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AN ANALYSIS OF THE PRODUCTIVITY OF THE VICTORIAN WATER INDUSTRY

Staff Research Paper No. 12/1

SUMMARY REPORT

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Preface

This research paper presents the results of initial research by staff of the Essential Services Commission into productivity trends and comparative productivity levels of the Victorian water industry in the context of a benchmarking study covering water utilities across Australia. The study is a first attempt only, and is intended to view Victoria water utilities within a national perspective. It is intended to be relevant to economic regulation in the Victorian water sector, and productivity trends in the Victorian water industry will be one of the considerations in the next price review (2013–2018). The Commission has indicated it expects Water Plans to have a greater emphasis on productivity improvement. At this stage, we intend to update the study every two or three years.

Some care is needed when interpreting the results of this analysis in light of limitations in the quality and completeness of data. Prior to publication, feedback was invited on the study from Victorian water businesses with an opportunity for them to correct any data shortcomings or provide explanations of productivity trends. Submissions were received from Barwon Water, Central Highlands Water, Coliban Water, Gippsland Water, South East Water, Victorian Water Industry Association, Wannon Water and Yarra Valley Water. These are available on the Commission's website alongside this paper. Our acknowledgement of, and response to, the issues raised in these submissions can be found in Appendix B.

Water utilities are again invited to correct their data or provide interpretations of the results, and these can be sent to: water@esc.vic.gov.au. That aside, water businesses now have comparative data on their own trend in productivity, and management and Board can decide what specific corrective actions to adopt, given their detailed knowledge of investments they make for other purposes which may adversely impact upon productivity.

Thanks to Joe Hirschberg at the University of Melbourne, who has provided valuable guidance and peer review of this study.

David Heeps
Chief Executive Officer

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Executive Summary

Over the period 2006 – 2010, the productivity of Victoria's four major water retailers[1] has remained virtually unchanged, or declined slightly. On the other hand, significant declines in productivity have been experienced by most of the large interstate water utilities.

Water utilities in regional Victoria saw productivity also decline significantly (by approximately 0.8 per cent per year on average) over the same period. This represented an underperformance relative to their interstate regional counterparts, for whom productivity also declined, but less rapidly.

The relative technical efficiency of the major metropolitan Victorian water utilities appears to remain favourable relative to most of their interstate counterparts. The best estimates suggest they are just inside the top 20 per cent of Australian water utilities in terms of technical efficiency. However, the same cannot be said for Victoria's regional water utilities, which appear to be less technically efficient, on average, than their interstate peers.

This research report has analysed productivity trends within the Australian water industry in order to provide a benchmark the performance of Victorian water utilities.

Three approaches have been used to productivity measurement:

- An index approach using a Cobb-Douglas index specification. The weights used for the output index are cost elasticity shares derived from subsidiary cost function analysis. The index is adjusted for scale economies.
- A stochastic frontier analysis, using the translog input distance function.
- A random effects model, which also uses the translog input distance function.

[1] Barwon Water, City West Water, South East Water and Yarra Valley Water.

The two econometric models are both considered satisfactory, yield similar results, and are preferred to the index approach. Among these the stochastic frontier model represents the preferred set of estimates.

This study assumes there are three outputs and three inputs. The outputs are: the number of customers supplied; a measure of water supplied which is both quality-adjusted (for drinking water quality) and normalised for the effect of temporary water restrictions; and the quantity of sewage treated which is quality adjusted (for the sewage treatment level). The inputs comprise capital and non-capital inputs. There are two different measures of capital inputs, and each of these measures is treated as a separate input. One measure of capital inputs is in quasi-physical units, as a function of the length of water supply and sewerage mains, the proportion of water that is sourced from a utility's own upstream facilities and groundwater, and the capacity of any desalination plants. The other measure of capital inputs is an accounting-based measure of fixed asset written-down replacement cost. Non-capital inputs are a composite index of bulk water purchased and all other non-capital inputs.

The main findings in relation to productivity trends over the period 2006 to 2010 were as follows (reporting the stochastic frontier model):

<u>Major utilities</u>[2]

- An average total factor productivity (TFP) decrease for the four major urban Victorian utilities of 0.1 per cent per year between 2006 and 2010.
- An annual decline in TFP for the major utilities in other states of 0.6 per cent per year over the same period. The investment in desalination plants in Perth, the Gold Coast and Sydney is a possible contributing factor.

<u>Non-major utilities</u>[3]

- The productivity of the regional Victorian urban water utilities is estimated to have decreased by 0.8 per cent per year between 2006 and 2010. Increases in capital and non-capital inputs per customer were key factors in this outcome.
- A productivity decrease of approximately 0.4 per cent per year is estimated for the non-major utilities in other states over the same period.

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[2] The major Victorian water utilities are listed in footnote 1. The major non-Victorian water utilities are: ACTEW, Hunter Water Corporation, Sydney Water Corporation, Brisbane Water, Gold Coast Water, SA Water Adelaide, Water Corporation Perth.

[3] Refers to the remaining water utilities in the sample. See Appendix A.

The analysis of comparative productivity levels for 2010 indicated the following:

Major utilities

- Taken together, the four major urban Victorian utilities were approximately 13 per cent *above* the average technical efficiency.
- The major utilities in other states, taken as a group, were approximately 8 per cent *below* the average technical efficiency.

Non-major utilities

- The water utilities in regional Victoria were on average approximately 9 per cent *below* the average technical efficiency.
- The non-major utilities in other states were on average approximately 4 per cent *above* the average technical efficiency.

There is uncertainty surrounding these estimates of comparative efficiency, not least of which is due to shortcomings in the measurement of capital inputs.

In regard to the sources of productivity change:

- Both measured environmental factors and returns-to-scale effects were found to be of minor importance. In the preferred model, the average returns-to-scale effect added approximately 0.3 per cent per year to productivity growth on average over all utilities.
- The combined effects of technological change and changes in the levels of technical inefficiency of utilities are likely to be difficult to distinguish. However, their combined effect appears to explain the greater part of the adverse productivity movements. Increases in technical compliance requirements, if important, would represent an adverse technology change because even best practice utilities may require more inputs to produce a given set of outputs. Sub-economic projects, such as providing sewerage to small townships or certain expenditures on environmental conservation initiatives, would increase technical inefficiency when they represent a departure from the best practice, or most efficient, water and sewerage supply.

1 Introduction

This summary report presents the key findings of research into the productivity of the Victorian water industry, in the context of a benchmarking study covering water utilities across Australia. The accompanying technical report presents supporting documentation of the analysis methodology, research approach and detailed results.

The study seeks to establish estimates for:

- trends in productivity of the Victorian water industry compared to productivity trends for the water industries in other states
- comparative levels of productivity of the different utilities.

It also explores the reasons for productivity change and differences between utilities. This includes taking into account the effects of economies of scale, technical inefficiency, technological progress and other factors.

The study examines the productivity of water retail/distribution utilities only. Bulk water suppliers such as Melbourne Water, SEQ Water and Sydney Catchment Authority are not included in the analysis. The inputs of the water retailer/distributors include the quantities of bulk water supplied, but do not reflect the efficiency of bulk water suppliers.

Primarily this study is intended to be relevant to economic regulation of the Victorian water sector. But it may also be of wider interest. Only a few studies of water industry productivity in Australia have been published and most of those are now out of date. It has also been suggested that the utilities and infrastructure industries may be significant contributors to Australia's poor productivity performance in recent years.[4] This study sheds some light on this in relation to the water sector.

[4] Eslake S & Walshe M (February 2011) *Australia's Productivity Challenge*, Grattan Institute, pp 16,19.

1.1 The data

The data set used in this study is primarily based on statistical reports published by the Water Services Association of Australia (WSAA) and the National Water Commission (NWC). This has been supplemented by data obtained directly from water utilities, city councils and other agencies, particularly for drinking water quality, bulk water purchases and water restrictions.

There are 54 utilities included in the sample, all of which have both water supply and sewage collection functions.[5] For larger utilities the data series typically extends from 1997-98 to 2009-10, while for smaller utilities data was available for 2005-06 to 2009-10. There is an average 7.6 years of data per utility.

Care needs to be taken when interpreting the results of this analysis in light of limitations in the quality and completeness of the data set. Although the WSAA and NWC data is the best available, it is dependent on the quality of information reported by water utilities, which may be variable. In some instances of incompleteness, interpolation has been necessary. Reviewing and enhancing the quality of summary data would be a valuable exercise for the water industry or the NWC.

1.2 Methodologies

Productivity is the ratio of outputs to inputs. Total Factor Productivity (TFP) is a measure of productivity when there are multiple outputs and multiple inputs. It is defined as an index of outputs divided by an index of inputs.

Broadly speaking there are two different approaches to measuring TFP. The first is an index number approach. An index is a method of combining data expressed in different units to produce a unit-free measure of an economic variable relative to a specified base period. By constructing index numbers for prices or quantities that would otherwise be in different units, it is possible to construct aggregate price or quantity measures using alternative averaging methods for the component indexes.

The index number approach in this study involves constructing a TFP index for each utility in each year using a Cobb-Douglas index with fixed weights. The use of fixed weights facilitates comparisons between utilities as well as over time. For comparing relative efficiencies of utilities, an adjustment is made to these

[5] In some localities, where water supply and sewerage are provided by separate bodies, those bodies have been combined. Examples include Water Corporation Kalgoorlie-Boulder and City of Kalgoorlie-Boulder, Water Corporation Bunbury and Aqwest.

indexes with the aim of taking out the influence of economies of scale on productivity.

The index-based approach is primarily used in this study as a cross-check against the other methodologies. It is relatively transparent because the sources of changes in TFP can most readily be traced back to specific data.

The second approach to measuring TFP is an econometric approach. In economic theory inputs and outputs are not independent. They are related to one another through a production technology or production function. The econometric approach seeks to estimate the efficient relationship between inputs and outputs. This aims to differentiate between changes in the mixes of inputs and outputs within a given technology from shifts in the technology. These two sources of productivity change are each of specific interest.

The econometric approaches involve estimating a 'distance function'. A distance function 'can be thought of as a multiple output version of a production frontier'.[6] This 'distance' is a measure of a firm's technical efficiency, such as:

- the ratio of an index of the firm's actual outputs to the maximum feasible outputs using the same inputs (an 'output-oriented' distance measure) or
- the ratio of an index of the firm's actual inputs to the minimum inputs needed to produce the same outputs (the 'input-oriented' distance).

In other words, the distance measure is the proportionate difference between the firm's technical efficiency and that of the best practice firm, given the mix of outputs, inputs and scale. The 'input distance' measure used in this study assumes the output mix is given. Optimisation by a business involves choosing the level and combinations of inputs, much like cost-minimisation. This approach is considered the most relevant to public utilities.[7]

Two econometric approaches are used in this study. They are:

- stochastic frontier analysis, and
- the random effects model.

Stochastic frontier analysis is an econometric method for fitting a function to data which represents an upper or lower bound to the observations.[8] It is used for

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[6] Coelli, Estache, Perelman & Trujillo (2003) *A Primer on Efficiency Measurement for Utilities and Transport Regulators*, The World Bank, p.43.

[7] ibid, p.47.

[8] This frontier is subject to 'white noise' random disturbance, hence the name 'stochastic frontier'.

estimating minimum or maximum value functions. In the stochastic frontier approach, firm-specific technical inefficiency is measured against an estimated efficiency frontier. The most efficient firms are on the frontier, and the others have positive inefficiency. The efficiency frontier is subject to random disturbance. In the stochastic frontier specification, the firm-specific inefficiencies are assumed to have a truncated-normal distribution, whereas in the random effects model they are normally distributed.

The random effects model is an econometric technique for analysing panel data (i.e. combined cross-sectional time series data) which includes a random cross-sectional disturbance (termed here the 'firm-specific effect') as well as a random disturbance over all observations in the sample (i.e. cross-sectional & time series without distinction). In the random effects model, the estimated input distance function is a central or representative estimate, rather than a frontier. The firm-specific effects are assumed to be distributed symmetrically and normally. Although the firm-specific effects do not have the strict interpretation as measures of relative technical inefficiency, they can be interpreted as such.

The random effects model is a useful comparative method, particularly when the estimated firm-specific inefficiencies appear to be close to normally distributed. If firms were observed to be more bunched toward an efficiency frontier, the stochastic frontier model would have clearer advantages. In this study we find the stochastic frontier and random effects models produce similar estimates overall.

The econometric approaches have advantages over the index approach because they can take account of a range of interactions and some environmental factors that the index approach cannot.[9] The econometric approaches also permit productivity change to be decomposed into its sources, including:

- technology improvement and reduction in the technical inefficiency of utilities
- returns to scale effects due to changes in the level of outputs
- the effects of other variables.

Technical efficiency involves adjusting the scale in inputs, including capital and labour, to the minimum level needed to supply the quality-adjusted outputs demanded.

[9] The environmental factors that were included in the econometric models were (a) groundwater as a proportion of all sourced water; and (b) proportion of customers with sewerage connected; and (c) trade waste as a proportion of all wastewater.

The econometric models assume a translog specification for the input distance function. This specification is similar to that of Saal & Parker (2006) and Saal, Parker & Weyman-Jones (2007).[10] The estimated stochastic frontier and random effects models are presented in Appendix C.

1.3 Previous water productivity studies

Only a few studies of water industry productivity in Australia have been published and most of those are now out of date. An early study by the Industry Commission used a Törnqvist index approach to estimate productivity trends for Melbourne Water.[11] Coelli & Walding[12] (2006) used Data Envelopment Analysis (DEA) with a sample of 18 Australian water utilities (excluding sewerage services) over an eight-year period ending 2002/03. It estimated that productivity decreased at 1.1 per cent per year over that period.

Among the more recent Australian studies, Byrnes et al.[13] used DEA with a sample of 52 regional water utilities in Victoria and NSW over four-years to 2003-04—again excluding sewerage services. The study used an unusual specification of outputs and inputs. Outputs were water supplied and a measure of consumer satisfaction, with a single input—deflated operating costs excluding labour. . More recently, a study commissioned by the National Water Commission adopted a broadly similar approach to the Byrnes et al study, using DEA analysis with a four-year sample period ending 2008-09, and excluding sewerage services.[14] A wider range of outputs was included, such as the quality of water

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[10] Saal D & Parker D (2006) 'Assessing in the performance of water operations in the English and Welsh water industry: a lesson in the implications of inappropriately assuming a common frontier', in Coells T & Lawrence D (eds) *Performance Measurements and regulation of network utilities*, Edward Elgar; Saal D, Parker D & Weyman-Jones T (2007) 'Determining the contribution of technical change, efficiency change and scale change to productivity growth in the privatized English and Welsh water and sewerage industry: 1985-2000', *Journal of Productivity Analysis* 28: 127-139.

[11] Industry Commission (1992), 'Measuring the Total Factor Productivity of Government Trading Enterprises', Steering Committee on National Performance Monitoring of Government Trading Enterprises.

[12] Coelli, T. & Walding, S. 2006, 'Performance Measurement in the Australia Water Supply Industry: A Preliminary Analysis', in *Performance Measurement and Regulation of Network Utilities*, eds T. Coelli and D. Lawrence, Edward Elgar.

[13] Byrnes, J., Crase, L., Dollery, B. & Villano, R. (2010), 'The relative economic efficiency of urban water utilities in regional New South Wales and Victoria', *Resource and Energy Economics*, vol. 32, no. 3, pp. 439-55.

[14] Worthington, A. (2011), 'Productivity, efficiency and technological progress in Australia's urban water utilities', in Waterlines report series no. 62, National Water Commission.

supplied, water losses, mains repairs, and a measure of customer satisfaction. A single input was used, deflated operating costs. The study estimated productivity to have increased by 1.0 per cent per year over this period.

Studies of the English and Welsh water industry by Saal & Parker (2006) and Saal et al. (2007) used stochastic frontier analysis (SFA) to estimate an input distance function. The second of these studies included a sample of 10 combined water and sewerage businesses over 16 years. It used as outputs the quality-adjusted volumes of water supplied and sewerage collected as well as the number of properties serviced.

The present study uses a method similar to the Saal et al. 2007 UK study. The authors of that study suggest that the choice of methodology was 'driven by the nature of production and regulation in the water and sewerage industry in England and Wales'.[15] They also have an emphasis on regulatory applications, so the method is considered suitable for the purposes of this study.

Although several previous Australian studies have used DEA analysis, in regulatory applications there is a need for relative stability of results as the sample period is incrementally extended over time. Comparative studies suggest that SFA is likely to be better suited than DEA:

> *The DEA series exhibits much greater volatility over time. We argue that these disagreements are due to the failure of DEA to account for noise, with DEA's assumption of CRS also playing a role.*[16]

It has also been suggested that DEA:

> *... is particularly susceptible to the effects of data noise (e.g. measurement error), which can lead to biased estimates of the shape and position of the frontier surface.*[17]

For these reasons the econometric method is preferred, and the approach chosen by Saal et al. (2007) provides a suitable methodology.

