River Murray Operations Economic Benchmarking Study

Report prepared for

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EXECUTIVE SUMMARY

This study is an exercise in economic benchmarking, which involves comparing a firm's performance over time and against other businesses using holistic economic measures such as productivity or cost efficiency. The aim of the study is to develop an appropriate economic benchmarking methodology, and carry out an initial trial benchmarking exercise, for the River Murray Operations (RMO). This is intended to assist the Joint Venture partner governments in their funding decisions in relation to the Murray-Darling Basin Authority (MDBA) and RMO.

To address the aim of developing an appropriate benchmarking methodology, this study considers some of the different approaches to benchmarking and the uses made of economic benchmarking within network regulation and cost control frameworks. Attention is given to the steps needed to develop ongoing data gathering and benchmarking processes. Methods of benchmarking and of measuring economic variables such as outputs and inputs, in the context of rural water services such as those provided by RMO, are evaluated.

The evaluation of methodologies concludes that data envelopment analysis (DEA) is the most suitable for the present purposes, given the small sample available for the study, and the scarcity and likely absence of data on output prices. DEA is a method of efficiency frontier analysis that can be used to measure the comparative technical efficiency and cost efficiency of a set of businesses, and can also be used to calculate total factor productivity (TFP) indexes based on the changes in technical efficiency of firms from year to year.

This study uses a functional output specification, which is based on the services produced that are of value to users rather than on the billing units against which customers are charged. The output measures that appear to be most suitable, and for which data is available for this study, are:

- the volume of water supplied
- the length of regulated river under management (which is an indicator of the area over which that water is supplied), and
- the storage capacity of reservoirs (which is an indicator of the capacity to supply in dry years).

The two inputs used are non-capital inputs (measured by deflating operating and maintenance costs) and capital inputs (measured by deflating the written-down replacement cost of fixed assets).

An initial trial benchmarking study is presented which relies largely on existing data collected to date by the National Water Commission (NWC), and aims only to demonstrate a feasible method of benchmarking that can be used to complement other methods of analysis within a regulatory or cost control framework. The preliminary results for technical and cost efficiency suggest that RMO has scores that are comparable to the more efficient comparator businesses in the sample. RMO's average annual TFP growth over the period 2007 to 2013 is estimated at 3.1 per cent, considerably higher than the sample average TFP growth rate of 1.0

per cent per year.

The robustness of the results of economic benchmarking analysis depends on the quality, quantity and consistency of the comparative data available. The data sample used in this study is relatively small, covering seven comparator businesses and a seven-year period. Data on capital input quantities, in particular, are relatively limited. And there is little or no data at present on relevant operating environment conditions that influence the efficiency of businesses beyond the control of management. It would be desirable to extend the coverage to other rural water businesses and include important output, input and operating environment measures not currently available.

While economic benchmarking can be used as the primary basis of regulation, it is more commonly used to supplement engineering assessments in building blocks and helps address information asymmetry among key stakeholders. Developing ongoing benchmarking requires investment in assembling consistent data and getting stakeholder support but there are a large number of positive spin-offs. In this context initial data gathering processes have been established by the NWC.

We recommend further development of the benchmarking database for rural water businesses with comparable operations to RMO, retaining and building on the existing framework established by the NWC, and including some additional items of information and some businesses not currently covered.[1] This is the first step toward further development of an ongoing benchmarking framework, which would be of considerable benefit to the RMO joint venture by providing a necessary information base that would assist it to develop its business strategies to improve efficiency.

[1] The Commonwealth Government has announced that the National Water Commission will close down in December 2014. The Productivity Commission will take over the role of monitoring and auditing water reform. The Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) will take over annual reporting on water markets, while the Department of Environment will be responsible for assessing payments to Murray-Darling Basin states. See: http://www.abc.net.au/news/2014-09-25/nrn-watercommission/5769206.

CONTENTS

1 INTRODUCTION

The aim of the study is to develop an appropriate economic benchmarking methodology, and carry out an initial trial benchmarking exercise, for the River Murray Operations Joint Venture (RMO). This is intended to assist the partner governments in their funding decisions in relation to the Murray-Darling Basin Authority (MDBA) and RMO.

The participants in RMO include the MDBA and four State Constructing Authorities (SCAs), namely State Water Corporation, NSW Office of Water, Goulburn-Murray Water and SA Water. In this study, RMO is treated as an entity and when State Water and Goulburn-Murray Water are included in benchmarking analysis as separate entities their activities as SCAs in the Murray and lower Darling River basins are excluded.

The benchmarking methodology takes into account multiple outputs and inputs and provides preliminary estimates of the relative efficiency and historical productivity trends of comparable rural water businesses. The rural water businesses included in our sample generally provide water to agricultural users and irrigation schemes, and to residential and industrial users via regional or major urban water utilities.

The analysis is only intended to represent a starting point for further development of the benchmarking techniques. Further work is needed to improve the scope, detail and comparability of the available data and to facilitate further refinement of the benchmarking techniques.

This study derives some preliminary economic benchmarking results for RMO. That said, the analysis in this report is an initial trial with the primary aim of demonstrating a method of benchmarking that could be used to complement other methods of analysis within a regulatory or cost control framework. In order to progress economic benchmarking of RMO for these purposes, we recommend further development of the benchmarking database for rural water businesses with comparable operations to RMO, building on the existing framework established by the National Water Commission (NWC), and including some businesses not currently covered.

This report is organised as follows. Section 2 explains what economic benchmarking is and distinguishes it from other forms of business benchmarking, and introduces the concepts of economic performance that economic benchmarking seeks to measure. Also discussed are the application of economic benchmarking methods within Australian energy network regulation, and the process of data gathering and benchmarking that is being progressed.

Section 3 discusses the outputs, inputs and other variables to be measured and used in the benchmarking study of RMO. Section 4 then briefly describes the candidate peer businesses, indicating those that were and were not included in the study. Section 5 describes the alternative benchmarking methods and evaluates their suitability for the present study. The preliminary results of the trial benchmarking study are presented in section 6, and section 7 presents the draft conclusions. Section 7 also discusses further steps for improving, extending and applying benchmarking for RMO's operations.

2 BENCHMARKING OVERVIEW

This section provides a brief introduction to what we mean by economic benchmarking, and its applications to date in the regulation of natural monopolies in Australia. This section also describes the processes of benchmarking and data gathering, with some insights drawn from the implementation of economic benchmarking in energy regulation.

2.1 Benchmarking concepts

Benchmarking involves measuring the performance of businesses over time and against their peers, and particularly against best practice or the best performers. Its purpose is to assist businesses to improve their performance by better identifying what is achievable and the best practice businesses or processes that can be emulated.

The different kinds of benchmarking may be broadly grouped as follows:

- *Process benchmarking:* which involves benchmarking specific processes within a business against similar processes in other business (see: Camp 1989)
- *Performance indicators:* in which a suite of key performance indicators (KPIs) are used, which individually reflect various aspects of the firm's overall purposes (see: Lynch and Cross 1991; Carter, Klein, and Day 1992)
- *Economic benchmarking:* in which a firm's performance over time and against other businesses is examined using holistic economic measures such as productivity or cost efficiency (see: Coelli et al. 2003; Bogetoft 2012, Economic Insights 2013).

The focus of the present study is on economic benchmarking, which provides the most fundamental or "bottom line" measures of the performance of an organisation against purely economic objectives. Performance indicators and process benchmarking are complementary to economic benchmarking, since they can provide more focus on identifying and implementing efficiency improvement at an activity level. However, they can be less effective in the absence of holistic economic performance measurement. For example, the limitations of the traditional use of KPIs include not only the difficulty of defining suitable and consistent KPIs across the businesses to be benchmarked, but also the difficulty in prioritising or weighting the performance outcomes when there is a large suite of KPIs to be considered. A common shortcoming is that poor choice of indicators or indicator definitions, or inappropriate balance in the range of KPIs reported, that do not adequately reflect the relevant business objectives, can bias the conduct of the benchmarked businesses and lead to detrimental and inefficient outcomes. There can also be a proliferation of KPIs without a clear logical framework integrating them into a measure of overall performance. Economic benchmarking provides a framework within which overall performance can be measured.

Economic benchmarking focuses on economic measures such as output and output quality, productivity and cost efficiency. This is suitable for businesses that largely pursue economic ends, or where non-economic ends can be represented as further output. For example, if part of an organisation's activities is oriented toward environmental goals, then the environmental outcomes can be treated as another output. Economic benchmarking provides comprehensive summary measures that provide an overall picture of the firm's performance.

There are four broad economic benchmarking methodologies to consider:

- *partial indicators* such as partial productivity measures (i.e., the ratio of output to a single input) or unit cost measures (i.e., cost divided by a single measure of output)
- *index number methods*, particularly total factor productivity (TFP) indexes and multilateral TFP (MTFP) indexes, which are used for trend and comparative productivity analysis
- *data envelopment analysis* (DEA), where mathematical programming techniques are used to identify an efficiency frontier and best practice firms, and the comparative technical efficiency of firms
- *stochastic frontier analysis* (SFA), in which econometric methods are used to identify the best practice efficiency frontier and measure comparative cost efficiency or productivity levels and trends.

The choice of method(s) will depend on the objectives of the benchmarking analysis, and on data availability. More than one method may be desirable because this would enable the results of different quantitative methods and model specifications to be compared, which would assist to determine or improve the robustness and credibility of the results. The methods of economic benchmarking mentioned above are discussed in detail in section 5.

2.2 Economic performance concepts

Economic performance measures that are usually the focus of economic benchmarking analysis can be defined as follows. *Productivity* is a measure of the physical output produced from the use of a given quantity of inputs. All enterprises use a range of inputs including labour, capital, land, fuel, materials and services. If the enterprise is not using its inputs as efficiently as possible then there is scope to lower costs through productivity improvements and, hence, lower the prices charged to consumers. This may come about through the use of better quality inputs including a better trained workforce, adoption of technological advances, removal of restrictive work practices and other forms of waste, and better management through a more efficient organisational and institutional structure. When there is scope to improve productivity, this implies there is *technical inefficiency*. This means that the business could, if operating at best practice, produce more outputs with the same inputs or use fewer inputs to produce the same amount of outputs.

