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Optimal Price-Cap Regulation

by

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Chapter 1

Introduction

Many industries are today, and have been in the past, overseen by some form of regulation, be it price, quality, or environmental regulation, to name a few. In recent history, transportation industries such as railroads and airlines and utilities such as gas, electric and telecommunications have been subject to regulation of prices. Without some authority influencing the decisions of firms in these industries, they would enjoy a significant amount of market power due to the fact that they may be natural monopolies.

A natural monopoly is defined as a market structured in such a way that only one firm can efficiently produce a given product. This contradicts the generally accepted idea that competition brings about the greatest efficiency in a market. In the normative sense, a natural monopoly occurs when the average costs of production are minimized if there is just one firm in the industry, as is often the case in industries that require a large fixed cost of investment specific to that industry. If left unregulated, the price-setting power that the single firm would enjoy would come to the detriment of consumers, as prices would be unnecessarily high. In such a situation, some form of price regulation is therefore required to force a more equitable environment in terms of social welfare.

There are a number of different arguments as public interest rationale for price regulation (Church and Ware, 2000). We will begin by briefly describing both allocative efficiency and cost efficiency. Allocative efficiency occurs when the social marginal cost of the last unit produced equals its social marginal benefit. In other words, consumers are willing to pay exactly what it cost to produce the last unit of the good and a price is thus set at that level. This, however, leaves minimal profit for the firm. If a firm is able to exercise market power it will inflate profits by pricing above marginal cost. In such a situation, allocative efficiency will be lost and it is possible that some form of regulation is required. Productive efficiency is defined by a firm's cost efficiency and efficient cost reduction. If the firm has the proper incentives for productive efficiency, it may be able to reap some of the rewards of reducing costs without leaving consumers worse off, thereby bringing about an increase in social welfare. Left to its own devices, however, a firm with market power could much more easily simply raise prices to a point where profits are maximized. Thus, in a situation where a firm can exercise excessive market power, some form of price regulation is required in the interest of both allocative and productive efficiency.

The existing regulatory economics literature has given a long-standing foundation on which current regulatory practices are based. Of the two widely accepted methods of price regulation, each comes with its respective advantages and disadvantages. Cost of Service (COS) Regulation was the traditional solution to the regulatory problem. The attractiveness of this method is its goal of allocative efficiency - it grants consumers the lowest price possible while still allowing the regulated firm to break even. In other words, the price will always be set at the level of the firm's average cost of production. Although this appears to be a suitable solution, proponents of Price-Cap (PC) Regulation provided their alternative in the late 1980's. Given that a firm under COS Regulation will always just break even, it is not provided with an incentive to reduce its costs. In order to reduce costs, the firm must exert effort, which itself comes at a cost. In the interest of productive efficiency, PC Regulation allows a price to be set according to the firm's cost and to remain fixed for a given period of time. Any profits that accrue as a result of the firm's cost-reducing effort are granted to the firm, giving it a high-powered incentive to reduce costs. Under PC Regulation, however, the price may no longer be at a level of average cost, compromising allocative efficiency. And thus the debate of COS versus PC Regulation has continued on the basis of allocative versus productive efficiency considerations.

The regulatory problem is addressed in the literature as a problem of asymmetric information between the regulator and the firm. The key assumption that drives the conclusions is that of a profit maximizing firm. It is assumed in the models of both COS and PC Regulation that the owners of the firm make all decisions with respect to cost-reducing effort in a purely self-interested manner. What is overlooked, however, is the similar information problem that exists between the owners and the managers of the firm (Waterson, 1988). The owners of many regulated firms are not the active decision makers and must rely on managers to run the business. The owners, therefore, are clearly not the people who are *running* the company. There is some management of the firm that must make decisions on behalf of the owners, exerting the costly effort that is required for cost efficiency. The owners of the firm must, therefore, compensate the management with the proper incentives so that their interests are acknowledged and cared for.

The objective of this paper is to combine the ideas from these two branches of the literature to create a more accurate portrayal of the regulatory problem. Adding the very realistic assumption that the regulated utility is a publicly traded company, the conclusions of the models of COS and PC Regulation change significantly. With the third player added to the traditional models of price regulation, we find that PC Regulation is, in fact, the optimal solution in the interest of both allocative efficiency and productive efficiency. By using the price as her only instrument, the regulator is able to ensure that both the owners and the management of the firm are given the proper incentives for efficiency.

We begin our analysis in Chapter 2 by introducing, in chronological order, the development of the literature in regulatory economics beginning with the concept of COS Regulation, which dates back to 1944. Chapter 3 introduces our three-player model of PC Regulation and demonstrates two different pricing solutions. Chapter 4 applies the concept of a three-player hierarchy to COS Regulation and demonstrates that the firm, in fact, does have a great incentive to exert cost-reducing effort, contrary to the conclusions in the existing literature. Since the firm's costs will always be recovered, the manager has an incentive to overinvest in effort. The manager is then compensated for her effort in the form of a greater salary. This drives up the firm's fixed costs, which are recovered in the form of a higher price charged for the product. This leads to the conclusions found in a comparison of the two three-player models in Chapter 5. Due to the overexertion of effort on the part of the manager under COS Regulation, costs have been driven up to a point where they are higher than under PC Regulation and the resulting price is also higher, making PC Regulation the optimal solution to the regulatory problem in terms of both allocative and productive efficiency.

Chapter 2

Existing Literature

In this chapter, we will establish the current position in the regulatory economics literature with respect to COS and PC Regulation. We will describe, in chronological order, innovations in the literature beginning in Section 2.1 with COS Regulation, which dates back to 1944. The Averch-Johnson effect will be analyzed as an often cited argument against COS Regulation. It is shown that, under COS Regulation, the firm has an incentive to inflate costs by overinvesting in capital. This leads to a higher price offered to the consumer and an inefficient outcome. This conclusion is supported by the findings of Chapters 4 and 5, which show that in the context of a three-player hierarchy, due to inflated costs, COS Regulation is no longer the efficient solution in terms of allocative efficiency. Section 2.2 introduces Bayesian models of price regulation. In these models, the productive efficiency effects of COS Regulation are improved upon by allowing the firm to exert cost-reducing effort. The model by Laffont and Tirole (1986) introduces the regulatory problem in adverse selection and moral hazard. By allowing the regulator to implement a non-linear pricing scheme, second-best efficiency is induced through the use of a monetary transfer from the regulator to the firm. Section 2.3 introduces PC Regulation as a linear pricing mechanism that induces productive efficiency on the part of the firm by offering a high-powered incentive for cost reduction. The conclusions of the PC models of regulation are confirmed in the three-player setting as shown in Chapter 3. Section 2.4 introduces Schmalensee's (1989) model of a "Good Regulatory Regime".

Schmalensee's concept is that of finding a balance between the allocative efficiency enhancing COS Regulation and the productive efficiency enhancing PC Regulation. It is found that this can in fact be achieved by allowing for some level of "cost-sharing" between consumers and the producer.

2.1 Cost of Service Regulation

COS Regulation is motivated purely by allocative efficiency and welfare considerations and dates back to the often cited *Hope* decision of 1944.[1] Under COS Regulation, periodic rate hearings are held where a price is set according to the firm's "break-even" constraint. This implies that rates will typically be set at the level of the firm's long-run average cost. This price allows the firm's revenues to just cover the costs faced. Both consumer and total surplus standards suggest that this is efficient in the allocative sense, as the second-best has been achieved by the use of a Ramsey pricing rule for a single-product monopolist. Under these conditions, however, firms may find it profitable to invest in an inefficiently high capital to labour ratio. This has been explained in various ways, all based on the seminal contribution of Averch and Johnson (1962).

The Averch and Johnson Model

Averch and Johnson's (1962) offering has contributed greatly to the regulatory economics literature. The key element in this paper is commonly referred to as the A-J effect. The model shows that there are two capital to labour ratios that will yield the same level of output. Given, however, that the firm is subject to Rate of Return

[1] *Federal Power Commission v. Hope Natural Gas Co.*, (1944).

(RoR) Regulation, this situation gives the incentive to inflate costs by overinvesting in capital, which in turn allows them a higher price and a greater profit.

For analysis of this model, we will use the profit function, $\pi = pF(K,L) - rK - wL$, where r and w are the rental rate of capital, K, and wage rate for labour, L, respectively. Given this function, we know that a cost minimizing firm would require the following condition to hold:

$$\frac{F_K}{F_L} = \frac{r}{w}, \tag{2.1}$$

which states that the marginal rate of technical substitution is equal to the ratio of factor input prices. However, this is not necessarily the way that the regulated firm would behave. RoR Regulation induces cost inefficiency, leading to higher regulated prices.

We can analyze this problem beginning with a firm-level maximization program for a COS regulated firm. The firm wishes to maximize profits subject to the following "rate of return" constraint:[2]

$$\frac{pF(K,L) - wL}{K} \leq s, \tag{2.2}$$

which states that the firm's return must be less than or equal to some specified level, s, as set by the regulator. Using these two relations, we can define a Lagrangian optimization program:

$$\max_{K,L} \mathcal{L} = pF(K,L) - rK - wL + \lambda(sK - pF(K,L) - wL), \tag{2.3}$$

[2]This analysis is based on that of Crew and Kleindorfer (1986).

with first-order conditions:

$$\frac{\partial \mathcal{L}}{\partial K} = (1-\lambda)pF_K(K,L) - (1-\lambda)r + \lambda(r-s) = 0, \tag{2.4}$$

$$\frac{\partial \mathcal{L}}{\partial L} = (1-\lambda)pF_L(K,L) - (1-\lambda)w = 0. \tag{2.5}$$

Dividing the left-hand side of (2.4) by that of (2.5), we are able to find the following condition:

$$\frac{F_K}{F_L} = \frac{r}{w} - \frac{\lambda(s-r)}{(1-\lambda)w}. \tag{2.6}$$

Given that the second term is positive,[3] the right hand side of this equation is less than the input price ratio, showing the result that a COS regulated natural monopolist will invest in an inefficiently high capital to labour ratio for a given level of output.

This is the essence of the A-J model. It appears as though, *ceteris paribus*, this type of regulatory mechanism could reduce efficiency greatly due to the cost inefficiencies induced by the goal of allocative efficiency. It is shown by Crew and Kleindorfer (1986), however, that output and price can be improved sufficiently to create a gain in total surplus.

