Pricing, Demand Analysis and Simulation: An Application to a Water Utility

by

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An Application to a Water Utility

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for the degree of Doctor of Philosophy
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We never know the worth of water till the well is dry.

Thomas Fuller
Gnomologia, 5451

PREFACE

Water, which we all take for granted, is a very important resource, but since it comprises such a small part of a household budget, its significance is usually overlooked. Since I originally come from a developing country (Pakistan), I have personally encountered numerous instances of water shortages. The rich can pay a higher price and get water delivered though water tanks, but the consequences of such mismanagement severely affect the poor, who have to queue for hours to fill a bucket of water. It has always made me wonder, being an economics student, why something cannot be done about the water problem. Is it because there are not enough water reserves or can this be attributed to total mismanagement of the resources? At that time I attributed the problem to a lack of funds and resources, which acts as an impediment for a developing nation, and to some extent, the limited application of economic pricing policies. Later, when I migrated to Australia and joined Sydney Water (then the Sydney Water Board), I thought Australia, being a developed nation, would never have a water shortage problem. But I was proved to be wrong because some time after I joined, there were rumours that the dam levels had dropped and that there might be scarcity of water - if there was no rain. Since there was hardly any rainfall that quarter, the dam's water levels fell below dangerous limits, and finally, there it came! the severe water restrictions of January 1994. Previously, I could not picture this happening in Sydney, the 'A' graded city of Australia but clearly this was a wrong assumption. I realised that this could happen in any country, third world or not, if the nation took its reserves and resources for granted. The consequences of such neglect can be long lasting water restrictions. Therefore, the efficient management of this resource requires serious thinking; otherwise serious water shortage problems can follow. This partly acted as a motivation for my research, and I asked myself the question, can this valuable resource be managed efficiently, and if yes, how?

ACKNOWLEDGMENTS

This thesis is an outcome of the research undertaken from 1992 to 1997, including four years of part-time effort, while I was working with Sydney Water and Energy Australia. I would like to thank both organisations for their immense support and encouragement. Above all I owe my highest gratitude to my supervisor Elizabeth Savage whose advice, comments, guidance and criticism have helped me in further improving my thesis. In addition to this, helpful discussions with Judy Yates have been constructive to my work. I would also like to thank Denise Doiron for her challenging comments on the demand analysis chapter, which have lead to further improvement of the analysis. Since it is not possible to conduct any type of empirical research without data availability, I am totally indebted to the Sydney Water, Competition and Pricing Branch for allowing me to have access to the household demand data. In particular, the names of the Principal Economist, Richard Warner and Senior Policy Analyst, Don Graham cannot go unmentioned. I would also like to thank the Government Pricing Tribunal, who allowed me to use their Survey data, which has been very important to this dissertation. And last but not least, I would like to thank my family for their support over the last five long years, especially my mother who has put up with my frustrations and has given me the encouragement that I required: Without her help, I could not have made it through.

ABSTRACT

Recent changes in the New South Wales water utilities show a trend towards usage-related pricing, with the aim of providing efficient signals for consumption. This thesis evaluates alternative pricing strategies for water against the criteria of efficiency and equity while maintaining the financial viability of the public utility. First, the water utility cost structure is examined by developing cost functions to estimate short and long-run marginal costs, using a quarterly time-series data from 1970/71 to 1995/96. Second, a residential water demand model is developed using a panel data set (constructed for the analysis), comprising 822 cross-sectional units and 23 quarterly time periods from 1990/91 to 1995/96. The purposes of developing the demand model are to test the sensitivity of water demand to changes in the tariff structure and to use it to simulate the impact of alternative pricing strategies. Third, the simulation model is developed to analyse various pricing reforms using both the cost and demand model results, where the individual welfare and aggregate efficiency gains are determined under each pricing policy. In addition to this, the distributional effects of various tariff structures are examined.

The empirical results of the cost structure estimates are comparable with previous studies. The demand estimation indicates that consumers respond to price, therefore price can be considered as a tool in the implementation of demand management strategies. However, the magnitude of the price elasticity suggests that substantial increases in price would be required to influence demand. Finally, the simulation results show that in the case of movement from the actual tariff structure to a two-part tariff policy (where the usage charge is equal to the short-run marginal cost), leads to highest efficiency gains.