Technical inefficiency is not the only source of economic inefficiency. For example, when a technically efficient business can produce the same set of outputs using a different mix of inputs, which is not a smaller quantity of inputs, but has lower cost at the prevailing input prices, then it has *allocative inefficiency*. Firms that are either technically or allocatively inefficient have cost inefficiency (which is the product of technical and allocative efficiency). Infrastructure network providers often do not charge cost–reflective prices for key output dimensions, some of which may not be explicitly charged for at all, which makes it difficult to define allocative efficiency accurately. For this reason, more attention is sometimes given to technical efficiency performance.

2.3 Application in Australian utility regulation

Government agencies and inquiries have given increasing attention to the role of productivity benchmarking in the economic regulation of natural monopolies. The Expert Panel on Energy Access Pricing (2006) advocated consideration of 'productivity based' approaches to regulation whereby X factors are set using information on industry productivity trends. A number of benchmarking studies were commissioned by stated-based economic regulators and network businesses over the period 2003 to 2008, and via the process of critical comment, these served to develop acceptable benchmarking techniques and wider consensus on the value of benchmarking within regulatory processes. Among the studies in this period were Lawrence (2003; 2007) and Pacific Economics Group (2004; 2006; 2008).

Unlike the Expert Panel's focus on benchmarking as an alternative means of price-cap regulation to the prevailing "building block method", the accepted use of benchmarking in network regulation today is to complement the assessments of efficiency within the building block method. Initial applications of the building blocks method typically used engineering assessments of the regulated business' efficiency and scope for future productivity improvement. However, over time regulated businesses have generally been able to exploit their information advantage relative to the regulator, often by providing increasingly more detailed expenditure proposals. Given their limited time and resources to assess these increasingly detailed proposals, regulators have looked to higher level benchmarking studies as a means of addressing the information asymmetry they face.

In 2012 the Australian Energy Market Commission (AEMC) examined the application of economic benchmarking within energy network regulation and concluded it has a crucial role in assessing the efficiency of energy network service providers and informing the public about their performance:

> *The Commission considers that benchmarking is a critical exercise in assessing the efficiency of a NSP [network service provider] and approving its capital expenditure and operating expenditure allowances. Benchmarking should take into account differences in the environments of the different NSPs, being those factors that are outside the control of the NSP (AEMC 2012, p.vii).*

Potential constraints within the governing regulatory instruments were removed by the AEMC to facilitate greater use of benchmarking by the Australian Energy Regulator (AER) in regulatory processes. A requirement that AER produce an annual benchmarking report was also introduced into the national electricity rules. The AER (2013a) has indicated it will be making greater use of benchmarking for assessing the efficiency of network businesses.

The AER has highlighted two forms of benchmarking that it intends to use as an integral part of future energy infrastructure price reviews. The first involves benchmarking a network business' expenditure when disaggregated into cost categories, termed 'category analysis'. The second is economic benchmarking of the efficiency of a network business' regulatory operations as a whole. The latter permits a comparison of the efficiency of peer network businesses and can be used for 'top down' forecasting of a network business' expenditure and productivity growth. The analysis in this report is a preliminary application of economic benchmarking in this sense.

The AER has commenced an information collection process for benchmarking purposes with electricity network service providers. This involved extensive consultation with regulated businesses and other stakeholders throughout 2013 which included a series of 8 workshops to progress agreement on the output and input specifications to be used, the definitions of key variables and scope of data to be collected (see Economic Insights 2013). This process culminated in the release of regulatory information notices (RINs) in November 2013. This process will provide eight years of historical data – the most recent five of years of which require full formal auditing – and, together with annual information collection going forward, will support the AER's now mandated annual benchmarking reports and its other benchmarking activities (AER 2013c). It will also enable interested parties to conduct their own analyses and modelling. This information collection process for electricity network service providers may later be extended to gas network service providers.

The AER has indicated that it intends to have regard, in its access arrangement reviews, to benchmarking techniques including multilateral TFP analysis, data envelopment analysis (DEA) and econometric modelling (AER, 2013b, p. 13) such as stochastic frontier analysis. It is expected to implement such analysis to assess regulated businesses' expenditure proposals as part of its current access arrangement reviews.

2.4 Process of benchmarking

When carrying out a benchmarking study, the objects of the analysis and the availability of data ultimately determine which methodology and specification will be most appropriate. The study objectives need to be defined in order to select among the various types of benchmarking, the method(s) that will best serve that purpose. Initial analysis and consultation with stakeholders on the key issues and industry features relevant to the study will assist to identify those issues that benchmarking can feasibly provide information on. The choice of benchmarking method should be informed by the outcomes of this initial analysis and consultation in light of the overall objectives.

To compare a water utility's performance against similar businesses it is necessary to obtain consistent data for those businesses, measured using common definitions. It is desirable to have information relating to the exogenous factors that may cause differences in performance, such as special characteristics of the market served, geographical and climate factors. The ability to adequately define the outputs and inputs to be used in productivity analysis may be constrained if relevant variables are not measured, or not measured consistently among the firms to be benchmarked. The process of defining the outputs, inputs and other indicators should draw from the expertise of industry participants relating to the businesses' operations and technology.

Although a number of broad types of benchmarking are briefly mentioned in section 2.1, our focus here is on economic benchmarking. The study objectives and available data will assist to choose among the economic benchmarking techniques to identify a suitable method. For example, should the focus be on technical efficiency or cost efficiency? Is it an aim of the study to identify sources of efficiency differences or changes over time? Ideally, the initial benchmarking analysis should be kept simple, and only require basic data, but should be defensible. More complexity or depth of analysis can be developed in light of the initial findings.

2.5 Data requirements & process for gathering data

The scope and nature of the data requirements will depend on the objectives of the study. If the aim is to compare the efficiency of a water business against a group of comparable businesses, then a consistent set of data will be needed for all of the businesses included in the study. This data may be cross-sectional if a snapshot of comparative productivity is the object. However, if the aims also include identifying the changes in efficiency over time and the factors that may cause those changes, then panel data will be needed. Analysis that focuses on the performance of a single business over time can be carried out using productivity indexes (partial or total). If frontier analysis is used for both efficiency comparisons over time and between businesses, then a panel data sample of sufficient size will be needed.

The first step is to collect data on the operations of the businesses being analysed and comparable businesses. Usually, significant amounts of data are needed. The quality of the analysis will depend crucially on the quality and completeness of the data on which it is based. In the initial analysis the data may not be fully audited or as complete as is desirable, but benchmarking can still be informative and provide impetus to improving data collection. That is the case in this study.

Key issues to be addressed at the initial stage of developing a database for benchmarking include:

- availability of data for relevant inputs, outputs, prices and costs
- data consistency (including consistency of data items and definitions)
- availability of measures for exogenous factors relevant to the different businesses, such as population, weather, geographical environment etc.

The NWC has collected and reported performance indicators for rural water service providers over the period 2006-07 to 2012-13. It currently reports on 32 performance indicators relating to service provider characteristics, customer service, the environment, water management and financial performance (see: NWC 2014). The indicators are defined in the *National Performance Framework: 2012–13 rural water performance report indicators and definitions handbook* ("Rural NPR"). Since the NWC already reports information for a wide number of rural water service providers, it would appear to provide the most practical starting point for developing a suitable set of data for benchmarking.

After assembling the raw data it needs to be screened carefully to ensure the quality and consistency of information or completeness of information gathered meets the requirements to carry out the analysis successfully. Inconsistency in definitions, missing values or data errors will need to be corrected, otherwise they can bias the analysis (Berg 2010).

2.6 Summary observations

While benchmarking can be used as the primary basis of regulation, it is more commonly used to supplement engineering assessments in building blocks and helps address information asymmetry among key stakeholders. Economic benchmarking requires investment in assembling consistent data and getting stakeholder support but there are a large number of positive spin-offs.

It can take time to get agreement on the measures to be used and to develop benchmarking databases (as evidenced by experience in energy networks) but the NWC data collection framework provides a useful starting point. It is desirable to retain and build on this framework, by collecting data on additional measures that are pertinent to economic benchmarking, further improving consistency where necessary and to include some organisations not currently covered by the NWC database (eg, Snowy Hydro).

The initial study presented in this report is only an initial trial of methods based on NWC data. There remain significant gaps in coverage of rural water businesses and in the data collected. An industry-wide commitment and agreement among businesses that manage reservoirs and regulated rivers is needed to develop an enhanced set of data to be collected and the processes and responsibilities for data collection.

We recommend further development of the benchmarking database for rural water businesses with comparable operations to RMO, retaining and building on the existing framework established by the NWC, and including some businesses not currently covered.[2]

[2] The Commonwealth Government has announced that the National Water Commission will close down in December 2014. The Productivity Commission will take over the role of monitoring and auditing water reform. The Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) will take over annual reporting on water markets, while the Department of Environment will be responsible for assessing payments to Murray-Darling Basin states. See: http://www.abc.net.au/news/2014-09-25/nrn-watercommission/5769206.

3 OUTPUTS, INPUTS & OTHER VARIABLES

Deciding on the outputs and inputs to include in the benchmarking analysis, and how they are to be measured, is a crucial step in the analysis and can have an important influence on measured productivity or comparative cost efficiency. Data limitations may require compromises on the number or nature of the outputs or inputs included in the analysis. It is preferable to start with a simple model and add complexity in light of initial results (Berg 2010). The quality and suitability of data used in benchmarking analysis is just as important as the techniques used (Coelli et al. 2005).

The production process that is used to provide bulk untreated water to customers in these markets is difficult to summarise in terms of the relationship between:

- input variables that are purchased inputs that contribute to the ability of the business to deliver its services, and
- outputs that are sold to consumers.

One reason for this difficulty is that some of the factors that influence production are not purchased inputs, they are naturally occurring streams or bodies of water, natural valley structures etc. While some of the naturally occurring factors can in principle be measured (e.g. climate and rainfall) others cannot be readily measured by a single indicator (e.g. topography). Another difficulty is that some of the outputs provided may be unpriced, even though they provide benefits to the community (e.g. amenity and recreation services, or flood control), and they are often not measured.

The types of variables that are often included in benchmarking studies include:

- outputs and output prices (see section 3.1)
- inputs and input prices (see section 3.2)
- quality measures for outputs or inputs where relevant and available (section 3.3)
- variables reflecting operating environment factors specific to each business (e.g. topology, weather, population density, or governance/ownership) (section 3.4).

