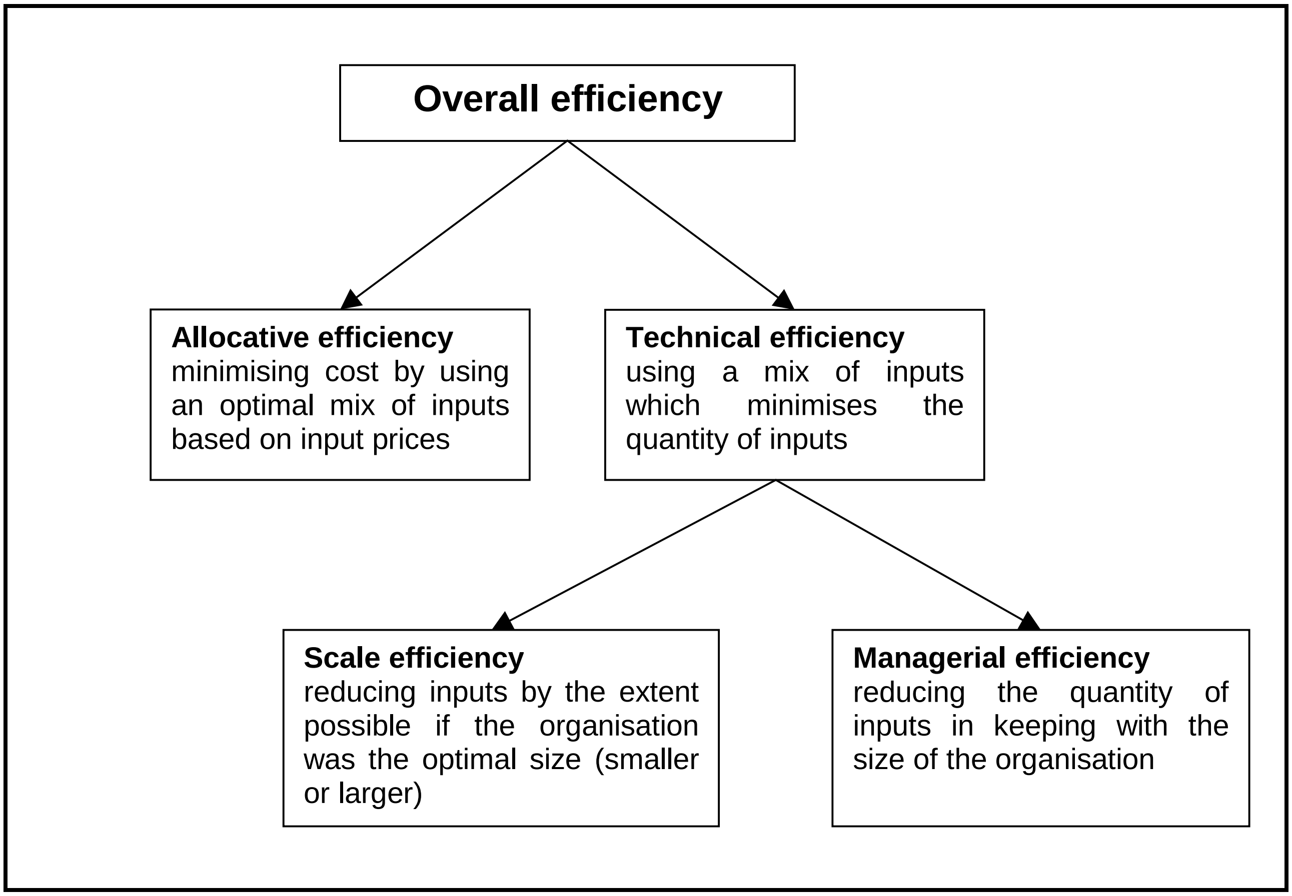
7 In an input-orientated DEA model, all efficiency scores lie between zero and one. An efficient organisation has an efficiency score of one.

8 It could be argued that Distributor 4 could reduce O&M costs further and move from point B to point 3 on the frontier. That is, the distributor has an input slack in O&M costs. Some people argue that both the efficiency score and the presence of input slacks should be reported to obtain a better assessment of the efficiency of the Distributor 4. Input slacks arise when a distributor is projected on to the vertical or horizontal sections of the frontier. However, a larger sample of distributors would minimise the vertical and horizontal sections of the frontier, reducing the probability of slacks occurring. See Coelli, Rao and Battese (1998) for further information on input slacks.

This is a simple example of using DEA to assess the efficiency of a distributor. If more outputs, inputs, distributors, or all three are included in the analysis, computer packages are required to solve the linear programs which reveal the efficiency of each distributor. The various linear programs and specialist DEA computer programs are explained by the Steering Committee for the Review of Commonwealth/State Service Provision (1997) and Coelli, Rao and Battese (1998). Attachment 2 presents the linear programs used in this benchmarking exercise.[9]

In theory, DEA can measure the overall efficiency of an organisation and decompose it into various measures of efficiency, see Figure 2.1. Determination of allocative efficiency requires reliable and comparable relative price data, which can be difficult to obtain.

Figure 2.1 Aspects of efficiency



DEA can determine whether the source of technical inefficiency is due to the managerial capabilities of an organisation, the scale of operations, or both.[10] In addition to informing managers about the efficiency of their organisation, DEA provides less efficient organisations with information on an efficient mix of outputs and inputs (ie targets), and lists role models (peers) the organisations could consult to help improve their efficiency.

9 DEAP Version 2.1 (Coelli 1996a) is used to calculate the various measures of technical efficiency.
10 Further analysis is required to determine if some inefficiency is due to the operating environment.

DEA can examine the influence of the operating environment (which is beyond the control of management), on the efficiency of an organisation, eg climate, population density and age of capital. Ali and Lawrence (1993), Coelli, Rao and Battese (1998) and the Steering Committee for the Review of Commonwealth/State Service Provision (1997) discuss various approaches including the operating environment in DEA.

This study assesses the impact of certain environmental variables (such as climate and age of the network) on the efficiency of gas distribution. If at least one of the environmental variables has a statistically significant influence on the efficiency of gas distribution, regression coefficients are used to adjust the efficiency of the distributors.

Despite its uses, DEA has its limitations. Like any model, it presents a simplified view of the real world. It cannot mirror all the factors which influence performance. Only those factors considered most important can be included in DEA, and decisions on the structure of the model are crucial to its success.

An important limitation is that DEA is a deterministic, rather than a statistical technique. Hence, there is limited scope for statistical tests of significance to assist model design. Reliance is often placed on expert advice and industry forums in designing the model. Furthermore, the results may be sensitive to outliers in the data, which may, in turn, be due to errors in the data or may reflect other random events such as climate. By distorting the frontier, the outliers reduce the apparent efficiency of similar organisations.[11]

Another limitation of DEA is that it is sensitive to the specification of the number of inputs and outputs included and the size of the sample. Increasing the sample size cannot increase the efficiency scores but can reduce them because the new organisations may push the frontier outwards. Conversely, inflating the number of inputs and/or outputs cannot decrease efficiency scores but could increase them because the number of potential peers for each organisation could decline.

Despite these limitations, if interpreted with caution, DEA can be a useful tool for gaining insights into the efficiency of organisations.

2.4 Parametric counterparts to DEA

Corrected ordinary least squares and stochastic frontiers are parametric counterparts to DEA. As in our DEA exercise, the efficient frontier that we estimate by the parametric techniques is an input distance function.

Like DEA, COLS assumes that distance from the frontier denotes inefficiency. Therefore, the technique is susceptible to outliers. By contrast, stochastic frontiers is less susceptible to outliers because it considers the distance from the frontier may be due to a combination of inefficiency and random influences or statistical noise in the data beyond the control of an organisation. Moreover, stochastic frontiers permits tests of hypotheses, such as the existence of inefficiency.

11 The statistical approaches used to identify potential outliers in this exercise are discussed in Chapter 5.

Estimates of technical efficiency produced by these techniques are similar to the DEA measure of managerial efficiency.

Before COLS or stochastic frontiers are used to estimate the efficient frontier, a functional form is imposed on the input distance function. The functional form assumes the organisations use similar technology. However, the functional form bounds the data less tightly than DEA. This means COLS generally produces lower measures of technical efficiency than DEA does. As stochastic frontiers allow for noise in the data, it is unclear whether this technique produces higher or lower measures of efficiency than DEA. If there is little noise in the data, stochastic frontiers may produce lower measures of efficiency.

For this study, the input distance function is assumed to have a translog functional form. Coelli and Perelman (1996) and London Economics (1999) discuss the estimation of translog input distance functions.

2.4.1 Corrected ordinary least squares

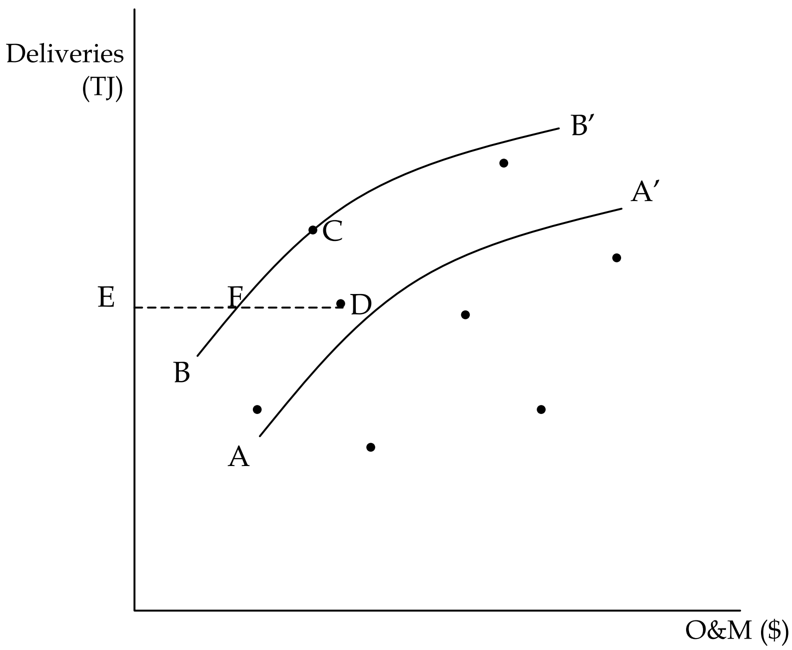
COLS uses a two step procedure to estimate the frontier, see Figure 2.2. The input distance function in this figure is simplified, with a single input (O&M costs) producing a single output (deliveries). The distributors are assumed to possess variable returns to scale.

COLS initially estimates the average practice frontier (AA') by OLS and then creates the efficient frontier (BB') by shifting the intercept upwards until all the estimates of the random influences (the residuals) are non-positive and at least one residual is zero (ie distributor C creates the efficient frontier BB').[12] The efficiency of other distributors is determined by the proportional reduction in O&M costs by holding deliveries constant. For example, the efficiency of distributor D is EF/ED.

The COLS frontier can be represented by the function, $x_i=\exp(g(y_i,\beta)-u_i)$, where x_i is the input of the i-th firm, y_i is the output of the i-th firm, β is a vector of parameters to be estimated, g() is a suitable functional form (eg translog) and the u_i are non-negative measures reflecting inefficiency.

12 The econometrics program, SHAZAM Version 7.0 (White 1993), is used to estimate the input distance frontier by COLS to produce measures of technical efficiency.

Figure 2.2 COLS input distance function



The corrected residual for distributor D is used to estimate its efficiency (ie EF/ED). Similarly, corrected residuals are used to calculate the technical efficiency of the other distributors in the sample.[13] No functional form is imposed on the disturbances, however, they are assumed to be independent of the explanatory variables in the input distance function (ie the disturbances are not correlated with the inputs and the outputs). Environmental variables, such as climate, can be directly included in the distance function to assess the impact that these variables have on the efficiency of the distributors.

Lovell (1993) notes several limitations associated with COLS. The technique adjusts the intercept coefficient to form the efficient frontier but leaves the original OLS estimates of the slope parameters unchanged. This implies that the structure of the technology of the efficient frontier (eg scale and substitution characteristics) is similar to technology used by inefficient organisations. Consequently, COLS applies same efficiency ranking to the organisations as OLS.

As noted above, COLS is susceptible to outliers. Outliers shift the frontier further to the left in Figure 2.2, which reduces the efficiency of all the less efficient organisations. By contrast, outliers reduce only the efficiency of nearby organisations in DEA.

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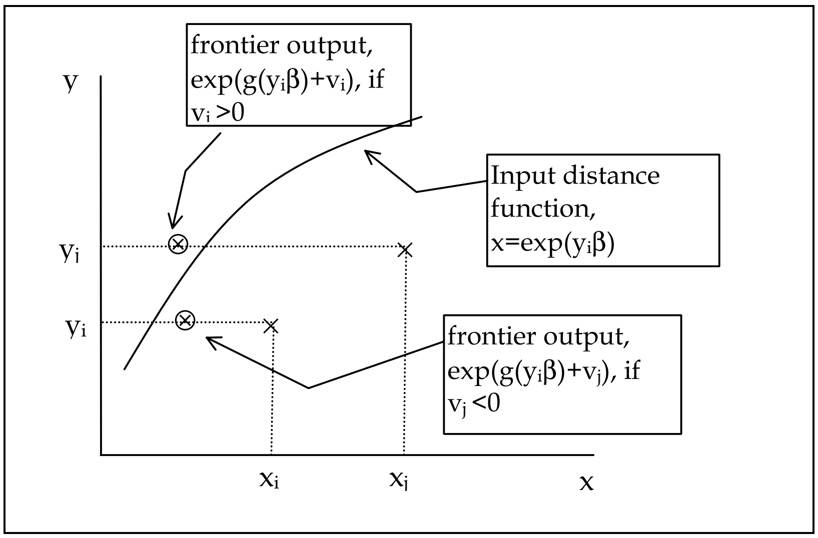
13 The expression to calculate technical efficiency is $TE_i=\exp\{u_i\}$, where TE_i is the technical efficiency score of the i-th organisation and u_i is the disturbance term (corrected residual) of the i-th organisation. All technical efficiency scores lie between zero and one (ie $0<TE_i \le 1$). See Lovell (1993) and Coelli, Rao and Battese (1998) for further details.

2.4.2 Stochastic frontiers

Stochastic frontiers differs from COLS in several important respects. First, it includes a random error (v_i) that reflects measurement error and other random effects that influence the outputs of an organisation. Thus the model becomes $x_i=\exp(g(y_{i,}\beta)+v_i-u_i)$. The random variable ($v_i$) can be positive or negative, which allows the stochastic inputs in Figure 2.3 to vary about the deterministic part of the frontier ($x=g(y,\beta)$[14])).[15] In this simple example, one input (x), say, O&M costs, produces one output (y), say, deliveries of gas, and the deterministic part of the frontier has varying returns to scale.

Figure 2.3 Stochastic frontier input distance function



The observed output and input for the i-th and j-th distributors is denoted by x in the figure above. The random variable associated with i-th distributor is positive, therefore the stochastic output lies above the deterministic part of the frontier. Conversely, the random variable associated with the j-th distributor is negative so the stochastic output lies below the deterministic part of the frontier.

The input distance stochastic frontier is estimated by the maximum likelihood method.[16] A statistical procedure (involving conditional expectations) is used to decompose the residuals into inefficiency and other random effects (Battese and Coelli 1988). Environmental variables, such as climate and age of network, may be included in the model to assess their influence on

14 β is a vector of parameters which must be estimated.

15 Figure 2.3 is adapted from Coelli, Rao and Battese (1998).

16 The program FRONTER Version 4.1 (Coelli 1996b) is used to estimate the input distance function. This program produces measures of technical efficiency and tests for the presence of inefficiency. The SHAZAM code used to estimate the input distance function by COLS is used to manipulate the inputs and outputs into a suitable form before FRONTIER is used to estimate the input distance frontier.

the inefficiency of gas distribution.[17] Statistical tests are used to detect inefficiency in gas distribution.

2.5 Total factor productivity measurement

Total factor productivity (TFP) measurement is often used to measure the productivity of a single organisation. However, it can also compare the productivity of several organisations. TFP measurement uses index number theory to form a ratio of aggregated outputs to aggregated inputs to measure productivity.[18] Price information is required to combine the outputs and inputs into a single measure of output and a single measure of input.[19]

Unlike DEA and stochastic frontiers, TFP measurement cannot decompose productivity growth into efficiency and technological change. Most researchers assume organisations are efficient and attribute productivity growth to changes in technology. Information for at least two periods (usually years) is required to form an index to measure productivity. The information for the current exercise is restricted to one year. This excludes the use of TFP measurement to benchmark the productivity of gas distribution. For further information on TFP measurement see Coelli, Rao and Battese (1998), Grosskopf (1993), and the Steering Committee on National Performance Monitoring of Government Trading Enterprises (1992).

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[17] An alternative method is to assume that environmental variables influence the shape of the technology for gas distribution, and to include environmental variables directly in the input distance frontier. With this approach, the efficiency scores exclude the influence of operating environment and are comparable to DEA scores adjusted for the operating environment. For the approach used in this study, further statistical manipulation of the efficiency scores is necessary if the operating environment has a significant influence on the distributors' efficiency. This will make the efficiency scores comparable to DEA scores adjusted for the operating environment. The method of adjusting the stochastic frontiers efficiency scores to exclude the operating environment, and further details on the two ways of including environmental variables in stochastic frontiers, are presented in Coelli, Perelman and Romano (1999).

[18] Index numbers are commonly used to measure changes in economic variables. The Consumer Price Index and financial indicators such as the All Ordinaries Index (Australia) and the Dow Jones Index (USA) are well-known index numbers.

[19] Price information is used in calculating Fisher and Tornqvist index numbers. When one has access to panel data one can also calculate Malmquist index numbers using DEA or parametric methods. See Coelli, Rao and Battese (1998) for further information on these index numbers.

3 PRODUCTIVITY AND EFFICIENCY TRENDS IN GAS DISTRIBUTION

Productivity and efficiency trends in gas distribution help to determine potential productivity growth for local gas distributors. Productivity estimates for other sectors of the Australian economy and the OECD also help to assess the relative performance of the local distributors.

3.1 Australia's productivity performance

Between 1964-65 and 1994-95, the average annual increase in the productivity of the Australian economy (measured by multifactor productivity (MFP)[20]) was about 1.5 per cent (ABS Cat. No. 5234.0). However, productivity growth varied markedly over the period. For example, between 1968-69 and 1973-74, MFP growth was 2.1 per cent. For the periods, 1973-74 to 1981-82 and 1981-82 to 1984-85 MFP growth was 1.5 per cent. For 1984-85 to 1988-89 MFP growth was only 0.8 per cent. The ABS does not present productivity figures for various sectors of the economy. However, the Industry Commission (1997) suggests that the contribution of various sectors towards improving the productivity of the economy is mixed.[21] The table below summarises Industry Commission estimates of sectoral productivity growth.

Table 3.1 Average annual rate of multifactor productivity growth in the market sector, by industry sector, various periods 1974-75 to 1994-95 (%)

Industry sector	1974-75 to 1981-82	1981-82 to 1984-85	1984-85 to 1988-89	1988-89 to 1994-95	1974-75 to 1994-95
Agriculture	2.3	3.7	-1.1	0.1	1.2
Mining	-3.7	5.2	0.3	1.0	-0.2
Manufacturing	2.4	1.8	1.7	1.8	2.0
Electricity, gas and water	2.2	1.4	4.4	3.6	2.9
Construction	2.5	0.1	-0.9	-0.4	0.6
Wholesale trade	0.3	-2.5	1.4	0.4	0.1
Retail trade	1.0	2.8	-2.0	0.4	0.5
Accommodation, cafes and restaurants	-0.7	-2.8	-1.7	-1.0	-1.3
Transport, storage and communication	3.6	2.1	3.1	3.6	3.3
Cultural and recreation services	0.1	-1.7	-3.5	-1.5	-1.4
Total	**1.5**	**1.1**	**0.7**	**1.2**	**1.2**

Source: Industry Commission (1997).

20 Multifactor productivity differs from TFP measurement in that it refers only to the ability of capital and labour to produce outputs. TFP measurement also includes other inputs such as materials and fuel.

21 ABS MFP growth estimates differ slightly from the totals in Table 3.1 because of different methodological assumptions adopted in the Industry Commission's calculations.

The transport, storage and communication sector, the electricity, gas and water sector and the manufacturing sector provided sustained strong contributions to MFP growth. Over the 20 years to 1994-95, the electricity, gas and water sector achieved average annual productivity gains of 2.9 per cent. Only in the period 1981-85 did the gains fall below an average of 2 per cent.

3.2 Australia's relative productivity performance

International comparisons of productivity growth provide a broader assessment of Australia's ability to improve productivity growth. According to the Industry Commission (1997), Australia's annual rate of MFP growth was about 0.8 per cent between 1970 and 1994. The OECD average was about 1 per cent and the average of the G7 countries (excluding the USA) was 1.3 per cent.

Only the USA and Canada had lower MFP growth than Australia. The ability of the USA to improve productivity is limited, because as a productivity leader, it does not have the scope to improve productivity through catch-up like other OECD countries. Canada's productivity growth is strongly linked to the US economy (Industry Commission 1997).