Efficiency Considerations

When a firm prices at a level of second-best, the goal of allocative efficiency may be attained. However, the trade-off as illustrated by the A-J model may have a significant enough effect on productive efficiency to offset the positive allocative

[3] Averch and Johnson (1962) define s, the rate of return allowed by the regulatory board, to be strictly greater than r, the rental rate of capital. Thus, $(s-r) > 0$.

effects of COS Regulation. This is due to the limited incentives available for the firm to minimize costs. Joskow (1974) argues, however, that the A-J model is flawed by the assumption that the pricing decision is left to the firm. Since the price is fixed at some level between regulatory hearings, COS regulation becomes "cost-plus" in the long-run and the firm does in fact have an incentive to reduce costs and extract available rents.

As we will find in the following section, incentive mechanisms can be created to induce an increase in productive efficiency at the cost of allocative efficiency. Brennan (1996) claims that this follows directly from the property rights given to the firm. It is argued further that "an agent who is not the claimant to the residual profit from his decisions lacks the incentive to make decisions that maximize profits" (Brennan, 1996, p. 26). Given the appropriate incentive-based mechanism, we will be able to find a productive efficiency enhancing solution to the regulatory problem.

2.2 Bayesian Models of Price Regulation

The Bayesian models of price regulation introduced primarily in the early 1980's added the idea of firm-level effort in the interest of productive efficiency. Laffont and Tirole (1986) use a non-linear pricing mechanism to achieve second-best efficiency.

Baron and Myerson (1982), Loeb and Magat (1979) and Sappington (1982) use in their respective studies the assumption that "the demand function is common knowledge and the cost function can be parameterized by one real number" (Laffont and Tirole, 1986, p. 615). Laffont and Tirole (1986) construct an adverse selection model of price regulation in which the assumption of cost observability is added to the analysis of Baron and Myerson (1982), while effort is left to be unobservable. In this model, the regulator wishes to maximize an expected social welfare function, which includes both consumer welfare and the utility of the firm. The firm is of the type set $\{\underline{\beta}, \bar{\beta}\}$, where $\bar{\beta} > \underline{\beta}$ and these parameter values are known by all players.[4] Costs are observable and represented by $C = \beta - e$, where e is firm-level effort. Effort in this model decreases marginal cost, but itself comes at an increasing, convex cost, or disutility, $\psi(e)$, to the firm.

The firm has the following utility function:

$$U(\beta) \equiv t(\beta) - \psi(\beta - C(\beta)), \tag{2.7}$$

where $t(\beta)$ is a transfer offered to the firm by the regulator in order to induce truth-telling. In order for the firm to stay in business, utility must be kept at a positive level. Therefore, the following individual rationality constraints for firms of the efficient and inefficient types, respectively, must hold:

$$t(\underline{\beta}) - \psi(\underline{\beta} - C(\underline{\beta})) \geq 0, \tag{2.8}$$

$$t(\bar{\beta}) - \psi(\bar{\beta} - C(\bar{\beta})) \geq 0. \tag{2.9}$$

Incentive compatibility constraints allow the regulator to write a contract that compensates the firm for exerting cost-reducing effort. The incentive compatibility constraints for firms of each type are as follows:

[4] Laffont and Tirole's (1993) two-type model is a simplification of Laffont and Tirole (1986) in which a continuum of types is analyzed.

$$t(\underline{\beta}) - \psi(\underline{\beta} - C(\underline{\beta})) \geq t(\bar{\beta}) - \psi(\underline{\beta} - C(\bar{\beta})), \tag{2.10}$$

$$t(\bar{\beta}) - \psi(\bar{\beta} - C(\bar{\beta}) \geq t(\underline{\beta}) - \psi(\bar{\beta} - C(\underline{\beta})). \tag{2.11}$$

The *ex post* social welfare function is given as follows and includes both consumer welfare and the firm's utility:

$$\begin{aligned} W(\beta) &= S - (1+\lambda)[t(\beta) + C(\beta)] + t(\beta) - \psi(\beta - C(\beta)) \\ &= S - (1+\lambda)[C(\beta) + \psi(\beta - C(\beta))] - \lambda U(\beta), \end{aligned} \tag{2.12}$$

where S is gross consumer surplus and $\lambda > 0$ is the shadow cost of consumer taxation implying that \$1 worth of taxation inflicts a $\$(1+\lambda)$ disutility on taxpayers. Given that there are two types of firms in the economy, the regulator must base her contract decision on expectations. The regulator wishes to maximize the following expected social welfare function:

$$\begin{aligned} E[W(\beta)] = \nu[S - (1+\lambda)[C(\underline{\beta}) + \psi(\underline{\beta} - C(\underline{\beta}))] - \lambda U(\underline{\beta})] + \\ (1-\nu)[S - (1+\lambda)[C(\bar{\beta}) + \psi(\bar{\beta} - C(\bar{\beta}))] - \lambda U(\bar{\beta})], \end{aligned} \tag{2.13}$$

subject to:

$$t(\bar{\beta}) = \psi(\bar{\beta} - C(\bar{\beta}) \tag{2.14}$$

$$t(\underline{\beta}) = \psi(\underline{\beta} - C(\underline{\beta})) + \psi(\bar{\beta} - C(\bar{\beta})) - \psi(\underline{\beta} - C(\bar{\beta})), \tag{2.15}$$

where ν is equal to the regulator's prior belief that the firm is of the efficient type, $\underline{\beta}$. By the single-crossing property that the firm's utility functions display, constraints (2.8) and (2.11) are implied by (2.9) and (2.10), respectively.[5] Substituting the two constraints in for $t(\bar{\beta})$ and $t(\underline{\beta})$ in the firm's utility functions, the regulator's objective is to maximize the following by choosing $C(\underline{\beta})$ and $C(\bar{\beta})$ and can now be solved unconstrained:

$$\begin{aligned} E[W(\beta)] = \nu[S - (1+\lambda)[C(\underline{\beta}) + \psi(\underline{\beta} - C(\underline{\beta}))] - \\ \lambda[\psi(\bar{\beta} - C(\bar{\beta})) - \psi(\underline{\beta} - C(\bar{\beta}))]] + \\ (1-\nu)[S - (1+\lambda)[C(\bar{\beta}) + \psi(\bar{\beta} - C(\bar{\beta}))]]. \end{aligned} \tag{2.16}$$

Differentiating the regulator's objective function with respect to each agent's cost function, $C(\underline{\beta})$ and $C(\bar{\beta})$, yields the two following first-order conditions, respectively:

$$\psi'(\underline{\beta} - C(\underline{\beta})) = 1, \tag{2.17}$$

$$\psi'(\bar{\beta} - C(\bar{\beta})) = 1 - \frac{\nu}{1-\nu}\frac{\lambda}{1+\lambda}(\psi'(\bar{\beta} - C(\bar{\beta})) - \psi'(\underline{\beta} - C(\bar{\beta})). \tag{2.18}$$

First-order condition (2.17) states that the efficient firm's effort is at a level of first-best. Given the parameter value assumptions of the model, $\frac{\nu}{1-\nu}\frac{\lambda}{1+\lambda}(\psi'(\bar{\beta} - C(\bar{\beta})) - \psi'(\underline{\beta} - C(\bar{\beta})) \geq 0$ and thus the inefficient firm's effort exerted is at suboptimal level. This result is driven entirely by the presence of λ in the model and leads to

[5]Rothschild and Stiglitz (1976) illustrate the use of the single-crossing property in their model of insurance markets. The single-crossing property is illustrated further in the context of our principal-agent problem in Chapter 3.

Laffont and Tirole's (1993) conclusion, which states that a firm of the efficient type exerts an efficient level of effort and acquires a positive rent, while the inefficient firm exerts too little effort and acquires no rent.

This result is driven by the single-crossing property and the constraints of the model. The contract must be written so that it is in the firm's best interest to reveal its true type. The regulatory response to these informational asymmetries requires that some rents be allowed to an efficient firm in order to induce effort.

In the following chapters we will derive two models of price regulation in moral hazard and adverse selection. The difference in the set-up of the models, however, is that we will not allow a lump-sum transfer from the regulator to the firm. Instead, we add a manager to the model who is given a salary by the firm to induce efficiency. The regulator, however, has the price as her only instrument to induce efficiency at all levels.

2.3 Price-Cap Regulation

Even given the known inefficiencies associated with COS and rate of return regulation, these mechanisms were preferred until the late 1980's. Added to these inefficiencies, as described by the A-J effect, managerial slack and X-inefficiency also provided motivation for a new form of price regulation. Leibenstein (1966) defines X-inefficiency as the rise in a firm's costs due to managerial slack. Prior to this conjecture, Hicks (1935) made the argument claiming that managerial slack is one negative effect of market power, as there is little to be gained by effort put into cost reduction. These conclusions are especially problematic when the firm is regulated, as the increased costs resulting from managerial slack are compensated for in the form of higher prices. This can be mitigated by the introduction of incentives for cost reduction as are present in PC Regulation.

COS Regulation, as indicated by Mansell and Church (1995), was replaced in the 1980's by PC Regulation of firms including British Telecom, British Gas, and American Telephone and Telegraph Company (AT&T). The idea is that an exogenous price-cap set by a regulator will "induce the regulated firm to minimize its production costs and pursue economically efficient innovation" (Braeutigam and Panzar, 1993, p. 193) much like an unregulated firm's behavior.

In order to ensure that firms are cost minimizing, there must be some incentive mechanism present. As we will see, these regimes allow for firms to retain any rents realized due to cost efficiencies. This acts as an incentive for firms to invest in cost-reducing effort, which is synonymous with productive efficiency. PC Regulation was introduced as an alternative to COS Regulation in the 1980's in the interest of productive efficiency. Acton and Vogelsang (1989) describe the following key properties of PC Regulation:

- The regulator sets a price ceiling for the regulated firm. However, the firm has the discretion to set prices at any level below this for a given basket of goods.
- The price ceilings are periodically adjusted by some exogenous factor as determined by the regulatory authority.
- Over longer periods of time, the price ceiling and the adjustment factor will be reviewed to reflect fairness with respect to changes in market conditions.

The most famous example of PC Regulation is Britain's RPI-X price regulation. "RPI-X" refers to how the price-caps change over time. The price ceiling adjusts exogenously according to Britain's retail price index (RPI) minus some 'X' factor, which is set by the regulator. This allows, over time, for an increasingly tight constraint on the available rents for the firm while keeping incentives for cost reduction in place. It may be argued, however, that the movement of price increasingly closer to average cost will restrict the rents that are available for the firm to capture.