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[15] Saal et al., p.129.

[16] Atkinson, S., Cornwall, C. & Honerkamp, O. 2003, 'Measuring and Decomposing Productivity Change: Stochastic Distance Function Estimation Versus Data Envelopment Analysis', *Journal of Business & Economic Statistics*, vol. 21, no. 2, pp.293-4.

[17] O'Donnell, C. & Coelli, T. 2005, 'A Bayesian approach to imposing curvature on distance functions', *Journal of Econometrics*, vol. 126, p.494.

1.4 Summary

This research report analyses productivity trends within the Australian water industry in order to provide a context for examining the performance of Victorian water utilities.

Two broad approaches have been used to productivity measurement in this study:

- An index approach using a Cobb-Douglas index specification. The weights used for the output index are fixed. For the analysis of comparative productivity between utilities, the index is adjusted for scale economies.
- Econometric approaches involving estimation of an input distance function. The two econometric approaches are the stochastic frontier model and the random effects model.

The two econometric models are both considered satisfactory, yield similar results, and are preferred to the index approach. The stochastic frontier model is the preferred econometric model, on both conceptual and goodness-of-fit grounds.

2 Defining the outputs & inputs

One of the most difficult aspects in productivity analysis is deciding on how many and which outputs and inputs to measure, and how they are to be measured. Data limitations and computational constraints require compromises on the number or nature of the outputs or inputs included in the analysis. These choices can have an important influence on measured productivity.

Abbot and Cohen have surveyed a wide number of water industry productivity and efficiency studies. Their description of the types of variables used in that study has provided a useful starting point for considering appropriate input and output measures.[18] The Saal, Parker & Weyman-Jones study used four quality-adjusted outputs—water supplied, the number of water customers, sewerage treated, and the number of sewerage customers. They used two inputs, non-capital inputs and capital services. This study uses a broadly similar approach.

2.1 Outputs

In this study, a combined water supply and sewerage utility is assumed to have the following outputs:

(a) the number of customers (the greater of the number of water or sewerage customers, but in almost all instances the former)

(b) the normalised and quality-adjusted quantity of water supplied to residential and industrial customers, not including water losses. Normalisation adjusts for the effects of temporary water restrictions. An index of drinking water quality is used for quality-adjustment.[19]

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[18] Abbott M & Cohen B (2009) 'Productivity and efficiency in the water industry', *Utilities Policy* 17: 233–44; see pp 241-243.

[19] Drinking water quality has been measured as of the product of: the percentage of zones in which health-related microbiological standards were met and the percentage of zones in which health-related chemical standards were met. The product of these measures can be interpreted as an indicator of the probability that any one zone may be receiving non-compliant water (assuming no correlation between microbiological and chemical non-compliance).

(c) the quality-adjusted quantity of sewage treated, including trade-waste. Quality-adjustment is in terms of the levels to which effluent has been treated.[20]

Temporary water restrictions (TWRs) have an impact on productivity if they arise from factors that are unexpected, and only during the short-run. The quantity of fixed inputs will be temporarily mismatched to the level of outputs. The normalisation for TWRs involves dividing the (quality adjusted) quantity of water supplied by a factor, N, defined as:

N = 1 – % water supplied to residential × % TWR impact on residential use

– % water supplied to non-residential × % TWR impact on non-residential use.

The % impact of TWRs on residential and non-residential use is calculated by the formula: (Restriction stage / maximum restriction stage) × Δ, where $\Delta = 0.25$ for residential and $\Delta = 0.135$ for non-residential. This assumes that outdoor water use represents 25 per cent of residential water use on average, while the impact of non-residential use includes watering of parks and gardens and outdoor water use by businesses.[21] At the maximum restriction stage all outdoor use is prohibited.[22] It is assumed that the impact of restrictions is a linear function of the restriction stage.

It must be emphasised that this is a simplifying assumption. In actuality the potential demand reduction associated with TWRs will vary by locality depending on a range of factors including differences in climate and urban density.

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[20] The quality of sewage treatment (WWQ) is measured by the following index: WWQ = (% primary × 1 + % secondary × 2 + % tertiary × 3) / 3. This formulation, while approximate, is supported by cost studies. See: Ong S & Adams B (1987) 'A Heuristic Method for Modelling of Treatment Cost Functions', *International Journal of Environmental Studies*, 29: 261-267, p 265 (see 25 MGD or less).

[21] A decade ago, approximately one third of household water use was for outdoor purposes: WSAA *facts* 2001, p26. There has since been reductions in average household consumption due to water conservation measures and increased use of rainwater tanks. See: ABS, 4602.0.55.003 *Environmental Issues: Water Use and Conservation*. The Victorian Department of Sustainability and Environment has estimated the impact of water restrictions of each stage on household water use in Melbourne in: DSE (2008) *Augmentation of the Melbourne Water Supply System Analysis of Potential System Behaviour*, p. 7. More recent DSE estimates were available for this study relating to the Melbourne area.

[22] Queensland and Western Australia each use a seven-stage scale, with stage 7 corresponding to total prohibition of outdoor water use. The other states use four-stage scales.

2.2 Inputs

The study uses two broad input categories: non-capital and capital inputs. This is common in productivity studies,[23] for example Coelli & Walding's (2006) study of the Australian water industry and the UK studies mentioned.

Although it would be useful to separate bulk water purchases from other non-capital inputs, not all utilities purchase bulk water. To avoid zero input values,[24] non-capital inputs are measured as a composite index of two non-capital inputs:

- purchases of raw or treated bulk water (in ML)
- the residual operating and maintenance expenditure (not including depreciation) appropriately deflated.[25]

The weight given to purchases of bulk water in this index is the average cost share of bulk water in total O&M for that utility. The quantities of the two non-capital inputs (bulk water and residual O&M inputs) are each normalised by their respective overall sample means before constructing the combined non-capital inputs index.

The capital inputs measure is problematic, due mainly to concerns about measurement error and the consistency of data between utilities. The National Water Commission (NWC) publishes data for the written-down replacement cost of fixed water supply and sewerage assets for each utility.[26] They show wide variation in the value of assets per km of main. Some of the possible reasons include:

- differences in the extent of headwork assets between utilities that source their own surface water and those that buy water in bulk, furthermore, utilities in Melbourne own little sewerage treatment plant
- differences in the cost of construction, for example, due to the terrain, soil conditions, depth of mains, pipe materials used

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[23] Economic Insights (December 2009) *Total Factor Productivity Specification Issues*, report prepared for the Australian Energy Markets Commission, p iv.

[24] One of the limits to disaggregating inputs is the translog specification used in this analysis, where inputs and outputs can't take zero values.

[25] The residual opex is deflated by the average of the following two price indices, chosen to represent labour input prices and prices for materials, energy and other resource inputs respectively: the ABS Labour Price Index: hourly rates of pay excluding bonuses, public, Electricity, gas, water and waste services (6345.0); the ABS deflator for general government expenditure, State and local government final consumption (5206.0).

[26] Measures F9 & F10 of the National Performance Report.

- differences in asset age. Coelli & Walding (2006) emphasised that the differences in age of assets between utilities were likely to make accounting-based measures unreliable
- differences in valuation methods and assumptions.

The likely importance of measurement error for capital inputs poses a problem for this study. For this reason, two measures of capital inputs have been used:

- Gross Capital Stock: The NWC data is used to measure the assets in 2009-10, and values of the Gross Capital Stock for other years are estimated using the perpetual inventory method.[27] This is described elsewhere in this report as the accounting-based measure of capital inputs.
- The length of mains with adjustment for headworks and desalination plants.[28] This is described hereafter as the quasi-physical measure of capital inputs.

In the preferred model, both these measures are used. Therefore, it is actually a three input model, although two of the inputs are different measures of capital services.

2.3 Environmental variables

In the econometric analysis various 'environmental' or contextual variables have been tested, including rainfall, customer mix, water sources, etc. Three variables were subsequently included in all of the econometric modelling: the proportion of water sourced from groundwater; the proportion of customers with sewerage connection; and the proportion of wastewater collected that is trade waste.

2.4 Summary

This study assumes there are three outputs and three inputs. The outputs are: the number of customers supplied; a measure of water supplied which is both

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[27] For backward extrapolation the formula is: $K_{t-1} = (K_t - I_t)/(1-\delta)$. Here K is the capital stock. I is investment and δ is the rate are which assets are retired/replaced. Capital expenditure is deflated by the ABS National Accounts deflator for Public Gross Capital Formation by State & Local Public Corporations (5206.0). The assumed asset depreciation rate is 2.0 per cent per annum. This is approximately equal to the average depreciation rate for property plant and equipment in 2010, namely 2.2%, which was calculated as a percentage of written down values at 30 June 2009 for 51 utilities in the sample using 2010 annual reports.

[28] The formula we have used is as follows: K(physical) = length of mains (km) × (1 + 0.1 × (1 – % of water sourced from bulk purchases or ground water)) + 4 × desal capacity (ML/day).

quality-adjusted (for drinking water quality) and normalised for the effect of TWRs; and the quantity of sewage treated which is quality adjusted (for the sewage treatment level). The inputs comprise capital and non-capital inputs. There are two different measures of capital inputs, and each of these measures is treated as a separate input. One of the measures of capital inputs is in quasi-physical units as a function of the length of water supply and sewerage mains, the proportion of water that is sourced from a utility's own upstream facilities and groundwater, and the capacity of any desalination plants. The other measure of capital inputs is an accounting based measure, using the depreciated replacement cost of assets in 2009-10, with all other years calculated using the perpetual inventory method. Non-capital inputs are a composite index of bulk water purchased and all other non-capital inputs.

3 Summary of findings

The main findings of the study are presented in this chapter and related to the preferred stochastic frontier model. More detailed results for all three methodologies are presented in the associated technical report.

3.1 Productivity trends

The main findings in relation to productivity trends over the period 2006 to 2010 were as follows (reporting the stochastic frontier model):

Major utilities

- An average total factor productivity (TFP) decrease for the four major urban Victorian utilities of 0.1 per cent per year between 2006 and 2010.
- An annual decline in TFP for the major utilities in other states of 0.6 per cent per year over the same period. The investment in desalination plants in Perth, the Gold Coast and Sydney is a possible contributing factor.

Non-major utilities

- The productivity of the regional Victorian urban water utilities is estimated to have decreased by 0.8 per cent per year between 2006 and 2010. Increases in capital and non-capital inputs per customer were key factors in this outcome.
- A productivity decrease of approximately 0.4 per cent per year is estimated for the non-major utilities in other states over the same period.

An overall average rate of change in TFP for all utilities in the sample was –0.5 per cent per year over the period 2006 to 2010. That is, nationally there was a decline in water industry productivity over the period

3.2 Decomposition of productivity change

Table 3.1 also shows a partial decomposition of the changes in TFP highlighting the effects of scale and the 'environmental variables'. The residual must be attributable to either technology change, changes in technical inefficiency or the result of other factors not explicitly modelled or identified. Since the latter are unknown, we must assume the residual primarily reflects the former two effects.

The effects of technology change and changes in technical efficiency are, in practice, likely to be difficult to disentangle using models that seek to identify each effect through a steady time-related trend. Hence that decomposition is not reported here because of the lack of certainty that it is meaningful.

The main findings are:

- The effects of changes in the 'environmental factors' (namely the relative importance of groundwater sources in water supply, the proportion of customer connected to sewerage and importance of trade waste in sewage treatment) have been a minor source of reduction in productivity. Note, however, that the influence of temporary water restrictions has been adjusted-for in the normalisation of water supplies.

- The effect of returns-to-scale, that is the improvements in productivity due to changes in the scale of operations, was found to be of relatively minor importance. On average, the returns-to-scale effect added approximately 0.3 per cent per year to productivity growth.

- The combined effects of technology change and changes in the technical efficiency of utilities were on average negative. Over the sample as a whole, these effects contributed to a decline of 0.7 per cent per year in productivity, offsetting the small gains from the other factors.

It might be speculated that technology change is unlikely to have been substantial in a relatively "traditional" industry, such as the water industry. If so, then most of the observed trends in productivity would be attributable to changes in the degree of technical inefficiency. That is, declines in productivity would be attributable largely to reduced efficiency.

Table 3.1 **Total Factor Productivity – Average Rates of Change – Stochastic Frontier Model**
(per cent compound rate over period 2006 to 2010)

Name	ΔOutputs	ΔInputs	ΔTFP	Environmental variable effects	Returns-to-scale effect	Remainder
Major urban Victoria						
Barwon Water	1.3	2.1	-0.8	-0.5	0.1	-0.4
City West Water	3.1	2.1	1.0	0.0	0.7	0.3
South East Water Ltd	1.5	1.6	-0.1	-0.1	0.2	-0.2
Yarra Valley Water	1.3	1.8	-0.5	0.0	0.2	-0.7
Simple average - major urban Vic	**1.8**	**1.9**	**-0.1**	**-0.1**	**0.3**	**-0.3**
Major urban Non-Vic						
ACTEW	0.5	1.4	-0.9	0.0	0.1	-1
Hunter Water Corporation	0.8	1.4	-0.7	0.0	0.0	-0.7
Sydney Water Corporation	0.3	1.7	-1.4	-0.3	0.1	-1.2
Brisbane Water	0.1	0.0	0.1	-0.3	0.0	0.4
Gold Coast Water	-0.1	0.9	-1.1	0.0	-0.1	-1
SA Water - Adelaide	0.9	2.0	-1.1	0.0	0.1	-1.2
Water Corporation - Perth	2.1	2.4	-0.3	-0.2	0.1	-0.2
Simple average - major urban non-Vic	**0.8**	**1.4**	**-0.6**	**-0.1**	**0.0**	**-0.5**
Regional Victoria						
Central Gippsland Water	0.6	3.9	-3.3	0.1	0.1	-3.5
Central Highlands Water	1.4	3.8	-2.3	-0.2	0.2	-2.3
Coliban Water	0.7	2.0	-1.3	0.1	0.0	-1.4
Goulburn Valley Water	-1.1	1.6	-2.6	-0.2	-0.1	-2.3
East Gippsland Water	1.0	3.1	-2.1	-0.7	0.1	-1.5
GWMWater	0.5	-1.2	1.7	-0.2	0.0	1.9
Lower Murray Water	1.3	1.8	-0.5	-0.1	0.1	-0.5

Name	∆Outputs	∆Inputs	∆TFP	Environmental variable effects	Returns-to-scale effect	Remainder
North East Water	1.8	2.0	-0.3	-0.1	0.2	-0.4
Wannon Water	0.9	1.8	-0.9	-0.6	0.1	-0.4
Western Water	2.7	3.9	-1.2	-0.4	0.3	-1.1
South Gippsland Water	1.3	3.7	-2.3	-0.1	0.3	-2.5
Westernport Water	3.2	2.1	1.1	0.6	0.8	-0.3
Simple average - regional Vic	**2.0**	**2.9**	**-0.8**	**-0.2**	**0.2**	**-0.8**
Regional Non-Vic						
Gosford City Council	2.5	0.2	2.3	0.2	0.7	1.4
Wyong Shire Council	0.3	1.6	-1.3	-0.4	0.1	-1
Albury City Council	-3.5	1.4	-4.9	0.5	-0.5	-4.9
Coffs Harbour City Council	1.2	2.8	-1.7	-0.5	0.2	-1.4
MidCoast Water	1.3	2.3	-1.0	0.0	0.2	-1.2
Port Macquarie Hastings Council	2.1	1.3	0.8	0.3	0.4	0.1
Shoalhaven City Council	1.2	1.8	-0.6	-0.8	0.1	0.1
Tweed Shire Council	4.5	3.1	1.4	-0.1	1.0	0.5
Wagga Wagga Council/Riverina Water	1.4	2.2	-0.8	0.4	0.0	-1.2
Ballina Shire Council	1.8	1.8	-0.1	-0.8	0.6	0.1
Bathurst Regional Council	1.5	1.7	-0.2	0.0	0.4	-0.6
Bega Valley Shire Council	1.8	3.5	-1.7	-1.0	0.3	-1
Byron Shire Council	2.1	1.3	0.8	1.0	0.6	-0.8
Clarence Valley Council	4.8	0.2	4.6	0.6	-0.1	4.1
Country Energy	0.7	1.9	-1.2	0.0	0.3	-1.5
Dubbo City Council	1.7	1.0	0.7	-0.1	0.4	0.4
Eurobodalla Shire Council	1.2	2.7	-1.5	-0.6	0.1	-1
Kempsey Shire Council	0.1	-0.5	0.5	0.4	0.0	0.1

Name	ΔOutputs	ΔInputs	ΔTFP	Environmental variable effects	Returns-to-scale effect	Remainder
Lismore City Council	1.7	0.5	1.2	0.0	0.3	0.9
Orange City Council	1.3	1.1	0.2	-0.7	0.2	0.7
Queanbeyan City Council	0.5	0.6	-0.2	0.0	0.1	-0.3
Tamworth Regional Council	2.6	3.3	-0.7	-0.1	0.4	-1
Wingecarribee Shire Council	2.8	2.0	0.9	-0.8	0.1	1.6
Power and Water - Darwin	2.2	2.9	-0.8	0.4	0.6	-1.8
Power and Water - Alice Springs	-3.4	2.3	-5.7	-0.1	-1.2	-4.4
Ipswich Water	3.2	3.2	0.0	-0.2	0.3	-0.1
Logan Water	9.3	6.6	2.6	0.8	1.1	0.7
Water Corporation - Mandurah	3.9	5.5	-1.6	-1.0	0.2	-0.8
Aqwest/Water Corp Bunbury	5.8	2.5	3.3	0.9	1.6	0.8
Kalgoorlie-Boulder (sewerage & water)	3.3	4.4	-1.0	-1.7	1.8	-1.1
Water Corporation - Albany	1.5	3.9	-2.4	-0.2	0.3	-2.5
Simple average - regional non-Vic	**3.6**	**4.1**	**-0.4**	**-0.1**	**0.3**	**-0.6**
Simple Average - all utilities	**1.6**	**2.1**	**-0.5**	**-0.1**	**0.3**	**-0.7**

Source: ESC.

