ABSTRACT

Title: **SERVICE QUALITY AND ASYMMETRIC INFORMATION IN THE REGULATION OF MONOPOLIES: THE CHILEAN ELECTRICITY DISTRIBUTION INDUSTRY**

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This study is an enquiry about the role that service quality, asymmetric information, scope of regulation and regulator's preferences play in the regulation of monopolies, with an application to the case of the Chilean electricity distribution industry. In Chapter 1, I present the problem of regulating a monopolist and introduce the special conditions that the electricity sector has. Later I discuss the main characteristics of the electricity system that operates in Chile. The literature on regulation is reviewed in Chapter 2. A special emphasis is given to the problems of quality and information, and the lack of its proper joint treatment. In Chapter 3, I develop four theoretical models of regulation that explicitly consider the regulation of price and quality versus price-only regulation, and a symmetric versus asymmetric information structure where only the regulator knows its true costs. In these models, I also consider the effect of a regulator that may have a preference between consumers and the regulated monopolistic firms. I conclude that with symmetric information and independent of the scope of regulation,

having a regulator that prefers consumers or producers does not affect the efficiency of the outcome. I also show that the regulator's inability to set quality, thus regulating only price, leads to an inefficient outcome, away from the first best solution that can be achieved by regulating both price and quality, even with asymmetric information, as long as the regulator does not have a "biased" preference for consumers or the monopolistic producers. If the regulator has a "bias," then the equilibrium will be inefficient with asymmetric information. But the effect on equilibrium price and quality depends on the direction of the effect of quality on the marginal effect of price in demand. More importantly, no closed-form solution can be derived unless drastic simplifications are made. To further investigate the outcome of the models, I use numerical simulation in Chapter 4, assuming flexible functional forms and alternative sets of parameters that represent the scenarios of interest. The results show that when the regulator is biased toward consumers (producers), symmetric information models yield higher (lower) quality except for the most efficient firm. Chapter 5 uses data from the electricity sector in Chile and estimates the price and quality elasticity of demand and finds a positive effect of quality on the price elasticity of demand.

SERVICE QUALITY AND ASYMMETRIC INFORMATION IN THE REGULATION OF MONOPOLIES: THE CHILEAN ELECTRICITY DISTRIBUTION INDUSTRY

by

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DEDICATION

To Daniela

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LIST OF ABBREVIATIONS

CDEC	*Centro de Despacho Económico de Carga*, Economic-Load Dispatch Center
CES	Constant elasticity of substitution
CNE	*Comisión Nacional de Energía*, National Energy Commission (of Chile)
FOC	First order conditions
GDP	Gross domestic product
IC	Incentive compatibility
IR	Individual rationality
SEC	*Superintendencia de Electricidad y Combustibles,* Superintendence of Electricity and Fuels (of Chile)
SIC	*Sistema Interconectado Central*, Central Interconnected Electrical System (in Chile)
SING	*Sistema Interconectado del Norte Grande*, Northern Interconnected Electrical System (in Chile)
SOC	Second order conditions
VAD	*Valor agregado de distribución,* distribution value-added
WTP	Willingness to pay

1 INTRODUCTION

In the past two decades several countries have started a process of privatization and deregulation of public enterprises and services. This trend has become increasingly important in developing countries and in transition economies. The main arguments behind these reforms have been increased efficiency, freeing of public funds, and the creation of new investment opportunities (Galal, et al., 1994). The increase in efficiency is supposed to come from competition among private firms, differences in the incentive structure due to private ownership (profit and property value maximization), and less political influence (Bhattacharyya, et al., 1995; Dixit, 1997; Poole and Fixler, 1987; Vinning and Boardman, 1992). In many cases, these firms were not able to pay their own costs. Thus, their divestiture was seen as a way of reducing the financial burden on the fiscal budget. Selling state-owned companies has been used to attract foreign investment (Edwards and Baer, 1993). Also, in some countries, privatization was promoted to achieve popular capitalism by expanding the number of shareholders in capital markets (Hachette and Luders, 1993).

Some authors have criticized the view that the mere change in ownership will produce the promised increase in efficiency. It has been pointed out, with theoretical and empirical arguments, that the factor that might have a greater influence on efficiency is the existence of competition (Emmons, 1997).Under this conjecture, the conversion of a public monopoly to private ownership might not necessarily have an effect on efficiency. Moreover, if not properly regulated, it may generate monopolistic rents and losses to society.

Creating a competitive environment for natural monopolies is not an easy task. Some authors have proposed franchising as a way of bringing competition to industries where economies of scale do not allow it. In this case, firms compete *for* the market through auctions or other allocation processes (see Demsetz, 1968). This kind of solution has been applied more commonly to projects involving the construction and operation of highways and ports (see Engel, Fischer and Galetovic, 1997). Another attempt to bring competition has been by horizontal or vertical separation of the market. In the phone service industry, for example, horizontal separation has been attempted by breaking up a national company into regional firms. In the electricity sector, vertical separation has been attempted by separating ownership of the generation, transmission and distribution systems.

The evaluation of early attempts at privatization has brought some consensus on the best approaches for implementing a privatization plan (Galal, et al., 1994). At the same time, these experiences have raised a series of new issues that where not foreseen at the time of implementation. Some of the issues that appear particularly relevant are regulatory capture, asymmetric information, and unfulfilled efficiency improvement and provision of quality. These issues may have the potential for significantly reducing the gains expected from the privatization process (Nellis, no date).

When the regulator sets prices, it takes into account the effects that this would have on the industry and the public. If regulatory policy is too lax, there is a political cost that comes from the public‘s perception of being harmed by the privatized industry. On the other hand, if the regulatory authority or any other institution appears to be excessively stringent or even arbitrary with the industry, it sends a message that may discourage investors and risk future investments.

Frequently, regulatory agencies lack the means (financial and technical) to confront private corporations. Corruption or lack of adequate capacity of authorities can lead to an improved stance for the regulated industry. This asymmetry of information can lead to inefficiencies and extraordinary rents. One of the concerns when regulating a monopoly is efficiency improvement. Because there is no competition, the incentives to reduce cost and become more efficient are absent. This is why different regulatory mechanisms have tried to incorporate incentives that promote increased efficiency.

Another concern has been the adequate provision of quality. Depending on the nature of the service being regulated, the monopolist may have an incentive to provide less than the economically efficient level of quality. Because most regulatory instruments focus most on prices, quality can be adversely affected when prices are reduced if no adequate mechanism to control quality is in place. To confront this problem, authorities can use standards and penalties. In many cases, enforcing these quality standards has not been an easy task; the significance of the welfare effects that this phenomenon has had in practice is still an open question.

The questions that I propose to answer deal with these issues from a theoretical, empirical, and policy-oriented perspective. What are the welfare effects of regulatory capture? Also, I examine the role of information in the regulatory process. Are information asymmetries significant to the outcome? I investigate the efficiency changes under a regulated environment. How can regulation induce efficiency improvements? What is the role of quality in the regulatory process? Does it work as a pressure valve that regulated companies can use when regulated prices are too low? Under what conditions is quality affected by the stringency of the pricing policy?

To answer these questions I develop a theoretical model based on the latest contributions to the literature. The model is based on a specific case for which an empirical analysis is conducted. This analysis answers the questions not answered by the theoretical model. In particular, I will consider the case of electricity distribution in Chile. Chile, a pioneer in the privatization of public utilities, started its privatization in the early 1980's, accumulating enough experience to allow its analysis as a consolidated system (Millan, no date).

In the next section, I give a general introduction to the regulation of electricity systems followed by a description of the electricity industry in Chile. Chapter 2 presents a review of the theoretical literature on regulation and empirical studies that have considered asymmetric information and studies about the Chilean system. Drawing from these literatures, I propose a model in Chapter 3 that represents this industry and addresses explicitly the issues of quality of service, asymmetric information, and regulator preferences that arises in the discussion of previous chapters. Because the theoretical model does not have a definite answer to the impact of these issues in the regulatory problem, Chapter 4 presents a numerical simulation based on the theoretical model developed in Chapter 3. Using actual data from the operation of the Chilean distribution system, an empirical model of demand that estimates the impact of quality on demand is presented in Chapter 5. Conclusions are presented in Chapter 6.

1.1 The Regulation of Electricity Systems

Electricity sectors have traditionally been viewed as natural monopolies, where economies of scale and scope justify the existence of public or strongly regulated private firms.[1] In many cases, these utilities are vertically integrated, owning generation units, transmission lines and distribution grids. They also commonly supply energy only to specific geographic areas, using connections with other areas merely as a means to overcome shortages. When utilities are not publicly owned, regulations are imposed to avoid monopolistic behavior. The most widely used regulations are entry control, price and service quality settings, coverage expansion requirements, and investments in new generation capacity. Often, prices are set to ensure a "fair rate of return" to investors.

Technological change has somewhat altered the view that electricity generation is a natural monopoly. The fact that new production units are economically efficient at smaller sizes has lowered barriers to entry and, therefore, increased competition.[2] Also, the increase in electricity consumption has dramatically expanded the market, opening opportunities to new sources of power and connecting markets that were previously isolated. This has resulted in increased opportunities for competition. In some places, these opportunities have been seized by the introduction of reforms that try to capture the benefits of restricted forms of competition.

Most of the reforms proposed, or actually implemented, try to disintegrate the electricity market vertically and horizontally by leaving the ownership of generation, transmission and distribution segments in different hands. This would allow for more competition and increased efficiency due to the new access that generators have to

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1 A public firm is defined here to be a government-owned firm.

2 Some authors argue that technological change has been driven by bad regulations, leading to generation units of "sub-optimal" size (Joskow, 1997).

distributors and/or consumers. Several variations have being proposed (and implemented) to increase competition in a disintegrated market by unbundling the energy bought by the final consumer.[3] Some of these alternatives suggest creating a competitive market at the wholesale level, where generators and distributors freely trade, keeping transmission and distribution regulated. Other approaches recommend creating a competitive retail market, where final consumers buy electricity from generators and pay for unbundled but regulated costs of transmission and distribution (Joskow, 1997). Free entry to the distribution and transmission markets has also been suggested, but these alternatives have not been well regarded because they can bring over-investment and other costly externalities to society.

In most of these cases, the distribution of electricity would remain as a monopoly and, therefore, would require regulation or public ownership. In a scenario where mainly private companies handle distribution, the government must set up a scheme to avoid monopolistic behavior and guarantee adequate supply.

1.2 The Chilean Electricity System

This section presents a general overview of the development, structure, and basic operation of the Chilean electricity system.[4] Electrification in Chile began in the 1880's. At this time, private companies did most of the investment and the role of the state remained minimal. Electric companies were located near consumption centers and isolated from other generators. Usually the same company carried out generation and

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[3] For a more detailed description of alternative schemes, see Joskow and Schmalensee, (1983) and Joskow (1997).

[4] While this chapter describes the Chilean electricity system and the laws that have regulated it since privatization, a discussion of the perceived successes and failures of regulation is delayed to the next chapter.

distribution. After many small companies emerged, they begun to interconnect with one another and, in some cases, merged. From this process, three large vertically integrated firms arose in different geographical areas of the country.

In the 1940's, lack of investment in areas of low profitability became apparent and a state-owned enterprise was created.[5] This institution made investment decisions; ran generation, transmission and distribution facilities; and planned long-term electricity supply of the country. Government intervention in the form of low tariffs halted private investment until the 1960's when government support expanded private investment. In the early 1970's, in the midst of deep political changes, most of the firms where nationalized and tariffs were kept artificially low.

In the late 1970's, state-owned companies were reorganized, reducing labor and selling assets not directly related to their business. In 1981, the largest state-owned companies were vertically and horizontally divided but remained state-owned. They were also given greater independence from the government and were required to self-finance their operations. Some of the small subsidiaries were privatized. During the late 1980's, the main distribution and generating companies were privatized. The transmission grids were privatized together with the largest generation company.

The Chilean electricity system is comprised of four geographically separated and independent systems. Two of them, located in southern Chile, are small and vertically integrated. The northern (SING) and central (SIC) interconnected systems are characterized mainly by private generation, transmission and distribution firms.[6] The northern system provides most of its energy to the mining sector and most of the energy

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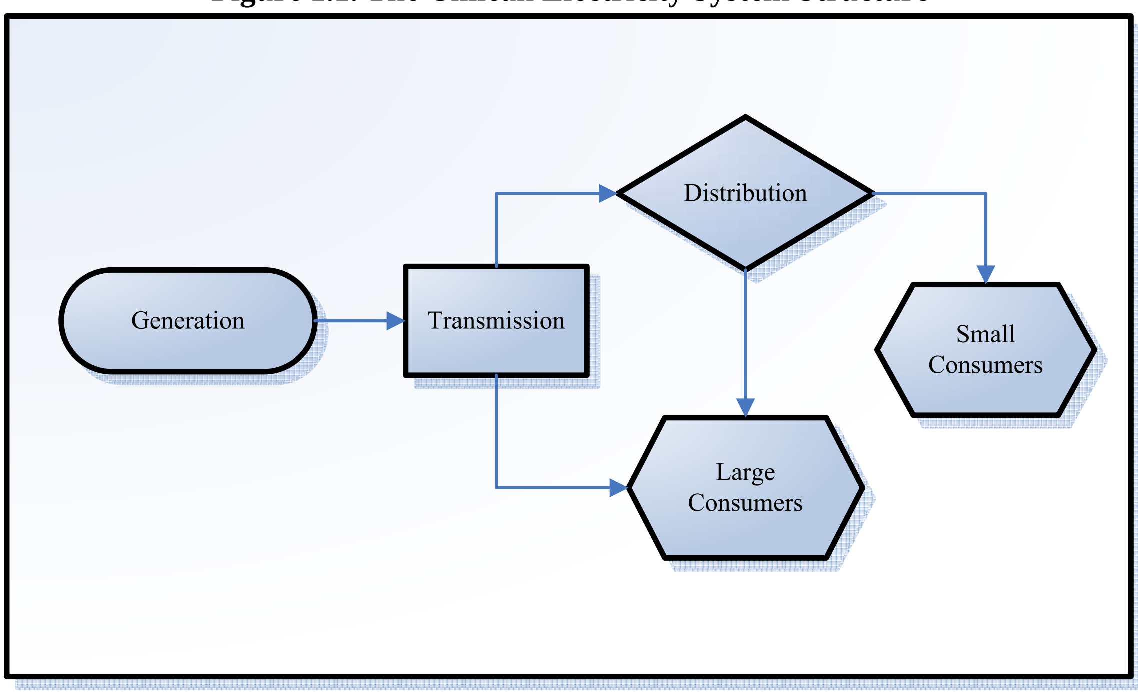
[5] Only 40% of the urban population had electricity, although per capita consumption was among the highest in the region (Soto, 1999).

[6] There are plans to connect these two systems in the future.

comes from thermoelectric generation. The central system is the largest in the country and its main source is hydroelectric generation.

In 1982, a new electricity law was introduced.[7] According to its authors, the objective was to expand society's welfare by allowing competition where possible (Bernstein, 1998). This law recognizes three different segments in the provision of electricity: generation, transmission and distribution. The first one is viewed as partially competitive and the other two are considered natural monopolies and are regulated as such. Final consumers are divided into two types: small and large.[8] The latter are allowed to buy electricity directly from the generators. Small consumers must buy electricity from distributors at a regulated price.

Figure 1.1. The Chilean Electricity System Structure



[7] See General Electricity Law (D.F.L. N° 1, 1982. Ministerio de Minería, República de Chile)
[8] Small consumers are defined as those that have a maximum instantaneous demand of less than 2 megawatts (MW).

Figure 1.1 presents a diagram of the structure of the Chilean electricity system. Node prices and distribution tolls are directly regulated by the authority. Transmission tolls can be freely agreed between firms. The "spot" market, where generators trade among one another according to clearance given by the system operator, has a price equal to "marginal cost" of the last generator to enter production. The following explains in more detail each of these segments and their regulation.

Historically, hydroelectric plants have generated most of the energy (about 80%) in years with normal precipitation. Thermoelectric plants have used coal and diesel as their main fuel. More recently, natural gas was becoming increasingly important until its import from Argentina was abruptly restricted. Whenever there have been deficits in hydro-power, thermoelectric facilities have been used to produce what is needed to meet the demand.

The composition of the generation facilities has been evolving towards more efficient and cheaper fuels. Upon the construction of natural gas pipelines from Argentina, gas-fueled electric production has become increasingly important. Until recently gas-fueled plants had emerged as a competitive alternative to hydro generation and were expected to increase their participation significantly in future years. But the sudden reduction in Argentina's gas exports has stopped generation based on natural gas.

The market operation is based on marginal cost pricing as a means of minimizing the costs of operation of the system. Depending on which agents are involved, the law defines three types of pricing mechanisms for energy and power exchanges:

- ***Spot Market*****:** Generators can trade among themselves when they have shortages or surpluses from their contracts. They trade at the short-run marginal cost of the system that is determined by the dispatch center. They can also buy energy from another generator at a lower cost to substitute their own generation.

- ***Free Price:*** Generators can negotiate contracts with large consumers who demand more than 2 MW. This market is not regulated because these consumers are supposed to be large enough to have a good bargaining position. For example, they could develop their own generation facilities at competitive rates. Commercial and industrial clients represent around 30% of the central interconnected system's (SIC) total consumption. These contracts, which typically specify energy and power prices, may also include provisions for service reliability.[9]
- ***Node Price****:* Generators can freely agree on the amount of energy and power to be offered to distributors, but transactions occur at the regulated node prices. The National Energy Commission (CNE) sets the node prices. Each node represents a point in the grid for which energy and power prices are determined.

The CNE estimates short-run average marginal costs of generation for the following four years. This estimate considers actual and forecasted future installed capacity, growth in demand, hydrological conditions, and generation input prices. After a regulated price is estimated, the law establishes that it must stay within a band of 10% of the free price.

To forecast future supply, the regulator uses a ten-year plan-of-work according to generators' intentions to invest in new capacity. Node prices are indexed by the exchange rate, fuel, and other input prices, and are recalculated twice a year to incorporate the hydrological conditions. Generators can request recalculation of node prices when

[9] Energy in this context is defined as the time integral of power.

significant changes in these variables occur, but no change larger than 10% can be made within the six-month period.

Node prices for power are intended to reflect the (long-run) marginal cost of increasing installed capacity to meet peak power demands. For this purpose, only hydro and natural-gas turbine costs are considered because only these forms of production are able to respond on short notice. Because hydro construction costs are very site-specific, the costs associated with developing a gas turbine of 50 MW are used in practice. These prices have the double incentive of reducing peak demand and increasing generation capacity. These prices are estimated for a reference node and then prices are derived for other nodes using penalization factors according to losses in transmission lines.

The load dispatch centers are the system operators. They oversee the smooth operation of each system. They are private institutions with a public mandate and are directed by representatives from the largest generators of each system. Their main duties are:

- Coordinating and verifying preventive maintenance of the generation plants.
- Determining the amount and value of energy transfer among generators.
- Calculating the instantaneous marginal cost of generation

Energy transfers take place at marginal cost, which is estimated according to the stated marginal costs of the last unit called into production. If this unit is at its maximum capacity, then the marginal cost of the next plant to be called into generation is used to determine the system's marginal cost. When demand is too high and there are no generators left to call into production, shortage costs are used as the system's marginal cost.[10]

The marginal storage cost of hydro plants is given mainly by the economic value of water, which is estimated by the dispatch center based on present and future water availability and demand conditions.

Although cost minimization is one of the main criteria used to order the entry into production, reliability of the generator is also taken into account. For this purpose, the central economic dispatch center (CDEC) uses the *firm power* of each facility to determine the order of dispatch in periods of peak demand. Firm power indicates the plant's fully available capacity during periods of peak power demand. For thermoelectric facilities, firm power is estimated taking into consideration the need for maintenance and unexpected failures. For hydroelectric facilities, firm power is estimated based on hydrological history and maintenance.

Privatization of the transmission segment was accomplished by franchising the electric lines. The owner of a transmission franchise is required to provide access to the network if transmission capacity is available. If there is no capacity available, they must build it and charge the user for it.

Transmission tolls can be freely agreed between the franchisee and the generators, but in the case of no agreement the law establishes a compensation scheme composed of three different charges:[11]

- *Tariff compensation*, which corresponds to the difference in node prices and is given by the power losses in transmission. Because this payment is, in general,

[10] For a description of how the outage costs are estimated, see Serra and Fierro (1997).
[11] Article 51, General Electricity Law (D.F.L. N° 1, 1982. Ministerio de Minería, República de Chile).

lower than total average cost due to economies of scale, it does not allow for the financing of the system and therefore other forms of compensation are required.

- *A Basic Toll*, which covers the remaining investment, operation and maintenance costs of all the equipment in the influence area of the generator, once the tariff compensation has been paid. The tolls are prorated among generators according to their use (load) of the line.
- *An Additional Toll*, which is a payment the generator must pay when the energy withdrawal is done through a node outside the area of influence.

The owner of the concession estimates these rates. If there are conflicts, the parties can request arbitration. Also the user can always build its own transmission line if an agreement cannot be reached with the transmission company.[12]

Distribution companies are granted rights to provide energy to consumers in a specific geographic location. The final consumer pays a regulated price that is equal to the sum of the node price and the *distribution value-added* (VAD). This value considers three types of costs to distribution companies:

- Fixed costs related to management, billing, and customer service.
- Electricity losses of distribution.
- Investment, operation, and maintenance cost per unit of power supplied.

These costs are calculated every 4 years through studies done by independent consultants hired by the authority. The distribution companies can hire their own studies and, if the results are different, the rates are averaged, weighting their rate estimates by 1/3 and the regulator's rate by 2/3.

[12] This has already happened. The case in which it happened is often mentioned as an example of the problems of this law.

The CNE establishes a set of final consumer tariffs based on node prices and VAD tariff formulas (each adapted to different ways of measuring consumption) that grants a rate of return between 6 and 14% to the distribution industry as a whole. For these calculations, firms provide estimates of income with the new tariff and the regulator estimates the costs considering an efficient (or ideal) distribution company. These tariff formulas are indexed to prices related to the costs of distribution companies. Whenever there is a change, the firms are allowed to change the rates, but if there is a reduction larger than 2% they are required to do so.

The Superintendence of Electricity and Fuels (SEC) is in charge of monitoring the quality of service. To do so, the law requires annual consumer surveys and a log of customers' complaints. Because, technically, the right of distribution is also a franchise, the only penalty the government can impose is the loss of the franchise. In practice, this is not a very credible threat. The other sanction is through private lawsuits that consumers may launch if they suffer losses due to bad service.

Table 1.1 shows the participation of firms in the main integrated systems in 1998. Endesa (controlled by the Enersis group) is the largest generator of the SIC with 54% of total electricity. At the same time, Endesa and its affiliate Transelec control 81% of the transmission lines in the SIC. Finally, Chilectra, also part of the Enersis group, owns 37% of the distribution networks. This vertically integrated structure was inherited from the privatization process.

This structure has been the source of many conflicts in the system. Many of the disputes have reached the Supreme Court. In spite of the last government's effort to revert this situation (of vertical integration), firms have been able to maintain this structure.

The fact that the largest national generating enterprise was divested together with its water rights (to the best available sources of hydro power) has deterred the entrance of new hydro generators, leaving the main role of generation to existing companies. This scenario has begun to change since natural gas has been shipped from Argentina. Nevertheless, these same generators have tried to secure their participation in new generation in spite of government efforts to avoid it.

Table 1.1. Chilean Electricity Industry Structure

Firms[a]	*Generation*		*Transmission lines*		**Distribution**	
	SIC	SING	SIC	SING	SIC	SING
	- - - - - - - - - - - - percentages of electricity - - - - - - - - - - - -					
Endesa (Controlled by Enersis)	54.8	4.7	12.3	3.6	-	-
Gener Group	26.3	17.5	7.7	8.0	-	-
Colbún	14.7	-	-	-	-	-
Tocopilla	-	40.2	-	31.6	-	-
Edelnor	-	26.3	.	28.9	-	-
Other Generators	4.2	11.3	0.5	-	-	-
Transelec (owned by Endesa)	-	-	69.5	-	-	-
Transnet	-	-	6.5	-	-	-
Private Transmission Lines (mining Co.)	-	-	-	27.9	-	-
Chilectra (controlled by Enersis)	-	-	-	-	37.0	-
Chilquinta	-	-	-	-	11.1	-
CGE	-	-	-	-	16.8	-
Other private distribution Co.	-	-	-	-	35.1	-
State Companies	-	-	-	-	-	100
Total	100	100	100	100	100	100

[a] SIC is the *Sistema Interconectado Central* (the Central Interconnected Electrical System).
SING is the *Sistema Interconectado del Norte Grande* (the Northern Interconnected Electrical System).
Source: Basañes, Saavedra, and Soto (1999) with data from CNE.

1.3 Conclusions to Chapter 1

A recent round of privatizations in many developing and transition economies is viewed as welfare improving policy. In these countries, regulated industries in many cases represent a significant proportion of the economy, and their growth is viewed as a means of accelerating development. In some cases, competition can be fostered with a privatized market. But in others, like electricity distribution, this cannot be done due, at least in part, to economies of scale where the provider is a monopolist. In these cases, the best approach has been to privatize and regulate, while providing an incentive to increase efficiency. But success depends crucially on how the regulation is actually implemented, because it poses its own set of problems. Appropriate price setting requires costly information, which may be known by the monopolist but not the regulator. Also, if the incentive to reduce costs is too high, the result can be a reduction in long-term investments or other activities not considered in the regulation. Quality of service is an example. If not included in the regulatory contract, changes in quality may serve as a "pressure valve" that the monopolist can use to increase profit while transferring the cost to consumers. Another problem that may emerge is that the regulator may be "captured" by the industry or other political constituency, leading to a regulation biased towards one of the interested parties.

Thus, a series of questions fundamental for a successful regulation need to be answered. I propose to answer some of the following questions from a theoretical, empirical, and policy-oriented perspective. What are the welfare effects of regulatory capture? Are information asymmetries significant to the outcome? How can regulation induce efficiency improvements? What is the role of quality in the regulatory process? Does it work as a pressure valve that regulated companies can use when regulated prices are too low? Under what conditions is quality affected by the stringency of the pricing policy?

Chile was one of the first countries to start a massive and broad privatization process, and thus represents a good subject for my analysis. In many cases, and in Chile in particular, the regulatory environment has been inherited from the privatization of state-owned or state-controlled utilities. Divestiture separated the electricity system in three basic components: generation, transmission and distribution. Among these, generation has admitted the greatest competition whereas distribution had remained as local monopolies. Thus, my empirical work is based on the distribution of electricity in Chile. One feature of the Chilean electricity sector, not common in developing countries, that facilitates my analysis is the systematic application of a survey to electricity consumers to evaluate the quality of the service provided.

2 THE LITERATURE ON REGULATION

This chapter presents a review of the literature relevant to the problem of regulating the electricity distribution industry in Chile. I first review the literature on the old and new theories of regulation. The latter is mainly an application of the economics of information. The theory of regulation provides the foundation for my analysis and the source of most of the tools applied in this dissertation. My aim is to examine the role of asymmetric information and consequent effects on quality. Only a few studies that have investigated regulatory problems like this one. That is, there have been only a few attempts to study an electricity system taking explicit account of the regulatory framework. Even fewer have focused on the institutional setting of a developing country. Thus, I also review that literature on the Chilean electricity system that has tried to describe, compare, and derive lessons from its operation. My purpose is to improve understanding of the system by developing evidence that supports or opposes some of the common beliefs about its behavior.

2.1 Regulation: Classical Theory and Practice

The problem of regulation has been studied extensively in economics and other disciplines. Dupuit (1952, originally published in 1844), who was probably the first to analyze a regulatory problem, studied the optimal pricing policy for a bridge. He concluded that the first-best price was a zero per cross charge and a fixed charge to cover the construction costs. Hotelling (1938) and Boiteux (1960) further developed the idea of marginal cost pricing. The latter extended the literature to consider cases with a capacity constraint and concluded that expansion costs should be added to the marginal cost of operation to get first-best prices (peak-load pricing). This approach requires constant returns to scale for the operation to break even. Otherwise, if the firm is required to stay within its budget constraint, marginal cost pricing cannot be used. In this case, average cost pricing is the second-best solution that minimizes the deadweight loss and satisfies the budget constraint.[13] This scheme is known in the literature as Ramsey-Boiteux pricing, since it was first proposed by Ramsey (1927) in the context of optimal taxation and later applied to optimal regulation by Boiteux (1960).

A gap between theory and practice is evident upon examining the policies actually implemented in most countries. The most common approach, although this has been changing in recent years, is cost-of-service regulation where the firms are allowed to charge a price that would allow them to obtain a "fair" rate of return on investment. Averch and Johnson (1962) proposed a model of input choice to analyze the implications of this kind of regulation. They concluded that this approach created the incentive to over-capitalize and make firms prone to resisting (favoring) any policy that would diminish (increase) capacity.

This literature failed to explain observed behavior, and to recommend regulatory arrangements that can be implemented in practice. Some of the issues it has failed to address are presence of asymmetric information, quality considerations, lack of commitment, and the imperfect nature of the regulator. If these elements are not considered, further advances in regulation seem hard to achieve. The next section presents a review of the main results of the literature that are most relevant to the problem I consider.

[13] This model assumes that the government is exogenously forbidden to make transfers to the firm (see Boiteux, 1971).

2.2 Regulation: Modern Approaches

The development of the literature on mechanism design (Green and Laffont, 1986; Mirrlees, 1971; Mussa and Rosen, 1978) brought new tools to the field. The first study to incorporate these tools was Loeb and Magat (1979). They considered the case where leaving rents to the firm had no social costs and therefore the first best is achieved by giving the firm a reward equal to the consumers' net surplus.[14] Later Baron and Myerson (1982) presented a model of adverse selection where the regulator could not observe cost (see also Guesnerie and Laffont, 1984; Sappington, 1982). In their model the regulator's objective is to maximize a linear social welfare function of the consumers' surplus and the firm's profit. The optimal policy (transfer and price) is based on stated costs and is constrained to nonnegative profits and truth-telling cost reports. They find that the second-best price will in general be higher than marginal cost, because part of it is given as an incentive to reveal true costs. They also found that, if the firm is given no weight in the social welfare function, then the selected price is equal to the highest marginal cost. When the firm is given the same weight as consumers, the price is equal to expected marginal cost. My model relies primarily on this literature and considers the relative weight in the social welfare function as a parameter to be estimated.

Baron and Besanko (1984a) extended this model introducing the ability of the regulator to perform costly audits of the firm costs.[15] The ex post observation of costs allows introduction of ex ante penalties for misreporting, which (weakly) improves the performance of the policies and generates a demand for auditing. They also establish that the unit price is independent of the auditing policy and, therefore, the same as the one

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[14] As a means of solving the equity issue, they propose auctioning the rights to the monopoly.

[15] Also see Townsend (1979) where information can be perfectly verified and Laffont and Tirole (1986) who do not consider uncertainty or the demand for auditing.

found by Baron and Myerson (1982).[16] They show in several situations that auditing (strictly) increases expected welfare.

If the regulatory agency were able to observe the level of invested capital, then the optimal pricing policy would lead to over capitalization. According to Besanko (1985), "Optimal revenue requirement regulation under asymmetric information makes the firm's output price a non-decreasing function of the amount of capital employed" (p. 51). When invested capital becomes part of the observed variables, an informational value is added to its productive worth. For that reason, the firm distorts its input decision to accommodate capital's new value. Averch and Johnson (1962) obtained this result in a rate-of-return regulation framework. But in their case, the optimal allowed rate of return is a decreasing function of the amount of capital employed, creating less incentive for overcapitalization.[17]

Sappington (1983) extended the basic one-output model assuming a separable cost function, a one-dimensional technological uncertainty, and unobservable costs. The standard results apply and optimal prices deviate from marginal cost to limit the informational rent. The regulator induces the firm to choose an inefficient technology for at least one of the products. He also found that incentives are fundamentally linked to prices as long as the hidden parameter affects marginal costs. This result is due to the assumption that costs are not observable. Laffont and Tirole (1993) also studied the problem, but allowed for cost observability. Working with a model that allows transfers,

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[16] Moreover, when the individual-rationality constraint is not binding and the global-incentive-compatibility condition can be represented by a local condition, the pricing policy is independent of the auditing policy.

[17] Klevorick (1966) proposed a graduated rate-of-return regulation, but not as an optimal regulatory policy.

they conclude that "optimal pricing requires that each product's Lerner index be equal to the sum of a Ramsey term and an incentive correction" (p. 200).

2.2.1 Moral Hazard and Adverse Selection

Some authors have considered the problem of opportunistic behavior in the regulator-firm relationship. Examples of moral hazard are exaggeration of costs when allowed revenues depend on them, and effort-shirking when costly information is needed to make better production decisions. Laffont and Tirole (1986) propose a model where the regulator can audit the firm's costs and the firm can make an effort to reduce cost (see also Baron and Besanko, 1986). Also, Sappington (1986) analyzes a model of information acquisition. In both models the simultaneous existence of moral hazard and adverse selection leads to policies that are quite different from those when only one is present. In particular, Besanko and Sappington (1987) state that when both are present the "optimal regulatory policy calls for marginal cost pricing, given the effort exerted by the firm" (p.36). In this specific case, the distortions brought by the two effects cancel out.

2.2.2 Regulation of Quality

The regulation of quality may be considered an extension to the literature on monopoly and product quality. One of the early efforts to incorporate quality in regulation is the work of Spence (1975). He finds that "for any fixed price, the firm sets quality too low" (p. 420). But this does not necessarily mean that quality is under-supplied, because in his model the unregulated monopolist might under- or over-supply quality depending on how the price elasticity changes with quality.

Besanko, Donnenfeld, and White (1987), using a modeling approach similar to that of Mussa and Rosen (1978), study the effect of minimum quality standards and price ceilings in a hidden information environment. They find that with a "price ceiling, the monopolist improves quality at the low quality end of the market," but for "minimum quality standards, the social welfare implications are ambiguous because the standards may exclude some consumers from the market" (p. 743). Lewis and Sappington (1988) examine the regulation of verifiable and unverifiable quality, and find that under unverifiable quality the regulator will allow prices in excess of marginal cost.[18] They also show that rent derived by the firm from private information about demand is higher when demand is verifiable.[19] Laffont and Tirole (1993) present a model that looks at the effect of quality on the power of incentive mechanisms. They use a model of moral hazard and distinguish between experience and search goods.[20] They argue that the incentive to reduce costs is in conflict with the provision of quality for experience goods, and that the power of the incentive mechanism will then depend on the (relative) importance of quality. For a search good, the effect of increasing the perceived cost of providing quality is not present because direct sales incentives can be provided. A high concern for quality leads to low powered incentive schemes only if quantity and quality are net substitutes.

2.3 Repeated Interaction and Commitment

When the regulatory process is characterized by more than one interaction, the behavior of the agents will adjust by taking into account the information available in

[18] Verifiable quality differs from observable quality in that a court cannot ascertain the latter.
[19] For a more general exposition, see Lewis and Sappington's (1991) model of procurement. For an application to energy conservation, see Lewis and Sappington (1992).
[20] With an experience (search) good, consumers perceive quality after (before) buying it.

future interactions. Vogelsang and Finsinger (1979) proposed a scheme that would force firms to lower prices in order to secure temporary profit. They assume that firms use a technology characterized by static and decreasing ray average costs, and that firms myopically maximize profit in each period. They conclude that only with the ability to observe the firm's expenditures can the regulator induce the firm to set prices in the social interest. However, this result does not take into account long-term strategic behavior of the firm.

In an environment of asymmetric information and multi-period regulation, Baron and Besanko (1984b) showed that the optimal contract with commitment is the repetition of the static contract. The ability to commit to long-term contracts becomes crucial to achieve ex-ante efficiency. However, the importance of non-commitment has been highlighted after observing the existence of legal prohibitions, politically unstable principals, the lack of knowledge about future conditions (the incomplete contracting argument), and the possibility that all agents are better off by renegotiating their contracts. Laffont and Tirole (1988) dropped the assumption of long-term commitment and assumed perfectly correlated marginal costs to obtain the no-separation result that, for any first-period incentive scheme, there exists no fully separating continuation equilibrium.

2.3.1 Yardstick Competition

A way in which the regulator can diminish the asymmetry of information is by comparing information available for multiple firms operating in separated markets. This additional information may help reduce the informational rents and induce incentives to reduce cost by introducing a competition against a standard set by the most efficient firm.