Efficiency Considerations

In analyzing the efficiencies associated with PC Regulation, a key factor is the trade-off between cost reduction incentives and the deadweight loss that could be created by a high price-cap. The importance of setting an appropriate price-cap is emphasized by Braeutigam and Panzar (1993). If the cap is set too high, there will be a resulting adverse allocative effect, while if the cap is set too low, the firm may not gain enough revenues to break even and stay in business.

PC Regulation is a solution to the regulatory problem that allows for productive efficiency. Under this form of regulation, the firm is allowed to absorb any difference between revenues and costs in the form of profits. This allows for a powerful incentive for cost minimization at the firm level. A positive allocative effect also results from the level of 'X' that is chosen by the regulator. As shown by Beesley and Littlechild (1989), the lower prices induced by the level of the 'X-factor' allow for an increase in allocative efficiency accompanying the productive effects over time.

PC or RPI-X regulation may, however, create some ill effects. First of all, it creates a regulatory lag longer than that of the traditional COS mechanism. While *ex post* rate hearings are required for price setting under a COS regime in each given time period, it is an *ex ante* price ceiling that is set under PC Regulation. RPI-X allows the price to move exogenously for multiple periods without review. An interesting implication of this, as argued by Vickers and Yarrow (1988), is that the incentives for the firm to invest in cost reduction decrease over time in the period between regulatory hearings. Because of this, and for allocative reasons as claimed by Beesley and Littlechild (1989), the 'X' factor should be set and reset relatively more frequently. The administrative costs associated with this more frequent review process may, in fact, counteract the positive productive effects of PC Regulation. These arguments suggest that PC Regulation alone may not allow for greater efficiencies than COS Regulation.

From the preceding efficiency analysis, we can see that PC Regulation may allow for the alleviation of some of the productive inefficiencies associated with COS Regulation. However, the increase in efficiency may come at the cost of allocative efficiency. The burden that these regulatory regimes must deal with is that costs are the private information of the firm. While this cannot be overcome, the problem could potentially be mitigated by another form of incentive scheme. In the following section, we will explore further developments in incentive regulation and then proceed to establish a mechanism that balances the trade-offs that come into play when choosing between COS and PC Regulation.

2.4 Linear Pricing

To balance the allocative and productive efficiencies, early incentive-based models of regulation were found by creating nonlinear pricing mechanisms in which a monetary transfer is provided by the regulator to the firm (Baron and Myerson, 1982; Laffont and Tirole, 1986). Although efficient solutions have been found using these methods, it seems as though linear models would be preferable and easier to implement than the regimes that require a monetary transfer from the regulator (or consumers) to a firm.

In his influential 1989 paper, Schmalensee suggests some level of "cost-sharing", which is defined as a point on the interval between the two extremes of COS Regulation and PC Regulation. This allows for the trade-off between allocative efficiency and productive efficiency to be optimized.

Schmalensee (1989) illustrates a model in line with the principal-agent literature in which a regulator uses the choice of an initial price-cap as well as some parameter for cost-sharing to maximize efficiency. The level of cost-sharing is the amount of firm-level cost embedded in the price and is, thus, passed directly through to consumers. In this model, the cost-sharing parameter takes on a value between zero and one where zero corresponds to a regime synonymous with pure PC Regulation and one represents COS Regulation. The cost-sharing parameter is the mechanism by which allocative and productive efficiencies will be balanced.

The model is set up as a three-stage game. In stage one, the regulator chooses a level of the price-cap, ρ, as well as a level of cost sharing, γ; in stage two, the firm chooses some profit-maximizing level of cost-reducing effort, δ, and in stage three, the costs become observable and the regulator sets the price according to the following linear pricing scheme:[6]

$$P = \rho + \gamma(C - \alpha) = \rho + \gamma(\epsilon - \delta).^{7}$$

Using an explicit functional form for price, Schmalensee (1989) is able to derive a feasible regulatory policy based on the firm exerting a welfare maximizing level of effort given the cost of effort, the regulated price-cap and level of cost-sharing.

Given the second-order condition of the model, it is found that the effect on effort of a change in the level of cost-sharing is negative for high values of γ and ambiguous for the low values. The numerical analysis performed by Schmalensee (1989), as discussed below, shows that "increases in γ generally raise the expected value of δ and lower the expected value of P when $\gamma < \frac{1}{2}$ and have the opposite effect when $\gamma > \frac{1}{2}$" (p. 421). This tells us that, although cost-sharing is more efficient than traditional regulatory mechanisms, the efficient solution will require a high value of γ, leading to a regime quite similar in workings to PC Regulation.

Relying on numerical methods for his analysis, Schmalensee (1989) investigates optimal cost-sharing and initial mark-up parameters under four distinct cases, which consist of all combinations of maximizing either: 1) total welfare; or 2) consumer surplus subject to one of: 1) nonnegative expected profit; or 2) nonnegative worst-case profit. It is found that the optimal level of cost sharing varies considerably across each of these four cases. Schmalensee's (1989) conclusions show that the two extreme

[6] Observable costs are defined by $C = \alpha + \epsilon - \delta$, where α is expected average cost, ϵ is a random cost shock and δ is the agent's effort.

[7] COS Regulation can be defined in this equation when $\rho = \alpha$ and $\gamma = 1$. In PC Regulation, $\gamma = 0$, as the price ceiling does not adjust in each period.

cases will be when: 1) total welfare is maximized subject to nonnegative expected profits; and 2) consumer surplus is maximized subject to nonnegative worst-case profits moving our results toward PC Regulation and COS Regulation, respectively. Similar results are found with regard to the optimal mark-up. It is found that the optimal mark-up (and thus the price-cap) must be set higher when the constraint is nonnegative worst-case profits rather than expected profits. This is because of the fact that this is a stronger constraint for which the producer must be compensated. Two key results can be taken from this analysis. First, the choice of welfare standard makes a significant difference. If total surplus is chosen to be the metric, there will be a bias toward PC Regulation. Secondly, it is found that the choice of zero-profit constraint will have an impact on the results. Because nonnegative worst-case profits would be a stronger constraint, it is not surprising that it is found to bias the results toward regulating with price-caps.

2.5 Conclusion

Some interesting arguments have been made with regard to the positive and negative aspects of both COS and PC Regulation. The arguments of Brennan (1996) and Beesley and Littlechild (1989) sum up the ongoing discussion between the two regimes. Brennan (1996) argues that the property rights of the rents accrued due to cost reduction is just the incentive required to motivate productive efficiency. While this is indeed accurate, Beesley and Littlechild (1989) claim that the resulting decrease in allocative efficiency may be enough to warrant a movement back toward COS Regulation. This emphasizes the fact that it is crucial to analyze the effects on a case-by-case basis and only then make an educated decision about which standard to use.

Schmalensee (1989) and Armstrong and Sappington (2005) suggest similar linear pricing models that balance the productive effects of PC Regulation with the allocative effects of COS Regulation. It is shown that PC and COS Regulation can be thought of as only special cases of a more complex regulatory model. The conclusions show that in order to balance allocative and productive efficiency, some hybrid of PC and COS Regulation must be adopted.

While these traditional standards create some interesting results, it is not a movement to more complex regimes that is required. In the current research we simply relax the assumption made in the existing literature of a profit maximizing firm as suggested by Waterson (1988). In its place, we allow for a separation of ownership from management, creating a regulatory hierarchy.[8] Adding a third player to the regulatory hierarchy, we derive both a PC and a COS pricing scheme and show that the regulator can in fact induce cost efficiency at the level of the firm by using only the price as an instrument, while taking into account allocative efficiency considerations. Not only does this create a more accurate portrayal of the relationships between regulator, firm and manager, it also shows that with an improved method of price-setting, PC Regulation is the efficiency enhancing solution, whether we are concerned with productive *or* allocative efficiency.

[8]Information hierarchies have been studied in game theory literature in the past. Tirole (1986) provides the initial study in which efficiency is induced by issuing lump-sum transfers from the top level to all lower levels of the hierarchy. There are not any works in this branch of literature that only allow interactions to span one level of the hierarchy as we do in the current models.

Chapter 3

Optimal Price-Cap Regulation

PC Regulation is currently deemed to be the productively efficient solution to the regulatory problem, as it encourages the firm to invest in cost-reducing effort. The incentives required to induce firm-level effort, however, create a deadweight loss to the detriment of consumers, compromising total surplus. In this chapter, we will introduce a model of PC Regulation with a third player added. Firm management will occupy the third level of the hierarchy and will be the driving force in the result that price-cap regulation is, in fact, surplus enhancing. The regulator will use only price as an instrument and will be able to induce effort on the part of the manager, while the firm will be left minimal rents.

In our models of PC Regulation, the timing will be as follows: At $\mathbf{t} = \mathbf{t}_0$, the manager will discover her type; at $\mathbf{t} = \mathbf{t}_1$, the regulator will set a price-cap p based on expectations regarding the manager's type; at $\mathbf{t} = \mathbf{t}_2$, the firm will offer the manager a contract;[1] at $\mathbf{t} = \mathbf{t}_3$, the management will accept or reject the contract; and at $\mathbf{t} = \mathbf{t}_4$, the contract will be executed. To solve this model, we will first find the equilibrium amount of effort to be put forth by the management of the firm. Taking into account the firm profits at this optimum, we will proceed to solve the regulator's problem of maximizing expected consumer surplus by choosing a single price-cap. We will then proceed to derive an optimal truth-telling price-cap menu

[1] In Section 3.2.2, the contract will be based solely on the regulator's (and implicitly the firm's) expectations regarding the manager's type. In Section 3.2.3, the manager will be offered a menu of contracts.

for the regulator to offer to the firm.

For the remainder of the analysis, we will define the manager's type as a negative real number in the open interval between negative one and zero. The efficient player's type value, θ, is denoted by $\underline{\theta}$ and is lower in absolute value than her inefficient counterpart, as denoted by $\bar{\theta}$. Bounding θ between the absolute value of zero and one allows us to use the manager's type as a base for marginal cost. In the two-type model, $\Theta = \{\bar{\theta}, \underline{\theta}\}$ and the values for both $\underline{\theta}$ and $\bar{\theta}$ are known to all players of the game. Which of the two types the manager actually is, however, is known only by the manager herself.