Many water utility benchmarking studies have been carried out, but most have focussed on urban water supply and sewage treatment businesses. There are fewer benchmarking studies of the operators of rural water reservoirs and river systems. This means there is less guidance available on defining the relevant outputs and inputs in this context. For a discussion of different output and input measures that have been, or could be, used in water productivity studies, particularly focussing on urban water businesses, see Berg (2010, app.1).

3.1 Outputs & output prices

Output variables refer to goods or services produced by the business that have some value to customers. The outputs used in productivity analysis are often physical outputs delivered to customers or services such as making capacity available that customers can use if needed. In some studies indirect outcomes such as customer satisfaction are used as a proxy for customer services that are not adequately measured. In some cases, “bads” may be treated as negative valued outputs, such as water losses or environmental impacts.

3.1.1 Output quantities

MDBA has indicated that the activities of RMO can be classified primarily as regulated river supply services. It also carries out:

- associated water planning, water resource management
- environment schemes, and
- the salt interception scheme.

We understand that other Australian rural water businesses do not have comparable salt interception and environmental programs. To aid comparability, the outputs and inputs associated with these two activities have been excluded from the benchmarking analysis. Ideally, these schemes could be benchmarked against a variety of comparable environment programs.

The national performance report provides separate information relating to regulated river supply services. The regulated river supply service category is described as a service of raw water supply that is dependent on assets such as dams and weirs, and its customers tend to be urban water utilities in regional areas, rural irrigation schemes and other rural water businesses. Some regulated river operators may also provide bulk water directly to smaller customers. There are other bulk water suppliers such as reservoir managers, which in some respects provide similar services to those of regulated river operators, particularly in regard to operating dams to supply bulk raw water. But they may use trunk water pipelines rather than rivers to deliver the water to customers. Several businesses of this kind are included in the urban national performance report.

The services of providing bulk water at customer service points can differ between businesses in relation to:

- whether water provided is raw or treated
- specified levels of service or obligations to customers
- the nature of any included water ordering, metering and measurement services.

In a bulk water supply business, the volume of water delivered to customers would normally be considered as an output, and the business will usually need to invest in dams or other infrastructure to enable it to provide the water to order. Different river systems will have different amounts of water relative to demand, and different river flow or flooding characteristics, which will affect the amount of inputs needed to achieve a given output. This can make productivity comparison between bulk water businesses in different localities problematic. Nevertheless, benchmarking studies relating to rural water supply have often used the quantity of water supplied as the only output (Bhattacharyya et al. 1985; Bhattacharyya, Harris, and Narayanan 1995; Sauer 2003; Sauer and Frohberg 2007).

The NWC also reports the number of customer accounts of each regulated river operator. A customer account is a single billable entity, but delivery can be at several off-take points. In principle, the number of customers can be a useful proxy for some of the services relating to water ordering and delivering, but noting there may be significant differences in the business models of regulated river operators in terms of the different types of customers they supply directly to, and the nature of the customer-related services they provide. Issues of this kind make the use of this measure problematic in this context, particularly as RMO does not directly bill customers, so there is a lack of comparable information for RMO. For these reasons, the number of customers was not regarded as a feasible output measure for this study.

An aspect of regulated river services which is not reflected by the quantity of water supplied is the need to install facilities such as weirs and operate the river system in such a way that water can be drawn off by customers in different localities. A rural water business that delivers water to a dispersed set of off-take points on an extended river system provides a different service to one that delivers a similar amount of water over a short distance to just a few major off-take points. The first business provides a greater amount of services related to controlling the functions of regulated rivers as water delivery systems (in addition to complex social amenity and environmental considerations that attend water supply operations in most cases). These considerations suggest that the spatial dimension of rural bulk water supply may be an important aspect of the services provided by a regulated river operator, and as a first approximation, the amount of this aspect of service may be related to the regulated rivers managed by a rural water business.

Another aspect of the water supply business that is not adequately reflected by the quantity of bulk water supplied relates to the service of making available the capacity to deliver. In many utility settings the provision of capacity is regarded as a service distinct from the delivery of throughput. In the case of rural water supply, the actual quantity of water delivered will depend on climate, particularly rainfall, which will influence the demand for irrigation water as well as the supply of water run-off in reservoir catchments. The rural water supplier is generally required to meet the entitlements of water users, and where it cannot meet entitlements, these may be carried over to subsequent years, and these effects need to be taken into account in capacity planning, which will be a key driver of supply costs. The quantity of entitlements that can be made available will be influenced by the water authority's activities in constructing and maintaining water management works.

In its productivity analysis of State Water Corporation, the Independent Pricing and Regulatory Tribunal (IPART) of NSW used the number of water entitlements as its preferred measure of output (IPART 2010, p.30). This was primarily because the number of water entitlements was considered to be less dependent on year-to-year climate fluctuations Compared to delivered water volumes. That said, there are a wide range of different types of entitlements that afford users different degrees of priority and certainty of supply, and a great deal of diversity between water utilities in regard to the types of entitlements made available. It may therefore be difficult to establish an unambiguous measure of the quantity of entitlements that can be compared between businesses on a like-for-like basis. For this reason, we do not use the quantity of entitlements as an output measure in this preliminary analysis. Although we regard the quantity of entitlements as a useful output measure, it is likely to take some time to develop a capacity measure based on entitlements that is consistent between businesses. In this study we use the total storage capacity of reservoirs under management as a measure of supply capacity. If a measure of capacity based on the quantity of entitlements is developed, it could be used in addition to the storage capacity measure. Some businesses also report a long-term expected supply volume of water, presumably to remove year-to-year variation due to weather, and it is possible that a measure of this kind might be used as an alternative measure of capacity.

It can in some cases be difficult to differentiate between outputs and inputs. For example, one output for a regulated river operator is to manage the flow of water over the length of the river, which will often involve investment in weirs (and locks for navigation) and associated operating and maintenance activities. We assume that the quantity of the service of managing the flows of the regulated river systems can be proxied by the length of the regulated rivers in kilometres (km), since a longer regulated river system is likely to require greater investment in weirs and use of associated non-capital inputs. In principle, these facilities are purchased investments used to deliver the services provided to users, and the associated service would appear to be that of regulating the river flow. Services are generally outputs that are sold to users, but although the service of regulating the river flow is not directly sold to users, delivered water is likely to have different values, and different costs of supply, in different locations and therefore the spatial dimension of water supply cannot be ignored.

In light of this discussion, the following three variables are used as candidate outputs for RMO:

- the quantity of water delivered at the delivery points
- the storage capacity of the reservoirs under management
- the length of the regulated rivers under management.

In this preliminary analysis we test models with these three outputs. Although alternative output specifications have been tested, such as only using two of the output measures, or using long-term expected supply volumes of water as an alternative to storage capacity (where available), we have insufficient confidence in the alternative specifications when using the data available at present, and they are not presented in this report.

3.1.2 Output prices

TFP indexes usually require information on output prices to calculate the weights for the output index, for example the Fisher Ideal TFP index and the MTFP index. Output prices are not needed for calculating the Malmquist TFP index, which does not use any price information. Nor are they needed for estimating the distance function or the cost function, the former does not include any prices while the latter only uses input price information.[3]

Prices of the outputs of water businesses often include fixed fees charged to customers for the right to take water and variable charges based on the volume delivered (for metered customers). In the case of RMO this is greatly complicated by a number of factors:

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[3] See section 5.5 for an explanation of “distance function” and “cost function”.

- much of its funding comes from government allocations to its current year-to-year expenditure
- to the extent that prices are charged for river extractions from the Murray River, these are usually charged by SCA's and do not come within the RMO joint venture[4]
- in some cases charges relating to the use of River Murray water are simply in the form of state government licence fees, and not easily connected to River Murray Operations.

Where output prices are unavailable or not structured to coincide with the outputs, the revenue shares associated with different outputs will not be closely related to the marginal costs of producing those outputs. In these circumstances it is desirable to use marginal costs in place of output prices to calculate the output weights (Fuss 1994). For example, Lawrence (2007) uses cost shares associated with each output derived from an econometric cost function. Estimating a cost function can require a considerable amount of data, and if the data sample is limited and output price information cannot be relied on, then constructing TFP indexes can be problematic.

3.2 Inputs & input prices

Input variables refer to purchased inputs that can contribute to the ability of the business to deliver its services. They generally reflect resource allocation decisions made by managers at some time, and are therefore in some sense controllable, at least in the long-term. Where detailed data are available it is often possible to include a number of non-capital and capital inputs. For example, non-capital inputs may include labour, energy, chemicals and other non-capital inputs. Capital inputs may include various types of buildings, facilities and equipment. In some studies, capital and non-capital inputs used in discrete business activities are accounted-for separately. In this study it is considered desirable to differentiate between the inputs used in regulated river activities, and those used in the salt interception scheme and the environmental programs. This separation assists to make more direct comparisons between RMO and its peers, and RMO's environmental and salt interception programs are excluded from its inputs for the purposes of benchmarking rural water supply activities. Ideally, these schemes could be benchmarked against a variety of comparable environment programs.

3.2.1 Input quantities

The data available for this study has limited the range inputs that can be included in the analysis. Like several previous studies of productivity in the water industry, only two broad inputs are included: capital and non-capital inputs—e.g., Coelli & Walding (2006), Saal et al (2007) and Cunningham (2013). The studies vary in their use of physical or monetary measures of capital inputs, however for this study it will only be possible to use a monetary measure of capital inputs because the NWC data does not provide sufficiently detailed

[4] For example, State Water Corporation reported that it earned $10.1 million of revenue in the Murray-Lower Darling valleys in 2012-13, mainly from water entitlement charges and consumptive charges, associated with delivering 2,126 GL of water to customers from this river system. Source: National Water Commission (NWC) 2014, 'National Performance Report 2012-13: Rural water service providers'.

information on the physical characteristics of capital assets which can be compared between businesses.

The quantity of non-capital inputs is generally based on operating expenditure deflated by a suitable index of non-capital input prices. Operating expenditure includes employee salaries, administrative costs, energy and other consumables, maintenance of existing assets, and so forth, but does not include depreciation of fixed assets, interest payments or taxes paid. Total operating expenditure can be expressed as the product of (i) a measure of the quantity of non-capital inputs and (ii) an index of non-capital input prices. If the index of non-capital input prices is known, or can be approximated from published input price indexes, then a measure of the quantity of non-capital inputs can be obtained by deflating nominal operating expenditure using that price index (see section 3.2.2).