PART I

PURPOSE

Chapter One
Introduction

Over recent years water authorities have resorted to pricing strategies to reduce water consumption. Previously, the main demand management tools were conservation and public education programs, advocating less use of water. If the utility perceived the situation to be more serious, then water rationing was taken as an alternative. In addition to this, engineering techniques like building more dams or reservoirs were used with little emphasis on economic instruments. However, this has changed, especially with urbanisation and environmental awareness the utilities have resorted to economic methodologies rather than traditional accounting techniques, which fail to look forward. To manage this resource efficiently, non-traditional methods like cost reflective pricing, water recycling, water efficient appliances and water meter accuracy have been given greater emphasis. Research on understanding consumer behaviour and the cost structure of utilities is also central to the application of economic methodologies for demand management.

1.1 Purpose

The purpose of this thesis is to develop an economic model to address issues related to water resource management. Public utility pricing theory is applied to a water utility, Sydney Water, which has characteristics of a natural monopoly: lumpy investment with large indivisible costs and significant joint or common costs. Recognising the interdependence of costing and pricing issues, this study emphasises cost based efficient pricing and evaluates alternative revenue neutral pricing strategies on the basis of efficiency and equity.

The driving force behind the price reforms has been a series of reports by the Industry Commission, relating to water, electricity, transport and other public utilities. The

Industry Commission report on Water Resources and Waste Water Disposal (Industry Commission, 1992) emphasised an efficient charging system which should meet the objectives of capacity rationing. They propose a mix of charging methods like access combined with usage. In addition to this, the Hilmer Report on "National Competition Policy," prepared in 1993, advocates market determined prices with emphasis on pro-competition policies and elimination of monopoly abuse. These reports have identified prevailing inefficiencies evident in the utilities and have also recommended a move towards corporatisation, commercialisation and privatisation. Corporatisation of the water industry is assumed to provide economic incentives for greater efficiency and is expected to promote competition via the market mechanism.

The trend which is evident in Australia is also visible in many other countries, some of which are trying to or have privatised their water utilities (like UK). However, the process relies upon the private sector being convinced that they can charge a profitable price for water. Asian governments (like Indonesia, Malaysia and Philippines) have also realised that unless they charge or move towards efficient pricing systems they may have severe drinking water shortages in the near future. Therefore, the step towards improvement of the existing water charging system appears to be a global pursuit.

1.2 Contribution of the Research

While there has been substantial discussion about efficient water pricing in Australia, there is very little research into the structure of costs and demands, which are so pertinent to the evaluation of price reforms. This dissertation evaluates price reforms, using estimated cost and demand models. The primary emphasis is on the demand side. Therefore, a fairly simple cost function is used to estimate the marginal costs for Sydney Water. Using quarterly time series data, both short and long-run marginal costs are estimated. In addition to this, the commonly advocated pricing structures of present worth incremental system cost and average incremental cost are calculated, based on the future demand and cost projections.

On the demand side, an error-component water demand model is estimated, using a panel data set. The first purpose of the demand analysis is to estimate both price and income elasticities and to observe if consumers respond to the marginal price, while faced with the non-uniform price schedule. An additional purpose of developing the demand model is to use it to simulate the impacts of various revenue neutral pricing regimes.

The simulation model applies public economic theory to estimate individual household welfare impacts and aggregate efficiency effects. Both the demand model coefficients and marginal cost results are used as inputs in the simulation model based on the pricing theory developed in chapter three. Welfare gains and losses under each pricing policy are calculated. In addition to this, the number of households that lose and gain under each price at a unit and aggregate level are also identified, along with changes in the bill. One objective of the analysis is to identify the most efficient pricing policy and to calculate the efficiency and distributional impacts of the alternative tariff structures. The pricing structures analysed are Ramsey, average price, two-part and multipart tariffs.

1.3 Structure of the Thesis

This study consists of four parts. Part I provides the context and discusses the institutional changes that have and are taking place, which have influenced the activities of public utilities to move towards a cost reflective pricing system. A general overview of Sydney Water: the organisation, the services it provides and the pricing strategies adopted over the years, is also presented.