Australia's overall performance on productivity growth is less than that of other OECD country groups. However, the information presented in Table 3.2 suggests that some sectors of the Australian economy achieved higher productivity growth than their international counterparts. In particular, the transport, storage and communication, and electricity, gas and water sectors achieved higher productivity growth. Rates of growth for these two sectors reflect a catch up in productivity growth because their productivity base was relatively low.

Table 3.2 Multifactor productivity growth by sector, selected OECD country groups, 1970-1994 (%)

Sector	Australia	USA	Other G7	Small OECD	OECD average
Agriculture	1.4	2.3	1.6	3.0	2.1
Mining	0.1	-1.0	-1.3	0.4	-1.1
Manufacturing	1.8	1.5	1.6	2.8	1.6
Electricity, gas and water	2.7	0.1	-0.6	2.1	-0.2
Construction	-0.2	-1.1	-0.4	0.2	-0.6
Wholesale and retail	-0.1	0.6	0.8	1.2	0.7
Transport, storage and communication	3.4	2.8	1.7	1.9	2.1
Finance, insurance and real estate	-0.7	-0.1	0.0	0.0	-0.1
Community, social and personal	0.1	-0.8	-1.1	0.1	-0.8

Source: Industry Commission (1997).

3.3 Scope for further productivity improvement

Potential for the increased productivity of various sectors of the Australian economy is presented in Table 3.3. Care is required in interpreting these results. For most countries, the estimates are an average for the period, 1990-93. The partial productivity measures, labour productivity and capital productivity, can vary for reasons other than inefficiency.[22] For example, variation in the productivity measures may reflect different resource endowments, industry composition, exploitation of catch-up opportunities, or the use of different technologies.

Table 3.3 Labour and capital productivity levels by sector, selected OECD countries, 1990-93

Type/sector	Australia	USA	Other G7	Small OECD	OECD
Labour					
Agriculture	54	100	37	59	51
Mining	95	100	45	64	75
Manufacturing	66	100	73	63	81
Electricity, gas and water	54	100	80	69	86
Construction	86	100	88	86	92
Wholesale and retail trade	75	100	80	84	89
Transport, storage and communication	63	100	57	54	71
Capital					
Agriculture	82	100	54	63	68
Mining	131	100	88	142	98
Manufacturing	94	100	97	73	97
Electricity, gas and water	67	100	117	75	105
Construction	49	100	68	54	74
Wholesale and retail trade	116	100	92	57	95
Transport, storage and communication	89	100	99	78	98

Source: Industry Commission (1997).

The data suggests that the sectors which have contributed strongly to Australia's productivity growth over recent years, such as transport, storage and communication, electricity, gas and water, and manufacturing have relatively low productivity compared to the USA, Other G7 countries and the OECD. These results suggest there is significant potential to further improve the productivity of these sectors.

22 Labour productivity levels are obtained by dividing sector output (value added at market prices at 1990 prices and 1990 purchasing power parity in $US) by the number of workers in the sector averaged over four years. Capital productivity is derived by dividing sector output by gross capital stock at 1990 prices and 1990 purchasing power parity ($US) averaged over four years.

3.4 Potential productivity improvements for local gas distribution

Productivity in the electricity, gas and water sector provides indicative information on the potential productivity growth for the local gas distributors. However, specific benchmarking studies on gas distribution provide a better indication of the potential productivity improvements for the local distributors because of the greater likelihood of comparing like with like.

Several industry and government exercises provide partial productivity measures which can be used to assess the productivity of gas distribution. The Australian Gas Association (AGA) (1998) presents partial productivity measures for gas distribution for most Australian states. The Access Arrangement Information (AAI) which distributors lodge with their state regulators, presents information on the efficiency of local gas distributors. Information on the measures of efficiency varies quite markedly. Whereas, Envestra (1999a) has a broad range of key performance indicators (KPIs) for its South Australian network, AGLGN (1999) has developed two partial productivity measures to benchmark its performance against local and US distributors. This paper extends AGLGN's approach by developing additional productivity measures, to provide a broader assessment of AGLGN's performance. The results of this exercise are discussed in Chapter 4. A Council of Australian Governments' (COAG) exercise (SCNPMGTE 1997) has developed consistent partial indicators of efficiency and effectiveness for government-owned gas distributors.

Several studies use total factor productivity techniques, such as DEA and TFP measurement, to help estimate potential improvements in productivity or efficiency for local gas distributors. The Bureau of Industry Economics (BIE) (1994) uses DEA to benchmark the efficiency of local gas distributors against international counterparts. Rushdi (1994) uses TFP measurement to estimate the productivity growth of the Gas and Fuel Corporation of Victoria.

International studies provide further insights into potential productivity gains for local gas distributors. Price and Weyman-Jones (1996) use DEA to measure the productivity change in gas distribution before and after the privatisation of the UK utility, British Gas. Kim et al (1999) use DEA and TFP measurement to compare the productivity and efficiency of a Korean gas distributor with international counterparts.

3.4.1 AGA productivity measures

AGA (1998) presents several partial productivity measures including customers per full-time equivalent (FTE) employee, customers per kilometre of main, and unaccounted for gas (UAG) as a percentage of gas issued.[23] It also presents information on market, operation, and customer and service indicators. Market indicators include households connected to gas as a percentage of all households and households with access to gas mains, number of customers and gas sold. Customer and service indicators include average sales per customer (GJ) and average bill per customer.

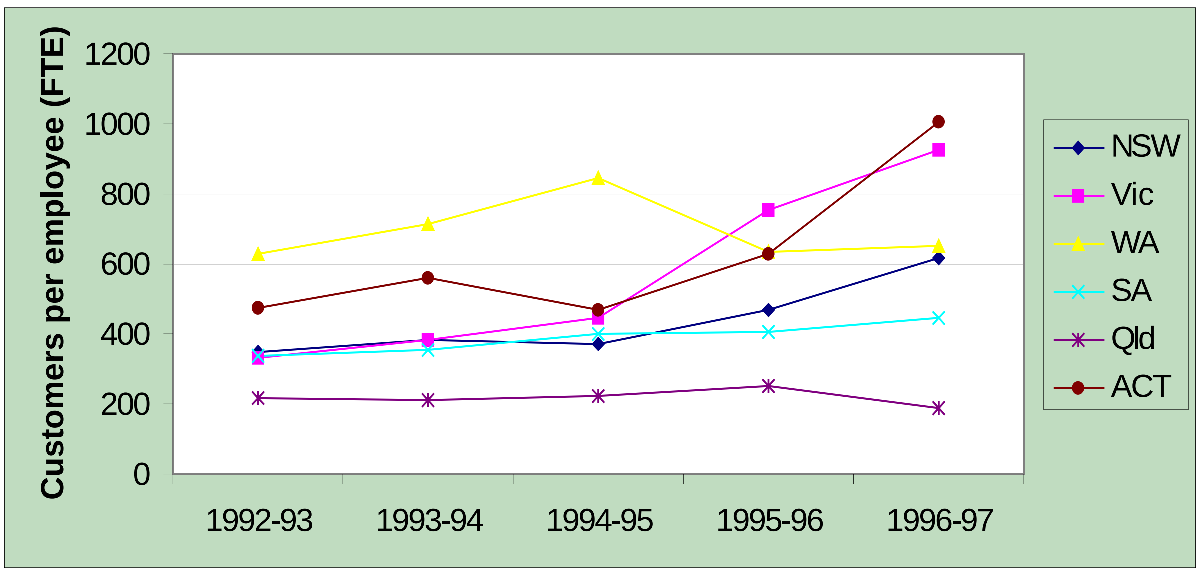
[23] UAG is the difference between the quantity of gas that is metered as having entered the gas system, and the (metered) amount delivered to end-users. UAG can arise from losses from the system, metering error or theft.

The AGA performance indicators are presented at the state level, only, providing limited insights into the performance of local distributors. However, the operation indicators developed by AGA are designed to provide broad insights into the productivity and efficiency of gas distribution in each state. The discussion on these indicators is confined to partial productivity measures.

Customers per employee is a measure of the labour productivity of gas distribution. Customers per kilometre of main is a measure of capital productivity. UAG is an aspect of quality of service because customers usually bear the cost of UAG according to prescribed targets set by state regulators.[24] Lowering prescribed targets for UAG will then lessen the costs of UAG that are borne by customers.

Labour productivity

Figure 3.3 Customers per FTE employee



Source: AGA (1998).

The labour productivity of distributors in most states improved between 1992-93 and 1996-97. In particular, the labour productivity of the VIC distributors increased by about 180 per cent and the labour productivity of the distributor in the ACT (AGLGN (ACT)) improved by about 110 per cent. Conversely, the labour productivity of distributors in QLD declined by about 12 per cent.

24 The distributor bears the cost of UAG which occurs in excess of the prescribed standard and reaps the benefit of the gains of UAG which are less than the prescribed standard.

In 1992-93, NSW, VIC and SA had similar ratios of customers per employee. However, by the end of the period, SA labour productivity was about half VIC labour productivity and NSW labour productivity was about 30 per cent less than VIC labour productivity.

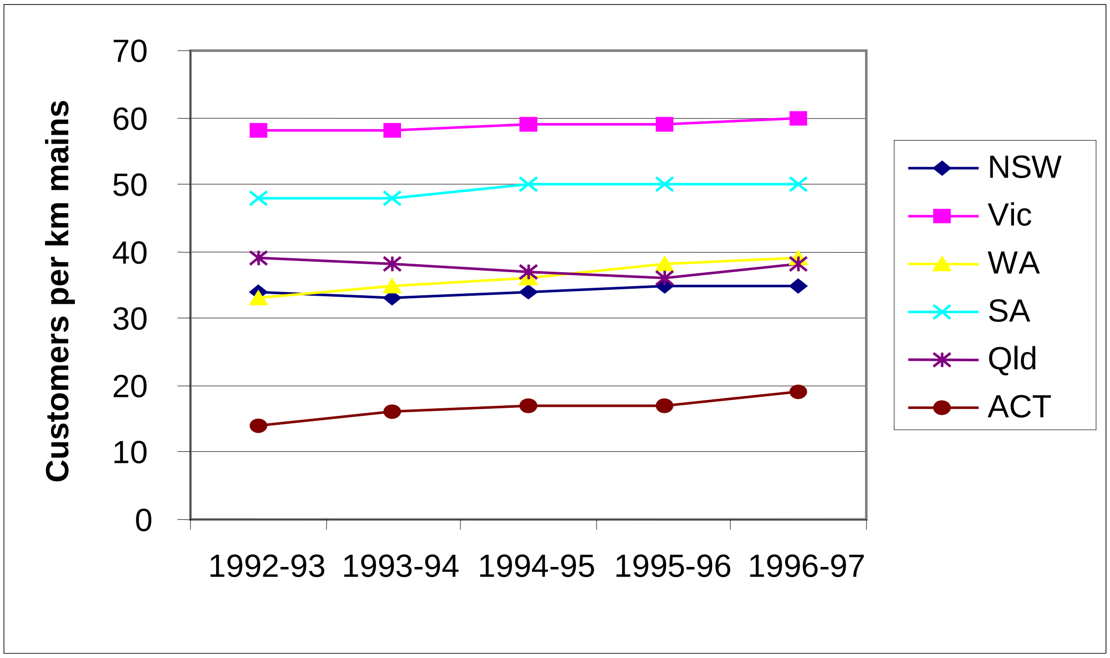
Caution is required in interpreting these results. The AGA does not use a consistent definition of employee numbers to construct customers per FTE employee. Some state figures include employees involved in utility functions only and exclude employees in appliance retailing and computer services. Employee numbers for other states include those employees. Therefore, differences in labour productivity may reflect differences in the definition of employees for each state. Furthermore, distributors are hiring contractors to undertake tasks such as meter reading, which were traditionally done by employees. Given that growth in customers was about 10 per cent for most states (AGA 1998), the differences in labour productivity, to a large extent, could reflect the distributors' decision to substitute contractors for employees.

Capital productivity

Growth in capital productivity in gas distribution has been relatively modest over 1992-93 to 1996-97. In the ACT and WA, capital productivity increased by 36 per cent and 18 per cent, respectively. However, these states do not have relatively high capital productivity. The other states achieved improvements in capital productivity of about 3 to 4 per cent. Capital productivity declined by about 2 per cent in QLD.

VIC has the highest capital productivity in Australia's gas distribution industry. Several factors, such as climate and the relative prices of retail gas and electricity, may contribute to the VIC distributors' superior capital productivity. Customers per kilometre of main is a proxy for population density. Therefore, the higher population density may enable the VIC distributors to achieve relatively high capital productivity compared to distributors in other states which have less dense urban populations. These factors are discussed in further detail in Chapter 4.

Figure 3.4 Customers per kilometre of main



Source: AGA (1998).

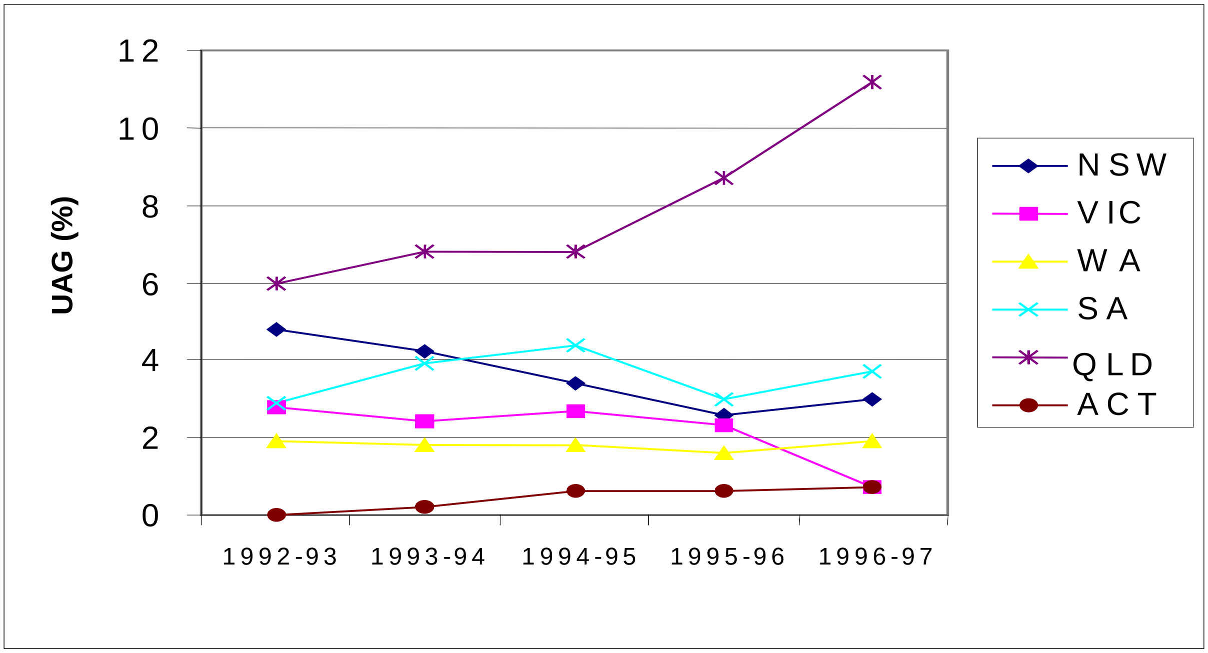
Nevertheless, the VIC distributors have continued to achieve capital productivity growth from a relatively high level of productivity. Although it may be argued that the VIC distributors had less scope to further improve their capital productivity, they achieved 3.4 per cent growth over the period, 1992–93 to 1996–97, which is higher than the NSW distributors' capital productivity growth of 2.9 per cent.

Unaccounted for gas

There are marked differences in the ability of distributors to reduce UAG as a percentage of gas issued. VIC and NSW distributors reduced UAG by 75 per cent and 37.5 per cent respectively over 1992-93 to 1996-97. The VIC result is driven mainly by reductions in UAG between 1995-96 and 1996-97. Prior to 1996-97, NSW achieved the largest reductions in UAG. However, in 1996-97, NSW UAG increased.

Between 1992–93 and 1996-97, UAG increased by about 87 per cent in QLD. This reflects a large increase in UAG for Envestra QLD, from 4.6 per cent to 14.1 per cent in 1992-1996. The increase is attributed to its decision to convert to natural gas from town gas in 1995-96. This caused the lead joint connections between the cast iron mains to deteriorate (Envestra 1997).

Figure 3.5 UAG as percentage of gas issued



Source AGA (1998).

The information on UAG should be treated with caution. The Tribunal has previously expressed concern over the accuracy of the AGA's statistics on UAG (IPART 1999b). The published UAG figure for NSW is 3 per cent for 1996-97. This figure appears relatively high compared with information supplied by AGLGN and the Albury Gas Company.[25] Consequently, the study has discounted the AGA's 1996-97 UAG figures.

3.4.2 COAG information

The Steering Committee on National Performance Monitoring of Government Trading Enterprises (1997) developed consistent performance indicators (KPIs) for the government-owned distributors, GASCOR (VIC)[26] and AlintaGas (WA). The project did not include privately owned utilities such as AGL. Selected efficiency, effectiveness and cost measures for these distributors are presented in Tables 3.4 and 3.5.

25 In 1997-98, AGLGN's UAG was 2.3 per cent and Albury Gas Company's UAG was 1.8 per cent.

26 On 11 December 1997, most functions, property, rights and liabilities of GASCOR were transferred to three grouped entities, each comprising a holding company, retailer, distributor, and two other companies that sell gas appliances or provide several services to the gas industry. The distributors are Multinet Gas Pty Ltd, Westar Pty Ltd and Stratus Networks Pty Ltd.

Table 3.4 KPIs for GASCOR 1991-92 to 1995-96

	units	1991-92	1992-93	1993-94	1994-95	1995-96
Efficiency						
Customers per employee	Cus	251	291	334	400	564
Gas sales per employee:						
- distribution	TJ/Emp	np	np	np	52.9	73.2
- overall	TJ/Emp	32.4	37.5	41.6	np	np
Reliability:						
- unplanned interruptions per 1000 customers	1/1000	1.4	0.9	1.6	1.2	2.1
- length of customer interruptions	Sec/Cus	93.8	17.3	349.5	60.0	384
Effectiveness						
Customers per kilometre of main	Cus	52.3	52.7	53.0	55.9	59.1
Gas sold per kilometre of main	TJ/km	6.7	6.8	6.6	7.4	7.7
UAG	%	1.7	1.7	1.4	2.7	2.3
Cost measure						
O&M costs per customer	$/Cus	259	241	203	199	194

Note: np – not provided.
Source: SCNPMGTE (1997).

The information presented in Table 3.4 indicates that GASCOR improved its performance over the period, 1991-92 to 1995-96, against most KPIs. Efficiency increased according to customers per employee, by 24.9 per cent per annum, and gas sales per employee-distribution and overall, which increased 19 per cent per annum and 9.5 per cent per annum, respectively. However, some improvement in efficiency is due to outsourcing services such as meter reading and mains and services maintenance. GASCOR's efficiency declined according to the reliability KPIs. Unplanned interruptions per 1000 customers increased by 10 per cent per annum. Length of customer interruptions increased by 61.9 per cent per annum.

GASCOR's effectiveness improved according to customers per kilometre of main, which increased by 2.6 per cent per annum. Gas sold per kilometre of main, increased by 3 per cent per annum. However, its effectiveness declined according to UAG, which increased by 7.1 per cent. O&M costs per customer declined by 5 per cent per annum.

The information available to assess AlintaGas' performance is less comprehensive. Nevertheless, the information in Table 3.5 suggests AlintaGas' performance is mixed. Its efficiency improved according to customers per employee, which increased by 8.8 per cent per annum. However, its efficiency declined according to the reliability KPIs. AlintaGas has stated that the decline in its performance is due to extensive damage to the network, which was caused accidentally by a third party.

Table 3.5 KPIs for AlintaGas

	Units	1991-92	1992-93	1993-94	1994-95	1995-96
Efficiency						
Customers per employee	Cus	424	481	419	585	611
Gas sales per employee:						
- distribution	TJ/Emp	np	np	np	117	119
Reliability:						
- unplanned interruptions per 1000 customers	1/1000	np	1.5	4.0	28.0	5.0
- length of customer interruptions	Sec/Cus	9	8	18	41	372
Effectiveness						
Customers per kilometre of main	Cus	30.8	32.1	33.5	36.1	38.8
Gas sold per kilometre of main	TJ/km	nr	nr	nr	5.1	5.0
UAG	%	0.4	0.3	0.9	nr	nr
Cost measure						
O&M costs per customer	$/Cus	np	np	np	nr	nr

Note: np – not provided, nr – not relevant.
Source: SCNPMGTE (1997).

In the period 1991-1992 to 1995-96, AlintaGas' effectiveness improved according to customers per kilometre of main by 5.2 per cent per annum. However, it declined according to UAG, which increased by 41.6 per cent per annum over 1991-92 to 1993-94.

3.4.3 Access Arrangement Information

The Code requires distributors to provide information on industry KPIs to justify 'reasonably incurred' costs (The Code, Attachment A). The information on KPIs presented in the Access Arrangement Information (AAIs) varies quite markedly. For example, Envestra (SA) Revised AAI (1999a) presents a broad range of KPIs, including several partial productivity measures used to assess its performance against other local distributors. These measures include:

- O&M costs/1000 kilometre of main ($m)[27]
- O&M costs/customer ($)
- O&M costs/throughput ($)/(GJ)
- system use gas (SUS) (GJ)/kilometre of main
- customers/kilometre of main
- average residential consumption (GJ/year).