Capital can be measured in physical or monetary terms. Physical measures include the numbers of different types of capital assets employed, or measures relating to the size or service capacity of assets of different types. 'Monetary' measures are derived from accounting data, and the most common measure is the value of gross fixed assets at the end of the year including work in progress deflated by a relevant price index.

Both physical- and value-based measures have strengths and weaknesses. Physical measures are more likely to approximate the productive services of capital inputs, which do not usually diminish with asset age as rapidly as value measures would suggest. While they are usually more disaggregated and detailed, physical measures will often not cover all of the capital inputs employed. Monetary measures more completely cover the assets employed, but they actually reflect the value of the services of assets over the remainder of their lives at a point in time rather than the flow of services in a particular period, and they can be affected by differences in accounting methods between businesses or changes in accounting methods over time.

Candidate physical measures for capital inputs, included in the NWC's Rural National Performance Report (NPR), include: number of storages; number of weirs; and number of 'other' regulated river assets. However, to be useable as capital input quantity measures, information is also required on the size and capacity of these assets rather than simply their number. Where applicable to a water business, the NPR also provides data for the length of channels and pipeline networks and the number of water treatment plants, although these are not relevant to RMO. It may be possible to make adjustments to such data to take into account characteristics of dams or the presence of locks in some weirs, but this is likely to require not only more data on key characteristics of the facilities than is published by the NWC, but also a much larger sample size to determine the relative importance of different physical attributes. An exercise of that kind is beyond the scope of this study.

The available value-based measure of capital inputs, which is published by the NWC for a range of rural water businesses, is the written-down replacement cost of fixed assets. An appropriate deflator can be used to convert from nominal asset values into real terms, and for this purpose the Net Capital Stock deflator of Electricity, Gas, Water and Waste industry is used here.[5]

3.2.2 Input prices

TFP indexes require information on input prices to calculate the weights for the index of input quantities. Input prices are not needed for estimating technical efficiency using frontier methods, including DEA or econometric estimation of the distance function, as these methods do not use price information. Nor are they needed for calculating the Malmquist TFP index, which is based on technical efficiency measurement over time. However, input prices are required for estimating cost efficiency and allocative efficiency using frontier methods (including DEA cost efficiency measurement), econometric estimation of the cost function and for calculating MTFP indexes.[6]

The non-capital inputs price index is the price index used to deflate nominal operating expenditure to obtain the quantity of non-capital inputs. For this study, an index has been developed based on four published price indexes, as shown in Table 3.1.

Table 3.1 **Non-capital inputs price index components**

Cost category	Proxy price index	Weight
Employee costs	Wage Price Index – Electricity, Gas, Water & Waste (Public Sector)[7]	62.5%
Consultants, Insurances	CPI, Australia - Financial services[8]	19.5%
Travel, motor vehicles	CPI, Australia - Transport[9]	2.5%
Materials, Electricity, Plant hire, Plant & Other	Input price index: Manufacturing excluding petroleum[10]	15.5%

The cost categories and weights shown in Table 3.1 were derived by examining the reported components of operating cost in the financial accounts of MDBA and Goulburn Murray Water. A publicly available price index was selected for each of these cost categories, drawn from the Australian Bureau of Statistics (ABS) 'Wage Price Index', 'Consumer Price Index'

[5] Australian Bureau of Statistics (ABS), *5204.0 Australian System of National Accounts*, Table 58: Capital Stock, by Industry.

[6] See section 5.5 for an explanation of "distance function" and "cost function".

[7] ABS, *6345.0 - Wage Price Index, Australia*, Jun 2014.

[8] ABS, *6401.0 Consumer Price Index, Australia*, Table 11.

[9] ABS, *6401.0 Consumer Price Index, Australia*, Table 11.

[10] ABS, *6427.0 Producer Price Indexes, Australia*, Table 13.

and ‘Producer Price Indexes’ publications.

The price of capital inputs is more complicated to calculate, and the method of calculation depends on the approach used to measure the quantity of capital inputs. In nominal terms the total cost of employing capital inputs in a given year is equal to the nominal written-down value of fixed assets (V) in that year multiplied by ($r + \delta$), where r is the real opportunity cost of capital and δ is the average rate of depreciation. Thus the input price for capital services (φ) is equal to:

(3.1) $$\varphi = V(r+\delta)/K$$

where K is the chosen measure for the quantity of capital inputs. If K is a value-based measure derived by deflating the nominal written-down value of fixed assets (V) using a chosen capital stock deflator (ρ) then the price of capital inputs simplifies to:

(3.2) $$\varphi = (r+\delta)\rho$$

The calculation of capital price is complicated by the fact that the chosen value of r is usually controversial. We have calculated r using a real pre-tax weighted average cost of capital, where:

- the risk-free rate of return, in each year, is equal to the average 10-year Commonwealth Bond yield in that year as published by the Reserve Bank of Australia,[11] and
- all other parameters are those previously adopted for rural water businesses in the Murray-Darling Basin by the Australian Competition and Consumer Commission (ACCC 2011, p. 63).

The average depreciation rate (δ) is assumed to be 2.0%, and as previously mentioned, the chosen capital stock deflator (ρ) is the Net Capital Stock deflator of Electricity, Gas, Water and Waste industry.

3.3 Quality

It is often desirable to adjust quantity measures of outputs and inputs by quality measures, if variation in quality between businesses or over time can be substantial. This is because producing higher quality outputs requires more inputs, but they are more valuable. Productivity comparisons that do not take this into account may make a high productivity producer of higher quality outputs appear to have low productivity.

Quality dimensions that may be relevant to regulated river services might include reliability of water delivery, continuity of supply, water salinity, or environmental management. At this stage it is not clear whether these quality measures are likely to be important, or whether there are common quality measures that are relevant all rural water businesses that would be included in the benchmarking analysis.

[11] RBA, *Historical Statistics*:

3.4 Operating environment variables

Because each water business operates in a discrete locality they will face different external conditions that can affect their ability to translate inputs into outputs and the minimum costs that can be achieved. Performance comparisons seek to control for such factors, to better enable like-for-like comparisons between the benchmarked firms. Operating environment variables attempt to capture external factors that can affect utility operations. In some situations these external factors are outside the control of businesses, while in other cases they can adapt to the external constraints.

Industry-specific knowledge and analyst judgement is needed when identifying the factors that are most likely to significantly affect costs. Little is known at this stage about the types of factors that would be most relevant to regulated river operations. They may include:

- whether the business provides other services as well (e.g. gravity network supply services or drainage services etc), which may be relevant if there are economies of scope
- density of the customer base, or length of rivers under management (if not included as an output)
- topography or other aspects of the locality in which the business operates
- variability of water demand, which may be related to variations in rainfall and average temperature
- regulatory environments, which may impose different obligations on peer organisations.

3.5 Summary observations

Among the outputs, the variables that appear to be most suitable, among those for which data is available for this study, are:

- the volume of water supplied
- the length of regulated river under management (which is an indicator of the area over which that water is supplied), and
- the storage capacity of reservoirs (which is an indicator of the capacity to supply in dry years).

Possible alternative measures of supply capacity include the quantity of priority water entitlements, and the long-term expected supply volumes. Since there is no uniform set of definitions of water entitlements and various practices, a measure of capacity based on entitlements is likely to take time to develop. The long-term expected supply volumes are reported in the NPR, but the data appears to be of mixed quality.

The two inputs used in this study are non-capital inputs (measured by deflating operating and maintenance costs) and capital inputs (measured by deflating the written-down replacement cost of fixed assets).

4 CANDIDATE PEER BUSINESSES

There are only a small number of water businesses that have operations that maybe comparable to RMO. Table 4.1 shows some details for a number of such businesses, although not all are sufficiently comparable with RMO to be included in this preliminary economic benchmarking study.

Some of these are summarised in Table 4.1. The following is a brief description of each of the businesses listed in the table. Not all of the businesses will necessarily by suitable to include in a benchmarking analysis. Those included in the study are:

- **Goulburn–Murray Water:** A Victorian state-owned bulk water supplier in Northern Victoria. It is responsible for managing 20 water storages and delivers bulk water to townships and other bulk supply points. It also manages the MDBA storages, weirs and salinity mitigation works situated in Victoria.
- **Southern Rural Water:** A state-owned corporation responsible for managing rural water across the southern half of Victoria. It operates three irrigation districts and seven storages, and supplies water to irrigation customers, urban water corporations and the Latrobe Valley power generators.
- **State Water Corporation:** A NSW state-owned corporation established in 2004 responsible for bulk water provision in regional and rural NSW. It delivers more than 4,600 GL of bulk water annually to regional NSW for town water supplies, industry, irrigation and other farming use, and about 9,000 GL annually to the environment. It is responsible for managing 7,000 km of rivers, 21 dams and more than 280 weirs and regulators, and has over 6,000 customers.
- **SunWater:** Owned by the Queensland Government, it owns and manages bulk water supply and distribution infrastructure in regional Queensland, including 23 water supply schemes, 19 major dams, 63 weirs and barrages, 84 major pumping stations, 2,700 km of pipelines and channels and 730 km of drains. It has more than 5,000 industry, local government and irrigator customers. The Rural NPR includes information on the regulated river and irrigation components of SunWater's business.
- **Sydney Catchment Authority:** A NSW state-owned body responsible for managing a network of 21 dams in the Blue Mountains and surrounding areas, with a combined storage capacity of more than 2,500 GL, and regulating activities in the catchment areas to protect the quality and quantity of drinking water. It supplies raw water to Sydney Water and other water supply authorities.

The other businesses shown in Table 4.1 that were not included in the study are:

- **Fitzroy River Water:** Owned by Rockhampton Regional Council it supplies reticulated water and sewerage services to several towns in the vicinity, and also supplies bulk water entitlement holders in the Fitzroy Barrage Water Supply Scheme. The NWC separately reports its regulated river supply services in the Rural NPR and its reticulated water and sewerage activities in the Urban NPR. Since it does not own and operate reservoirs, it is not closely comparable to RMO.