Part II contains the theoretical background related to pricing and welfare. Chapter three lays out the theoretical framework for 'efficient pricing,' by discussing the 'ideal' economy case where competitive markets operate to achieve optimum price. Some instances of market failure are also discussed, to specify why natural monopolies like water, electricity, transport and other public utilities facing technological and budget constraints are unlikely to achieve optimal prices, and have

to resort to second-best approaches. This is then followed by the discussion of the general theory of second-best in the context of the water utility.

Chapter four examines a number of welfare measures. Initially the common welfare measure, consumer surplus is discussed, this is then followed by a discussion of Hicksian welfare measures - compensating and equivalent variations. The theory of duality is used to show how the welfare measures may be expressed in terms of expenditure and indirect utility functions.

The empirical contribution of the thesis is contained in Part III. Chapter five surveys empirical studies which apply pricing theory to utilities like electricity, water, gas, telecommunications and transport. It focuses on the studies related to the pricing theory developed in chapter three.

Chapter six consists of two sections. The first section applies marginal cost theory to estimate short-and long-run marginal costs, using an econometric model estimated on quarterly time series data. The rationale for marginal cost pricing is also discussed. In contrast to chapter three, which highlights the importance of the theoretical framework, this chapter focuses on estimation techniques and the application of theory. The second section of the chapter adopts a more pragmatic approach based on the methodology developed by Ralph Turvey to calculate present worth incremental system cost (see Turvey 1968) and average incremental cost (see Saunders and Warford 1976). Both these approaches avoid estimation by using the future demand and cost projections.

Chapter seven estimates the residential water demand model based on the micro-level data. This chapter begins by surveying past approaches used to address similar demand modelling issues. It specifies the data set used and presents the methodology adopted in estimating the demand function adopted in the analysis. Finally, the results of the demand function along with some implications conclude the chapter.

The methodology of estimating the measure of welfare change and the price reforms is discussed in Chapter eight. Using cost estimates from chapter six and demand coefficients from chapter seven a simulation model is developed to evaluate welfare, efficiency and distributional effects of the price reforms. The welfare gains for each household are calculated using the equivalent gains method. For all price reforms the tariff structures are constrained to meet the same revenue requirement.

Part IV concludes the thesis. The contribution of the dissertation is discussed: the development of marginal cost, demand and simulation models, the evaluation of various pricing reforms and the identification of the most efficient pricing policy. In addition to this, the pricing reforms that have taken place in the water industry are highlighted and finally future developments in the field are discussed.

Chapter Two

Institutional Changes and Background

Public utilities play a vital role in our national economy. In Australia they account for 10 per cent of the gross domestic product, 8 per cent of the total wages bill, 13 per cent of gross operating surplus and 13 per cent of gross fixed capital expenditure (Industry Commission 1994). In assessing the total factor productivity of the major business area, the Industry Commission and the Bureau of Industry Economics have reported improved performance of public utilities over the years. However, the water, electricity and rail industries still have some way to go to achieve the OECD international best practice. As indicated in one of the OECD surveys, Australian labour productivity lies below the OECD average. It states:

> *"OECD comparisons of productivity levels in the public utility sector indicate that labour productivity in Australia is less than half the OECD average and capital productivity is a little more than half."* (OECD 1989/90, pages 50-51).

It is argued in the OECD Australian surveys that the price structure of electricity and telecommunications had significant cross-subsidisation which distorts prices and fails to give correct signals to the consumers. It has been suggested that an improvement in the government policy which favours competition can increase productivity and reduce costs which can be passed on to the users in lower prices. The issue of marginal cost pricing in regulated industries is another question which has to be addressed to promote allocative efficiency.

The following section discusses the institutional changes that have taken place in Australia in the recent past, and that are currently on the government agenda, and which have influenced the activities of public utilities to move towards efficient pricing system. In addition to this, the chapter gives a general overview of Sydney Water, the organisation, the services it provides and the price reforms it adopted over the years. Finally, Section 2.3 summarises and discusses these changes in light of the study.