3.3 Comparative productivity

Figures 3.1 and 3.2 shows the estimated technical efficiency score for each utility in the sample, ranked from highest to lowest, for the stochastic frontier approach and for the average of the three approaches used in this study respectively. The technical efficiency scores of the stochastic frontier model have been normalised so that the mean is equal to one. (The other two methods have a mean close to one.)

The difference between a utility's technical efficiency score and the highest scores in the sample is a measure of that firm's technical inefficiency. Technical inefficiency means that a utility is either:

- not using the minimum quantity of inputs needed to produce a given output or
- not producing the maximum outputs from a given set of inputs.

The analysis of comparative productivity levels for 2010 indicated the following:

Major utilities

- Taken together, the four major urban Victorian utilities were approximately 13 per cent *above* the average technical efficiency.
- The major utilities in other states, taken as a group, were approximately 8 per cent *below* the average technical efficiency.

Non-major utilities

- The water utilities in regional Victoria were on average approximately 9 per cent *below* the average technical efficiency.
- The non-major utilities in other states were on average approximately 4 per cent *above* the average technical efficiency.

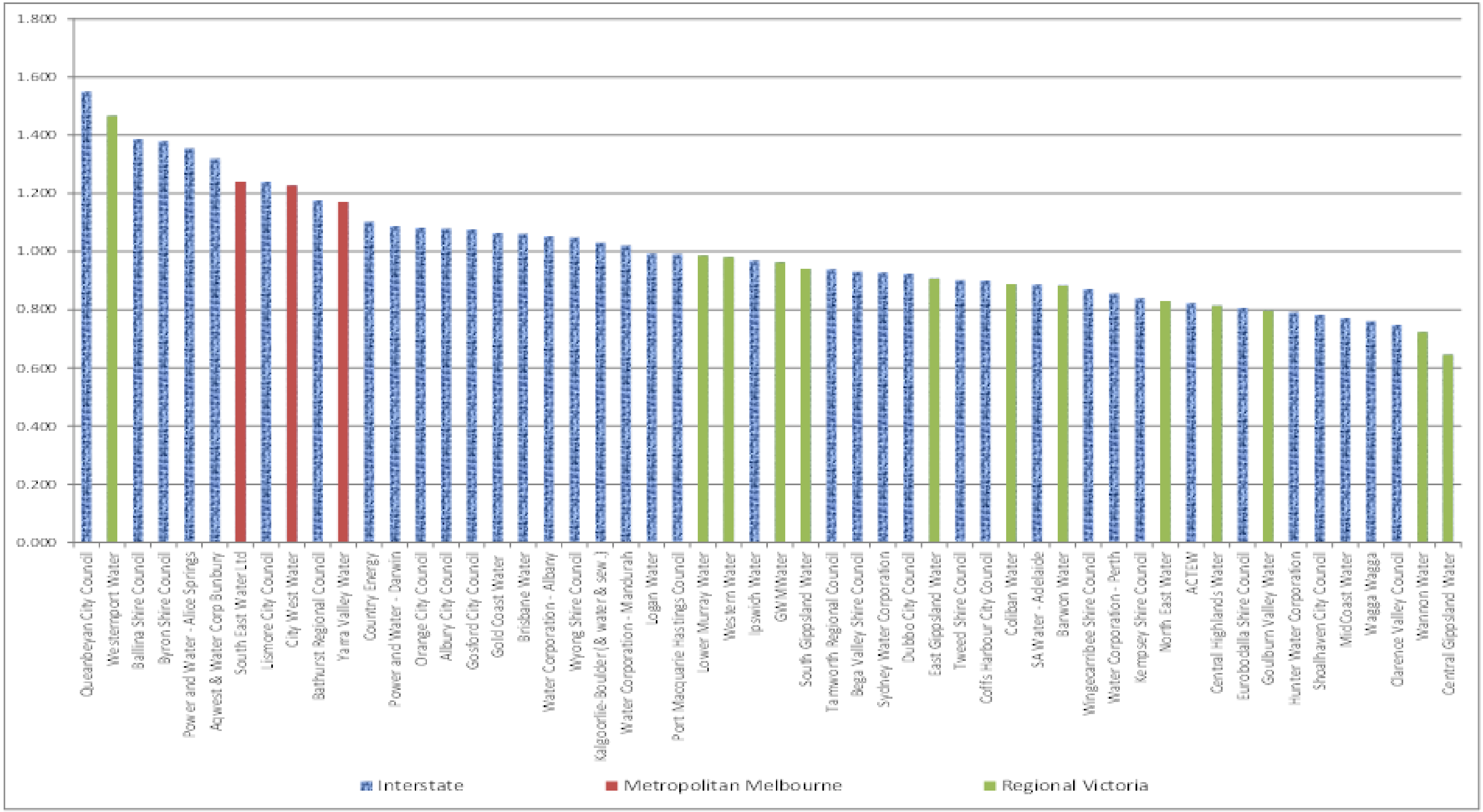
There is uncertainty surrounding these estimates of comparative efficiency, not least of which is due to shortcomings in the measurement of capital inputs.

The results from the three approaches showed the following similarities.

- City West Water, South East Water and Yarra Valley Water were usually, but not consistently, ranked in the upper end of the ordering (top 25 per cent). Barwon Water was consistently ranked in the lower part of the ordering (bottom 25 per cent).

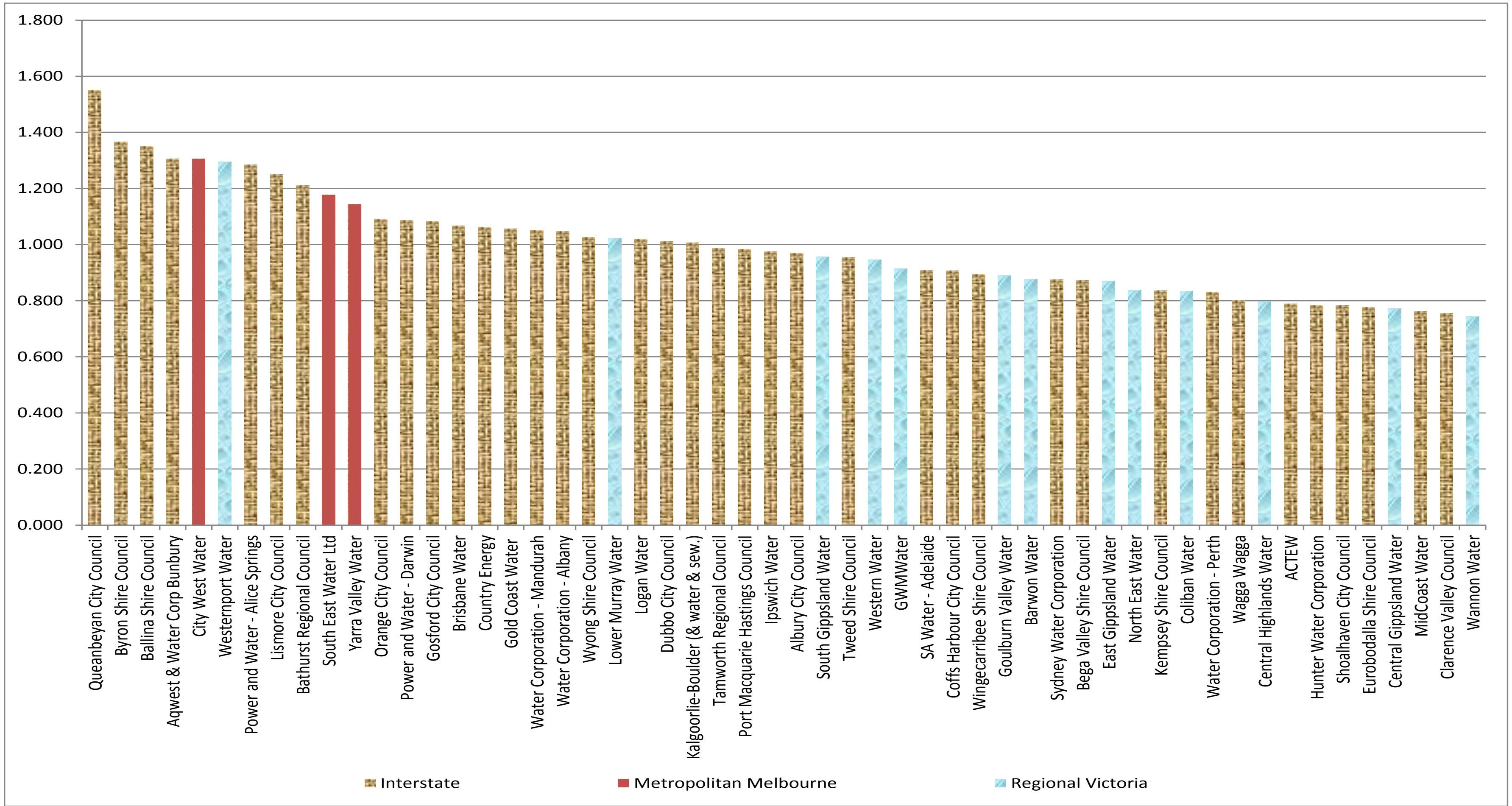
- Several of the largest interstate utilities were consistently ranked toward the lowest quartile of the technical efficiency range.
- Brisbane Water and Gold Coast Water had above average technical efficiency. However, the three methods produced widely varying technical estimates for Brisbane Water.
- In regional Victoria, Westernport Water was ranked among the more efficient utilities in the econometric models, but of average efficiency by the index-based approach. Several regional Victorian water utilities were in the lowest quartile irrespective of the method of analysis. These included Central Gippsland Water, Central Highlands Water, Coliban Water, East Gippsland Water, North East Water and Wannon Water. Several had large capital works programs in recent years.
- Several of the interstate regional utilities were ranked in the top quartile of technical efficiency.

Figure 3.1 **Technical efficiency estimates – Stochastic Frontier model**



Source: ESC.

Figure 3.2 **Technical efficiency estimates – Average of three models**



Source: ESC.

Appendix A | Glossary

Allocative efficiency	Allocative efficiency in input selection involves selecting that mix of inputs which produces a given quantity of output(s) at minimum cost, given the input prices that prevail. Allocative efficiency in output selection involves producing a mix of outputs with a given quantity of input(s) which maximises revenue, given the output prices that prevail.
Cost efficiency	The degree to which a firm achieves minimum cost for producing a given set of outputs and given the set of input prices. It is the product of allocative efficiency and technical efficiency.
Cost function	Maps the minimum cost of producing a given set of outputs for a given set of input prices.
Distance function	An index measure of technical inefficiency. It refers to either the factor by which all inputs can equiproportionately be scaled down while still producing the same output (input oriented) or the factor by which all outputs can be equiproportionately increased without increasing the quantity of inputs used.
Economies of density	When it is proportionately less costly to supply customers where there is greater density (eg, in terms of the number of connections in a given area).
Economies of scale	Increasing returns to scale—see definition of 'returns to scale'.
Economies of scope	When the combined cost of producing two products in given quantities is lower when they are produced jointly by a single firm than if the same products are produced separately by two different firms.
Gross capital stock	The accumulation of investments corrected for retirement. Assets are treated as new until they are retired. It is assumed that they retain their full productive capacity until they are removed from the stock.

Index number	Indicator of average percentage change in a set of quantities or prices, where one figure (called the base) is assigned an arbitrary value of 100, and other figures are adjusted in proportion to the base. Examples include the Consumer Price Index (CPI) and the S&P/ASX 200.
Panel data	A set of data which has both cross-sectional and time series dimensions. A panel is 'balanced' if all cross-sectional units are represented in all sample time periods. Otherwise it is 'unbalanced'.
Production function (or **production frontier**)	The maximum output attainable from each possible level of inputs. It reflects the current state of technology in the industry.
Productivity	The ratio of the output(s) a firm produces to the input(s) it uses.
Random effects model	A method of regression for use with panel data in which a firm-specific effect is estimated in addition to the other parameters of the model. This reflects unobserved heterogeneity between groups within the panel. Unlike the "fixed effects" model, where the firm-specific effect is estimated as a separate intercept for each group, in the random effects model they are assumed to be drawn from a normal random distribution.
Returns to scale	The rate by which output changes if all inputs are changed in the same proportion. With constant returns to scale a k-fold increase in inputs will lead to a k-fold increase in outputs. Under increasing returns to scale the change in output is more than k-fold.
Stochastic Frontier Analysis (SFA)	A method of econometric estimation of functions that represent a lower or upper bound to the observed data. Used for estimating functions that describe an optimum, such as cost, revenue, profit, production and distance functions. It involves decomposing the random error into two components, the "noise" (a symmetric normally distributed variable) and a technical inefficiency component (which is either non-negative or non-positive depending on the type of function being estimated).

Technical change	The shift in the production function (production frontier) over time due to advances in technology.
Technical efficiency	A technically efficient firm is one that operates on the frontier. A technically inefficient firm operates beneath the production frontier or above the minimum input frontier.
Total factor productivity	A measure of productivity that uses all outputs and all factors of production. Used interchangeably with the term 'multifactor productivity', but the latter more correctly applies to the ratio of several types of outputs to several types of inputs.

Sources: OECD, *Measuring Productivity: Measurement of Aggregate and Industry-Level Productivity Growth* (2001), Annex 1; Coelli, Rao, O'Donnel& Battese, *An Introduction to Efficiency and Productivity Analysis* (2nd edition, 2005) pp 2-5; Stone & Webster, *Investigation into evidence for economies of scale in the water and sewerage industry in England and Wales: Final Report* (2004), Annex 1.

Appendix B Submissions from Victorian water utilities

In October 2011 a draft research report on water industry productivity was circulated to the water businesses. The purpose of the consultation process was to provide the Victorian water utilities with the opportunity to comment in detail on the data and the findings in relation to productivity trends for their businesses. Submissions were received from Barwon Water, Central Highlands Water (CHW), Coliban Water, Gippsland Water, Goulburn Valley Water, South East Water (SEW), Victorian Water Industry Association Inc (VWIA), and Wannon Water. Although a wide range of comments were provided, there was very little advice provided in relation to the accuracy of the data on which this study is based. This appendix summarises the comments received.

Some utilities (e.g. CHW) highlighted the differences in results between this study and the Worthington study commissioned by the NWC. However, the submitters provided no analysis of their own to support a view about which study they considered more accurate.[29] Little or no comment was received in relation to the accuracy of the data used for their own utility.

[29] The Worthington study does not include capital inputs, and among the outputs it does not include the number of customers serviced (which measures the service of providing households with the capacity to use reticulated water) or the quantity of water supplied, which other studies such as Saal et al (2007) use as the only two water supply outputs. We consider capital to be an important and indeed major input to the provision of water supply services. Given the increasing capital requirements in the industry highlighted by several submitters, and analysis that excludes capital is likely to upwardly bias measured productivity. Finally, the Worthington study does not include sewerage collection and treatment services. This represents an important part of water utility activities and according to Saal & Parker (2006), it is not fully separable from water supply because of economies of scope between the activities.