According to Demski and Sappington (1984), even the first-best can be achieved in a setting with two risk-neutral firms with correlated costs.[21,22] Nalebuff and Stiglitz (1983) considered a model with risk-averse firms and showed how the first-best can be achieved as a Nash equilibrium.[23] However, when there are differences in the firms that cannot be observed by the regulator, the fist-best cannot be implemented (see Shleifer, 1985).

2.3.2 The Political Economy of Regulation

In general, the problem of regulation is viewed as a contract between a regulator and a firm. This simplification overlooks the existence of other agents affecting the results of the regulatory process. The firm, for example, can be viewed as having an incentive problem between the owner and the manager and also between the manager and other employees. On the other hand, the regulator will usually be an agency that is controlled by a congress (or other sections of government), but can also be influenced by interest groups (such as the regulated industry or consumers). These hierarchical relationships increase the complexity of strategic behavior among agents.

Stigler (1971) postulated that interest groups choose to influence government at a level where their marginal benefit is equal to their marginal cost of organization. He also states that influence is more likely in policies where there is a high stake. Also, Becker (1983) proposed a model where interest groups exert costly "pressure" to increase the chances of obtaining a political favor. Another approach, proposed by the Virginia school (Buchanan, 1965; Tollison, 1982; and Tullock, 1967), suggests that politicians or bureaucrats have the power to create rents for which the firms will compete through

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[21] See d'Aspremont and Gerard-Varet (1979) for a similar solution in the context of revelation of preferences for public goods.
[22] See also Cremer and McLean (1985) who worked with a bidding model.
[23] For a model in a context of symmetric ex ante information, see Mookherjee (1984).

bribes and kickbacks. At the same time, bureaucrats compete to become rent granters. The social cost (deadweight loss) of these activities has to be considered when evaluating the benefits of regulation.

Tirole (1986) proposes a model of collusion where two agents (the regulatory agency and the firm), in a 3-level hierarchy, reach an agreement that is detrimental to the third agent (congress). This leads to additional inefficiencies because now congress has to give additional incentives to avoid the capture of the agency by the firm. According to Laffont and Tirole (1991), such a scheme would lead to lower social welfare levels, and would force the agency to choose a less powerful incentive scheme, yielding worse cost performance. Using a model of hidden information, Spiller (1990) looks at a regulatory problem where two principals, congress and the regulated industry, compete for "favors" by the regulatory agency. He proposes a testable hypothesis derived from his model: "…conditioned on a regulator quitting the commission, the probability of going to work (directly or indirectly) for the industry falls with the agency's budget during the regulator's last period at the agency" (p.88). His empirical analysis applied to the U.S. regulatory sector cannot reject the existence of this agency problem.

2.4 Empirical Studies of Regulation with Asymmetric Information

Many of these developments in the theoretical literature have not been accompanied by empirical studies that test or apply the models developed. Based on these studies, only a few have attempted the estimation of the underlying structural models.[24] Testing of the theory of incentives has been done mainly in insurance, financial, and labor markets. There have been few attempts to estimate structural models of regulation

[24] For a brief review see Salanié (1998).

on infrastructure-intensive industries where regulation plays a fundamental role. One of the first attempts is the work of Wolak (1994) on water utilities in California. He estimates production functions taking into account the presence of private information. Using a non-nested test, he finds that a model where only the distribution of the private information is observable by the regulator is superior to one with no private information. The major effect he finds is a welfare loss to consumers due to reduced output under asymmetric information. Another study by Dalen and Gomez-Lobo (1997) estimates cost functions that include both a moral hazard and adverse selection variable for the Norwegian bus transport industry. Assuming a non sophisticated regulator, they show that traditional cost function estimates may produce biased results, which provides a possible explanation to overestimated scale economies in regulated industries. Thomas (1995) tries to explain the joint use of emission taxes and individual contracts to regulate pollution using data from a French water agency. He postulates that individual contracts to most efficient firms can improve performance when the effluents are not perfectly observed by the regulator, which is the case where the regulator cannot use an optimal tax. His estimations allow him to sort different industries according to their abatement efficiency and to find that actual pollution taxes are only 50% of the Pigouvian level.

2.5 Classification of Current Regulatory Mechanisms

Laffont and Tirole (1986) suggest that current incentive schemes can be classified into two groups: those that allow public transfers and those that do not.[25] These transfers are more common in public enterprises, but are also present in private ones as different

[25] This is not a theoretical issue but rather a political one that regulators face when trying to implement a regulatory scheme.

forms of subsidies. Nevertheless, from a theoretical perspective, these authors suggest that there is no significant difference in modeling with or without transfers.[26] Another pattern used to classify incentive schemes is their incentive power. This is understood as the degree of association between the performance of the firm and the compensation it gets. So, for example, with respect to cost efficiency, if the compensation a firm receives is fixed and relatively independent of the firm's action, then it will have a high powered incentive to reduce costs because there will be a direct relation between the effort exerted and its performance. An example of a low powered scheme is a cost-of-service regulation where compensation is designed to cover the total cost. A rate-of-return regulation would be an intermediate power plan because usually the price adjustment is lagged allowing the firm to obtain part of the gains of improving performance. Price caps are usually seen as high powered because the firm will get most of the short run gains from reducing costs.[27]

My work will extend previous studies by considering the effect of regulation on quality and the possibility of an imperfect regulator. Also, the regulatory setup that I propose differs fundamentally from the ones considered by the studies of Laffont and Tirole (1986; 1993), because in one case the regulation involves investment control (as is essentially the case with a rate-of-return regulation) and the other allows for direct transfers from the regulator. The next section presents a review of the available literature devoted to the Chilean Electricity Industry.

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[26] The results will be different since in the latter case the shadow price depends on the marginal cost of the firm and managerial compensation. (See Laffont and Tirole, 1993).

[27] Typical implementations adjust prices using (*RPI* – *X*) where *RPI* represents the retail price index and *X* represents a rate of technological change.

2.6 Literature on the Chilean Electricity Industry

The aim of most of the literature on the Chilean electricity industry is to describe the system and its evolution, analyze the actual system and its privatization process, and investigate outages and the recent crises of the system. Because privatization in Chile was done early in the era of privatization, some studies in the literature offer lessons for other countries (see Hachette and Luders, 1993; and Luders, 2000). Some studies discuss more closely the link between privatization and regulation (see Bitrán and Saéz, 1994; Bitrán and Serra, 1994; 1998; Chumacero, Paredes and Sánchez, 2000; Laffont and Tirole, 1986). Much of this discussion focuses on the requirements of a regulatory body to handle the recently privatized industries. One conclusion derived from this literature is that the privatization process brought increased efficiency. But it is not apparent who the beneficiaries of this gain were. Moreover, according to Bitrán and Serra (1998), because the information available to regulators is limited, these benefits where only transmitted to consumers when competition was present. According to Muñoz (1992), this is explained, in part, by the lack of an adequate regulatory body before and after privatization took place. As a result, interest groups could affect their own regulatory framework.

The official description of the electricity system can be found in CNE (1996), but an earlier work by Bernstein (1998) gives a first-hand description of how it was designed and what are the economic principles behind the system.[28] Other studies criticize the policies that were implemented and outline the lessons from regulation of the Chilean electric system.[29] Among the most common problems mentioned are the lack of independence and freedom of choice of the regulatory agency, which makes it prone to

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[28] Also see Jadresic (1999) for an update on the policies that were implemented.

[29] See, for example, Blanlot (1992), Cano (1997), Basañes, Saavedra and Soto (1999) and Soto (1999) for an institutional perspective.

capture and political influence. Also, the lack of resources and the resulting asymmetry of information impede an adequate job by the regulator. Another criticism is that the policy caused increased costs due to regulation and resolution of conflicts. In particular, Paredes (no date) suggests that efficiency gains from privatization are about the same as the costs of regulation for electricity distribution.

Some studies present a comparison of the Chilean experience with that of other countries. Spiller and Martorell (1996) contrast the relative success of Chile in its privatization process with other South American countries.[30] They suggest that the main difference stems from the creation of regulatory institutions previous to divestiture.

Galal, et al. (1994) is one of the few studies that attempts an empirical evaluation of the welfare effects of divestiture of some of the generation and distribution companies in Chile. In the case of the main distribution company, they find that consumers and shareholders were made better-off, but taxpayers and government ended up worse-off with the divestiture process.

A few studies have focused on specific segments of the electricity sector. Beyer (1988) looks at the privatization of the major distribution company of the country and concludes that there is not enough evidence to support or reject its privatization. Soto (1998) analyzes the problem of pricing in the transmission system.[31] Halabí (2000) uses a stochastic efficiency frontier approach to estimate efficiency measures and other parameters for the hydroelectric generation industry. She finds minor increases in productivity and the existence of market power in the generation segment of the market.

[30] For a more recent comparison with other Latin American countries, see Hennemeyer (1999). Also see Rudnik (1997) who compares regulatory laws and institutions in Chile, Peru and Venezuela.

[31] See also Díaz and Soto (1999) who examine open access issues in the transmission and distribution segments.

Rozas (1999a) examines consumer rights from a legal perspective and concludes that, even after the new law of 1998 (Decreto Supremo N° 327, Ministerio de Minería, Septiembre de 1998), the right of consumers to receive adequate quality of service is not guaranteed. This would mean that distribution companies are not fully subjected to consumer's complaints and, therefore, a gap may exist between the quality provided and that desired with the consequent loss of welfare. If this is true, the burden of quality control relies mainly on the regulator's decisions.

More recent discussion has centered on the outages of 1998-1999 in Chile by trying to explain and extract lessons from the crises (see Bernstein, 1999; Díaz, Galetovic and Soto, 2000; and Rozas, 1999b). A few studies that discuss the use of outage cost in the pricing system.[32] Little work has been done on the impact of privatization and deregulation of the electric power sector on the environment.[33]

Westley (1992) compares different studies of econometric estimation of electricity demands in Latin America and the U.S. He defines a minimal set of standards necessary for a demand study to be considered acceptable. Unfortunately, only a few studies meet these standards and none of them are for Chile.[34]

2.7 Conclusions to Chapter 2

After reviewing this literature, it is clear that there have been only a few attempts to evaluate the performance of the regulatory system since the Chilean privatization

[32] Serra and Fierro (1997) present the empirical estimation of outage costs. Bernstein and Agurto (1992) present the methodology used by the regulator to include outage costs in the pricing system. Serra (1997) proposes a pricing system based on the Chilean model, but with voluntary reductions in consumption in the presence of outages.

[33] For a description of the problem, see Blum (1996). A seminar by CEPAL (Altomonte, 1999) presents the view of the agents involved in the problem.

[34] A more detailed review of the econometric estimation of electricity demand functions is presented in section 5.2 of Chapter 5.

process. These attempts have been rather limited in scope and have mainly focused on the advantages of privatization. The studies with more analytic content that have examined the regulatory process have done it without (explicitly) using economic models or econometric estimation. The studies on the distribution segment have also been mainly descriptive, very limited in scope, or focused on estimating benefits from privatization. Though the diagnostics done by some of these studies are consistent with the general framework of this dissertation, no solid evidence is presented to support their statements.

The main questions that remain unanswered by this literature are as follows. What is the effect of having a regulator that is biased in its preferences? How significant are the asymmetries of information in the regulatory outcome? How have regulated prices been linked in practice to the quality of the service provided? These are some of the questions addressed in following chapters.

3 THE MODELS

3.1 Introduction

In this chapter, I develop regulation models that use the stylized facts of the problem described in the previous chapter. The models developed here represent four basic situations that could be representative of a regulated monopolist. I have tried to capture two important issues that arise when regulating a monopolist. First, there is the problem of the number of instruments being used to regulate the firm. I consider this problem as one where the regulator sets a (maximum) price and possibly also a (minimum) quality in regulating the monopolist. That is, I consider two cases: one where price and quality are regulated and the other where only price is directly regulated. The latter case assumes that the regulator is aware that both quantity and quality affect consumer welfare, but for some exogenous reason does not use quality as a regulatory instrument. The reasons why this might be the case are many, varying from technical difficulties in implementing an index for quality, to the political viability of such an instrument. In many cases, quality might be observable but not necessarily enforceable, which would limit its use in a regulatory scheme. I do not consider the case where there are costs associated with the inclusion of an additional regulatory instrument such as quality.[35]

Second, I consider the problem of asymmetric information. In one case, both agents, the regulator and the firm, have access to all information. In the other case, the regulator has imperfect information about the costs of the firm. In the latter case, the

[35] An extension to this model would be to consider non-constant costs by, for example, having enforcement effort affecting the degree of compliance.

regulator only knows the cost function up to a parameter, sometimes called the efficiency parameter, which distinguishes firms according to their cost. Thus, two scenarios are used: one under symmetric information and the other under asymmetric information. As is common in the literature, it is assumed that the principal knows the distribution of the efficiency parameter.

Combining the number of instruments considered for regulation and the alternative informational structures gives rise to the four models to be developed.

3.2 Functions and Their Properties

I will first define the functions used in the models, establish their properties, and make assumptions about their curvature. I will use a gross willingness to pay function $V(p,s)$ where p and s are price and quality, respectively. The relationship between this function and the derived demand $Q(p,s)$ is given by

$$V(p,s) = \int_p^{\infty} Q(\tilde{p},s)d\tilde{p} + pQ(p,s).$$

It should be noted that $Q(p,s)$ represents the total amount consumed in the market. Thus $V(p,s)$ is an aggregated function. The demand function is assumed to be thrice differentiable with

$$Q(p,s) > 0, \quad (3.2.1)$$

$$Q_p(p,s) < 0, \quad (3.2.2)$$

$$Q_s(p,s) > 0, \quad (3.2.3)$$

$$Q_{ss}(p,s) < 0, \quad (3.2.4)$$

where, as usual, $Q_i(.)$ represents the derivative of the function with respect to variable i. Note that, without loss of generality, a higher quality increases the amount demanded, according to assumption (3.2.3), and at a decreasing rate, according to assumption (3.2.4). These two assumptions imply decreasing marginal willingness to pay for quality, as is evident from

$$V_{ss} = \int_p^\infty Q_s(\tilde{p}, s)d\tilde{p} + pQ_{ss} \tag{3.2.5}$$

I also assume weak complementarity between the consumption of electricity and its quality (Mäler, 1974), which rules out changes in welfare due to changes in quality when $Q = 0$.

Consumer surplus, $K(p,s,T) = V(p,s) - p \cdot Q - T$, can then be defined as [36]

$$K(p,s,T) = \int_p^\infty Q(\tilde{p}, s)d\tilde{p} - T$$

where T represents a fixed transfer payment independent of the quality or quantity consumed. Conditions (3.2.1) and (3.2.2) assure standard assumptions applicable to consumer surplus: $K_p = -Q < 0$ and $K_{pp} = -Q_p > 0$.

The cost function $C(q,s,\theta)$ represents the minimum cost of producing q units with a quality level of $s \geq 0$ for a firm of type θ. To represent the problem in the context of an electricity market, q is taken by the firm as determined by consumers in response to the firm's actions. Each consumer at each point in time determines how much to consume depending on the price and quality, $Q(p,s)$. Depending on the case, quality (s) may or may not be chosen by the firm. The role of θ is explained further in the asymmetric information section, but is assumed exogenous to the firm. The cost function is assumed to be thrice differentiable, convex in (p,s), and to have the following curvature properties:

$$C_q(q,s,\theta) > 0, \tag{3.2.6}$$

[36] I use the term "consumer surplus" to fix ideas, but the expression can also represent compensating or equivalent variation since the income or utility level is suppressed from notation.

$$C_s(q,s,\boldsymbol{\theta}) > 0, \tag{3.2.7}$$

$$C_{qq}(q,s,\boldsymbol{\theta}) > 0, \tag{3.2.8}$$

$$C_{ss}(q,s,\boldsymbol{\theta}) > 0, \tag{3.2.9}$$

$$C_{qs}(q,s,\boldsymbol{\theta}) > 0, \tag{3.2.10}$$

$$C_{\theta}(q,s,\boldsymbol{\theta}) > 0. \tag{3.2.11}$$

Assumptions (3.2.7) and (3.2.8) assume cost is increasing in both quantity and quality. Assumptions (3.2.9) and (3.2.10) are imposed by convexity of the cost function in (q,s). Assumption (3.2.10) presumes that marginal cost is increasing in quality, which is very likely in the electricity industry because reliability, for example, is known to require additional investments and increased operational costs. Assumption (3.2.11) is arbitrary and could be set in the opposite direction without loss of generality. This condition only plays a role in the asymmetric information models.

In the following two sections, I present two models of regulation under symmetric information. The first considers the case of price and quality regulation and the second considers the case of price-only regulation. The general setting is one where there is a regulator who fixes the level of the regulatory instrument, then a firm chooses the level of the remaining variables to maximize its profit, and then consumers decide the amount consumed depending on price and quality. In the first case, the regulator sets price and quality, and then consumers decide quantity given price and quality. Here the firm maximizes profit only by minimizing its cost of producing a given quantity and quality. In the second case, the regulator sets only the price, then the firm decides on a profit-maximizing quality, and then consumers decide upon the quantity.

The price set by the regulator takes the form of a two part tariff composed of the per unit price p and the fixed transfer payment T. This type of pricing is commonplace in electricity and other services where fixed costs are significant. Because q was defined as the aggregate quantity, $p \cdot q + T$ represents total revenue collected by the firm where T is the total fixed transfer collected from all clients served by the firm.

The regulator is assumed to maximize a weighted sum of producer and consumer surplus where producer surplus is given by the firm's profit function,

$$\pi(p,s,T,\theta) = T + p\,Q(p,s) - C(Q(p,s),s,\theta). \qquad (3.2.12)$$

3.3 Price and Quality Regulation under Symmetric Information

Suppose the regulator chooses price, quality, and the transfer payment by solving

$$\max_{T,p,s} \quad W^*(p,s,T,\theta) = \alpha K(p,s,T) + (1-\alpha)\,\pi(p,s,T,\theta))$$

$$\text{s.t.:} \qquad K(p,s,T) \geq K_0,$$

$$\pi(p,s,T,\theta) \geq \pi_0.$$

where K_0 and π_0 represent reservation levels of surplus for consumers and producers, respectively, and are assumed to be nonnegative so that participation is voluntary; and θ is the efficiency parameter that in this case is assumed to be common knowledge.[37] Using the definitions of consumer and producer surplus, this objective function can be rewritten as

$$W^*(p,s,T,\theta) = \alpha V(p,s) - (1-\alpha)\,C(Q(p,s),s,\theta) + (1-2\alpha)(T+p\,Q(p,s)), \qquad (3.3.1)$$

and the constraints become

$$V(p,s) - p\,Q(p,s) - K_0 \geq \mathrm{T}, \qquad (3.3.2)$$

$$C(Q(p,s),s,\theta) - p\,Q(p,s) - \pi_0 \leq \mathrm{T}. \qquad (3.3.3)$$

[37] I use W^* so that W can be used later as a concentrated version of this function.

When the regulator has symmetric preferences for consumers and producers represented by $\alpha = 0.5$, T can be set to any value that satisfies the restrictions without affecting the optimum and, hence, the problem for the regulator becomes

$$\max_{p,s} \ \tfrac{1}{2}\,\{V(p,s) - C(Q(p,s),s,\theta)\},$$

for which first order conditions (FOC) and assumption (3.2.2) imply[38,39]

$$p = C_q, \tag{3.3.4}$$

$$K_s = C_s. \tag{3.3.5}$$

These conditions state the regular result that, under perfect information and in the absence of a "biased" regulator, quantity and quality will be set at a level where their social marginal benefits is equated to their social marginal costs.[40]

The second order conditions (SOC) for this problem are $W_{pp} < 0$, $W_{ss} < 0$, and $W_{pp}W_{ss} - (W_{ps})^2 > 0$ where

$$W(p,s,\theta) = V(p,s) - C(Q(p,s),s,\theta).$$

Upon substituting from FOC,

$$W_{pp} = Q_p - C_{qq}\, Q_p^{\,2},$$

$$W_{ss} = K_{ss} - C_{qq}\, Q_s^{\,2} - 2\, C_{qs}Q_s - C_{ss},$$

$$W_{ps} = -\, C_{qq}Q_pQ_s - C_{qs}Q_p.$$

These conditions are met by assumptions (3.2.2)-(3.2.4) and (3.2.6)-(3.2.10). By the definition of consumer surplus and assumptions (3.2.3) and (3.2.4),

$$K_s(p,s,T) = \int_p^{\infty} Q_s(\tilde{p},s)\,d\tilde{p} > 0\,,$$

$$K_{ss}(p,s,T) = \int_p^{\infty} Q_{ss}(\tilde{p},s)\,d\tilde{p} < 0\,.$$

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[38] Note that in these expressions the arguments of the functions have been omitted to save space.

[39] The FOC with respect to quality implies $V_s = C_qQ_s + C_s$, which after replacing the left hand side with $V_s = K_s + pQ_s$, and upon substitution of (3.3.4) yields (3.3.5).

[40] Enforcement of regulations is assumed to be costless.

Note that these assumptions do not impose a specific sign on V_{ps}.

Once p and s have been chosen according to the FOC, T can take any value that satisfies

$$V(p^1,s^1) - p^1Q(p^1,s^1) - K_0 \geq T \geq C(Q(p^1,s^1),s^1,\theta) - p^1\, Q(p^1,s^1) - \pi_0,$$

where p^1 and s^1 represent the optimal price and quality, respectively. Any such T satisfies the reservation value constraints.

The case where the regulator favors consumers is represented by $\alpha > 0.5$ and $(1 - 2\alpha) < 0$. Because the first two terms of (3.3.1) are independent of T, the regulator chooses the minimum T allowed by the restrictions. Therefore, the transfer is given by

$$T = C(Q(p,s),s,\theta) - pQ(p,s) - \pi_0, \tag{3.3.6}$$

which means that producer surplus will be set at the reservation level by the regulator. Replacing the value of T in (3.3.1) the regulator's problem can thus be restated as

$$\max_{p,s}\ \alpha\,\{V(p,s) - C(Q(p,s),s,\theta)\} - (1 - 2\alpha)\pi_0,$$

where (3.3.2) is not binding assuming a feasible solution exists, and (3.3.3) is binding and thus imposed by substitution in the objective function. This problem is equivalent, aside from a multiplicative constant, to the problem where $\alpha = 0.5$. Thus, the solution is the same except for T, which in this case is given by

$$T = C(Q(p^1,s^1),s^1,\theta) - p^1Q(p^1,s^1) - \pi_0.$$

If the regulator favors producers, then $\alpha < 0.5$ and $(1- 2\alpha) > 0$. Therefore the regulator chooses the maximum T allowed by the restrictions. Therefore, the transfer is given by

$$T = V(p,s) - pQ(p,s) - K_0, \tag{3.3.7}$$

which means that consumer surplus will be set at the reservation level by the regulator. Replacing this value of T in (3.3.1), the regulator's problem can be restated as

$$\max_{p,s}\ (1-\alpha)\{V(p,s) - C(Q(p,s),s,\theta)\} - (1-2\alpha)K_0,$$

where (3.3.3) is not binding assuming a feasible solution exists, and (3.3.2) is binding and thus imposed by substitution in the objective function. This problem obviously has the same first- and second-order conditions as the case where $\alpha \geq 0.5$ aside from a multiplicative constant. Once p and s have been chosen according to (3.3.4) and (3.3.5), T is set so that

$$T = V(p^1,s^1) - p^1\, Q(p^1,s^1) - K_0.$$

In this model, α, which reflects the preference or "bias" of the regulator, does not have a distorting effect on the outcome. The "first best" is reached independent of regulator bias. The difference is in the distribution, which is affected in extremes depending on the direction of bias. Thus, I have shown how, under perfect information with the use of two instruments, regulatory bias does not affect the efficiency of the outcome, but only the allocation of surplus within the bounds set by reservation values.

3.4 Price Regulation under Symmetric Information

In the case where the regulator only sets the price, a monopolist chooses the quality level to maximize profits given price, type (θ), and the size of transfer payment. I start with the problem of the monopolist who takes as given the price set by the regulator. Later I solve the problem where the regulator considers the optimal response function of the monopolist. The problem for the firm is

$$\max_s\ \pi(s;p,T,\theta). \tag{3.4.1}$$

The FOC for this problem is

$$\pi_s = p\, Q_s - (C_q\, Q_s + C_s) = 0. \tag{3.4.2}$$

This means that the firm will set quality so that marginal revenue equates to the marginal cost of providing an additional unit of quality, which is composed of the direct cost of providing quality and the indirect cost due to the change in quantity demanded. The SOC is given by

$$\pi_{ss} = p\, Q_{ss} - (C_{qq}\, Q_s^2 + C_q\, Q_{ss} + 2\, C_{qs}\, Q_s + C_{ss}) < 0, \tag{3.4.3}$$

and is met under the convexity of the cost function and assumption (3.2.4) because $p - C_q > 0$. Thus, define the firm's profit function as $\pi^*(p,T,\theta) = max_s\, \pi(s;p,T,\theta)$.

A comparative static analysis can be used to find the effect of the regulated price on the quality chosen by the firm. From (3.4.2), we have

$$S_p = \frac{ds}{dp} = -\frac{\pi_{sp}}{\pi_{ss}} \tag{3.4.4}$$

where $\pi_{sp} = Q_s + (p - C_q)Q_{ps} - C_{qq}Q_pQ_s - C_{qs}Q_p$. Using the FOC, this implies that if $Q_{ps} > 0$ then $S_p > 0$, or more generally, that $S_p <$ (>) 0 as $Q_{ps} <$ (>) $(C_{qq}Q_pQ_s + C_{qs}Q_p - Q_s)/(p - C_q)$. The former means that if demand is such that increasing quality has a positive effect on the marginal amount demanded, then the quality chosen by the monopolist is increasing in the price set by the regulator.

Next, let

$$S(p,\theta) = \text{argmax}_s\, \pi(s;p,T,\theta) \tag{3.4.5}$$

represent the monopolist's optimal choice in (3.4.1) and consider the regulator's problem if the regulator knows that the monopolist uses this rule. Replacing quality with the monopolist's choice function for quality, the regulator's problem becomes

$$\max_{T,p}\ \alpha K(p,S,T) + (1 - \alpha)\, \pi(p,S,T,\theta) \tag{3.4.6}$$

$$\text{s.t.: } K(p,S,T) \geq K_0,\ \pi(p,S,T,\theta) \geq \pi_0,$$

where the arguments of $S(p,\theta)$ are suppressed for ease of notation, and K_0 and π_0 again represent reservation levels of surplus for consumers and producers, respectively. Alternatively, using the definition of $K(.)$ and $\pi(.)$, the regulator's problem can be expressed as

$$\max_{T,p}\ \alpha V(p,S) - (1-\alpha)\, C(Q(p,S),S,\theta) + (1-2\alpha)(T + p\, Q(p,S))$$

$$\text{s.t.:}\quad V(p,S) - pQ(p,S) - K_0 \geq T \tag{3.4.7}$$

$$C(Q(p,S),S,\theta) - p\,Q(p,S) - \pi_0 \leq T. \tag{3.4.8}$$

Again with symmetric regulator preferences, $\alpha = 0.5$, T can be set to any value that satisfies the restrictions without affecting the optimum. The problem for the regulator becomes

$$\max_p\ \tfrac{1}{2}\{V(p,S) - C(Q(p,S),S,\theta)\}, \tag{3.4.9}$$

for which the FOC together with (3.4.2) implies

$$(p - C_q)\, Q_p + K_s S_p = 0, \tag{3.4.10}$$

and the SOC requires

$$Q_p + (p - C_q)(Q_{pp} + Q_{ps}S_p) - Q_p(C_{qq}(Q_p + Q_sS_p) + C_{qs}S_p) + K_{ps}S_p + K_{ss}S_p^2 + K_sS_{pp} < 0.$$

This condition is assumed to hold so that $W(p,S,\theta) = V(p,S) - C(Q(p,S),S,\theta)$ is concave in p.[41]

Once p has been chosen according to (3.4.10), T can take any value that satisfies

$$V(p^2,s^2) - p^2\, Q(p^2,s^2) - K_0 \geq T \geq C(Q(p^2,s^2),s^2,\theta) - p^2\, Q(p^2,s^2) - \pi_0,$$

where p^2 and $s^2 \equiv S(p^2,\theta)$ represent the equilibrium price and quality for this case.

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[41] In the standard monopoly pricing problem, where $\pi = pQ(p) - C(Q(p))$, the FOC is $Q + (p - C_q)Q_p = 0$ and the SOC is $(p - C_q)Q_{pp} + 2Q_p - C_{qq}Q_p^2 < 0$. That is, the standard monopoly problem requires $Q_{pp} < (C_{qq}Q_p^2 - 2Q_p)/(p - C_q)$. Thus, Q_{pp} can be either positive or negative but within limits that depend on the properties of both demand and cost. Just as the standard monopoly pricing literature does not find careful scrutiny of these conditions fruitful, neither is careful scrutiny of the SOC in this problem interesting other than to determine a condition that excludes nonsensical cases. The parallel requirement in this problem is $Q_{pp} + Q_{ps}S_p < [Q_p(C_{qq}(Q_p + Q_sS_p) + C_{qs}S_p) - Q_p - K_{ps}S_p - K_{ss}S_p^2 - K_sS_{pp}]\ /(p - C_q) < 0$, which is an equivalent condition after concentrating the problem in p.

If the regulator's preferences favor consumers, then $\alpha > 0.5$ and $(1 - 2\alpha) < 0$ implies that the regulator will choose the minimum T within the limits allowed by the restrictions, which in turn implies that the transfer will be $T = C(Q(p,S),S,\theta) - pQ(p,S) - \pi_0$. Thus, producer surplus will be set at the reservation level by the regulator. The regulator's problem for this case can then be restated as

$$\max_p \; \alpha\,(V(p,S) - C(Q(p,S),S,\theta)) - (1 - 2\alpha)\pi_0,$$

where (3.4.7) is not binding and (3.4.8) is imposed by substitution in the objective function. Because the FOC of this problem is the same as for the previous problem, *i.e.*, (3.4.10) applies, the optimal solution will be the same except for T, which is now given by

$$T = C(Q(p^2,s^2),s^2,\theta) - p^2Q(p^2,s^2) - \pi_0.$$

If the regulator's preferences favor producers, then $\alpha < 0.5$ and $(1 - 2\alpha) > 0$ implies that the regulator will choose the minimum T allowed by the restrictions. Therefore, the transfer will be $T = V(p,S) - pQ(p,S) - K_0$. Thus, consumer surplus will be set at the reservation level by the regulator. The regulator's problem for this case can then be restated as

$$\max_p \; (1-\alpha)\,(V(p,S) - C(Q(p,S),S,\theta)) - (1-2\alpha)K_0,$$

where (3.4.8) is not binding and (3.4.7) is imposed by substitution in the objective function. Again, because the FOC of this problem is the same as (3.4.9), the optimal solution will be the same except for T, which is now given by

$$T = V(p^2,s^2) - p^2\,Q(p^2,s^2) - K_0.$$

From (3.4.2), if only price is regulated, then quality is chosen by equating its marginal cost to its marginal private benefit (which is measured by marginal revenue,

pQ_s). This is in contrast with price and quality regulation where using (3.3.5), replacing with $C_s = V_s - pQ_s$ and using (3.3.4), yields $V_s = C_qQ_s + C_s$, which implies that marginal cost is equated to the marginal willingness to pay for quality.

In both cases the marginal cost of providing quality has not only a direct effect but also an indirect effect that works through the change in quantity. Also, when only price is regulated, it is determined by (3.4.10). Compared to the rule used when both price and quality are regulated, $(p - C_q)\, Q_p = 0$, it is clear that price will not equate to marginal cost unless price has no effect on quality or quality has no effect on consumer surplus, which are uninteresting cases.

Comparing price and quality regulation with price-only regulation, it is possible to identify three outcomes depending on the signs of S_p and

$$C_{qp} = \frac{dC_q}{dp} = C_{qq}Q_p + \left(C_{qq}Q_s + C_{qs}\right)S_p\,, \tag{3.4.11}$$

the latter of which can be obtained by a comparative static analysis of equilibrium marginal cost under price-only regulation. This expression states that the impact of a change in price on marginal cost can be decomposed into the impact it has through a change in quantity ($C_{qq}Q_p$) and the impact it has through quality ($C_{qq}\,(Q_s + C_{qs})S_p$). Because $S_p < 0$ implies $C_{qp} < 0$, (3.4.10) and (3.3.4) imply that $p^1 > p^2$, which then translates into $s^1 < s^2$ and $q^1 < q^2$ where $q^i \equiv Q(p^i,s^i)$ and, as above, x^i represents the outcome in case i ($i = 1$ for price-quality regulation and $i = 2$ for price-only regulation). If $S_p > 0$ and $C_{qp} < 0$, then $p^1 < p^2$, which in this case implies that $s^1 < s^2$. If also $S_p > 0$ and $C_{qp} > 0$, then $p^1 > p^2$, which implies that $s^1 > s^2$. Table 3.1 indicates which of the two types of regulations, price-quality or price-only, have higher prices, quality, and quantity in equilibrium contingent on the signs of S_p and C_{qp}. Price and quality are lower with price-only regulation unless $S_p > 0$ and $C_{qp} < 0$, in which case the opposite is true. That is, price and quality are lower with price-only regulation when $-C_{qq}Q_p > S_p\ (C_{qq}\ Q_s + C_{qs})$, i.e., when the negative of the impact of price on cost through quantity is greater than the impact of price on cost through quality.

Table 3.1. Main Results From Symmetric Information Regulation[a]

Sign of S_p	Sign of C_{qp}	Highest Price	Highest Quality	Highest Quantity
$S_p > 0$	$C_{qp} > 0$	P&Q reg.	P&Q reg.	Indeterminate
$S_p > 0$	$C_{qp} < 0$	P-only reg.	P-only reg.	Indeterminate
$S_p < 0$	$C_{qp} < 0$	P&Q reg.	P-only reg.	P-only reg.

[a] "P&Q reg." means price and quality regulation; "P-only reg." means price only regulation; "Indeterminate" means quantity is not clearly higher in either of the two types of regulations

3.5 Conclusions for Regulation with Symmetric Information

From the analysis of the price and quality regulatory problem under symmetric information I find that, independent of the number of instruments available for regulation, having a "biased" regulator does not affect the efficiency of the outcome. That is, it does not matter whether the regulator can set price and quality or only price. Efficiency will be the same irrespective of the bias of the regulator. Therefore with symmetric information, the preference of the regulator does not affect the efficiency of the outcome, but only the distribution of surplus between consumers and producer.

I have also shown that it is theoretically possible for a regulator to achieve the first best when it has the ability to set price and quality under symmetric information. This is achieved by setting price equal to the marginal cost and setting quality so that the marginal benefit of quality is equal to its marginal cost, as in equations (3.3.4) and (3.3.5). This is no longer the case when the regulator can only set price and quality is chosen instead by the monopolist. The regulator's inability to set quality leads to an inefficient outcome. Moreover, price and quality will be lower with price-only regulation unless the negative of the impact of price on cost through quantity is greater than the impact of price on cost through quality, as implied by equation (3.4.11).

3.6 Price and Quality Regulation under Asymmetric Information

The models developed in this section and the next follow the mechanism design literature and assume that the cost function is perfectly known by the firm but is known by the regulator only up to an efficiency parameter (θ).

The methodology first defines the requirement for an implementable decision, and then incorporates the individual rationality (IR) constraint in the objective function to search for an optimal mechanism (see Guesnerie and Laffont, 1984; or Mirrlees, 1971). I first analyze the case of joint price and quality regulation. The next section considers the case of price-only regulation.

In addition to function properties assumed in the previous sections, I make the following assumptions.

Assumption 1. The regulator only knows the distribution of θ, represented by $F(\theta)$ on support $\theta \in [\theta_0, \theta_1]$. The associated (prior) density function, $f(\theta)$, is assumed to be differentiable and have $f(\theta_0) > 0$.

Assumption 2. $C_{q\theta} > 0$ and $C_{s\theta} > 0$ $\forall$ q, s, and θ.

Assumption 3. Reservation utility is independent of type: $\bar{\pi}(\theta) \equiv \bar{\pi}$.

Assumption 4. $C_\theta(Q(p,s),s,\theta)$ is convex in (p,s).

Assumption 5. $C_{\theta\theta\theta} \geq 0$, $C_{\theta s\theta} \geq 0$, and $W_{ps} \leq - W_{pp}Q_s$.[42]

Assumption 6. $F(\theta)f'(\theta)\big/ f(\theta)^2 \leq 1$.

Assumption 7. $\pi^*_{p\theta} \geq 0,\ \pi^*_{p\theta\theta} \leq 0,\ \pi^*_{pp\theta} \leq 0$.