- **Goldenfields Water (Bulk):** Supplies bulk water to townships and bulk users in South West NSW between the Lachlan and Murrumbidgee rivers. It sources water from the Murrumbidgee River, groundwater and irrigation canals. Since it does not own and operate reservoirs, it is not closely comparable to RMO.
- **Melbourne Water:** Victorian government-owned enterprise responsible managing 10 major reservoirs, treating water at two major filtration plants, and supply of bulk water to the Greater Melbourne area and nearby regional water authorities such as Western Water and Gippsland Water. Provides bulk sewerage services for the greater Melbourne area by operating trunk sewers, pumping stations and two major sewage treatment plants. Manages flows in a number of rivers, including the Werribee and Yarra Rivers. At present Melbourne Water does not provide data for its river and reservoir management activities separately from its other business activities and for this reason could not be included in this study. It would be desirable to obtain separate information of that kind for future benchmarking studies.
- **Rous Water:** The regional water supply authority providing bulk potable water Lismore, Ballina, Byron and Richmond Valley in NSW. It operates the Rocky Creek Dam, with a storage capacity of 14 GL, and other water sources with capacity of approximately 4 GL. Its supplies bulk water via a trunk main system. It is considered too small to be included in the present study, but may be considered for inclusion in future studies.
- **Seqwater:** A Queensland statutory authority formed in 2013 from Seqwater, SEQ Water Grid Manager and LinkWater. Responsible for supplying bulk water to South East Queensland, providing flood mitigation services, catchment management, recreation facilities and long term planning. It manages 26 dams, 47 weirs and 46 water treatment plants; the Gold Coast Desalination Plant; the Western Corridor Recycled Water Scheme; and a 600 km bulk water pipeline network. It also supplies water to approximately 1,200 rural irrigators. Seqwater has reported separate information for its regulated river activities in recent years, but not for the whole period under study. Seqwater is unable, at present, to provide comparable data for the earlier years of the sample, and for this reason has been excluded from this study. However, this is a matter that should be revisited in future benchmarking studies.
- **Snowy Mountains Scheme:** Owned and managed by Snowy Hydro, a major hydro electricity generator, the scheme includes 16 reservoirs with a combined capacity of almost 8,500 GL. It has obligations to divert water for irrigation via the Murray and Murrumbidgee river systems, and for environmental flows. To date, Snowy Hydro has not reported data in the National Performance Report, but it would be desirable to obtain relevant data and include Snowy Hydro in future benchmarking studies.

Table 4.1 **Candidate Peer Organisations**

State	Organisation	Reservoirs (No.)	Reservoirs (GL)	Regulated Rivers (km)	Customers[2] (no.)	Water supplied[2] (GL)
Inter-jurisdictional	RMO	4	9,306	2,375	n.a.	4,099
New South Wales	Sydney Catchment Authority	14	2,500	178	n.a.	522
	State Water	18	9,187	7,920	5,848	6,503
	Snowy Mountains Scheme[1]	16	8,472	n.a.	n.a.	n.a.
	Rous Water	2	14	n.a.	n.a.	10
	Goldenfields Water (Bulk)	0	0	n.a.	n.a.	9
Queensland	Seqwater	6	2,600	491	n.a.	279
	SunWater	17	6,288	3,254	1,841	469
	Fitzroy River Water	0	0	55	216	1
Victoria	Melbourne Water	10	1,812	n.a.	5	408
	Goulburn-Murray Water	12	4,340	2,774	21	411
	Southern Rural Water	4	94	301	93	22

Notes: 1. Not reported in the rural or urban NPR; 2. Customers & water supplied from reservoirs and regulated rivers only.

Data Source: NPR & business websites.

5 ECONOMIC BENCHMARKING METHODS

This section describes the main methods of economic benchmarking that could possibly be applied in the present study. The methods generally apply to one or both of the following efficiency concepts:

- *Productivity:* a measure of the total output quantity produced by a firm in proportion to the total quantity of inputs used to produce those outputs.
- *Cost efficiency:* a measure of the degree to which costs are minimised when producing particular levels of outputs, and for a given set of input prices.

5.1 Partial indicators

Partial measures of efficiency generally represent simple relationships between two measures to form indicators of partial productivity (ie, a single output in ratio to a single input), partial cost efficiency (eg, cost divided by a single output measure), financial performance (e.g. measures of profitability in relation to capital employed) or financial sustainability. Partial indicators are to some degree related to KPIs, which usually have a heavy emphasis on cost reduction and productivity measures, often by activity (Carter, Klein, and Day 1992, p.145).

Partial benchmarks have the advantage that they can focus on those specific measures for which there is good data available, but this inherently raises the risk of obtaining a biased perspective if more difficult to measure aspects of performance are overlooked. They also have the advantage of being simple to calculate. But there are a number of further shortcomings of partial measures. They:

- ignore the interaction between factors of production, including the scope for using different mixes of factors in the production process, and may thereby create misleading comparisons
- may not be directly comparable between firms due to differences in scale, or differences in the characteristics of the markets they serve
- are subject to what is known as Fox's Paradox, whereby a firm may have higher partial productivity outcomes than another firm in all its activities, but still have a lower total productivity if its activities are more concentrated in the lower productivity areas (Bogetoft 2012, p.4).

Partial indicators can sometimes be combined into a single overall performance measure using a weighted average, and where the weights reflect either the relative importance (or value) that the regulator or customers place on each aspect of the firm's performance, or else the incremental costs of improving particular performance areas. This approach can be convenient to derive an overall indicator of relative performance if it has general acceptance. However, its effectiveness will depend crucially on the validity of the weights used (Berg 2010).

Partial indicators are not presented in this report.

5.2 Total factor productivity indexes

When there are multiple outputs and/or multiple inputs, total factor productivity (TFP) is measured by the ratio of an index of the outputs (*Y*) to an index of the inputs (*X*). It is an encompassing measure of productivity:

(5.1) $$TFP_{t,b} = Y_{t,b} \big/ X_{t,b}$$

where *t* is the time period of the index and *b* is the base period against which the index is defined.

An index number is a real number that measures a set of related variables relative to a base period. Index numbers are perhaps the most commonly used means of measuring economic variables (Coelli et al. 2005, p.85). The output index is a weighted aggregate of the quantities of individual outputs and likewise the input index is a weighted aggregate of individual inputs. The weights used for calculating the output and input indexes will depend on the indexing method.

The main types of TFP indexes are:

- those that measure only the trends in productivity for individual businesses, such as the Fisher Ideal TFP index
- those that can be used to compare productivity levels between businesses and also measure their productivity trends, including the Multilateral TFP.

To operationalize TFP measurement we need to combine changes in diverse outputs and inputs into measures of change in total outputs and total inputs. There are alternative index number methods that calculate the weighted average change in outputs or inputs in different ways. For example, The Fisher Ideal index is calculated as the square root of the product of indexes using base period weights and using current period weights. The Törnqvist index uses growth rates for individual outputs and inputs, which are averaged using as weights the output revenue shares (for the output index) and input cost shares (for the index of inputs).

Diewert (1993) reviewed alternate index number formulations to determine which index was best suited to TFP calculations. Indexing methods were tested for consistency with a number of axioms which an ideal index number should always satisfy. Diewert found that only the Fisher ideal index passed all of the axiomatic tests. On the basis of his analysis, Diewert recommended that the Fisher ideal index be used for TFP work although he indicated that the Törnqvist index could also be used as it closely approximates Fisher's ideal index. Since the Törnqvist index produces similar results to the Fisher Ideal index, and the latter has superior properties, the Fisher Ideal index method is preferred.

Index methods have a number of advantages, including that few observations are needed to calculate an index. A disadvantage is that index-based measures of TFP cannot be decomposed into the sources of changes in efficiency, such as the influence of changes in technology, economies of scale or improvement in the technical efficiency of firms relative to best practice. They are focussed on overall cost efficiency and cannot shed light on its component parts of technical efficiency and allocative efficiency. The methods discussed in the following section are capable of addressing these matters.

Note that the Fisher Ideal TFP index requires information on prices. In the context of River Murray Operations, revenues might be proxied by the revenues per ML obtained by State Water and Goulburn-Murray Water in the Murray and Lower Darling Basins. However, output prices are not available in terms of the functional outputs used in this study. In order to calculate the Fisher Ideal TFP index it may be necessary to obtain some proxy prices, if possible.

It is common in infrastructure network industries that the billing units used in output pricing do not necessarily coincide with the outputs, and output prices need not be closely related to the marginal costs of production. In these circumstances it may be desirable to estimate the marginal costs of each output via an econometric estimation of the cost function. The estimated marginal costs can then be used in place of output prices to calculate the output weights (Fuss 1994). However, robust estimation of the cost function may be problematic if the sample size is small. In the context of this study we have taken the view that there is insufficient data to support robust econometric estimation of the cost function in order to derive output weights.

These limitations make it more difficult to apply the Fisher Ideal index method, and since a benchmarking method which does not require output prices is available, the Fisher Ideal index method is not used in this study.

5.3 Efficiency Frontier methods

Frontier models are motivated by the idea that, in economic theory, certain relationships describe the maximum set of outputs that can be produced by a given set of inputs, or the minimum cost set of inputs that can produce a given set of outputs. An efficiency frontier may represent the maximum degree of technical efficiency or of cost efficiency.

The two most commonly used methods of estimating efficiency frontiers are data envelopment analysis (DEA) and stochastic frontier analysis (SFA). DEA is a method that uses linear programming techniques as discussed in section 5.4. DEA is the frontier method used in this study. SFA is a set of econometric techniques for estimating efficiency frontiers. As this method is not used in this study, it is discussed only briefly in section 5.5.