[27] O&M costs is defined as non capital costs less system use gas. Envestra defines 'system use gas' as gas that is 'lost' or unaccounted for in the network, predominantly due to leakage and metering tolerances.

By contrast, the AGLGN (NSW) AAI (in various forms) (1999) provides only two KPIs – O&M costs per customer, and O&M costs per kilometre of main - to assess its performance against local and US counterparts. Selected KPIs for Envestra (SA) are presented in Table 3.6.

Table 3.6 KPIs for Envestra (SA) 1998-99

KPI	Envestra (SA)	Multinet	Stratus	Westar	AGLGN
O&M costs ($m)	33.9	38.5	32.3	31.9	101.8
$m/1000 km main	4.92	4.41	4.00	4.21	4.89
$/customer ($)	103	65	77	75	135
$/GJ	1.26	0.65	0.57	0.43	0.99
SUS (GJ)/main (km)	232	140	123	127	117
Customers/main (km)	48	67	56	57	36
Average residential consumption (GJ pa)	24.1	63.9	54.3	54.8	21.1

Note: Westar, Multinet and Stratus O&M costs exclude meter reading/billing costs as reported for the year ending 31 December 1999.
Source: Envestra (1999a).

These KPIs suggest that the VIC distributors are generally more efficient than Envestra (SA) and AGLGN (NSW). However, as previously mentioned, partial measures of efficiency may, to some extent, reflect different operating environments. Further, it is often difficult to make accurate assessments of some aspects of performance. For example, the distributors use different definitions of O&M costs. Assistance was sought from local distributors to reconcile differences in the cost components included in the public O&M figures released by the distributors. This issue is discussed further in Chapter 4. Nevertheless, the information in the COAG publication and the AAIs is superior to the information published by the AGA because it permits comparisons of performance for individual distributors.

3.4.4 Other information on the performance of local gas distributors

Several studies use techniques like DEA and TFP measurement which consider various trade-offs between inputs and outputs to measure the performance of gas distributors. The BIE (1994) and Price and Wayman-Jones (1996) examine the influence of different operating environments, such as climate and population density, on the efficiency of gas distribution. The results should be interpreted with care because the techniques have particular strengths and weaknesses, and the quality of the data influences the results.

Bureau of Industry Economics (1994)

The BIE (1994) uses DEA to benchmark the technical efficiency of local gas utilities against international counterparts in the USA, UK, Canada and Japan. The sample includes 42 utilities: five Australian utilities, 23 US utilities, nine Canadian utilities, four Japanese utilities and one UK utility. The study focuses on the efficiency of transmission and distribution activities. BIE recommends separate analyses for the transmission and distribution activities because they have different cost structures. However, the available information could not support this approach. Therefore, BIE includes the following outputs in the study to help ensure that transmission utilities are not compared to distribution utilities:

- gas throughput (TJ)
- number of customers.

A transmission utility requires less capital than a distribution utility. Thus, transmission utilities could achieve superior performance relative to distribution utilities if only throughput is included in the analysis. For instance, a transmission utility is unlikely to have medium or low pressure mains or meters. Therefore, if the utilities had similar throughput, the transmission utility would appear more efficient. Customers are included in the analysis to help distinguish transmission utilities from distribution utilities.

The inputs of the transmission and distribution systems are:

- number of employees
- kilometres of transmission mains
- kilometres of distribution mains.

The BIE notes that there are several limitations to the data on inputs. First, some utilities' services include the sale of appliances and repairs. This could increase employee numbers relative to utilities that did not provide these services. Furthermore, some utilities contract out some services, such as meter reading and maintenance. This lowers employee numbers.

Second, there are differences in the age of the network system and the type of material used for mains. Older systems with cast iron mains usually require more maintenance to reduce gas leakages. This maintenance work is not reflected in the measures of capital, viz kilometres of transmission mains and kilometres of distribution mains. Finally, utilities use a range of other inputs, such as marketing, to deliver services. Information is not available on these inputs.

Two variables which influence the efficiency of a utility, but are beyond control of management are included as inputs in the analysis. These variables are:

- climate (heating degree days)
- population density (customers per kilometre of main).

The BIE argues that excluding climate from the analysis would improve the efficiency of a utility located in a cooler climate relative to a utility located in a warmer region. This is because people in cooler climates have a greater demand for gas for heating homes and buildings.

Utilities located in regions with dense populations have greater potential to achieve scale economies compared with utilities located in sparsely populated regions. Therefore, a utility located in a sparsely population region may appear less efficient to a similar sized utility located in a metropolitan region. The BIE uses customers per kilometre of distribution main to measure population density.

The BIE initially examined the potential for distributors to improve their efficiency under the assumption of constant returns to scale, without considering the influence of climate and population density on efficiency. The BIE's measure of efficiency reflects the potential for distributors to reduce all inputs given outputs. The Australian utilities achieved an average efficiency score of 81 per cent. Therefore, the local utilities, on average could produce the same outputs with 19 per cent less inputs. On average, the local utilities were relatively more efficient than the US utilities, which achieved an average efficiency score of 71 per cent, and the UK utility (British Gas) which had an efficiency score of 57 per cent. However, the local utilities are less efficient than the Canadian and Japanese utilities, which achieved, on average, efficiency scores of 85 per cent and 90 per cent, respectively.

Nine utilities were placed on the production frontier. The utilities are:

- State Energy Commission of Western Australia (Aust)
- NICOR (USA)
- Peoples Energy (USA)
- Brooklyn Gas (USA)
- Centra Gas Ontario (Canada)
- The Consumers Gas Co (Canada)
- Gaz Metropolitan (Canada)
- Tokyo Gas Co (Japan)
- Osaka Gas (Japan).

Allgas/Gas Corporation of Queensland obtained the lowest efficiency score (42 per cent). AGL's score was 61 per cent, which is below the average technical efficiency of the local utilities.

In the second stage of the analysis, BIE included climate and population density in the DEA model to account for the influence these variables have the technical efficiency of the utilities. The average technical efficiency score of the local utilities increased to 90 per cent. The average technical efficiency scores for the US, Japanese and Canadian utilities were 80 per cent, 90 per cent and 92 per cent, respectively. The UK utility was now on the frontier.

Fourteen utilities were found to be efficient:

- State Energy Commission of Western Australia (Aust)*
- NICOR (USA)*
- Atlanta Gas Light (USA)
- Oneok (USA)
- Peoples Energy (USA)*
- Brooklyn Gas (USA)*
- Saskatchewan Energy (Canada)

- Centra Gas Ontario (Canada)*
- The Consumers Gas Co (Canada)*
- Union Gas (Canada)
- Gaz Metropolitan (Canada)
- Tokyo Gas Co (Japan)*
- Osaka Gas (Japan)*
- British Gas (UK).

* indicates the company was on the frontier for both stages of the analysis.

The technical efficiency score of AGL increased from 61 per cent to 96 per cent and the technical efficiency score of the Gas and Fuel Corporation of Victoria (GFCV) increased from 79 per cent to 84 per cent. NICOR, British Gas, Osaka Gas and State Energy Commission of Western Australia set the best practice benchmarks in gas supply for AGL. However, the benchmarks set by NICOR are the most relevant to AGL's business.

Caution is required in interpreting the results of the BIE study. The number of inputs and outputs in the DEA model is high, relative to the sample size after the environmental variables are included as additional inputs. Therefore, the improved efficiency scores for the distributors reflects the fact that the model has difficulty in comparing like with like. Indeed, when the BIE examines the potential of distributors to improve efficiency under the assumption of variable returns to scale, it found that 84 per cent of the distributors, which includes all the local distributors, are managerially efficient. This suggests that most of the distributors were placed on the frontier by default. Further, the approach to directly include the environmental variables in the DEA model depends on assumptions about the environmental variables' influence on the efficiency of the distributors. Consequently, the approach precludes tests of hypotheses of the actual influence that the environmental variables have on efficiency.

Peakiness in demand for the residential and other markets is not incorporated in the analysis. Including population density as an environmental variable adds little to the analysis because customers per kilometre of distribution main is already accounted for in the initial model. A utility located in a cold climate may not achieve superior efficiency compared to utilities located in warm climates. A cold climate increases the demand for gas for heating. However, utilities located in cold climates may also incur additional costs, such as installing additional capacity to meet peak winter demand. Despite these criticisms, it is acknowledged that the BIE study is important as one of the earliest DEA studies conducted in Australia.

Rushdi (1994)

Rushdi (1994) uses TFP measurement to assess the productivity growth of the GFCV from 1970-71 to 1988-89.[28] The single output is the quantity of reticulated gas (TJ). The inputs are FTE employees, gas purchases (TJ), and capital (which is derived using the perpetual inventory

[28] Rushdi uses a Tornqvist index to produce measures of TFP. See Coelli, Rao and Battese (1998) for further information on the Tornqvist index.

method).[29] The compound growth rate for reticulated gas 1970-71 to 1988-89 was 12.4 per cent per annum and the compound growth rate for the inputs was 3.6 per cent per annum. Therefore, annual TFP growth over the period was 8.45 per cent.

Rushdi also presents information on the distribution of productivity gains between GFCV and consumers. The ratio of input prices paid and output prices received by GFCV, or the terms of trade, declined sharply from 1970-71 to 1976-77. The terms of trade were relatively stable between 1977-78 and 1980-81. However, a sharp increase in the terms of trade commenced between 1981-82 and 1983-84 due to an increase in payments to the Victorian Government. For the remainder of the period from 1970-71 to 1988-89, the terms of trade is relatively stable. Rushdi states that results indicate that GFCV endeavoured to share its productivity gains with consumers.

3.4.5 The performance of international gas distributors

Price and Wayman-Jones (1996)

Price and Wayman-Jones use DEA to estimate the efficiency and productivity of 12 distribution regions of British Gas to assess whether privatisation improved its performance. The period of the analysis was 1977-78 to 1990-91. British Gas was privatised in 1986.

The authors define the inputs of the distribution regions as:

- number of employees
- length of gas mains transmission and distribution system.[30]

The outputs for the distribution regions are:

- residential gas sales (therms)
- industrial gas sales (therms)
- commercial gas sales (therms)
- number of customers
- gas appliances sold.

To ensure that regions are compared with other regions with similar population densities, Price and Wayman-Jones include population density as an input. This prevents regions appearing efficient only because they have high population densities. However, this approach precludes testing the actual influence of population density on efficiency. The various categories of gas sale are used in preference to total sales to reflect the different peakiness of demand for each market.

Price and Wayman-Jones examine the potential for the regions to reduce inputs given outputs to assess the technical efficiency of the regions under the assumption of constant returns to scale

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29 For further information on the perpetual inventory method see Steering Committee on National Performance Monitoring of Government Trading Enterprises (1992).

30 The authors do not specify the unit of length for the gas mains.

between 1978-79 and 1990-91. For this exercise, the authors pool the sample data, which creates 168 regions. The DEA results indicate that 28 regions are technically efficient - most are post-privatisation regions. The minimum efficiency of regions before and after privatisation was 63 per cent and 75 per cent, respectively. Price and Wayman-Jones argue that the differences in technical efficiency remaining after privatisation indicate that further gains in efficiency were foregone because the integrated activities of the regions were not separated to encourage direct competition or indirect competition through yardstick regulation.

The authors then use DEA to assess productivity growth for the regions over 1977-78 to 1990-91.[31] The results suggest that productivity of the regions increased by 137 per cent or 10.5 per cent per annum over the period, however most of the improvement in productivity occurred after British Gas was privatised. Prior to privatisation (ie between 1977-78 and 1984-85), the productivity of British Gas increased by 37 per cent or 5.5 per cent per annum. Virtually all the productivity growth before and after privatisation is due to technical change.

Kim et al (1999)

Kim et al (1999) present international comparisons of the productivity and efficiency of transmission and distribution companies. They use TFP measurement and DEA to measure the productivity and efficiency of the natural gas companies. Our observations on the study are confined to the analysis of distribution companies.

Kim et al examines the productivity and efficiency of 19 gas companies. The sample includes three US companies, four Canadian companies, one French company, one Italian company, nine Japanese companies, and one Korean company.

The output of the distributors is defined as total volume of supplied gas by thermal unit (10^9 kcal). The inputs are FTE employee numbers, capital (measured by tangible assets reported in the companies' balance sheets), and administration. The administration input is calculated in the following manner. First, labour and capital costs are subtracted from total costs. The residual cost is assumed to be administration cost. Second, administration cost is regressed against pipeline length and labour. The inverse of this relation is used to obtain the unit cost of administration. Third, administration input is derived by dividing total administration cost by unit cost of administration.

The price of labour is calculated by dividing labour cost by employee numbers. The price of capital is obtained by dividing the capital cost by capital service. Capital service is assumed to be proportional to capital stock. The cost of capital is the sum of expenditures required to purchase and maintain existing capital. The costs of the distributors are converted into 1991 US constant dollars using purchasing power parity exchange rates.

The sample period for the TFP measurement exercise is 1987 to 1995. The results suggest the European and North American companies are more productive than the Japanese and Korean companies.[32] Average productivity for the European and North American companies over the

31 The authors use a Malmquist index to measure productivity. See Grosskopf (1993) and Lovell (1993) for further details on the Malmquist index.

32 The authors use a multilaterial Tornqvist index to measure productivity.

sample period ranges from 280.7 to 839.3 and 365.2 to 770.7, respectively. The Italian company (Snam) had the highest productivity. Average annual productivity growth for the European and North American companies varies from –0.8 per cent to 4 per cent and zero to 9.7 per cent, respectively. Average annual productivity growth for the European and North American companies was 1.6 per cent and 3.4 per cent, respectively.

Average productivity of the Japanese companies ranges from 98.2 to 195.3, and average annual productivity growth varies from –2.3 per cent to 5.7 per cent. Average annual productivity growth for the Japanese companies was 1.6 per cent. The Korean company's average productivity was 117.1 and average annual productivity growth was 31.2 per cent. The highest average annual growth in productivity for each region is associated with a company with relatively low productivity.

Kim et al explain that the differences in productivity reflect different accounting practices, market structure and endowment of natural gas resources. For example, the Japanese and Korean industries rely heavily on liquid natural gas (LNG). Additional capital is required to handle the LNG.

To obtain balanced data for the DEA exercise, Kim et al restrict the sample to 1991-1995. They examine the extent to which companies can reduce their inputs, given the output (volume of gas supplied) and present five year averages for technical efficiency, managerial efficiency and scale efficiency. Only the Italian company is technically efficient, on average. The least technically efficient company (Osaka Gas) could potentially reduce its inputs by 81 per cent. Scale efficiency is the main source of inefficiency for the companies.[33]

The authors argue their results are robust because there is a strong correlation between the overall economic efficiencies obtained from the DEA exercise and the productivity levels suggested by the TFP measurement exercise.

3.5 Assessment

Past performance indicates that the local electricity, water and gas sector achieved annual productivity growth rates of about 3 per cent. However, the productivity of the electricity, water and gas sector appears low compared with that of international counterparts. The performance of the Gas and Fuel Corporation of Victoria indicates that local distributors have achieved annual productivity growth of about 8.5 per cent. This is supported by the COAG partial productivity measures for GASCOR which indicate reductions in O&M costs per customer of 5 per cent per annum. The BIE (1994) study suggests there is scope for local distributors to improve their technical efficiency, on average, by about 20 per cent before considering the influence of climate and population density on efficiency.

International studies suggest that European and North American distributors achieved annual productivity growth of about 1.6 per cent and 3.4 per cent, respectively. Distributors in Japan and Korea achieved annual productivity growth of 1.6 per cent and 31.3 per cent, respectively.

[33] The authors also present results for overall efficiency and allocative efficiency. The Italian company achieved the highest average overall and allocative efficiency with scores of 97.9 per cent.

However, the Korean distributor's productivity growth reflects catch-up in productivity because its productivity is relatively low compared to the European and North American distributors. The UK study suggests that productivity gains of 10 per cent per annum are possible for gas distributors located in western countries.

4 PARTIAL PRODUCTIVITY MEASURES AND POTENTIAL COST DRIVERS FOR GAS DISTRIBUTION

The study's approach to the development of partial productivity measures follows the approach developed by AGLGN, which allows its performance to be assessed against local and US gas distributors. However, the study's approach differs from AGLGN's approach in two important respects, having a broader perspective and no allowance for environmental variables.

Additional partial productivity measures were developed to provide a broader perspective of performance. A broader suite of indicators encourages discussion on reasons for differences in performance. It also reduces the risk of interpreting a KPI in isolation from other factors influencing the efficiency of gas distribution.

In the study, the partial productivity measures were not adjusted to account for different operating environments such as climate. To some extent, differences in the efficiency of local distributors reflect factors beyond the control of management, eg climate, population density, the relative price of competing fuels, and economic growth. Little is known about how these factors influence the efficiency of gas distribution. Consequently, it is unclear whether AGLGN's adjustment of partial productivity measures for environmental factors is justified.

The study's approach is consistent with the COAG exercises (SCNPMGTE 1997, SCRCSSP 1998) which attempt to develop consistent national performance indicators to measure the effectiveness and efficiency of government businesses (eg gas distribution, electricity distribution, and water services) and services (eg law and order, education and health). COAG acknowledges that the broader environment influences performance. Government agencies deliver services to communities with vastly different physical and socioeconomic characteristics. Moreover government agencies are obliged to deliver services to certain communities, which are often uneconomic. For example, a government-owned electricity distributor uses additional poles and wires to deliver electricity to rural and isolated communities. Further, government agencies face different input prices, and the States use different accounting methods and different definitions to describe aspects of service delivery (eg there are several definitions of waiting time for public housing).

COAG argues that if they are interpreted with care, and local differences in the broader environment are acknowledged, partial productivity measures can provide valuable insights into the performance of government agencies. Moreover, when combined with other information on community views and client groups, this information can assist in understanding why differences in service delivery produce different outcomes. This knowledge encourages reforms to improve service delivery (SCRCSSP 1998).

The Tribunal adopted a similar view to assess the relative efficiency of rural and metropolitan hospitals in NSW (IPART 1999c). Distributors like Envestra present a broad range of KPIs to help assess performance without adjusting for the broader environment. To assess the influence of environmental factors on the efficiency of gas distribution, the study used alternative benchmarking techniques.

A common problem with the use of partial productivity measures is that various indicators yield different results for relative performance. There is often no way of determining the weight that should be to given to the various partial indicators. A statistical exercise was undertaken to help identify the potential cost drivers of O&M costs. The exercise helped evaluate suggestions that emphasis be placed on certain partial indicators in assessing the performance of AGLGN. The results of the exercise are discussed in Section 4.3.

AGLGN's approach to benchmarking its efficiency is explained below as background to the study's approach to the development of partial productivity measures for gas distribution. AGLGN has developed two approaches to benchmark its efficiency. The first approach presents variants of two KPIs (O&M costs per customer and O&M costs per thousand kilometres of main) to assess the efficiency of AGLGN relative to other local distributors. The second approach uses similar KPIs to assess the efficiency of AGLGN against US distributors.

4.1 KPIs for local gas distribution

4.1.1 KPIs developed by AGLGN

The current set of KPIs in AGLGN's Access Arrangement Information (AAI) (in various forms) reflects an attempt to reconcile differences in public O&M costs for local distributors. The KPIs are presented in Table 4.1.

Table 4.1 AGLGN's KPIs for local gas distribution, 1998[34]

KPIs	AGLGN	Multinet	Stratus	Westar
O&M costs ($m)	122.1	46.2	41.2	38.5
Marketing costs ($m)	35.7	0.9	4.9	2.1
O&M costs less marketing costs ($m)	86.4	43.5	36.6	36.4
Government levies, meter reading and call centre costs ($m)	14.6			
O&M costs less marketing costs and government levies, etc. ($m)	71.8			
Customers	716,326	576,703	404,742	412,151
Mains (km)	20,830	8,601	7,314	7,185
O&M/customer ($)	170	80	102	93
O&M/('000) km main	5.9	5.4	5.6	5.4
O&M (less marketing costs, etc.)/customer ($)	100			
O&M (less marketing costs, etc.)/('000) km main	3.4			
O&M (less marketing costs, etc) adjusted to reflect Victorian market penetration rate /customer ($)	73.7			
O&M (less marketing costs, etc) adjusted to reflect Victorian market penetration rate/('000) km main	4.1			

Source: AGLGN AAI (in various forms).

34 Information for AGLGN is for 1997-98.

The information on O&M costs per customer and O&M costs per thousand kilometres of main suggests that AGLGN has higher costs than the VIC distributors. However, AGLGN's O&M costs include government levies, meter reading, and call centre costs which are not included in the VIC distributors' O&M costs. After excluding these costs, AGLGN's O&M costs are $107.5m. Therefore, O&M costs per customer are $150 and O&M costs per thousand kilometres of main are $5.1. The O&M costs for AGLGN include UAG ($8.9m), which is not included in the VIC distributors' O&M costs.

AGLGN states that differences in the efficiency of distributors is mostly due to climate. Victoria has a cooler climate than those regions of NSW served by AGLGN. The greater household demand for gas for heating in VIC, enables the VIC distributors to achieve economies of scale which lower costs per customer.