There was some debate about the usefulness of productivity measurement. CHW suggested TFP 'measures scale effects only, or nothing of practical use', but South East Water (SEW) considered it 'a long accepted measurement of productivity', albeit reliant on the quality of data. SEW queried the use of productivity in price review processes, noting that many components of the inputs and outputs are not controllable by water businesses, and many costs do not lead to growth in customers or demand. On the other hand, CHW considered that allocative efficiency was also important and should not be overlooked.

Productivity measurement is most useful where the scale of inputs can be adjusted over time to the minimum level needed to supply the quantity and quality of outputs demanded.[30] These measures would not normally be used in isolation. Commonly used cost efficiency measures combine both productivity and allocative efficiency. While productivity is not the only dimension of performance, it is an important performance measure, a view widely shared by governments and leading policy bodies in Australia.

Several submissions highlighted the underlying decline in water use per customer due to influences such as improved appliance efficiency or changes in dwelling structures or growth in the penetration of rainwater tanks. Although water supplied is only one output, these trends could affect productivity over time if the quantity of some inputs cannot be adjusted accordingly. However, the study has found that the index of outputs has been growing over the sample period. When output is growing, it is much easier to tailor inputs to the minimum required level, even when some are fixed.

A range of other views or observations provided in submissions are summarised and commented upon in Table B.1.

[30] See: Worthington, p.52

Table B.1 **Comments received and response**

Comment	Response
CHW claimed that the adjustment for the effect of TWRs (25 per cent at stage 4) was insufficient because it had 'experienced a 40 per cent water demand reduction under maximum water restrictions'.	Partially disagree: This analysis only seeks to make adjustments for the effects of temporary water restrictions (TWRs), not long-term shifts in demand patterns. CHW did not differentiate the sources of reduced demand that make up its estimate of 40 per cent, which is not necessarily a measure of the impact of TWRs.

Comment	Response
Some argued that normalisation for the effects of temporary water restrictions should include effects on the non-residential sector.	Agree: The model has been revised to include normalisation for the effects of temporary water restrictions on non-residential demand. The effect is assumed to be 13.5 per cent at stage 4. This assumption draws from unpublished work by the Department of Sustainability and Environment which relates to Victoria only. It is consistent with the 25 per cent assumed for the residential market. However, it is recognised that the actual effects of TWRs will vary with climate and other factors.
Several submitters (e.g. SEW, Barwon) emphasised the bunching of capital expenditure in recent years.	Partially agree: These observations do not account for comparisons of efficiency between utilities. However, they may account for a substantial part of the differences in the results of this study compared to the Worthington study, which does not include capital inputs.

Comment	Response
Several (e.g. GVW, SEW) highlighted the investment required to meet technical regulation standards. Goulburn Valley Water (GVW) stated that it had invested around $300m for upgraded water filtration plants and expanded capacity in wastewater treatment and water recycling. Coliban referred to this as 'hidden productivity'.	Partially agree: Increases in the demand of technical regulation may be reflected in part as negative technological change, although some of the benefits would be reflected through the quality-adjustment of water supplied and wastewater treated. Where investments are undertaken primarily for risk mitigation purposes and do not affect drinking water quality outcomes, then this may show up in this analysis as reduced productivity.
Submissions by GVW, Coliban and VWIA noted the effect of extending sewerage to smaller towns at high cost. Coliban & VWIA suggested this was a government-imposed requirement.	Agree: While there is no *a priori* reason why extending sewerage should reduce productivity, if these projects were sub-economic they would detract from productivity.

Comment	Response
Initiatives to use recycled water, improve water efficiency and stormwater harvesting have been another impediment to productivity improvement. Wannon Water suggested: "… adding water conservation, recycled water or stormwater harvesting initiatives to a smaller non metropolitan business' cost base is likely to have a greater proportional impact on their costs because of their smaller scale, relative to the impact that these programs have on a larger business."	Agree: The productivity study measures the technical efficiency of the water supply and sewerage collection and treatment businesses. Sub-economic projects which increase non-capital inputs without corresponding increases in outputs will be detrimental to productivity. To the extent that such projects are carried out more intensively by smaller businesses, this would affect their productivity relative to larger water utilities.
Wannon Water noted that comparative productivity levels may be influenced by step-changes associated with amalgamation in the past, prior to the sample period.	Disagree: Wannon Water also noted that its own structural changes occurred prior to the sample period.
The VWIA noted that fees such as the environmental contribution vary between utilities.	Agree: In the revised analysis, the environmental contributions for the Victorian businesses have been excluded from non-capital costs before calculating the index of non-capital inputs.

Comment	Response
Wannon argued that productivity trends largely reflect whether customer growth is infill development or on the fringe where density of customer connections may be lower, and whether in areas more difficult to service. Thus productivity outcomes will, to some degree, be exogenous to the water utility.	Insufficient information: While it is possible that productivity trends could be influenced by these factors, the extent to which this has influenced the observed productivity trends is an empirical question and would need investigation based on more detailed data. The NWC data does not provide a breakdown between infill and fringe growth. However, water utilities are usually referral authorities for residential development plans and should encourage development in areas that maximise their productivity.
Coliban noted there was past overestimation of the length of water mains due to poor asset management systems, and suggested that other water utilities may have had similar problems as the outcome of earlier amalgamations.	Agree: If so, this would suggest the true increase in capital inputs was underestimated, and productivity growth overestimated. Or decline underestimated.

Comment	Response
Some businesses indicated that the study failed to take water security of supply into account as an output. They had invested significant amounts during the drought to improve security of supply.	Partially agree: It is true that security of supply is not measured in this study. But this is not sufficient to suggest that measured productivity trends are biased. For example, if there has been under-provision for security of supply in the past this may suggest the underlying productivity decline has had a longer gestation period, only fully revealed as supply constraints materialised.[31]
Wannon Water maintained that the study failed to correct for differences in the density of locations.	Disagree: The analysis found that the density of urban areas is correlated with the size of the market. Smaller utilities service the remoter areas that are least dense, while the largest utilities service the capital cities which are most dense. For this reason, in this sample, it was considered infeasible to separately distinguish between scale and density effects. We consider that density effects should be captured within the measured scale effects.

[31] E.g. Moran suggested there was under-provision of storage facilities after 1985: Moran, Alan (2008) *Water Supply Options for Melbourne: An examination of costs and availabilities of new water supply sources for Melbourne and other areas of Victoria*, Institute of Public Affairs Occasional Paper.

Appendix C Detailed charts Victorian water utilities

This appendix presents detailed charts showing productivity trends for the Victorian water utilities. The results using all three methods are shown, noting however, that the stochastic frontier model is the preferred measure.

Barwon Water

Figure C.1 shows the productivity of Barwon Water. The econometric methods give similar results and suggest that between 1998 and 2010, productivity decreased by approximately 8 per cent. Figure C.2 shows that since 2000, there has been a slight decline in capital inputs per customer, but these were offset by an increasing trend in non-capital inputs per customer. Prior to that, the trend is affected by a large increase in water mains from 2558 km in 1998 to 3147 in 2000.

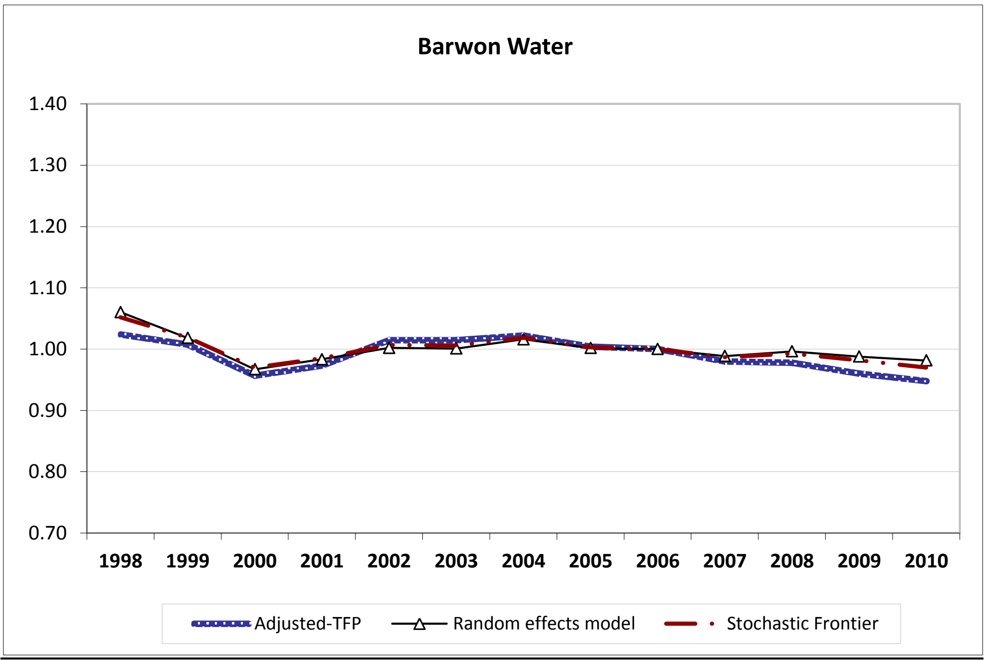
City West Water

Figure C.3 depicts City West Water's consistent productivity growth over the sample period. Between 1998 and 2010 the productivity improvement was more than 20 per cent in total. Capital and non-capital inputs per customer are shown in Figure C.4. Although capital inputs per customer have declined steadily, a major source of productivity improvement was reduction in non-capital inputs per customer.

South East Water

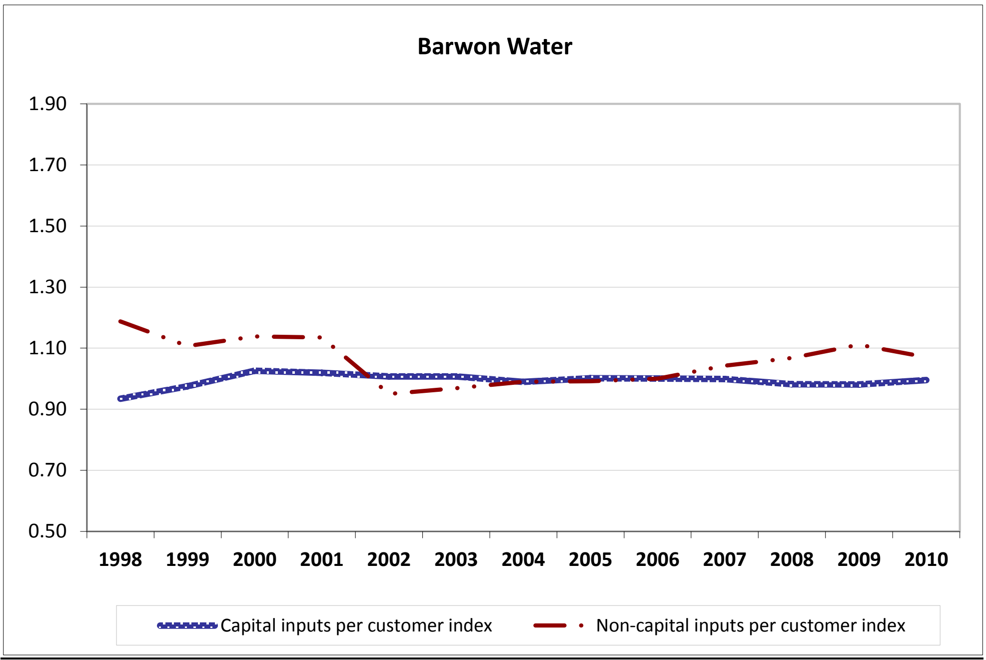
Figure C.5 shows that South East Water has had relatively consistent, but slow, productivity growth. Over the period 1998 to 2010 the two econometric measures suggest that productivity increased by more than 10 per cent in total. The trends in inputs per customer depicted in Figure C.6 show reductions in non-capital inputs per customer in the early part of the sample period. But there has been little gain since then. Productivity improvements have also reflected gains in asset utilisation.

Figure C.1 **Productivity trend – Barwon Water** (2006 = 1.00)



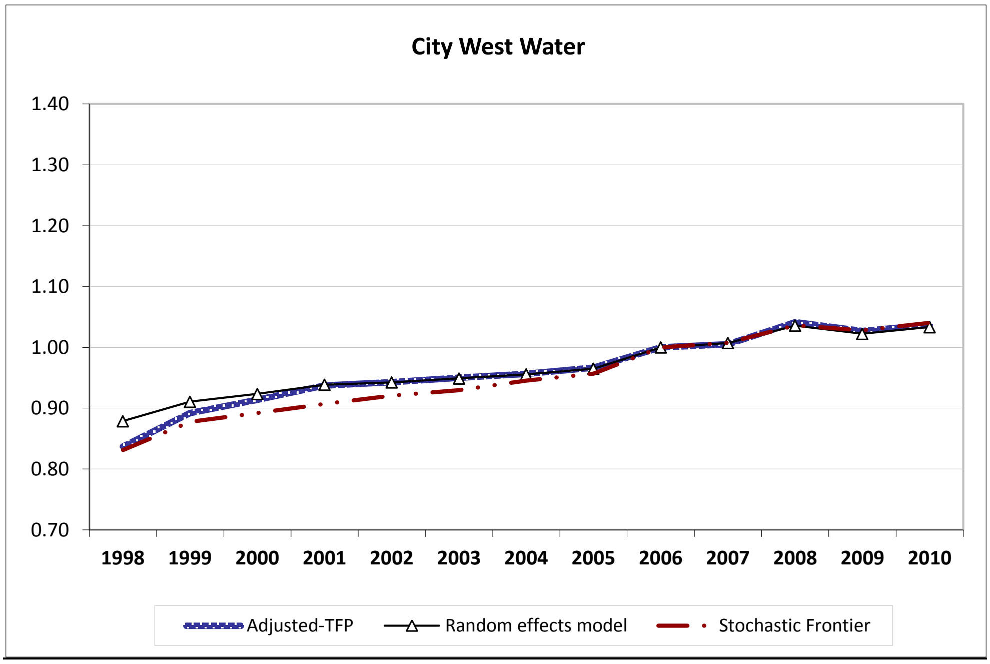
Source: ESC.

Figure C.2 **Inputs per customer – Barwon Water** (2006 = 1.00)



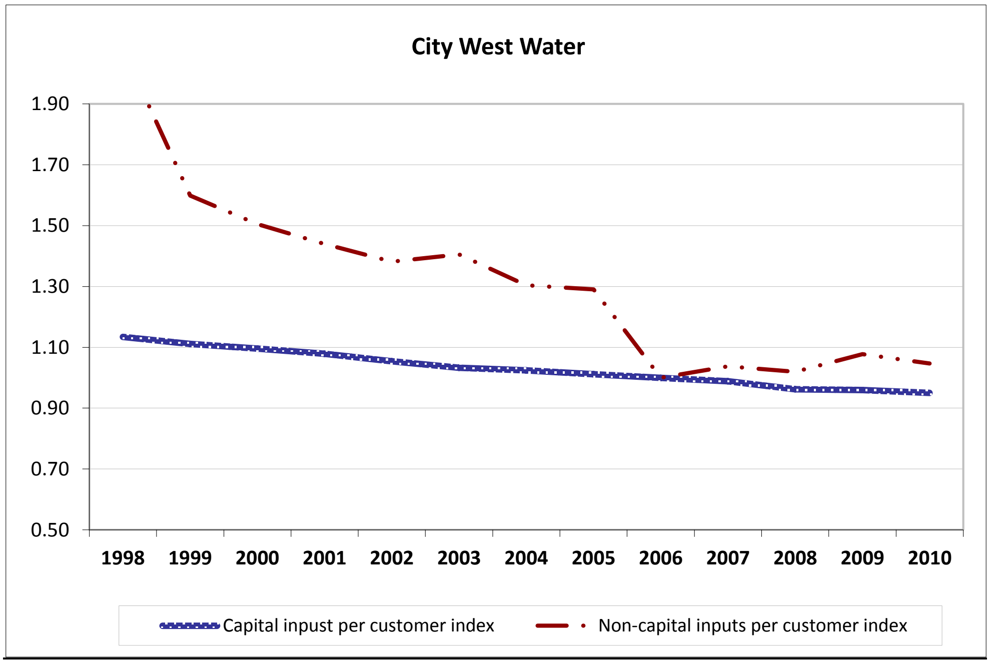
Source: ESC.