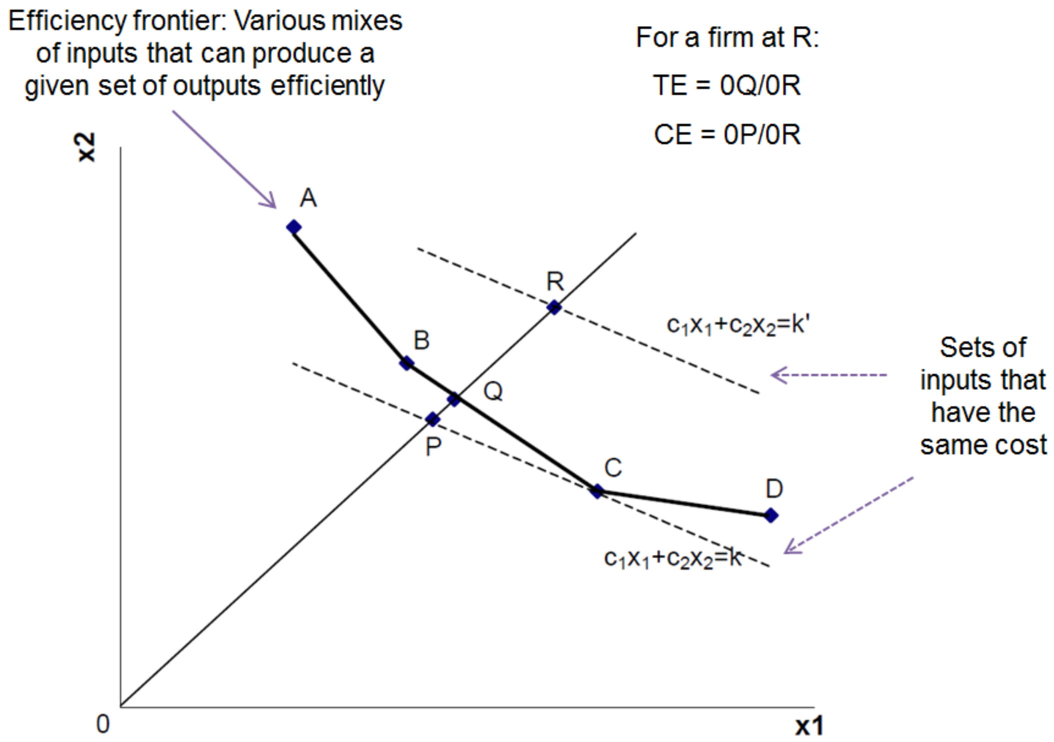
Frontier methods are generally used in conjunction with a TFP index methodology which differs from those discussed in section 5.2. When frontier benchmarking methods are used, the Malmquist index is “the most popular approach to dynamic evaluations” (Bogetoft 2012, p.39). This index is discussed in section 5.6.

5.4 Data envelopment analysis

The DEA technique uses linear programming to estimate an efficiency frontier that just fits a set of data. Different assumptions may be made in regard to returns-to-scale (e.g., constant, non-increasing, variable) and convexity. DEA is applied to data on multiple outputs and inputs for a set of comparable businesses and solves for the tightest fitting piecewise linear convex efficiency frontier that contains all of the observations.

Technical efficiency is measured in terms of "Farrell" measures of input-oriented or output-oriented technical efficiency. The input-oriented efficiency concepts are depicted in Figure 5.1, which shows combinations of two inputs that can produce a given set of outputs. The bold line connecting points A, B, C and D represents the technical efficiency frontier, estimated using DEA. It forms a lower bound of a set of observations where firms A, B, C and D are the best practice firms that define the frontier. For a technically inefficient firm such as firm R, the Farrell measure of technical efficiency (TE) is equal to: TE = 0Q/0R, where Q is the mix of inputs that R would use if it scaled down all of its inputs in the same proportion until it reached the efficiency frontier.

Figure 5.1 **Input-Oriented Efficiency Measurement**



DEA can also be used to solve the cost minimisation problem and thereby identify the cost efficiency frontier (see: Coelli et al. 2005, p.184). The cost frontier describes the minimum cost given the levels of outputs and of input prices. The concept of cost efficiency is also shown in Figure 5.1. Firm C is the only cost efficient firm since it is producing on the technical efficiency frontier and has a lower total cost than the other firms on the technical efficiency frontier. The cost efficiency (CE) of firm R is measured by: CE = 0P/0R, which is the ratio of the minimum cost to firm R's cost at prevailing input prices (reflect by the slope of the dotted lines).

A firm's cost efficiency can be formally decomposed into technical efficiency and allocative efficiency. Technical efficiency, as the forgoing discussion implies, refers to an absence of pure slack in relation to input use. A firm is technically inefficient if all inputs can be proportionately reduced while still producing the same output. Allocative efficiency is a measure of the degree to which inputs are used in the least cost combinations, given the prevailing input prices. A firm is allocatively inefficient if a different *mix* of inputs could produce the same output at lower cost.

Using the measures of technical efficiency (TE) derived from solving the DEA productive efficiency problem and the measures of cost efficiency (CE) obtained from solving the 'cost minimisation DEA' problem, measures of allocative efficiency (AE) can be obtained using the relationship: AE = CE / TE (see: Coelli et al. 2005, ch.3).

DEA analysis is a widely used and well accepted benchmarking methodology. Its strengths and weaknesses in comparison with stochastic frontier analysis are discussed in the next section.

5.5 Stochastic Frontier Analysis - Distance Functions & Cost Functions

Among the econometric approaches to efficiency analysis, the most important technique is stochastic frontier analysis (SFA). SFA has some important advantages compared to DEA, particularly as it allows for measurement error or random factors in its estimation, which makes the estimated efficiency frontier less sensitive to outliers. According to Agrell and Bogetoft, "the single most problematic feature of DEA is the risk of mistaking noise for efficiency or inefficiency" (Agrell and Bogatoft 2001, p.10).

SFA may be used for estimating various economic relationships such as:

- the *production function*, which defines the maximum amount of output that can be produced with a given set of inputs;
- the *cost function*, which refers to the minimum cost that can be achieved while producing a given amount of output, and given the set of input prices;
- the *profit function*, which defines the maximum profit that can be achieved by a firm facing a given set of output and input prices;
- the *distance function*, which defines the technical relationship between outputs and inputs and explicitly incorporates a firm-specific inefficiency measure. As with the Farrell measures of technical efficiency, distance functions may be output-oriented or input-oriented. For example, the input-oriented distance function describes firm's mix of outputs and inputs in terms of the minimum set of inputs that can produce a given set of outputs, and a measure of the firm's inefficiency relative to that minimum set of inputs (Berg 2010).

SFA methods are increasingly being used in benchmarking. For an application to Australian urban water distribution businesses see Cunningham (2012). An important advantage is that, as a statistical method, it enables formal hypothesis testing, such as in regard to the best set of inputs and outputs to include. However, SFA requires a large data set, preferably of panel data, to obtain reliable results, which is not available in the present study.

DEA has two features which may be particularly useful in the present context:

- It can be estimated with smaller data sets than are usually required for SFA. That said, the smaller the sample, the cruder the approximation, and the greater will be the under-estimation of inefficiency.
- Real peers are identified, which are those businesses that are unambiguously of greater or equal efficiency when compared to the business of interest. This allows more detailed attention to be focussed on the relevant peers when identifying practices that might be used to improve efficiency.

5.6 Malmquist indexes

The Malmquist TFP index is defined in terms of Farrell measures of input-oriented or output-oriented technical efficiency. The Malmquist index is a dynamic index in the sense that it measures changes in technical efficiency between two periods. The Farrell measures of efficiency refer to the degree to which inputs can be reduced in unchanged proportions while producing the same outputs, or the degree to which outputs could be increased in unchanged proportions while using the same inputs. The "Farrell" measures of technical efficiency are the "single most widely used approach to measuring the degree of efficiency in a general multi-input and multi-output setting" (Bogetoft 2012, p.26).

Technical efficiency refers to producing the most outputs with the least inputs. More specifically, output-oriented technical efficiency refers to producing the most outputs with a given set of inputs, and input-oriented technical efficiency refers to using the least inputs to produce a given set of outputs. In public utility settings, the input-oriented measure is usually considered to be most relevant, since output is rarely a discretionary variable for these businesses.

The input-oriented Malmquist index can be defined as (Färe, Grosskopf, and Roos 1998):

(5.1) $$M_I^s = \frac{TE_I^s(y_{t+1}, x_{t+1})}{TE_I^s(y_t, x_t)}$$

where y_t is the set of outputs in period t, x_t is the set of inputs in the same period, TE_I refers to the Farrell measure of input-oriented technical efficiency, and s represents the date of the technology.

The Farrell measure of technical efficiency is defined relative to an efficiency frontier (or technology) in a given period and the input-oriented efficiency measure (TE_I) is equal to the smallest scalar λ such that λx is able to produce y. That is, the maximum proportionate contraction of inputs that can produce an unchanged set of outputs. Therefore, $TE_I \leq 1$. If we define the minimum input set (when proportionately contracted) as: $x^* = \lambda x$, then:

(5.2) $$TE_I = x^*/x \quad \text{for a given } y$$

Usually, M_I is calculated against technology frontiers at both $s = t$ and $s = t+1$, and the geometric average of the two measures is used.

The Malmquist index has the convenient feature that changes in productivity can be decomposed into:

- technical change: that is, the productivity improvement of best practice firms at the efficiency frontier, and
- firm-specific changes in technical efficiency relative to the efficiency frontier.[12]

5.7 Summary Comments

This section has briefly surveyed the main alternative approaches to economic benchmarking and evaluated their usefulness for the present study. Our conclusion is that the DEA method of efficiency frontier analysis is the most suitable for the present purposes, given the small sample available for the study, and the scarcity and likely unreliability of data on output prices, given the functional output specification used in this study.

DEA has several advantages in the context of this study:

- It can take into account multiple inputs and outputs and provides measures of technical efficiency without the need for prices of outputs (or inputs). Index methods require output prices, although econometric analysis of costs can be used to develop proxy output values. Given the lack of reliable output price data, DEA is preferred to index methods in this initial analysis.
- When data for input prices is available (as is the case for this study), DEA can be used to measure cost efficiency and allocative efficiency.
- It can be used with smaller data samples than is required for statistical methods of frontier analysis (although accuracy is obviously greatly improved with larger data samples). SFA generally requires a larger sample than is available for this study.
- DEA can be used to identify the peer firms for each of the inefficient firms—that is, the firms that define the vertexes of the frontier segment directly facing the inefficient firm.
- It can be used to calculate the Malmquist TFP index to measure productivity trends for each of the firms in the sample.

[12] The Malmquist index does not satisfy the transitivity test unless the technology is Hicks-Neutral, a shortcoming shared by a number of other index methods. See: Agrell, P. & Bogatoft, P. 2001, 'DEA-Based Incentive Regimes in Health-Care Provision', The Royal Veterinary and Agricultural University Unit of Economics Working Papers 2001/10.