Further, AGLGN argues that its network marketing costs are relatively high because gas is a discretionary fuel.[35] To achieve economies of scale, AGLGN must heavily promote gas in a relatively warm climate to offset the additional costs of gas connection and the higher cost of gas appliances relative to electrical appliances. To offset the disadvantage of delivering gas in a warm climate, AGLGN excludes network marketing costs from O&M costs and increases its customers and O&M costs to reflect the same market penetration that is achieved by the VIC distributors.[36]

Excluding network marketing costs, AGLGN appears marginally more efficient than Stratus, according to O&M costs per customer. However, it is less efficient than the other distributors. AGLGN appears relatively efficient according to O&M costs per thousand kilometres of main. After adjusting O&M costs further to reflect the market penetration achieved by the VIC distributors, AGLGN arrives at an O&M cost per customer which is lower than the actual O&M per customer for the VIC distributors.

Assessment

There are some concerns that the KPIs used by AGLGN for benchmarking:

- display inconsistencies in the O&M costs used to develop KPIs
- are adjusted for the influence of climate
- are limited in number.

The cost components included in the O&M figures for the local distributors are inconsistent. For example, AGLGN's O&M costs include UAG and customer accounts expenses (eg meter reading and customer records and collection expenses) whereas these costs are not included in the VIC distributors' O&M costs. AGLGN attempts to reconcile the differences by removing government levies, and meter reading and call centre costs. Nevertheless, UAG is included in AGLGN's O&M costs and there is still uncertainty over the presence of other cost discrepancies. However, it is acknowledged that the O&M costs used by AGLGN are sourced from public

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35 Most network marketing costs relate to energy retailer rebates which aim to increase gas consumption in the tariff market by increasing either new customers, or the average consumption of existing customers.

36 AGLGN assumes the marginal cost of an additional customer is $30.

documents and are used by both regulators and distributors to develop KPIs for gas distribution.

4.1.2 Reconciling O&M costs

To help reconcile the inconsistency in O&M costs, local distributors were requested to align their O&M costs with O&M cost codes used by the US Federal Energy Regulatory Commission (FERC). These cost codes are broadly similar to AGLGN's activity-based costs.[37] The FERC codes are presented in Attachment 3. This exercise confirmed that the VIC distributors' O&M costs do not include:

- government levies
- UAG
- customer accounts expenses.

AGLGN's O&M costs are $97.1m after these costs are excluded from its O&M costs ($122.1m) for 1997-98.[38] Other distributors' O&M costs are adjusted to reflect the VIC distributors' O&M cost structure.[39]

4.1.3 Adjusting KPIs for the operating environment

There is little support for AGLGN's adjustment of the KPIs to offset the disadvantage of delivering gas in relatively warm regions because climate is just one of several factors influencing the demand for gas. Envestra (1999b) suggests that the demand for gas is determined by:

- network marketing
- gas connection penetration and growth
- climate
- economic growth
- population growth
- building activity

37 AGLGN provided the Tribunal with the mapping of its activity-based costs to FERC codes on 12 August 1998. AGLGN stressed that the mapping was not a direct match, but was rather the best alignment of its activity-based costs to the FERC codes.

38 The activity-based O&M costs for AGLGN (NSW) are presented on p 67 of the Revised AAI.

39 AGLGN provided alternative O&M costs for the NSW and ACT networks derived by mapping the General Ledger accounts to those FERC codes which are broadly consistent with its activity-based costs, on 25 August 1999 and 27 August 1999. This resulted in lower O&M costs for the networks. However, the author of this study could not reconcile differences with these O&M costs and the activity-based O&M costs presented in the RAAI for the NSW network and the AAI for the ACT network. Furthermore, AGLGN provided the information on a commercial-in-confidence basis. Therefore, the public information was used in its analysis. However, the lower O&M costs for AGLGN (NSW) and AGLGN (ACT) do not significantly influence their relative efficiency when included in the DEA and stochastic frontiers exercises (which are presented in Chapter 5).

- the price of gas relative to competing fuels (eg especially, electricity).

Other factors influencing the demand for gas include:

- the socioeconomic characteristics of households (eg income and number of people)
- whether household appliances use gas or electricity for space heating, cooking and water heating
- patterns of use of household appliances
- the cost of acquiring and maintaining gas appliances relative to electricity appliances
- the quality of management decisions to construct or develop networks to service retail markets.

Several participants query AGLGN's approach to benchmarking local gas distribution. Carlton and United Breweries Ltd state that AGLGN's lower density of customer connections is not due to climate, but rather:

> … over-investment in the tariff market network and this part of the asset base should be written down by IPART.[40]

The Public Interest Advocacy Centre (PIAC), Energy Australia, and Duke Energy International, express concern with AGLGN's method of adjusting the KPIs to remove network marketing costs to offset the disadvantage of delivering gas to regions which have a relatively warm climate.[41] The participants said that the AGLGN's network marketing costs are relatively high because they include activities which should be undertaken by AGL Retailing. The issue of whether it is legitimate for AGLGN to undertake network marketing to promote gas sales is discussed in the *Draft Access Arrangement for AGLGN*. The extent of the difference in network marketing costs for AGLGN and other local and US distributors is discussed below.

4.1.4 Additional KPIs for local gas distribution

KPIs for local gas distribution are presented in Table 4.2.[42] Additional distributors and KPIs, (eg O&M costs per delivery (TJ), deliveries (TJ) per kilometre of main, customers per kilometre of main, UAG and age of gas system), contribute to a broader assessment of the performance of AGLGN. Deliveries (TJ) per kilometre of main is included as a KPI because this is consistent with AGLGN's view that the aim of network marketing is to increase throughput to achieve economies of scale. Furthermore, given that the regulator's assessment of performance is limited to a particular point in time, confining observations on performance to the two performance indicators developed by AGLGN - O&M costs per kilometre of main and O&M

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40 Submission from Carlton and United Breweries, March 23, p 2.

41 Submission from Public Interest Advocacy Centre, March 19, p 10, Submission from EnergyAustralia, March 22, pp 8-9, Submission from Duke Energy International, pp 4-5.

42 Great Southern Energy Gas Networks and the Albury Gas Company are excluded because information allocating overheads to business activities is unreliable.

costs per customer – can provide a misleading impression of performance because a distributor could appear relatively efficient because it deferred expenditure on maintenance.

As noted above, a broader suite of indicators encourages discussion about the reasons for differences in performance. It also reduces the risk of interpreting a KPI in isolation from other factors influencing the efficiency of gas distribution. It also reduces the incentive to adjust KPIs for environmental factors which are beyond the control of management. Local differences in the broader environment, such as climate, population density, the mix of customers, and input prices can influence performance, and must be taken into account when interpreting KPIs.

The information presented in Table 4.2 suggests that AGLGN (NSW) is on par with O&M costs per kilometre of main for Envestra (SA) and Westar. This ratio is 12 to 18 per cent below other gas distributors except for AGLGN (ACT) which achieved the lowest O&M cost per kilometre of main. However, AGLGN is less efficient in terms of O&M costs per customer, O&M cost per delivery (TJ), deliveries (TJ) per kilometre of main and customers per kilometre of main.

An important element in improving the efficiency of the network will be AGLGN's ability to increase the demand for gas. However, it is important to stress that these are only partial measures which cannot give a complete view of performance.

Table 4.2 KPIs for local gas distributors, 1998

Company	State	O&M ($m)	Cus/main (km) (no.)	O&M/cus ($)	O&M/main (km) ($)	O&M/delivery (TJ) ($)
AGLGN	NSW	97.1	35	134	4666	954
AGLGN	ACT	11.1	19	171	3255	2142
Envestra	SA	33.6	48	102	4875	938
Envestra	QLD	8.9	37	119	4350	2236
Multinet	VIC	45.8	68	78	5325	782
Stratus	VIC	40.8	57	98	5578	714
Westar	VIC	33.7	57	82	4684	461

Note: Figures for Envestra (SA) 1998-99, AGLGN, and Envestra (QLD) 1997-98.

Source: Estimates based on information from AAI (various), Envestra (1998), Envestra (1997) and information supplied by local distributors.

Table 4.3 KPIs for local gas distributors, 1998 (continued)

Company	State	Deliveries (TJ)/ main (km) (TJ)	NM costs/O&M (%)	UAG (%)	Asset life expired (%)
AGLGN	NSW	4.9	37	2.3	21
AGLGN	ACT	1.5	46	0.9	23
Envestra	SA	6.7	17	4.4	22
Envestra	QLD	5.2	11	13.3	20
Multinet	VIC	10.2	2	2.0	33
Stratus	VIC	7.8	12	1.6	28
Westar	VIC	8.7	2	1.3	31

Notes: Asset life expired is the ratio of depreciated optimised replacement cost to optimised replacement cost. Envestra's (QLD) UAG is for the 12 months to 31 May 1999. NM-network marketing.
Source: Estimates based on information from AAI (various), Envestra (1998), Envestra (1997) and information supplied by local distributors.

AGLGN's UAG is higher than VIC distributors, but it is lower than for most of the other distributors. The proportion of cast iron mains in AGLGN's system would assist in interpreting this result. The VIC distributors have 13 to 21 per cent of cast iron mains in their systems. This information is not available for AGLGN. The high UAG for Envestra (QLD) is due mainly to deterioration of the lead joint connections between the cast iron pipes. This deterioration was caused by the switch from town gas to natural gas in 1995 and 1996. Cast iron mains account for about 60 per cent of the system and Envestra (QLD) has commenced a program to insert plastic pipe inside the cast iron mains to reduce UAG.

The KPIs for network marketing, which are presented in Table 4.3 and Table 4.4, indicate that AGLGN's network marketing costs are high relative to most local distributors, including Envestra (QLD) which is located in a sub-tropical region.

Table 4.4 Additional KPIs for network marketing for local gas distributors, 1998

Company	State	NM costs/ cus ($)	NM costs/ new cus ($)
AGLGN	NSW	49	1489
AGLGN	ACT	79	1020
Envestra	SA	18	1450
Envestra	QLD	13	553
Multinet	VIC	2	180
Stratus	VIC	11	377
Westar	VIC	5	210

Notes: Figures for Envestra (SA) are for 1998-99, and figures for AGLGN and Envestra (QLD) are for 1997-98. NM - network marketing.
Source: Estimates based on information from AAI (various) and information supplied by local distributors.

BHPP said that the information presented in Table 4.5 indicates AGLGN's network marketing costs are considerably higher than costs incurred by the VIC distributors. Moreover, BHPP states that the higher market penetration of gas in VIC (71 per cent for residential heating and 61 per cent for domestic hot water) makes it more difficult for the VIC distributors to expand the market than in NSW. Gas has a much lower market penetration in NSW (15 per cent for residential heating and 20 per cent for domestic hot water). BHPP suggests best practice benchmarks for network marketing are about $1-4/GJ.

Table 4.5 BHPP's KPIs for network marketing

Financial year	State	98	99	00	01	02	03	04
AGLGN	NSW							
Network marketing ($m)		35.7	27.6	28.6	27.7	28.4	28.8	29.1
Tariff market growth TJ/pa		1094	483	1625	1357	1356	1348	1236
$/GJ of growth		32.63	57.14	17.60	20.41	20.94	21.36	23.54
AGLGN	ACT							
Network marketing ($m)		5.1	4.5	4.3	4.3	4.3	4.0	3.9
Tariff market growth TJ/pa		na	215	206	190	188	182	168
$/GJ of growth		na	20.93	20.87	22.63	22.87	21.98	23.21
Envestra	SA							
Network marketing ($m)		na	5.8	5.9	6.1	6.2	6.4	6.5
Tariff market growth TJ/pa		na	na	100	110	100	90	100
$/GJ of growth		na	na	59.00	55.45	62.00	71.11	65.00
Calender year								
Multinet	VIC							
Network marketing ($m)		0.9	0.8	0.8	0.8	0.9	na	na
Tariff market growth TJ/pa		na	722	669	674	694	na	na
$/GJ of growth		na	1.11	1.20	1.19	1.30	na	na
Stratus	VIC							
Network marketing ($m)		4.9	4.1	4.1	4.5	4.5	na	na
Tariff market growth TJ/pa		na	975	994	961	1015	na	na
$/GJ of growth		na	4.21	4.12	4.68	4.43	na	na
Westar	VIC							
Network marketing ($m)		2.1	1.9	1.9	2.0	2.0	na	na
Tariff market growth TJ/pa		na	820	826	832	816	na	na
$/GJ of growth		na	2.32	2.30	2.40	2.45	na	na

Note: na – not available.
Source: BHPP submission, August 24, p 4.

Table 4.6 compares KPIs for O&M costs excluding network marketing costs. This information suggests that if network marketing costs are not included in O&M costs, AGLGN's O&M costs are, in general, comparable with, or below, those of other distributors.

Table 4.6 KPIs for local gas distributors with network marketing costs excluded, 1998

Company	State	O&M/cus ($)	O&M/ main(km) ($)	O&M/delivery (TJ) ($)
AGLGN	NSW	85	2950	603
AGLGN	ACT	93	1760	1158
Envestra	SA	89	4222	813
Envestra	QLD	106	3874	1988
Multinet	VIC	77	5220	767
Stratus	VIC	87	4908	628
Westar	VIC	80	4578	451

Notes: Figures for Envestra (SA) are for 1998-99, and figures for AGLGN and Envestra (QLD) are for 1997-98.
Source: Estimates based on information from AAI (various) and information provided by local distributors.

4.2 AGLGN's performance compared to US gas distributors

4.2.1 KPIs developed by AGLGN

AGLGN has developed two KPIs to compare the efficiency of its total network in NSW and ACT against 35 US distributors.[43] The KPIs are:

- O&M costs ($US) per kilometre of main
- O&M costs ($US) per customer.

The US distributors often deliver retail and network services. Therefore, AGLGN uses FERC codes to develop O&M costs for the US networks. The FERC codes used by AGLGN are presented in Attachment 4. AGLGN uses the market exchange rate to convert AGLGN's O&M costs into US dollars. To account for volatility in the exchange rate between the US and the Australian dollar, AGLGN uses two market exchange rates, 62 and 78 US cents per Australian dollar, in the benchmarking exercise.

AGLGN compares its performance for 1997-98 against the US distributors' performance in 1997. AGLGN also presents a comparison of the percentage change in the KPIs from 1988 to 1997. The results of each approach are presented in a histogram.[44] AGLGN states that these results indicate that it is relatively efficient. In 1997-98, AGLGN's O&M costs per kilometre of main ranged between $US3683 and $US4634, while O&M costs per customer ranged between $US112 and $US142.

[43] The distributors are listed in Attachment 5 in the Revised AAI.
[44] The histograms are presented in the RAAI on pp 41-42.

Assessment

There are concerns that in AGLGN's analysis:

- KPIs are not developed for the NSW network
- the FERC cost codes used to construct the O&M cost for the US distributors are different from the cost codes that relate to AGLGN's activity-based costs
- the use of market exchange rates to convert AGLGN's costs into US dollars instead of purchasing power parity exchange rates
- the limited number of KPIs used in the analysis
- the substantial change in the regulation of gas distribution and the structure of utilities over recent years, both in Australia and overseas, casts doubt on assessing AGLGN performance over 1988 to 1997.

There are concerns about apparent inconsistencies in the FERC codes used to develop O&M costs for the US distributors, and in the FERC codes associated with AGLGN's activity-based costs. AGLGN advised on 12 August 1999 that it used a different mapping to construct the O&M costs for the US distributors. AGLGN said it mapped items from its General Ledger to FERC codes to develop the O&M costs for the US distributors. This mapping includes additional FERC codes compared to the mapping based on its activity-based costs. Consequently, the O&M costs for the US distributors, that are included in both AGLGN's and the study's analyses, are higher, on average, by 20 - 30 per cent, compared with the study's estimates, which rely on the activity-based cost mapping.

Purchasing power parity exchange rates reflect the real purchasing power of a national currency. Therefore, they should be used in preference to market exchange rates to convert AGLGN's O&M costs into US dollars. Purchasing power parity exchange rates:

> … equalise the internal purchasing power of different currencies by eliminating differences in the general price levels between countries. A given sum of money, converted into other currencies at PPP [purchasing power parity] rates, should buy the same broad and representative basket of final goods and services in each country.
>
> This would not necessarily be the case if market exchange rates are used. Market exchange rates are determined by trade in a smaller (traded) basket of goods, by capital inflows and outflows, government policies on quotas, tariffs and taxes, and by expectations. Consequently, comparisons based on market exchange rates are volatile. The rates shift abruptly with changed expectations, government trade and tax policies, trade patterns and monetary conditions – thus they can quickly become dated (*Productivity Commission 1999a*, p 100).

The purchasing power parity exchange rate for the USA and Australia in 1997-98 was $A0.75=$US (OECD 1998).

4.2.2 Additional KPIs for AGLGN and US distributors

The study revised AGLGN's US comparisons to address most of the above concerns. The study's sample includes the 51 US distributors which are included in the DEA exercise, along with AGLGN (NSW). The results are presented in Attachment 5.[45] The KPIs used to compare AGLGN (NSW) with US counterparts are similar to the suite of KPIs which were developed in this study to compare its performance with local distributors. As mentioned above, it is important to note that these are only partial indicators, which cannot give a complete view of performance.

The O&M costs for the US distributors are developed from the activity-based cost mapping to the FERC codes which AGLGN provided last year. Customer accounts expenses are included in O&M costs to provide a better comparison of AGLGN's business with the US distributors. Consequently, AGLGN's O&M costs are $103.4m, which includes $6.3m in customer accounts expenses. AGLGN's O&M costs are equivalent to $US 77.6m.

The partial productivity measures suggest that AGLGN has the 14th lowest O&M costs per customer and O&M costs per kilometre of main. However, AGLGN has the 11th highest O&M costs per delivery (TJ).

AGLGN has the 24th lowest customers per kilometre of main. However, it has the 48th lowest deliveries (TJ) per kilometre of main, and the 32nd highest UAG.

In response to matters raised by other participants, AGLGN states that its general administration costs to O&M costs are similar to those of US distributors in arguing against claims by NERA and BHPP that its overheads are relatively high.[46] It appears NERA's analysis uses FERC codes which are inconsistent with AGLGN's mapping of its activity-based costs to FERC codes.[47] Consequently, network marketing costs, customer accounts expenses, and total O&M costs are overstated. However, AGLGN uses additional FERC codes to construct the O&M costs for the US distributors, which inflates the costs of the US distributors. When the FERC codes which correspond with AGLGN's activity-based costs are used, AGLGN has the 20th lowest general administration costs per O&M cost.

AGLGN did not compare its network marketing costs with those of US distributors to argue against concerns that its network marketing costs are relatively high. The analysis indicates that AGLGN's marketing costs comprise about 35 per cent of its O&M costs. Network marketing costs do not exceed 14 per cent of O&M costs for the US distributors. For most US distributors, network marketing costs are about 5 per cent or less of O&M costs.

The apparent efficiency of AGLGN relative to the US distributors needs to be interpreted with care. To some extent, differences in performance, may be due to reasons other than inefficiency. For example, the distributors deliver gas to regions with different population densities, climate and geography. To better assess AGLGN's efficiency relative to the US distributors, the study

45 The study's analysis uses information on the kilometres of main for the US distributors for 1997. AGLGN's analysis uses information for 1996.

46 Submission from AGLGN, June 1, p 24.

47 Submission from BHP Petroleum Pty Ltd, April 19, pp 56-58.

selected several US distributors that deliver gas to regions with a similar population density (ie customers per kilometre of main) or climate to coastal NSW (ie California and Florida).

The information presented in Table 4.7 suggests that AGLGN's performance is mixed. AGLGN appears to have relatively lower costs in terms of O&M costs per customer and O&M costs per kilometre of main. However, AGLGN appears to have higher costs in terms of deliveries (TJ) per kilometre of main, O&M costs per delivery (TJ), and network marketing costs per O&M cost. Furthermore, AGLGN's UAG is relatively high.

Comparisons with Atlanta Gas Light, Citizens Utilities and South Carolina Electric and Gas are of particular interest, given these statistics. Citizens Utilities and South Carolina Electric and Gas both have lower numbers of customers and deliveries (TJ) per kilometre of main. This may suggest greater scope to expand the market. However, each spends significantly less on network marketing than AGLGN. Citizens Utilities achieves lower O&M costs per customer but higher O&M costs per delivery (TJ). South Carolina Electric and Gas has a comparable O&M costs per customer, but significantly lower O&M costs per delivery (TJ).

Atlanta Gas Light is of a comparable size to AGLGN. It has 20 per cent fewer customers per kilometre of main but 10 per cent higher deliveries (TJ) per kilometre of main. This is indicative of higher volumes of gas per customer. However, its costs are substantially below those of AGLGN, reflecting very low costs per kilometre of main. South Carolina Electric and Gas is the only other distributor in this group to achieve lower O&M costs per kilometre of main than AGLGN.