Figure C.3 **Productivity trend – City West Water** (2006 = 1.00)



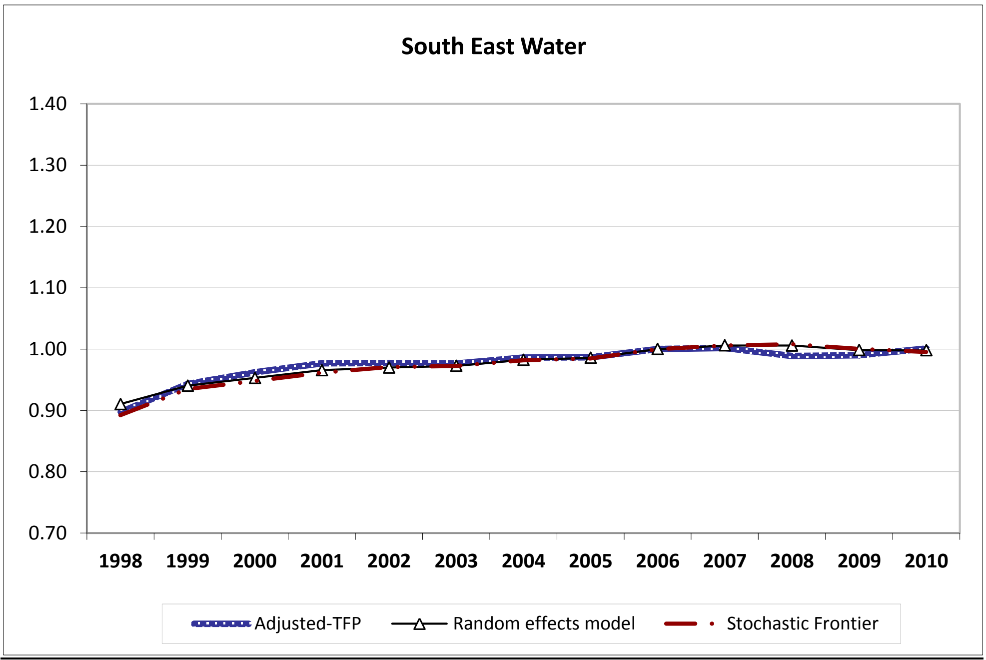
Source: ESC.

Figure C.4 **Inputs per customer – City West Water** (2006 = 1.00)



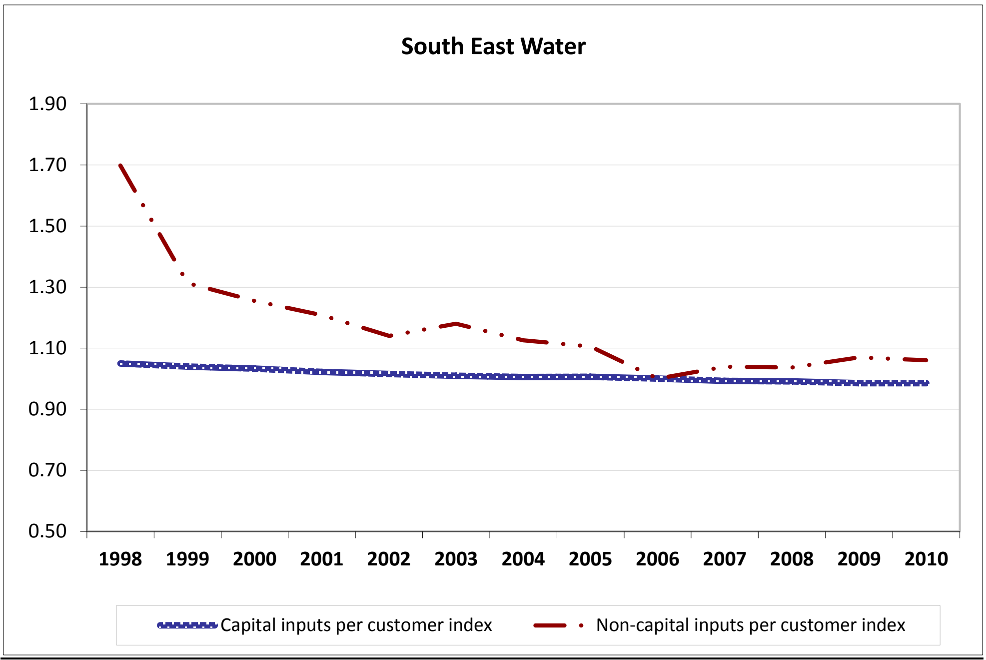
Source: ESC.

Figure C.5 **Productivity trend – South East Water** (2006 = 1.00)



Source: ESC.

Figure C.6 **Inputs per customer – South East Water** (2006 = 1.00)



Source: ESC.

Yarra Valley Water

The productivity performance of Yarra Valley Water was similar to that of South East Water, with slightly slower productivity growth (see Figure C.7). While there were some improvements in the early part of the sample period, there were slight deterioration since 2006. The overall productivity increase between 1998 and 2010 was approximately 9 per cent. Inputs per customer are shown in Figure C.8. There was a minor decline in capital inputs per customer in the early part of the sample period. Non-capital inputs decreased before 2006, but have slightly increased since then.

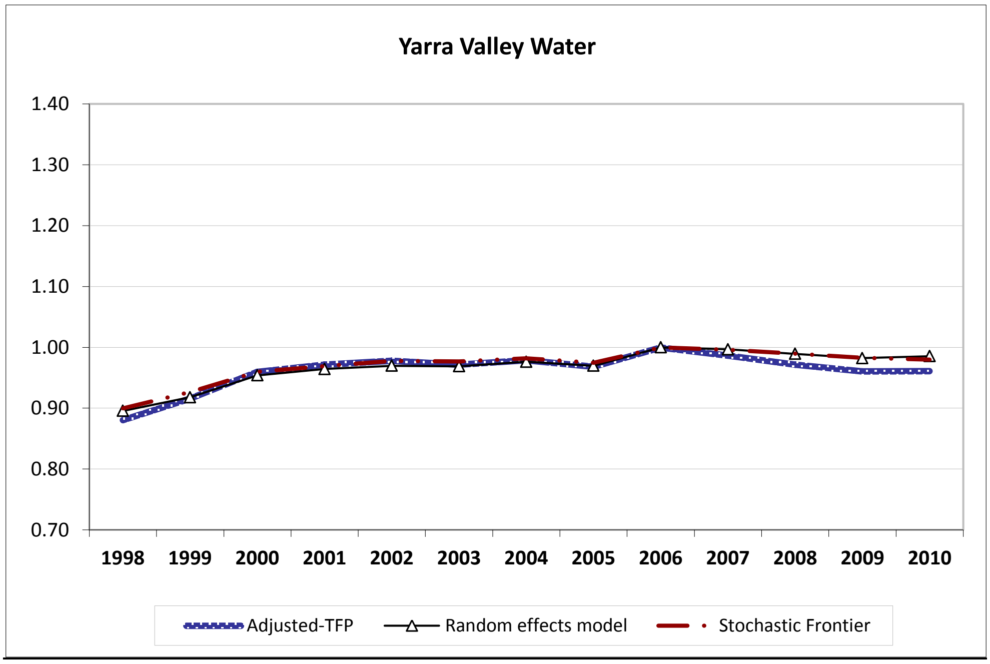
Gippsland Water

Gippsland Water's productivity has shown an overall decline between 1999 and 2010 of approximately 18 per cent. As shown in Figure C.9, the SFA model suggests this was a relatively steady declining trend over the whole period. The movement in inputs per customer for Gippsland Water is presented in Figure C.10. The data for non-capital inputs in 1999 appears anomalous, and this has contributed to the observed fall in productivity in the first few years of the sample. The econometric models appear to have been less influenced by this anomaly. Since 2001, capital and non-capital inputs per customer have been relatively constant, although there is a slight increasing trend in capital inputs per customer (in contrast to the underlying slow decline seen for most other utilities).

Central Highlands Water

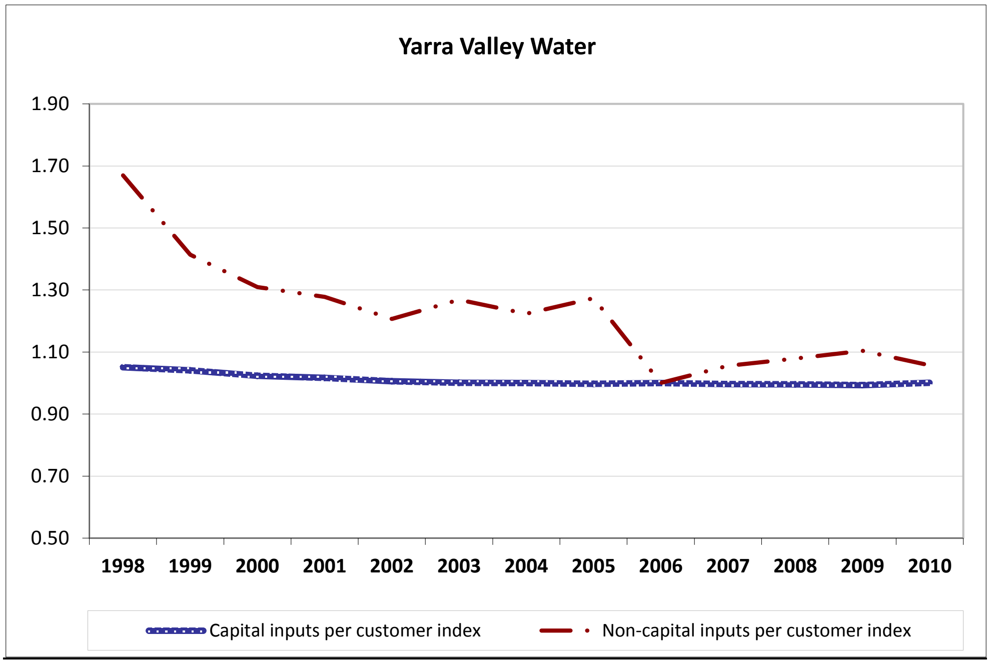
As shown in Figure C.11, Central Highlands Water's productivity decreased by almost 25 per cent overall between 1998 and 2010. The econometric models show that this decline was relatively steady through most of the period. The indexes for inputs per customer in Figure C.12 indicate that non-capital inputs per customer doubled between 2002 and 2010.

Figure C.7 **Productivity trend – Yarra Valley Water** (2006 = 1.00)



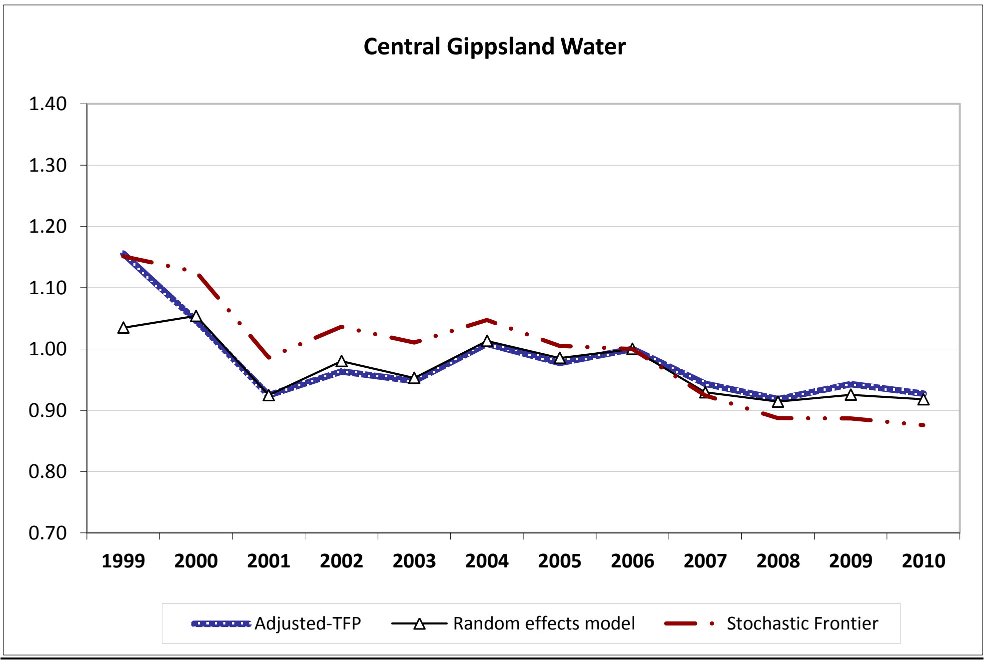
Source: ESC.

Figure C.8 **Inputs per customer – Yarra Valley Water** (2006 = 1.00)



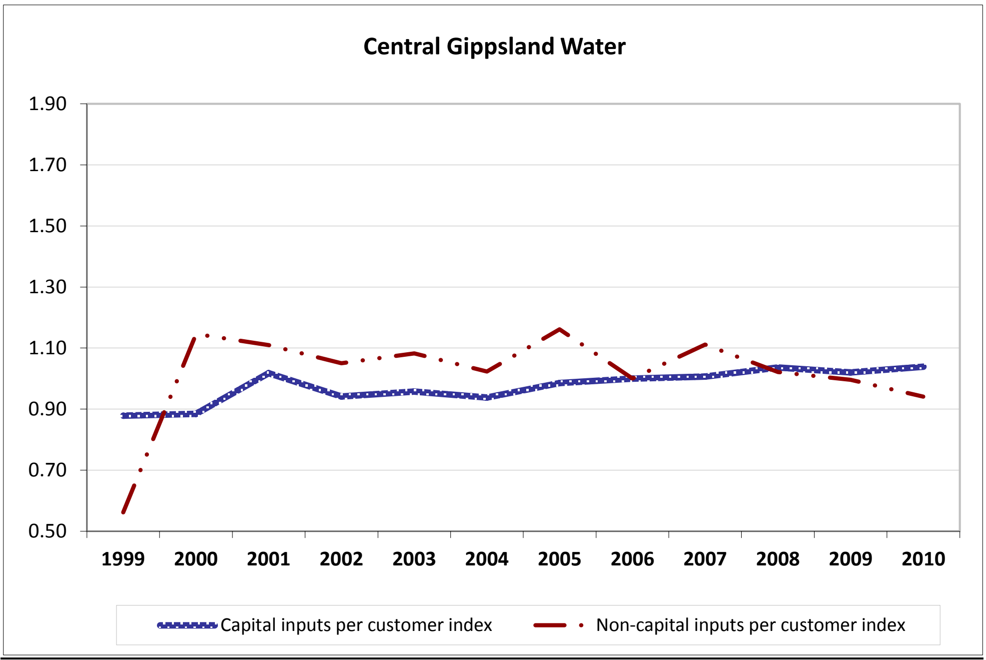
Source: ESC.

Figure C.9 **Productivity trend – Gippsland Water** (2006 = 1.00)



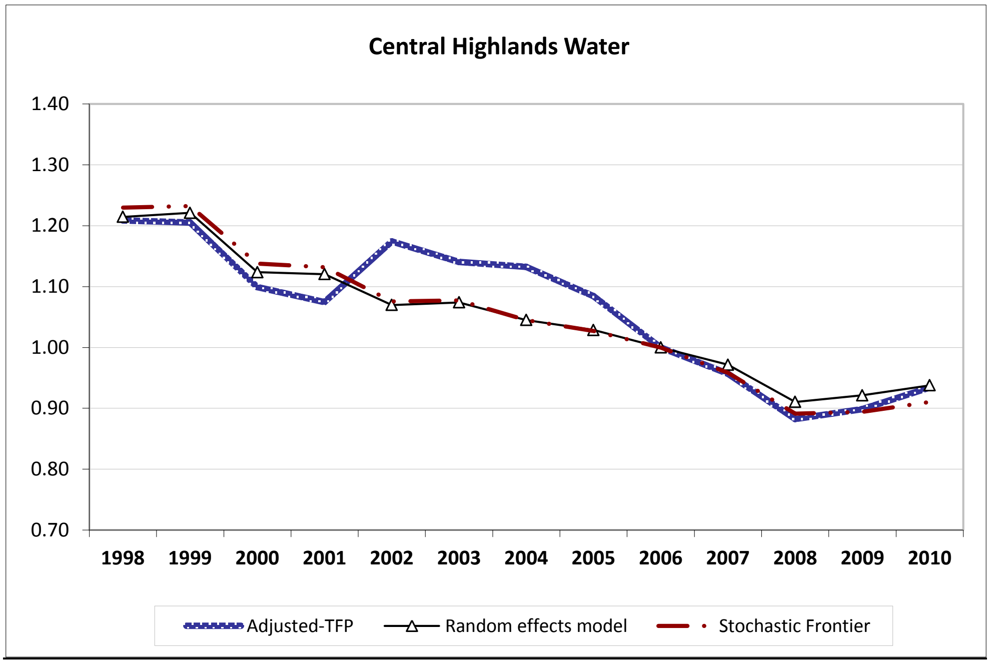
Source: ESC.