This set of assumptions guarantee that the problems are well defined and that a solution exists in each case. Assumption 1 reduces the problem of asymmetric information to one where there is only uncertainty about the exact realization of the firm's type, and not about the distribution of types. This assumption is standard in the mechanism design literature (Mirrlees, 1971; Mussa and Rosen, 1978). Assumption 2 states that the marginal cost of output and marginal cost of quality are increasing with type. In other words, as a firm is less efficient, its marginal costs increase. Assumption 3 is standard in the mechanism design literature and is an appropriate assumption for the electricity sector.[43] Assumptions 4 to 7 are sufficient but not necessary conditions that guarantee SOC. Extreme behavior would likely be observed if they fail. Assumption 4 requires the marginal effect of type on the cost function is convex in price and quality. Assumption 5 imposes specific signs on third order derivatives of the cost function. Assumption 6 is standard in the mechanism design literature and distributions as general as the Beta distribution will meet this condition. This means that the distribution of firm types could be uniform, or concentrated at one end or the other of the distribution, or have a central concentration. Assumption 7 requires the marginal effect of price on the profit function is non-decreasing in type.

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[42] Note that this condition amounts to having $V_{ps} - C_{qs} < - z(\alpha)F(\theta)/f(\theta)C_{\theta qs}$ which is satisfied when $V_{ps} \leq 0$, $C_{qs} \geq 0$ and $C_{\theta qs} \leq 0$ (or if $C_{\theta qs}$ is very small).

[43] The reservation utility may be dependent on size, e.g., on the number of clients, but not on intrinsic efficiency of the firm. Since this condition is necessary for voluntary participation, it is relevant at the ex ante decision where the firm may not yet know its type.

3.6.1 Implementable Decisions with Price and Quality Regulation

By definition, the price and quality (p, s) set by the regulator are implementable decisions if there exists a transfer (T) such that the allocation $(p(\theta), s(\theta), T(\theta))$ satisfies the incentive compatibility (IC) constraint,

$$\pi(p(\theta),s(\theta),T(\theta),\theta) \geq \pi(p(\theta^*),s(\theta^*),T(\theta^*),\theta) \text{ for all } (\theta,\theta^*) \in [\theta_0,\theta_1] \times [\theta_0,\theta_1]. \quad (3.6.1)$$

If $p(\theta)$ and $s(\theta)$ are piecewise continuously differentiable, a necessary condition for them to be implementable is that[44]

$$\frac{\partial}{\partial\theta}\left(\frac{\pi_p}{\pi_T}\right)\frac{dp}{d\theta}+\frac{\partial}{\partial\theta}\left(\frac{\pi_s}{\pi_T}\right)\frac{ds}{d\theta}\geq 0\,. \quad (3.6.2)$$

Because $\pi(p,s,T,\theta) \equiv pq(p,s) - C(Q(p,s),s),\theta) + T$, it follows that $\pi_T = 1$. Therefore (3.6.2) can be rewritten as

$$\pi_{p\theta}\, dp/d\theta + \pi_{s\theta}\, ds/d\theta \geq 0. \quad (3.6.3)$$

If $p(\theta)$ is non-decreasing and $s(\theta)$ is non-increasing (monotonicity), condition (3.6.3) is met under Assumption 2, which guarantees that $\pi_{p\theta} > 0$ and $\pi_{s\theta} < 0$. In this case, the single-crossing condition applies to the two-dimensional decision space for (p,s).[45] The intuitive interpretation of this condition is that the marginal rate of substitution between each decision and the transfer is affected in a systematic way by the firm's type.

Following Guesnerie and Laffont (1984), a sufficient condition for implementability is reached under the single-crossing condition and a boundary behavior condition,

$$\forall\, k = (p, s)\ \exists\, K_0 \text{ and } K_1 \text{ such that } \left|\frac{\partial\pi/\partial k}{\partial\pi/\partial T}\right| \leq K_0 + K_1\left|T\right| \text{ uniformly over } p, s, T \text{ and } \theta,$$

[44] The proof of this result is given by Fudenberg and Tirole (1991).

[45] This condition is also known as the constant sign or Spence-Mirrlees condition. In the case here, it takes a slightly unusual form, but transforming quality into $-s$, yields the usual form.

that guarantees existence of a solution to a differential equation. Intuitively, this means that the marginal rate of substitution between the price and the transfer, and between quality and the transfer, does not increase too fast when the transfer increases. This condition is trivially met because $\boldsymbol{\pi}(p,s,T,\boldsymbol{\theta})$ is linear and additive in T.

3.6.2 Optimal Mechanism Design with Price and Quality Regulation

A feasible mechanism is one that is implementable and satisfies the individual rationality (IR) condition. To incorporate this constraint, a regular assumption in the literature is that the reservation utility is independent of type (Assumption 3). This makes the IR condition take the following form,

$$\pi\left(p(\theta),s(\theta),T(\theta),\theta\right)\geq\bar{\pi}\qquad\forall\theta\in\left[\theta_0,\theta_1\right],\tag{3.6.4}$$

where $\bar{\pi}$ represents the reservation utility of the firm, which is the analog of $\boldsymbol{\pi}_0$ of the previous section.

The firm's profit function in (3.2.12) is linear in T and thrice differentiable Again the regulator's objective function is given by

$$W^*(p,s,T,\boldsymbol{\theta}) = \boldsymbol{\alpha}\,K(p,s,T) + (1-\boldsymbol{\alpha})\,\pi(p,s,T,\boldsymbol{\theta}),$$

which after substituting the definitions of consumer and producer surplus yields (3.3.1), which is also linear in T.

The regulator's maximization problem is then to $max_{p,s,T}\,E_{\boldsymbol{\theta}}\{W^*(p,s,T,\boldsymbol{\theta})\}$ subject to monotonicity and the IR condition in equation (3.6.4). For the models with incomplete information, I am only concerned with cases where $\boldsymbol{\alpha} \geq ½$, thus ensuring a nonnegative consumer surplus for any outcome. From the assumption of an independent-of-type reservation utility (Assumption 3) and (3.6.4), IR must be satisfied only at $\boldsymbol{\theta} = \boldsymbol{\theta}_l$ and will bind only at this point. Therefore, the IR condition can be reduced to:

$$\pi\left(p(\theta_1),s(\theta_1),T(\theta_1),\theta_1\right)=\bar{\pi}\ . \tag{3.6.5}$$

From (3.2.12), $T = \pi(p,s,T,\theta) - pQ + C(Q,s,\theta)$. Thus, the regulator's objective function for known θ can be rewritten as

$$W^*(p,s,T,\theta) = \alpha V(p,s) - (1-\alpha)\, C(Q,s,\theta) + (1-2\alpha)\,(\pi(p,s,T,\theta) + C(Q,s,\theta))$$
$$= \alpha\,(V(p,s) - C(Q,s,\theta)) + (1-2\alpha)\, \pi(p,s,T,\theta). \tag{3.6.6}$$

Following Mirrlees (1971), the envelope theorem and the IR condition in equation (3.6.5) yield a producer surplus function independent of the transfer,

$$\pi^{**}\left(p(\theta),s(\theta),\theta\right)=\bar{\pi}+\int_{\theta}^{\theta_1} C^*_{\tilde{\theta}}(\tilde{\theta})d\tilde{\theta} \tag{3.6.7}$$

where $C^*(\theta)\equiv C\left(Q\left(p(\theta),s(\theta)\right),s(\theta),\theta\right)$.[46]

To consider the case where the regulator has only statistical rather than specific knowledge about firm efficiency, substituting (3.6.7) into the regulator's objective function (3.6.6), and taking expectations with respect to the distribution of efficiency, obtains the true regulator's maximization problem,

$$\max_{p(\cdot),s(\cdot)} \int_{\theta_0}^{\theta_1}\{\alpha[V^*(\theta)-C^*(\theta)]+(1-2\alpha)[\bar{\pi}+\int_{\theta}^{\theta_1} C^*_{\tilde{\theta}}(\tilde{\theta})d\tilde{\theta}]\}dF(\theta)$$
$$\text{s.t.: } p(\theta_1)\geq p(\theta_2), \text{ and } s(\theta_1)\leq s(\theta_2)\ \forall\ \theta_1>\theta_2. \text{ (monotonicity)} \tag{3.6.8}$$

where $V^*(\theta)\equiv V(p(\theta),s(\theta))$.

Integrating by parts, the last term in the objective function becomes

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46 Note that $\pi^{**}(p(\theta),s(\theta),\theta)=max_{\hat{\theta}}\,\pi(p(\hat{\theta}),s(\hat{\theta}),T(\hat{\theta}),\theta)$ where θ and $\hat{\theta}$ represent the true and announced types, respectively. The FOC for this problem can then be replaced in the FOC of $max_{\theta}\,\pi(p(\theta),s(\theta),T(\theta),\theta)$, which after integration yields (3.6.7).

$$\int_{\theta_0}^{\theta_1}\left[\int_{\theta}^{\theta_1} C_\theta\left(Q\left(p(\tilde{\theta}),s(\tilde{\theta})\right),s(\tilde{\theta}),\tilde{\theta}\right)d\tilde{\theta}\right]dF(\theta)=\int_{\theta_0}^{\theta_1}\left[C^*(\theta_1)-C^*(\theta)\right]dF(\theta)$$
$$=-\int_{\theta_0}^{\theta_1} C^*(\theta)dF(\theta)+C^*(\theta_1)$$
$$=-C^*(\theta)F(\theta)\Big|_{\theta_0}^{\theta_1}+\int_{\theta_0}^{\theta_1} C_\theta^*(\theta)\frac{F(\theta)}{f(\theta)}dF(\theta)+C^*(\theta_1)$$
$$=\int_{\theta_0}^{\theta_1} C_\theta^*(\theta)\frac{F(\theta)}{f(\theta)}dF(\theta),$$

and thus the objective function of problem (3.6.8) becomes

$$E_\theta\left(\hat{W}(p,s,\theta)\right)=\int_{\theta_0}^{\theta_1}\left[\alpha\left(V(p,s)-C\left(Q,s,\theta\right)\right)+(1-2\alpha)\frac{F(\theta)}{f(\theta)}C_\theta\left(Q,s,\theta\right)\right]dF(\theta),$$

where the constant term has been eliminated for simplicity.

The problem can now be written as $\max_{p,s} E_\theta(\hat{W}(p,s,\theta))$ subject to monotonicity. To find the solution to this problem, I first find the solution to the problem without taking into account the monotonicity constraint, and then determine whether the solution satisfies the stated conditions in (3.6.8).

The solution to this relaxed program, as it is called in the mechanism design literature, can be found from the FOC, $\hat{W}_p=0$ and $\hat{W}_s=0$. Expanding and rearranging yields the conditions[47]

$$p=C_q-\frac{(1-2\alpha)}{\alpha}\frac{F(\theta)}{f(\theta)}C_{q\theta} \qquad \forall\,\theta\in[\theta_0,\theta_1]\text{, and} \tag{3.6.9}$$

$$K_s=C_s-\frac{(1-2\alpha)}{\alpha}\frac{F(\theta)}{f(\theta)}C_{s\theta} \qquad \forall\,\theta\in[\theta_0,\theta_1]. \tag{3.6.10}$$

Comparing these conditions with the ones obtained under symmetric information, (3.3.4) and (3.3.5), these are equivalent except for the second right-hand-terms. Under

[47] Note that $C_{s\theta}\equiv C_{s\theta}\left(Q(p,s),s,\theta\right)$ represents the partial derivative with respect to its second and third arguments and, hence, does not include the indirect effect of *s* through *Q*(*p*,*s*).

Assumption 2, these terms are negative for $\alpha > ½$. Thus, in contrast to (3.3.4) and (3.3.5), $p > C_q$ and $K_s > C_s$. Thus, if the regulator places more weight on consumers (as with a "biased" regulator), prices and qualities will be different under asymmetric information. But when the regulator places the same weight on consumers and producers ($\alpha = 0.5$), the results under asymmetric information are the same as under symmetric information.[48]

Note also that, when conditions (3.6.9) and (3.6.10) are evaluated at the most efficient type (θ_0), the symmetric information conditions in (3.3.4) and (3.3.5) are again reached because $F(\theta_0) = 0$. This result is known in the literature as "no distortion at the top." Note that the SOC hold by the concavity of $\hat{W}(p,s,\theta)$ in (p,s) and Assumption 4.

3.6.3 When is the Relaxed Program Legitimate for Price-Quality Regulation?

Under Assumptions 2 and 3, the monotonicity constraint can be ignored if $p(\theta)$ is non-decreasing and $s(\theta)$ is non-increasing. To check if the solution meets these conditions, total differentiation of the FOC in (3.6.9) and (3.6.10) yields

$$\frac{dp}{d\theta} = \frac{\hat{W}_{p\theta}\hat{W}_{ss} - \hat{W}_{s\theta}\hat{W}_{ps}}{(\hat{W}_{ps})^2 - \hat{W}_{ss}\hat{W}_{pp}} \tag{3.6.11}$$

and

$$\frac{ds}{d\theta} = \frac{\hat{W}_{s\theta}\hat{W}_{pp} - \hat{W}_{p\theta}\hat{W}_{ps}}{(\hat{W}_{ps})^2 - \hat{W}_{ss}\hat{W}_{pp}}. \tag{3.6.12}$$

By SOC, the denominators of these expressions are negative. To examine the signs of the numerators, SOC also imply

$$\hat{W}_{pp} = Q_p - C_{qq}Q_p^2 + z(\alpha)\ \frac{F(\theta)}{f(\theta)}\left(C_{\theta qq}Q_p^2 + C_{\theta q}Q_{pp}\right) < 0,$$

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[48] This assumes a risk neutral regulator.

$$\hat{W}_{ss} = \left(K_{ss} - C_{qq}Q_s^{\,2} - 2C_{qs}Q_s - C_{ss}\right) + z(\alpha)\ \frac{F(\theta)}{f(\theta)}\left(C_{\theta qq}Q_s^{\,2} + 2C_{\theta qs}Q_s + C_{\theta q}Q_{ss} + C_{\theta ss}\right) < 0,$$

where $z(\alpha) = (1-2\alpha)/\alpha \le 0$ because $½ \le \alpha \le 1$. The signs of

$$\hat{W}_{ps} = -Q_p\left(C_{qq}Q_s + C_{qs} + z(\alpha)\ \frac{F(\theta)}{f(\theta)}\left(C_{\theta qq}Q_s + C_{\theta qs}\right)\right),$$

$$\hat{W}_{p\theta} = \left(-C_{q\theta} + z(\alpha)\left[\left(1-\Phi(\theta)\right)C_{q\theta} + \frac{F(\theta)}{f(\theta)}C_{\theta q\theta}\right]\right)Q_p, \text{ and}$$

$$\hat{W}_{s\theta} = \left(-C_{q\theta} + z(\alpha)\left[\left(1-\Phi(\theta)\right)C_{q\theta} + \frac{F(\theta)}{f(\theta)}C_{\theta q\theta}\right]\right)Q_s + \left(-C_{s\theta} + z(\alpha)\left[\left(1-\Phi(\theta)\right)C_{s\theta} + \frac{F(\theta)}{f(\theta)}C_{\theta s\theta}\right]\right),$$

where $\Phi(\theta) = F(\theta)f'(\theta)\big/ f(\theta)^2$ are determined by the SOC and Assumptions 2, 4, 5 and 6. In particular, $\hat{W}_{p\theta} \ge 0$, $\hat{W}_{s\theta} \le 0$ and $\hat{W}_{ps} \ge 0$. Therefore, using (3.6.11) and (3.6.12), $p(\theta)$ is non-decreasing and $s(\theta)$ is non-increasing.

3.6.4 Results with Price and Quality Regulation

The main result of this section is a set of conditions that characterize the equilibrium levels of price and quality. Comparing the solution under asymmetric information in equations (3.6.9) and (3.6.10) to those obtained under symmetric information in (3.3.4) and (3.3.5), the difference lies in the additional terms, $z(\alpha)\left(F(\theta)/f(\theta)\right)C_{i\theta}$, with $i = q, s$, respectively. These are both negative when $\alpha > 0.5$ by Assumption 2. Therefore, $p^3 > C_q(q^3, s^3, \theta)$ and $K_s(p^3, s^3) > C_s(q^3, s^3, \theta)$ $\forall\ \theta \in [\theta_0, \theta_1]$ where (p^3, s^3) are the asymmetric equilibrium levels of price and quality and $q^3 = Q(p^3, s^3)$. By comparison, for the symmetric information, $p^1 = C_q(q^1, s^1, \theta)$ and $K_s(p^1, s^1) = C_s(q^1, s^1, \theta)$ $\forall\ \theta \in [\theta_0, \theta_1]$ where (p^1, s^1) are the equilibrium levels of price and quality under regulation with symmetric information and $q^1 = Q(p^1, s^1)$. Depending on the cost and value functions, all of the following results are possible: both price and quality increase or decrease jointly, price increases and quality decreases, price increases and quality remains the same, or quality decreases and price remains the same.

3.7 Price Regulation under Asymmetric Information

Consider next the case where the regulator only sets price and the firm is free to choose quality. The process is abstracted as a game where the firm first learns its type, then the regulator sets the price, and then the firm chooses the level of quality to provide. This level will, of course, be the minimum allowed unless it has an effect on quantity demanded (*i.e.* $Q_s \neq 0$). I solve the problem using backward induction: first the problem of the firm is solved, obtaining a quality response function for changes in price. This function is then placed in the regulator's problem.

3.7.1 Implementable Decisions with Price Regulation

The price (p) set by the regulator is an implementable decision if there exists a transfer (T) such that the allocation $[p(\theta), T(\theta)]$ satisfies the incentive compatibility constraint,

$$\pi^*(p(\theta),T(\theta),\theta) \geq \pi^*(p(\theta^*),T(\theta^*),\theta) \text{ for all } (\theta,\theta^*) \in [\theta_0,\theta_1] \times [\theta_0,\theta_1].$$

If $p(\theta)$ is piecewise continuously differentiable, a necessary condition for an implementable decision is that

$$\frac{\partial}{\partial\theta}\left(\frac{\pi_p^*}{\pi_T^*}\right)\frac{dp}{d\theta} \geq 0\,.$$

Again, if $\pi^*(p,T,\theta) = pQ(p,S) - C(Q,S,\theta) + T$, then $\pi_T^* = 1$.[49] Thus, this condition can be rewritten as

$$\pi_{p\theta}^* \, dp/d\theta \geq 0 \,. \tag{3.7.1}$$

Therefore, under Assumptions 2 and 3, $p(\theta)$ is implementable if it satisfies $dp/d\theta \geq 0$ (monotonicity).[50]

3.7.2 Optimal Mechanism Design with Price Regulation

In this case, the IR condition takes the form

$$\pi^*\left(p(\theta), T(\theta), \theta\right) \geq \bar{\pi} \qquad \forall \theta \in \left[\theta_0, \theta_1\right] \tag{3.7.2}$$

where $\bar{\pi}$ represents the reservation utility of the firm. Thus, because $d\pi^*/d\theta < 0$, (3.7.2) is only binding at θ_1.

The regulator's objective function for given θ is

$$W^*(p,S,T,\theta) = \alpha K(p,S,T) + (1-\alpha)\,\pi(p,S,T,\theta)$$

$$= \alpha V(Q,S) - (1-\alpha)\,C(Q,S,\theta) + (1-2\alpha)(pQ+T),$$

where $Q \equiv Q(p,S)$ and $S \equiv S(p,\theta)$, which is linear in T.

Considering statistical uncertainty, the regulator's maximization problem is thus to $max_{p,T}\ E_\theta\{W^*(p,S,T,\theta)\}$ subject to monotonicity and the IR condition in equation (3.7.2). From Assumption 3 and (3.7.2), the IR condition holds if $\theta = \theta_1$, and is binding only at this point. Therefore the IR condition in (3.7.2) can be reduced to

$$\pi^*\left(p(\theta_1), T(\theta_1), \theta_1\right) = \bar{\pi} \tag{3.7.3}$$

---

[49] Note that S is defined by (3.4.5).

[50] See Theorem 7.3 in Fudenberg and Tirole (1991). Also note that this assumptions implies the required conditions for $\pi^*(p,T,\theta)$.

as before. Using the fact that $T = \boldsymbol{p}^*(p,T,\ \boldsymbol{q})$ **-** $pQ + C(Q,S,\boldsymbol{q})$, the regulator's objective function can be rewritten as

$$W^*(p,S,T,\boldsymbol{q}) = \boldsymbol{a}V(Q,S)\ \textbf{-}\ (1\text{-}\boldsymbol{a})\ C(Q,S,\boldsymbol{q}) + (1 - 2\boldsymbol{a})\ (\ \boldsymbol{p}^*(p,T,\boldsymbol{q}) + C(Q,S,\boldsymbol{q})\ )$$

$$= \boldsymbol{a}\{V(Q,S)\ \textbf{-}\ C(Q,S,\boldsymbol{q})\} + (1 - 2\boldsymbol{a})\ \boldsymbol{p}^*(p,T,\boldsymbol{q})$$

By the envelope theorem and the IR condition in (3.7.3),

$$\pi^*\left(p(\theta),T(\theta),\theta\right) = \bar{\pi} + \int_{\theta}^{\theta_1} \pi^*_{\tilde{\theta}}\left(p(\tilde{\theta}),T(\tilde{\theta}),\tilde{\theta}\right)d\tilde{\theta}$$

where $\pi^*_{\theta}(p,T,\theta) = \left(Q_s(p - C_q) + C_s\right)S_{\theta} - C_{\theta}$ is independent of T.[51] Substituting this relationship in the regulator's objective function obtains the maximization problem

$$\max_p \int_{\theta_0}^{\theta_1}\left[\alpha\left(V^*(\theta) - C^*(\theta)\right) + (1-2\alpha)\left(\bar{\pi} + \int_{\theta}^{\theta_1}\hat{\pi}_{\tilde{\theta}}\left(\tilde{\theta}\right)d\tilde{\theta}\right)\right]dF(\theta)$$

where

$$V^*(\theta) \equiv V\left(p(\theta), S\left(p(\theta),\theta\right)\right),$$

$$\mathrm{C}^*(\theta) \equiv C\left(Q\left(p(\theta), S\left(p(\theta),\theta\right)\right), S\left(p(\theta),\theta\right),\theta\right), \text{ and}$$

$$\hat{\pi}(\theta) \equiv \pi^*\left(p(\theta),T(\theta),\theta\right).$$

Integrating by parts, the last term becomes

$$\begin{aligned}\int_{\theta_0}^{\theta_1}\left[\int_{\theta}^{\theta_1}\hat{\pi}_{\theta}(\tilde{\theta})d\tilde{\theta}\right]dF(\theta) &= \int_{\theta_0}^{\theta_1}\left[\hat{\pi}(\theta_1) - \hat{\pi}(\theta)\right]dF(\theta)\\ &= -\int_{\theta_0}^{\theta_1}\hat{\pi}(\theta)dF(\theta) + \hat{\pi}(\theta_1)\\ &= -\hat{\pi}(\theta)F(\theta)\Big|_{\theta_0}^{\theta_1} + \int_{\theta_0}^{\theta_1}\hat{\pi}_{\theta}(\theta)\frac{F(\theta)}{f(\theta)}dF(\theta) + \hat{\pi}(\theta_1)\\ &= \int_{\theta_0}^{\theta_1}\hat{\pi}_{\theta}(\theta)\frac{F(\theta)}{f(\theta)}dF(\theta).\end{aligned}$$

[51] Again, $C_s \equiv C_s(Q(p,s),s,\boldsymbol{q})$ represents the partial derivative with respect to its second argument and, hence, does not include the indirect effect of s through $Q(p,s)$.

Thus the objective function simplifies to

$$E_\theta\left(\hat{W}^*(p,\theta)\right)=\int_{\theta_0}^{\theta_1}\left[\alpha\left(V(Q,S)-C(Q,S,\theta)\right)+(1-2\alpha)\frac{F(\theta)}{f(\theta)}\pi_\theta^*\left(p,T,\theta\right)\right]dF(\theta),$$

(3.7.4)

where the constant term has been eliminated. The problem can now be written as $\max_p E_\theta\left(\hat{W}^*(p,\theta)\right)$ subject to monotonicity. Again, the solution can be found without considering the restriction and then later checking to see that it is met. For ease of notation, the integrand of the objective function can be rewritten as

$$\hat{W}^*(p,\theta)=\alpha\left(V(p,S)-C\left(Q,S,\theta\right)\right)+(1-2\alpha)\frac{F(\theta)}{f(\theta)}\pi_\theta^*\left(p,T,\theta\right)$$
$$=\alpha W(p,S,\theta)+(1-2\alpha)\frac{F(\theta)}{f(\theta)}\pi_\theta^*\left(p,T,\theta\right).$$

The solution to this relaxed program must satisfy

$$(p-C_q)Q_p+K_sS_p=-H(\alpha,\theta)\,\pi_{p\theta}^*\left(p,T,\theta\right) \tag{3.7.5}$$

where $H(\alpha,\theta) = z(\alpha)\,F(\theta)/f(\theta)$ and

$$\pi_{p\theta}^*\left(p,T,\theta\right)=(Q_s+p(Q_{ps}+Q_{ss})-C_{ss})S_p)S_\theta+$$
$$(Q_s-C_s)S_{p\theta}-(C_{qs}+C_{\theta q}(Q_p+Q_sS_p)+C_{\theta s}S_p.$$

The SOC for this problem is

$$W_{pp}+2W_{ps}S_p+W_{ss}S_p^2+W_sS_{pp}+H(\alpha,\theta)\,\pi_{pp\theta}^*\left(p,T,\theta\right)<0$$

and is met by Assumption 7 and the concavity of $W(p,S,\theta)$ in p as assumed in Section 3.4.

3.7.3 When is the Relaxed Program Legitimate for Price Regulation?

Totally differentiating the FOC in (3.7.5) implies

$$\frac{dp}{d\theta} = -\frac{\hat{W}^*_{p\theta}}{\hat{W}^*_{pp}} .$$

Note that $\hat{W}^*_{pp}$ is negative by the SOC, and $\hat{W}^*_{p\theta} = W_{p\theta} + H_\theta(\alpha,\theta)\pi^*_{p\theta} + H(\alpha,\theta)\pi^*_{p\theta\theta} > 0$ by Assumptions 2, 6 and 7. Therefore, $dp/d\theta \geq 0$, implying that the relaxed program is legitimate.

Comparing (3.7.5) with the result obtained for the case of symmetric price regulation in (3.4.10) reveals that the most likely outcome will be $p^2 \leq p^4$, where p^2 and p^4 are the equilibrium prices for the symmetric and asymmetric information cases when only price is regulated, respectively.

3.8 Conclusions to Chapter 3

This chapter has developed four models that represent two issues in the regulation of a monopolist. First, it considers the issue of regulating only price *vis-à-vis* regulating price and quality. Then it considers these two cases when the information structure is such that the regulator has limited information about the real costs of the monopolist, *i.e.*, the case when there is asymmetric information between the regulator and monopolist. A third element included in the analysis is a simple representation of the preferences of the regulator. With symmetric information, the relative preference of the regulator for consumers versus the monopolist does not have an impact on the efficiency of the outcome. This preference or "bias" only affects the allocation of surplus between consumers and the monopolist. If the regulator sets both price and quality, then achievement of the first best is possible depending on the informational structure and regulator's preferences. But when the regulator sets only price, and quality is chosen instead by the monopolist, the outcome is inefficient. Moreover, under certain conditions, the price and quality will be lower if only price is regulated.

A somewhat surprising result is that the information gap does not have an impact on efficiency as long as both instruments of regulation, price and quality, can be used by the regulator, and the regulator does not favor consumers over the monopolist. When the regulator favors consumers, then several results are plausible, including the possibility that prices will be higher and quality lower under asymmetric information. Most of the other possible outcomes result in lower surplus for consumers.

This result also applies to the case of price-only regulation, where a distortion away from the outcome under symmetric information occurs when the regulator favors consumers. If the regulator favors consumers, then a further wedge, in addition to the one due to using only one instrument, is placed between price and marginal cost, reducing efficiency further. The most likely situation is that price will be higher than with price-only regulation under symmetric information.

4 SIMULATION OF THE REGULATION MODELS

4.1 Introduction

In Chapter 3, I developed a general model of regulation in the presence of asymmetric information and considered cases when either price and quality or only price are regulated. The development of these models led to a set of conditions that do not yield unambiguous qualitative implications unless some assumptions are made. Most such assumptions require a reduction in the generality of the problem. Some authors who have examined similar models have assumed simple functional forms to obtain an analytic solution (see Laffont and Tirole, 1986; and Lewis and Sappington, 1988). Such an approach has the advantage of rendering a solution that is general with respect to the remaining parameters of the model. However, the use of simple functional forms may assume away critical aspects of the problem because generality is lost for some fundamental functions.

A different approach is to postulate a more complex functional form, assume numeric values for the parameters, and solve the model using numerical methods. This approach allows modeling more realistic behavior and exploring the consequences of different curvatures in the basic functions. This type of analysis, however, may yield results that do not apply to all possible parameter values. This problem can be partially overcome by a sensitivity analysis that considers alternative values of the main parameters and evaluates the impact of various parameter values on model results.

This chapter follows the latter approach. Prior to presenting the solution to specific models, I give some basic description of the functional forms that are chosen and their properties. Then I present a brief description of the methods used to solve the systems of equations. Finally, I present a discussion of the main findings.

4.2 Simulation Method

I first present the functional forms I have chosen and discuss their main characteristics. I also make explicit the restrictions imposed on parameters so functions have adequate economic properties. Then I present the theoretical models developed in the previous chapter after incorporating proposed functional forms. Later in the chapter, parameter values are chosen for the simulation and a discussion is provided regarding how they were chosen.

As discussed in the previous chapter, the solution to the models may be, in part, driven by the sign of the cross derivative of the demand function. This suggests selection of forms that allow a positive, zero, and negative cross derivative. The demand function I have chosen,

$$Q(p,s) = \beta_0 e^{-p^{\beta_1}/\beta_3 s^{\beta_2}} p^{-\beta_4}, \tag{4.2.1}$$

with β_0, β_1, β_2, β_3 and β_4 all positive, is derived from an exponential form, and is second order flexible in *p*. This function defines only the relation between quantity (*Q*), price (*p*), and quality (*s*). This demand function was selected because the signs of its derivatives depend only on relationships of the parameters and not on values of variables. Thus, they can be meaningfully altered for sensitivity analysis without causing nonsensical results.[52]

[52] For this reason, no attempt was made to match this functional form of demand to the demand function estimated in Chapter 5. Since no data were available to estimate the cost function, the results of this simulation, which is based on a full model of demand and cost, cannot be made to fit a complete empirically-based model anyway.

For this reason, the main objective of the simulations in this chapter is to derive qualitative conclusions rather than quantitative results.

Although demand clearly depends on other factors, these are added later for the econometric estimation. Because the purpose of this simulation is to solve the model and observe the effects of key parameter values that determine the relationship of these three variables, other variables are not incorporated, although they could be potentially added to derive, for example, policy implications.

The properties of this function required by the model in Chapter 3 [(3.2.1)-(3.2.4)] are

$$Q(p,s)=\frac{\beta_0}{e^{(p^{\beta_1}/\beta_3 s^{\beta_2})}p^{\beta_4}}>0 \tag{4.2.2}$$

$$Q_p(p,s)=-\frac{\beta_0(\beta_1 p^{\beta_1}+\beta_3\beta_4 s^{\beta_2})}{\beta_3 p^{(1+\beta_4)}s^{\beta_2}e^{(p^{\beta_1}/\beta_3 s^{\beta_2})}}<0 \tag{4.2.3}$$

$$Q_s(p,s)=\frac{\beta_0\beta_2 p^{(\beta_1-\beta_4)}}{\beta_3 s^{\beta_2+1}e^{(p^{\beta_1}/\beta_3 s^{\beta_2})}}>0 \tag{4.2.4}$$

$$Q_{ss}(p,s)=\frac{\beta_0\beta_2(\beta_2 p^{\beta_1}-s^{\beta_2}(1+\beta_2)\beta_3)}{\beta_3^2 p^{(\beta_4-\beta_1)}s^{2(1+\beta_2)}e^{(p^{\beta_1}/\beta_3 s^{\beta_2})}}<0 \tag{4.2.5}$$

Properties (4.2.2)-(4.2.4) are met because all parameters are positive. To meet (4.2.5) requires that $\beta_2 p^{\beta_1}<s^{\beta_2}(1+\beta_2)\beta_3$. The cross derivative Q_{ps} is given by:

$$Q_{ps}(p,s)=\frac{\beta_0\beta_2\left((\beta_1-\beta_4)\beta_3 s^{\beta_2}-\beta_1 p^{\beta_1}\right)}{\beta_3^2 p^{(1-\beta_1+\beta_4)}s^{(1+2\beta_2)}e^{(p^{\beta_1}/\beta_3 s^{\beta_2})}}. \tag{4.2.6}$$

A sufficient condition for $Q_{ps}<0$ is $\boldsymbol{b}_1<\boldsymbol{b}_4$ and a necessary and sufficient condition is $(\beta_1-\beta_4)\beta_3 s^{\beta_2}<\beta_1 p^{\beta_1}$. On the other hand, a necessary condition for $Q_{ps}>0$ is $\boldsymbol{b}_1>\boldsymbol{b}_4$ and a necessary and sufficient condition is $(\beta_1-\beta_4)\beta_3 s^{\beta_2}>\beta_1 p^{\beta_1}$. The sign of $Q_{pp}(p,s)$ is flexible. A sufficient condition for $Q_{pp}(p,s) > 0$ is $\beta_1 \le 1 + 2\beta_4$ or, more generally, $Q_{pp}(p,s) > (<) 0$ as

$$\beta_1^2 p^{2\beta_1} + \beta_4(1+\beta_4)\beta_3^2 s^{2\beta_2} > (<)\ p^{\beta_1} s^{\beta_2} (\beta_1 - 1 - 2\beta_4)\beta_1\beta_3 .$$

The cost function is postulated to follow a form related to the constant elasticity of substitution (CES) form. This form is very flexible with respect to the curvature and the effect of quality on marginal cost, thus allowing alternative levels of substitution between the two and at the same time enabling an intuitive characterization of the results. The modified CES cost function is

$$C(q,s,\theta) = \alpha_0 n + \alpha_1 \left[\lambda + (1-\lambda)(\theta - a)\right]\left(q^{\alpha_2} + \alpha_6 s^{\alpha_3}\right)^{\alpha_4} n^{\alpha_5},$$

where θ is the firm's type or efficiency parameter, a is the minimum value that θ can take, λ represents the proportion of variable cost that is influenced by firm type, and n is the number of clients served by the firm, which is assumed to be exogenous. All α_i parameters are assumed to be positive. With this specification, conditions (3.2.6)-(3.2.9) of Chapter 3 require

$$C_q(q,s,\theta) = \alpha_1\alpha_2\alpha_4 \left[\lambda + (1-\lambda)(\theta - a)\right] q^{\alpha_2 - 1}\left(q^{\alpha_2} + \alpha_6 s^{\alpha_3}\right)^{\alpha_4 - 1} n^{\alpha_5} > 0 \qquad (4.2.7)$$

$$C_s(q,s,\theta) = \alpha_1\alpha_3\alpha_4\alpha_6 \left[\lambda + (1-\lambda)(\theta - a)\right] s^{\alpha_3 - 1}\left(q^{\alpha_2} + \alpha_6 s^{\alpha_3}\right)^{\alpha_4 - 1} n^{\alpha_5} > 0 \qquad (4.2.8)$$

$$\begin{aligned} C_{qq}(q,s,\theta) = \alpha_1\alpha_2\alpha_4 &\left[\lambda + (1-\lambda)(\theta - a)\right]\left[(\alpha_2\alpha_4 - 1)q^{\alpha_2} + (\alpha_2 - 1)\alpha_6 s^{\alpha_3}\right] \\ &\times q^{\alpha_2 - 2}\left(q^{\alpha_2} + \alpha_6 s^{\alpha_3}\right)^{\alpha_4 - 2} n^{\alpha_5} > 0 \end{aligned} \qquad (4.2.9)$$

$$\begin{aligned} C_{ss}(q,s,\theta) = \alpha_1\alpha_3\alpha_4\alpha_6 &\left[\lambda + (1-\lambda)(\theta - a)\right]\left[(\alpha_3 - 1)q^{\alpha_2} + (\alpha_3\alpha_4 - 1)\alpha_6 s^{\alpha_3}\right] \\ &\times s^{\alpha_3 - 2}\left(q^{\alpha_2} + \alpha_6 s^{\alpha_3}\right)^{\alpha_4 - 2} n^{\alpha_5} > 0 \end{aligned} \qquad (4.2.10)$$

Because $a \le \theta$, $0 \le \lambda \le 1$, and all parameters are positive, properties (4.2.7) and (4.2.8) are met without further restrictions. Sufficient conditions are $\alpha_2 > 1$ and $\alpha_2\alpha_4 > 1$ for property

(4.2.9) and $\alpha_3 > 1$ and $\alpha_3\alpha_4 > 1$ for property (4.2.10). Necessary conditions to meet these properties are $(\alpha_2\alpha_4 - 1)q^{\alpha_2} + (\alpha_2 - 1)\alpha_6 s^{\alpha_3} > 0$ and $(\alpha_3 - 1)q^{\alpha_2} + (\alpha_3\alpha_4 - 1)\alpha_6 s^{\alpha_3} > 0$, respectively. Thus, alternative conditions to meet these latter properties are that, if α_2 and α_3 are less than one, then $\alpha_2\alpha_4 > 1$ and $\alpha_3\alpha_4 > 1$, or if $\alpha_2\alpha_4 < 1$ and $\alpha_3\alpha_4 < 1$ then α_2 and α_3 must be greater than one.