We also define in this analysis the inverse demand function $q(p) = 1 - p$ for simplicity. Marginal cost will be decreasing and linear in effort and equal to $-\theta(1 - e(\theta))$. Average cost will be always greater than marginal cost and equal to $-\theta(1 - e(\theta)) + \frac{t(\theta)}{1-p}$, where $t(\theta)$ is a transfer from the firm to the manager. The manager's utility function will include a convex cost of effort, θe^2, which takes away from the transfer received from the firm. The convex cost of effort, with the firm's linear benefit of effort, allows for a unique regulatory contract.

The regulator's, the firm's and the manager's utilities will be given, respectively, by the following:

$$CS = \int_p^1 (1-p)dp, \tag{3.1}$$

$$\pi(e(\theta), t(\theta), p, \theta) = (p + \theta(1 - e(\theta)))(1-p) - t(\theta), \quad \forall \theta \in \Theta, \tag{3.2}$$

$$U(e, \theta) = t + \theta e^2, \quad \forall \theta \in \Theta. \tag{3.3}$$

Equation (3.1) represents consumer surplus, which is defined as the difference between what consumers are willing to pay and the price that they actually face. It is shown mathematically as the area between the demand curve, $(1 - p)$ and the regulated price, p. Maximizing consumer surplus allows for consumers to get the greatest value from the product. By letting the regulator maximize consumer surplus, the price is set at a level where the firm is just able to break even.

The firm's profit is given in Equation (3.2). Given that the regulator is setting the price to maximize consumer surplus, the firm will not be able to act as a profit maximizer, but it will always at least break even. In Equation (3.2), the firm's profit is composed of a revenue component and a fixed cost component. The firm's revenue is dependent upon price, p, the demand function, $(1 - p)$, and the manager's type and effort level, θ and $e(\theta)$, respectively. The firm's fixed cost comes in the form of a lump-sum, effort-inducing transfer, $t(\theta)$, that is offered to the manager as an incentive contract.

When making its production decision, however, the firm must take into account the utility of the manager. The manager is acting to maximize her utility, as given by Equation (3.3). This function is composed of the benefit of effort, which is the salary, $t(\theta)$, offered by the firm, and the negative effect, which is the cost, or disutility, of effort, which enters negatively into the utility function as θe^2.

3.1 Full Information Benchmark

As an introduction to the three-player model, we will first analyze the problem with full information at all levels. This general analysis can be carried through as a benchmark for the two-type model to be explored in asymmetric information below.

3.1.1 Optimal Managerial Contract

In order to find the optimal managerial contract in full information, the firm must maximize profits subject to the manager's participation constraint. This is represented by the following maximization program:

$$\max_{\{t(\theta),e(\theta)\}} \pi = (p + (\theta)(1 - e(\theta)))(1 - p) - t(\theta) \tag{3.4}$$

subject to the following participation constraint:

$$t(\theta) + \theta e^2 \geq 0. \tag{3.5}$$

The participation constraint ensures that by working the manager's utility will be at a level greater than or equal to her best outside option. For simplicity, the manager's outside option has been set to a utility level of zero. By substituting the constraint in for $t(\theta)$, the problem reduces to the following maximization by a choice of $e(\theta)$:

$$\max_{e(\theta)} \pi = (p + (\theta)(1 - e(\theta)))(1 - p) + \theta e^2 \tag{3.6}$$

Optimization yields the following first-order condition for profit maximization for a given price-level:

$$\frac{\partial \pi}{\partial e} = -\theta(1 - p) + 2\theta e = 0 \tag{3.7}$$

We can see that, in the first-best solution at the firm-level, the optimum is found by equating the firm's marginal benefit from effort to the manager's marginal cost of effort. This is illustrated in Figure 3.1 as a tangency between the binding participation constraint and the profit level set. Solving this equation for the manager's

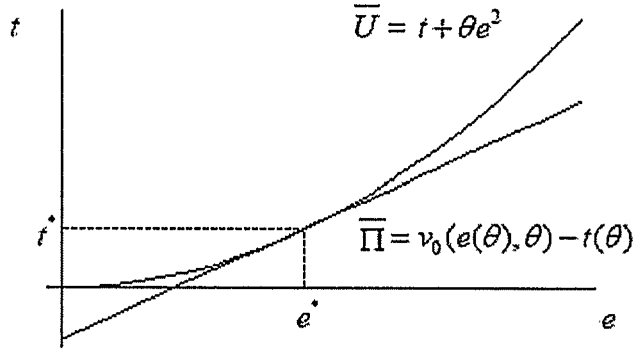

Figure 3.1: Optimal effort-inducing transfer.

effort level, the solution to the problem in full information reduces to the following:

$$e^* = \frac{(1-p)}{2}, \quad \forall \theta \in \Theta. \tag{3.8}$$

Given the initial set-up of the model, the optimal level of effort is not dependent on the agent's type. This is solely due to the relationship between the functional forms of profit and utility in terms of how θ enters the functions. This seems to oversimplify the model at this stage, but will aid in the analysis of the more complex models of asymmetric information.

Since the firm is acting in perfect information, in order to implement the first-best effort level, it need only be concerned with the participation constraints for each type. Normalizing the manager's outside option to a utility level of zero, the first-best-inducing transfer from the firm to the manager is equal to her cost of effort and is given as follows:

$$t^*(\theta, p) = -\frac{\theta(1-p)^2}{4}, \quad \forall \theta \in \Theta. \tag{3.9}$$

We can now find the firm's profit at the optimal managerial effort level, which includes the optimal effort inducing transfer.

$$\pi(\theta, p) = \left(p + \frac{\theta(1+p)}{2}\right)(1-p) + \frac{\theta(1-p)^2}{4}, \quad \forall \theta \in \Theta. \tag{3.10}$$

With this information, we can continue to solve the regulatory problem backwards. Entering the firm's profit at the optimum into the regulator's objective of maximizing total surplus, we can find the price-cap that maximizes welfare.

3.1.2 Optimal Price-Cap

With the results found above, we can proceed to solve the regulator's problem of maximizing consumer surplus with respect to a single price-cap subject to the firm's break even constraint:[2]

$$\left(p + \frac{\theta(1+p)}{2}\right)(1-p) + \frac{\theta(1-p)^2}{4} = 0 \tag{3.11}$$

[2]Since this problem is being solved in full information, we need only be concerned with one price-cap, as the manager's type is known. In Section 3.2, we will derive two types of price-cap contracts and analyze their respective efficiencies. First, we will find one optimal price-cap for a firm of either type and second, we will find a menu of pricing contracts based on direct revelation of the manager's type.

Given the zero profit condition, we know that the solution to the problem is going to be driven by this constraint. Therefore, the regulator's objective reduces to one of restricting the firm's profits to zero, by setting the price equal to the firm's average cost. Setting (3.11) equal to zero, we find the following optimal price-cap:

$$\hat{p}^* = -\frac{3\theta}{4+\theta}, \tag{3.12}$$

This second-best price corresponds to an effort level and a transfer as a function of θ:

$$\hat{e}^*(\theta) = \frac{2(1+\theta)}{4+\theta}, \tag{3.13}$$

$$\hat{t}^*(\theta) = -\frac{4\theta(1+\theta)^2}{(4+\theta)^2} = -2\theta\hat{e}(\theta)^2. \tag{3.14}$$

From Equations (3.8) and (3.9), it is obvious that both the effort and transfer are decreasing functions of price. Given that the second-best price is greater than first-best – average cost is greater than marginal cost – we know that the second-best levels of effort and transfer will be lower than those in the first-best optimum.

3.2 Asymmetric Information in a Two-Type Model

The information issues that arise in the relationship between a regulator, the regulated firm, and the firm's management are two-fold. The first information problem is explained by a model of moral hazard and adverse-selection at the level of the firm in which the owners must formulate a truth-telling contract for the management of the firm. The solution to this problem is well documented and allows for second-best efficiency at the firm level.[3] The objective of the regulator in this model is to maximize consumer surplus by choosing a single price-cap that the firm must follow. However, a second information problem exists at this level. The regulator must base her decision on expectations, as the manager's type is not known. Each of these problems has been studied extensively. Combining the two in one model, however, is a new idea that we will investigate in two different forms below. We will first allow the regulator to set a single price-cap based on expectations regarding the manager's type, while in the second model, a price-cap menu will be laid out in the regulatory contract. We will find conditions when the regulator can induce truth-telling at the firm level and, thus, create a net gain in consumer surplus by setting a price-cap menu based on truthful revelation of the manager's type.

In this section, we will use the objectives for all parties as defined above. The objectives of the regulator and the firm must be modified slightly, however, to take into account their expectations regarding the value of θ. They are given, respectively, as follows:

$$\max_{p} CS = \int_{p}^{1} (1-p)dp \tag{3.15}$$

$$\max_{\{(t(\underline{\theta}),e(\underline{\theta})),(t(\bar{\theta}),e(\bar{\theta}))\}} \nu(\pi(e(\underline{\theta},p),t(\underline{\theta},p),\underline{\theta},p)) + (1-\nu)(\pi(e(\bar{\theta},p),t(\bar{\theta},p),\bar{\theta},p)) \tag{3.16}$$

where $\nu \in [0,1]$ represents a prior belief of the probability that the agent is of the efficient type, $\underline{\theta}$. The regulator must now maximize consumer surplus, while the firm is acting to maximize *expected* profit. We will begin by deriving the optimal managerial contract. We can then proceed to find the price-cap that will induce the

[3]Prendergast (1999) provides an excellent discussion of incentives and the principal-agent problem.

second-best optimum in the three-player hierarchy along with a second-best inducing optimal price-cap menu in which, under certain conditions, a direct revelation mechanism will allow the regulator to set a unique price-cap for each type of firm based on the firm truthfully revealing the manager's type.

3.2.1 Optimal Managerial Contract

Recall the firm's objective:[4]

$$\max_{\{(t(\underline{\theta}),e(\underline{\theta})),(t(\bar{\theta}),e(\bar{\theta}))\}} \nu((p-\underline{\theta}(1-e(\underline{\theta})))(1-p)-t(\underline{\theta}))+(1-\nu)((p-\bar{\theta}(1-e(\bar{\theta})))(1-p)-t(\bar{\theta})) \tag{3.17}$$

which is constrained by the following individual rationality constraints for the efficient and inefficient types, respectively:

$$t(\underline{\theta}) + \underline{\theta}e(\underline{\theta})^2 \geq \underline{U}, \tag{3.18}$$

$$t(\bar{\theta}) + \bar{\theta}e(\bar{\theta})^2 \geq \bar{U}. \tag{3.19}$$

As in the full information benchmark, these constraints guarantee that a manager of either type will work for the firm. We can normalize the managers' outside options, $\bar{U}$ and $\underline{U}$, to zero and set constraint (3.19) to bind.