Figure C.10 **Inputs per customer – Gippsland Water** (2006 = 1.00)



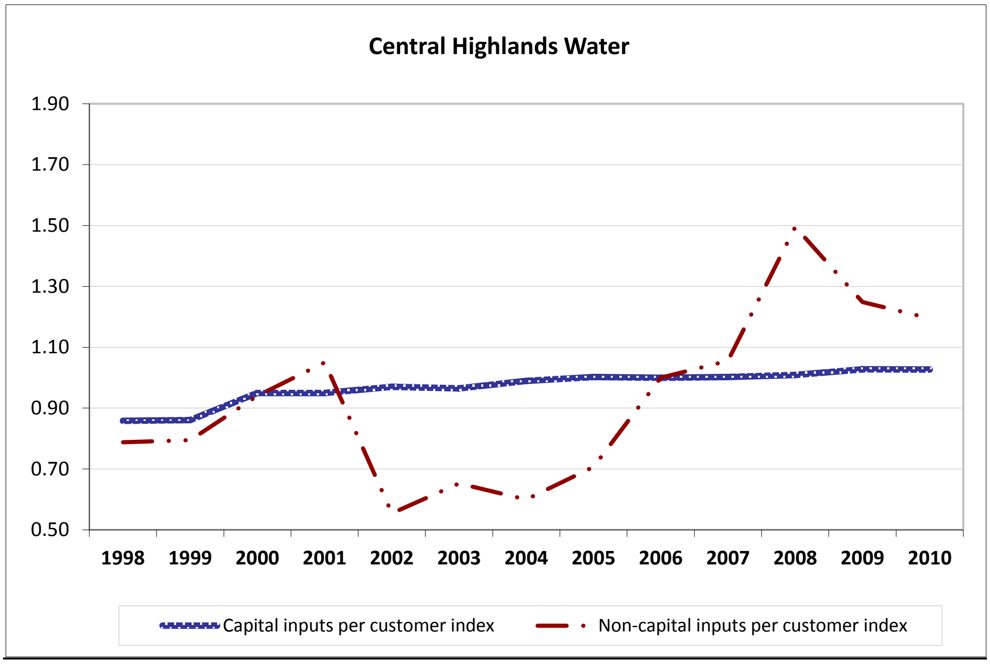
Source: ESC.

Figure C.11 **Productivity trend – Central Highlands Water** (2006 = 1.00)



Source: ESC.

Figure C.12 **Inputs per customer – Central Highlands Water** (2006 = 1.00)



Source: ESC.

Coliban Water

Coliban Water is another large regional Victorian water utility that has experienced a substantial and relatively steady decline in productivity over the whole sample period. As depicted in Figure C.13, productivity decreased by more than 20 per cent between 1998 and 2010. As shown in Figure C.14, there was a significant and steady increase in both capital and non-capital inputs per customer between 1998 and 2010. An important driver of increased capital inputs per customer has been the increase in mains from 2700 km in 1998 to 3900 in 2010—an increase of 44 per cent. Over the same period its customers increased by only 18 per cent. Although there have been a small increase in the proportion of customers with sewerage, this doesn't explain the observed increase in mains per customer.

Goulburn Valley Water

Goulburn Valley Water (GVW) is another large regional Victorian water utility that has seen a substantial decline in productivity between 1998 and 2010. This is shown in Figure C.15. Its productivity only started to decline around 2002, but decreased by around 19 per cent since that time. Indexes of capital and non-capital inputs per customer are shown in Figure C.16. This graph shows that there has been an ongoing and relatively steady increase in both capital and non-capital inputs per customer between 1998 and 2010.

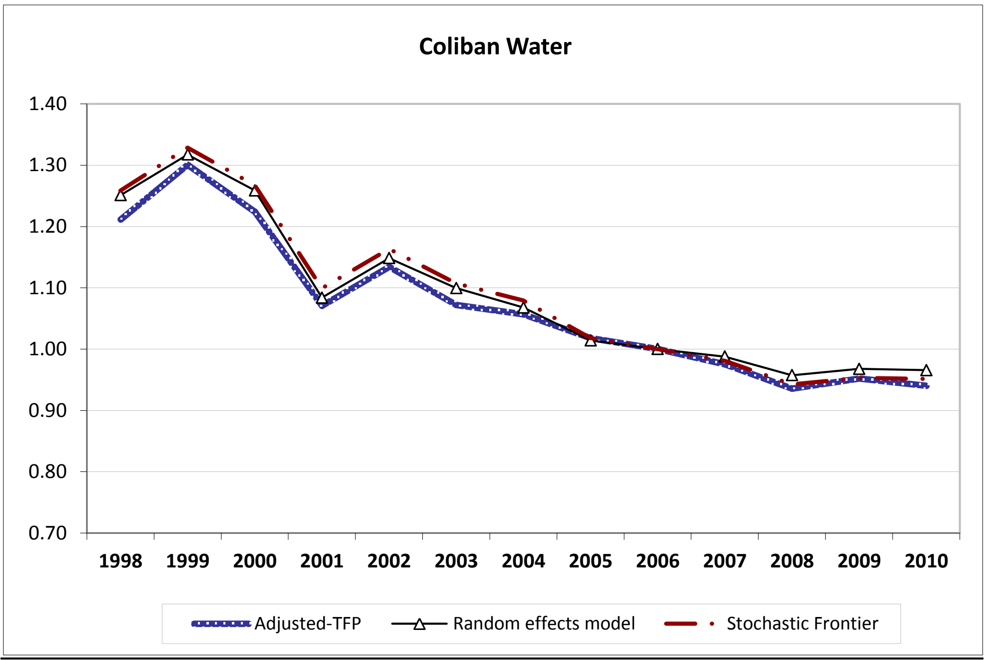
East Gippsland Water

East Gippsland Water is one of the smaller utilities for which there is only five years of data in the sample. Figure C.17 shows productivity was relatively flat over this period. Both inputs, on a per customer basis, were relatively constant (Figure C.18).

Grampians-Wimmera-Mallee (GWM) Water

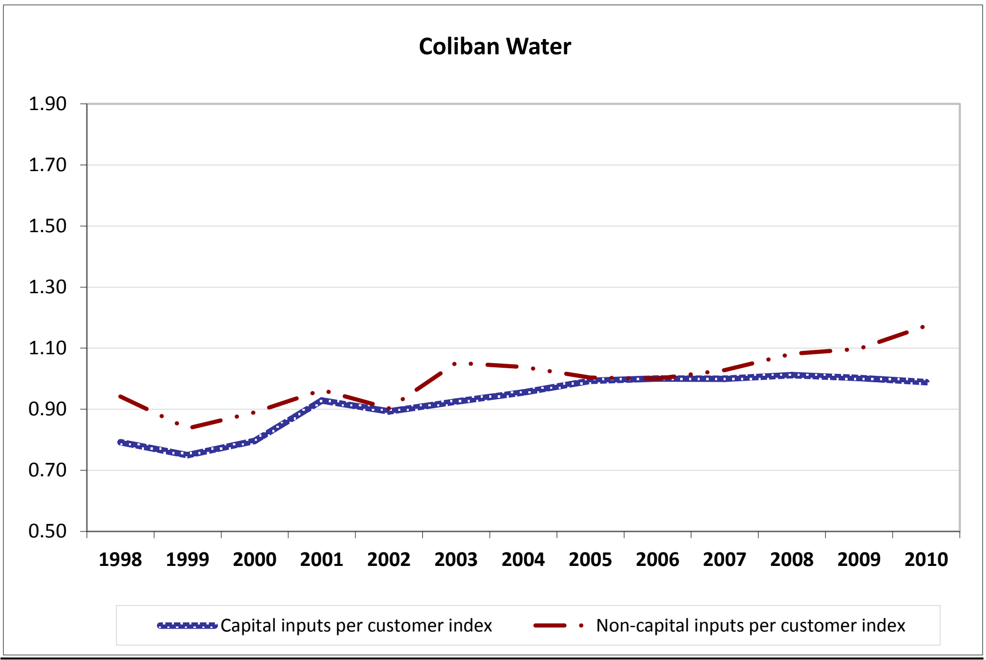
As depicted in Figure C.19, the econometric models indicate that GWM Water enjoyed an increase in productivity of approximately 7 per cent between 2006 and 2010. The improvement in productivity has been associated, in part, with reduced capital inputs per customer, as shown in Figure C.20. However, this is because the NWC data indicates that GWM's mains reduced from 1872 km in 2006 to 1675 in 2010, while its customers increased slightly over the same period. There is also a large unexplained increase in non-capital inputs per customer in 2010.

Figure C.13 **Productivity trend – Coliban Water** (2006 = 1.00)



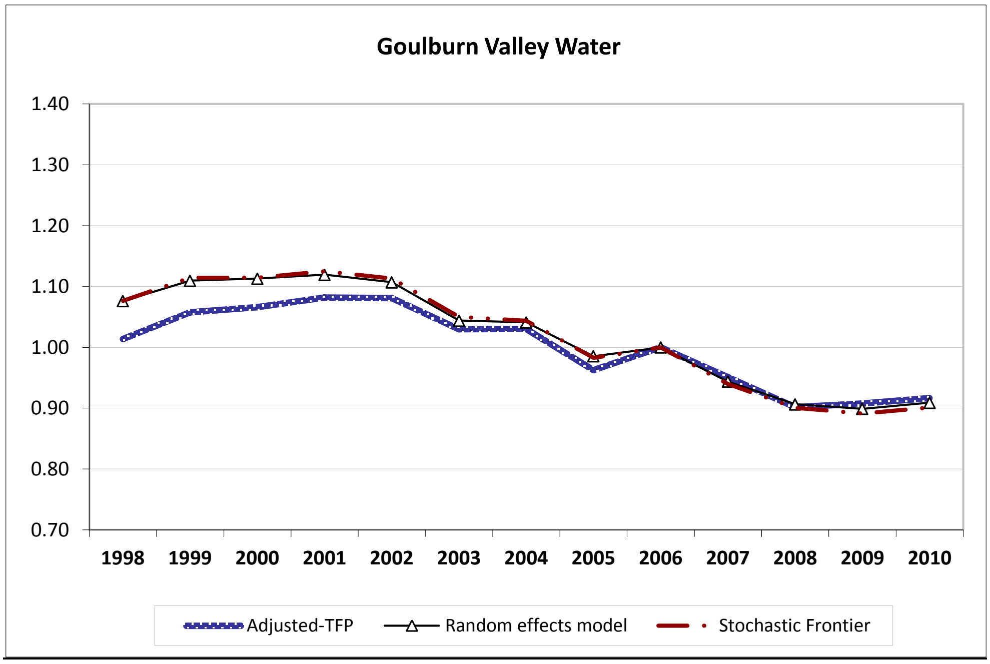
Source: ESC.

Figure C.14 **Inputs per customer – Coliban Water** (2006 = 1.00)



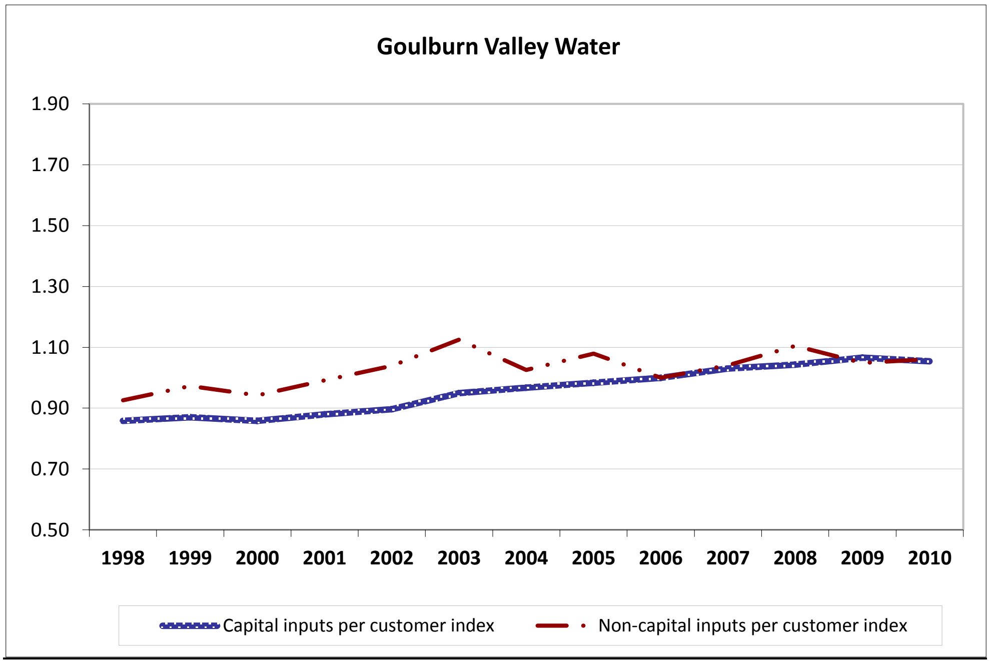
Source: ESC.

Figure C.15 **Productivity trend – Goulburn Valley Water** (2006 = 1.00)



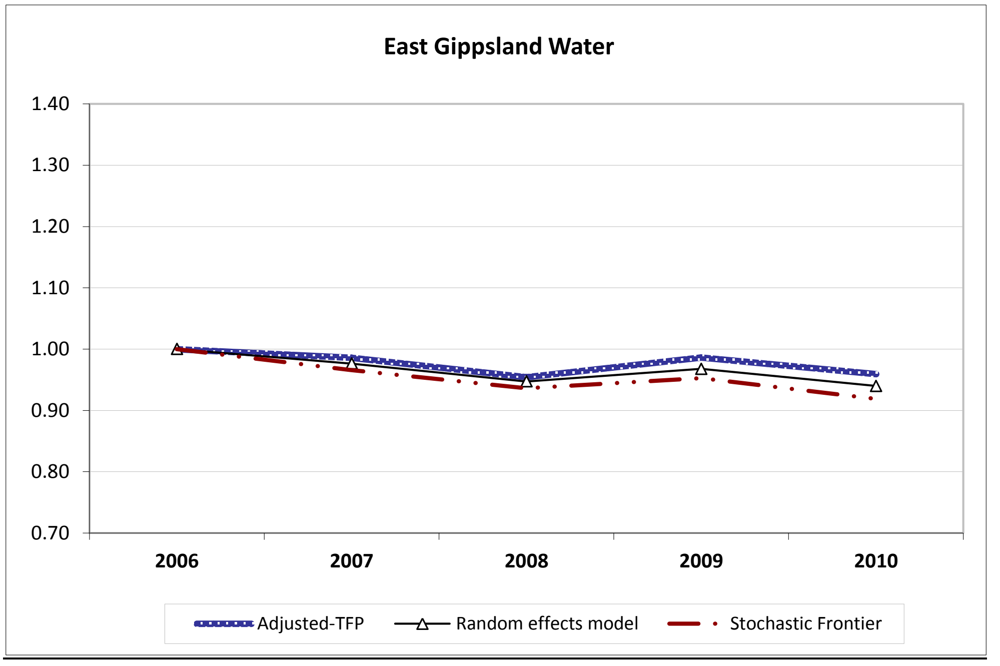
Source: ESC.

Figure C.16 **Inputs per customer – Goulburn Valley Water** (2006 = 1.00)



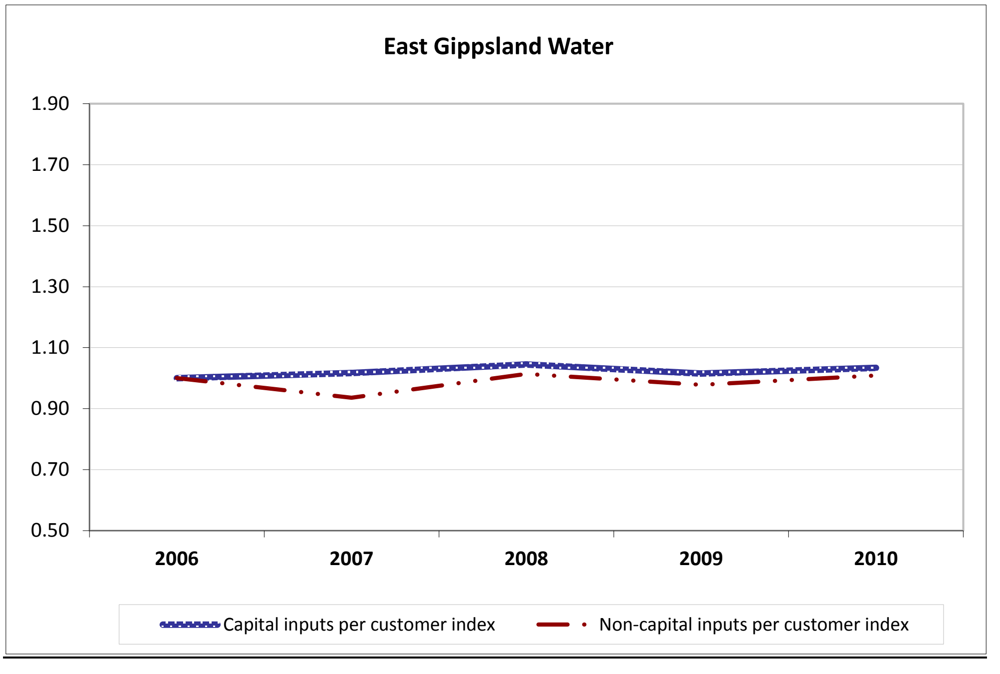
Source: ESC.