The cross derivative C_{qs} is

$$
\begin{aligned}
C_{qs}(q,s,\theta) = \alpha_1\alpha_2\alpha_3\alpha_4\alpha_6(\alpha_4 - 1)\left[\lambda + (1-\lambda)(\theta - a)\right] \\
\times s^{\alpha_3 - 1} q^{\alpha_2 - 1}\left(q^{\alpha_2} + \alpha_6 s^{\alpha_3}\right)^{\alpha_4 - 2} n^{\alpha_5} > 0
\end{aligned}
. \qquad (4.2.11)
$$

With all parameters positive, C_{qs} is negative (positive) if $\alpha_4 < 1$ ($\alpha_4 > 1$) and zero otherwise. I have assumed $C_{qs} > 0$ in condition (3.2.10) of Chapter 3, because marginal cost very likely increases with the quality of service provided in the electricity industry. Thus I impose this condition in the simulations.

4.2.1 Equations Used in the Simulation

Applying the functional forms defined above to the theoretical model of Chapter 3, equilibrium conditions can be obtained to characterize operation of the market in each scenario. The functional form chosen for the demand function, equation (4.2.1), yields the following total willingness-to-pay (WTP) function,

$$
V(p,s) = \beta_0\left(\int_p^{\infty} \tilde{p}^{-1} e^{-(\tilde{p}^{\beta_1}/\beta_3 s^{\beta_2})} d\tilde{p} + e^{-(p^{\beta_1}/\beta_3 s^{\beta_2})}\right).
$$

Thus, the FOC of the regulator’s problem in Section 3.3 with price and quality regulation under symmetric information are

$$
\begin{aligned}
p - C_q &= 0, \\
V_s - pQ_s - C_s &= 0.
\end{aligned}
\qquad (4.2.12)
$$

The FOC of the regulator's problem in Section 3.6, equations (3.6.9) and (3.6.10), with price and quality regulation under asymmetric information can be rewritten as

$$p - C_q + \frac{(1-2\alpha)F(\theta)C_{q\theta}}{\alpha f(\theta)} = 0,$$

$$V_s - pQ_s - C_s + \frac{(1-2\alpha)F(\theta)C_{s\theta}}{\alpha f(\theta)} = 0,$$

where $f(\theta)$ and $F(\theta)$ are the probability density function (p.d.f.) and cumulative distribution function of firms type (*q*) distribution, respectively. Suppose these functions are given by

$$f(\theta) = \frac{1}{1+d}\left[d + \frac{(a-\theta)^{v-1}(1+a-\theta)^{w-1}}{\beta(v,w)}\right] \text{ for } a \le \theta \le 1+a \text{, and} \qquad (4.2.13)$$

$$F(\theta) = \int_a^\theta f(x)dx,$$

where

$$\beta(v,w) = \int_0^1 u^{v-1}(1-u)^{w-1}du, \text{ and}$$

d is an adjustment parameter that avoids a value of zero for the p.d.f. when $\theta = a$. This distribution is a modified Beta distribution with shape parameters *v* and *w* (see Evans, Hastings and Peacock, 2000). This distribution was selected because it is very flexible and able to represent a wide range of forms for the p.d.f. that could be used to test the influence of p.d.f. shape in the results (Nadarajah and Gupta, 2004). This form also satisfies Assumption 6 in Chapter 3. Further, it is convenient for numerical simulation because it can be compiled within the software used for simulation, thus avoiding approximation errors.

The problems of price-only regulation are solved by adding the firms' first-order conditions as a constraint to the maximization problem of the regulator.[53] This problem was solved numerically using a system of three equations comprised of the first-order condition for the firms profit maximization problem with respect to quality and the regulator's first-order conditions with respect to price and quality. Thus, corresponding to Section 3.4 with price regulation under symmetric information, this system is given by

$$\begin{aligned} &W_p^* + \gamma\pi_{ps} = 0 \\ &W_s^* + \gamma\pi_{ss} = 0 \\ &(p - C_q)Q_s - C_s = 0 \end{aligned} \tag{4.2.14}$$

where $W^* = \alpha K + (1 - \alpha)\boldsymbol{p}$ is the weighted average between consumer and producer surplus and $\boldsymbol{g}$ is the Lagrangian multiplier of the constrained maximization problem.

The first-order conditions of the regulator's problem presented in Section 3.7 with price regulation under asymmetric information are

$$\begin{aligned} &\hat{W}_p^* + \gamma^*\pi_{ps} = 0 \\ &\hat{W}_s^* + \gamma^*\pi_{ss} = 0 \\ &(p - C_q)Q_s - C_s = 0 \end{aligned} \tag{4.2.15}$$

where

$$\hat{W}^* = \alpha(V - C) + (1 - 2\alpha)C_{s\theta}\frac{F(\theta)}{f(\theta)} \tag{4.2.16}$$

and $\boldsymbol{g}^*$ is the Lagrangian multiplier of the constrained maximization problem.

---

[53] See section 3.4 in Chapter 3.

4.2.2 Parameters Chosen for Simulation

The parameters values were chosen according to three main criteria. First, some of the parameters are chosen so that the variables have values that are close in magnitude to averages of the actual Chilean industry data to facilitate interpretation. The parameters that modify qualitative properties of the functions and those that define the different scenarios of interest where chosen so that these alternative conditions highlighted by Chapter 3 are generated. Other parameters are chosen through a calibration algorithm so that the functions have the economic properties assumed above [(4.2.2)-(4.2.5) for demand and (4.2.7)-(4.2.10) for cost], and so that the maximization problems have (real number) solutions.

To find parameter values that conform to the requirements described above, I used the following procedure. First, I choose values for the parameters for which I was interested in testing effects. Then I selected scaling parameters that are calibrated to the mean values of the data. Then I gave some initial values to the rest. To obtain values for the scaling parameters, I used the first-order conditions of the theoretical models. Then I verified that all models could be solved and gave reasonable solutions. Finally, I iterated with different starting values and solved for scaling parameters using the different theoretical models until the set of parameter values met the assumed economic properties and all the models could be solved. This procedure allowed solutions to exist and the results to yield reasonable values of the variables. In the rest of this section, a detailed description of the parameter choices is presented.

Table 4.1 presents the parameter values used in the total cost and total WTP functions.

Table 4.1. Parameter Values Used

a_0	8,294	b_0	9,484
a_1	225×10^{-7}	b_1	0.90
a_2	2.00	b_2	2.00
a_3	2.34	b_3	2.00
a_5	2.00	b_4	1.00
a_6	0.90	λ	0.70

These parameters yield cost and WTP functions with the desired properties (as explained above). Figure 4.1 and Figure 4.2 depict cost and WTP as functions of price for a given quality and of quality for a given price, respectively. The shapes and qualitative differences of these functions are similar for levels of given quality (or price). In these figures, cost and WTP are presented on a per client basis, and the magnitudes represent thousand of pesos (Chilean currency). Figure 4.1 demonstrates that the two functions are decreasing in price and that the difference in the two is maximized for prices above 30 (pesos per Kw/hr), whereas industry average values (in Chile) are close to 60 and prices below 20 are very unlikely. Figure 4.2, on the other hand, presents the relationships between cost, WTP, and quality, with price held constant. Both, cost and WTP are increasing in quality but at decreasing and increasing rates, respectively. Quality is measured by an index where initial values used for calibrating the model are close to 100.

Figure 4.1. Cost and WTP as Functions of Price

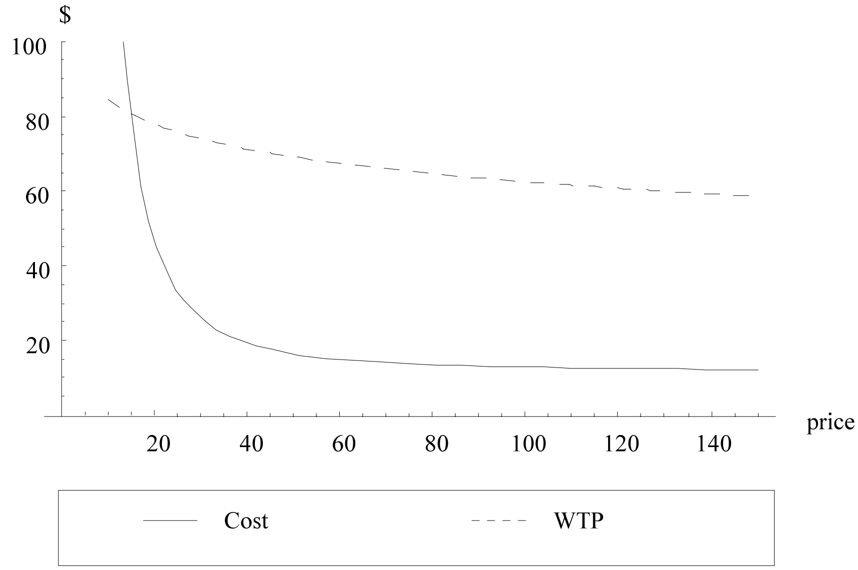
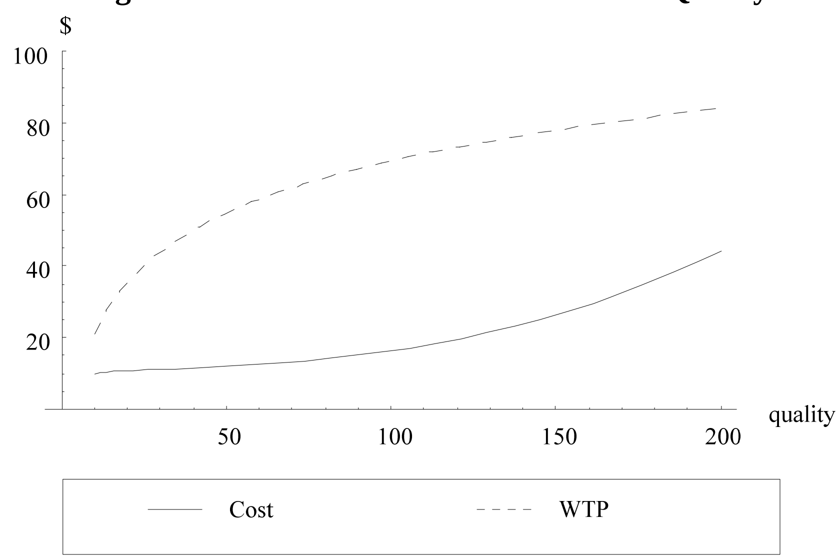


Figure 4.2. Cost and WTP as Functions of Quality

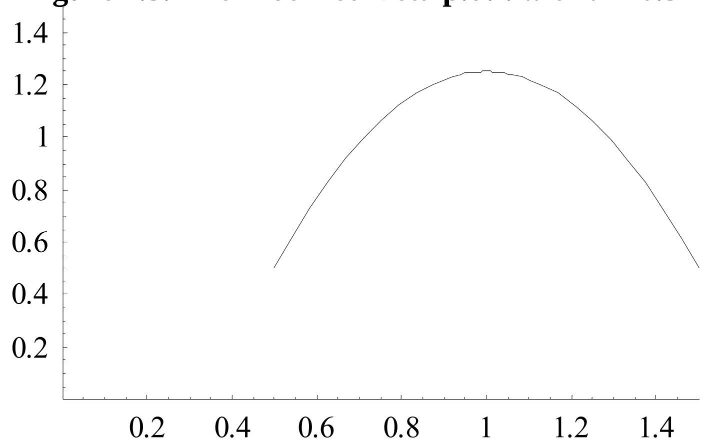


Alternative parameter values were used to assess the effect of a different sign of the cross derivative of the demand function on the results. Specifically, the value of $\boldsymbol{b}_1$ was set alternatively to values greater and less than one. This yields alternative sets of parameter values that have different signs of cross derivatives.

The parameters of the p.d.f. in (4.2.13) are assumed to take the following values: $v = 2$, $w = 2$, $a = 0.5$, and $d = 1$. These parameter values are chosen so that the range of types is bounded away from zero, and to avoid having (4.2.16) undefined at the lower support of the distribution (because the p.d.f. could otherwise take a value of zero).

The p.d.f. of the modified Beta distribution in (4.2.13) evaluated at these parameter values is depicted in Figure 4.3. Even though the shape presented here could have been achieved with a simpler form, a better performance in numeric calculations together with a flexibility to represent alternative shapes by a small change in parameters motivates the use of this form.

Figure 4.3. The Modified Beta p.d.f. with *a* = 0.5



This distribution of types plus the value selected for λ yields a difference in cost between the most efficient and most inefficient firm types of about 20% of the former. No data are available giving direct evidence on variation in firm efficiencies. However, Lomuscio (2004) presents variations of up to 8% for prices set to different companies in similar areas in Chile using data for the year 2000. This could be an indication of the distribution of firm types in the industry as evidenced by differences in costs.

4.2.3 Scenarios Considered

To investigate the effect that different curvatures in the demand function have on the model's outcome, I solved the model numerically using several possible scenarios. The marginal effect of price on demand (Q_p) can be decreasing or increasing in quality. If the effect is decreasing (increasing), then quality acts as a complement (substitute).

I consider two different scenarios with opposite signs of the cross derivative of the demand function characterizing different consumer preferences. In addition, other scenarios are generated by considering characteristics of the regulator framework such as the number of instruments used for regulation (scope of regulation), the information structure, and the regulator's "bias" or preference. The number of instruments refers to whether only price is regulated or both price and quality are regulated. The information structure refers to whether information is symmetric or asymmetric between the regulator and the firm. Specifically, asymmetry exists when the regulator cannot perfectly observe the firm's costs.

The regulator's preference refers to the weights on consumer versus producer surplus in the regulator's objective function. To keep the model as simple as possible, I have assumed this function to be a linear weighted-average of producer and consumer surpluses. The important cases for α (the preference parameter) are $\alpha = 0.5$, $0.5 < \alpha \leq 1.0$, and $0.0 \leq \alpha < 0.5$. Thus, three scenarios are considered with $\alpha = 0.75$ for a regulator that favors consumer, $\alpha = 0.5$ for a neutral regulator, and $\alpha = 0.45$ for a regulator that favors the producer.[54] I also consider alternative parameters for the modified Beta distribution where $v = 1$ and $w = 1$ represents a uniform distribution of firms' types.

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[54]` Although a value of $\alpha = 0.25$ was initially considered, the calibration of model parameters proved very difficult for this set of values of alpha.

Considering the information structure and scope of regulation, four main scenarios arise:

- Price-only regulation with symmetric information
- Price and quality regulation with symmetric information
- Price-only regulation with asymmetric information
- Price and quality regulation with asymmetric information

Considering all variants in models and scenarios yields a total of 32 alternative configurations. The models were solved numerically for each of the scenarios, although I only report those for which the most interesting results where found.

4.2.4 Numerical Solution

In this section, I present a discussion of the approach to numerical solution of the model. Once the functional forms and parameters were specified, Mathematica® was used to solve the analytical models numerically. First, the basic functions (demand and cost) were defined and then derived functions (consumer and producer surplus) based on the chosen functional forms were obtained. Using the built-in analytical derivative function, the first-order conditions were obtained for each of the models. Then the numerical values selected for each coefficient were assigned and the system of equations was solved to find the optimal price and quality for each value of q, i.e., for each firm type. Although, the theoretical models assume that type is a continuous variable, by taking an arbitrarily large number of values of q in the interval 0.5 to 1.5, the solution was approximated with a discrete firm type distribution. In other words using numerical methods, a finite but arbitrarily large number of point solutions that belong to the continuous problem were examined. Then the functions were evaluated at each of these points.

Because first-order conditions are solved numerically as a system of equations, finding a maximum is only guaranteed under the specific conditions discussed above. Therefore, the second-order conditions were derived analytically and tested numerically to make sure they were met at each solution point.

The computation of the transfer payment plays a key role in the numerical solution of the models. Its computation differs depending on the informational structure and the number of instruments that are regulated. In what follows, I discuss how the transfer was computed in each of the four main scenarios depending on which of the two information structures applies and whether only price or both price and quality are regulated.

Following equation (3.3.6), when price and quality are regulated and the regulator is biased toward consumers in a symmetric information environment, I replace the transfer variable in the objective functions with

$$T(p,s,\theta) = C(Q(p,s),s,\theta)/n - p \cdot Q(p,s) \ . \qquad (4.2.17)$$

This transfer expression differs slightly from equation (3.3.6) because the firm's reservation value is assumed to be zero and the cost function is divided by the number of clients. With a zero reservation value, the transfer is never negative in equilibrium for the parameter values used here. The division by the number of clients ($n > 0$) is necessary because the cost function represents the total cost of the utility, which depends on the number of clients and their individual demands for electricity, $Q(p,s)$. This expression replaces T in the regulator's objective function, which therefore becomes a function of only price and quality for the given parameters.[55] After equilibrium values of p and s are found using (4.2.12), they are replaced in equation (4.2.17) to obtain the equilibrium transfer.

The computation of the transfer when only price is regulated in a symmetric information environment also uses expression (4.2.17), but with the exception that equilibrium price and quality are estimated using (4.2.14). If $\alpha \leq 0.5$, then the transfer is computed following equation (3.3.7), assuming a zero reservation value for consumers.

In the models of asymmetric information, the IC and IR constraints [equations (3.6.1) and (3.6.4), respectively] are imposed through transformation of the objective function and the way the transfer is computed. Following Fudenberg and Tirole (1991), the transfer is calculated as:

$$T^*(\theta_a, \theta_t) = C[Q^*(\theta_a), s^*(\theta_a), \theta_t]/n - p^*(\theta_a)\, Q^*[p^*(\theta_a), s^*(\theta_a)] + \{C[Q^*(\theta_1), s^*(\theta_1), \theta_1] - C[Q^*(\theta_1), s^*(\theta_1), \theta_t]\}/n \qquad (4.2.18)$$

where $Q^*(\theta) \equiv Q^*[p^*(\theta), s^*(\theta)]$, $p^*(\theta)$ and $s^*(\theta)$ represent the equilibrium quantity, price and quality for firm type θ, respectively, and θ_1 is the least efficient type. When the IC constraint is met, the announced type (θ_a) will be the true type of the firm (θ_t). Thus the IC constraint requires that the solution of the problem

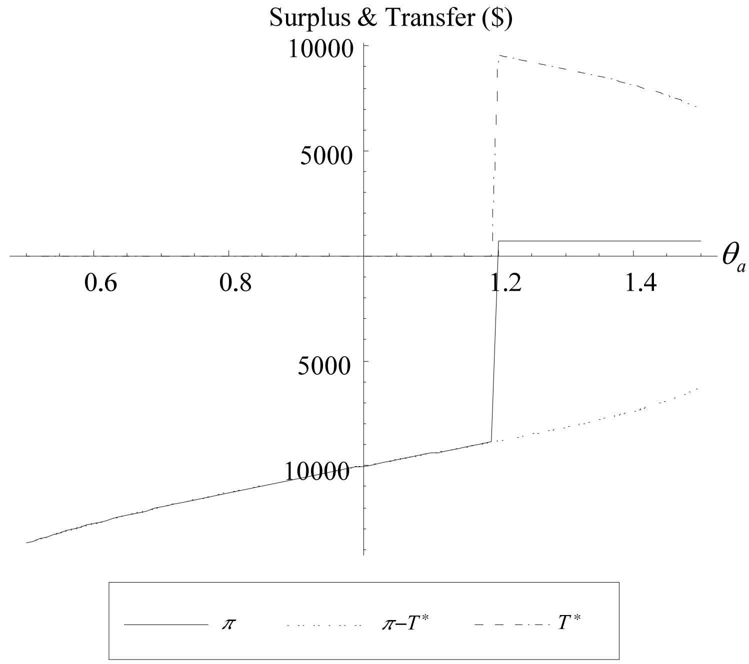
$$Max_{\theta_a}\ \pi[p^*(\theta_a), s^*(\theta_a), T^*(\theta_a, \theta_t); \theta_t]$$

satisfies $\theta_a = \theta_t$. To illustrate, Figure 4.4 shows the (per client) producer surplus, π, obtained by a firm whose true type is $\theta_t = 1.2$ for all possible announced types, θ_a, with transfer T^* and producer surplus net of the transfer, $\pi - T^*$. This figure demonstrates that the transfer is such that, for any (true) firm type, producer surplus is maximized where

[55] Note that the number of clients (n) is assumed exogenous and therefore behaves as a parameter with individual values for each firm.

the announced type is is the true type. Thus, there is no incentive to misrepresent the true type. Figure 4.4 also shows that the transfer can be decomposed in two amounts. The first reflects the IR constraint and is thus the amount that would make the producer surplus equal to zero for the true type, approximately \$6.264. The second is the cost of having an IC compliant transfer, approximately \$734.

Figure 4.4. Per Client Transfer and Producer Surplus for All Possible Announced Types of a Firm Whose True Type is 1.2



When only one instrument can be regulated under asymmetric information, the equilibrium price and quality are computed using (4.2.15) following a procedure similar to that described for one-instrument regulation under symmetric information except that in this case (4.2.18) must be used.

When $\alpha < 0.5$, then under asymmetric information the transfer is calculated as

$$T^*(\theta_a,\theta_t) = V[p^*(\theta_a),s^*(\theta_a)] - p^*(\theta_a)\, Q^*[p^*(\theta_a),s^*(\theta_a)]$$
$$+ \{C[Q^*(\theta_1),s^*(\theta_1),\theta_a] - C[Q^*(\theta_1),s^*(\theta_1),\theta_t]\}/n.$$

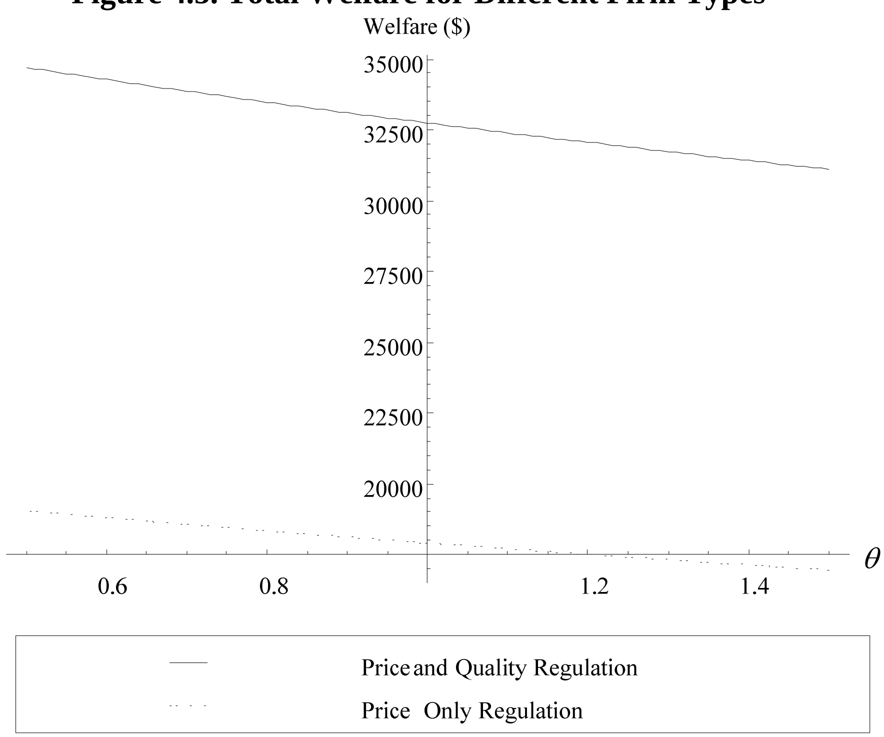
4.3 Results

The main findings of the numerical simulations are presented in this section. They display the behavior of the most relevant indicators such as welfare measures and values of the regulated variables. Additionally, the effects of changing other parameters on these results are presented.

4.3.1 Effects on Welfare

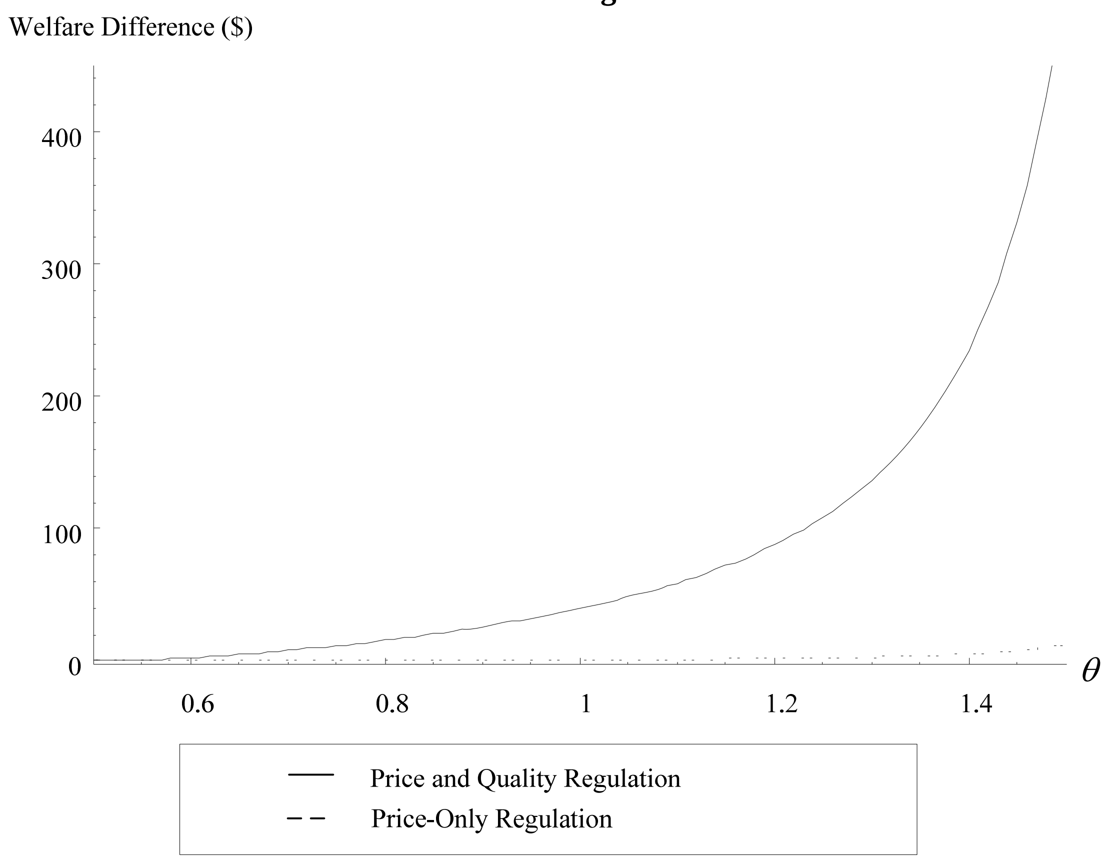
Total welfare, defined as the sum of consumer and producer surplus or as the difference between total WTP and total cost, is larger when price and quality are regulated vis-à-vis when only price is regulated (see Figure 4.5). Also, in the symmetric information models, aggregate welfare is at least as great as in asymmetric models when considering the same number of instruments, except if the regulator is unbiased, in which case it is equal for all firm types.

Figure 4.5. Total Welfare for Different Firm Types



Not surprisingly, the gap between the two becomes increasingly larger for less efficient firms (higher q) for both price-and-quality and price-only regulation, but on average is larger under price-and-quality regulation (see Figure 4.6). This gap can be understood as the welfare loss due to hidden information. It is also larger when the regulator favors consumers (Figure 4.6) over the case when it favors producers (Figure 4.7).

Figure 4.6. Differences in Welfare, Symmetric Minus Asymmetric Information Models: The Case Where the Regulator Favors Consumers



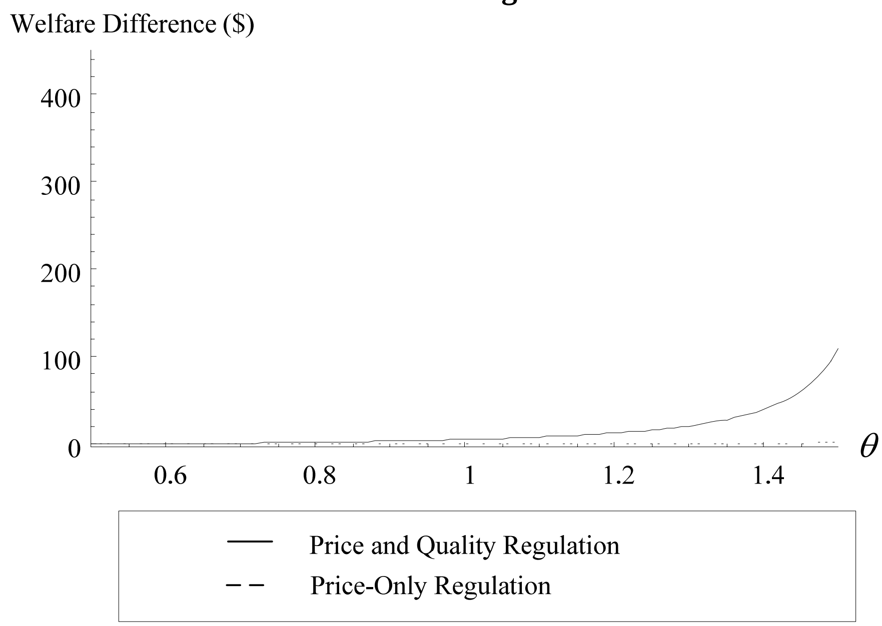
For the most efficient regulated firm, welfare is the same under both information structures, a result known in the literature as *no-distortion at the top*.[56] Therefore, as

[56] As expected, this result does not hold when a uniform distribution is assumed.

expected, the highest welfare levels are achieved with an unbiased regulator under symmetric information when both price and quality are regulated. The loss in welfare in the presence of asymmetric information is due to the existence of a preference or bias by the regulator.

Also the effect of asymmetric information on welfare is smaller than the effect of having an additional instrument to use for regulation, i.e., the ability to regulate both price and quality rather than only price (Figure 4.5 and Figure 4.6)

Figure 4.7. Differences in Welfare, Symmetric Minus Asymmetric Information Models: The Case Where the Regulator Favors the Producer



The effect of the demand function's curvature is such that, when Q_{ps} is greater than zero (as in Figure 4.5), welfare is lower independent of the information structure or the number of instruments that are used. Additionally, the gap in welfare between price-and-quality regulation and price-only regulation is larger when Q_{ps} is less than zero. Moreover, these two results hold for all regulator's preferences and both distributions of firm type (not shown).

Table 4.2 presents a summary of the relative values of expected welfare resulting from the main scenarios considered.[57] With symmetric information, the effect of regulator preference is irrelevant in terms of welfare. With a neutral regulator, information asymmetry has no impact on welfare. These results are consistent with the theoretical findings of Chapter 3. When $Q_{ps} > 0$, the impact of information asymmetry is proportionally higher than when Q_{ps} has the opposite sign. When $Q_{ps} < 0$, the impact of the scope of regulation is also proportionally higher. That is, under this condition regulating price and quality vis-à-vis regulating price only has larger effect on welfare.

Table 4.2. Qualitative Comparison of Expected Welfare for the Different Scenarios

Preference of the Regulator	Consumers		Neutral		Producer	
	$Q_{ps} < 0$	$Q_{ps} > 0$	$Q_{ps} < 0$	$Q_{ps} > 0$	$Q_{ps} < 0$	$Q_{ps} > 0$
Price and Quality Regulation, Symmetric Information	A	D	A	D	A	D
Price and Quality Regulation, Asymmetric Information	C	F	A	D	B	E
Price Only Regulation, Symmetric Information	G	J	G	J	G	J
Price Only Regulation, Asymmetric Information	I	L	G	J	H	K

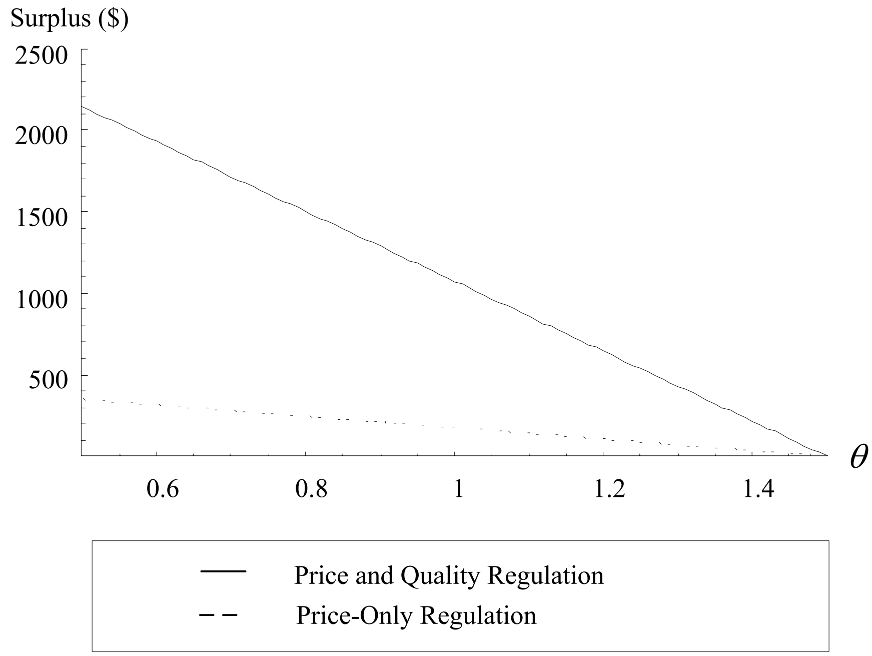
4.3.2 Producer and Consumer Surplus

With a consumer-biased regulator, producer surplus is zero for all firm types in the symmetric information scenarios because zero reservation values are imposed. As expected, the regulator can extract the entire surplus from producers, whether regulating price and quality or only price. With asymmetric information, producers are left with information rents that decrease with type. Figure 4.8 presents the estimated producer surplus for each model with asymmetric information. This surplus represents the information rents earned by the producer. Also, as is the case with welfare, producer

[57] The summary is presented in terms of expectations with respect to the unknown firm type with A representing the highest and L the lowest.