Table 4.7 KPIs for AGLGN and US distributors 1997

Company	State	Cus/main (km)	O&M/cus ($US)	O&M/ main (km) ($US)	Deliveries (TJ)/main (km) (TJ)	O&M/ delivery (TJ) ($US)	UAG (%)	NM cost/ O&M (%)	Gen admin/ O&M (%)
AGLGN	NSW	35	107	3726	4.9	762	2.3	35	35
Atlanta Gas Light Co	GA	28	68	1902	5.5	343	0.5	3	11
Citizens Utilities Co, Louisiana Gas Div	LA	32	94	3051	3.3	932	4.0	5	36
Indiana Gas Co	IN	28	157	4420	8.4	523	0.8	2	52
MidAmerican Energy Co	IA	38	107	4055	11.9	342	1.3	5	27
National Fuel Gas Distribution Corp	NY	31	153	4755	9.7	489	5.8	0	27
Northern Indiana Fuel & Light Co	IN	26	152	4009	5.7	699	0.3	0.5	39
Peoples Gas System	FL	21	193	4071	7.8	519	1.6	5	42
Piedmont Natural Gas Co	NC	21	219	4587	9.1	505	1.4	2	46
Questar Gas Co	UT	33	155	5100	15.6	326	0.7	0	42
South Carolina Electric & Gas Co	SC	27	105	2826	4.7	602	2.6	12	28
Southern California Gas Co	CA	70	99	6927	16.3	426	0.4	0	38

Notes: Figures for AGLGN are for 1997-98. NM – network marketing.

Source: Estimates based on information from AGLGN AAI (in various forms), Opri (1998) and the *Pipeline & Gas Journal (November 1998)*.

4.3 Potential cost drivers for gas distribution

4.3.1 Operation and maintenance expenditure

AGLGN states that length of mains is a significant cost driver of O&M costs.[48] Furthermore, AGLGN stated, in discussions with the Secretariat, that it placed particular emphasis on O&M costs per kilometre of main in assessing the performance of its NSW network. These comments highlight a common problem with the use of partial indicators. Almost inevitably, different partial indicators will yield different results for relative performance. Yet there is often no basis for determining the weight that should be given to the different partial indicators.

To test AGLGN's proposition that length of mains is a significant cost driver, a simple exercise was undertaken to assess the potential cost drivers of O&M costs. Potential cost drivers include:

- customer numbers
- deliveries (TJ)
- length of mains (km)
- climate (heating degree days)
- age of network (percentage of asset life expired).

The study examined the relationship between O&M costs and potential cost drivers from a statistical viewpoint only. The exercise is not based on the economic theory that underpins the production or cost functions of gas networks, which requires information on input prices and outputs (Varian 1992; Coelli, Rao and Battese 1998). However, the exercise may help the regulator determine the weight to be placed on the various partial indicators.

The study used regression analysis to assess the potential cost drivers for AGLGN's O&M costs.[49] The sample includes 45 local and US distributors.[50] Several functional forms were estimated to determine the appropriate relationship between O&M costs and the potential cost drivers. Statistical tests of hypotheses suggest that the translog functional form provides the best explanation for the technical relationship between O&M costs and the potential cost drivers.

The results as presented in Attachment 6, suggest that customers, deliveries, and age of the network are significant cost drivers of O&M costs. Length of mains and climate are not significant cost drivers. Thus, the available evidence suggests there is little reason to place particular emphasis on O&M costs per kilometre of main as a measure of performance. Other partial productivity measures are needed to form views on the efficiency of AGLGN. The results suggest that AGLGN's observed O&M costs ($97.1m) are marginally better than the

48 Submission from AGLGN, 16 July, p 7.

49 The variables and the data used in the exercise are explained in detail in Chapter 5.

50 The sample is smaller than that used for the DEA exercise, which is reported in Chapter 5, due to a lack of information on the age of the network for some US distributors.

predicted O&M costs ($97.7m) for AGLGN. In other words, the statistical analysis suggests AGLGN's O&M costs reflect average practice.

The insignificance of mains as a cost driver for O&M costs is consistent with an OFWAT (1999) finding that length of mains is not a significant cost driver of the operating costs for water companies. However, OFWAT found that the proportion of large mains (300mm diameter or more) was a significant cost driver of operating costs. There is insufficient information to test the proposition that the proportion of large mains is a significant cost driver for gas distribution.

It should be emphasised that this statistical analysis was designed to determine the relative weight to be given to certain cost drivers. It is not designed to model input-output relationships. Considerable care should be exercised in interpreting these results as a guide to relative efficiency.

4.3.2 Unit cost

Further analysis was undertaken to determine potential cost drivers of the unit cost (O&M costs per kilometre of main) of gas distribution. The results of the exercise, which are presented in Attachment 6, suggest that the translog functional form provides the best explanation of the technical relationship between unit cost and the potential cost drivers. Customers, deliveries, length of mains, and age of network are significant cost drivers. Climate does not have a significant influence on unit cost. The results indicate that customers, deliveries, and age of network have a positive influence on unit cost. However, length of mains has a negative impact on unit cost. This is consistent with the notion that there are economies of scale in gas distribution.

The results suggest AGLGN's observed unit costs ($4666) are slightly better than its predicted unit costs ($4695). However, AGLGN's unit cost reflects average practice rather than best practice for gas distribution.

To gain further insights into the performance of AGLGN, the study used benchmarking techniques which produce measures of performance for gas distribution which relate to observed best practice. The results of this exercise are discussed in the next chapter.

5 A BROADER PERSPECTIVE ON THE EFFICIENCY OF GAS DISTRIBUTION

The partial productivity measures for gas distribution provide useful insights into the efficiency of local gas distributors. However, the measures must be interpreted with care because they do not consider the relationships or trade-offs between various inputs and outputs. Furthermore, the measures can vary for reasons other than inefficiency. The information on potential cost drivers for gas distribution presents measures of performance which relate to average practice rather than best practice for gas distribution.

To gain a broader perspective on the performance of local distributors, several techniques were used which derive a single measure of efficiency by combining information on the major inputs and outputs of the distributors. The objective was to produce measures of performance which relate to observed best practice. The techniques could also assess the influence of the operating environment on the efficiency of gas distribution.

This chapter provides a brief discussion of the major inputs and outputs of gas distribution, and environmental factors which may influence the efficiency of gas distributors. The preferred model for gas distribution is presented, and sensitivity analysis is undertaken to test the robustness of the preferred model. The sensitivity analysis includes the use of DEA, stochastic frontiers and COLS, to measure the distributors' technical efficiency. The choice of benchmarking technique does not unduly influence the efficiency of the local distributors.

5.1 Characteristics of gas distribution

The least cost method of transporting natural gas from the wellhead to the customer is usually by dedicated pipelines and mains (BIE 1994; Industry Commission 1995; Energy Information Agency 1997). This specialised method of transporting gas has the characteristics of a natural monopoly[51] because it:

- requires large and lumpy capital investments that have no alternate use (ie large sunk costs)
- embodies large-scale economies
- requires special rights-of-way.

To ensure that the owners of these assets do not abuse their monopoly power, governments usually regulate the transmission and distribution of gas. The regulations often aim to control entry, prices, and profits. In NSW, IPART regulates access to distribution assets and the prices charged for access to the assets.

51 Gas pipelines are generally presumed to be a natural monopoly. However competition in gas networks has commenced in NSW and electricity competes with gas in several industrial and household applications.

According to Gascor Holdings No. 2 (the Holding Company for Westar):

> [g]as distribution involves the transportation of gas,
>
> - from one or more exit point(s) from a long distance, high pressure transmission pipeline (these points are generally at or near the perimeter of populated areas),
> - through a diverse and widely spread network of pipes within the supply area,
> - to supply points where consumers' gas meters are located on their premises.
>
> A gas distributor is typically responsible for building, owning and operating the pipelines which transport the gas, and is not involved in owning, buying or selling gas, nor, generally, in dealing with gas consumers (*Gascor Holdings No. 2 1998, p 4*).

Energy retailers purchase gas from the distributors to sell to customers. Retailers issue accounts, market gas, and handle customer inquiries. Some retailers read their customers' meters.

Distributors use a combination of assets to reticulate gas from city gate stations to customers served by retailers. The assets include: high and medium to low pressure mains, services (pipes connecting households to mains), meters, and regulators to maintain the pressure of the gas. A detailed description of AGLGN's distribution assets is presented in Ewbank Preece (1999).

5.2 Model specification

The technical relationship that describes how resources are used to distribute gas to different categories of customer provides the foundation for specifying the inputs and outputs for the benchmarking exercise. Discussions with participants and previous studies of the efficiency of gas distribution help further to define the inputs and outputs of gas distribution. Several workshops were held for industry and community participants to explain the benchmarking exercise and present the initial results of the exercise. The participants' comments on the inputs and outputs, data and choice of techniques helped refine the data and the analysis. Literature on the efficiency of gas distribution, reviewed for this study and presented in Chapter 3, provided additional guidance on these matters.

DEA is initially used to measure the technical efficiency of the local distributors. As mentioned in Chapter 2, DEA is sensitive to the specification of the inputs and the outputs and the size of the sample. Inflating the number of inputs and outputs relative to the sample will increase the efficiency of the distributors, because DEA has limited opportunities to compare like with like. The BIE (1994) study provides an example of a relatively large number of inputs and outputs resulting in a view that most of the distributors were managerially efficient. This situation suggests DEA has difficulty comparing like with like.

Given the relatively small sample of distributors, the focuses are on the major outputs and inputs of gas distribution and restricted the number of variables to five. Environmental variables, such as climate and age of network, were regressed against the DEA efficiency scores to assess their influence on the distributors' efficiency. The following section focuses on major inputs and outputs for gas distribution.

5.2.1 Inputs

Capital

As mentioned above, distributors use capital equipment to deliver gas. Capital is a major expense incurred by the distributors. The stock of capital can be represented by physical or monetary measures. Both approaches have strengths and weaknesses.

Technical efficiency reflects the ability of organisations to convert physical inputs to physical outputs. Thus, physical measures are often used in studies which focus on the technical efficiency of organisations. However, physical measures have disadvantages. Firstly, physical measures cannot capture all the capital equipment used in the production process. Secondly, it is difficult to account for differences in asset quality, age, and composition eg different sizes of mains or materials used to construct the mains.

Monetary measures better reflect the capital used in the production process. However, creating monetary measures of capital is problematic. Firstly, it is difficult to obtain a consistent series of capital values because accounting methods and revaluation policies are not uniform within organisations. This means variations in efficiency may reflect different accounting standards. Secondly, controversy prevails over the correct method of calculating the monetary values of capital.

For this exercise, the length (kilometres) of distribution mains is used to measure capital for several reasons. Mains are usually the major capital item used to distribute gas and the information on mains is likely to be accurate because distributors collect this information to help monitor and report on performance. Using, a physical measure to represent capital is consistent with other studies which examine the efficiency of gas distribution (BIE 1994; Price and Wayman-Jones 1996), and studies which examine the efficiency of other network businesses, such as electricity distribution, water and sewerage services, and rail services (London Economics 1999; ACT Auditor General 1995; Productivity Commission 1999b). Using a physical measure avoids the problems associated with developing monetary values of capital, such as trying to reconcile the different accounting methods and valuation policies of local and US distributors.

It should be noted that length of mains may not readily account for different sizes of main, or the different material composition of the mains, which could influence the efficiency of a distributor. For example, a distributor with a higher proportion of cast iron mains is likely to have higher O&M costs than another distributor with similar sized mains because cast iron mains require greater maintenance to prevent gas leakages.

The extent to which distributors can ‘control’ the length of mains is limited. To a large extent, the length of the mains reflects the size of the region where customers reside or conduct business activities. However, a distributor, to some extent, can influence the length of mains through system design and by making decisions not to serve certain areas.

O&M costs

The O&M costs incurred by distributors include labour, network marketing, corporate overheads, expenses on contracting, and spare parts. Consequently, O&M costs are included as an input in the study. A monetary measure is used for O&M because it is not possible to combine the diverse range of inputs into a single physical measure.

FERC codes consistent with AGLGN's activity-based cost structure are used to develop O&M costs for local and US distributors. As noted in the previous chapter, customer accounts expenses, UAG, and government levies are excluded from the distributors' O&M costs because certain local distributors do not incur these costs. Still, differences in O&M costs could arise because distributors use different definitions and assumptions to allocate costs to FERC codes.

5.2.2 Outputs

AGLGN has stated that the main outputs of gas distribution are:

- distribution capacity
- the area of the network
- the reliability of the network.[52]

It is considered that the area of the network (measured by kilometres of main) is an input rather than an output of gas distribution because the network is necessary for the distributor to provide a fundamental output – the capacity to deliver gas. The outputs of gas distribution and output measures used in the study are discussed below.

Capacity to deliver gas

The capacity to deliver gas is a fundamental output of gas distribution. AGLGN charges *contract customers* for the transportation of gas in accordance with their maximum daily throughput per annum. By contrast, *tariff customers* are charged for throughput plus a fixed charge for access to the network. Other local distributors have similar charging regimes.

However, the information on capacity to deliver gas is inconsistent. Some distributors present information on maximum daily quantities of gas (eg AGLGN) or maximum hourly quantities (MHQ) of gas for contract customers (eg Westar). AGLGN presents information on average and peak flow rates for the tariff and contract markets. Some distributors present information on the system load profile as a percentage of annual throughput (eg Westar and Stratus). Envestra presents information on system load profile by month for various regions. This is expressed as a ratio of a load for a certain month to the region's annual minimum monthly load. AGLGN presents information on regional monthly load profiles for both the contract and tariff markets. However, the other distributors provide scant information on the capacity requirements of tariff customers. The VIC distributors present information on MHQ for the tariff market. Similar information on capacity to deliver gas is generally not available for US distributors because the unbundling of gas services is not as advanced in the USA as it is in Australia.

52 Submission from AGLGN, July 23, p 8.

Because data for the benchmarking exercise is restricted to one year, total deliveries (TJ) was used as a proxy for the capacity to transport gas.[53] It is assumed that greater deliveries imply a greater capacity to deliver gas. Deliveries of gas are used in lieu of sales, because it includes the transport of gas for other parties. This practice is common in the USA and the Code provides for these arrangements in Australia. Other studies often use deliveries as an output of gas distribution (BIE 1994; Kim et al 1999; Price and Wayman-Jones 1996). The Tribunal recognises that this measure of capacity may, to some extent, reflect different sizes of mains or load factors rather than differences in efficiency.

Ability to deliver gas to sites

The ability to deliver gas to sites is influenced by the number of supply or connection points, and the mix of retail and contract customers that retailers serve. Consistent information on connection points is not available. Therefore, customers are used as a proxy for connection points in this study. Distributors incur greater costs in delivering gas to retail customers than to contract customers. This is because more infrastructure (mains, services and meters) is required to deliver gas to retail customers. In Australia, retail customers include residential customers and some small businesses. However, definitions of business and industrial customers vary between the USA and Australia. Customers are spilt into residential customers and other customers to mitigate the differences in customer definitions. This helps to ensure DEA compares distributors with similar output and input mixes.[54]

Customer numbers are included as an output in other studies which assess the efficiency of gas distribution (BIE 1994; Price and Wayman-Jones). Customer numbers are included as a KPI in the Envestra Revised AAI and Regulator-General's draft KPIs for the VIC distributors includes domestic and non-domestic customers.

Quality of service

Quality of service is influenced by several factors, including the price of services. Customers require a reliable supply of gas for business and household activities. However, there is little information on the reliability of services, such as interruptions to gas supply. UAG (expressed as a ratio of UAG to deliveries) reflects some aspects of quality because customers usually bear the cost of UAG according to prescribed targets set by regulators. The lower the prescribed targets are for UAG, the lower the costs of UAG borne by customers. The reciprocal of UAG is used to measure quality because a higher UAG will result in a smaller output.

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53 UAG is excluded from total deliveries.

54 Some distributors (eg Stratus) group customers according to gas consumption in the AAI – eg less than 500 GJ per annum, 500GJ to 2000 GJ per annum, 2000 GJ to 5000 GJ per annum and so on. Residential customers generally consume less than 500 GJ per annum. However, some small businesses may be included in this customer class.

5.2.3 The preferred model

The preferred model is presented in Table 5.1. The model specification was selected on the basis that:

- key inputs of the capacity to deliver gas are included in the model
- the model's output measures provide the best representation of activities associated with gas distribution, given limited information on outputs
- the number of inputs and outputs is reasonable, given the limited sample size
- the model provides a reasonable comparison between similar sized distributors
- sensitivity analysis (which is discussed below) suggests the model is robust.

Table 5.1 Preferred model specification

Inputs	Outputs
Length of mains (km)	Deliveries (TJ)
O&M costs ($A)	Residential customers (number)
	Other customers (number)

The reciprocal of UAG is included in an alternative DEA model developed to help test the robustness of the preferred model. The outputs of the alternative model are:

Table 5.2 Alternative model specification

Inputs	Outputs
Length of mains (km)	Deliveries (TJ)
O&M costs ($A)	Customers (number)
	The reciprocal of UAG (%)

It should be noted that interpretation of the DEA results depend on the assumptions that underpin the technique, restrictions of the sample size, and available information on the inputs and outputs of gas distribution. Additional observations would allow an increase in the dimensions of the preferred model to include quality of service. Opri recently advised that US data for 1998 is now available. Future analysis could expand the sample of distributors by pooling the data for 1997 and 1998.

5.2.4 Accounting for the operating environment

The operating environment, such as climate and age of network, may influence distributors' efficiency. A better assessment of the technical efficiency of the distributors requires that the environmental influences be measured and, where relevant, excluded from the DEA efficiency scores.

AGLGN has stated that the following environmental factors could influence the gas distributors' efficiency:

- climate
- soil type
- topography
- mains materials
- age of mains
- degree of urbanisation
- location of industrial loads within the network.[55]

AGLGN provided little information on the relative importance these environmental factors have on the efficiency of gas distribution and did not suggest sources of information for the environmental factors. Information was obtained on climate and age of network only and these factors are included in the analysis. This does not mean other environmental variables do not influence the efficiency of the distributors. However, information is not available to include these variables in the analysis. Further effort is required to assess the influence of the other environmental variables on the efficiency of gas distribution. It is noted that Ofwat requires water companies:

> … to explain, justify and quantify the weight to be placed on these [environmental] factors. The burden of proof should rest on the higher cost companies to justify why they should not be classed as less efficient than their peers (Ofwat 1998, p 3).

The study adopted two approaches to account for the influence of the operating environment on the efficiency of each distributor:

- specification of the DEA model
- a second stage Tobit regression which tested the influence of the environmental variables.

Specification of the DEA model helps to ensure that the model considers aspects of the operating environment. The technique compares distributors that use a broadly similar mix of inputs and outputs. For example, residential customers per kilometre of main is a proxy for population density.

Further analysis of environmental factors can be undertaken by regressing climate and age of network against the managerial efficiency scores produced by DEA.[56] If these environmental variables are statistically significant, the DEA scores are adjusted to account for the environmental differences faced by distributors. Estimated regression coefficients are used to adjust the DEA scores for differences in the environment. This approach produces biased estimates if the inputs or outputs are highly correlated with the environmental variables.

55 Submission from AGLGN, July 23, p 9.

56 A Tobit procedure is used instead of OLS because the managerial efficiency scores are censored from above at one. Under these circumstances OLS produces biased and inconsistent results (Judge et al 1988).

Further information on this approach is presented in Coelli, Rao and Battese (1998) and London Economics (1999).

Other approaches to account for the operating environment in DEA are discussed in Coelli, Rao and Battese (1998) and Ali and Seiford (1993). One approach is to include the environmental variables directly in the DEA model as inputs or outputs (BIE 1994; Price and Wayman-Jones 1996). However, assumptions must be made about the influence of the environmental variables on managerial efficiency. This precludes testing hypotheses of the actual influence that environmental variables have on efficiency. Further, the approach increases the dimensions of the model. This may make it difficult to compare like with like for a limited sample. The BIE (1994) is an example where the dimensions of the model become large relative to the sample after environmental variables are included as inputs. Consequently, most distributors were deemed to be managerially efficient.

Another approach is to calculate managerial efficiencies for a sub-sample of distributors operating in similar operating environments. However, this approach is restricted to instances where a single discrete environmental variable influences the technical efficiency of the distributors. Another disadvantage is that this approach reduces the number of peers in each subset. This means valuable knowledge from potential peers in other subsets is lost to the analysis. AGLGN suggests that distributors face varying environmental conditions which precludes the use of this approach in this study.

5.3 Description of the data

5.3.1 Data sources

Inputs

Length of mains (kilometres) is obtained from the AAI or annual reports for local distributors. Otherwise, the study obtained this information from the distributors. The local distributors present this information on a financial or calender year. Information for 1997-98, 1998 or 1998-99 is used in the analysis. Information on length (miles) of mains for the US distributors for 1997 is obtained from the *Pipeline & Gas Journal (*November 1998*)*. The US distributors' miles of main are converted into kilometres of main.

O&M costs for the local distributors are presented in the AAI for either a financial or calender year. O&M costs were obtained directly from distributors who had yet to produce an AAI. As mentioned in Chapter 4, additional information was sought from local distributors in order to align their costs to the FERC codes which correspond with AGLGN's activity-based cost activities. Thus the cost structures have been made as consistent as possible. The study excluded customer account expenses, UAG, and government levies from O&M costs. Information on the local distributors' O&M costs for 1997-98, 1998 or 1998-99 have been used in this analysis.

The FERC codes corresponding to AGLGN's activity-based cost activities are also used to develop O&M costs for the US distributors. The US distributors' O&M costs are adjusted so that they have similar cost structures to those of local distributors. The Natural Gas LDC Database (Opri 1998) provides information on the US distributors' O&M costs by various FERC codes.[57] Information on US O&M costs for 1997 is used in the analysis. The purchasing parity exchange rate for Australia and the USA is used to convert the US distributors' O&M costs into Australian dollars. The purchasing power exchange for 1997-98 is $US0.75=$A (OECD 1998).