Figure C.17 **Productivity trend – East Gippsland Water** (2006 = 1.00)



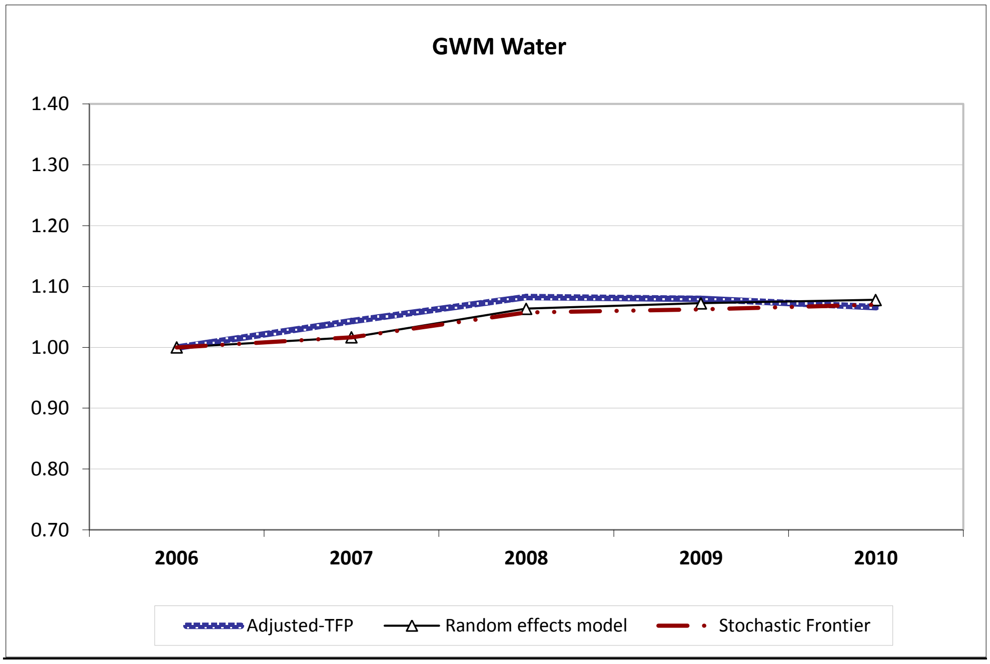
Source: ESC.

Figure C.18 **Inputs per customer – East Gippsland Water** (2006 = 1.00)



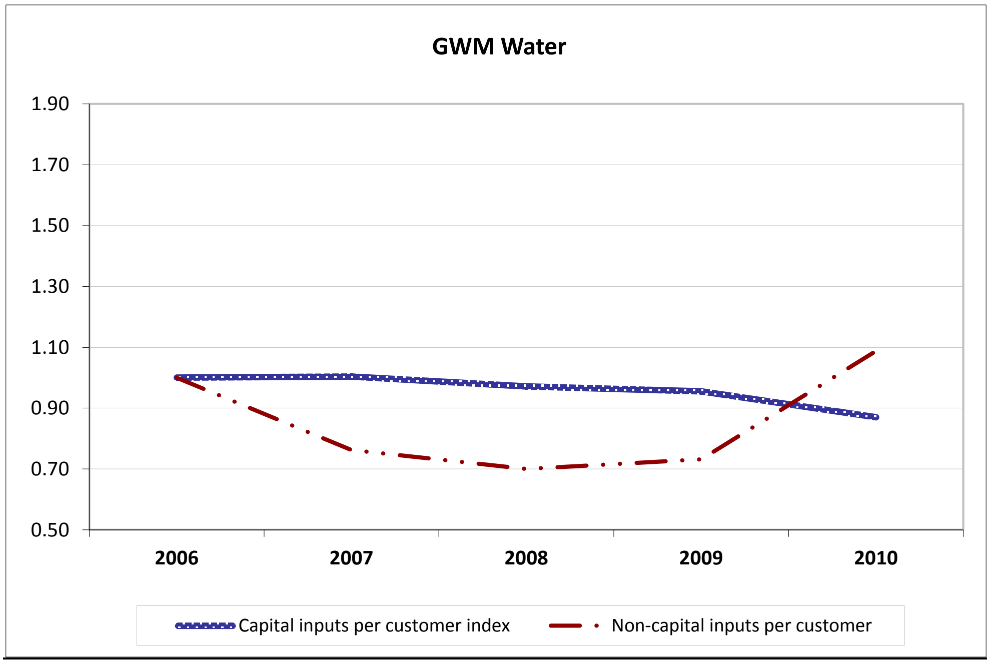
Source: ESC.

Figure C.19 **Productivity trend – GWM Water** (2006 = 1.00)



Source: ESC.

Figure C.20 **Inputs per customer – GWM Water** (2006 = 1.00)



Source: ESC.

Lower Murray Water

Lower Murray Water's productivity is depicted in Figure C.21. Over the period 2006 to 2010 there was deterioration in productivity of less than 2 per cent in total. As Figure C.22 shows, although there were reductions in non-capital inputs per customer offset by increased capital inputs per customer.

North East Water

The productivity trend of North East Water was similar to that for Lower Murray Water, with the econometric models indicating that productivity declined of about 1 per cent between 2006 and 2010 (see Figure C.23). Once again, although there appears to have been a reduction in non-capital inputs per customer, this has been offset by increased capital inputs per customer (see Figure C.24).

Wannon Water

As depicted in Figure C.25, the econometric models indicate that Wannon Water's productivity decreased between 2006 and 2010 by over 3 per cent. Figure C.26 suggests that the index of Wannon Water's non-capital inputs per customer increased significantly between 2006 and 2010.

Western Water

Figure C.27 shows that the productivity of Western Water decreased by approximately 5 per cent between 2005 and 2010. Figure C.28 shows there were increased non-capital inputs per customer over this period.

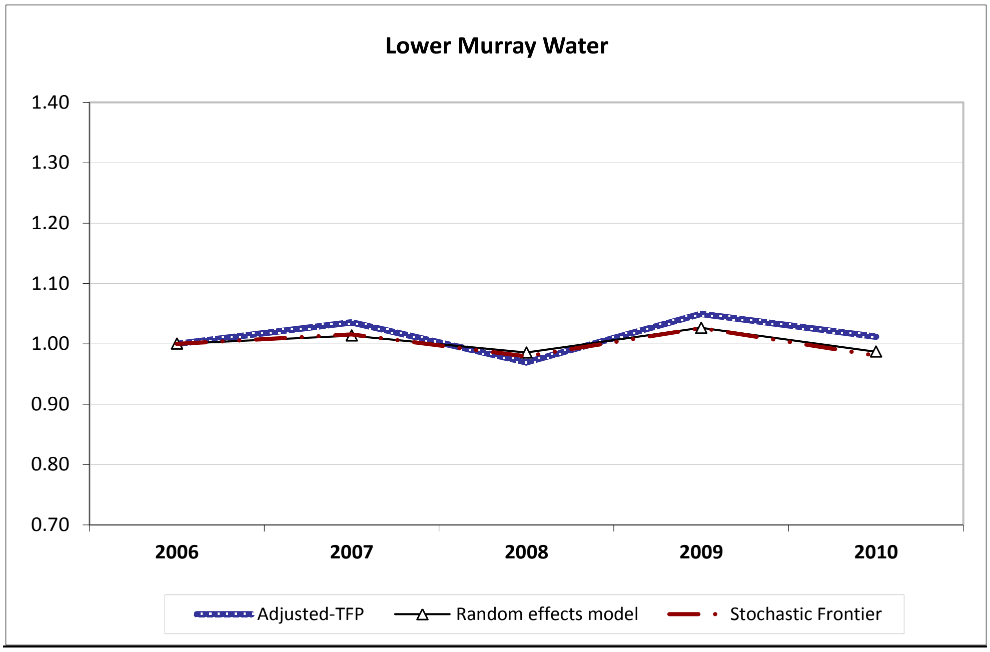
South Gippsland Water

Figure C.29 shows productivity trend for South Gippsland Water, indicating a productivity decline of approximately 9 per cent from 2006 to 2010. The inputs per customer depicted in Figure C.30 indicate that there has been a large increase in non-capital inputs per customer. This increase was more than 30 per cent in total between 2006 and 2010.

Westernport Water

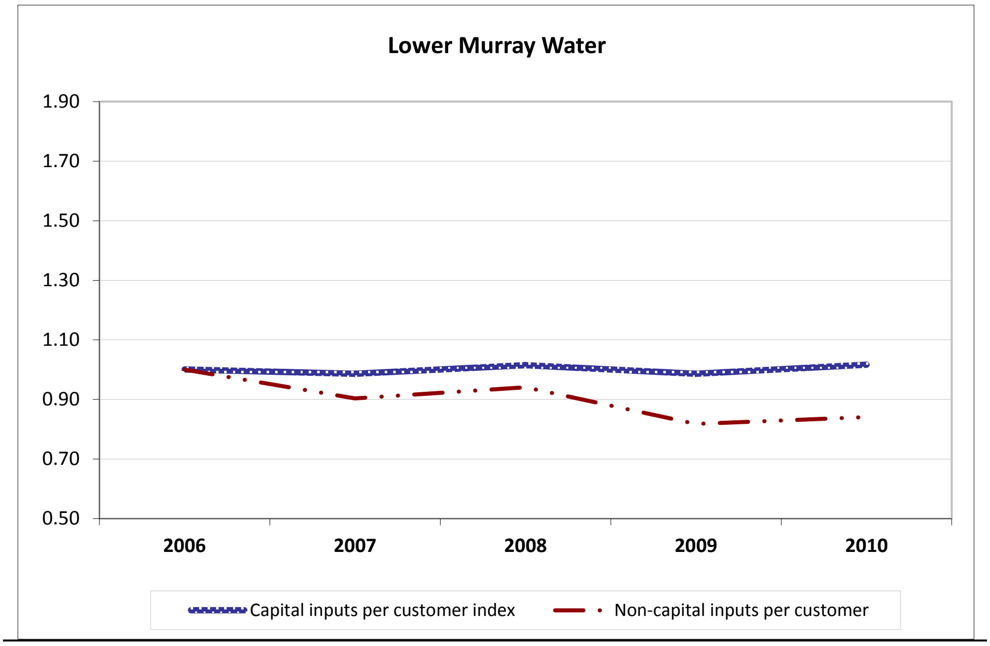
The different methods of measuring productivity showed somewhat different productivity trends for Westernport Water, as shown in Figure C.31. The econometric models suggest that productivity increased by approximately 5 per cent between 2006 and 2010. Figure C.32 indicates there has been a steady decline in capital inputs per customer, and a more recent decrease in non-capital inputs per customer.

Figure C.21 **Productivity trend – Lower Murray Water** (2006 = 1.00)



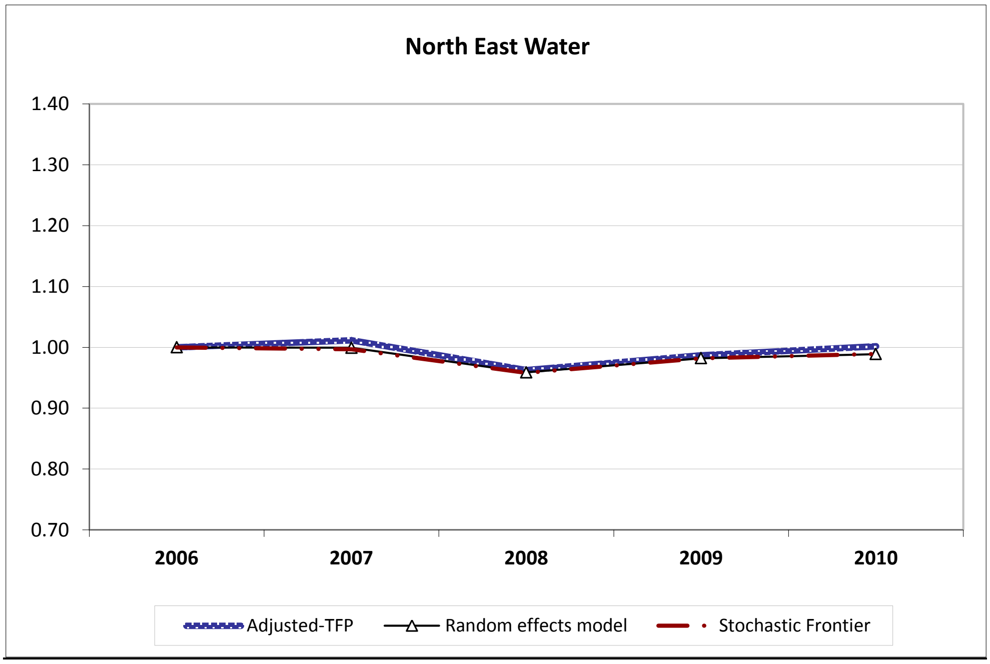
Source: ESC.

Figure C.22 Inputs per customer – Lower Murray Water (2006 = 1.00)



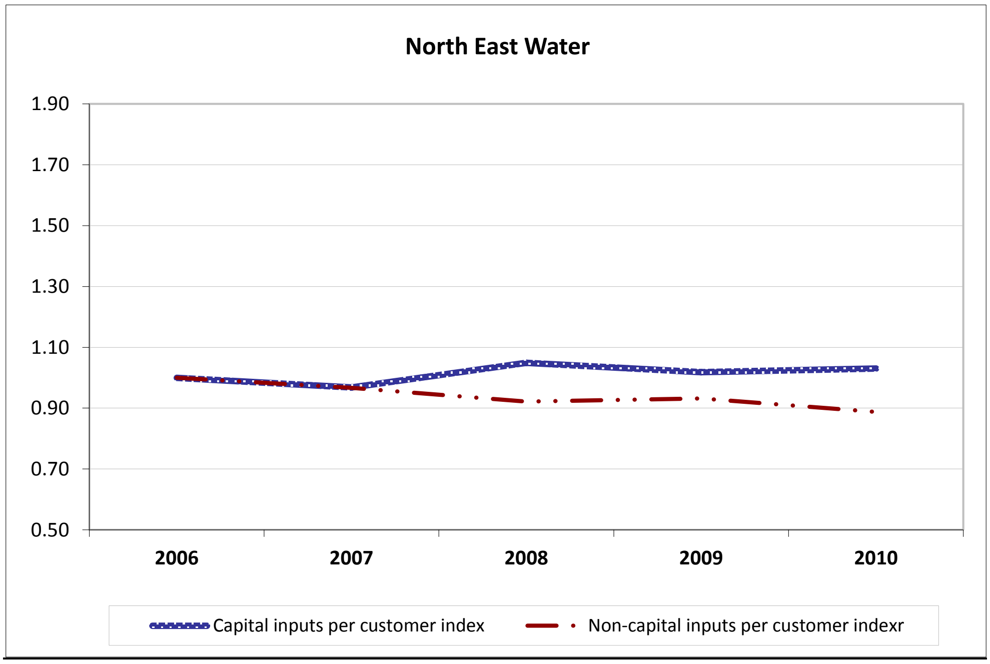
Source: ESC.

Figure C.23 **Productivity trend – North East Water** (2006 = 1.00)



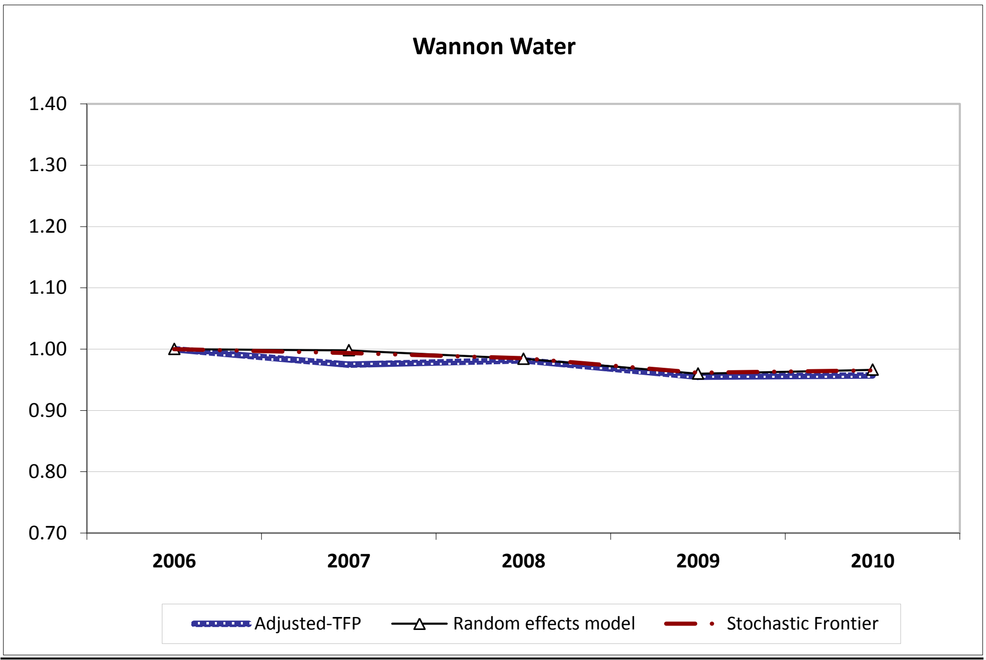
Source: ESC.