2.1 Institutional Changes

The process of institutional change has been motivated by the broader microeconomic reform agenda, which was initiated in the 1980s. Microeconomic reform aims to promote competition among the government trading enterprises to remove any barriers which reduce efficiency. The Economic Planning Advisory Council (EPAC) in their report on microeconomic reform state:

> *"Microeconomic reform in its broadest sense is about making markets work better, improving incentives and enhancing the effectiveness of government operations. It is mainly concerned with removing market impediments which discourage or prevent resources being used in the most efficient manner, or which limit the flexibility and responsiveness of workers and enterprise."* (EPAC 1990, page 7)

Reforms are expected to make the markets perform better and provide incentives to the public enterprises to increase their productivity. It is argued that this may be achieved by promoting corporatisation and commercialisation of government trading enterprises.[1] The dominant view is that it is no longer the role of public utilities to provide goods and services to the general public at subsidised rates and recover any losses incurred from the government consolidated funds. The public utilities are encouraged to act like commercial organisations because they are required to be self sufficient, to recover their costs by charging rates that are cost reflective and to eliminate cross-subsidies inherent in the rate structure.[2] In addition to this, user pays pricing principles are also advocated.

The cause of microeconomic reform has been further encouraged by the Hilmer report on "National Competition Policy" prepared for the federal and state governments in 1993. It emphasises competition between the private sector and the main government trading enterprises. Hilmer reforms focus mainly on the changes to the legislative and regulatory environment to promote competition. It has placed more pressure on the utilities, which are forced to operate in a commercial environment. Competition policy aims to achieve economic efficiency, which is an amalgamation of technical or

[1] This to a certain extent has already taken place.

[2] Cross-subsidy is said to exist when one or more groups of customers are paying more than its stand alone costs ie, the true cost attributed to that group. Often it is interpreted more loosely in public discussion of utility pricing.

productive efficiency, allocative efficiency and dynamic efficiency (Hilmer 1995). Productive efficiency is expected to improve capital and labour productivity, where firms try to produce goods and services at minimum cost. Allocative efficiency is achieved with the implementation of pricing policies which are more cost reflective with no cross-subsidies. Dynamic efficiency is attained with productivity gains by keeping up to date with the innovative and modern technology, where firms adjust the changes in technology to the market demand and supply conditions. Each of these aims to improve the operation of markets and together they are expected to achieve economic efficiency.

Though it is difficult to assess the actual gains from the Hilmer and related reforms at this early stage, the Industry Commission has predicted that a gain of 5.4 per cent in the Gross Domestic Product will flow from the reforms (Industry Commission 1995). While examining the benefits of the microeconomic reform Quiggin (1996) argues that the figures given by the Industry Commission might be grossly over optimistic. Taking into account the realistic assumptions about employment, he estimates the total benefits to be 0.5 per cent rather than 5.4 per cent of the Gross Domestic Product.

Currently all the government trading enterprises are required to raise their own revenue to cover their expenses and provide services within the regulatory environment. The federal government is also urging the public authorities to improve their productivity. While reporting on the performance of NSW businesses, the NSW government states:

> *"The improved productivity performance has resulted in a more commercial return to the taxpayer, with dividend and tax equivalent payments increasing from $165 million in 1987/88 to $1,064 million in 1993/94 (each expressed in 1993/94 dollars)."* (New South Wales Government report, page 5)

As part of the reform the water, electricity and transport industries are going through enormous changes. The restructuring of the electricity industry has lead to the separation of the vertically integrated generation, transmission and distribution. The main purpose of the disintegration is to encourage competition within and between the generation and distribution sectors via spot, futures and long term contracts (options or swaps). The establishment of the competitive markets in generation and distribution in

NSW and Victoria have substantially changed the industry. For example, Pacific Power which is the main power supply authority in NSW with 90 per cent of market power is expected to have its market share reduced to 36 per cent once the four state eastern coast electricity markets are operational (Hilmer 1995). The regulation of the NSW and Victorian electricity industry and the privatisation of the distribution and generation in Victoria is part of the microeconomic reform to establish cost reflective prices and to let the markets operate and achieve efficiency levels. In the transport industry, the operations of all interstate rail services are progressively taken over by the National Rail Corporation, to further improve the performance.