The two incentive compatibility constraints are given as follows:

$$t(\underline{\theta}) + \underline{\theta}e(\underline{\theta})^2 \geq t(\bar{\theta}) + \underline{\theta}e(\bar{\theta})^2, \tag{3.20}$$

[4]This section relies heavily on the introductory analysis of Laffont and Martimort (2002) in which optimal contracts are derived with a discrete number of manager types.

$$t(\bar{\theta}) + \bar{\theta}e(\bar{\theta})^2 \geq t(\underline{\theta}) + \bar{\theta}e(\underline{\theta})^2. \tag{3.21}$$

The incentive compatibility constraints add an element to the problem that eliminates the possibility of the manager lying about her type. Constraints (3.20) and (3.21) force the firm to write contracts such that the manager prefers the one written for her true type and prefers not to misrepresent herself. In (3.20), for example, the manager is of the efficient type. The right hand side of the equation shows an efficient manager exerting a lower effort level and receiving the transfer of an inefficient manager. This constraint, however, forces a contract such that the manager would prefer not to mask her type. A similar story can be told for equation (3.21) – the inefficient manager is better off truthfully revealing her type.

Given the above constraints, figure 3.2 shows where the optimal contracts in such

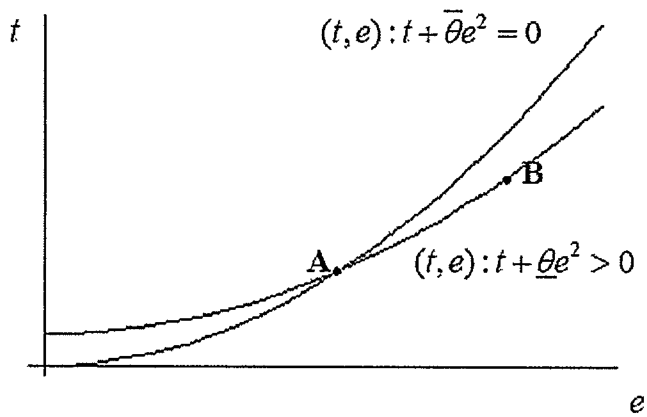

Figure 3.2: Separating equilibrium of optimal contracts for agents of high and low types.

a situation will lie relative to each other on the managers' respective indifference curves. Given the relative values of $\underline{\theta}$ and $\bar{\theta}$, the efficient manager's indifference curve is flatter than the inefficient manager's indifference curve at all points. Neither manager would ever benefit by masking their type. If the highlighted contracts, **A** and **B** are are offered, they optimal for the inefficient and efficient managers, respectively. This demonstrates the essence and importance of the single-crossing property. The optimal contract for the inefficient manager will lie at point **A**, where the two indifference curves cross, while the contract for the efficient manager will correspond to a point, say **B**, on her indifference curve to the right of the crossing point. This is consistent with a higher level of effort along with a higher transfer for the efficient manager. Notice where the contracts lie relative to each other on the indifference map of each agent. The efficient type is just indifferent between the two contracts, while the inefficient agent strictly prefers her contract to that of her efficient counterpart.

Due to the relative values of $\underline{\theta}$ and $\bar{\theta}$, the efficient manager's indifference curve is flatter. Because of this, she will always weakly prefer a contract that lies on the inefficient manager's binding participation constraint to one that is on her own binding participation constraint. This being the case, the inequality (3.18) will always hold and will not bind at the optimum. Therefore, constraint (3.18) can be eliminated from our problem. Due to the layout of the managers' indifference maps, Equation (3.21) can also be eliminated, as the efficient type's indifference map shows that she would never benefit by misrepresenting herself as an inefficient manager. In order for the efficient manager to represent her type truthfully, we will allow her to be indifferent between the two representations of type by setting (3.20) to bind.

Elimination of two of our four constraints is possible only due to the fact that the two agents' indifference curves cross only once. The single-crossing property allows for a separating equilibrium in which all agents will truthfully reveal their type, yielding a second-best outcome.

By rearranging the remaining constraints – constraints (3.19) and (3.20), respectively – we can find the following values for second-best transfers for agents of each type:

$$t(\bar{\theta}) = -\bar{\theta}e(\bar{\theta})^2 \tag{3.22}$$

$$t(\underline{\theta}) = t(\bar{\theta}) + \underline{\theta}(e(\bar{\theta})^2 - e(\underline{\theta})^2) \tag{3.23}$$

Substituting these two values into (3.17) for $t(\bar{\theta})$ and $t(\underline{\theta})$, respectively, we have the following unconstrained problem of maximizing the firm's expected profit.

$$\begin{aligned}\max_{\{e(\underline{\theta}),e(\bar{\theta})\}} E\pi = \nu((p - \underline{\theta}(1 - e(\underline{\theta})))(1 - p) - ((\underline{\theta} - \bar{\theta})e(\bar{\theta})^2 - \underline{\theta}e(\underline{\theta})^2))+ \\ (1 - \nu)((p - \bar{\theta}(1 - e(\bar{\theta})))(1 - p) + \bar{\theta}e(\bar{\theta})^2)\end{aligned} \tag{3.24}$$

This optimization leads to the following first-order conditions with respect to the effort levels for the efficient and the inefficient firms, respectively:

$$\underline{\theta}(1 - p) = 2\underline{\theta}e(\underline{\theta}) \tag{3.25}$$

$$\bar{\theta}(1 - p) = 2\hat{e}(\bar{\theta})\left(\frac{\nu}{1 - \nu}(\underline{\theta} - \bar{\theta}) - \bar{\theta}\right).^5 \tag{3.26}$$

Rearranging these results, we can see that the effort levels of the efficient and inefficient types, respectively, are given as follows:

$$e^*(\underline{\theta}) = \frac{(1 - p)}{2} \tag{3.27}$$

[5] $\hat{e}(\theta)$ represents the second-best level of effort.

$$\hat{e}^*(\bar{\theta}) = -\frac{\bar{\theta}(1-p)}{2\left(\frac{\nu}{1-\nu}(\underline{\theta}-\bar{\theta})-\bar{\theta}\right)} \tag{3.28}$$

Equation (3.27) is identical to the condition found in the full information benchmark and, thus, is equivalent to the first-best result. The inefficient manager's second-best effort level can be represented as a function of the efficient manager's effort.

$$\hat{e}^*(\bar{\theta}) = -e^*(\underline{\theta})\frac{\bar{\theta}}{\frac{\nu}{1-\nu}(\underline{\theta}-\bar{\theta})-\bar{\theta}}. \tag{3.29}$$

We find the interesting result that the efficient manager gets a positive information rent and exerts effort optimally at the same level as the first-best result found above. Since $0 < -\frac{\bar{\theta}}{\frac{\nu}{1-\nu}(\underline{\theta}-\bar{\theta})-\bar{\theta}} < 1$,[6] we know that the inefficient manager's optimal effort level is less than the efficient manager's. The inefficient manager receives no information rent and exerts a second-best level of effort due to informational asymmetries. Substituting these efforts into the program's constraints, as defined in (3.22) and (3.23), the optimal transfers to managers of each type, which have the information rents embedded, are given as follows:

$$t(\underline{\theta},p) = -(\bar{\theta}-\underline{\theta})\left(\frac{\bar{\theta}(1-p)}{2\left(\frac{\nu}{1-\nu}(\underline{\theta}-\bar{\theta})-\bar{\theta}\right)}\right)^2 - \underline{\theta}\left(\frac{(1-p)}{2}\right)^2, \tag{3.30}$$

$$t(\bar{\theta},p) = -\bar{\theta}\left(\frac{\bar{\theta}(1-p)}{2\left(\frac{\nu}{1-\nu}(\underline{\theta}-\bar{\theta})-\bar{\theta}\right)}\right)^2. \tag{3.31}$$

We can now insert the optimal levels of effort and transfer as found above into the

[6] Given the assumptions of the model, $\bar{\theta} < 0$, $\frac{\nu}{1-\nu} > 0$, and $(\underline{\theta}-\bar{\theta}) > 0$. It easily follows that $0 < -\frac{\bar{\theta}}{\frac{\nu}{1-\nu}(\underline{\theta}-\bar{\theta})-\bar{\theta}} < 1$.

firm's profit function given that the manager is of type $\underline{\theta}$ or $\bar{\theta}$, respectively:

$$\pi(\underline{\theta},p) = \left(p + \underline{\theta}\left(\frac{1+p}{2}\right)\right)(1-p) + \\ (\bar{\theta}-\underline{\theta})\left(\frac{\bar{\theta}(1-p)}{2\left(\frac{\nu}{1-\nu}(\underline{\theta}-\bar{\theta})-\bar{\theta}\right)}\right)^2 + \underline{\theta}\left(\frac{(1-p)}{2}\right)^2 \tag{3.32}$$

$$\pi(\bar{\theta},p) = \left(p+\bar{\theta}\left(1+\frac{\bar{\theta}(1-p)}{2\left(\frac{\nu}{1-\nu}(\underline{\theta}-\bar{\theta})-\bar{\theta}\right)}\right)\right)(1-p)+\bar{\theta}\left(\frac{\bar{\theta}(1-p)}{2\left(\frac{\nu}{1-\nu}(\underline{\theta}-\bar{\theta})-\bar{\theta}\right)}\right)^2. \tag{3.33}$$

The profits for the efficient and inefficient firms, respectively, correspond to first and second-best efficient production. In the following sections, we will use these values for firm profit in the regulator's consumer surplus maximization program.

3.2.2 Optimal Price-Cap

Given the preceding results at the firm-level, we can use the derived profit functions to find the optimal price cap using two different methods. The first is through the use of the regulator's expectations regarding the type of the manager.