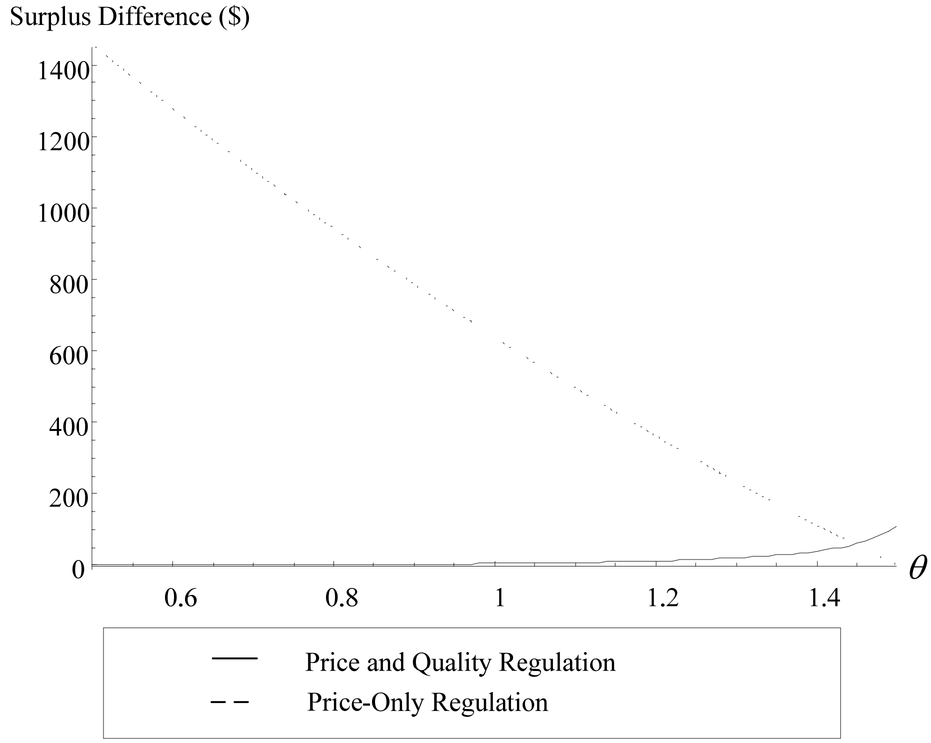
surplus is higher for all types except the least efficient type when both price and quality are regulated compared to the case where only price is regulated. This result implies that, in a regulatory environment with asymmetric information, producers should prefer regulation of both price and quality because it increases their information rents. This is consistent with findings by Lewis and Sappington (1988), where quality is observable.

Figure 4.8. Producer Surplus with Asymmetric Information and a Regulator Biased Toward Consumers



When the regulator is biased toward producers, producer surplus will no longer be zero with symmetric information, and will be higher when regulating price and quality vis-à-vis regulating only price. But the difference in producer surplus between the symmetric and asymmetric models is on average higher for price-only regulation as shown in Figure 4.9. In this case, the regulator tries to favor producers but must still meet the IR constraint. Thus, the surplus is higher the more control the regulator has, e.g. when only price is controlled there is hidden information and thus information losses to the producer.

Figure 4.9. Differences in Producer Surplus with a Regulator Biased Toward Producers: Symmetric Minus Asymmetric Information



With a regulator biased toward consumers, consumer surplus is higher when regulating price and quality as opposed to regulating only price as shown in Figure 4.10. This figure also shows that the gap in consumer surplus between scenarios of symmetric and asymmetric information is larger with price and quality regulation, and that this gap decreases with type. These results hold across changes in the curvature of the WTP function as well as for the two different distributions of firm types. With no regulatory bias, consumer surplus with the most inefficient firm is equal for the symmetric and asymmetric scenarios.[58] With a regulator biased toward producers, consumer surplus will be zero for all scenarios and firm types, except when regulating only price with asymmetric information. In this case, consumer surplus is also decreasing in type but equal to zero for the most inefficient firm, as shown in Figure 4.11. This result arises

[58] In this case, the surplus is arbitrarily allocated to consumers.

because the regulator has to identify the type of the firm before assigning a transfer that is incentive compatible and favors producers.

Figure 4.10. Consumer Surplus With a Regulator Biased Toward Consumers

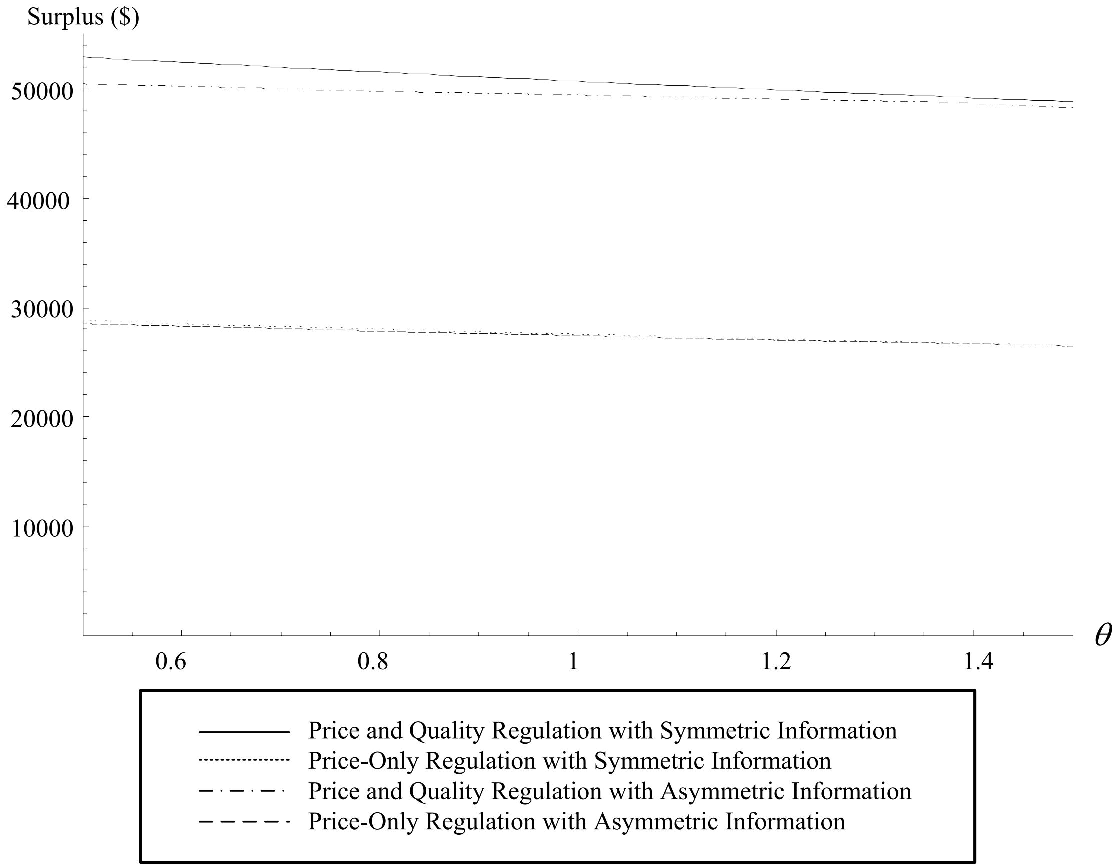
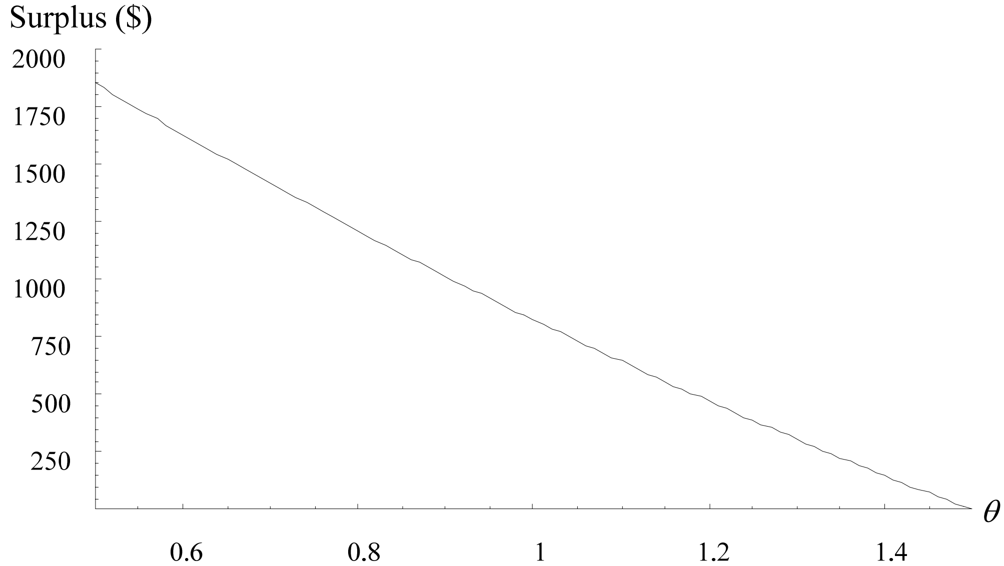


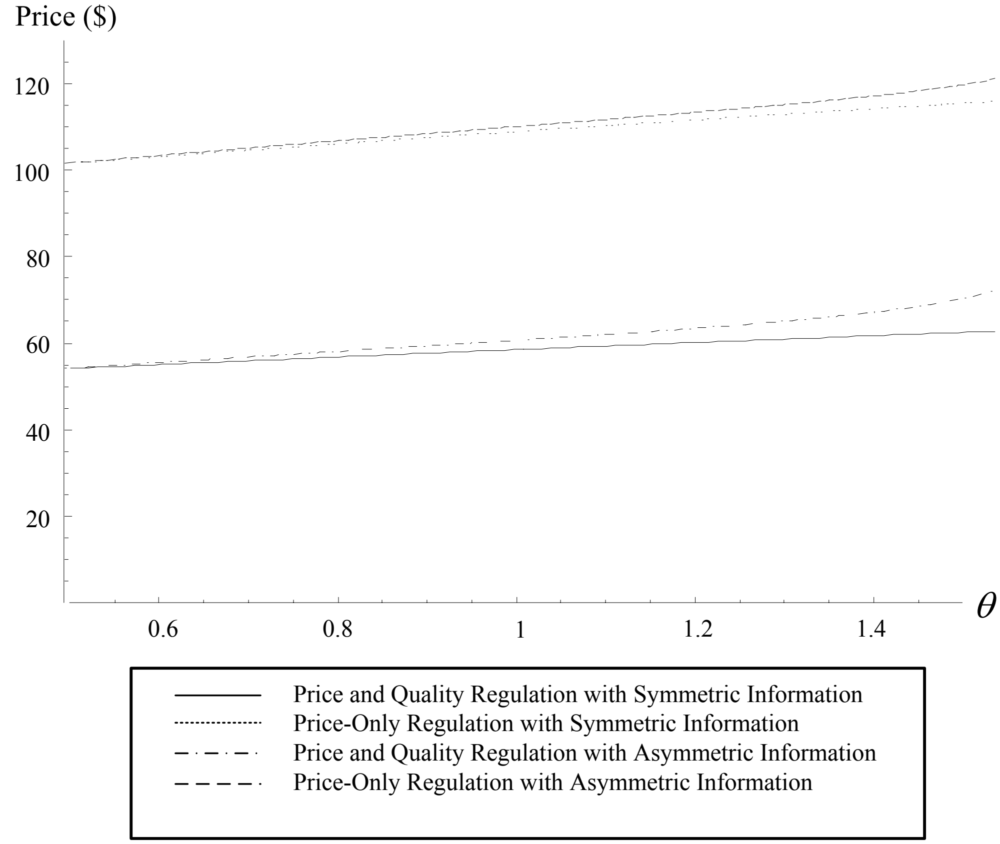
Figure 4.11. Consumer Surplus With a Regulator Biased Toward Producers: The Case of Price-Only Regulation with Asymmetric Information



4.3.3 Price

Price is higher when regulating only price compared to the models when both price and quality are regulated, as shown in Figure 4.12. With a regulator biased toward consumers, price is higher in the scenarios with asymmetric information vis-à-vis symmetric information, regardless of the scope of regulation (price and quality versus only price) or curvature of the WTP function. This difference is zero for the most efficient firm type and increases with firm type (decreases with firm efficiency). With a regulator biased toward producers, the same results apply except that symmetric information models yield higher prices than asymmetric models.

Figure 4.12. Equilibrium Prices by Firm Type with a Regulator Biased Toward Consumers



4.3.4 Quality

The highest levels of equilibrium quality are found for two-instrument regulation scenarios (see Figure 4.13). Quality is always lower with a less efficient firm. When regulating price and quality with a regulator biased toward consumers, the asymmetric information model yields lower quality, except for the most efficient type, and the gap between the two is higher for less efficient firms. When regulating only price, this difference in quality is significantly smaller and the scenario with asymmetric information yields higher quality than the scenario with symmetric information (see Figure 4.14). If the regulator is biased toward producers then the opposite is true.

With a regulator that favors the producer, the model with asymmetric information yields higher quality than the one with symmetric information when regulating price and quality. In contrast, the model with symmetric information yields higher quality than the one with asymmetric information when regulating only price (see Table 4.3). This result is reversed with a regulator that favors consumers. That is, the model with asymmetric information yields lower quality than the one with symmetric information when regulating price and quality. But the model with symmetric information yields lower quality than the one with asymmetric information when regulating only price. This result is explained by the fact that the regulator tries to attain the highest welfare for the party of interest (consumers or the producer) but information asymmetries prevent her from reaching that level, thus achieving a lower (higher) quality when she prefers consumers (the producer) and can set price and quality.

Figure 4.13. Equilibrium Quality with a Regulator Biased Toward Consumers

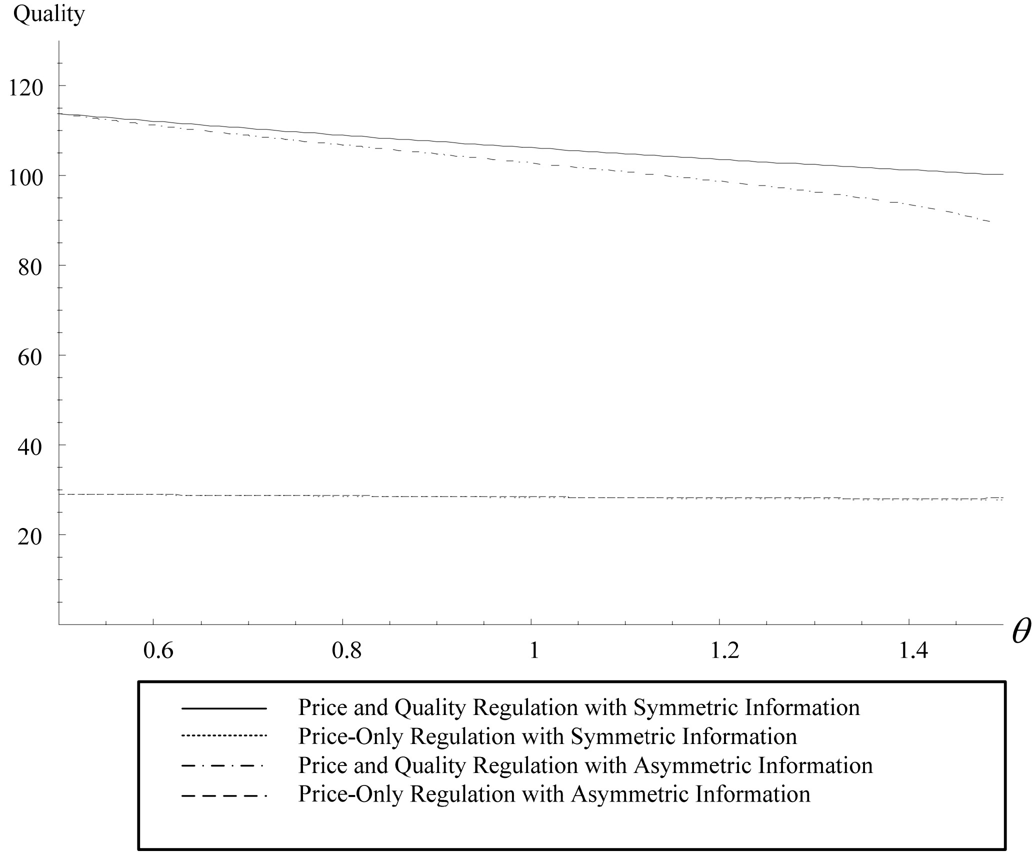
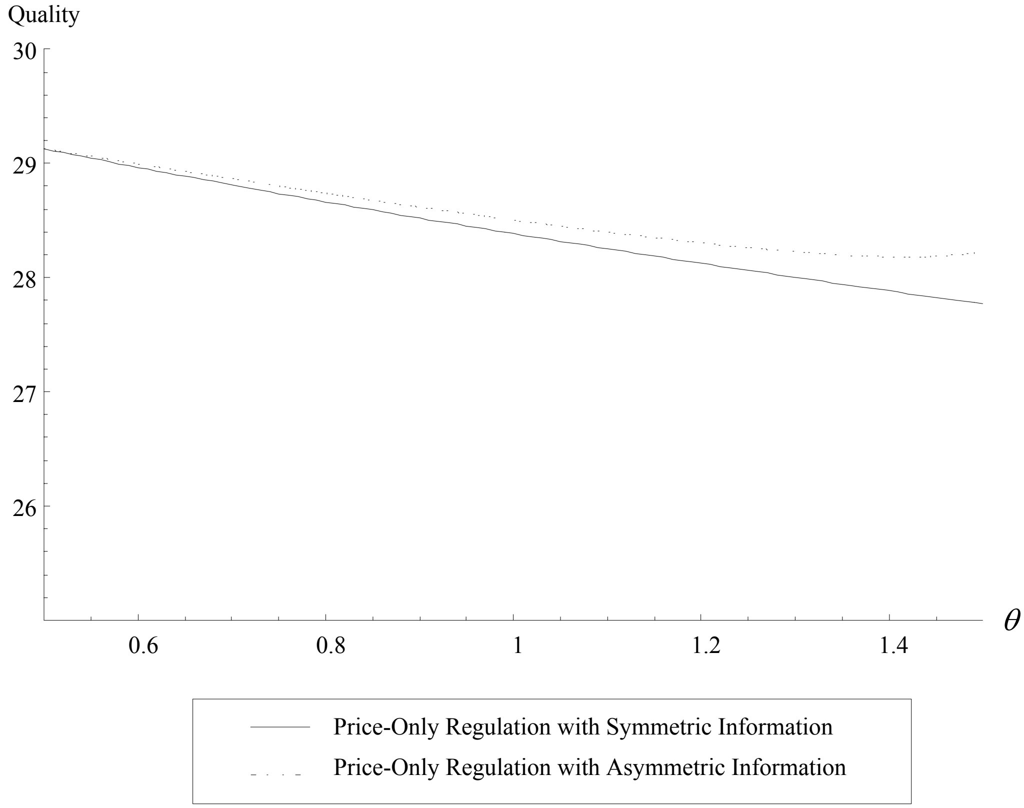


Figure 4.14. Equilibrium Quality with a Regulator Biased Toward Consumers: The Case With Price-Only Regulation



Because the values obtained for the quality variable do not have a direct interpretation, I present a summary table where the expected quality level is replaced by a categorical representation where "A" represents the highest quality and "L" represents the lowest quality (Table 4.3).[59] This table shows that, with a neutral regulator, information has no effect on quality and that, with symmetric information, the regulator's preference has no impact on quality. Interestingly, when regulating price and quality under asymmetric information, expected quality is lower with a regulator that favors consumers than with a neutral regulator, and higher than either of these with a regulator

[59] See footnote 57.

that favors the producer. The opposite is true when regulating only price with asymmetric information.

Table 4.3. Qualitative Comparison of Expected Quality for the Different Scenarios[a]

Preference of the Regulator	Consumer		Neutral		Producer	
	$Q_{ps} < 0$	$Q_{ps} > 0$	$Q_{ps} < 0$	$Q_{ps} > 0$	$Q_{ps} < 0$	$Q_{ps} > 0$
Price and Quality Regulation, Symmetric Information	B	E	B	E	B	E
Price and Quality Regulation, Asymmetric Information	C	F	B	E	A	D
Price Only Regulation, Symmetric Information	K	H	K	H	K	H
Price Only Regulation, Asymmetric Information	J	G	K	H	L	I

[a] Expected quality is represented categorically such that A is the highest and L the lowest.

Equilibrium price and quality can be grouped in two classes of solutions, high-price-low-quality (HPLQ) and low-price-high-quality (LPHQ). For all scenarios and models considered here, HPLQ is reached with price only regulation and LPHQ is reached with price and quality regulation. With a regulator biased toward consumers, the equilibrium price and quality coincide only for the most efficient firm. When regulating price and quality, the difference between symmetric and asymmetric information models is such that they have similar slope in the price to quality function, but the asymmetric information model yields solutions with higher dispersion among firm types (see Figure 4.15). When regulating only price, this slope is no longer similar and the asymmetric information model yields higher prices but also higher qualities than the symmetric information model. The difference in price and quality between the two models is higher for more inefficient firms, and zero for the most efficient firm (see Figure 4.16).

When the regulator favors producers, then also HPLQ is found with price-only regulation and LPHQ is found with price and quality regulation (not shown). But in this case, when regulating both price and quality, the symmetric information model yields solutions with higher dispersion among firm types. And when regulating only price, the symmetric information model yields higher prices and higher qualities than the asymmetric information model.

Figure 4.15. Equilibrium Price and Quality with Price and Quality Regulation by a Regulator Biased Toward Consumers

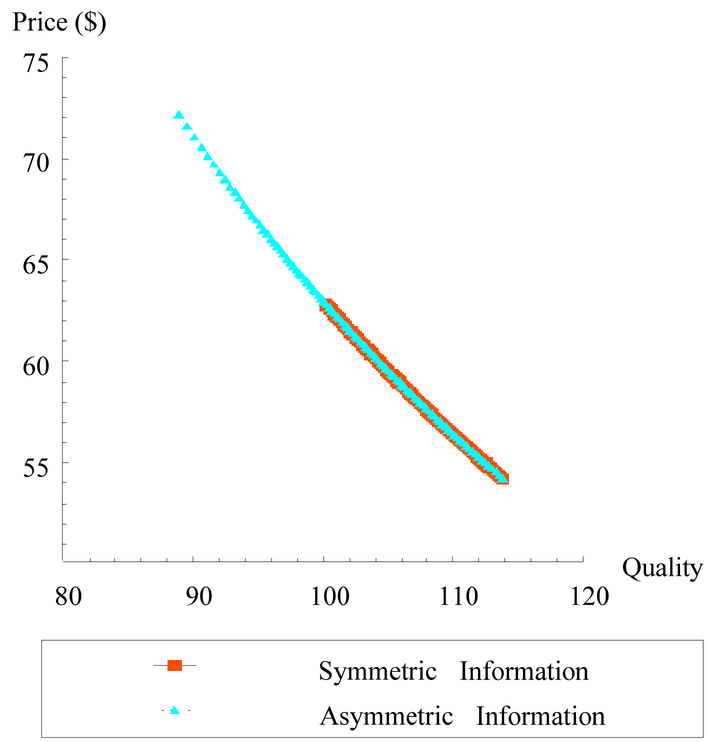
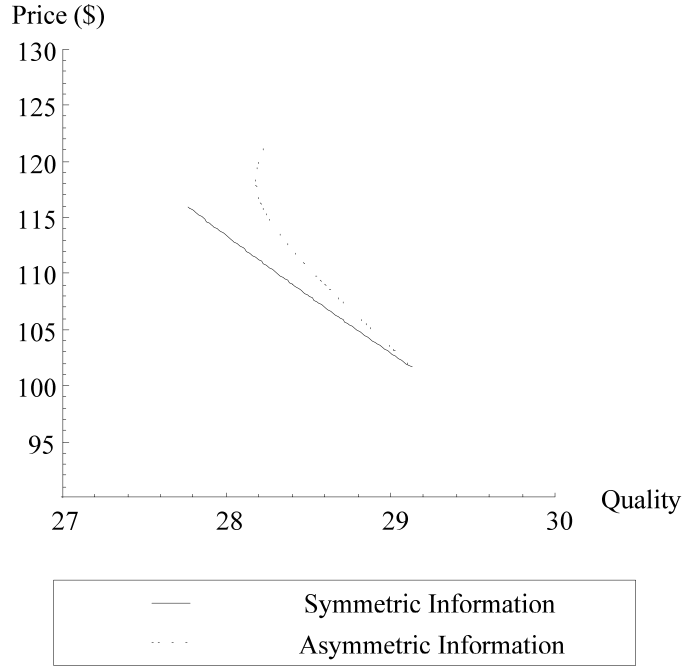


Figure 4.16. Equilibrium Price and Quality with Price-Only Regulation by a Regulator Biased Toward Consumers



4.3.5 Quantity

In all models, quantity is completely determined by price and quality and, thus, provides no additional information about the solution. Nevertheless presenting the results in terms of quantity facilitates understanding of the results. Although the unit of measurement of quantity is not given explicitly in the figures, quantity is measured in per client annual kilowatts per hour. As with the price-quality relationship, there is no difference between the solutions with symmetric and asymmetric information. This figure shows that price and quality regulation yields a high-quality-high-quantity equilibrium compared to price-only regulation, which yields a low-quality-low-quantity solution.

4.3.6 Transfers

Transfers to producers are higher when both price and quality are regulated as opposed to regulating only price (see Figure 4.17 and Figure 4.18). Also, transfers decrease with firm type (increase with efficiency) except when regulating only price under symmetric information with a regulator that is unbiased or biased toward consumers (see Figure 4.18). With a regulator biased toward consumers, the models with asymmetric information yield higher transfers for the more efficient firms and lower transfers for the more inefficient firms when compared to models of symmetric information that use the same instruments. This implies existence of at least one firm type for which the information structure has no effect on the transfer. With a regulator biased toward producers, transfers are higher with asymmetric information when regulating both price and quality but lower when regulating only price (not shown). With an unbiased regulator, transfers are equal for the most inefficient firm when comparing asymmetric and symmetric information models (not shown).

Figure 4.17. Equilibrium Transfers When Regulating Both Price and Quality With a Regulator Biased Toward Consumers

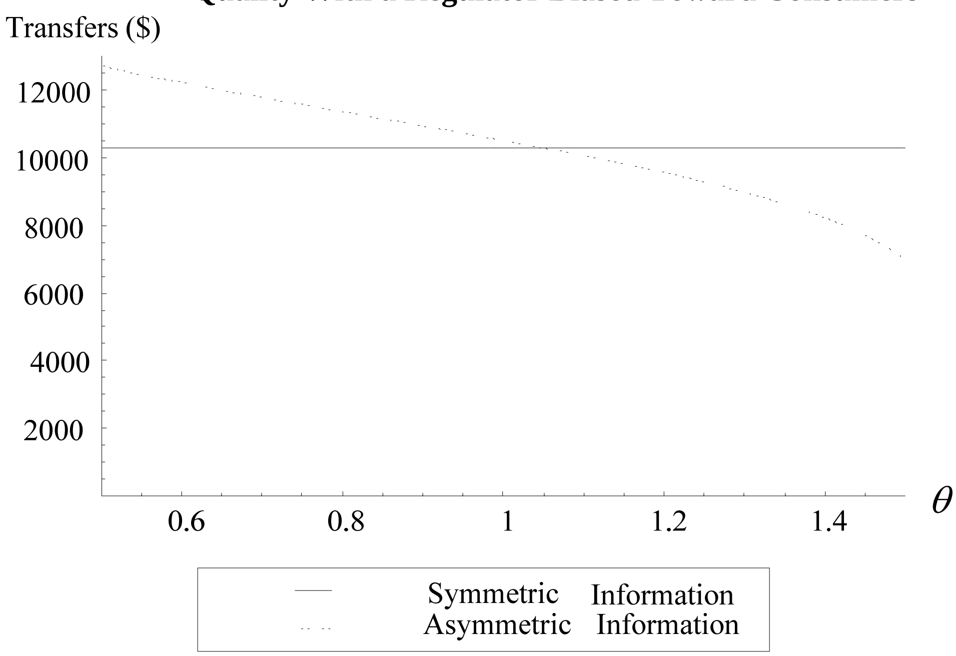
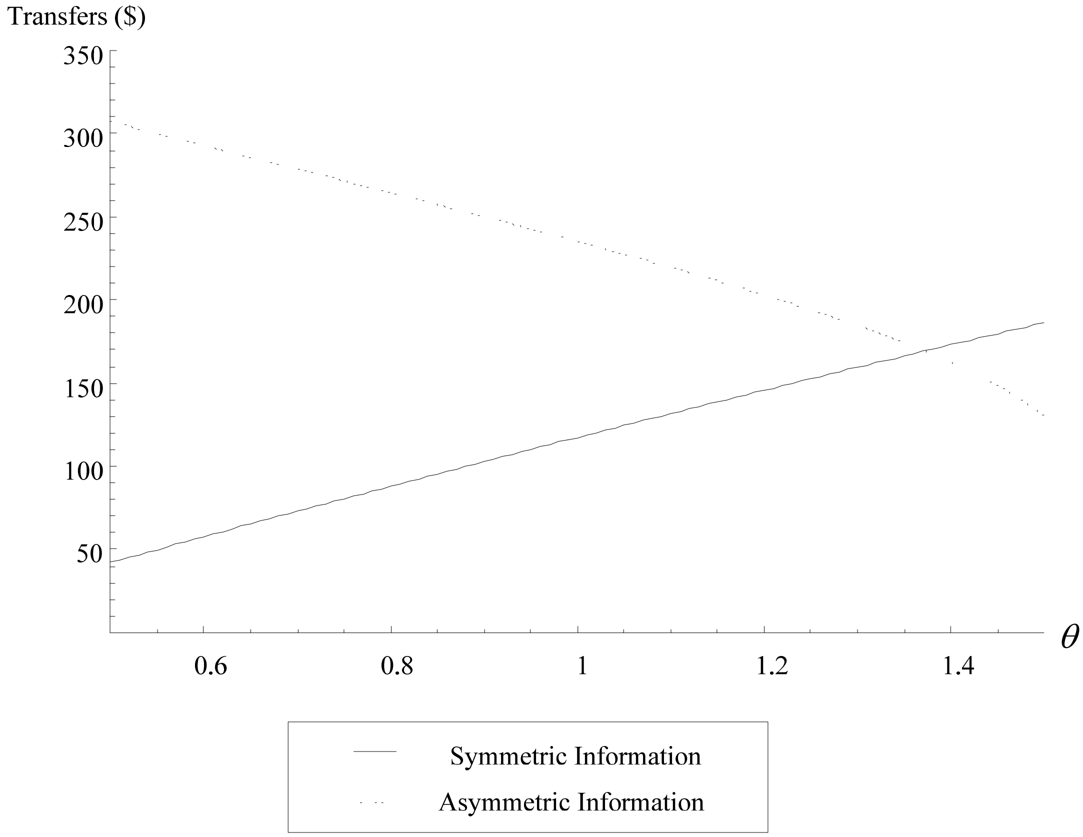


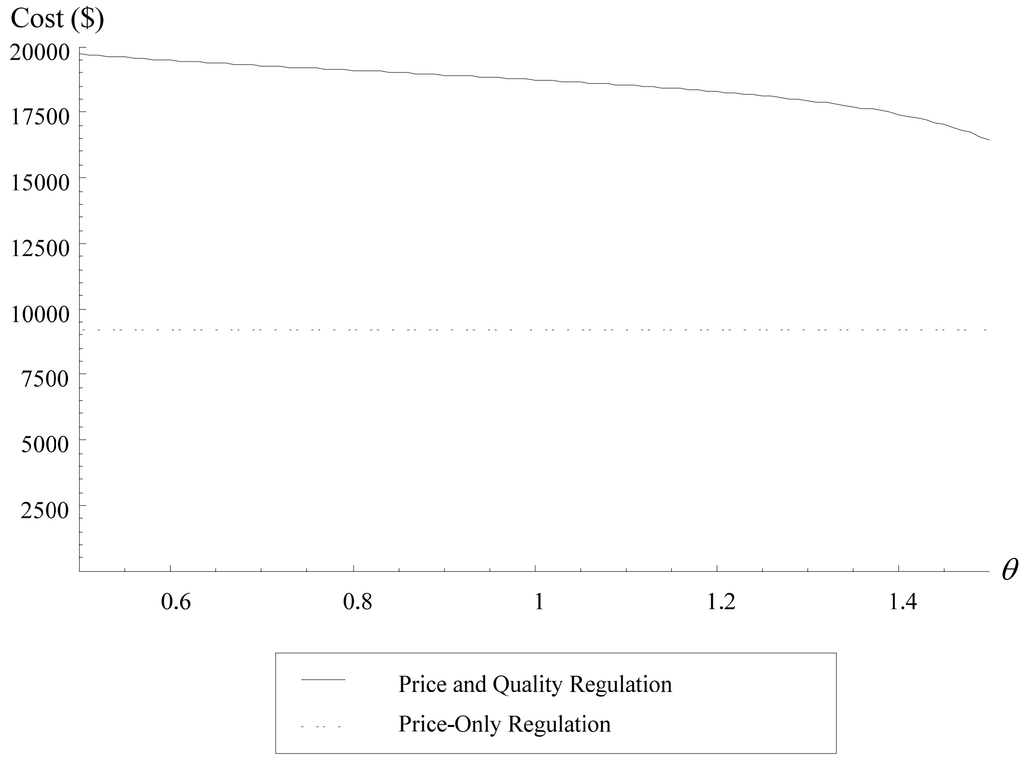
Figure 4.18. Equilibrium Transfers When Regulating Only Price With a Regulator Biased Toward Consumers



4.3.7 Cost

The information structure has no impact on total costs across firm types. From Figure 4.19, they are the same with price and quality regulation as with price-only regulation. This figure also shows that cost is lower when regulating only price vis-à-vis regulating price and quality, and this difference is higher for more efficient firms. This is true for different curvatures of the WTP function. But with a regulator biased toward producers, this difference is lower for more efficient firms.

Figure 4.19. Equilibrium Cost With a Regulator Biased Toward Consumers

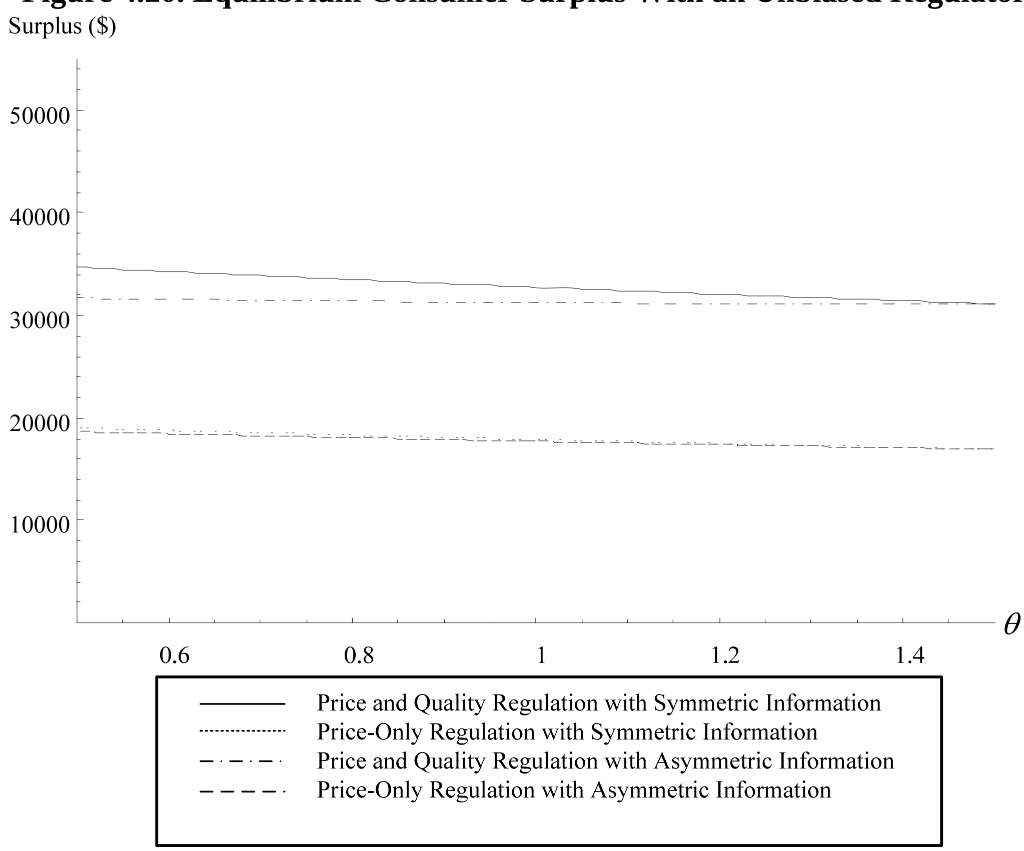


4.3.8 The Impact of the Regulator's Preference

When the regulator is not biased (α = 0.5), the welfare levels achieved under asymmetric and symmetric information models are the same. Price and quality levels are also the same. However, results differ according to the scope of regulation (price-and-quality vis-à-vis price-only regulation). The use of two instruments yields higher levels of welfare, quantity and quality, and lower prices. When the regulator's preference does not favor consumers, the information structure has no effect on consumer surplus for the most inefficient firm (see Figure 4.20). When regulating both price and quality, transfers in the models of asymmetric information are always higher except for the least efficient firm, where they are the same as those under symmetric information (not shown). But when regulating only price the opposite is true, reflecting the fact that the regulator has fewer instruments to achieve its goal. When the regulator does not favor producers, transfers are higher in the asymmetric information models.