In the water industry in NSW the evolution is evidenced by the corporatisation of Hunter Water Corporation and Sydney Water.[3] Both organisations aim to operate commercially, implement cost reflective prices, move towards user pays systems, achieve allocative efficiency, implement the investment schemes which are economically viable and introduce market trading for water entities. In the case of Sydney Water, one of its subsidiaries, Australian Water Technologies (AWT), which acts as its trading arm, has to compete with other water entities to bid for the Sydney Water tender, to enhance competition. In Victoria the corporatisation and further restructuring of Melbourne Water Corporation into three regional retail units and a headwork operation is expected to further encourage competition and economic efficiency.[4]

Competition has been further promoted by the NSW government which in 1992 established the price regulatory authority, the Government Pricing Tribunal. They have emphasised the use of cost reflective prices, stating:

> *"The Tribunal supports and intends to pursue the introduction of more cost-reflective pricing structures. The movement toward cost-reflective prices must take into account the practical aspects of pricing and the impacts of these charges. The pace of reform will be influenced by the extent of the efficiency gains achieved, and the efficacy of safety nets put in place by*

[3] Hunter Water Corporation was corporatised in January 1992 and the Sydney Water Corporation was corporatised in January, 1995.
[4] Melbourne Water was corporatised in the early 90s.

> *government."* (Government Pricing Tribunal, 1993, page 10)

Therefore, all utilities, whether private or public, are to implement commercial prices and operate in a manner to achieve efficiency. In addition to this, the utilities are urged to eradicate cross subsidies and use prices as signals to the community, free of all distortions. In reference to distributional issues in water pricing the Government Pricing Tribunal states:

> *"The Tribunal acknowledges the arguments put by some community groups in support of "social pricing", but, on balance, does not accept that water services should be priced to meet social or other non-commercial objectives. If the government wishes to pursue such objectives, the Tribunal believes that this should be done by way of explicit and transparent budgetary and tax instruments."* (Government Pricing Tribunal, 1993, page (iii))

Similar institutional changes are evident in the UK, which has lead to the privatisation of major public utilities, starting in 1984 with British Telecommunications. The process has involved other utilities like airports, gas, water, electricity and railways. Since these utilities have the characteristics of natural monopolies they are regulated, and are expected to act in a manner which should promote competition, protect customers and promote the cause of the community (Odgers 1995). The achievement of all the objectives has not been an easy task and has lead to considerable complexity in UK competition law (Whish 1993).

2.2 Sydney Water

2.2.1 Organisation and Area of Operation

Sydney Water (then Sydney Water Board) was corporatised on 1 January, 1995. After being corporatised it was granted an "Operating Licence," under the Water Board (Corporatisation) Section 12 of the Act, for a term of five years. The licence:

> *"permits Sydney Water to provide, construct, operate, manage and maintain systems and services for: (a) storing and supplying water; and (b) provide sewerage services and disposing of waste water; and (c)*

providing certain stormwater drainage services."
(Sydney Water Operating Licence, page 4)

The licence is be renewed every five years, subject to the condition that Sydney Water acts in compliance to the licence terms and conditions.[5] The licence does not impose any barriers to entry for any other person or organisation in providing the same services in the market that Sydney Water provides, which is in agreement with the National Competition Policy. An important feature of the licence is the "Customer Contract," which outlines the rights and conditions of the Sydney Water customers. The licence also imposes a limit on the charges that Sydney Water can impose, the determination of all its prices being subject to the approval of the Government Pricing Tribunal. In addition to this, the "Statement of Corporate Intent" specifies Sydney Water's relationship to the State Government and the dividend Sydney Water is required to pay.

Sydney Water is an unlisted public company registered with the Australian Securities Commission, with Sydney Water as its new trading name. Its shares are held by the NSW State government Ministers[6] on behalf of the people of NSW. It serves approximately 3.7 million people and has a staff of 6,500. In 1995/96 it generated a revenue of $1,300 million (Sydney Water, 1995a). Its area of operation covers approximately 13,000 square kilometres, extending to the Hawkesbury River in the north to Gerroa in the south and from the Pacific Ocean westward to Mount Victoria in the Blue Mountains.[7] In addition to water, sewer and drainage facilities, it also provides some other ancillary services like the approval of relevant aspects of building, plumbing and drainage, the issue of water meters and conveyancing applications.

The assets of Sydney Water are worth $12 billion. They fall into the following three categories:

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[5] The conditions imposed very broadly are: to provide the systems and services to the customers and to maintain the quality and performance of the services.
[6] Treasurer and Minister of Arts, Minister for Education , Training and Youth Affairs, Minister for Tourism, Minister Assisting the Premier, Minister for Industrial Relations and Employment, Minister for Status of Women, Minister for Community Services and Minister for Consumer Affairs.
[7] Some of the Sydney Water catchment area are outside its area of operation.