Outputs

Information on deliveries (TJ), residential and other customers and UAG is derived from the AAIs or annual reports of most local distributors. Information was obtained directly from the distributors. UAG is excluded from deliveries. The category, 'other customers' includes all customer groups except residential customers. The local distributors present information on outputs for a financial or calender year. Information for 1997-98, 1998 or 1998-99 has been used in this analysis.

Information on the outputs for the US distributions was obtained from the Natural Gas LDC Database (Opri 1998) and relates to 1997. The information originally came from the Energy Information Agency (EIA) form EIA-176. Deliveries for the US distributors are quoted in thousands of cubic feet and include UAG. UAG is excluded from the US distributors' deliveries before the conversion tables in the AGA (1997) are used to convert the deliveries into terajoules (TJ). Distributors with a negative UAG are excluded from the sample because it is not possible to include a negative output in the alternative model.

The EIA defines residential customers as customers that use gas for heating, air conditioning, cooking, water heating, and other residential users in single and multi-family dwellings, apartments and mobile homes. Minor differences in residential customer numbers for the local and US distributors may be attributed to different definitions for residential customers. Other customers comprises the remaining classes of customer, eg industrial users and utilities.

Environmental variables

The study used information on heating degree days (HDD) to measure climate. The AGA (1998) presents information on HDD for Australian State capital cities for 1993-1997. An HDD is defined as the 'sum of degrees by which the mean temperature is below 18°C in any day' (AGA 1998, p 72). The average of the five yearly observations is included in the analysis. The American Gas Association (1996) presents an average (30 year) series on HDD for the USA. However, given the large discrepancy between the average HDD for California and the average (20 year) HDD presented by Southern California Gas Company (1997) the latter is used in the analysis.[58] Although the US data is in degrees Fahrenheit, the reference temperature is 65°F, which is equivalent to 18°C. For the analysis, the US data is converted into a series based on degrees Celsius.

57 Some US distributors had a negative expenditure for some FERC codes. However, the amounts are relatively minor compared to total O&M costs. Opri confirmed that negative costs are constant with the filings lodged by the distributors with the relevant US regulators, but could not provide reasons to explain the negative costs. The study erred on the side of conservatism and set the negative costs to zero.

58 Whereas, the average (30 year) HDD for California presented in the American Gas Association (1996) is 2663, the average (20 year to 1997) HDD presented in Southern California Gas Co. is 1358. Both averages are based on degrees Fahrenheit.

Age of network is estimated by the ratio of depreciated optimised replacement cost (DORC) to optimised replacement cost (ORC) for the local distributors. The AAIs present information on DORC and ORC values for the local distributors. This information, or the ratio of DORC to ORC, was obtained from distributors that do not have an AAI. For the US distributors, the age of network is calculated as one minus the ratio of accumulated depreciation to asset value.[59] Information on accumulated depreciation and asset value is presented in the Natural Gas Database (Opri 1998).

5.3.2 Measures to check data

A sample of 59 distributors is used to calculate the technical efficiency of local and US distributors. Local distributors included in the sample are: AGLGN (NSW), AGLGN (ACT), Envestra (SA), Envestra (QLD), Multinet Gas (VIC), Stratus Networks (VIC), Westar (VIC) and Allgas (QLD). The Albury Gas Company and Great Southern Energy Gas Networks are excluded because they are too small to include in the analysis, and because there are concerns over the reliability of the allocation of overheads between various aspects of their business.

The sample is screened by the following procedures to limit inconsistencies in the data:

- descriptive statistics are used eliminate obvious errors in the data
- the data is checked for potential outliers.

Table 5.3 presents descriptive statistics, such as maximum and minimum values, which are used to identify obvious errors in the data.

Table 5.3 Descriptive statistics for local and US distributors (59 observations)

	Mean	Std Dev	Maximum	Minimum
Outputs				
Residential customers (no.)	411,796.90	83,712.46	4,597,685	28,609
Other customers (no.)	32,337.35	4,748.26	206,703	1,623
Deliveries (TJ)	122,040.50	23,131.43	1,119,140	3,975
Inputs				
Mains (km)	10,866.39	1,576.90	68,786.41	800
O&M ($A)	59,755,899	9,348,018	477,148,207	5,479,549

Furthermore, because DEA is susceptible to outliers, output-input ratios are calculated for each distributor. Observations which are more than two and a half standard deviations from the sample mean are considered to be potential outliers. Potential outliers include:

- Peoples Gas, Light & Coke (IL)
- Brooklyn Union Gas (NY)
- NICOR (IL)

59 Attachment 7 presents algebra which proves that the two expressions are equal and independent of the value of the asset base.

- PSC of Colorado (CO)
- North Carolina Natural Gas (NC).

As there are no obvious errors in the data for these distributors, potential outliers are not excluded from the sample.

5.4 DEA results

5.4.1 DEA scores

The DEA scores presented in Table 5.4 indicate the potential for local distributors to reduce inputs while maintaining existing outputs. The distributors may not be able to achieve maximum savings in inputs because of regulatory constraints, labour constraints, limited opportunities to reduce length of mains and the broader environment. However, the DEA scores do reflect some aspects of the broader environment, such as population density (residential customers per kilometre of main) and customer mix. A list of the efficiency scores for the entire sample is presented in Attachment 8.

Table 5.4 Summary statistics: efficiency of gas distributors (59 observations)

Distributor	Technical efficiency (%) (1)	Managerial efficiency (%) (2)	Scale efficiency (%) (3)=(1)÷(2)
AGLGN (NSW)	59.1	**59.2**	99.8
AGLGN (ACT)	41.6	**67.4**	61.7
Envestra (SA)	77.3	**81.2**	95.2
Envestra (QLD)	63.8	**98.3**	64.9
Multinet (VIC)	100.0	**100.0**	100.0
Stratus (VIC)	84.8	**86.6**	98.0
Westar (VIC)	96.9	**100.0**	96.9
Allgas (QLD)	59.3	**100.0**	59.3
Aust. mean	72.9	**86.6**	84.5
Sample mean	73.0	**82.0**	89.9
Minimum	41.6	**47.8**	42.1
Maximum	100	**100**	100
Efficient distributors (no.)	8	**16**	9

The technical efficiency scores indicate the presence and extent of the inefficiency of input use. For example, on average, the local distributors are 73 per cent efficient. This suggests they could reduce their inputs, on average, by 27 per cent. The extent of the inefficiency is a combination of managerial efficiency (ie how well a distributor converts inputs into outputs) and the scale or size of the distributor. A score of 100 per cent indicates that the distributor is technically efficient.

The emphasis of the exercise is on managerial efficiency. To a certain extent, the size of a distributor is beyond the control of current management. The local distributors' managerial efficiency ranges from 59.2 per cent to 100 per cent, compared to the sample mean of 82 per cent. Most local distributors are more efficient than the sample average.[60]

The managerially efficient distributors are:

- Multinet (VIC)
- Westar (VIC)
- Allgas (QLD)
- Arkansas Okalahoma Gas (AR)
- Berkshire Gas (MA)
- Brooklyn Union Gas (NY)
- Columbia Gas of Pennsylvania (PA)
- Fall River Gas (MA)
- NICOR (IL)
- North Carolina Natural Gas (NC)
- Northern Indiana Fuel & Light (IN)
- Peoples Gas, Light & Coke (IL)
- PSC of Colorado (CO)
- Roanoke Gas (VA)
- Southern California Gas (CA)
- Valley Gas (RI).

The dominant peer for the less efficient local distributors is presented in Table 5.5. The *dominant peer* is a managerially efficient distributor which has a similar input-output mix to the less efficient distributor, and may be able to provide important insights and lessons to help less efficient distributors improve their performance.

[60] The presence of input and output slacks suggests there is further scope to improve managerial efficiency. However, in this study they are relatively minor for the sample as a whole. On average, the input slack for O&M costs was 1.4 per cent of total O&M costs and the input slack for mains was less than 1 per cent of total mains. On average, the output slack for residential customers was 1.9 per cent of total residential customers, the output slack for other customers was 3.5 per cent of total other customers and the output slack in deliveries was 12.6 per cent of total deliveries.

Table 5.5 Dominant peer for local distributors

Distributor	Dominant Peer
AGLGN (NSW)	Multinet
AGLGN (ACT)	Allgas
Envestra (SA)	Multinet
Envestra (QLD)	Allgas
Stratus	Multinet

The scale efficiency scores suggest that scale is not a major source of inefficiency for the larger distributors (ie AGLGN (NSW), Envestra (SA), Multinet, Stratus and Westar (VIC)). However, scale is a significant source inefficiency for the smaller distributors (ie AGLGN (ACT), Envestra (QLD) and Allgas (QLD)).

5.4.2 Influence of the operating environment on efficiency

Managerial efficiency scores are regressed against climate and age of network to assess their impact on efficiency. The sample has 45 observations due to lack of data on age of network for some US distributors. The regression results presented in Attachment 9 indicate that these two factors explain about 5 per cent of the variation in the managerial efficiency scores, and the estimated coefficients of climate and the age of the network are not significantly different from zero at the 5 per cent level of significance. Therefore, the DEA scores are not adjusted for these environmental factors. Similar results are obtained when environmental variables are included in the COLS and stochastic frontiers analyses.

The insignificant influence of climate on efficiency may appear counter-intuitive to some participants. However, it is not unreasonable for the net benefits of delivering gas in a cold climate to be small. A cold climate increases the demand for gas for heating, but the distributors located in cold regions may have to install additional capacity to satisfy peak winter demands. Adverse climatic conditions and peak loads may impact on the cost of operating and maintaining the system. Additional costs may be incurred for: maintaining and repairing mains and other assets in adverse conditions, managing the risks of interruptions, reduced asset lives and constraints on scheduling maintenance.

5.5 Sensitivity analysis

Several approaches were adopted to test the sensitivity of the DEA results of the preferred model. Sensitivity analysis assesses the robustness of DEA results under different assumptions. Various approaches to test the sensitivity of the results include changing:

- the O&M costs for AGLGN (NSW) and AGLGN (ACT) to include the O&M estimates provided by AGLGN (on 25 August 1999 and 27 August 1999) that are consistent with the mapping of General Ledger costs to FERC codes, resulting in lower O&M costs for AGLGN (NSW) and AGLGN (ACT)
- the manner in which efficiency is measured relative to the frontier by assuming that the distributors can reduce their O&M costs only (ie mains are held fixed)

- the distributors that form the frontier by removing the original set of peers
- the model for gas distribution
- the method of estimating the preferred model (ie COLS and stochastic frontiers).

The sensitivities are presented in Table 5.6.

Table 5.6 Summary of sensitivity analysis of managerial efficiency scores

Distributor	Original DEA scores (%)	AGLGN's O&M costs derived from General Ledger (%)	Network fixed (%)	Peers removed (%)	Alternative model (%)	Stochastic frontiers (%)	COLS (%)
AGLGN (NSW)	**59.2**	60.6	50.0	89.4	57.6	57.1	52.7
AGLGN (ACT)	**67.4**	72.0	67.4	79.8	69.0	59.6	59.3
Envestra (SA)	**81.2**	81.2	76.2	96.8	79.5	79.5	73.7
Envestra (QLD)	**98.3**	98.3	96.9	100	98.0	89.4	72.9
Multinet (VIC)	**100**	100	100	-	100	88.9	76.8
Stratus (VIC)	**86.6**	86.6	80.4	100	86.0	69.9	62.7
Westar (VIC)	**100**	100	100	-	99.7	99.9	100
Allgas (QLD)	**100**	100	100	-	100	90.0	89.9
Aust. mean	**86.6**	87.3	84.0	93.2	86.2	79.3	73.5
Sample mean	**82.0**	82.1	72.7	92.0	77.9	78.8	71.4
Minimum	**47.8**	47.8	35.0	61.9	41.6	47.3	44.7
Maximum	**100**	100	100	100	100	99.9	100
Observations (no.)	**59**	59	59	43	59	59	59
Efficient distributors (no.)	**16**	16	16	21	15	0	1

The general patterns of efficiency and the ranking of distributors' efficiency are consistent between most of the models.[61] Except where peers are excluded from the sample, most of the distributors that form the DEA frontier for the preferred model also form the frontier for the other DEA models.

Efficiency scores for local distributors increase by about 10-30 per cent after the original peers are excluded from the sample. This result is not unexpected. DEA is beginning to have difficulty in comparing like with like with a smaller sample. Nearly half the sample, 21

61 The correlation coefficient and the spearman rank correlation coefficient between the efficiency scores of the preferred model are 0.65 and 0.62 respectively when estimated by DEA and stochastic frontiers. The correlation coefficient and spearman rank correlation between the efficiency scores of the preferred model are 0.64 and 0.57 respectively when estimated by DEA and COLS. Stronger correlations exit between patterns of efficiency produced by the various DEA models. The correlation coefficient and the spearman rank correlation coefficient between the efficiency scores of the preferred model and the model with mains fixed are 0.95 and 0.95 respectively. And the correlation coefficient and spearman rank correlation between the efficiency scores of the preferred model and the alternative model are 0.90 and 0.91, respectively.

distributors, are efficient. Four distributors are efficient because they cannot be compared with other distributors in the sample. Two distributors are a weak peer for a distributor.

As expected, the parametric techniques produce lower efficiency scores for the preferred model because the estimated frontier bounds the data less tightly than DEA. However, in some instances (eg Envestra (QLD) and Multinet), the efficiency scores are about 20-30 per cent lower than the DEA results. Nevertheless, as noted above, for the sample as a whole, the techniques produce results that are similar to DEA.

Fewer efficient distributors are identified when the frontier is estimated by the parametric techniques. Stochastic frontiers recognise that some of the distance from the frontier is due to random events or statistical noise in the data. Therefore, it is common not to have efficient organisations in a sample. As explained in Chapter 2, the COLS frontier is formed by a two step procedure. First, the average frontier is estimated by ordinary least squares (OLS). Then the intercept is adjusted upwards until all the residual are non-positive and at least one residual is zero. Distributors associated with the residuals that are zero form the frontier. Therefore, the COLS frontier is often formed by a single organisation. Parameter estimates of the input distance function that is estimated by stochastic frontiers and COLS are presented in Attachment 10. A list of stochastic frontiers scores and COLS scores for the sample are presented in Attachment 11.

5.6 Concluding remarks

The benchmarking study suggests that there is scope for most local distributors to improve performance. The choice of benchmarking technique does not unduly influence the results of the study. Therefore, the sensitivity analysis suggests that the results of the preferred model are quite robust. Furthermore, the sensitivity analysis does not contradict initial impressions of the efficiency of the local distributors, formed after examining partial productivity measures for gas distribution.

For example, the DEA results for the preferred model suggest that the local distributors' managerial efficiency ranges from 59.6 per cent to 100 per cent, compared to the sample mean of 82 per cent. On average, local distributors have the potential to produce the same outputs with 18 per cent less inputs. Most local distributors are more efficient than the sample average.

The DEA exercise did not suggest that climate or network age have a significant influence on efficiency. These environmental variables were also not significant in the COLS and stochastic frontiers analyses. This may appear counter-intuitive to some industry participants. However, it is not unreasonable for the net benefits of delivering gas in a cold climate to be small. A cold climate increases the demand for gas for heating. However, the distributors located in cold regions may have to install additional capacity to satisfy peak winter demands. Adverse climatic conditions and peak loads may also impact on the cost of operating and maintaining the system.

6 FUTURE DIRECTIONS

Recent government reforms of gas distribution aim to encourage the sector to meet world best practice in the delivery of gas. However, the results of this study suggest that the ability of local distributors to achieve and maintain world best practice for efficient delivery of gas varies. Some distributors possess efficient networks, but for most local distributors there is scope to improve performance.

The study provides indicative information on performance and should not be used in a mechanical manner to set efficiency targets for the distributors. A wide range of factors, including the operating environment, influences performance. Moreover, the regulatory issue of whether the targets for the improvement in performance for the less efficient distributors are set according to their best practice peers requires further consideration.

The results of the study need to be interpreted with care because of variations in the quality of data. The Tribunal sought assistance from local distributors to reconcile differences in local and overseas data. However, there remains significant scope for improving the data. Further effort is required to ensure consistent and reliable information is collected in the future. In particular, information presented in AAIs on O&M costs and network capacity requires greater consistency. Further effort is required to determine the actual influence of the operating environment on the efficiency of gas distribution. The onus is on the distributors to explain and quantity the influence of the operating environment on the efficiency of gas distribution.

Regardless of the approach taken to benchmark gas distribution, better information about the sector will assist governments, managers, regulators and the broader community to gain further insights into the performance of local distributors. Such insights are important to setting a regulatory framework which encourages the sector to improve its performance.

World best practice is a moving target. In a dynamic global economy, countries continue to set new standards of service delivery in response to changing patterns of demand. Australia must strive to meet these new challenges. Otherwise its living standard may drop relative to other countries. Furthermore, commitments to improve the measurement of the performance of gas distribution can encourage similar initiatives in other energy sectors - electricity distribution, for example.

That said, the Tribunal welcomes comments on this discussion paper and any other information that will assist in assessing the efficiency of AGLGN's non capital costs. The Tribunal is keen to assemble a wide range of information on potential efficiency gains and to have this information available to all stakeholders for comment. This will ensure that inputs to the regulator's views on potential efficiency gains are transparent and subject to testing by stakeholders.

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GLOSSARY AND ABBREVIATIONS

AAI	Access Arrangement Information
ABS	Australian Bureau of Statistics
Access arrangement	An arrangement for access to a covered pipeline that has been approved by the Relevant Regulator under the National Third Party Access Code for Natural Gas Pipeline Systems
ACT	Australian Capital Territory
AGL	Australian Gas Light Company
AGLGN	AGL Gas Networks Limited
Allocative efficiency	A measure of the ability of an organisation to use a combination of inputs to minimise the cost of production, given input prices
BHPP	BHP Petroleum Limited
BIE	Bureau of Industry Economics
City gate	Transmission point from high pressure transmission pipelines to a distribution network
COAG	Council of Australian Governments
Contract customer	End use gas customer consuming more than 10 TJ per annum
Corrected ordinary least squares (COLS)	A parametric counterpart to data envelopment analysis
Cus	Customer
DAC	Depreciated actual cost
Data envelopment analysis (DEA)	A linear programming technique which identifies best practice within a sample and measures efficiency based on differences between observed and best practice organisations
Distribution	Transmission of gas over a combination of high pressure and low pressure pipelines from a city gate to various customers' usage points. Also known as reticulation
Dynamic efficiency	A measure of the success to which organisations alter production patterns over time in response to changes in consumption patterns or

	technology
Efficiency	A measure of performance that compares an organisation's actual ratio of outputs to inputs to its optimal ratio of outputs to inputs
EIA	Energy Information Agency
Emp	Employment
FERC	Federal Energy Regulatory Commission – US energy industry regulatory
FTE	Full time equivalent
GFCV	Gas and Fuel Corporation of Victoria
GJ	Gigajoule, a measure of the heat content of gas (an average residential customer in NSW consumes about 20 GJ of gas per year)
Heating degree days (HDD)	A measure of climate that is the sum of degrees by which the mean temperature is below 18 degrees Celsius in any day
km	Kilometre
KPI	Key performance indicator
IPART	Independent Pricing and Regulatory Tribunal of NSW, otherwise referred to as "the Tribunal"
LNG	Liquid natural gas
Load factor	A measure of the degree to which a customer's load can cause peak demands on the system, measured as the relationship between the customer's average daily demand and its peak day demand
MDQ	Maximum daily quantity
Multifactor productivity (MFP)	A measure of productivity that refers to a ratio of all outputs to a subset of inputs, capital and labour
MHQ	Maximum hourly quantity
NERA	National Economic Research Associates
NM	Network marketing
NSW	New South Wales

OECD	Organisation for Economic Cooperation Development
Ofgem	Office of Gas and Electricity Market – UK energy industry regulator
Ofwat	Office of Water Services – UK water regulator
O&M	Operation and maintenance
OLS	Ordinary least squares
Overall efficiency	A measure that combines technical efficiency and allocative efficiency
PIAC	The Public Interest Advocacy Centre
QLD	Queensland
Reticulation	See distribution
SA	South Australia
SCNPMGTE	The Steering Committee on National Performance Monitoring of Government Trading Enterprises
SCRCSSP	The Steering Committee for the Review of Commonwealth/State Service Provision
Sec	Second
Stochastic frontiers	A parametric counterpart to data envelopment analysis
Technical efficiency	A measure of an organisation's ability to convert inputs into outputs.
The code	The National Third Party Access Code for the National Gas Pipeline Systems
Tariff customer	An end use gas customer consuming less than 10 TJ per annum
TJ	Terajoule, equal to 1,000 GJ
Total factor productivity (TFP)	Ratio of the quantity of all outputs to the quantity of all inputs. TFP can be measured by an index of the ratio of all outputs (weighted by revenue shares) to all inputs (weighted by cost shares)
Transmission	Long haul transportation of gas via high pressure pipelines
Trunk mains	High pressure pipelines within the distribution network used to transport large quantities of gas to sections of the network downstream from the city gate

UAG	Unaccounted for gas
UK	United Kingdom
USA	United States of America
VIC	Victoria
WA	Western Australia

ATTACHMENT 1 LIST OF PARTICIPANTS WHO ATTENDED THE WORKSHOPS ON BENCHMARKING GAS DISTRIBUTION

Workshops were held on 24 March 1999 and 28 April 1999 to explain the benchmarking exercise to industry and community participants. Participants were:

Organisation	Name
AGL Gas Networks Ltd	C Harvey
AGL Gas Networks Ltd	S Ronan
AGL Gas Networks Ltd	E Kwok
Boral Pty Ltd	J Lawrence
Stratus Networks Pty Ltd	G Foley
Stratus Networks Pty Ltd	P Walsh
Westar Pty Ltd	P Tonkin
Multinet Gas Pty Ltd	P Kettle
Great Southern Energy Gas Networks Pty Ltd	L Elder
East Australian Pipeline Ltd	D Gibbons
Business Council of Australia	B Lim
BHP Petroleum Pty Ltd	B Henson
National Economic Research Associates	P Fitzgerald
Australian Competition and Consumer Council	J Bastic
Office of the Regulator-General, Victoria	K Gelling
Public Interest Advocacy Centre	T Benson

ATTACHMENT 2 DATA ENVELOPMENT ANALYSIS

Data envelopment analysis (DEA) involves the use of linear programming to construct a non-parametric piece-wise frontier over the data. Measures of efficiency are calculated relative to this frontier. Several linear programming models are solved to obtain the measures of efficiency presented in this study. The software DEAP Version 2.1 (Coelli 1996) is used to solve the linear programs and calculate measures of efficiency for gas distribution. For further information on DEA see Ali and Seiford (1993), Coelli, Rao and Battese (1998), Lovell (1993), and the Steering Committee for the Review of Commonwealth/State Service Provision (1997).