Much like analysis in Section 3.1, we wish to minimize the firm's profits by the choice of the regulated price. In this case, we have two types and must therefore use expectations in our analysis. By setting the firm's expected profit to zero, the price is equal to the firm's expected average cost and is given as follows:

$$\hat{p}^* = \frac{\left[\underline{\theta}\bar{\theta}(1-4\nu)\nu + 3\underline{\theta}^2\nu^2 + \bar{\theta}^2(\nu^2+2\nu-3)\right]}{\left[\bar{\theta}^2(-1+\nu)^2 + (\bar{\theta}-\underline{\theta}\nu)(4+\underline{\theta}\nu)\right]} \tag{3.34}$$

The price-cap at a level of zero expected profits is the total surplus maximizing, "Ramsey" price, as the price is equal to the firm's expected average cost. The inefficient firm's participation constraint, however, will never be satisfied, while the efficient firm will receive positive profits. Given the regulator's prior belief regarding the type of the firm, the risk of firm shut-down may be too great for this to be a feasible solution.

Schmalensee (1989) defines two different types of break-even constraints. The first is based on expected profits and is identical to the one used in this analysis. The second is a zero "worst-case" profit constraint. This idea applied to our regulatory problem would require a zero-profit constraint for a firm of type $\bar{\theta}$. In a case where this type of constraint is used, the regulator will be forced to set the price such that the inefficient firm just breaks even. This price-cap is found by setting the inefficient firm's profits to zero:

$$\pi(\bar{\theta}, p) = \left(p + \bar{\theta}\left(1 + \frac{\bar{\theta}(1-p)}{2\left(\frac{\nu}{1-\nu}(\underline{\theta} - \bar{\theta}) - \bar{\theta}\right)}\right)\right)(1-p) + \bar{\theta}\left(\frac{\bar{\theta}(1-p)}{2\left(\frac{\nu}{1-\nu}(\underline{\theta} - \bar{\theta}) - \bar{\theta}\right)}\right)^2 = 0. \tag{3.35}$$

Rearranging the above equation, we can find the price that allows the inefficient firm to just break even, which is equal to this firm's average cost.

$$\tilde{p}^* = \frac{\left[\bar{\theta}(4\underline{\theta}^2 - 2\underline{\theta}\bar{\theta}\nu(3+\nu) + \bar{\theta}^2(3+\nu^2))\right]}{\left[8\underline{\theta}\bar{\theta}\nu - 4\underline{\theta}^2\nu^2 - 2\bar{\theta}^2(2 - \underline{\theta}(1-\nu)\nu) - \bar{\theta}^3(1-\nu^2)\right]} \tag{3.36}$$

Since this price allows the inefficient firm's participation constraint to just bind, we know that this firm will just break even and achieve zero profits. Because of this, it follows that an efficient firm will acquire a positive level of profits and the individual rationality constraint of either firm will always be satisfied.

We have derived two different pricing schemes in which the regulator has the discretion to set a single price-cap, but what are the tradeoffs? In Figure 3.3, we can see how the two price-caps compare to the first best price (marginal cost) as $\bar{\theta}$ approaches $\underline{\theta}$. There will be a net increase in price when we move to the second type

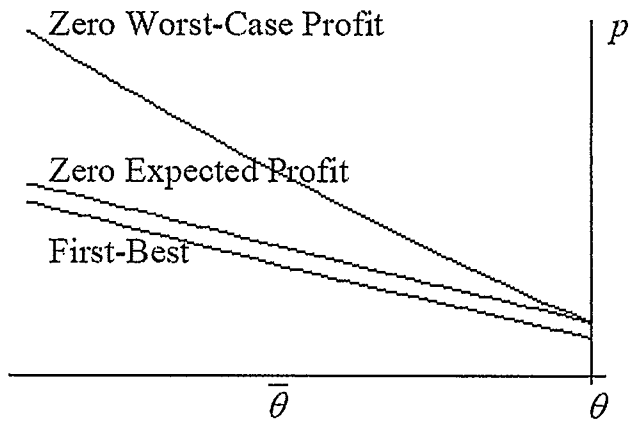

Figure 3.3: The optimal price-cap compared with those found under the constraints of zero expected profit and zero worst-case profit.

of zero profit constraint as put forth by Schmalensee (1989). Given that the first-best price is consumer surplus maximizing, we know that any movement away from this point will decrease surplus. However, a firm of either type will stay in business under the zero worst-case profit constraint and this type of constraint is therefore necessary. If the firm is of the efficient type, it will be allowed a positive surplus at the cost of consumer surplus, while an inefficient firm would be left with zero surplus. The fact that the manager's type is unobservable leads to the optimal price being the break-even price of the inefficient firm. This is the only way that, with a single price-cap as her only instrument, the regulator can guarantee that the firm will not shut down. Total surplus is at a suboptimal level, however, as an efficient firm would be allowed a positive level of profit, leading to deadweight loss.

	Price	$e(\underline{\theta})$	$e(\theta)$	$\pi(\underline{\theta})$	$\pi(\theta)$	q	CS
Optimal (First-Best) Price	0.2075	0.3962	0.2642	0.0234	-0.0967	0.7925	0.3140
Zero Expected Profit	0.2566	0.3717	0.2478	0.0575	-0.0575	0.7434	0.2763
Zero Worst-Case Profit	0.3415	0.3293	0.2195	0.1052	0	0.6585	0.2168

Table 3.1: Equilibrium prices, profit, consumer surplus and effort levels after optimization with three different constraints based on set parameter values.

Table 3.1 shows, for specific parameter values, how the regulator's choice of price along with consumer surplus, firm profit and either type of manager's effort will change as we change the constraint in the maximization program. Although the first-best price would yield the greatest effort levels, the price will cause an inefficient firm to shut down. Given a zero worst-case profit constraint, the individual rationality constraints will both hold, but a firm of the efficient type will always be allowed a positive surplus.

3.2.3 Optimal Price-Cap Menu

We have now determined the importance of the zero worst-case profit constraint. It is required for an inefficient firm to remain in business. In turn, though, an efficient firm will be allowed a greater profit. This problem can be mitigated by using a direct revelation mechanism to induce truth-telling on the part of the firm by offering a menu of incentive compatible price-cap contracts. Individual rationality and incentive compatibility constraints for firms of both types will be added to the regulator's optimization program to eliminate the possibility of the firm shutting down and reduce the profits allowed to an efficient firm. In this section, we will use the same managerial contract as given in Section 3.2.1 and proceed to find the optimal menu of price-cap contracts that maximizes consumer surplus.

Recall the constraints that were derived above using the single-crossing property. As was the case in the previous section, the results are going to be driven by the constraints imposed in the interest of rationality and incentive compatibility.

$$\pi(\underline{\theta}, p(\underline{\theta})) = \pi(\underline{\theta}, p(\bar{\theta})), \tag{3.37}$$

$$\pi(\bar{\theta}, p(\bar{\theta})) = 0. \tag{3.38}$$

Constraint (3.38) is equivalent to worst-case profit constraint (3.35) as discussed above. Therefore, we know that the efficient firm's nonnegative profit constraint will always be satisfied just as was the case in the optimal managerial contract in Section 3.2.1.[7] Because of this, the efficient firm's participation constraint has been omitted. If we set the efficient firm's incentive compatibility constraint to bind, the inefficient firm's constraint will still hold due to single-crossing.

Solving constraints (3.37) and (3.38) for $p(\underline{\theta})$ and $p(\bar{\theta})$, respectively, we find one interior solution which is a menu of prices as a function of the manager type parameters.

Proposition 1. *If the monopoly price of the efficient firm is less than the average cost of the inefficient firm, then the solution to the regulatory problem is characterized by a separating equilibrium. The optimal price-cap for the inefficient firm, $p^*(\bar{\theta})$, is equal to that firm's average cost, while the efficient firm's price-cap is some lesser value $p^*(\underline{\theta})$ such that $\pi(\underline{\theta}, p^*(\underline{\theta})) = \pi(\underline{\theta}, p^*(\bar{\theta}))$.*

[7] Section 3.2.1 discusses the single-crossing property applied to the individual rationality and the incentive compatibility constraints of the agent. The single-crossing property also holds for the firm and will be used in the following optimization.

Proof. Let $p^*(\bar{\theta})$ be the break-even price for a firm of type $\bar{\theta}$ and equal to the average cost of that firm, $AC(\bar{\theta})$. If $\frac{\partial \pi}{\partial p}(\underline{\theta}, p) < 0$ at $p^*(\bar{\theta})$, then $p^*(\bar{\theta}) > p^m(\underline{\theta})$ and $\exists p^*(\underline{\theta})$ such that $\pi(\underline{\theta}, p^*(\bar{\theta})) = \pi(\underline{\theta}, p^*(\underline{\theta}))$. Given the assumed concavity of the profit function, $p^*(\underline{\theta}) < p^*(\bar{\theta})$ and $\pi(\bar{\theta}, p^*(\bar{\theta})) < 0$. Therefore, the price-cap menu of $p(\bar{\theta}) = p^*(\bar{\theta})$ and $p(\underline{\theta}) = p^*(\bar{\theta})$ will yield a seperating equilibrium in which all of the model's constraints hold and perfect revelation ensues. □

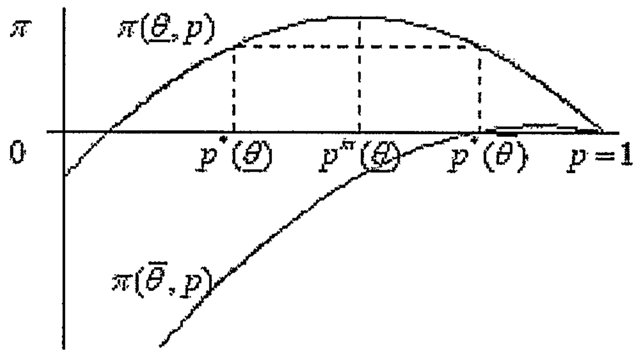

Figure 3.4: The optimal price-cap menu under the separating equilibrium driven by a large difference in efficiency between types.

Figure 3.4 illustrates the proof of Proposition 1. When the two agents' efficiency parameters are sufficiently far apart, it is clear that neither firm can benefit from accepting the pricing contract of the other type. Constraining the inefficient firm's profits to zero, we can then allow the efficient firm to be just indifferent between the two pricing contracts.

In this scenario, truth-telling is a dominant strategy for an agent of either type. Due to the relatively large difference between $\underline{\theta}$ and $\bar{\theta}$, the regulator will offer a price-cap menu in which $p(\underline{\theta}) < p(\bar{\theta})$ and the firm will truthfully reveal the manager's type.