Notably, the results differ according to the number of instruments used by the regulator without information asymmetries. This is also true in the absence of regulator "bias" under information asymmetries. Thus, the welfare levels achieved by regulating both price and quality are higher than those achieved by regulating only price. This difference owes mainly to the difference in consumer surplus because producer surplus remains low when the regulator favors consumers, which in turn owes to larger quantities and higher qualities when both price and quality are regulated. This difference represents inefficiency due to the fact that both affect the objective function regardless of whether both are regulated.

Figure 4.20. Equilibrium Consumer Surplus With an Unbiased Regulator



4.3.9 The Case of a Uniform Distribution

Setting the parameters of modified Beta distribution to $v = 1$ and $w = 1$, a uniform distribution of firm types is obtained. For this distribution, results differ slightly from the case above, but the more fundamental results remain intact. Price for the most efficient type is no longer the same across information structures in the various regulatory models (see Figure 4.21). Also the price–quality relation no longer coincides for the most efficient firm with price and quality regulation (compare Figure 4.22 with Figure 4.15) or price only regulation (compare Figure 4.23 with Figure 4.16). This is due to the fact that the initial effect of firm inefficiency is not smooth with a uniform type distribution. Thus information asymmetry and regulator bias introduce a difference in the price-quality ratio.

Figure 4.21. Equilibrium Prices With a Regulator Biased Toward Consumers and Uniformly Distributed Firm Types

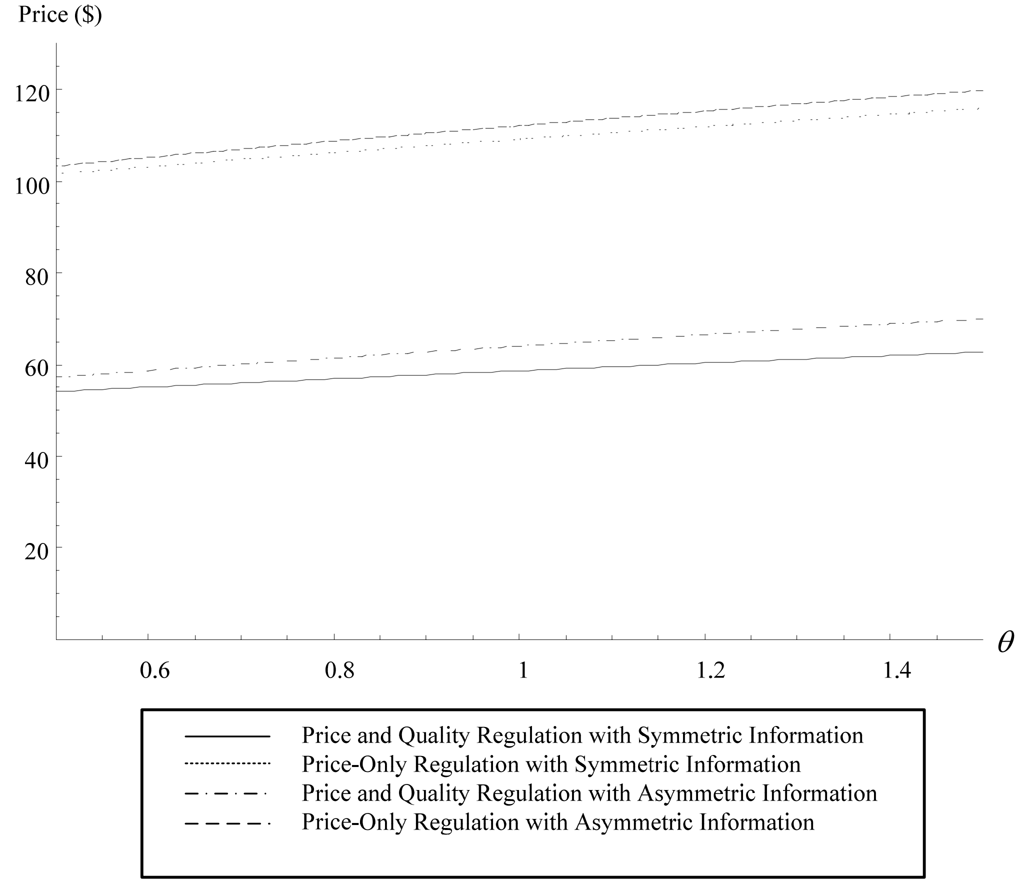


Figure 4.22. Price and Quality With Price and Quality Regulation by a Regulator Biased Toward Consumers and Uniformly Distributed Firm Types

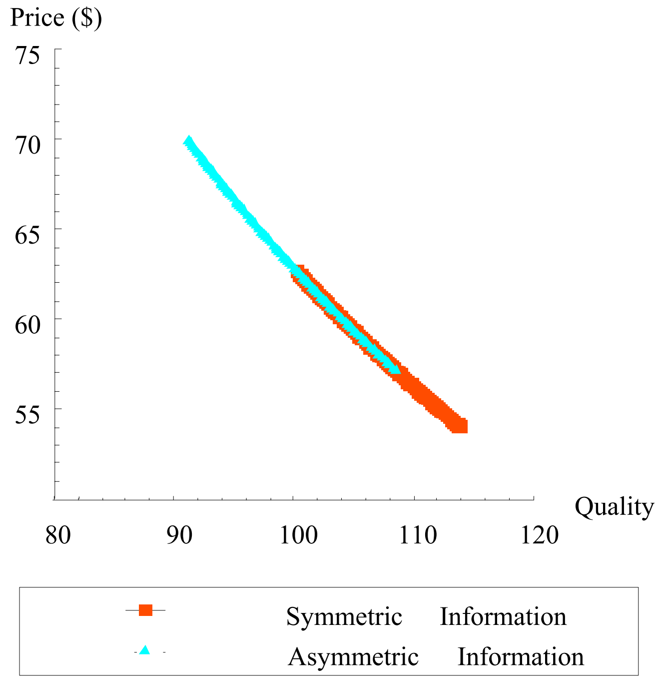
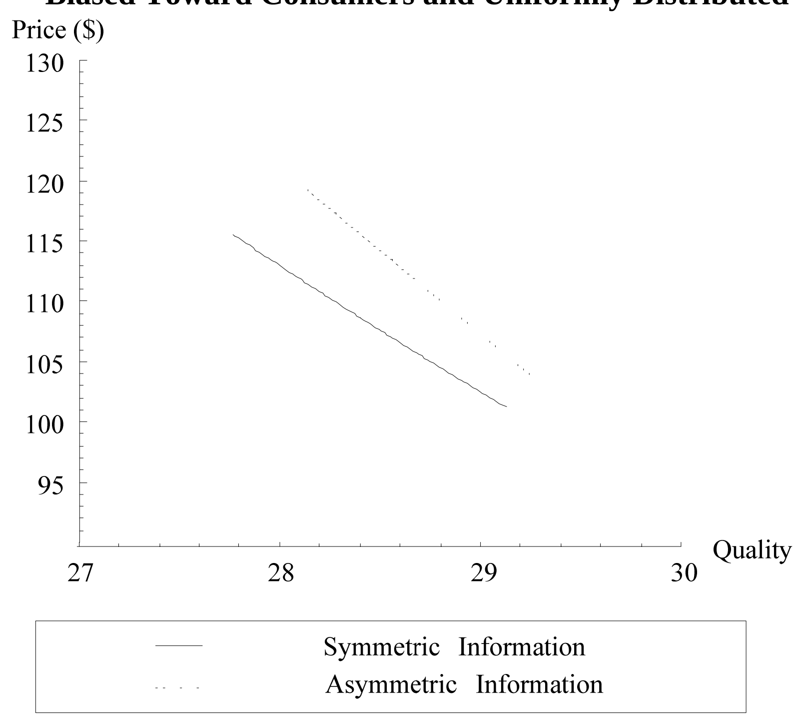


Figure 4.23. Price and Quality with Price-Only Regulation by a Regulator Biased Toward Consumers and Uniformly Distributed Firm Types



4.3.10 Marginal Costs

Marginal costs for the different models with a regulator biased toward consumer are depicted in Figure 4.24. When both price and quality are regulated, marginal costs are higher than when only price is regulated, regardless of the information structure. As expected, the difference in marginal costs between symmetric and asymmetric information models increases with firm type, although this is less evident under a uniform distribution (not shown). This difference is positive with a regulator biased toward consumers, negative with a regulator biased toward producers, and zero with an unbiased regulator (not shown).

However, when marginal costs are compared to prices under symmetric information, they are equal when price and quality are regulated whereas equilibrium prices are higher than marginal costs when only price is regulated (see Figure 4.25). The latter remains true with an unbiased regulator, in which case this is also true for the asymmetric information models. With a regulator biased toward consumers, price is higher than marginal cost for the asymmetric information models except for the most efficient firm type when both price and quality are regulated, in which case they are equal (see Figure 4.26). When the regulator is biased toward producers, price is lower than marginal cost when regulating price and quality except for the most efficient firm type, for which they are equal (not shown). In this case, price is also higher than marginal cost when regulating only price. Independent of the regulator's bias, equilibrium price when regulating only price is higher that the equilibrium price when regulating both price and quality, and marginal cost is lower when regulating only price as compared to models where both price and quality are regulated (see Figure 4.26).

Figure 4.24. Equilibrium Marginal Costs With a Regulator Biased Toward Consumers

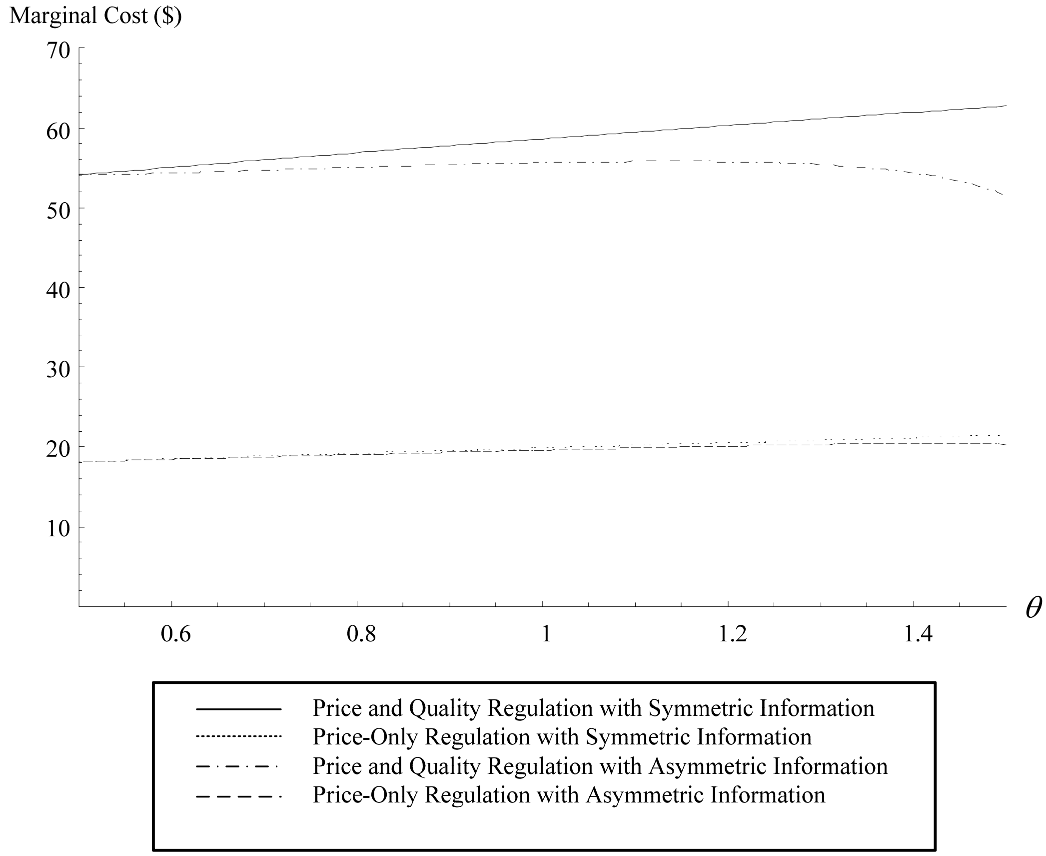


Figure 4.25. Marginal Cost and Price With Symmetric Information and a Regulator Biased Toward Consumers

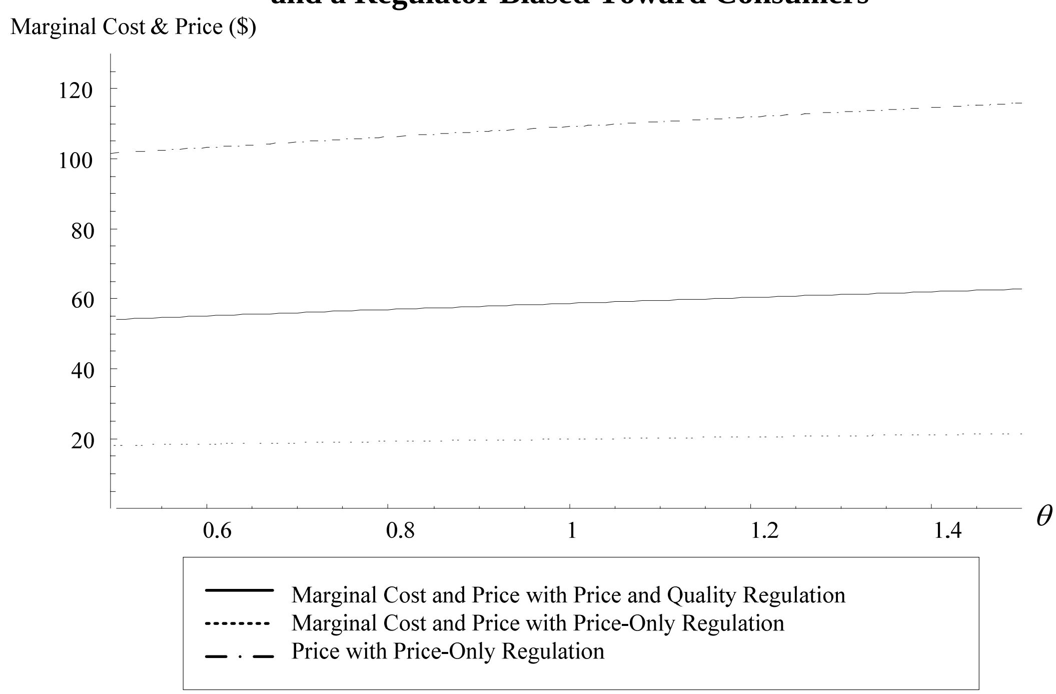
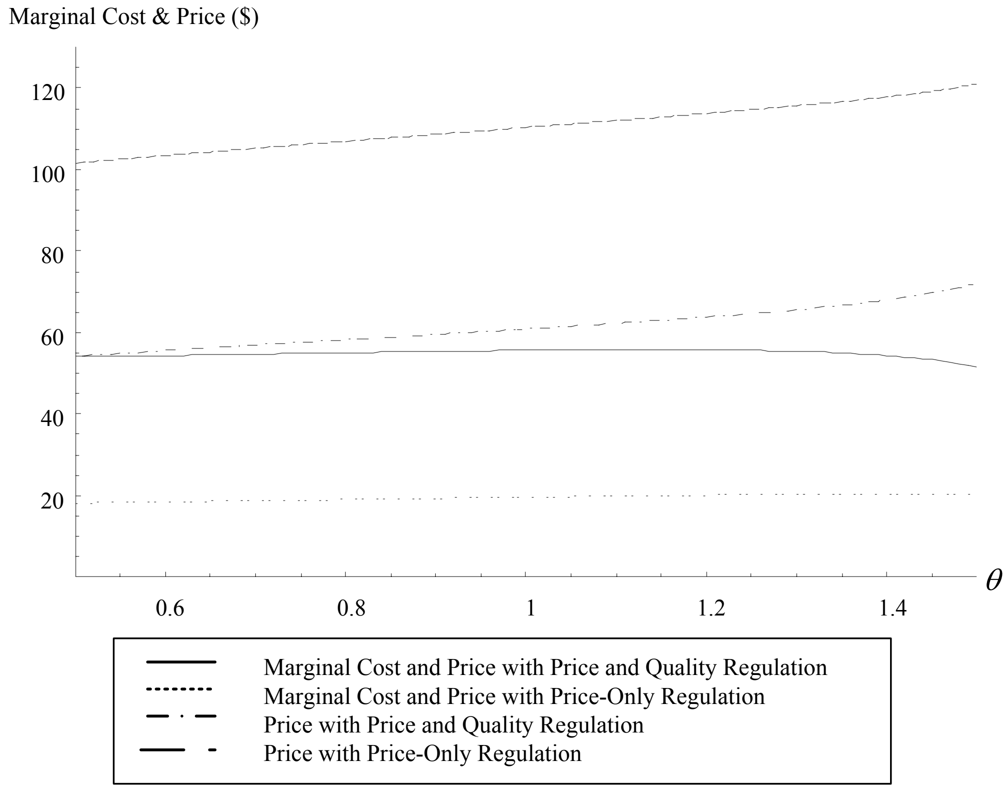


Figure 4.26. Marginal Cost and Price With Asymmetric Information and a Regulator Biased Toward Consumers



4.4 Conclusions to Chapter 4

From the analysis in this chapter, clear patterns are observed with respect to the effect of the information structure and the number of instruments used for regulation on the distribution of price, quality and transfers across firm types, and on overall welfare and its allocation. The results also demonstrate the impact of different consumer and regulator preferences, and different firm efficiency distributions.

The use of two instruments instead of one yields higher welfare levels independent of the information structure and independent of the regulator's preference. That is, when regulating both, price and quality, higher levels of welfare are achieved than when only price is regulated. Asymmetric information has no effect on welfare unless the regulator has biased preferences, which causes a reduction in welfare (vis-à-vis the symmetric information case) that is higher for less efficient firms but nil for the most efficient firm. These results hold for both curvatures of the WTP function that were examined.[60]

A regulator biased toward consumers cannot extract all producer surplus when information is asymmetric. Thus, consumers pay information rents. More importantly, regulation of both price and quality is weakly preferred by the regulator and by regulated firms independent of the information structure. Therefore, if a quality index can be developed, one should expect to see it implemented because both parties prefer it.[61] These results hold for all consumer preferences and distributions of firm types examined here. Thus, if complete regulation is defined as the use of all instruments available, then incomplete regulation should be observed only when at least one of the available instruments is not verifiable.

The highest provision of quality is obtained when both quantity and quality are regulated jointly regardless of the information structure. As expected, lower quality is provided by less efficient firms. This is true for both curvatures of the WTP function that were examined. The effects of information asymmetries depend on the regulator's preferences. When the regulator has no bias, quality remains equal between symmetric and asymmetric models. But when the regulator's preference is biased toward consumers (producers), symmetric information models yield higher (lower) quality except for the most efficient firm, which yields the same quality.

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[60] Also the simulations where run using values of λ in the range 0.05 to 0.95 and no qualitative changes where observed.
[61] This assumes quality is perfectly verifiable.

The results obtained here are consistent with other studies that have examined similar problems (see Baron and Myerson, 1982). That is, with a regulator biased toward consumers or unbiased, prices are a non-decreasing function of firm type, quantities are a non-increasing function of firm type and, in the presence of asymmetric information, prices (quantities) are higher (lower) than under symmetric information due to an extra incentive necessary to reveal the firm's type. When considering a regulator biased toward producers, prices are lower than marginal costs (except for the most efficient firm) when regulating with both instruments under asymmetric information. This result can hold in this study because of the non-linear pricing made possible through transfer payments.

Transfers are higher when regulating price and quality, which reflects the greater ability of the regulator to transfer surplus from producer to consumers. In the absence of regulator bias, transfers under asymmetric information are higher for all firm types. But when the regulator is biased toward consumers, this is not the case. Rather, efficient (inefficient) firms will receive a higher (lower) transfer than they receive under symmetric information. With a regulator biased toward producers, transfers are higher when regulating both price and quality vis-à-vis regulating only price and, when regulating both price and quality, transfers are also higher with asymmetric information vis-à-vis symmetric information. But when regulating only price, the symmetric information model yields higher transfers vis-à-vis asymmetric information, except for the most inefficient firm, in which case they are equal.

The highest overall welfare levels are achieved when regulating both price and quality under symmetric information. This amounts to a first best, where the total surplus is maximized, but allocated toward consumers or producers according to the regulator's preference. In this case, price and marginal cost are equal. In the cases analyzed here, the number of instruments (one or two) has a larger impact in this reduction than information asymmetry, which has no effect in the presence of an unbiased regulator.

5 ESTIMATION OF THE DEMAND FOR ELECTRICITY IN CHILE

5.1 Introduction

Some of the results from the theoretical model developed in Chapter 3 were dependent upon the marginal effect of quality. In Chapter 4, I answered some of the questions left open from the theoretical analysis of Chapter 3 by numerically simulating plausible scenarios, including two alternative parameter specifications that yielded opposite signs on the marginal effect of quality on the demand price elasticity. To further narrow the results sought in this research, this chapter undertakes an empirical enquiry regarding the demand elasticity.

To evaluate the effect of quality, no local experiment of variation is available, so extra-market information is required (Spence, 1975). Thus, the only way for a regulator to achieve the highest welfare levels is to retrieve information about the effects of quality through surveys or other means.

In this chapter, I estimate a demand function for electricity in Chile that includes quality as a variable determining quantity demanded. Quality is taken from an index constructed by the regulator based on a survey conducted among clients of each electric utility. The model assumes that prices are set exogenously by the regulator and quality is also determined exogenously by the electric utility. Ideally, these assumptions could be relaxed by estimating a complete system including the supply side, but data limitations do not allow estimating the cost function parameters of firms.

5.2 Literature Review

The estimation of joint demand systems for electricity and other energy sources, such as natural gas, has presented a challenge due to the regulated nature of these industries and the distinctive characteristics of home energy goods. Although some authors have estimated complete demand systems using an almost ideal demand system and other specifications (Berkhout, Ferrer-i-Carbonell and Muskens, 2004), most studies estimate an independent demand equation for electricity alone, or a system with one equation for each electric appliance (Barnes, Gillingham and Hagemann, 1981). One of the characteristics of many electricity markets is the use of nonlinear pricing schemes. Some authors have estimated the effects of declining block rates, concluding that different blocks have different elasticities (Halvorsen, 1975; Herriges and King, 1994). The difficulty with these studies is that the precise rate schedule is not always available and, many times, is averaged among many consumers.

The literature also includes substantial discussion about how or when estimates represent long- or short-term elasticities. Recognizing that demand for electricity is derived from services that electric appliances provide, many studies have proposed detailed models considering the electricity consumption of each appliance. These models assume that short-term demand is determined by the stock of appliances and its energy efficiency attributes. On the other hand, a long-term decision adjusts the stock of appliances, thus permitting full adjustment to price variations. Joint estimation of the demand for appliances and electricity requires testing for exogeneity of the appliance effect in the electricity demand equation because, otherwise, the coefficient estimates will be biased (Bernard, Bolduc and Belanger, 1996; Dubin and McFadden, 1984). The studies that model the demand for appliances explicitly are not very common because this type of data is not widely available. This is especially true in the context of developing countries.

Since the seminal work of Balestra and Nerlove (1966), the convenience of working with panel data has been established. Kaserman and Mayo (1985) estimate the effect of conservational advertisement on demand using a firm-level panel, and Berkhout, Ferrer-i-Carbonell, and Muskens (2004) consider the effect of an energy tax using a household-level panel. Also, when only long series are available, some authors have used cointegration analysis to estimate price and income elasticities (see Engle, Granger and Hallman, 1989; and Erdogdu, 2007).

The estimation of demand and especially demand for energy is not very common in developing countries, mainly because of the lack of data. Early studies were very aggregated and closer to macroeconomic models or engineering models. These models were advanced significantly by the work of Westley (1984; 1992). In Chile, one recent study has made a serious effort to estimate the demand for electricity (Benavente, et al., 2005). This study addressed the challenge of estimating a panel of small size and duration by using a Monte Carlo simulation to select their estimator.

This chapter presents new estimates of demand for electricity in Chile using an aggregated model based on data from several distribution companies for 3 years. The estimation explicitly considers the quality of service perceived by consumers. Econometric estimations that consider quality of service are not very common, most studies only focus on estimating outage costs or reliability problems, which is only one of the many dimensions of the quality of service concept considered here (Bernstein and

Agurto, 1992; Klytchnikova, 2006; Serra and Fierro, 1997; Serra, 1997; Westley, 1984). Another line of research has been to apply a stated-preference experiment to consumers asking them to choose between specific quality attributes and different price levels (see Söderberg, 2007; Yongxin, Deilami and Train, 1998).

5.3 The Econometric Model

The demand function considered in equation (4.2.1) in Chapter 4 is a function of price and quality. To capture at least a second-order approximation of the effect of quality on demand, I estimate a translog specification, which includes an interaction term between these two variables. This function has the advantage of linearity in parameters, which facilitates greater flexibility and diagnostic analysis in the estimation even though it does not impose qualitative relationships globally as does the function used in Chapter 4. In particular, a term that reflects the impact of quality on the marginal effect of price on quantity demanded is included in the estimated demand equation because the theory of Chapter 3 and results of Chapter 4 suggest that determining the sign of this term is critical in resolving remaining ambiguities. I have also included a variable reflecting the role of population density, urbanization, and accompanying lifestyles in different sized cities. A number-of-clients variable is used for this purpose because no other information on population density or rurality was available.

The general form of the estimated demand function is thus of the form

$$\ln Q_{it} = \beta_0 + \beta_1 \ln p_{it} + \beta_2 s_{it} + \beta_3 \left(\ln p_{it}\right)^2 + \beta_4 s_{it}^2 + \beta_5 s_{it} \ln p_{it} + \beta_6 \ln cl_{it} + \beta_7 \left(\ln cl_{it}\right)^2 + e_{it}, \tag{5.3.1}$$

where Q_{it} is the annual per household consumption of electricity served by firm i in year t, s_{it} is the associated quality, p_{it} is the associated price (the variable part of a two part tariff), cl_{it} is the number of clients served by each firm i in year t as an indicator of the size and density of each service area, and e_{it} represents an error term. The raw rather than logarithmic form of the quality variable is used because it is merely an index. For estimation, this demand equation is augmented in several alternative ways to capture the effects of variation in economic characteristics and climate using either fixed regional and time effects or income and temperature variables.

5.4 The Data

The main sources of information for the electricity industry in Chile are the regulatory agencies, which collect the data from firms, consumers, and operators. These regulatory institutions are the National Energy Commission (CNE) and Superintendence of Electricity and Fuels (SEC), which collect statistical information to regulate the industry. Part of the information is generated by these institutions but some also comes from the regulated firms. Also, the centralized electricity system operator or economic load dispatch center (CDEC) generates all of the information on electricity generation, transmission, and transactions.

The data available for each distribution company are the (regulated) prices charged to their customers, the volume of electricity sold, and the number of clients. Volumes traded and prices are obtained from the CNE. Information on quality is obtained from the SEC, which receives the data from surveys that firms are required to conduct of their customers. Prices are measured in constant (December 1998) Chilean pesos per kW-h per client for the variable part and in constant Chilean pesos per client for the fixed part, which is considered below even though not included in equation (5.3.1). Electricity consumption is measured in megawatt-hours (MW-h) per client per year.[62]

Quality is measured by a survey that each electric utility has to conduct by law. Consumers are asked to evaluate the quality of the service based on technical parameters (such as variations in power, blackouts duration, etc.) and technical and commercial customer service (e.g., bill payment assistance). Data on quality of service is not usually available for developing countries. Thus, this data presents an important opportunity to evaluate the role of a broad measure of quality in demand and the related regulatory process. The final index value is a weighted average of these three sections of the survey.[63] Unfortunately, the only information available from the survey is the final index, which thus prevents evaluating the role of each separate measure of quality that contributes to the index.

Chile is divided into 13 regions that reflect regional variation in climate and economic circumstances, (see Figure 5.1).[64] Because Chile is a narrow country, regions are ordered form north to south with Region 1 in the extreme north and Region 12 in the extreme south. Region 13 is the Metropolitan Region (RM) where Santiago, the capital, is located in the middle of the country. Regional variation in climate and economic circumstances can be represented in the model in (5.3.1) either by introducing specific climate and economic variables or by introducing fixed effects of time and regions. To represent local economic circumstances, I use Regional GDP which is estimated by the Central Bank of Chile and measured in constant (1996) thousand pesos per capita. To

[62] One megawatt-hour is the amount of (usually electrical) energy expended by a one megawatt load drawing power for one hour.

[63] For more details on how this index is constructed see, for example, Annex 1 of "OF. CIRCULAR: Nº 06557/DIE 2086 /SE 1174 /" from the Superintendence of Electricity and Fuels of Chile.

[64] Two more regions have been created more recently.

represent climate, I use the long-term mean winter temperature measured in degrees Celsius.[65] Alternatively, climate and income variation among regions is represented by incorporating fixed effects for 12 of the 13 regions and for 2 of the 3 time periods. Because of the proximity of regions and similarity of economic and climatic circumstances, I also consider a less-detailed regional representation with just one fixed effect for Regions 3 through 9 representing the central zone and one other fixed effect representing the metropolitan zone (Region 13 or RM). The metropolitan zone stands apart from the rest of the central region because Santiago concentrates close to 40% of the population and nearly 50% of the GDP in a single region.

The dataset used for the estimation is an unbalanced panel consisting of 69 observations on 22 firms for 1996 and 1997, and 25 firms for 1998. At least one firm operates in each of the 13 regions of the country. The data available for each firm during this period is total electricity sales, price charged to consumers (variable and fixed rates), number of clients served, and an indicator of the quality of service.[66] The GDP data are available for each region and each time period (Banco Central de Chile, 2007). Long-term mean winter temperatures reflect the climate of the main populated areas of each region. The temperatures can be considered 30-year averages for the months of June, July and August for each region, and are thus constant across the time period considered in this study (see Departamento Geofísica - Universidad de Chile, 2006).

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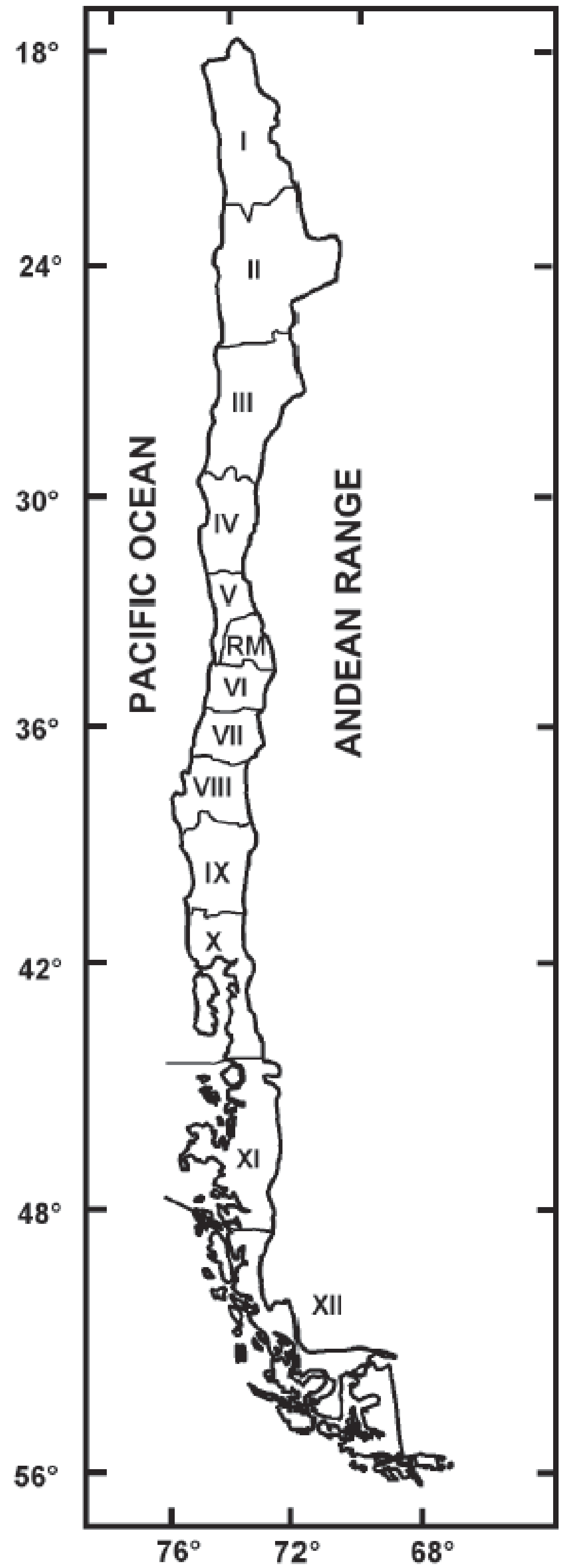
[65] Unfortunately, no systematic aggregation of local temperatures is available that reflects year-to-year variation and yet corresponds with firm-level data. Because the use of air conditioning by residential consumers is not very common, summer temperature are not included, nor did preliminary analysis suggest doing so.

[66] See footnote 63.

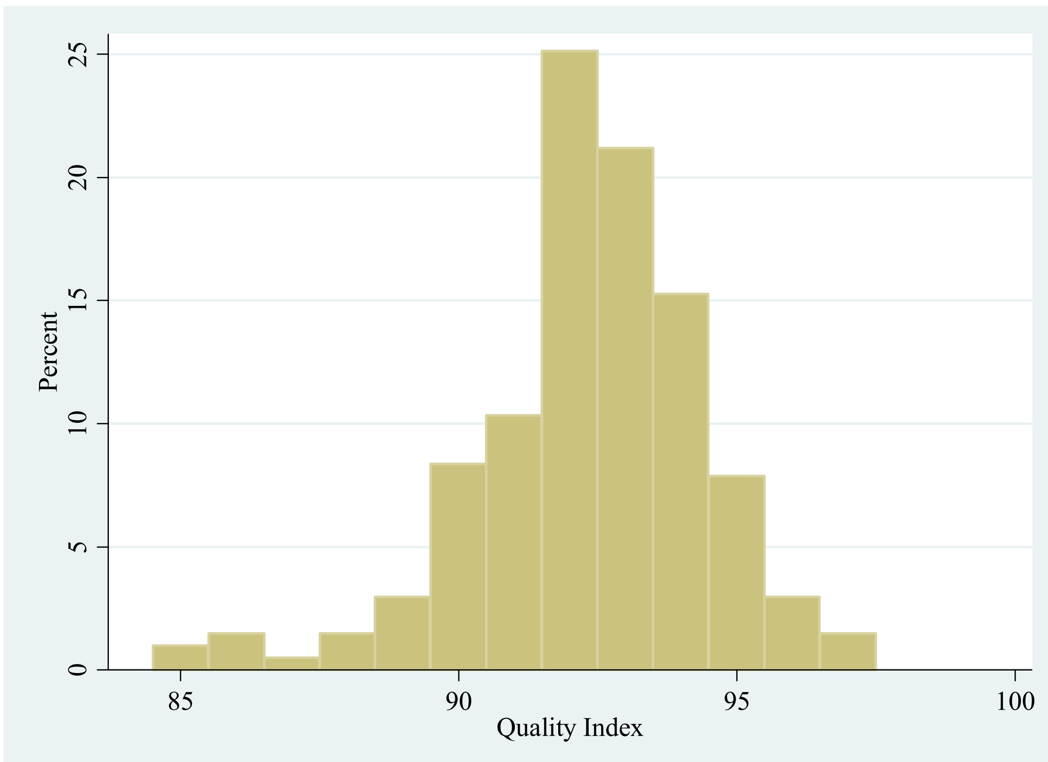
Figure 5.1. Map of Chile and its Regions



Source: Iriarte, Lobos and Jaksic (2005).

Although the quality index does not have much dispersion in values, it seems to have a distribution close to normal (see Figure 5.2). According to agents from the industry, an explanation for this concentration is that it was politically unadvisable for the regulatory agency to have some scores "too far away from the group." This could have had consequences on company value that the regulator was not prepared to face. This is understandable given that this was an initial effort to include quality in a regulatory scheme that was itself relatively new.

Figure 5.2. Histogram of the Quality Index



Source: Data from the SEC.

In the period 1996 to 1998, national per-client residential energy consumption increased as indicated in Table 5.1. This table also shows per client consumption for different regions. In some of these regions, a decrease in consumption is observed, which may be explained by the economic crisis of 1997, which had different effects among regions according to economic activities and weather.