This study focuses on the technical efficiency of gas distribution. Gas distributors rarely deliver gas in competitive markets and are therefore unlikely to possess optimal scale. Therefore, an assumption of variable returns to scale must be imposed on the linear programming model used to derive measures of managerial efficiency for gas distribution. However, this assumption is relaxed to examine the scale efficiencies of the gas distributors. Further, it is assumed that gas distributors seek to deliver gas with minimal inputs. General formulations of input-orientated DEA models which assume variable returns to scale (VRS) and constant returns to scale (CRS) are presented below.

A2.1 The variable returns to scale model

To develop an input-orientated VRS model, assume there is data on K inputs and M outputs for each of the N gas distributors. For the i-th distributor the data is represented by the column vectors, x_i and y_i. Observations for all the distributors are represented by X, a (K×N) matrix of inputs, and Y, a (M×N) matrix of outputs.[62]

The input-orientated VRS envelopment model is defined as:

$$\min_{\theta,\lambda}\theta, \qquad (1)$$

$$\begin{aligned} \text{s.t.}\quad & -y_i+Y\lambda\geq 0,\\ & \theta x_i-\lambda\geq 0,\\ & N1'\lambda=1\\ & \lambda\geq 0 \end{aligned}$$

In this model:

θ is a scalar representing a proportion of current inputs which can produce the given level of outputs

λ is a N×1 vector of constants

N1 is an N×1 vector of ones

$N1'\lambda=1$ is the convexity constraint (ie the assumption of variable returns to scale).

62 In this study, N is equal to 59 because 59 distributors are included in the sample. Two inputs and three outputs are included in the preferred model. Therefore X is a (2×59) matrix of inputs, and Y is a (3×59) matrix of outputs.

Solved N times, once for each distributor, the linear program provides solutions for θ and $\lambda=(\lambda_1,\lambda_2,...,\lambda_N)$ for each distributor. The optimal value of θ is bounded by zero and one, where θ corresponds to measures of managerial technical efficiency. A value of one signifies that the i-th distributor is efficient. The solution $\lambda_j>0$ indicates the j-th distributor is a peer for the i-th (inefficient) distributor.

The convexity constraint ensures that distributors with similar scales of production are benchmarked against each other. This may not be the case under the CRS model, which is essentially the VRS model with the convexity constraint ($N1'\lambda=1$) excluded.

A2.2 Scale efficiency

The CRS model is solved to examine the scale efficiency of the distributors. The CRS model produces technical efficiency measures (TE^{CRS}) that are the product of managerial efficiency (TE^{VRS}) and scale efficiency (SE). Consequently, scale efficiency for the i-th distributor is defined as

$$SE_i = TE_i^{CRS} / TE_i^{VRS} \qquad (2)$$

Scale efficiency represents the proportion of inputs which can be reduced further after managerial technical inefficiency has been eliminated, provided scale adjustments are possible. The scale efficiency measure is bounded by zero and one. If scale efficiency is equal to one, the distributor is operating at an optimal scale. A score less than one indicates that the distribution has the potential to reduce its inputs by altering its size.[63]

63 To determine whether a distributor should expand or reduce its size to achieve optimal scale, a third linear programming problem, the non increasing returns to scale (NIRS) model, is solved. The NIRS model is similar to the VRS model except that the constraint $N1'\lambda=1$ is replaced by $N1'\lambda\leq1$. The linear programming problem is solved for each distributor. If the $TE_i^{NIRS} = TE_i^{VRS}$ then the i-th distributor has decreasing returns to scale (ie is too big). Otherwise, the distributor has increasing returns to scale (ie is too small).

A2.3 Non discretionary inputs

The standard input-orientated DEA models, which are discussed above, assume that all inputs can be reduced radially. In other words, that the distributor can alter all inputs. As part of the sensitivity analysis to test the robustness of the DEA results for the preferred model, it is assumed that the distributor cannot reduce the length of mains, but can reduce operating and maintenance expenses to improve efficiency. The standard DEA model is adjusted to divide the inputs into discretionary inputs (X^D), which the distributor can change, and non discretionary inputs (X^{ND}) which the distributor cannot change. Equation (1) is rewritten as

$$\min_{\theta,\lambda}\theta, \qquad (3)$$

$$\begin{aligned} \text{s.t.}\quad & -y_i+Y\lambda\geq 0, \\ & \theta x^D_i-X^D\lambda\geq 0, \\ & x^{ND}_i-X^{ND}\lambda\geq 0 \\ & N1'\lambda=1 \\ & \lambda\geq 0 \end{aligned}$$

ATTACHMENT 3 US FEDERAL ENERGY REGULATORY COMMISSION FORM NO. 2 CODES USED BY IPART TO DEVELOP OPERATING AND MAINTENANCE COSTS

The study used the Federal Energy Regulatory Commission (FERC) Form No. 2 codes to develop similar O&M costs for local and US distributors. On 12 August 1998, AGLGN provided the Tribunal with a mapping of its activity-based costs in accordance with the FERC codes. AGLGN stressed that the mapping is the best alignment of its costs to the FERC codes, but is not a direct match. The mapping is used to develop the O&M costs for distributors included in the study. FERC codes used to develop O&M costs are:

Code	Account
	Distribution expenses
	Operation
870	Operation supervision and engineering
871	Distribution load dispatching
874	Mains and services expenses
878	Meter and house regulator expenses
879	Customer installation expenses
880	Other expenses
	Maintenance
885	Maintenance supervision and engineering
887	Maintenance of mains
889	Maintenance of measuring and regulating station equipment - general
891	Maintenance of measuring and regulating station equipment – city gate check station
892	Maintenance of services
893	Maintenance of meters and house regulators
894	Maintenance of other equipment
	Customer accounts expenses
	Operation
901	Supervision
902	Meter reading expenses
903	Customer records and collection expenses
	Customer service and informational expenses
	Operation
907	Supervision
	Sales expenses
	Operation
911	Supervision
912	Demonstration and selling expenses
916	Miscellaneous expenses

Code	Account
	Administration and general expenses
	Operation
920	Administration and general salaries
921	Office supplies and expenses
923	Outside services employed
928	Regulatory commission expenses
930.2	Miscellaneous general expenses

ATTACHMENT 4 US FEDERAL ENERGY REGULATORY COMMISSION FORM NO. 2 CODES USED BY AGLGN TO DEVELOP OPERATING AND MAINTENANCE COSTS

On 12 August 1999, AGLGN advised that it had mapped costs from its General Ledger in accordance with the Federal Energy Regulatory Commission (FERC) Form No. 2 codes to develop O&M costs for US distributors. This information is used to help compare the efficiency of the AGLGN's total network (which includes the ACT network) relative to US distributors. The analysis is presented in the Revised Access Arrangement Information. The FERC codes used by AGLGN to develop the O&M costs for the US distributors are:

Code	Account
	Distribution expenses
	Operation
870	Operation supervision and engineering
871	Distribution load dispatching
872	Compressor station labour and expenses
873	Compressor station fuel and power
874	Mains and services expenses
875	Measuring and regulating station expenses - general
876	Measuring and regulating station expenses - industrial
877	Measuring and regulating station expenses – city gas check station
878	Meter and house regulator expenses
879	Customer installation expenses
880	Other expenses
881	Rents
	Maintenance
885	Maintenance supervision and engineering
886	Maintenance of structures and improvements
887	Maintenance of mains
888	Maintenance of compressor station equipment
889	Maintenance of measuring and regulating station equipment - general
890	Maintenance of measuring and regulating station equipment - industrial
891	Maintenance of measuring and regulating station equipment – city gate check station
892	Maintenance of services
893	Maintenance of meters and house regulators
894	Maintenance of other equipment

Code	Account
	Customer accounts expenses
	Operation
901	Supervision
902	Meter reading expenses
903	Customer records and collection expenses
904	Uncollectable accounts
905	Miscellaneous customer accounts expenses
	Customer service and informational expenses
	Operation
907	Supervision
908	Customer assistance expenses
909	Information and instructional expenses
910	Miscellaneous customer service and informational expenses
	Sales expenses
	Operation
911	Supervision
912	Demonstration and selling expenses
913	Advertising expenses
916	Miscellaneous expenses
	Administration and general expenses
	Operation
920	Administration and general salaries
921	Office supplies and expenses
(Less) 922	Administrative expenses transferred - credit
923	Outside services employed
924	Property insurance
925	Injuries and damages
926	Employee pensions and benefits
927	Franchise requirements
928	Regulatory commission expenses
(Less) 929	Duplicate charges - credit
930.1	General advertising expenses
930.2	Miscellaneous general expenses
931	Rents
	Maintenance
935	Maintenance of general plant

ATTACHMENT 5 PARTIAL PRODUCTIVITY MEASURES FOR AGLGN AND US DISTRIBUTORS, 1997

Company	O&M ($USm)	cus/main (km) (no.)	O&M/ cus ($US)	O&M/ main (km) ($US)	O&M/ deliveries (TJ) ($US)	deliveries (TJ)/ main (km) (TJ)	NM costs/ O&M (%)	AdmGen/ O&M (%)	UAG (%)
AGLGN	77.6	35	107	3726	762	4.9	34.5	35	2.3
AmerenCIPS	17.1	22	100	2211	456	4.9	0.5	28	1.6
Arkansas Oklahoma Gas Corp	6.7	16	108	1778	241	7.4	0.4	37	1.2
Atlanta Gas Light Co	92.6	28	68	1902	343	5.5	3.3	11	0.5
Bay State Gas Co	62.5	31	255	7848	1048	7.5	3.6	58	2.0
Berkshire Gas Co	7.4	30	224	6735	848	7.9	9.4	32	0.5
Boston Gas Co	95.4	56	180	10019	534	18.7	0.0	30	3.7
Brooklyn Union Gas Co	232.7	178	204	36309	807	45.0	2.5	29	0.2
Central Illinois Light Co	22.9	35	113	3994	297	13.4	2.7	40	0.7
Citizens Gas & Coke Utility	35.5	45	140	6254	454	13.8	0.0	43	2.1
Citizens Utilities Louisiana Gas Div	24.9	32	94	3051	932	3.3	4.5	36	4.0
Colonial Gas Co	21.1	30	146	4310	719	6.0	6.3	35	4.3
Columbia Gas of Pennsylvania, Inc	68.6	34	179	6170	393	15.7	0.1	43	2.3
Columbia Gas of Virginia, Inc	35.5	27	208	5698	479	11.9	0.0	30	3.1
Commonwealth Gas Co	49.9	52	213	11031	1083	10.2	5.4	30	2.6
Delta Natural Gas Co, Inc	7.6	15	207	3147	701	4.5	0.0	44	4.7
Equitable Gas Co	50.8	47	194	9005	669	13.5	1.6	40	4.3
Essex County Gas Co	7.8	34	183	6161	1149	5.4	8.6	43	2.3
Fall River Gas Co	9.2	60	192	11504	1139	10.1	14.1	22	3.1
IES Utilities, Inc	28.7	30	162	4801	675	7.1	0.2	56	1.8
Illinois Power Co	37.8	30	96	2882	472	6.1	6.2	38	10.5
Indiana Gas Co, Inc	75.0	28	157	4420	523	8.4	2.0	52	0.8
Intermountain Gas Co	18.7	28	104	2873	307	9.4	7.8	43	0.2
Laclede Gas Co	82.3	50	133	6617	576	11.5	3.3	20	1.8
MidAmerican Energy Co	65.6	38	107	4055	342	11.9	5.0	27	1.3
Mountaineer Gas Co	26.9	32	135	4286	391	11.0	0.9	33	2.4
National Fuel Gas Distribution Corp	113.0	31	153	4755	489	9.7	0.0	27	5.8
New Jersey Natural Gas Co	44.1	41	117	4817	314	15.3	3.1	42	0.2
Niagara Mohawk Power Corp	82.8	43	157	6680	773	8.6	0.0	46	8.4

Company	O&M ($USm)	cus/main (km) (no.)	O&M/ cus ($US)	O&M/ main (km) ($US)	O&M/ deliveries (TJ) ($US)	deliveries (TJ)/ main (km) (TJ)	NM costs/ O&M (%)	AdmGen/ O&M (%)	UAG (%)
Nicor Gas Co	116.7	40	62	2512	163	15.4	5.0	41	0.8
North Carolina Natural Gas Corp	16.7	65	153	9929	266	37.4	8.7	37	2.0
North Shore Gas Co	21.2	41	151	6199	423	14.7	4.8	41	0.03
Northern Indiana Fuel & Light Co, Inc	5.1	26	152	4009	699	5.7	0.5	39	0.3
Northern Indiana Public Service Co	88.0	30	134	4091	249	16.4	6.2	46	0.7
NW Natural (Northwest Natural Gas Co)	55.3	26	125	3185	425	7.5	9.6	42	0.5
Peoples Gas, Light & Coke Co	163.5	130	196	25440	546	46.6	3.5	35	1.5
Peoples Gas System, A Division of Tampa Electric	45.1	21	193	4071	519	7.8	4.9	42	1.6
Piedmont Natural Gas Co Inc	96.3	21	219	4587	505	9.1	2.2	46	1.4
PSC of Colorado	67.9	40	69	2747	253	10.9	4.4	24	5.6
Questar Gas Co	96.9	33	155	5100	326	15.6	0.0	42	0.7
Roanoke Gas Co	6.7	29	139	4016	544	7.4	3.6	34	3.7
Rochester Gas & Electric Corp	49.5	41	176	7149	943	7.6	0.8	51	4.4
South Carolina Electric & Gas Co	26.2	27	105	2826	602	4.7	12.0	28	2.6
South Jersey Gas Co	28.3	34	103	3524	560	6.3	1.3	34	2.3
Southern California Gas Co	476.5	70	99	6927	426	16.3	0.0	38	0.4
Southern Connecticut Gas Co	28.6	46	183	8335	534	15.6	1.7	51	2.0
Union Light, Heat & Power Co	11.4	43	149	6449	333	19.3	0.0	37	0.7
Valley Gas Co	10.6	59	193	11444	618	18.5	2.3	33	1.4
Virginia Natural Gas, Inc	29.9	32	144	4635	540	8.6	0.5	40	1.5
Washington Gas Light Co	128.2	49	160	7847	806	9.7	3.4	38	3.1
Wisconsin Power & Light Co	15.4	28	105	2975	318	9.4	0.9	41	1.0
Yankee Gas Services Co	43.1	41	235	9625	727	13.2	7.2	41	2.9

Note: Figures for AGLGN are for 1997-98.

ATTACHMENT 6 POTENTIAL COST DRIVERS FOR GAS DISTRIBUTION

This attachment presents the results of the analysis of potential cost drivers for gas distribution. The analysis was undertaken to verify AGLGN's view that length of mains is a significant cost driver for operation and maintenance (O&M) costs, and that particular emphasis should be placed on O&M costs per kilometre of main as a measure of performance. This view reflects a common problem associated with interpreting partial productivity measures. Inevitably, different partial indicators present different results of relative performance. There is often no basis for determining the emphasis that should be given to various partial indicators.

A6.1 Operation and maintenance costs

To test AGLGN's proposition that length of mains is a significant cost driver, a simple exercise was undertaken to assess the potential cost drivers of O&M costs. Potential cost drivers include:

- customer numbers
- deliveries (TJ)
- length of mains (km)
- climate (heating degree days)
- the age of network (percentage of asset life expired).

The relationship between O&M costs and these potential cost drivers is examined purely from a statistical viewpoint. It is not based on economic theory which underpins the production or cost functions of gas networks, as this requires information on input prices and outputs (Varian 1992; Granvelle and Rees 1987; Coelli, Rao and Battese 1998). However, the analysis may help assess the weight to be placed on the various partial indicators.

The ordinary least squares (OLS) technique is used to assess potential cost drivers for O&M costs.[64] The sample includes 45 local and US distributors.[65] To determine the appropriate relationship between O&M costs and potential cost drivers, several functional forms were estimated. Functional forms included in the analysis are:

- linear
- linear-log (semilog)
- log-log (doublelog)
- translog.

64 The variables and data used in the exercise are explained in further detail in Chapter 5.

65 The sample is smaller than that used for the DEA exercise, which is reported in Chapter 5. This is due to a lack of information on age of network for some US distributors.

A series of J-tests (Griffiths, Hill and Judge 1993) lead us to conclude that the translog functional form provides the best explanation of relationship between O&M costs and the potential cost drivers (among these four functional forms).

The OLS estimates of the translog functional form are presented in Table A6.1. The data was mean-corrected prior to estimation. Hence, the first-order coefficients may be interpreted as elasticities, evaluated at the sample means. The t-ratios on the first-order coefficients of customers, deliveries and the age of the network are observed to be significantly different from zero at a 5 per cent level of significance, while the first-order coefficients of the length of mains and climate are not significant. This suggests that the length of mains is not a significant cost driver, at the sample means. However, mains could, perhaps, be a significant cost driver of O&M costs away from the sample mean. To address this possibility we conducted an additional F test, to test the hypothesis that all coefficients involving mains in the model (six in all) were equal to zero. This hypothesis was not rejected, indicating that length of mains was not a significant addition to the model.

Overall, the model appears to be a good explanatory of variation in O&M costs. The value of the F statistic supports the hypothesis that the cost drivers influence O&M costs at the 5 per cent level of significance. Furthermore, the R^2 measure indicates that the cost drivers explain about 92 per cent of the variation in O&M costs.

Therefore, the available evidence suggests that there is little support to place particular emphasis on O&M costs per kilometre of main as a measure of performance. Other partial productivity measures are necessary to form views on the efficiency of AGLGN.

Table A6.1 Potential cost drivers for O&M costs

Variable	Parameter	Estimates
Intercept	β_0	17.376* (0.165)
ln(customers)	β_1	0.726* (0.188)
ln(deliveries)	β_2	0.329* (0.166)
ln(mains)	β_3	-0.244 (0.181)
ln(climate)	β_4	-0.013 (0.230)
ln(network age)	β_5	0.667* (0.317)
$[\ln(\text{customers})]^2$	β_{11}	0.663 (0.969)
$[\ln(\text{deliveries})]^2$	β_{22}	1.077 (0.867)
$[\ln(\text{mains})]^2$	β_{33}	-0.223 (0.555)
$[\ln(\text{climate})]^2$	β_{44}	-0.242 (0.391)
$[\ln(\text{network age})]^2$	β_{55}	0.831 (2.188)
ln(customers) × ln(deliveries)	β_{12}	-0.909 (0.839)
ln(customers) × ln(mains)	β_{13}	-0.189 (0.534)
ln(customers) × ln(climate)	β_{14}	0.937 (0.657)
ln(customers) × ln(network age)	β_{15}	0.295 (0.743)
ln(deliveries) × ln(mains)	β_{23}	0.277 (0.442)
ln(deliveries) × ln(climate)	β_{24}	-0.660 (0.494)
ln(deliveries) × ln(network age)	β_{25}	-0.455 (0.797)
ln(mains) × ln(climate)	β_{34}	-0.672 (0.597)
ln(mains) × ln(network age)	β_{35}	0.361 (0.972)
ln(climate) × ln(network age)	β_{45}	1.187 (0.863)
ln(likelihood function) (N)		**8.037 (45)**
R^2 adjusted		**0.921**
F statistic		**8550.461**

Notes: Standard errors are presented in brackets. * Statistically significant at 5 per cent level.

The results of the model indicate that AGLGN's observed O&M costs ($97.1m) are marginally better than its predicted O&M costs ($97.7m). In other words, this statistical analysis suggests AGLGN's O&M costs reflect average practice.