6 BENCHMARKING RESULTS

This section presents the results of an initial benchmarking analysis carried out using data envelopment analysis (DEA), which is used to quantify:

- the comparative technical efficiency of each water business in the sample with respect to its water reservoir and regulated river management functions
- comparative cost efficiency of the same water businesses, and their comparative degrees of allocative efficiency.

Associated with the DEA analysis is the calculation of Malmquist TFP indexes which show the productivity trends for these businesses over the period 2006-07 to 2012-13.

The analysis is confined to Australian water businesses that manage reservoirs and regulated rivers. RMO has significant salt interception and environmental works programs that do not have close comparisons with other peer businesses, and the costs and assets associated with these activities have been excluded from RMO's data for the purposes of this analysis.

6.1 Initial DEA analysis

The data discussed in section 4 was assembled primarily from published sources, namely from NWC reports, for six businesses, including: RMO, Sydney Catchment Authority, State Water (not including SCA functions), SunWater, Goulburn-Murray Water (not including SCA functions) and Southern Rural Water. SunWater provided further data, particularly for 2011-12 and 2012-13, which was not previously reported by the NWC. Data was available for each of the six businesses for the seven years from 2006-07 to 2012-13 — a total of 42 observations. This data was pooled in the DEA analysis for the purpose of obtaining a single efficiency frontier relevant to the whole of that period.

In the preferred specification presented here, the outputs include the following variables:

- Quantity of water delivered to customers via regulated river systems (ML)
- Length of regulated rivers (km)
- Combined storage capacity of reservoirs (GL).

The inputs are defined as follows:

- Capital inputs (2011-12 $): The nominal written-down replacement value of fixed assets deflated by the ABS net capital stock deflator for Electricity Gas Water & Waste.
- Non-capital inputs (2011-12 $): Nominal operating expenditure (not including depreciation) deflated by the non-capital inputs price index defined in Table 3.1.

Input prices are used for calculating cost efficiency. The rental price of capital inputs was estimated by calculating a real pre-tax WACC in accordance with the parameters adopted by the ACCC for Murray-Darling Basin businesses (ACCC 2011), together with average Commonwealth 10-year bond rates as published by the Reserve Bank of Australia (RBA). This WACC estimate was used in conjunction with an estimated depreciation rate of 2% annually and the capital stock deflator discussed. The non-capital input price index has been discussed.

Our preferred DEA specification is the variable returns-to-scale formulation, although we also present results for the constant returns-to-scale case. The observations for each of the seven businesses for each of the seven years from 2007 to 2013 were pooled under the assumption that a common and fixed efficiency frontier applies to these businesses over that period, without any technical change, which would shift the efficiency frontier. Hence there are 42 observations in the DEA analysis.

The results are presented in table 6.1 for technical efficiency, cost efficiency and allocative efficiency.[13]

Table 6.1 **DEA Results[1]**

	Business					
Model & Efficiency Measure	RMO	A	B	C	D	E
A. Variable Returns-to-Scale						
Input-oriented technical efficiency[2]	0.955	0.981	0.938	0.755	0.677	0.555
Cost efficiency[2]	0.925	0.944	0.779	0.853	0.093	0.510
Allocative efficiency[2]	0.968	0.963	0.823	0.700	0.144	0.917
B. Constant Returns-to-Scale						
Input-oriented technical efficiency[2]	0.763	0.981	0.327	0.744	0.195	0.504
Cost efficiency[2]	0.708	0.865	0.314	0.745	0.072	0.466
Allocative efficiency[2]	0.926	0.882	0.959	0.696	0.389	0.922

Notes:

1. Outputs include water delivered (ML), length of regulated river (km) & storage capacity of reservoirs (GL).

2. *Technical efficiency* refers to the degree to which the firm is producing the maximum quantity of outputs given its prevailing input use, or is minimising its use of inputs in producing its current amounts of outputs. Cost efficiency refers to the degree to which the firm is minimising its cost in producing its current amounts of outputs. A*llocative efficiency* refers to the degree to which the firm has adopted the best mix of inputs given their marginal productivities and the prevailing set of input prices.

Because the observations are pooled, there are actually seven different efficiency scores for each business, one for each year. The results shown in table 6.1 are averages of the scores obtained by each business over each of the years 2007 to 2013,

[13] The DEA and Malmquist index analysis presented here was carried out with LIMDEP v 9.0 (Econometric Software Inc).

which are all assessed against a common efficiency frontier. None of the scores shown in table 6.1 is equal to 1.0 because none of the businesses achieved an efficiency score of 1.0 in every year. Even the most efficient business in the sample was not fully efficient in every year, although it was on the efficiency frontier in some years. The average efficiency score provides a useful measure of the relative efficiency of each business against the other and their average efficiency relative to the frontier. It reduces the impact of year-to-year fluctuations due to climatic effects and other sources of random noise.

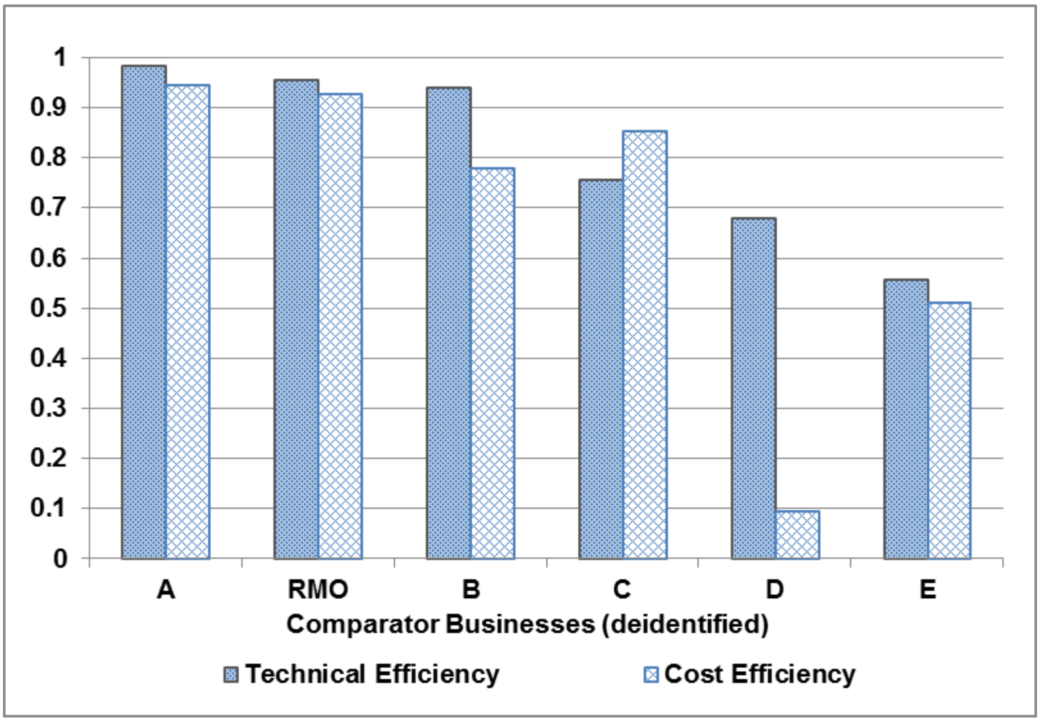
The preliminary results for technical and cost efficiency, under the preferred variable returns-to-scale specification, suggest that RMO has scores of over 90%, and is comparable to the more efficient businesses in the sample. The results under the more restrictive constant returns-to-scale model suggest a lower degree of technical and cost efficiency for RMO, but there are insufficient grounds for imposing the constant returns-to-scale constraint. RMO's comparatively good efficiency scores are likely due to an operational focus on input and cost minimisation. We also need to be aware that some of the less efficient businesses may face special environmental conditions. For example, one of these businesses is actually dissimilar to the others, as it is not a rural water business and mainly manages reservoirs for metropolitan use. The sample includes those businesses with functions of managing regulated rivers and reservoirs, for which data on those operations was available, and with a sufficiently comparable scale.

Figure 6.1 summarises the comparative technical efficiency and cost efficiency results for the preferred variable returns-to-scale case. Figure 6.1 shows that RMO is ranked second in terms of technical efficiency and has the same ranking for cost efficiency. Its closest peers in terms of technical efficiency are State Water and Southern Rural Water.

It needs to be emphasised that these measures of technical and cost efficiency are not assessed against an external standard of efficiency. The estimated efficiency frontier is derived from the observations on outputs and inputs for the businesses and periods included in the sample. The quality of the estimate of the frontier is crucially dependent on the size of the sample of comparator businesses and also depends on the validity of the definitions of outputs and inputs.

Ideally, a second-round analysis would be carried out to test whether some of the operating environment differences may explain the comparative efficiency findings. For example, these factors might in principle include topography, weather and institutional structure. However, in this context measures and data for operating environment factors are currently severely limited or not available at all, and the sample is also unlikely to be large enough to robustly identify any effects of this kind. In future analysis this may be possible, if the data sample were expanded and with improved collection of measures of different operating environment characteristics.

Figure 6.1 **DEA Efficiency Scores**



6.2 Malmquist Indexes

DEA analysis can also be used to produce total factor productivity (TFP) indexes based on a method that assesses changes in each business' technical efficiency scores over the period 2007 to 2013. In Figure 6.2, the TFP index for RMO is plotted against the average index for all businesses in the sample. Table 6.2 shows the results of the Malmquist TFP index analysis in detail.

The key results of the Malmquist index analysis are:

- The preliminary estimate of RMO's average growth of TFP between 2007 and 2013 is 3.1% per year. Only one comparator business has enjoyed a higher rate of productivity growth.
- The average TFP growth for the sample was 1.0% per year over the same period.