Table 5.1. Average per Capita Energy Consumption (MW-h per Client per Year)

Region	**1996**	**1997**	*1998*
1	1,672	1,850	2,004
2	1,366	1,613	1,747
3	1,146	1,221	1,287
4	1,177	1,205	1,257
5	1,181	1,361	1,395
6	1,012	1,053	1,095
7	1,543	1,255	1,349
8	1,331	1,189	1,258
9	1,301	1,603	1,323
10	2,050	2,170	2,087
11	1,272	1,310	1,352
12	1,700	1,601	1,672
13	1,749	1,812	1,917
Country Average	1,749	1,812	1,917

Source: Data from the CNE.

In the period of study, prices have been falling as indicated by Table 5.2. Also, prices are lower in the more densely populated area of Chile (regions 5 through 8 and 13) than in the remote regions of the country (regions 1 through 3 and 10 through 12). For the period 1996 through 1998, national average per capita GDP increased only slightly (not shown).

5.5 Estimation Results

Because available data is rather limited, the estimation does not attempt to recover the parameters explicitly corresponding to the demand function used in Chapter 4 for the simulation [see equation (4.2.1)], which would require the use of nonlinear estimation methods. Rather, I estimate a linearized model that considers the main variables affecting demand.

Table 5.2. Average Electricity Price (Chilean 1998 Pesos per kW-h)

Region	1996	1997	1998	*Period average*
1	70.20	65.33	64.88	66.80
2	69.67	64.08	62.95	65.57
3	70.56	65.86	61.74	66.06
4	67.72	63.65	59.36	63.58
5	60.92	57.71	53.86	57.50
6	68.82	65.41	60.74	64.99
7	54.73	59.95	55.77	57.23
8	60.20	57.60	53.22	56.72
9	63.18	60.08	57.40	60.22
10	64.65	62.19	60.33	62.11
11	86.26	80.48	80.42	82.39
12	66.59	67.49	69.49	67.86
13	56.77	53.42	49.22	53.14
National average	63.80	60.69	57.64	60.58

Source: Data from the CNE.

5.5.1 Estimation with Fixed Effects

Table 5.3 presents the results of the estimation of several alternative models along with associated diagnostic tests in Table 5.4. All models include the quality index lagged one-period, price (in log-linear form), a cross term between quality and price (in log form), and the number of clients served (log-linear and log-squared forms). Model M1, the most general model, also includes squared forms of price and quality as well as fixed effects for regions and years.[67] Adding the fixed rate of the two part tariff (both log-linear and log-squared terms) was also considered but, as Table 5.5 shows, an F-statistic of 0.63 for the hypothesis that both coefficients are simultaneously zero supports excluding these terms with a p-value of 0.537. These variables are also excluded on economic grounds because the fixed part of the tariff does not affect marginal behavior according to economic theory. Also, unlike some other areas of the world, the variable component of

[67] Random effects models were also estimated but performed very poorly. No coefficient was significant, which is probably due to the small number of time periods available.

Table 5.3. Regression Results[a]

Dependent variable Ln (quantity) Model:	M1[b]	M2[b]	M3	M3R	M4	M4R	M5	M6	M6R	M7	M7R
Quality	2.135	1.668	1.378	1.378	-1.061	-1.061	1.128	-2.659	-2.659	-1.201	-1.201
	(1.27)	(1.10)	(0.91)	(1.20)	(-1.84)	(-1.80)	(0.74)	(-1.30)	(-1.76)	(-1.52)	(-1.40)
	[0.209]	[0.277]	[0.368]	[0.235]	[0.070]	[0.078]	[0.462]	[0.198]	[0.084]	[0.134]	[0.168]
Quality squared	-0.013	-0.011	-0.012	-0.012			-0.010	0.007	0.007		
	(-1.82)	(-1.68)	(-1.70)	(-1.83)			(-1.41)	(0.78)	(0.86)		
	[0.074]	[0.099]	[0.095]	[0.072]			[0.165]	[0.441]	[0.392]		
Ln(price)	-1.711	-3.307	-4.856	-4.856	-24.821	-24.821	-5.039	-31.832	-31.832	-28.085	-28.085
	(-0.10)	(-0.20)	(-0.31)	(-0.35)	(-1.92)	(-1.90)	(-0.32)	(-1.50)	(-1.68)	(-1.58)	(-1.48)
	[0.922]	[0.839]	[0.754]	[0.729]	[0.059]	[0.062]	[0.751]	[0.139]	[0.099]	[0.118]	[0.144]
Ln(price) squared	-0.666	-0.876	-1.591	-1.591			-1.323	0.096	0.096		
	(-0.58)	(-0.78)	(-1.98)	(-2.26)			(-1.53)	(0.08)	(0.12)		
	[0.563]	[0.439]	[0.052]	[0.028]			[0.132]	[0.933]	[0.904]		
Quality*Ln(price)	0.076	0.109	0.189	0.189	0.264	0.264	0.166	0.332	0.332	0.300	0.300
	(0.47)	(0.74)	(1.33)	(1.49)	(1.89)	(1.86)	(1.17)	(1.67)	(1.67)	(1.56)	(1.46)
	[0.643]	[0.464]	[0.187]	[0.141]	[0.063]	[0.067]	[0.248]	[0.100]	[0.101]	[0.123]	[0.151]
Ln(clients)	-0.934	-0.941	-0.676	-0.676	-0.710	-0.710	-0.757	-0.793	-0.793	-0.775	-0.775
	(-5.11)	(-5.18)	(-4.60)	(-4.53)	(-4.74)	(-4.72)	(-4.77)	(-3.58)	(-3.56)	(-3.56)	(-3.38)
	[<0.001]	[<0.001]	[<0.001]	[<0.001]	[<0.001]	[<0.001]	[<0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Ln(clients) squared	0.043	0.043	0.031	0.031	0.033	0.033	0.035	0.036	0.036	0.035	0.035
	(5.11)	(5.15)	(4.46)	(4.53)	(4.59)	(4.72)	(4.65)	(3.46)	(3.65)	(3.43)	(3.42)
	[<0.001]	[<0.001]	[<0.001]	[<0.001]	[<0.001]	[<0.001]	[<0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Central Zone			-0.480	-0.480	-0.431	-0.431	-0.484				
			(-8.57)	(-11.02)	(-8.21)	(-11.74)	(-7.61)				
			[<0.001]	[<0.001]	[<0.001]	[<0.001]	[<0.001]				
Metropolitan Region			-0.192	-0.192	-0.204	-0.204	-0.177				
			(-2.56)	(-2.46)	(-2.70)	(-2.94)	(-2.10)				
			[0.013]	[0.017]	[0.009]	[0.005]	[0.041]				
Ln(GDP per capita)							-0.050	0.182	0.182	0.204	0.204
							(-0.59)	(1.87)	(2.35)	(2.23)	(2.72)
							[0.557]	[0.066]	[0.022]	[0.030]	[0.008]
Mean winter temperature							-0.021	-0.073	-0.073	-0.071	-0.071
							(-0.64)	(-1.76)	(-2.53)	(-1.77)	(-2.38)
							[0.522]	[0.083]	[0.014]	[0.081]	[0.020]
Mean winter temperature squared							0.002	0.005	0.005	0.004	0.004
							(0.99)	(1.68)	(2.26)	(1.63)	(2.06)
							[0.326]	[0.099]	[0.028]	[0.108]	[0.044]
Constant	-82.950	-57.641	-42.717	-42.717	111.006	111.006	-29.828	197.819	197.819	122.592	122.592
	(-0.80)	(-0.61)	(-0.45)	(-0.61)	(2.09)	(2.04)	(-0.32)	(1.57)	(2.21)	(1.68)	(1.55)
	[0.431]	[0.543]	[0.652]	[0.542]	[0.041]	[0.046]	[0.753]	[0.123]	[0.031]	[0.098]	[0.128]
R^2	0.749	0.741	0.671	0.671	0.643	0.643	0.689	0.353	0.353	0.346	0.346
Adjusted R^2	0.637	0.640	0.621	0.621	0.602	0.602	0.622	0.242	0.242	0.259	0.259

[a] Numbers in parentheses are *t*-ratios and numbers in brackets are *p*-values. All models are estimated with 69 observations.

[b] Estimated coefficients of regional and time dummy variables included in models M1 and M2 are reported in Table A.1 of the appendix.

Table 5.4. Joint Effects and Diagnostics Tests[a]

Tests of Significance	M1	M2	M3	M3R	M4	M4R	M5	M6	M6R	M7	M7R
F-tests for joint effects											
All price terms	0.19	0.69	3.71	7.16	3.70	5.80	2.99	1.47	2.88	2.01	3.52
	[0.904]	[0.563]	[0.016]	[<0.001]	[0.031]	[0.005]	[0.039]	[0.233]	[0.044]	[0.143]	[0.036]
All quality terms	2.07	1.97	3.44	5.98	3.45	5.80	2.66	1.87	2.73	2.58	4.17
	[0.118]	[0.131]	[0.022]	[0.001]	[0.038]	[0.005]	[0.057]	[0.145]	[0.052]	[0.084]	[0.020]
Number of clients	13.09	13.40	11.48	10.27	12.35	11.15	12.00	7.16	7.11	7.28	5.91
	[<0.001]	[<0.001]	[<0.001]	[<0.001]	[<0.001]	[<0.001]	[<0.001]	[0.002]	[0.002]	[0.001]	[0.005]
Mean winter temperature	.	.	.	.	.	.	1.56	1.57	3.30	1.67	3.37
	.	.	.	.	.	.	[0.220]	[0.217]	[0.044]	[0.196]	[0.041]
Diagnostics											
Breusch-Pagan / Cook-Weisberg	1.273	1.183	0.001	.	0.394	.	0.065	0.011	.	0.002	.
	[0.259]	[0.277]	[0.974]	.	[0.530]	.	[0.799]	[0.916]	.	[0.969]	.
Ramsey RESET	1.04	1.15	1.92	[1.924]	2.84	2.84	1.95	1.52	1.52	1.77	1.77
	[0.384]	[0.338]	[0.136]	[0.136]	[0.046]	[0.046]	[0.133]	[0.219]	[0.219]	[0.162]	[0.162]
Cameron and Trivedi Decomposition of Information Matrix											
Heteroskedasticity	69.00	69.00	57.59	.	48.11	.	69.00	66.06	.	57.74	.
	[0.443]	[0.443]	[0.068]	.	[0.019]	.	[0.443]	[0.126]	.	[0.043]	.
Skewness	23.14	21.68	14.23	.	12.35	.	13.81	16.20	.	13.74	.
	[0.336]	[0.300]	[0.115]	.	[0.090]	.	[0.313]	[0.094]	.	[0.089]	.
Kurtosis	1.62	1.58	1.19	.	1.53	.	1.41	1.17	.	0.93	.
	[0.203]	[0.208]	[0.274]	.	[0.215]	.	[0.236]	[0.279]	.	[0.336]	.
Total	93.77	92.26	73.01	.	62.00	.	84.22	83.43	.	72.40	.
	[0.372]	[0.357]	[0.036]	.	[0.008]	.	[0.381]	[0.062]	.	[0.021]	.

[a] Numbers in brackets are *p*-values.

Table 5.5. *F*-Tests Regarding Model Specification

Model	Hypothesis Test	*F*-Statistic	Degrees of Freedom	*p*-value
M1	Eliminate fixed rate terms if added to M1	0.63	2,45	0.537
M1	Eliminate fixed year effects	0.75	2,47	0.480
M1	Central zone vs. 12 regional effects	1.80	11,47	0.082
M1	Central zone vs. 12 regional & 2 year dummies	1.65	13,47	0.106
M1	Central & Metropolitan zones vs. 12 regional effects	1.37	10,47	0.223
M1	Central & Metropolitan vs. 12 regional & 2 year effects	1.21	12,47	0.303
M2	Central zone vs. 12 regional dummies	1.83	11,49	0.074
M2	Central & Metropolitan zones vs. 12 regional dummies	1.32	10,49	0.246
M3R	Combine Central & Metropolitan zones into one fixed effect	11.35	1,59	0.001
M3R	Eliminate squared price & quality terms	2.96	2,59	0.060

Chile's electricity rates are constant rather than block declining so no additional income effects of rate variation require consideration.

Starting from Model M1 in Table 5.3, the hypothesis that fixed effects for years, have no effect is supported according to the *F*-statistic of 0.75 with a *p*-value of 0.480 (see Table 5.5). The replacement of fixed effects for all individual regions with a fixed effect for the central zone alone is marginally rejected (at the 0.10 level but not at the 0.05 level) with a *p*-value of 0.082 (Table 5.5). When these two changes are considered jointly (a central zone fixed effect instead of both individual regional and year fixed effects), the change is supported but only marginally with a *p*-value of 0.106 (Table 5.5). However the central and metropolitan zone fixed effects satisfactorily replace either all individual regional effects or all regional and year fixed effects. The replacement of fixed effects for all individual regions with fixed effects for the central zone and metropolitan zones alone is supported by an *F*-test with a *p*-value of 0.223. The *F*-test for jointly replacing both individual region and year fixed effects with only the central and metropolitan zone fixed effects is supported with a *p*-value of 0.303.

Although these results suggest eliminating fixed effects for both individual regions and years in favor of a model with fixed effects for only the central and metropolitan zones, Model M2 presents further confirming results based on the regressions after eliminating fixed effects for years (Table 5.3). Compared to Model M1, these results yield a small increase in the adjusted R^2 and *F*-statistics for regression significance (the latter is not shown). The *F*-tests for fixed effects specifications are similar to those for Model M1. Replacement of fixed effects for all individual regions with a fixed effect for the central zone alone is marginally rejected (at the 0.10 level but not at the 0.05 level) with a *p*-value of 0.074 (Table 5.5). But the replacement of fixed effects for all individual regions with fixed effects for the central and metropolitan zones is supported by an *F*-test with a *p*-value of 0.246 (Table 5.5).

The *F*-tests associated with Models M1 and M2 support the estimation of Model M3 as the final form of the model with fixed effects. Although the Breusch-Pagan/Cook-Weisberg test for heteroskedasticity does not reject homoskedasticity, the Cameron and Trivedi test based on decomposition of the information matrix rejects homoskedasticity with a *p*-value of 0.068 (see Table 5.4). For this reason, robust test statistics are estimated for Model M3 using White's corrected standard errors as presented in Model M3R. Thus, the standard errors associated with Model M3R are considered the appropriate basis for evaluating various hypotheses regarding the final fixed-effects model. By comparison, conventional spherical-distribution assumptions are not rejected for Models M1 and M2 by the diagnostic tests in Table 5.4. Thus, standard errors are not re-estimated for these models.

The adjusted R^2 for Model M3R (or Model M3) is slightly lower than for models M1 and M2 at 0.62. However, Model M3R yields much better significance in estimating the effects of price and quality because regional differences in demand due to differences in price and quality are not also "explained" by regional fixed effects. The first four lines of Table 5.4 present *F*-statistics depicting the significance of joint effects of terms involving the key variables. The joint hypothesis of removing all price terms from the equation has an *F*-statistic with *p*-value less than 0.001 compared to 0.904 and 0.563 with Models M1 and M2, respectively. The joint hypothesis of removing all quality terms from the equation has an *F*-statistic with *p*-value 0.001 compared to 0.118 and 0.131 with Models M1 and M2, respectively.

The results also demonstrate a significant joint role for the number of clients suggesting an importance of population density as a life-style explanation of demand. The results also yield considerable statistical significance of the fixed effects with a *p*-value less than 0.001 for the central zone effect and a *p*-value of 0.017 for the metropolitan zone effect. A similar test also soundly rejects the hypothesis of combining the central and metropolitan zones into one fixed effect (see Table 5.5). Thus, life-style factors appear to have a further significant difference in the extreme urban circumstances of Santiago not reflected by the number of clients.

Model M4 considers removing the squared terms involving price and quality from the model. Even though removing these squared terms from Model M3R, is rejected at the 10 percent level either individually (see Table 5.3 where *p*-values are 0.028 and 0.072, respectively) or jointly (see Table 5.5) where the *p*-value is 0.060), the estimation results without them are presented in Model M4 as a reference point. Because homoskedasticity is rejected at least with the Cameron and Trivedi test based on decomposition of the information matrix, the results are also presented with robust estimation of standard errors using White's method in Model M4R. As expected, dropping the significant squared terms causes a decline in the adjusted R^2 although only slightly. Also, the significance of the key quality and price variables increases substantially in this model, and the critical cross term between price and quality becomes significant at the 0.067 level, confirming the importance of the interaction effect and showing that it is positive (as estimated in all models). However, the Ramsey RESET test rejects the hypothesis that this model has no omitted variables whereas it does not do so in Models M1 through M3R.

5.5.2 Estimation Based on Income and Temperature

The final three columns of Table 5.3 report results with three other specifications of the model that investigate the effects of income and climate on demand. Income and climate vary relatively little within regions over the short three-year span of observed data compared to their variation among regions. For example, a regression of GDP per capita (in log-linear form) on the twelve regional fixed effects alone shows that 99.1% of the variation in income is accounted by regional fixed effects. Further, the available climate variables for this study are long-term climate variables that vary only by region. Thus, because Models M1 through M4R do not include income and climate, the fixed regional effects likely capture most of the effects of these variables. In these circumstances with very few time series observations, fixed regional effects can prevent identification of the effects of income and climate and even over-explain the variation in demand because of random region-specific variation. By comparison, more precise estimation of the effects of income and climate may be possible in absence of regional fixed effects because differences in demand due to differences in income and climate are not also "explained" by the regional fixed effects. This is the motivation for reporting results for these three additional models.

Model M5 adds regional per capita GDP (log-linear form) and mean winter temperature (in both linear and squared forms) to Model M3. The adjusted R^2 is almost identical to Model M3 (or Model M3R) and none of the three additional variables are significant. Consistent with the above explanation, this low significance of income and climate is due to the presence of fixed regional effects in the model. Further, the estimated income elasticity (the coefficient of the GDP variable) is negative (-0.050) and thus implausible, although insignificant.

Models M6R and M7R revise Models M3R and M4R, respectively, by replacing the two fixed effects (central and metropolitan zones) with the three income and climate variables added in Model M5. This change causes a dramatic decline in the adjusted R^2 from 0.602-0.622 in Models M3R, M4R, and M5 to 0.242-0.259 in Models M6R and M7R. Although the diagnostic statistics in Table 5.4 do not reject conventional calculation of standard errors for Model M5, several of the results from the Cameron and Trivedi test based on decomposition of the information matrix associated with Models M6 and M7 (shown in Table 5.4) suggest calculation of White's robust standard errors. These are the standard errors reported for Model M6R and M7R in Table 5.3.

The results for Model M6R show that the significance of each of the three income and climate variables is very high when the fixed effects are dropped, confirming that income and climate effects are included in fixed effects when fixed effects are estimated.

The *p*-values for the coefficients of all three income and climate variables are in the range of 0.014-0.028. The *F*-test for joint exclusion of temperature variables in Table 5.4 also yields a high level of significance with a *p*-value of 0.044. Moreover, the joint significance of all price terms and of all quality terms remains high, although not quite as high as in Model M3R (see Table 5.4). Further, the climate variables have plausible effects whereby lower winter temperatures cause greater demand, although with tempered effects in the extreme regions of either the far north or far south. The income elasticity is also positive as expected and of a plausible magnitude, 0.182.

The 90 percent confidence interval on the income elasticity is (0.053, 0.312). This estimate is in line with many other studies. For the United States, Halvorsen (1975) estimates an income elasticity of 0.28 or 0.66 depending on the estimation method, Chang and Hsing (1991) find values between 0.13 and 0.36 using firm level aggregation, and Kaserman and Mayo (1985) find values between 0.062 and 0.156 depending on the model. In Latin America, (see Westley, 1984; 1989), using GDP per household, finds an elasticity of 0.42 for Paraguay and 0.25 for Costa Rica. In Chile, Benavente, et al. (2005) find income elasticities of 0.2 in the long-term and 0.079 in the short-term working with monthly data, and Chumacero, Paredes and Sánchez (2000) find a short-term elasticity between 0.27 and 0.51.

The results for Model M7R compare to Model M4R where the two fixed effects (central and metropolitan zones) are replaced with the three income and climate variables. While the significance of the individual price and quality variables in this regression are somewhat less than for Model M4R, the joint significance of all price variables (*p*-value of 0.036) and all quality variables (*p*-value of 0.020) is quite high as is the significance of income and temperature variables both individually (see Table 5.3) and jointly (see Table 5.4). The most interesting result in this regression is that the Ramsey RESET test does not imply significance of missing variables even when squared price and quality terms are omitted as does Model M4R.

All the models in Table 5.3 include an interaction term between price and quality to capture the cross effects discussed in Chapters 3 and 4. This effect captures the cross derivative of quantity with respect to quality and price, which if positive implies that quality chosen by the monopolist is increasing in the price set by the regulator following equation (3.4.4). In all models, the regression results indicate that this term is positive. While only marginally significant in the final model with fixed effects (with a p-value of 0.14 in Model M3R), it is significant in Model M4R (with a p-value of 0.067), and essentially significant in Model M6R (with a p-value of 0.101). Thus, the empirical results resolve the theoretical ambiguity remaining from Chapters 3 and 4.

Also, the qualitative implications of other estimated parameters are in general agreement with assumptions (3.2.1)-(3.2.4) of Chapter 3 and the associated qualitative assumptions of Chapter 4. As the results presented in Section 5.5.4 below confirm, the estimated price elasticities are negative and the estimated quality elasticities are positive except for a small set of extreme data points. Also, although exceptions occur for some extreme values of p and s in some models, the estimated parameters imply that $Q_{pp} > 0$ for all models in Table 5.3, corresponding to cases in Chapter 3 where second-order conditions clearly hold. Similarly, the results also confirm that $Q_{ss} < 0$ as assumed in Chapters 3 and 4 for all sample values in Models 1, 2, 3 and 5.

5.5.3 Estimation with First-Differences

Another way to control for fixed effects is to estimate a model with variables in first-differenced form. The results from four different models are presented in Table 5.6.

Table 5.6. Regression Results from First-Differenced Models[a]

Variable	MD1	MD2	MD3	MD4
Ln(quantity) lagged			0.061	0.157
			(0.38)	(1.15)
			[0.712]	[0.269]
Quality	0.014	-0.192	0.105	-0.481
	(0.03)	(-0.97)	(0.19)	(-2.59)
	[0.978]	[0.338]	[0.848]	[0.020]
Quality squared	-0.001		-0.003	
	(-0.47)		(-1.17)	
	[0.641]		[0.260]	
Ln(price)	-5.028	-5.504	-9.629	-11.551
	(-0.78)	(-1.23)	(-1.55)	(-2.75)
	[0.441]	[0.225]	[0.144]	[0.014]
Ln(price) squared	0.004		-0.006	
	(0.01)		(-0.01)	
	[0.994]		[0.993]	
Quality*Log(price)	0.043	0.049	0.100	0.120
	(0.85)	(1.01)	(2.00)	(2.63)
	[0.400]	[0.319]	[0.065]	[0.018]
Ln(clients)	1.352	1.363	-2.035	-1.751
	(3.38)	(3.55)	(-2.19)	(-2.12)
	[0.002]	[0.001]	[0.046]	[0.050]
Ln(clients) squared	-0.084	-0.085	0.096	0.076
	(-3.32)	(-3.50)	(1.71)	(1.54)
	[0.002]	[0.001]	[0.109]	[0.142]
R2	0.511	0.508	0.779	0.757
Adjusted R2	0.418	0.444	0.653	0.666
Observations	44	44	22	22

[a] All variables are used in first-differenced form by time.
Numbers in parentheses are *t*-ratios and numbers in brackets are *p*-values.

When variables are used in first-differenced form, the number of usable observations is reduced by the number of observations in a given time period. Also, only 22 of the 25 observations for 1998 can be used because only 22 observations exist for the comparison year in 1997, which is the same as exists for comparing 1997 to 1996. Thus, only 44 first-differenced observations are available for estimation of Models MD1 and

MD2. Models MD1 and MD2 correspond in specification to Models M3 and M4 in Table 5.3 because fixed effects disappear with first differencing. Models MD3 and MD4 have forms corresponding to Models MD1 and MD2, respectively, aside from adding a lagged dependent variable as a right-hand side variable. The presence of a lagged dependent variable reduces the number of observations further to 22 so that these models represent only a cross section rather than a panel.

Table 5.7. Joint Effects of Terms in the First-Differenced Models[a]

Hypothesis Test	MD1	MD2	MD3	MD4
F-tests for joint effects				
All price terms	10.34	16.83	2.63	7.34
	[<0.001]	[<0.001]	[0.091]	[0.005]
All quality terms	0.89	1.28	3.34	4.51
	[0.457]	[0.289]	[0.050]	[0.028]
Number of clients	5.74	6.32	9.12	12.08
	[0.007]	[0.004]	[0.003]	[<0.001]

[a] This table reports *F*-statistics with *p*-values in brackets.

The results for Models MD1 and MD2 have low precision for all individual price and quality variables (Table 5.6) and for all quality terms jointly (Table 5.7). Although the joint significance of all price terms is quite high (Table 5.7), the implication is that dropping a full year's worth of observations in order to enable estimation by first differencing gives up too much ability to identify the critical quality parameters of interest for this study.

Interestingly, when the lagged quantity variable is added to the estimation problem, the significance of coefficient estimates for individual quality variables improves substantially (Models MD3 and MD4). However, the coefficient of the lagged quantity variable is not significant at customary levels (*p*-values of 0.712 and 0.269 with Models MD3 and MD4, respectively), which thus does not provide clear support this generalization of the model. Nevertheless, all price terms are jointly significant with

Models MD3 and MD4 with respective *p*-values of 0.091 and 0.005 as are all quality terms with respective *p*-values of 0.050 and 0.028.

Based on these results, the estimates in Table 5.3 appear to be preferable in terms of precision and significance to the results based on first differences. Apparently, a major part of the explanation lies in the substantial reduction in the number of observations available for estimation when first-differenced data are used (a result not atypical when time series are extremely short). Although the first-differenced results appear somewhat more significant upon addition of a lagged dependent variable, the addition of a lagged dependent variable in the non-differenced estimation approach of Table 5.3 did not produce satisfactory results (aside from the coefficient of the lagged dependent variable, no coefficient was individually significant nor was the group of terms involving any individual variable jointly significant).

5.5.4 Estimated Elasticities of Price and Quality

To assess the crucial information provided by the estimation of this chapter about price and quality elasticities, both are estimated at a variety of percentiles of the price and quality data. Based on the model in equation (5.3.1), the price elasticities are estimated by $\eta = \beta_2 + 2\beta_3 \ln p + \beta_5 s$ and $\eta = \beta_2 + \beta_5 s$ for models with and without the squared price term, respectively. And quality elasticity is estimated by $\upsilon = (\beta_2 + 2\beta_4 s + \beta_5 \ln p)s$ and $\upsilon = (\beta_2 + \beta_5 \ln p)s$ for models with and without squared quality, respectively. The price and quality elasticities for models without the squared terms are evaluated at the 10th, 25th, 50th, 75th and 90th percentiles of the sample values for *p* and *s*, respectively.[68] For

[68] The calculations were made using the lincom command in Stata 9.2, which uses the variance-covariance matrix of the estimated coefficients to compute the variance of the expression that is evaluated.

models that have squared terms, both price and quality elasticities at a given percentile are evaluated where both price and quality are at that percentile of their respective sample distributions. In the first-differenced models, the elasticities are estimated similarly, except for models with lagged quantity as the independent variable. In model MD3, the short-run elasticities are estimated similarly but the long-run price and quality elasticities are estimated following

$$\eta = (\beta_2 + 2\beta_3 \ln p + \beta_5 s)/(1-\alpha) \text{ and}$$

$$\upsilon = (\beta_2 + 2\beta_4 s + \beta_5 \ln p)s/(1-\alpha),$$

respectively, and in model MD4 they are estimated by $\eta = (\beta_2 + \beta_5 s)/(1-\alpha)$ and $\upsilon = (\beta_2 + \beta_5 \ln p)s/(1-\alpha)$, respectively, where α is the coefficient of lagged quantity.[69]

Estimated price elasticities corresponding to selected models in Table 5.3 are given in Table 5.8. In the preferred fixed-effects model, Model M3R, the price elasticities are negative and significant at all corresponding percentiles of the price and quality distributions except the 10th and 25th, where they are negative but not significant. The values of the significant elasticities range from -0.42 to -0.60. In Model M2, all estimated elasticities are negative but none are significant, a result that is probably explained by the fact that extensive representation of fixed effects permits the fixed effects to "explain" much of the variation due to price and quality. In Model M4R, price elasticities are all negative except at the 90th percentile, which along with the 75th percentile is not significant. The values of the significant elasticities of this model range from -0.37 to -0.78. The interesting contrast between price elasticities between Models M3R and M4R is that price elasticities are increasing in price in Model M3R but decreasing in price with

[69] The estimation of these elasticities was done using the command nlcom in Stata 9.2, which uses the delta method.

Model M4R. However, the results of Models M6R and M7R, where fixed effects are replaced by income and climate variables, are roughly in harmony with the results of Model M4R including the effects of increasing price as well as in magnitude and significance. As a reference point, the case of Model M3R where price elasticities are increasing in price is the case where demand has less curvature than a constant elasticity function, whereas the other cases are more sharply convex to the origin.

Table 5.8. Price Elasticity of Demand at Different Percentiles[a]

Percentile	M2	M3R	M4R	M6R	M7R
10th percentile	-0.163	-0.029	-0.784	-0.864	-0.772
	(-0.320)	(-0.060)	(-3.400)	(-2.210)	(-2.600)
	[0.751]	[0.950]	[0.001]	[0.031]	[0.012]
25th percentile	-0.252	-0.200	-0.520	-0.510	-0.471
	(-0.800)	(-0.710)	(-2.780)	(-2.160)	(-2.220)
	[0.430]	[0.481]	[0.007]	[0.035]	[0.030]
50th percentile	-0.370	-0.420	-0.369	-0.300	-0.300
	(-1.190)	(-2.140)	(-1.790)	(-1.190)	(-1.240)
	[0.239]	[0.037]	[0.079]	[0.237]	[0.220]
75th percentile	-0.431	-0.537	-0.168	-0.031	-0.071
	(-1.000)	(-2.200)	(-0.620)	(-0.080)	(-0.210)
	[0.322]	[0.032]	[0.537]	[0.936]	[0.838]
90th percentile	-0.464	-0.603	0.008	0.202	0.129
	(-0.830)	(-1.770)	(0.020)	(0.380)	(0.280)
	[0.413]	[0.081]	[0.982]	[0.703]	[0.782]

[a] Numbers in parentheses are *t*-ratios and numbers in brackets are *p*-values.

Estimated price elasticities resulting from the differenced models in Table 5.6 are presented in Table 5.9. These models yield significance for a wider range of percentiles, with price elasticities ranging from -0.257 to -0.760 in the long run and from -0.241 to -0.61 in the short run. In these models, elasticities are always smaller in magnitude at higher percentiles, which also implies sharper curvature than a constant elasticity function. In general, long-run elasticities are higher than short-run elasticities.

These results are also roughly consistent with other results found in the literature. For example, Ferrer-i-Carbonell, Muskens, and Leeuwen (2002) present a survey where short-run elasticities range from -0.02 to -1.10 and long-run elasticities that range from -0.26 to -1.10. Also Benavente, et al. (2005) present a summary of price elasticity estimation from various other studies that find price elasticities between -0.13 and -0.90 for the short run and between -0.17 and -1.89 for the long run. These authors also present their own estimates of price elasticities for Chile, which are -0.27 and -0.39 for the short and long run, respectively. This last value seems to be relatively low compared to other studies in Chile. For example, Chumacero, Paredes and Sánchez (2000) find values up to –0.79.

Table 5.9. Price Elasticities from First-Differenced Models[a]

	Short Run				Long Run	
Percentile	MD1	MD2	MD3	MD4	MD3	MD4
10th percentile	-1.050	-1.063	-0.538	-0.641	-0.573	-0.760
	(-3.990)	(-5.740)	(-2.030)	(-3.280)	(-1.830)	(-3.030)
	[<0.001]	[<0.001]	[0.062]	[0.005]	[0.088]	[0.008]
25th percentile	-1.006	-1.014	-0.439	-0.521	-0.468	-0.618
	(-5.260)	(-5.760)	(-2.120)	(-2.730)	(-1.940)	(-2.630)
	[<0.001]	[<0.001]	[0.053]	[0.015]	[0.072]	[0.018]
50th percentile	-0.980	-0.986	-0.383	-0.452	-0.408	-0.537
	(-5.260)	(-5.590)	(-1.670)	(-2.340)	(-1.610)	(-2.310)
	[<0.001]	[<0.001]	[0.118]	[0.032]	[0.130]	[0.035]
75th percentile	-0.946	-0.949	-0.307	-0.361	-0.327	-0.428
	(-4.140)	(-5.160)	(-1.060)	(-1.790)	(-1.060)	(-1.800)
	[<0.001]	[<0.001]	[0.306]	[0.092]	[0.307]	[0.090]
90th percentile	-0.917	-0.916	-0.241	-0.281	-0.257	-0.334
	(-3.290)	(-4.680)	(-0.700)	(-1.320)	(-0.700)	(-1.340)
	[0.002]	[<0.001]	[0.098]	[0.206]	[0.495]	[0.200]

[a] Numbers in parentheses are *t*-ratios and numbers in brackets are *p*-values,

Estimated quality elasticities corresponding to selected models in Table 5.3 are given in Table 5.10. As Table 5.4 shows, quality has a significant effect on demand according to almost all the estimated models, and is marginally significant in the only exceptions (Models M1 and M2). Using estimates from model M3R, the quality elasticity of demand ranges from 1.268 to 1.859 across different corresponding percentiles of the price and quality distributions (see Table 5.10). This impact is high, especially if compared to the estimated price elasticities of demand. However, none of the estimated elasticities at various percentiles are significant according to Model M3R. Alternatively, Models M4R, M6R, and M7R estimate significant elasticities at the upper price and quality levels that range between 4.22 and 9.56 (see Table 5.10). Further, the precision of quality elasticity estimates (as measured by standard errors not shown) is roughly similar across the various price levels. Thus, the results suggest that the quality elasticity varies widely among the population with much greater sensitivity at higher price levels.

Table 5.10. Quality Elasticity of Demand at Different Percentiles[a]

Percentile	M2	M3R	M4R	M6R	M7R
10th percentile	2.406	1.405	-3.046	-5.506	-3.090
	(0.610)	(0.440)	(-0.800)	(-1.130)	(-0.55)
	[0.546]	[0.663]	[0.428]	[0.263]	[0.586]
25th percentile	1.482	1.268	-0.330	-0.788	<0.001
	(0.700)	(0.580)	(-0.130)	(-0.230)	(<0.001)
	[0.487]	[0.566]	[0.896]	[0.817]	[0.999]
50th percentile	1.334	1.859	2.188	3.134	2.864
	(0.930)	(1.110)	(1.420)	(1.240)	(1.25)
	[0.357]	[0.272]	[0.161]	[0.221]	[0.218]
75th percentile	0.567	1.682	4.228	6.723	5.185
	(0.240)	(0.800)	(3.150)	(2.210)	(2.68)
	[0.810]	[0.430]	[0.003]	[0.031]	[0.010]
90th percentile	-0.230	1.325	5.761	9.560	6.929
	(-0.070)	(0.470)	(3.390)	(2.400)	(2.87)
	[0.948]	[0.642]	[0.001]	[0.020]	[0.006]

[a] Numbers in parentheses are *t*-ratios and numbers in brackets are *p*-values.

The estimated quality elasticities implied by the first-differenced models in Table 5.6 are presented in Table 5.11. As Table 5.7 shows, quality does not have a significant effect on quantity according to Models MD1 and MD2, but is significant according to the first-differenced models with lagged dependent variables, Models MD3 and MD4. From the first-differenced models, only Model MD4 yields significant elasticities. These quality elasticities are significant when evaluated at the 50th, 75th, and 90th percentiles of both the price and quality distributions. These quality elasticities range from 0.998 to

2.620 in the short run and from 1.185 to 3.109 in the long run (see Table 5.11). As for Models M4R, and M7R, quality elasticities of demand are estimated to increase as both the price and quality levels increase for Model M6R.

The estimated quality elasticities of demand for electricity in this study apparently have no appropriate comparisons in the literature with which to judge their plausibility. However, intuitive reasoning suggests that the quality elasticity is likely to be higher at when the price is higher consistent with these results.