This is similar to the results found in Section 3.2.2. In this case, however, the inefficient firm would arrive at negative profits were they to mask as an efficient firm, whereas we were forced in the previous section to constrain the inefficient firm's profits to zero. With these conditions placed on the price-cap menu, neither firm has an incentive to cheat and, as a result, the regulator is able to acquire a truthful account of the firm's type before the contract is executed and there is a net gain in consumer surplus if the firm is of type $\underline{\theta}$.

Proposition 2. *If the efficient firm's monopoly price is greater than or equal to the inefficient firm's average cost, then the solution to the regulatory problem is characterized by a pooling equilibrium. The regulator will set the price-cap for a firm of either type equal to the break-even price for a firm of type $\bar{\theta}$, $p^*(\bar{\theta})$.*

Proof. Let $p^*(\bar{\theta})$ be the break-even price for a firm of type $\bar{\theta}$ and equal to the average cost of that firm, $AC(\bar{\theta})$. If $\frac{\partial \pi}{\partial p}(\underline{\theta}, p) \geq 0$ at $p^*(\bar{\theta})$, then $p^*(\bar{\theta}) \leq p^m(\underline{\theta})$ and $\exists p^*(\underline{\theta})$ such that $\pi(\underline{\theta}, p^*(\bar{\theta})) = \pi(\underline{\theta}, p^*(\underline{\theta}))$. Given the concavity of the profit function, $p^*(\underline{\theta}) \geq p^*(\bar{\theta})$ and $\pi(\bar{\theta}, p) > 0$, $\forall p \in (p^*(\bar{\theta}), 1)$. If $p^*(\underline{\theta}) > p^*(\bar{\theta})$, then $\pi(\bar{\theta}, p^*(\underline{\theta})) > \pi(\bar{\theta}, p^*(\bar{\theta}))$ and the incentive compatibility constraint no longer holds, while if $p^*(\underline{\theta}) = p^*(\bar{\theta})$, then both incentive compatibility constraints bind and $p^*(\bar{\theta})$ is equal to $p^m(\underline{\theta})$. The efficient solution to this problem is a pooling equilibrium at $p(\bar{\theta}) = p(\underline{\theta}) = p^*(\bar{\theta})$. □

Figure 3.5 shows a situation in which the two type parameters are relatively similar. In this case, single-crossing allows for two interior solutions. In one instance, however, the inefficient firm's participation constraint does not necessarily bind. Separation would allow the inefficient firm to arrive at positive profits by masking as an efficient firm, while the efficient firm would be indifferent between $p(\underline{\theta})$ and $p^*(\bar{\theta})$. In Figure 3.5, we can see that, if two separate contracts were to be created, a firm

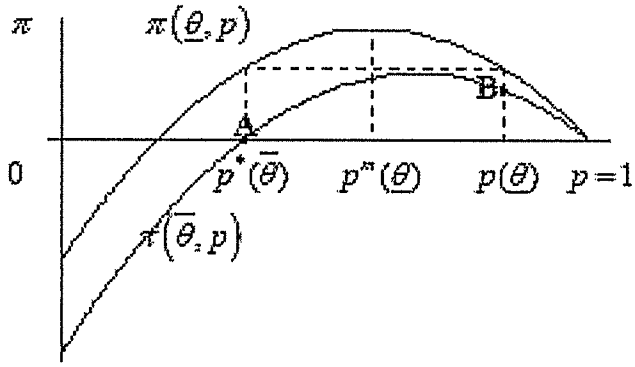

Figure 3.5: The optimal price-cap menu is represented by a pooling equilibrium at the break-even price for the inefficient firm when the two types' relative efficiencies are similar.

of the inefficient type would always mask as an efficient firm, as the level of profits associated with the price $p(\underline{\theta})$ at point **B** exceed those associated with the price $p^*(\bar{\theta})$ at point **A**. As a result, no new information would be revealed through this contract and a firm of either type would receive positive profits. For this reason, the regulator will offer a single regulatory contract that a firm of either type will accept at the initial price-cap of $p^*(\bar{\theta})$. A firm of type $\underline{\theta}$ would receive positive profits, while a firm of type $\bar{\theta}$ would just break even in this pooling equilibrium.

From Proposition 1, we know that, in order for a separating equilibrium to exist, the monopoly price for the efficient firm must be lower than the average cost of the firm of type $\bar{\theta}$. If this is the case, the firm cannot benefit from misrepresenting the type of the manager to the regulator. The regulator has induced truth-telling through the use of a direct revelation mechanism. If this condition does not hold, a pooling equilibrium exists, as stated in Proposition 2, in which the regulator will set the initial price-cap for a firm of either type at a level of zero profits for a firm of the inefficient type. From these two propositions, we can see that the relationship between the efficient firm's monopoly price and the inefficient firm's average cost, or break-even price, can be used to indicate what type of equilibrium will exist in the regulatory problem and, thus, how the price should be set. Figure 3.6 shows

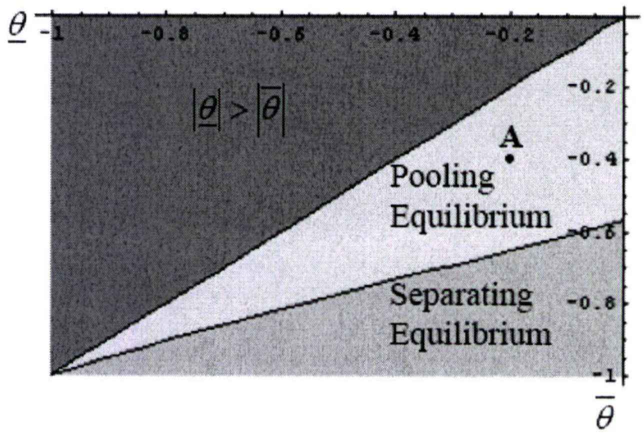

Figure 3.6: Conditions for equilibrium when ν is set to equal $\frac{1}{2}$.

all possible combinations of $\bar{\theta}$ and $\underline{\theta}$. For each combination, an equilibrium exists. If the values of θ are relatively close to one another, the solution will be a pooling equilibrium, while if they are relatively far apart, the solution will be a separating equilibrium. We have made an assumption on the value of the regulator's prior belief of the firm's type as an illustration parallel to that in Table 3.1. Taking the parameter values as presented in the table, we can see that this corresponds to a pooling equilibrium at point **A** in which the regulator must set a single price optimally at $p = .3415$. As this prior changes, the border between the separating and pooling equilibria in Figure 3.6 would pivot. As an example, if the regulator's prior belief of the likelihood that the firm is of the efficient type increases, the border in Figure 3.6 would pivot upward. The area labeled "Separating Equilibrium" would now be larger, as it is more likely that the agent is of the efficient type, $\underline{\theta}$.

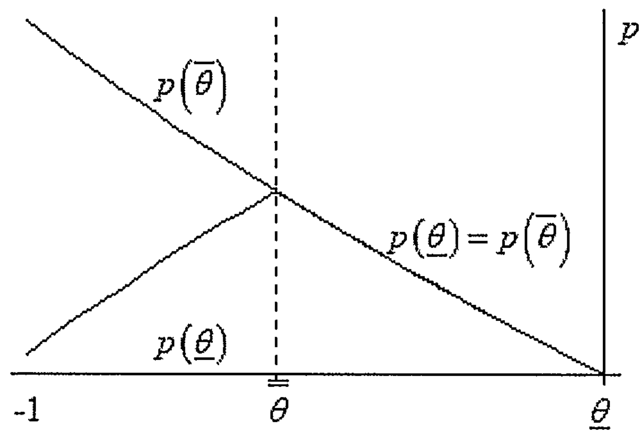

Figure 3.7: The optimal price-cap menu as $\bar{\theta}$ approaches θ.

We can see in Figure 3.7 that there is some threshold value, $\bar{\bar{\theta}}$, as $\bar{\theta}$ approaches $\underline{\theta}$ where the equilibrium changes from a separating to a pooling equilibrium, given the values of the θ parameters. In particular, if the θ's are relatively similar to each other, we will find a pooling equilibrium in which the regulator cannot induce truth telling. In this case, the price-cap must be set, as in the previous section, at the level of zero worst-case profits. If, however, there is sufficient difference in efficiency between the two types of firms, we find that there exists a separating equilibrium in which the regulator can induce truth-telling with a type-dependent price-cap as her only instrument. In Figure 3.7, the price for the inefficient firm is marked $p(\bar{\theta})$. For certain parameter values in the price-cap menu, this represents the pooling equilibrium. It is, however, identical to the price under the zero worst-case profit constraint in Section 3.2.2 for *all* parameter values. Given that for certain parameter values a separating equilibrium exists in Section 3.2.3 and that the efficient firm's price would be the lower of the two prices, while keeping profits nonnegative, we know that the price-cap menu is surplus enhancing. With any given set of parameter values, the regulator is now able to offer a consumer surplus-maximizing contract that, in terms of expectations, is superior to the single price-caps found in Section 3.2.2.

3.3 Conclusion

In the preceding analysis, we have derived an important variation of the current regulatory benchmark. Beginning with the problem in full information, we can see the importance of the regulator's prior beliefs along with choice of break-even constraint when we move to analyze the problem in asymmetric information. An interesting solution to the problem in asymmetric information is the derivation of the price-cap menu. Some parameter values yield a pooling equilibrium in which a single price-cap will be set by the regulator. This is in line with the current regulatory standard and guarantees that a firm of either type will participate while failing to uncover any additional information about the manager's type. The most important conclusion found with regard to the optimal price-cap menu, however, is the fact that there are some instances in which there will exist a separating equilibrium in which the firm will truthfully reveal their type and a menu of pricing contracts can be offered accordingly. This will bring about a gain in expected surplus when compared to the pooling equilibrium, as the price offered to an efficient firm is less than that found under the pooling equilibrium while the firm is still allowed nonnegative profits.

The assumptions of the adverse selection model state that the values of the θ's are known, but what is unknown is which one truly represents the type of the manager. Given this prior knowledge, the regulator will know which equilibrium will exist before establishing the conditions of the regulatory contract. If it is a pooling equilibrium that exists, the worst-case profit will be set to zero and we will have second-best efficiency just as is present in current PC Regulation. If however, it is a separating equilibrium that exists, there are potentially large efficiency gains that can be realized with a movement from a single price-cap to an optimal price-cap menu, while the risk of a net decrease in consumer surplus is zero.