Figure 6.2 **Malmquist TFP Indexes**

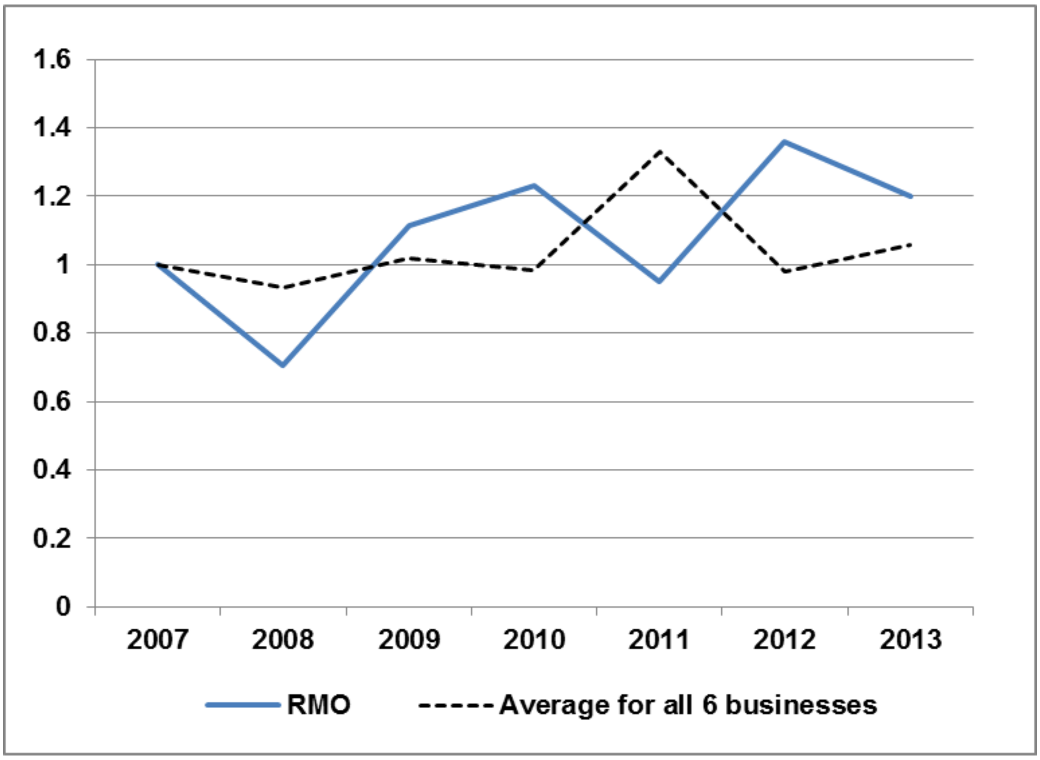


Table 6.2 **Malmquist Productivity Indexes***

Year ending June	Business						
	RMO	A	B	C	D	E	Average
2007	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2008	0.704	0.737	1.073	1.117	0.876	1.098	0.934
2009	1.114	1.165	0.912	0.963	0.945	1.012	1.018
2010	1.232	0.949	1.034	1.025	0.945	0.705	0.982
2011	0.949	1.260	2.080	1.654	0.924	1.121	1.331
2012	1.359	1.059	0.936	0.570	1.000	0.961	0.981
2013	1.200	1.240	1.070	0.980	1.001	0.861	1.059
Avg. Growth	**3.09%**	**3.65%**	**1.13%**	**-0.34%**	**0.02%**	**-2.46%**	**0.95%**

* Outputs include water delivered (ML), length of regulated river (km) & storage capacity of reservoirs (GL).

6.3 Summary comments

The economic benchmarking study presented in this section is only an initial trial of methods relying largely on existing data collected by the NWC. The aim is mainly to demonstrate a method of benchmarking that could be used to complement other methods of analysis within a regulatory or cost control framework.

The preliminary results for technical and cost efficiency suggest that RMO has scores that are comparable to the more efficient comparator businesses in the sample. RMO's average TFP growth over the period 2007 to 2013 was considerably higher than the sample average TFP growth rate. The sample average TFP growth rate was close to 1 per cent over this period.

As previously emphasised, the robustness of the results of economic benchmarking analysis depends on the quality, quantity and consistency of the comparative data available. It would be desirable to extend the coverage to other rural water businesses and include measures not currently available. To develop economic benchmarking further will require an investment of effort in further data gathering. Experience in other industry sectors, such as energy, suggests that this can take time, as it is important to have industry-wide agreement on all of the elements of the data collection process. Although there is effort involved in getting stakeholder support and participation, there are a number of positive spin-offs from having a robust and consistent database available. These include providing a better starting point for more detailed benchmarking studies and providing a more informed basis for policy analysis and evaluation.

We recommend further development of the benchmarking database for rural water businesses with comparable operations to RMO, building on the existing framework established by the NWC, and including some businesses not currently covered.

7 CONCLUSIONS

This draft report discusses economic benchmarking methods and processes, with the aim of measuring the efficiency of RMO against its peers in terms of productivity and cost efficiency. The processes of data gathering and benchmarking are discussed (sections 2.4 & 2.5). Candidate measures of outputs and inputs for RMO are developed for the purpose of benchmarking (section 3), and peer water businesses are identified (section 4). An assessment is made of the suitability of alternative benchmarking methods in light of the data available (section 5). A preliminary economic benchmarking analysis was carried out using data envelopment analysis (section 6). This benchmarking analysis demonstrates a method of benchmarking that could be used to complement other methods of analysis within a regulatory or cost control framework. This remainder of this section briefly outlines work that can be undertaken to further develop benchmarking methods and frameworks suitable for RMO.

In this study we have relied on data that has been collected in the past by the NWC. Being readily available for a number of comparator businesses for the seven years to 2012-13, this dataset was the logical place to begin trialling benchmarking methods. However, in order to progress economic benchmarking of the RMO joint venture for future regulatory and cost control purposes, we recommend further development of the benchmarking database for rural water businesses with comparable operations to RMO, building on the existing framework established by the NWC, and including some businesses not currently covered.

Further development of the database is needed for at least two reasons. Firstly, we have noted that the scope of the data available from the NWC's National Performance Report has limitations, for example in relation to lack of sufficiently detailed information about physical capital assets employed or breakdown of operating and maintenance costs, which would be useful in a more comprehensive benchmarking exercise. Other examples of additional information that it would be desirable to collect are as follows.

- In order to develop a further output measure based on water entitlements, it would be necessary to obtain an industry consensus on the appropriate classification of entitlements and for rural water businesses to collect and report data in accordance with those classifications.
- Information about environmental water flows would allow the feasibility of including these as a further output measure to be tested.
- At present, information on business environment factors, that is, the various external factors which can differ between rural water businesses and affect their comparative efficiency, is scarce or not available. Industry input would be needed to identify the most relevant factors that could be measured.

A second reason why further database development is needed relates to the uncertainty surrounding the future of the National Performance Report data reporting framework in light of the winding up of the NWC.[14] Although these functions may be taken up by another body, there remain questions about the future scope of the data collection and reporting framework, and it is timely to re-examine whether the component that relates to rural water businesses is meeting all of the needs of the businesses in the industry.

Most of the benefits of benchmarking will only be achieved when it is carried out regularly over time, as benchmarking methods are refined and the dataset's coverage is widened and extended. Complementary activities such as process benchmarking and case studies can be used to focus on efficiency improvement at an activity level, and further assist to develop business strategies to improve efficiency. We would expect that establishing an ongoing benchmarking framework would be likely to have significant benefits to RMO by assisting it to ensure that it meets efficiency objectives.

It is important to recognise the crucial importance of high-quality and relevant information databases for evidence-based policy development and implementation, and for management of businesses and programs (Head 2009). Data analysis and benchmarking needs to be built into management systems to continually provide a focus on the formulation of objectives and the assessment of whether they are being met. The collection of comprehensive and robust data is a prerequisite for effective program evaluation and improvement.

We strongly recommend the Department of Environment and RMO initiate a consultation process with rural water supply businesses with the aim of establishing an ongoing data collection and reporting framework to provide an adequate basis for ongoing benchmarking. This would involve consultation with rural water supply businesses that would be the data providers and its primary users, to address issues such as:

- settling on and establishing standard definitions for data items;
- specification of outputs, inputs, and business environment conditions relevant for benchmarking;
- establishing data collection and auditing processes and responsibilities;
- information reporting arrangements and the uses of benchmarking studies.

The process that the Australian Energy Regulator (AER) undertook to establish a database for the purposes of benchmarking is instructive. Following lengthy consultation with electricity distribution and transmission network businesses (and other stakeholders) over the course of 2013, the AER issued regulatory information notices which required the businesses to supply and document detailed data on the values and quantities of outputs, inputs and operating environment factors for the 8–year period 2005–06 to 2012–13. These notices specified the definitions of all included variables and business activities, and the requirements of

[14] The Commonwealth Government has announced that the National Water Commission will close down in December 2014. The Productivity Commission will take over the role of monitoring and auditing water reform. The Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) will take over annual reporting on water markets, while the Department of Environment will be responsible for assessing payments to Murray-Darling Basin states. See: http://www.abc.net.au/news/2014-09-25/nrn-watercommission/5769206.

businesses in relation to certifying the accuracy of the data they provide. After receiving the initial data, the AER carried out detailed data checking to identify any errors or anomalies to be rectified by the data provider. The data was then published, and the businesses were given the opportunity to comment on the data provided by other businesses to highlight any differences in the bases of preparation. This process resulted in as robust a dataset as is reasonably feasible.

With adequate and extended data collection, the benchmarking methods discussed and presented in this report can be further refined and extended. This may include:

- the use of other benchmarking methods such as SFA, to test or corroborate the comparative efficiency findings of this study. Comparison of the technical efficiency scores derived from both DEA and SFA methods would enable formal testing of the results for mutual consistency (Bauer et al. 1998; Berg & Lin 2008);
- analysis to test the effects of various external factors on firm efficiency scores, if data on those factors is available. This may shed light on key factors underlying the findings, including the influence of business environment factors;
- addressing a wider set of questions, for example, in relation to institutional or regulatory arrangements. Experiences in overseas jurisdictions can also be examined to address questions of interest.

We reiterate that the development of improved benchmarking methods and their application to a wider set of questions depends importantly on development of a suitable body of data that is collected on an ongoing basis. Once sufficiently developed, benchmarking can assist the participating governments and RMO in a number of ways. For example, it can be used to provide greater transparency and accountability, or as part of formal incentive mechanisms within the RMO joint venture to facilitate efficient planning, project cost control and service delivery. It may also be used as part of a regulatory framework relating to prices of water use relating to the Murray and Lower-Darling Rivers, if that is relevant.

The first step, is to commence a consultation process with rural water service providers in relation to the retention and further development of the benchmarking database for these businesses, building on the existing framework established by the NWC, and including some additional items of information and addition businesses not currently covered.

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