The insignificance of mains as a cost driver for O&M costs is consistent with an OFWAT (1999) finding that length of mains is not a significant cost driver of the operating costs for water companies. However, OFWAT found that the proportion of large mains (300mm diameter or more) was a significant cost driver of operating costs. There is insufficient information to test the proposition that the proportion of large mains is a significant cost driver for gas distribution.

It should be stressed that this is a statistical analysis designed to test the proposition about the relative weight to be given to certain cost drivers. It is not designed to model input-output relationships. Considerable care should be exercised in interpreting these results as a guide of relative efficiency.

A6.2 Unit cost

Further analysis was undertaken to assess the potential cost drivers of the unit cost (O&M costs per kilometre of main) of gas distribution. The appropriate functional form for unit cost and the potential cost drivers is a translog functional form, according to the J test. The OLS estimates of the translog function are presented in Table A6.2. The data was mean corrected. The OLS estimates suggest that customers, deliveries, length of mains and the age of the network are significant cost drivers. Climate does not have a significant influence on unit cost.

The estimates suggest customers, deliveries and the age of the network have a positive influence on unit cost. However, length of mains has a negative impact on unit cost, which is consistent with the notion that there are economies of scale in gas distribution. The F statistic suggests that the cost drivers influence unit cost at the 5 per cent level of significance. Moreover, the cost drivers explain 76.5 per cent of unit cost.

Table A6.2 Potential cost drivers for O&M costs per kilometre of main

Variable	Parameter	Estimates
Intercept	β_0	8.466* (0.165)
ln(customers)	β_1	0.723* (0.188)
ln(deliveries)	β_2	0.328* (0.166)
ln(mains)	β_3	-1.241* (0.181)
ln(climate)	β_4	-0.011 (0.230)
ln(network age)	β_5	0.660* (0.317)
$[\ln(\text{customers})]^2$	β_{11}	0.658 (0.970)
$[\ln(\text{deliveries})]^2$	β_{22}	1.086 (0.868)
$[\ln(\text{mains})]^2$	β_{33}	-0.231 (0.556)
$[\ln(\text{climate})]^2$	β_{44}	-0.247 (0.391)
$[\ln(\text{network age})]^2$	β_{55}	0.829 (2.189)
ln(customers) × ln(deliveries)	β_{12}	-0.912 (0.840)
ln(customers) × ln(mains)	β_{13}	-0.181 (0.534)
ln(customers) × ln(climate)	β_{14}	0.949 (0.658)
ln(customers) × ln(network age)	β_{15}	0.302 (0.743)
ln(deliveries) × ln(mains)	β_{23}	0.274 (0.442)
ln(deliveries) × ln(climate)	β_{24}	-0.671 (0.494)
ln(deliveries) × ln(network age)	β_{25}	-0.444 (0.798)
ln(mains) × ln(climate)	β_{34}	-0.676 (0.597)
ln(mains) × ln(network age)	β_{35}	0.350 (0.972)
ln(climate) × ln(network age)	β_{45}	1.188 (0.864)
ln(likelihood function) (N)		**8.006 (45)**
R^2 adjusted		**0.765**
F statistic		**2056.249**

Notes: Standard errors are presented in brackets. * Statistically significant at 5 per cent level.

The results of the model suggest that AGLGN's observed unit cost ($4666) are slightly better than predicted unit cost ($4691). Nevertheless, AGLGN's unit cost reflects average practice rather than best practice for gas distribution.

ATTACHMENT 7 THE AGE OF GAS NETWORKS

This attachment presents the approach to determine the age of the gas distributors' networks. The approach indicates the extent that the life of the networks has expired. Moreover, the approach can accommodate different asset valuation methods.

Let x = the age of the assets; and

y = the total life of the assets.

If the distributors use the straight-line depreciation method to depreciate assets then accumulated depreciation is given by:

Accumulated depreciation = (x/y) × asset value.

The Natural Gas LDC Database (Opri 1998) presents information on the US distributors' networks, which are valued according to historic cost, and the accumulated depreciation of the network assets. If actual cost of the assets = AC, then:

Depreciated actual cost (DAC) = (AC- (x/y) × AC)

And, DAC/AC = 1 - (x/y)

The local distributors present information on the optimised replacement cost (ORC) and the depreciated optimal replacement cost (DORC) for the networks in Access Arrangement Information. Consequently,

DORC = (ORC- (x/y) × ORC)

And, DORC/ORC = 1 - (x/y)

Therefore, the asset life of the networks is independent of the asset valuation.

ATTACHMENT 8 DATA ENVELOPMENT ANALYSIS EFFICENCY SCORES

Company	Technical efficiency score	Managerial efficiency score	Scale efficiency score
AGLGN (NSW)	0.591	0.592	0.998
AGLGN (ACT)	0.416	0.674	0.617
Envestra (SA)	0.773	0.812	0.952
Envestra (QLD)	0.638	0.983	0.649
Multinet	1	1	1
Stratus	0.848	0.866	0.98
Westar	0.969	1	0.969
Allgas	0.593	1	0.593
AmerenCIPS	0.621	0.735	0.845
Arkansas Oklahoma Gas Corp	0.75	1	0.75
Atlanta Gas Light Co	0.88	0.899	0.979
Bay State Gas Co	0.662	0.683	0.969
Berkshire Gas Co	0.662	1	0.662
Boston Gas Co	0.784	0.827	0.948
Brooklyn Union Gas Co	1	1	1
Central Illinois Light Co	0.76	0.804	0.946
Citizens Gas & Coke Utility	0.757	0.757	0.999
Citizens Utilities Co, Louisiana Gas Div	0.752	0.838	0.897
Colonial Gas Co	0.653	0.717	0.91
Columbia Gas of Pennsylvania, Inc	1	1	1
Columbia Gas of Virginia, Inc	0.514	0.515	0.997
Commonwealth Gas Co	0.695	0.71	0.979
Delta Natural Gas Co, Inc	0.458	0.787	0.582
Equitable Gas Co	0.617	0.628	0.983
Essex County Gas Co	0.62	0.925	0.67
Fall River Gas Co	0.714	1	0.714
IES Utilities, Inc	0.677	0.7	0.966
Illinois Power Co	0.705	0.727	0.971
Indiana Gas Co, Inc	0.584	0.601	0.971
Intermountain Gas Co	0.781	0.869	0.899
Laclede Gas Co	0.798	0.801	0.996
MidAmerican Energy Co	0.828	0.853	0.971
Mountaineer Gas Co	0.652	0.678	0.962
National Fuel Gas Distribution Corp	0.656	0.683	0.96
New Jersey Natural Gas Co	0.804	0.804	1
Niagara Mohawk Power Corp	0.675	0.707	0.955
Nicor Gas Co	1	1	1
North Carolina Natural Gas Corp	1	1	1
North Shore Gas Co	0.679	0.738	0.92
Northern Indiana Fuel & Light Co, Inc	0.421	1	0.421

Company	Technical efficiency score	Managerial efficiency score	Scale efficiency score
Northern Indiana Public Service Co	0.838	0.921	0.91
NW Natural (Northwest Natural Gas Co)	0.639	0.645	0.99
Peoples Gas, Light & Coke Co	1	1	1
Peoples Gas System, A Division of Tampa Electric	0.47	0.478	0.983
Piedmont Natural Gas Co, Inc	0.472	0.494	0.954
PSC of Colorado	1	1	1
Questar Gas Co	0.678	0.788	0.86
Roanoke Gas Co	0.632	1	0.632
Rochester Gas & Electric Corp	0.624	0.629	0.992
South Carolina Electric & Gas Co	0.686	0.759	0.903
South Jersey Gas Co	0.917	0.97	0.946
Southern California Gas Co	1	1	1
Southern Connecticut Gas Co	0.731	0.736	0.992
Union Light, Heat & Power Co	0.762	0.963	0.792
Valley Gas Co	0.808	1	0.808
Virginia Natural Gas, Inc	0.633	0.664	0.953
Washington Gas Light Co	0.764	0.83	0.921
Wisconsin Power & Light Co	0.77	0.886	0.869
Yankee Gas Services Co	0.638	0.674	0.946
Average	**0.73**	**0.82**	**0.899**

ATTACHMENT 9 ACCOUNTING FOR THE OPERATING ENVIRONMENT IN DATA ENEVELOPMENT ANALYSIS

A two stage method is used to assess the influence of the operating environment on the efficiency of gas distribution. The first stage involves solving the standard DEA model for gas distribution to obtain managerial technical efficiency scores for the distributors. In the second stage, the efficiency scores are regressed against environmental variables (eg climate and age of network), which are beyond the control of management.

The sign of the coefficients of the environmental variables indicates the direction of the influence on efficiency. Standard statistical tests of hypotheses can assess the strength of the influence. For example, a positive coefficient indicates that the environmental variable may increase the efficiency of a distributor. The estimated coefficients of the regression are used to adjust the distributors' efficiency scores to exclude the influence of the operating environment on the efficiency of gas distribution. This is done only if statistical tests indicate that at least one of the environmental variables exerts significant influence on efficiency.

The two stage method is used in preference to other approaches to analyse the influence of the operating environment on the efficiency of gas distribution in DEA because:

- more than one environmental variable can be included in the analysis
- the approach can accommodate continuous and discrete variables
- no assumptions are required about the environmental variables influence on efficiency before they are included in the DEA model
- tests of hypotheses can determine the environmental variables’ influence on efficiency.

One disadvantage of the two stage method is that the regression results are biased if the environmental variables are strongly correlated with the inputs or the outputs of gas distribution.

Other methods of including the operating environment in DEA are not used in the study because they lack the advantages and have greater disadvantages than the two stage method. The other approaches are discussed in Ali and Seiford (1993), Coelli, Rao and Battese (1998), and Lovell (1993).

A9.1 Tobit regression

Instead of ordinary least squares (OLS), Tobit regression is used to assess the influence of the climate and age of network on the efficiency of gas distribution because the efficiency scores are censored at one. Under these circumstances, OLS produces biased and inconsistent estimates.[66]

[66] Further details on Tobit regression are presented in Judge et al (1988).

The following model is used to test the proposition that climate and age of network have a significant influence on managerial efficiency.

$y_i = x_i'\beta + e_i \qquad i=1, 2, \ldots, N$

where $x_i'=(x_{i1}, x_{i2}, \ldots, x_{iK})$, K is the number of environmental variables (including a constant term), $\beta=(\beta_1, ..., \beta_K)$ is the vector of parameters to be estimated, and N is the number of distributors in the sample. For this study, K=3 and N=45. The sample for the Tobit regression is less than the sample for the DEA exercise because no information is available on age of network for 14 US distributors.

The results of the Tobit regression are presented in Table A9.1.[67] The t-ratios suggest that climate and age of network do not have a significant influence on efficiency of gas distribution at the 5 per cent level of significance.[68] There is no need to adjust the DEA scores because these environmental factors do not have a significant influence on the efficiency of gas distribution. The environmental variables are not strongly correlated with the inputs or outputs of gas distribution because the correlation coefficients between the environmental variables and the inputs and the outputs lie between –0.07 and 0.15. Therefore, the Tobit regression results are unbiased.

Table A9.1 Results of Tobit regression

Variable	Normalised coefficient (a)	Standard error	t-ratio	Regression coefficient
Climate	0.00006	0.00017	0.34638	0.00001
Age of network	-1.31680	1.12000	-1.17570	-0.25867
Constant	4.912900	0.82344	5.96620	0.96506
Managerial efficiency (b)	5.09080	0.67437	7.54890	
Log-likelihood function = -5.0369				
Standard error of estimate (σ) = 0.19643				
Squared correlation between observed and actual values = 0.05325				

(a) Normalised coefficient = regression coefficient/σ
(b) Dependent normalised coefficient = 1/σ

67 The SHAZAM econometrics software (White 1993) is used to undertake the Tobit regression.

68 The environmental variables required a t-ratio greater than 1.96 to be significant at the 5 per cent level of significance.

ATTACHMENT 10 PARAMETRIC APPROACHES TO MEASURE THE TECHNICAL EFFICIENCY OF GAS DISTRIBUTION

In addition to data envelopment analysis (DEA), parametric techniques are used to estimate the technical efficiency of the gas distributors to ascertain whether the distributors' efficiency is sensitive to the choice of benchmarking technique. For this exercise, a translog input distance function is used to estimate the technical efficiency of the gas distributors.

A distance function is chosen because it is capable of describing the multiple-input and multiple-output production technology of gas distributors and does not require assumptions about the behaviour of the distributors (eg cost minimisation or profit maximisation). And a translog functional form is used because it provides a second-order approximation to any arbitrary functional form. This is what is commonly termed a 'flexible' functional form. The derivation of the translog input distance function is presented in Coelli and Perelman (1996) and London Economics (1999).

The translog input distance function for gas distribution is estimated by two parametric techniques - stochastic frontiers and corrected ordinary least squares (COLS). The environmental variables, climate and age of network, were initially included in the analysis. However, they were not significant at the 5 per cent level of significance and were excluded from the analysis. Consequently, the stochastic frontiers and the COLS efficiency scores are comparable to the DEA managerial efficiency scores.

A10.1 Stochastic frontiers

The stochastic translog input distance function for gas distribution is estimated by maximum likelihood procedures in FRONTIER Version 4.1 (Coelli 1996b). The technical inefficiencies of the distributors are assumed to have a normal distribution truncated at zero. The logarithms of the variables of the input distance function are mean adjusted to allow the first order parameter estimates to be interpreted as elasticities. The maximum likelihood estimates are presented in Table A10.1.[69]

[69] The parameter symbols in Table A10.1 and Table A10.2 follows that of Coelli and Perelman (1996).

Table A10.1 Stochastic frontiers parameter estimates

Variable	Parameter	Estimates
Intercept	α_0	0.285*
		(0.113)
ln(residential customers)	α_1	-0.568*
		(0.133)
ln(other customers)	α_2	-0.447*
		(0.150)
ln(deliveries)	α_3	0.112
		(0.124)
$[\ln(\text{residential customers})]^2$	α_{11}	-0.037
		(0.620)
$[\ln(\text{other customers})]^2$	α_{22}	-0.173
		(0.312)
$[\ln(\text{deliveries})]^2$	α_{33}	0.063
		(0.450)
ln(residential customers) × ln(other customers)	α_{12}	0.433
		(0.462)
ln(residential customers) × ln(deliveries)	α_{13}	-0.280
		(0.823)
ln(other customers) × ln(deliveries)	α_{23}	0.115
		(0.807)
ln(mains/O&M costs)	β_1	0.414*
		(0.084)
$[\ln(\text{mains/O\&M costs})]^2$	β_{11}	-0.049
		(0.351)
ln(mains/O&M costs) × ln(residential customers)	δ_{11}	-0.041
		(0.533)
ln(mains/O&M costs) × ln(other customers)	δ_{12}	0.520
		(0.696)
ln(mains/O&M costs) × ln(deliveries)	δ_{13}	-0.313
		(0.707)
Variance parameters		
	σ_s^2	0.056*
		(0.018)
	γ	0.999*
		(0.124)
	μ	0.156
		(0.094)
ln(likelihood function) (N)		**26.222 (59)**

Notes: Figures in brackets are asymptotic standard errors. * Indicates statistically significant at 5 per cent level of significance.

The results indicate that the first order terms have the correct sign and are significant at the 5 per cent level of significance, except for deliveries (which has an incorrect sign but is not significantly different from zero). The value of the likelihood ratio test statistic rejects the null hypothesis that there is no technical inefficiency in distributing gas. The test statistic has a value of 8.92, which exceeds the 5 per cent critical value of 5.14 (Kodde and Palm 1986). The estimate of gamma suggests that the vast majority of the residual variation is explained by the technical inefficiency of the gas distributors.

A10.2 Corrected ordinary least squares

The econometric software package SHAZAM (White 1993) is used to estimate the translog input distance function for gas distribution by COLS. As in the stochastic frontiers exercise, the logarithms of the variables of the input distance function are mean adjusted to allow the first order parameter estimates to be interpreted as elasticities. The COLS estimates are presented in Table A10.2.

Table A10.2 COLS parameter estimates

Variable	Parameter	Estimates
Intercept	α_0	-0.010 (0.047)
ln(residential customers)	α_1	-0.572* (0.077)
ln(other customers)	α_2	-0.284* (0.089)
ln(deliveries)	α_3	-0.038 (0.080)
[ln(residential customers)]^2	α_{11}	0.224 (0.275)
[ln(other customers)]^2	α_{22}	-0.008 (0.193)
[ln(deliveries)]^2	α_{33}	0.286 (0.345)
ln(residential customers) $\times$ ln(other customers)	α_{12}	0.414 (0.347)
ln(residential customers) $\times$ ln(deliveries)	α_{13}	-0.640 (0.476)
ln(other customers) $\times$ ln(deliveries)	α_{23}	-0.226 (0.545)
ln(mains/O&M costs)	β_1	0.350* (0.044)
[ln(mains/O&M costs)]^2	β_{11}	-0.068 (0.102)
ln(mains/O&M costs) $\times$ ln(residential customers)	δ_{11}	-0153 (0.166)
ln(mains/O&M costs) $\times$ ln(other customers)	δ_{12}	0.575 (0.189)
ln(mains/O&M costs) $\times$ ln(deliveries)	δ_{13}	-0.251 (0.168)
ln(likelihood function) (N)		**21.76 (59)**
R^2		**0.971**
R^2 adjusted		**0.962**
F statistic		**99.26**

Notes: Figures in brackets are standard errors. * Indicates statistically significant at 5 per cent level of significance.

The COLS results indicate that the first order terms have the correct sign and are significant at the 5 per cent level of significance, except for deliveries. The R^2 value indicates that the estimated model explains about 97 per cent of the variation in the norm of the input vector and the value of the F statistic indicates that this model is statistically significant at the 1 per cent level.

A list of the stochastic frontiers and COLS efficiency scores are presented in Attachment 11. The correlation coefficient and the spearman rank correlation coefficient between the DEA managerial efficiency scores and the stochastic frontiers efficiency scores of the preferred model are 0.65 and 0.62, respectively. And the correlation coefficient and the spearman rank correlation coefficient between the DEA managerial efficiency scores and the COLS scores of the preferred model are 0.64 and 0.57, respectively. These results suggest that the distributors' efficiency is not unduly influenced by the choice of benchmarking technique.

ATTACHMENT 11 PARAMETRIC EFFICIENCY SCORES

Company	Stochastic frontiers efficiency scores	COLS efficiency scores
AGLGN (NSW)	0.571	0.527
AGLGN (ACT)	0.596	0.593
Envestra (SA)	0.795	0.737
Envestra (QLD)	0.895	0.729
Multinet	0.889	0.768
Stratus	0.699	0.627
Westar	0.999	1.000
Allgas	0.900	0.899
AmerenCIPS	0.784	0.711
Arkansas Oklahoma Gas Corp	0.965	0.863
Atlanta Gas Light Co	0.626	0.568
Bay State Gas Co	0.845	0.665
Berkshire Gas Co	0.881	0.728
Boston Gas Co	0.791	0.751
Brooklyn Union Gas Co	0.824	0.702
Central Illinois Light Co	0.885	0.849
Citizens Gas & Coke Utility	0.815	0.770
Citizens Utilities Co, Louisiana Gas Div	0.865	0.751
Colonial Gas Co	0.851	0.751
Columbia Gas of Pennsylvania, Inc	0.971	0.810
Columbia Gas of Virginia, Inc	0.547	0.514
Commonwealth Gas Co	0.873	0.727
Delta Natural Gas Co, Inc	0.629	0.528
Equitable Gas Co	0.568	0.541
Essex County Gas Co	0.921	0.759
Fall River Gas Co	0.727	0.609
IES Utilities, Inc	0.809	0.690
Illinois Power Co	0.806	0.730
Indiana Gas Co, Inc	0.624	0.577
Intermountain Gas Co	0.926	0.856
Laclede Gas Co	0.811	0.749
MidAmerican Energy Co	0.859	0.799
Mountaineer Gas Co	0.756	0.720
National Fuel Gas Distribution Corp	0.663	0.612
New Jersey Natural Gas Co	0.847	0.833
Niagara Mohawk Power Corp	0.755	0.642
Nicor Gas Co	0.895	0.878
North Carolina Natural Gas Corp	0.932	0.849
North Shore Gas Co	0.704	0.672
Northern Indiana Fuel & Light Co, Inc	0.565	0.607

Company	Stochastic frontiers efficiency scores	COLS efficiency scores
Northern Indiana Public Service Co	0.654	0.670
NW Natural (Northwest Natural Gas Co)	0.669	0.605
Peoples Gas, Light & Coke Co	0.960	0.913
Peoples Gas System, A Division of Tampa Electric	0.540	0.509
Piedmont Natural Gas Co, Inc	0.473	0.447
PSC of Colorado	0.971	0.895
Questar Gas Co	0.573	0.586
Roanoke Gas Co	0.930	0.839
Rochester Gas & Electric Corp	0.730	0.626
South Carolina Electric & Gas Co	0.831	0.726
South Jersey Gas Co	0.996	0.818
Southern California Gas Co	0.820	0.705
Southern Connecticut Gas Co	0.809	0.741
Union Light, Heat & Power Co	0.737	0.675
Valley Gas Co	0.797	0.702
Virginia Natural Gas, Inc	0.748	0.708
Washington Gas Light Co	0.880	0.707
Wisconsin Power & Light Co	0.957	0.883
Yankee Gas Services Co	0.769	0.682
Average	**0.788**	**0.714**