Figure C.24 **Inputs per customer – North East Water** (2006 = 1.00)



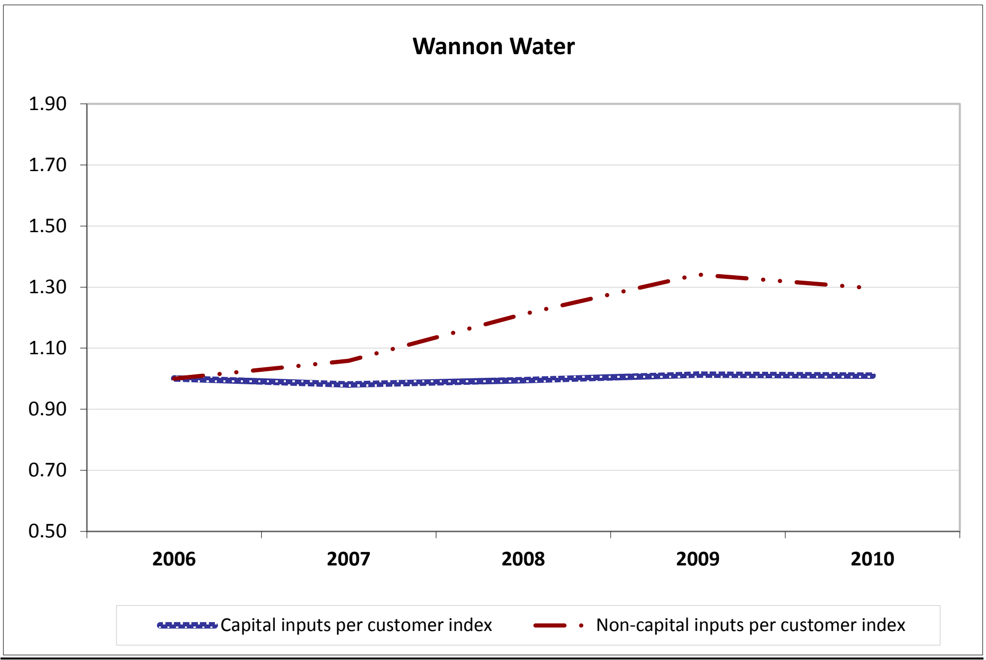
Source: ESC.

Figure C.25 **Productivity trend – Wannon Water** (2006 = 1.00)



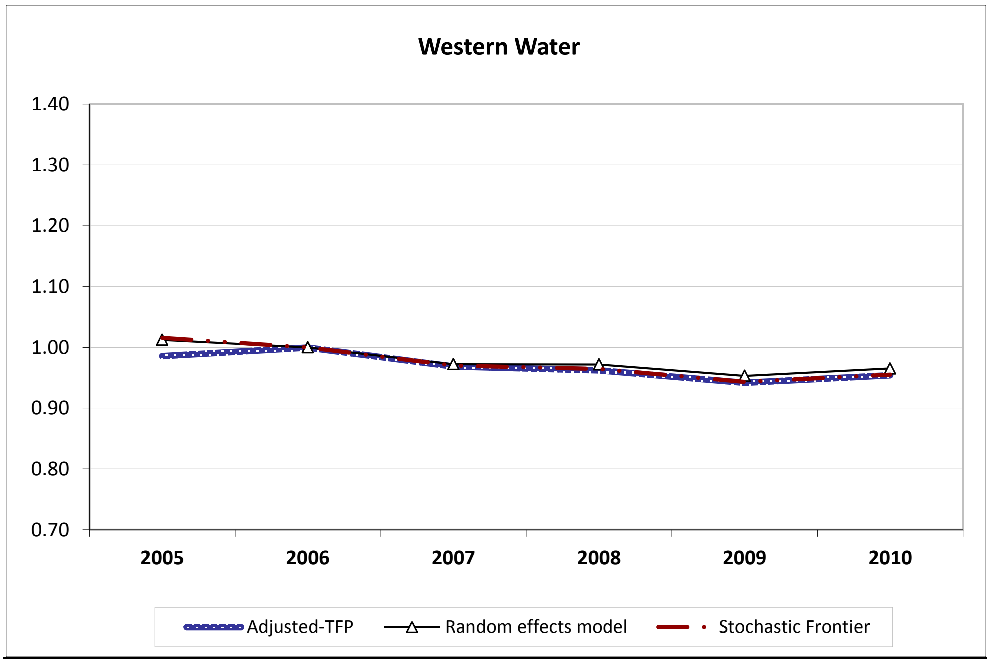
Source: ESC.

Figure C.26 **Inputs per customer – Wannon Water** (2006 = 1.00)



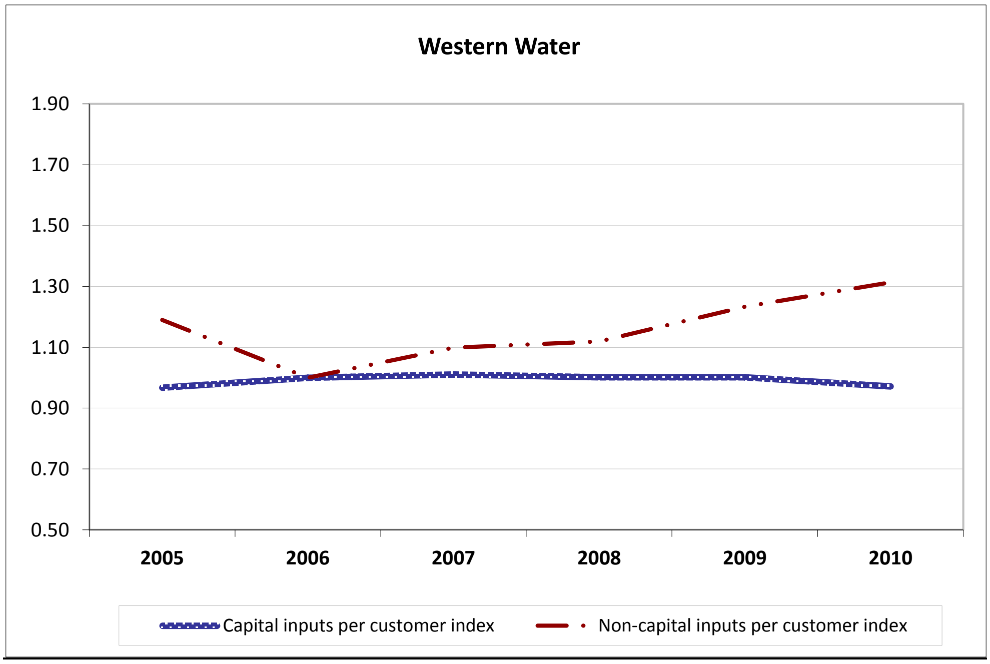
Source: ESC.

Figure C.27 **Productivity trend – Western Water** (2006 = 1.00)



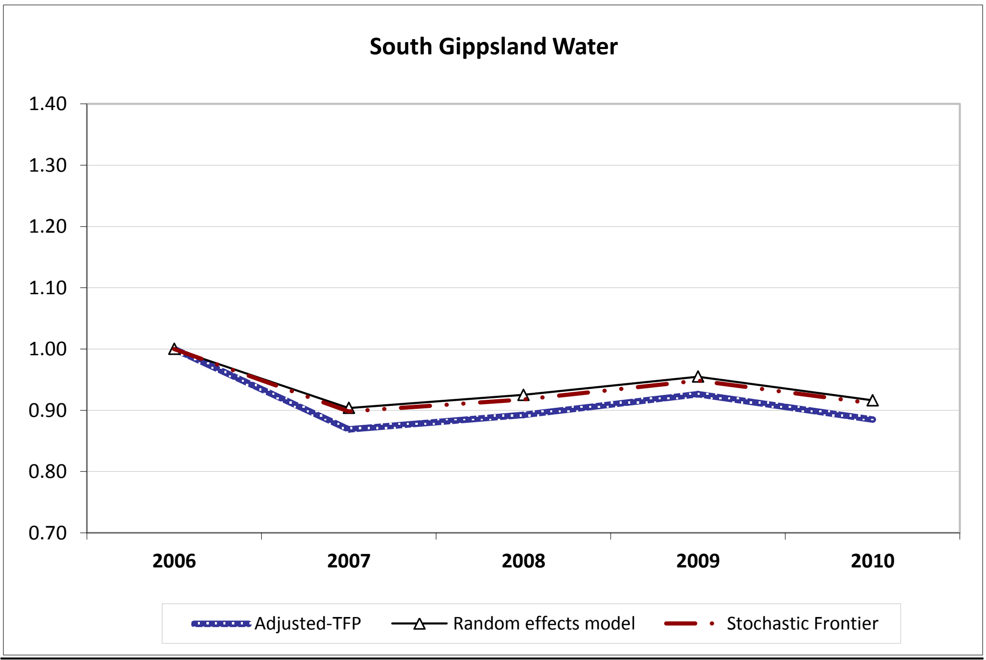
Source: ESC.

Figure C.28 **Inputs per customer – Western Water** (2006 = 1.00)



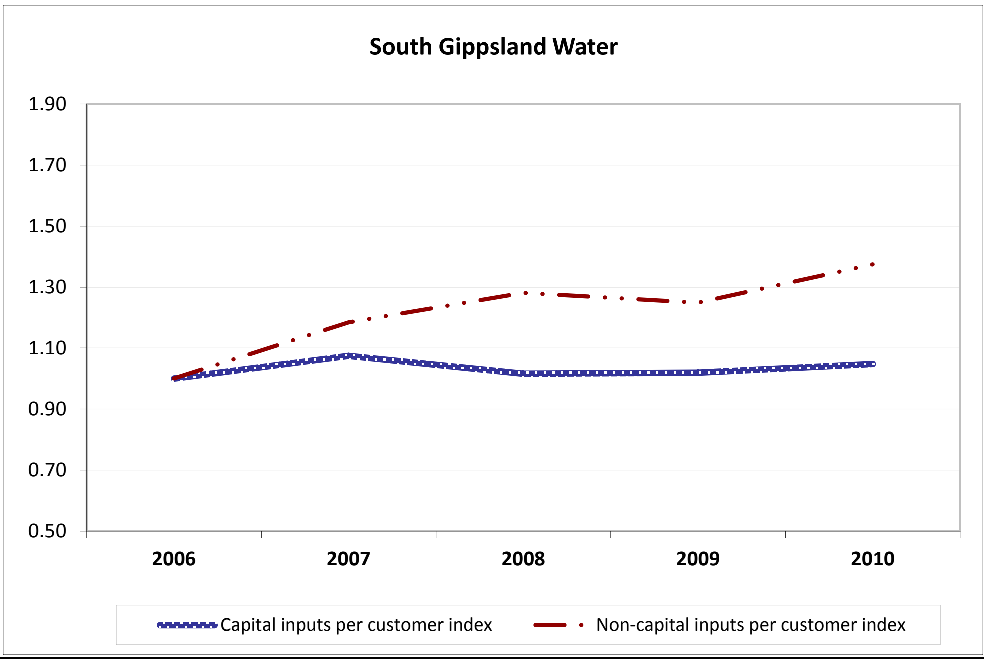
Source: ESC.

Figure C.29 **Productivity trend – South Gippsland Water** (2006 = 1.00)



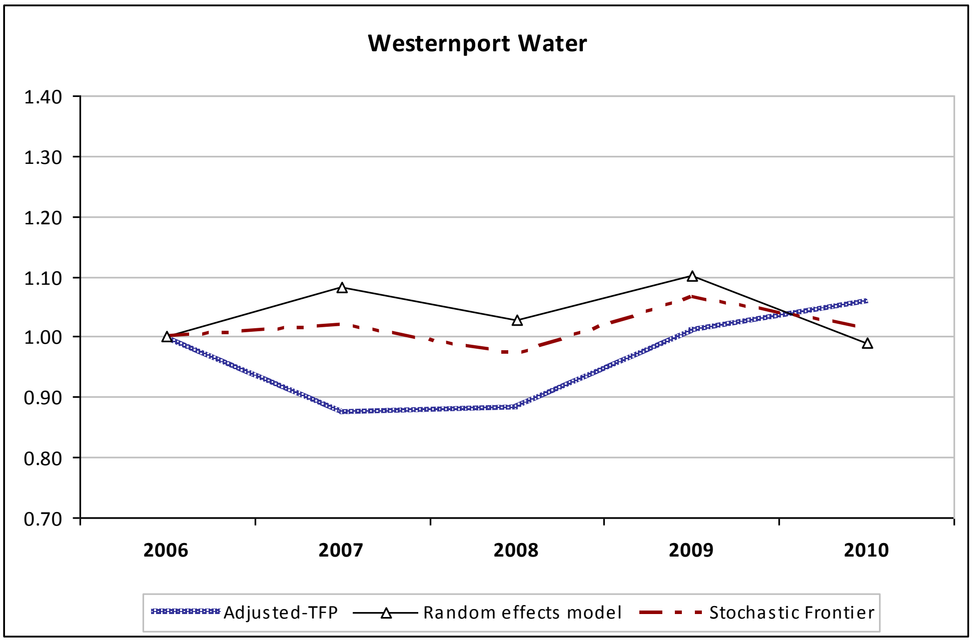
Source: ESC.

Figure C.30 **Productivity trend – South Gippsland Water** (2006 = 1.00)



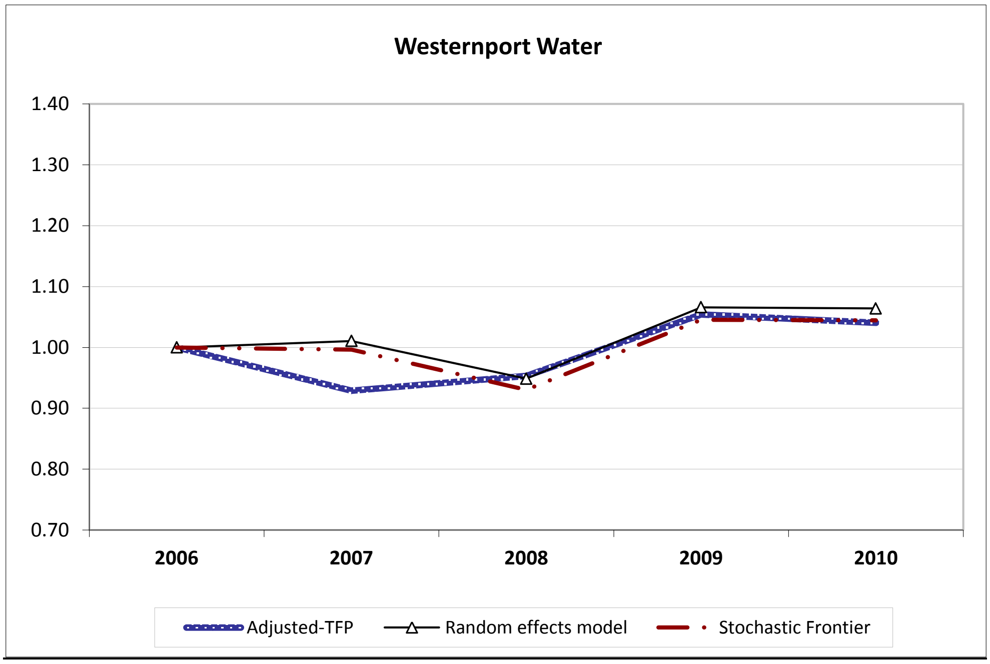
Source: ESC.

Figure C.31 **Productivity trend – Westernport Water** (2006 = 1.00)



Source: ESC.

Figure C.32 **Inputs per customer – Westernport Water** (2006 = 1.00)



Source: ESC.