Table 5.11. Quality Elasticities from First-Differenced Models[a]

	Short Run				Long Run	
Percentile	MD1	MD2	MD3	MD4	MD3	MD4
Valued at 10th percentile	0.076	-0.208	-0.406	-1.378	-0.433	-1.635
	(0.060)	(-0.200)	(-0.310)	(-1.500)	(-0.310)	(-1.440)
	[0.952]	[0.846]	[0.758]	[0.152]	[0.762]	[0.170]
Valued at 25th percentile	0.345	0.298	0.129	-0.144	0.138	-0.171
	(0.480)	(0.420)	(0.667)	(-0.250)	(0.190)	(-0.250)
	[0.637]	[0.673]	[0.849]	[0.804]	[0.848]	[0.805]
Valued at 50th percentile	0.655	0.765	0.797	0.998	0.849	1.185
	(1.020)	(1.330)	(1.460)	(2.020)	(1.340)	(1.880)
	[0.313]	[0.192]	[0.167]	[0.060]	[0.202]	[0.079]
Valued at 75th percentile	0.851	1.145	1.182	1.924	1.259	2.283
	(0.870)	(1.600)	(1.270)	(2.870)	(1.140)	(2.480)
	[0.388]	[0.118]	[0.226]	[0.011]	[0.273]	[0.024]
Valued at 90th percentile	0.978	1.431	1.417	2.620	1.510	3.109
	(0.720)	(1.570)	(1.040)	(2.990)	(0.950)	(2.560)
	[0.474]	[0.125]	[0.314]	[0.009]	[0.356]	[0.021]

[a] Numbers in parentheses are *t*-ratios and numbers in brackets are *p*-values.

5.6 Conclusions to Chapter 5

To understand the affect of various regulatory schemes on the behavior of a monopolist, information on the quality of the good or service and its effect on demand are crucial. This issue has been investigated extensively in the theoretical literature but, in most cases, results depend on the marginal effect of quality on relevant agent functions. On the other hand, there have been few attempts in the empirical literature of electricity demand to incorporate quality of service, defined comprehensively, in the estimation of these functions. This chapter uses data from the electricity sector in Chile to estimate a demand function that includes quality. The available data allow estimation only at the aggregated firm level for a 3-year period. The novelty in this estimation is the inclusion of a variable that reflects the quality of service as perceived by consumers and, specifically, of an interaction term between price and quality that is crucial in signing qualitative theoretical effects.

The results of estimation suggest a price inelastic short-run demand, which is consistent with other studies, although slightly higher than the most recent study done in Chile. The statistical significance of the interaction term indicates that the price elasticity of demand increases with quality. As indicated in Chapter 2, Spence (1975) incorporated quality in regulation and found that, if the price elasticity of demand declines (increases) with quality, then the monopolist tends to under(over) supply quality.[70] Thus, given the empirical results found in this chapter, an unregulated monopolist will tend to oversupply quality in this market.

The joint implication of the results in this chapter and Chapter 4 is that the impact of information asymmetry on welfare is proportionally higher and the impact of the scope of regulation is proportionally lower than if the cross derivative of demand with respect to price and quality were negative. While the results of estimation in this chapter vary somewhat among models, most models show that quality has a statistically significant and relatively high impact on demand. The implication is that regulatory policy should take this into account. Specifically, when setting only price, the impact on quality should be considered because of the significant indirect welfare implications.

[70] Spence derived this result assuming an elasticity that does not depend on price.

The impact of quality on demand also has interesting implications that differ among corresponding price and quality segments of the population. Some consumer segments have higher demand for quality than others. Thus, regulator pricing policy could lead to inefficient results if these differences are not considered. At a minimum, this could lead to differences in regulations by zone, region, or price level.

One of the limitations of the results in this chapter is the fact that quality effects may be better reflected in long-run elasticities than short-run elasticities. Thus, future studies should attempt estimation with longer time series of data. Data limitations also prevented distinguishing firm effects and quality effects. Because the time span of available data was short, the variation in data were insufficient to distinguish (if any) the effects of regulation on different firms and their qualities.

6 SUMMARY AND CONCLUSIONS

This chapter begins with a brief summary of the dissertation, stating the main issues addressed in each chapter. The latter section is intended for the reader who wants an overview of the work done and is mainly concerned with conclusions. Therefore, Section 6.1 can be skipped with out loss of content. Section 6.2 presents the general conclusions that can be derived from this dissertation and suggests futures lines of research on this topic.

6.1 Brief Dissertation Summary

The goal of this dissertation is to analyze the role that service quality, asymmetric information, scope of regulation, and regulator's preferences play in the regulation of monopolies, with an application to the case of the Chilean electricity distribution industry. When this work was begun, Chile was in the midst of one of its worst crises on electricity provision in many years. An important discussion was initiated to determine who was to blame. Although not the focus of this dissertation, these events clearly suggested that quality of service cannot be neglected in a regulated market.

In Chapter 1, I present the problem of regulating a monopolist and introduce the special conditions of the electricity sector. In many cases, and in Chile in particular, the regulatory environment has been inherited from the privatization of state-owned or state-controlled utilities. In some cases, competition can be fostered in a privatized market, but in others, and for electricity distribution in particular, this cannot be done due, at least in part, to the economies of scale. In these cases, the best approach has been to privatize and regulate, while providing an incentive to increase efficiency.

This approach poses its own set of problems. Appropriate price setting requires costly information, which may be known by the monopolist but not the regulator. Also, if the incentive to reduce costs is too high, the result can be a reduction in long-term investments or other activities that may not be considered in the regulation. Quality of service is an example. If not included in the regulatory contract, changes in quality may serve as a "pressure valve" that the monopolist can use to increase its profit while transferring the cost to consumers. Another problem that may emerge is that the regulator may be "captured" by the industry or other political constituency, leading to a regulation biased towards one of the interested parties.

The electricity utilities in Chile had been state-owned companies until the early 1980s. Then a process of horizontal and vertical disintegration began with a requirement of financial independence. This was in preparation for the privatization process that began in the mid to late 1980s. The vertical disintegration led to a system where several companies generate electricity and sell it to distribution companies and other large customers. Different companies are in charge of transmission of electricity and get paid by the generators for the services they provide. For each independent electricity system, a centralized operator defines which generator is to increase or reduce production in order to instantaneously meet demand changes. Generators are called into production according to their marginal cost as a way of operating at minimum cost. The regulator sets the prices of energy and power as well as the distribution toll to small consumers. At the same time, large consumer can negotiate freely with distribution or generation companies. Although the divestiture effort apparently attempted to place ownership in different hands in the late 1990s, property was quite concentrated. Some groups held significant ownership in generation, transmission and distribution.

The literature on regulation is reviewed in Chapter 2. A special emphasis is given to the problems of quality and information, and the lack of its proper joint treatment. The first approaches to regulation proposed pricing schemes that would be efficient and feasible, such as marginal cost pricing, peak load pricing, and Ramsey-Boiteux pricing. On the other hand, most common schemes implemented were very different than the ones proposed by theory. Rather, they tended to impose a cost-of-service regulation where firms are allowed to charge a price that gives them a “fair” rate of return.

The newer theory is based on the mechanism design literature and considers adverse selection and moral hazard, focusing principally in the revelation of unknown true costs. Chapter 2 uses this approach to analyze quality in the context of a monopolist. Results in the literature show that setting a minimum quality can cause the exclusion of lower end consumers, and that verifiability of quality can generate higher rents to the monopolist. Results also show that a high concern for quality can lead to low-powered incentive schemes only if quality and quantity are net substitutes.

Chapter 2 also presents a review of the literature on the Chilean electricity system. This literature basically describes its history and privatization, describes and comments on the regulatory system, and analyzes some of the problems it has presented (such as outages, regulatory capture and other problems of quality of service). None of the existing studies for the Chilean electricity system have proposed a model that addresses these issues. This motivates Chapter 3 where I develop a model to address them analytically.

In Chapter 3, I develop four theoretical models of regulation that explicitly consider the regulation of price and quality versus regulation only of price, and symmetric versus asymmetric information depending on whether the regulator knows the monopolist's true costs. In these models, I also consider the effect of a regulator that may have a preference favoring consumers or the regulated firm. I conclude that with symmetric information and independent of the scope of regulation, having a regulator that prefers consumers or producer does not affect the efficiency of the outcome. I also show that the regulator's inability to set quality, thus obviating price-only regulation, leads to an inefficient outcome compared to the first best solution that can be achieved by regulating both price and quality. Regulation of both price and quality can also achieve efficiency with asymmetric information as long as the regulator does not have a preference biased toward consumers or the monopolist. When the regulator has a bias, then the equilibrium will be inefficient with asymmetric information. The effect on equilibrium price and quality depends on the direction of the effect of quality on the marginal effect of price in demand. Also, no closed-form solution can be derived unless drastic simplifications are made in the theory.

To further investigate properties of Chapter 3 theoretical models, Chapter 4 presents a numerical simulation by assuming flexible functional forms and assuming alternative sets of parameters that represent the scenarios of interest. In particular, implications of the four main models (price and quality regulation with symmetric information, price-only regulation with symmetric information, price and quality regulation with asymmetric information, and price-only regulation with asymmetric information) are investigated in a combination of possibilities where the marginal effect of quality on the price elasticity of demand is positive or negative and the regulator favors consumers, the monopolist or both equally. The results show that when the regulator is biased toward consumers (the monopolist), symmetric information models yield higher (lower) quality except for the most efficient firm.

Chapter 5 uses data from the electricity sector in Chile for the years 1996 to 1998, including a survey to evaluate quality of service to clients, to estimate price and quality elasticities of demand, and to determine if the effect of quality on price elasticity of demand is positive.

6.2 Conclusions

Instead of presenting the conclusion derived from each chapter separately, which are presented at the end of each chapter, this section discusses the main issues addressed throughout this dissertation, summarizing the overall implications. These issues examine the role that scope of regulation, asymmetric information, and regulator's preferences have on the regulation of monopolies and the consequent impact on welfare, price and service quality. A primary purpose is to understand how these apply to the case of the Chilean electricity distribution industry

6.2.1 Scope of Regulation

By scope of regulation, I mean the number of policy instruments set by the regulator, in this case, only price or price and quality. A somewhat unexpected result, derived from the analytical models, is the important effect that scope of regulation has on inefficiency. If for some exogenous reason the regulator cannot monitor quality and thus can set only price, then important welfare losses are incurred. In fact, this is the only condition, of the ones analyzed here, that always causes a departure from the first best. If the regulator sets both price and quality, then the first best is achieved by setting price equal to marginal cost and setting quality so that the marginal benefit of quality is equal to its marginal cost. This result is not achieved when the regulator sets only price and the monopolist chooses quality. Price and quality are lower with price-only regulation, assuming the most likely form of the cost function.

The simulation exercise corroborates these results, finding that the use of two instruments instead of one yields higher welfare levels independent of the informational structure or the regulator's preference. That is, when regulating both price and quality, higher levels of welfare are achieved than when only price is regulated. The highest overall welfare levels are achieved when regulating both price and quality under symmetric information. This amounts to a first best, where the total surplus is maximized, but allocated toward consumers or producers according to the regulator's preference. In this case, the price is set equal to marginal cost by the regulator. As regulation becomes incomplete, the solution moves away from this social optimum into equilibriums that are closer to the monopolistic solution. In the cases analyzed here, the scope of regulation has a larger impact in this reduction than the effect of the information asymmetry, which has no effect when the regulator is unbiased.

More importantly, regulation of both price and quality is weakly preferred by the regulator and by regulated firms, independent of the information structure. Therefore, if a quality index observable to the regulator can be developed, one should expect to see it implemented because both parties prefer it. These results hold for all consumer preferences and distributions of firm type examined here. Thus, if complete regulation is defined as the use of all available instruments, then incomplete regulation should be observed only when at least one of the available instruments of regulation is not verifiable.

The highest provision of quality is obtained when both quantity and quality are regulated jointly regardless of the information structure. As expected, lower quality is provided by less efficient firms. This is true for both curvatures of the WTP function that were examined. Moreover, under plausible conditions, price and quality are lower if only price is regulated. Also, transfers are higher when regulating price and quality, which reflects the greater ability of the regulator to transfer surplus from the producer to consumers.

The results thus hinge critically on whether quality is regulated. An important assumption in cases that consider quality's regulation is that quality is verifiable and therefore subject to regulation. In reality, however, monitoring of quality may not be easy to implement due to legal limitations, political opposition, or costs of monitoring and enforcement (which are assumed to be zero here).

In reality, however, regulation of quality may be difficult. Certainly, quality could not be regulated directly in terms of a quality index like the one considered in Chapter 5 because some of the components are based on unpredictable events such as outages. Rather, some components that go into the index may be used as regulatory instruments in the form of measurements of real phenomena such as voltage variations, downtime, etc., rather than survey responses that would be subject to strategic bias. Further, since these measurements could only be enforced ex post, they would likely have to be enforced by means of a system of penalties that considers the stochastic nature of most quality issues.

Future research should consider how results could change if regulation is in the form of penalties rather than standards. Such research should investigate optimal penalties and how the use of penalties rather than standards would alter regulated firm behavior.

6.2.2 Regulator Preferences

With symmetric information, the relative preference of the regulator for consumers versus the monopolist does not have an impact on the efficiency of the outcome, only on the distribution of surplus between consumers and the monopolist. However, a regulator biased toward consumers cannot extract the producer's entire surplus under asymmetric information. Thus, consumers pay information rents.

The effects of information asymmetries depend on the regulator's preferences. When the regulator has no bias, quality remains equal between symmetric and asymmetric models. But when the regulator's preference is biased toward consumers (producers), symmetric information models yield higher (lower) quality except for the most efficient firm, which is unchanged.

With a regulator that is unbiased or biased toward consumers, prices are a non-decreasing function of firm type, quantities are a non-increasing function of firm type, and, in the presence of asymmetric information, prices (quantities) are higher (lower) than under symmetric information due to an extra incentive necessary to reveal the firm's type. These results, obtained in the simulation exercise, are consistent with other studies that have examined similar problems. For a regulator biased toward producers, prices are lower than marginal costs when regulating with both instruments under asymmetric information, except for the most efficient firm. This result can hold because of the non-linear pricing made possible through transfer payments.

6.2.3 Asymmetric Information

A somewhat surprising result derived from the analytical models is that the information gap does not have an impact on efficiency as long as the regulator uses both instruments of regulation (price and quality) and does not favor consumers over the monopolist. This result holds for both curvatures of the WTP function that were examined.

When the regulator favors consumers, then several results are plausible, including the possibility that prices will be higher and quality lower under asymmetric information. Most of the other possible outcomes result in lower surplus for consumers.

This result also applies to the case of price-only regulation where a distortion away from the symmetric information outcome occurs when the regulator favors consumers. If the regulator favors consumers, then a further wedge, in addition to the one due to using only one instrument, is placed between price and marginal cost, thus reducing further the efficiency of the outcome. The most likely situation is that price will be higher than with price-only regulation under symmetric information.

The simulation reveals that, in absence of regulator bias, transfers under asymmetric information are higher for all firm types. When the regulator is biased toward consumers, efficient (inefficient) firms receive a higher (lower) transfer than under symmetric information. With a regulator biased toward producers, the transfer is also higher when regulating both price and quality vis-à-vis regulating only price, and, when regulating both price and quality, is also higher with asymmetric information vis-à-vis symmetric information. But when regulating only price, the symmetric information model yields higher transfers, except for the most inefficient firm, in which case they are equal.

From the econometric estimation in Chapter 5, I find that the Q_{ps} is positive. Together with simulation exercise of Chapter 4, this implies that the impact of information asymmetry on welfare is proportionally higher and the impact of the scope of regulation is proportionally lower compared to the case where the sign of Q_{ps} is negative.

6.2.4 Electricity Demand in Chile

Regulatory policy should take into account the fact that quality has a clear impact on demand and, thus, on welfare. Specifically, even if the regulator sets only price, the impact on quality should be considered. Otherwise, significant welfare losses may result.

The results from the econometric estimation also suggest a relatively high price elasticity when compared to other studies. The results also show that the elasticity of quality is large. This estimation also suggests that the price elasticity of demand increases with quality, which according to Spence (1975) means that an unregulated monopolist is likely to over supply quality.

Future studies of this type will likely benefit from an expanded dataset that includes longer time series and better variables to represent the variation in characteristics among regions, firms, or individuals.

APPENDIX

Table A.1. Estimated Fixed Effects Associated with Table 5.3

	M1	M2
Year 1997	0.066	
	(1.20)	
	[0.235]	
Year 1998	0.042	
	(0.61)	
	[0.545]	
Region 2	-0.085	-0.082
	(-0.68)	(-0.67)
	[0.499]	[0.507]
Region 3	-0.430	-0.424
	(-3.73)	(-3.73)
	[0.001]	[0.001]
Region 4	-0.508	-0.508
	(-4.33)	(-4.37)
	[<0.001]	[<0.001]
Region 5	-0.628	-0.651
	(-4.99)	(-5.40)
	[<0.001]	[<0.001]
Region 6	-0.635	-0.631
	(-5.47)	(-5.49)
	[<0.001]	[<0.001]
Region 7	-0.343	-0.373
	(-2.73)	(-3.16)
	[0.009]	[0.003]
Region 8	-0.580	-0.608
	(-5.18)	(-5.78)
	[<0.001]	[<0.001]
Region 9	-0.670	-0.701
	(-4.18)	(-4.59)
	[<0.001]	[<0.001]
Region 10	-0.089	-0.112
	(-0.81)	(-1.07)
	[0.425]	[0.292]
Region 11	-0.287	-0.227
	(-1.55)	(-1.33)
	[0.128]	[0.188]
Region 12	-0.072	-0.073
	(-0.64)	(-0.65)
	[0.526]	[0.519]
Region 13	-0.279	-0.317
	(-2.13)	(-2.71)
	[0.038]	[0.009]
Constant	-82.950	-57.641
	(-0.80)	(-0.61)
	[0.431]	[0.543]

[a] Numbers in parentheses are *t*-ratios and numbers in brackets are *p*-values.
[b] These coefficients are part of the regression results for Models M1 and M2 presented in Table 5.3 of Chapter 5.

REFERENCES

Altomonte, H. (1999) Relatorio del Seminario Nacional Energía y Desarrollo Sustentable en Chile. Santiago, Chile, CEPAL.

Averch, H., and L. L. Johnson. "Behavior of the Firm Under Regulatory Constraint." *American Economic Review* 52(1962): 1052-1069.

Balestra, P., and M. Nerlove. "Pooling Cross Section and Time Series Data in the Estimation of a Dynamic Model: The Demand for Natural Gas." *Econometrica* 34, no. 3(1966): 585-612.

Banco Central de Chile (2007) Producto Interno Bruto Regional 2002-2003, Base 1996

Barnes, R., R. Gillingham, and R. Hagemann. "The Short-Run Residential Demand for Electricity." *The review of economics and statistics* 63(1981): 541.

Baron, D. P., and D. Besanko. "Regulation and Information in a Continuing Relationship." *Information Economics and Policy* 1(1984a): 267-302.

Baron, D. P., and D. Besanko. "Regulation, Asymmetric Information and Auditing." *Rand Journal of Economics* 15(1984b): 447-470.

Baron, D. P., and D. Besanko (1986) Monitoring, Moral Hazard, Asymmetric Information and Risk Sharing in Procurement Contracting, Stanford Graduate School of Business

Baron, D. P., and R. Myerson. "Regulating a Monopolist with Unknown Cost." *Econometrica* 50(1982): 911-930.

Basañes, C., F. E. Saavedra, and R. Soto (1999) Post-Privatization Renegotiations and Disputes in Chile, IFM Publications/IDB.

Becker, G. "A Theory of Competition among Pressure Groups for Political Influence." *Quarterly Journal of Economics* 98(1983): 371-400.

Benavente, J. M., A. Galetovic, R. Sanhueza, and P. Serra. "Estimando la Demanda Residencial por Electricidad en Chile: El Consumo es Sensible al Precio." *Cuadernos de Economía* 42(2005): 31-61.

Berkhout, P. H. G., A. Ferrer-i-Carbonell, and J. C. Muskens. "The ex post impact of an energy tax on household energy demand." *Energy economics* 26(2004): 297.

Bernard, J.-T., D. Bolduc, and D. Belanger. "Quebec Residential Electricity Demand: A Microeconometric Approach." *The Canadian journal of economics* 29(1996): 92.

Bernstein, S. "Competition, Marginal Cost Tariffs and Spot Pricing in the Chilean Electric Power Sector." *Energy Policy* (1998): 369-77.

Bernstein, S. "Racionamiento Eléctrico: Causas y Posibles Soluciones." *Puntos de Referencia, CEP* 209(1999).

Bernstein, S., and R. Agurto. "Use of Outage Cost for Electricity Pricing in Chile." *Utilities Policy* (1992): 299-302.

Besanko, D. (1985) On the Use of Revenue Requirements Regulation Under Imperfect Information, ed. M. A. Crew. Lexington, MA, Lexington Books, pp. 39-55.

Besanko, D., S. Donnenfeld, and L. White. "Monopoly and Quality Distortion: Effects and Remedies." *Quarterly Journal of Economics* 102(1987): 743-768.

Besanko, D., and D. E. M. Sappington. *Designing Regulatory Policy with Limited Information*. Fundamentals of Pure and Applied Economics. Edited by J. L. a. H. Sonnenschein. New York: Hardwood Academic Publishers, 1987.

Beyer, H. "La Privatización de la Distribución de Energía Eléctrica: el Caso de Chilectra Metropolitana." *Estudios Públicos* 32(1988).

Bhattacharyya, A., T. R. Harris, R. Narayanan, and K. Raffie. "Specification and estimation of the effect of ownership on the economic efficiency of the water utilities." *Regional Science and urban Economics* 25(1995): 759-784.

Bitrán, E., and R. E. Saéz (1994) Privatization and Regulation in Chile, ed. R. D. a. R. L. B.P. Bosworth. Washington D.C., The Brookings Institution.

Bitrán, E., and P. Serra. "Regulatory Issues in the Privatization of Public Utilities: The Chilean Experience." *The Quarterly Review of Economics and Finance* 54, no. Special Issue(1994): 179-97.

Bitrán, E., and P. Serra. "Regulation of Privatized Utilities: The Chilean Experience." *World Development* 26, no. 6(1998): 945-62.

Blanlot, V. (1992) La Regulación del Sector Eléctrico: la Experiencia Chilena, ed. O. Muñoz G. Chile, Cieplan.

Blum, P. J. "An Approach to Evaluating Deregulation of the Chilean Electric Power Sector and its Environmental Implications." Stanford University, 1996.

Boiteux, M. "Peak-Load Pricing." *Journal of Business* XXXIII(1960): 157-79.

Boiteux, M. "On The Management of Public Monopolies Subject to Budgetary Constraints." *Journal of Economic Theory* 3(1971): 219-40.

Buchanan, J. "An Economic Theory of Clubs." *Econometrica* 33(1965): 1-14.

Cano, B. R. "La Regulación del Sector Eléctrico en Chile." *Lecturas de Economía* 46(1997).

Chang, H. S., and Y. Hsing. "The Demand for Residential Electricity - new Evidence on Time-Varying Elasticities." *Applied Economics* 23, no. 7(1991): 1251.

Chumacero, R., R. Paredes, and J. M. Sánchez. "Regulacion para crisis de abastecimiento: lecciones del racionamiento electrico en Chile." *Cuadernos de Economía* 37, no. 111(2000): 323-338.

Comisión Nacional de Energía (CNE-. *El Sector Eléctrico en Chile*, 1996.

Cremer, J., and R. P. McLean. "Optimal Selling Strategies under Uncertainty for a Discriminating Monopolist when Demand are Interdependent." *Econometrica* 53(1985): 345-61.

d'Aspremont, C., and L. Gerard-Varet. "Incentives and Incomplete Information." *Journal of Public Economics* 11(1979): 25-45.

Dalen, D. M., and A. Gomez-Lobo. "Estimating Cost Functions in Regulated Industries Characterized by Asymmetric Information." *European Economic Review* 41(1997): 935-42.

Demsetz, H. "Why Regulate Utilities?" *Journal of Law and Economics* 11(1968): 55-65.

Demski, J., and D. Sappington. "Optimal Incentive Schemes with Multiple Agents." *Journal of Economic Theory* 33(1984): 152-71.

Departamento Geofísica - Universidad de Chile. "Estudio de la Variabilidad Climática en Chile para el siglo XXI." CONAMA, December.

Díaz, C., and R. Soto (1999) Open Access Issues in the Chilean Telecommunications and Electricity Sectors. Washington D.C.

Díaz, C. A., A. Galetovic, and R. Soto. *Causas, Consecuencias y Lecciones de la Crisis Eléctrica*, 2000.

Dixit, A. "Studies of incentives in government Bureaucracies, Power of Incentives on Private versus Public Organization." *The American Economic Review* 87, no. 2(1997): 378-382.

Dubin, J. A., and D. L. McFadden. "An Econometric Analysis of Residential Electric Appliance Holdings and Consumption." *Econometrica* 52, no. 2(1984): 345-362.

Dupuit, J. "On the Measurement of the Utility of Public Works." *International Economic Papers* 2(1952): 83-110.

Edwards, J., and W. Baer. "The State and Private Sector in Latin America: Reflections on the Past, Present and the Future." *The Quarterly Review of Economics and Finance* 33, no. Special(1993): 9-19.

Emmons, W. M. "Implications of Ownership, Regulation, and Market Structure for Performance: Evidence from the U.S. Electric Utility Industry Before and After the New Deal." *Review of Economics and Statistics* 79, no. 2(1997): 279-289.

Engel, E., R. Fischer, and A. Galetovic. "Highway Franchising: Pitfalls and Opportunities." *American Economic Review* 87, no. 2(1997): 68-72.

Engle, R. F., C. W. J. Granger, and J. J. Hallman. "Merging short- and long-run forecasts: An application of seasonal cointegration to monthly electricity sales forecasting." *Journal of Econometrics* 40(1989): 45-62.

Erdogdu, E. "Electricity demand analysis using cointegration and ARIMA modeling: A case study of Turkey." *Energy policy* 35(2007): 1129.

Evans, M., N. Hastings, and B. Peacock. *Statistical Distributions*. Third ed. New York: Wiley-Interscience, 2000.

Ferrer-i-Carbonell, A., A. C. Muskens, and M. J. v. Leeuwen. "Behavioural responses to energy-related taxes: A survey." *International Journal of Global Energy Issues* 18, no. 2-4(2002): 202.

Fudenberg, D., and J. Tirole. *Game Theory*. Cambridge: The MIT press, 1991.

Galal, A., L. Jones, P. Tandon, and I. Vogelsang. *Welfare Consequences of Selling Public Enterprises: An Empirical Analysis*. New York, New York: Published for the World Bank by the Oxford University Press, 1994.

Green, J., and J. J. Laffont. "Partially Verifiable Information and Mechanism Design." *Review of Economic Studies* 53(1986): 447-456.

Guesnerie, R., and J. J. Laffont. "A Complete Solution to a Class of Principal-Agent Problems with an Application to the Control of a Self-Managed Firm." *Journal of Public Economics* 25(1984): 329-369.

Hachette, D., and R. J. Luders. *Privatization in Chile an Economic Appraisal*. San Francisco, California: International Center for Economic Growth, ICS Press, 1993.

Halabí, C. E. "Productivity and Efficiency Analysis of Privatized Hydroelectric Generation with a Sometimes Free Input." University of Georgia, 2000.

Halvorsen, R. "Residential Demand for Electric Energy." *The review of economics and statistics* 57(1975): 12.

Hennemeyer, P. (1999) Energy Reform and Privatization: Distilling the Signal from the Noise, ed. C. F. E. U. a. R. W. Basañes. Washington D.C., Inter-American Development Bank.

Herriges, J. A., and K. K. King. "Residential Demand for Electricity under Inverted Block Rates: Evidence from a Controlled Experiment." *Journal of Business & Economic Statistics* 12, no. 4(1994): 419-430.

Hotelling, H. "The General Welfare in Relation to Problems of Taxation and of Railway and Utility Rates." *Econometrica* 6(1938): 242-269.

Iriarte, A. J., G. A. Lobos, and F. M. Jaksic (2005) Especies de vertebrados invasores en Chile y su control y monitoreo por agencias gubernamentales, vol. 2007, pp. 143-151.

Jadresic, A. in El Desarrollo Energético Chileno en el Último Quinquenio. ed. H. Altomonte. CEPAL, Naciones Unidas. 1999.

Joskow, P. L. "Restructuring Competition and Regulatory Reform in the U.S. Electricity Sector." *Journal of Economic Perspectives* 11, no. 3(1997): 119-38.

Joskow, P. L., and R. Schmalensee. *Markets for Power An Analysis of Electric Utility Deregulation*. Cambridge, Massachusetts: MIT Press, 1983.

Kaserman, D. L., and J. W. Mayo. "Advertising and the Residential Demand for Electricity." *The journal of business* 58(1985): 399.

Klevorick, A. K. "The Graduated Fair Return: A Regulatory Proposal." *American Economic Review* 56, no. 3(1966): 477-84.

Klytchnikova, I. "Methodology and Estimation of the Welfare Impact of Energy Reforms on Households in Azerbaijan." University of Maryland, 2006.

Laffont, J. J., and J. Tirole. "Using Cost Observation to Regulate Firms." *Journal of Political Economy* 94(1986): 614-641.

Laffont, J. J., and J. Tirole. "The Dynamics of Incentive Contracts." *Econometrica* 56(1988): 1153-75.

Laffont, J. J., and J. Tirole. "The Politics of Government Decision Making : A Theory of Regulatory Capture." *Quarterly Journal of Economics* 106(1991): 1089-1127.

Laffont, J. J., and J. Tirole. *A Theory of Incentives in Procurement and Regulation*. Cambridge: MIT Press, 1993.

Lewis, T., and D. Sappington. *Monitoring Quality Provision in Regulated Markets*. Bellcore Economics Discussion Paper: 43, 1988.

Lewis, T., and D. Sappington. "Incentives for Monitoring Quality." *Rand Journal of Economics* 22, no. 3(1991): 370-84.

Lewis, T., and D. Sappington. "Incentives for Conservation and Quality-Improvement by Public Utilities." *The American Economic Review* 82, no. 5(1992): 1321-40.

Loeb, M., and W. Magat. "A Decentralized Method for Utility Regulation." *Journal of Law and Economics* 22(1979): 399-404.

Lomuscio, L. "Rentabilidad de las Empresas de Distribución y su Relación con las Fijaciones Tarifarias." Pontificia Universidad Católica de Chile, 2004.

Luders, R. J. (2000) Early, Massive, Broad, and Successful Privatization: The Case of Chile, ed. M. H. B. a. J. Haa. Coral Gables, Florida, North South Center Press, University of Miami.

Mäler, K.-G. *Environmental Economics A Theoretical Inquiry*. Washington D.C.: Resources for The Future, Inc., 1974.

Millan, J. (no date) La Segunda Generación de Bolsas de Energía: Lecciones para América Latina.

Mirrlees, J. "An Exploration in the Theory of Optimum Income Taxation." *Review of Economic Studies* 33(1971): 175-208.

Mookherjee, D. "Optimal Incentive Schemes with Many Agents." *Review of Economic Studies* 51(1984): 433-46.

Muñoz, O. (1992) Hacia el Estado Regulador, ed. O. Muñoz. Santiago, Chile, CIEPLAN.

Mussa, M., and S. Rosen. "Monopoly and Product Quality." *Journal of Economic Theory* 18(1978): 301-317.

Nadarajah, S., and A. K. Gupta. "Characterizations of the Beta Distribution." *Communications in Statistics Theory and Methods* 33, no. 12(2004): 2941–2957.

Nalebuff, B., and J. Stiglitz. "Information, Competition and Markets." *American Economic Review* 73(1983): 278-83.

Nellis, J. (no date) Time to rethink Privatization in Transition Economies?, International Finance Corporation.

Paredes, R. *Regulación Económica en Chile: la Opción por un Enfoque no Estructural. (*no date*)* mimeo.

Poole, R. W., and P. E. Fixler. "Privatization of Public-Sector Services in Practice: Experience and Potential." Journal of Policy Analysis and Management 6, no. 4(1987): 612-625.

Ramsey, F. "A Contribution to the Theory of Taxation." *Economic Journal* 37(1927): 47-61.

Rozas, P. *Las Debilidades del Marco Regulatorio Eléctrico en Materia de los Derechos del Consumidor*. Serie Medio Ambiente y Desarrollo. Santiago, Chile: CEPAL, Naciones Unidas, 1999a.

Rozas, P. *La Crisis Eléctrica en Chile: Antecedentes para una Evaluación de la Institucionalidad Regulatoria*. Serie Recursos Naturales e Infraestructura. Santiago, Chile: CEPAL/Naciones Unidas, 1999b.

Rudnick, H. *Regulación del Sector Eléctrico en Chile, Perú y Venezuela.* Santiago, Chile. CEPAL/ Naciones Unidas. 1997.

Salanié, B. *The Economics of Contracts A Primer*. Cambridge, Massachusetts: The MIT Press, 1998.

Sappington, D. "Optimal Regulation of Research and Development under Imperfect Information." *Bell Journal of Economics* 13, no. 354-368(1982).

Sappington, D. "Optimal Regulation of a Multiproduct Monopoly with Unknown Technological Capabilities." *Bell Journal of Economics* 14(1983): 453-463.

Sappington, D. "Commitment to Regulatory Bureaucracy." *Information Economics and Policy* 2, no. 4(1986): 2543-58.

Serra, P., and G. Fierro. "Outage Cost in Chilean Industry." *Energy Economics* 19(1997): 417-34.

Serra, P. J. "Energy Pricing Under Uncertain Supply." *Energy Economics* 17(1997): 209-23.

Shleifer, A. "A Theory of Yardstick Competition." *Rand Journal of Economics* 16(1985): 319-27.

Söderberg, M. "A choice modeling analysis on the similarity between distribution utilities' and industrial customers' price and quality preferences." *Energy Economics* in press(2007).

Soto, R. *Ambigüedades en la Tarificación de la Transmisión Eléctrica en Chile*, mimeo. 1998.

Soto, R. (1999) Institutional Reforms in the Electricity Sector. mimeo.

Spence, A. M. "Monopoly, Quality, and Regulation." *Bell Journal of Economics* 6, no. 2(1975): 417-29.

Spiller, P. "Politicians, Interest Groups, and Regulators: A Multi-principals Agency Theory of Regulation (or "let them be bribed")." *Journal of Law and Economics* 33(1990): 65-110.

Spiller, P. T., and L. V. Martorell (1996) How Should it be Done? Electricity Regulation in Argentina, Brazil, Uruguay and Chile, ed. R. J. G. a. E. P. Kahn. New York, New York, Cambridge University Press.

Stigler, G. "The Theory of Economic Regulation." *Bell Journal of Economics* 2(1971): 3-21.

Thomas, A. "Regulating Pollution under Asymmetric Information: The Case of Industrial Wastewater Treatment." *Journal of Environmental Economics and Management* 28(1995): 357-73.

Tirole, J. "Hierarchies and Bureaucracies." *Journal of Law, Economics and Organization* 2(1986): 181-214.

Tollison, R. D. "Rent Seeking: a Survey." *Kyklos* 35(1982): 575-602.

Townsend, R. "Optimal Contracts and Competitive Markets with Costly State Verification." *Journal of Economic Theory* 21(1979): 265-293.

Tullock, G. "The Welfare Cost of Tariffs, Monopoly and Theft." *Western Economic Journal* 5, no. 181-214(1967).

Vinning, A. R., and A. E. Boardman. "Ownership versus competition: Efficiency in public enterprise." *Public Choice* 73(1992): 205-239.

Vogelsang, I., and J. Finsinger. "A Regulatory Adjustment Process for Optimal Pricing of Multiproduct Monopoly Firms." *Bell Journal of Economics* 10(1979): 157-71.

Westley, G. D. "Electricity Demand in a Developing Country." *The review of economics and statistics* 66(1984): 459.

Westley, G. D. "Nontraditional Partial Adjustment Models and Their use in Estimating the Residential Demand for Electricity in Costa Rica." *Land Economics* 65, no. 3(1989): 254.

Westley, G. D. *New Directions in Econometric Modeling of Energy Demand; With Applications to Latin America*. Washington D.C.: Inter-American Development Bank, 1992.

Wolak, F. A. "An Econometric Analysis of the Asymmetric information, Regulator-Utility Interaction." *Annales D'Economie et de Statistique* 34(1994): 13-69.

Yongxin, C., I. Deilami, and K. Train. "Customer retention in a competitive power market: Analysis of a `double-bounded plus follow-ups'." *Energy Journal* 19, no. 2(1998): 191.