We have shown here that the optimal price-cap menu is able to reveal whether it is optimal to offer either one or multiple pricing contracts. Given the assumption that a second information problem exists between the firm and its management, a shift from single price-caps as present in the existing regulatory literature to a menu of pricing contracts will create a net gain in expected consumer surplus proving that, regardless of the efficiency standard, there is room for a great improvement in the effectiveness of PC Regulation.

Chapter 4

Optimal Cost Of Service Regulation

In our price-cap model, the regulator must create an incentive contract that will induce both the firm and the manager to truthfully reveal the manager's type, θ. In order to properly explain the COS model as a hierarchy, the timing must change. The timing of the COS model will be as follows: At $\mathbf{t} = \mathbf{t}_0$, the manager will discover her type; at $\mathbf{t} = \mathbf{t}_1$, the firm will offer the manager a type-contingent contract; at $\mathbf{t} = \mathbf{t}_2$, management will accept or reject the contract; at $\mathbf{t} = \mathbf{t}_3$, the firm's realized costs will be communicated to the regulator; based on this level of costs, at $\mathbf{t} = \mathbf{t}_4$, the regulator will set a price; and at $\mathbf{t} = \mathbf{t}_5$, the contract will be executed.

Given the timing of the COS model, revelation mechanisms are not necessary, as the manager will be the first mover and she will be the only player allowed to make a utility maximizing decision based on her type. Due to the nature of COS Regulation, the firm will be indifferent between any of a continuum of managerial contracts, as a profit level of zero will be the result of any contract. For any given level of average cost, the regulator's objective will also be satisfied, as price will be set at a level of second-best. Because the manager is making a maximizing decision based on her type, the regulator knows that this type will not be misrepresented. Subject to a zero profit constraint for the firm, the utility maximizing level of effort, transfer, and price will be chosen. After the manager accepts the type contingent contract, all informational asymmetries are eliminated and the regulator can set the price accordingly.

Traditionally, there are two arguments against COS Regulation. The first is based on Hicks' (1935) Quiet-Life Hypothesis, which states that "managerial slack, or X-inefficiency, is larger the greater the market power of a firm" (Church and Ware, 2000, p.145). The second argument is the idea of gold-plating that stems from Averch and Johnson's (1962) theory that the firm has an incentive to overinvest in capital (Zajac, 1972). Although this argument has been overstated due to the typical presence of regulatory constraints on firm investment (Laffont, 1994), we find that both of these arguments are in fact false in the current setup of the regulatory model. In response to the Quiet Life Hypothesis and X-inefficiency (Leibenstein, 1966), we find that the manager's utility maximizing decision leads to an inefficiently *high* level of effort. Instead of exerting an amount of effort such that the cost of effort equals the benefit, the manager will in fact have an incentive to exert more effort and, in turn, inflate the firm's fixed costs. Although inflated costs are found in the COS literature to date, this result has not been found to be attributable to excess cost-reducing effort. Traditionally, gold-plating and managerial slack are blamed for the high average costs in the analysis of COS Regulation.

In our model of COS Regulation, the regulator's, the firm's and the manager's utilities will again be given by the following functional forms, respectively:

$$CS = \int_p^1 (1-p)dp, \tag{4.1}$$

$$\begin{aligned}\pi(e(\theta), t(\theta), p(e(\theta), t(\theta), \theta), \theta) = (p(e(\theta), t(\theta), \theta) + \\ \theta(1-e(\theta)))(1-p(e(\theta), t(\theta), \theta)) - t(\theta),\end{aligned} \tag{4.2}$$

$$U(e,t,\theta) = t + \theta e^2. \tag{4.3}$$

These objective functions are very similar to the ones used in Chapter 3. However, since the regulator is the last mover, all informational asymmetries will be resolved and there is no need for expectations or a revelation mechanism in these objectives. In the following section, the model will be solved in just one stage as a Lagrangian optimization of the manager's utility constrained by the firm's zero profit condition.

4.1 The Model

In this section, we will develop the optimal COS mechanism as a function of θ with a single maximization program. As described above, the utility maximizing level of effort, transfer, and price will all be chosen subject to a zero-profit constraint for the firm. In this model, θ can take any value between -1 and 0 and we are not restricted to the assumption of two types as in the previous model.

The manager wishes to maximize the following program:

$$\max_{\{e,t\}} U(e,t,\theta) = t + \theta e^2, \tag{4.4}$$

subject to the firm's break-even constraint:

$$(p + \theta(1-e))(1-p) - t = 0. \tag{4.5}$$

Substituting the constraint into the utility function in place of t, the manager's maximization program can be represented as follows:

$$\max_{\{e,p\}} U(e,p) = (p + \theta(1-e))(1-p) + \theta e^2, \tag{4.6}$$

which can now be solved unconstrained to find two first-order conditions with respect to effort and price, respectively:

$$\frac{\partial U}{\partial e} = \theta(1-p) + 2\theta e = 0, \tag{4.7}$$

$$\frac{\partial U}{\partial p} = (1-p) - (p + \theta(1-e)) = 0, \tag{4.8}$$

Solving this two equation system, we can find the following as the effort level and price in equilibrium:

$$p^*(\theta) = \frac{2-\theta}{4+\theta},^{1} \tag{4.9}$$

$$e^*(\theta) = \frac{1+\theta}{4+\theta}. \tag{4.10}$$

We can enter these two values into the firm's break-even constraint to find the following solution for the equilibrium transfer:

$$t^*(\theta) = \frac{4(1+\theta)^2}{(4+\theta)^2} = 4e(\theta)^2. \tag{4.11}$$

At this equilibrium the costs are defined by the levels of both effort and transfer.

[1] We can verify that this is, in fact, the second-best price by entering the given equilibrium values into the firm's average cost function:

$$AC = -\theta(1-e(\theta)) + \frac{4e^2}{1-p} = \frac{2-\theta}{4+\theta}$$

The equilibrium price is equivalent to a second-best, "Ramsey" price. Therefore, consumer surplus is maximized subject to the firm being allowed to break even. One result that the existing literature does not find is the positive managerial effort level. This follows from adding the manager to the regulatory model and relaxing the assumption that the firm is profit maximizing. The firm still just breaks even, while the manager is allowed to make a surplus maximizing choice of effort and transfer.

An interesting result is the level of the manager's equilibrium utility. Recall the manager's utility function:

$$U(e(\theta), t(\theta), \theta) = t(\theta) + \theta e(\theta)^2.$$

Substituting the equilibrium level of effort and transfer into this utility function, we find the following:

$$U^*(\theta) = \frac{(1+\theta)^2}{4+\theta} = (1+\theta)e^*(\theta), \tag{4.12}$$

which has a value that is strictly positive for all relevant parameter values. The comparative static results are as expected. The optimal price is decreasing in manager efficiency, while effort and transfer are increasing in manager efficiency. It is the fact that the manager is making a utility maximizing choice that leads to an inefficiently high effort level and transfer, causing the firm's costs and, in turn, break-even price to be higher than is necessary. Although it appears as though consumer surplus has been maximized, it is diminished due to the inefficiently high price that the regulator must set to compensate the firm for the added fixed cost of effort.

4.2 Conclusion

We have found some interesting results in the model of COS Regulation with a separation of ownership from management, the most important of which is that management has the incentive to exert a positive level of effort. The existing literature claims that setting the price at a level of second-best does not offer the incentives for cost reduction that PC Regulation may offer. In this model, the manager is able to choose a utility-maximizing level of effort and transfer at no loss to the firm. The result of this effort is a reduction in marginal cost, but an offsetting increase in fixed cost of effort. This positive surplus to the manager is, therefore, to the detriment of consumers, as manager surplus comes directly from consumer surplus. Therefore, the allocative efficiency cited in the existing literature is misleading. An inefficiently large amount of managerial surplus is hidden as a part of the firm's cost function and is therefore accounted for in the high price set by the regulator.

Chapter 5

Efficiency Considerations

In the previous two chapters, we derived two regulatory mechanisms in which there is a separation of ownership from the management of a regulated firm. Now we must examine the differences in efficiency of the two regimes in order to make a judgment as to which regulatory regime the regulator will choose. The argument in the existing literature is that COS Regulation does not allow for productive efficiency, while PC Regulation provides greater incentives for cost reduction. These incentives, however, come at the cost of consumer surplus. In this chapter, we add a period to the beginning of the games of the previous two chapters. In this time period, the regulator must make the decision as to which of the two regulatory regimes will maximize efficiency. Here, we will compare the efficiencies of PC and COS Regulation from the standpoint of both expected consumer surplus and expected productivity using the regulator's prior, ν, for weighting. This will allow for a simple assessment of which regime is optimal. It will be shown numerically that PC Regulation is always the optimal solution by use of both metrics in the context of this three-player hierarchy.

5.1 Productive Efficiency

We will first look at the effect that the choice of regulatory regime has on expected average cost. As average cost is negatively related to managerial effort, expected average cost will be used as a proxy for productive efficiency.

Proposition 3. *Expected average cost is greater under COS Regulation than under PC Regulation.*

Proposition 3 is shown numerically in Section A.1 by comparing the following two relations for expected average cost under PC Regulation and expected average cost under COS Regulation, respectively:

$$-\frac{\bar{\theta}(-1+\nu)(4\underline{\theta}^2\nu^2-2\underline{\theta}\bar{\theta}\nu(3+\nu)+\bar{\theta}^2(3+\nu^2))}{8\underline{\theta}\bar{\theta}\nu-4\underline{\theta}\bar{\theta}\nu-4\underline{\theta}^2\nu^2-2\bar{\theta}^2(2+\underline{\theta}(-1+\nu)\nu)+\bar{\theta}^3(-1+\nu^2)}-$$

$$\frac{1}{4(\bar{\theta}-\underline{\theta}\nu)^2}\Bigg(\nu\Bigg(\bar{\theta}^3(-1+\nu)^2-6\underline{\theta}^2\bar{\theta}\nu+3\underline{\theta}^3\nu^2+\underline{\theta}\bar{\theta}^2(2+2\nu-\nu^2)+$$

$$-\bar{\theta}^3(-1+\nu)^2-2\underline{\theta}^2\bar{\theta}\nu+\underline{\theta}^3\nu^2+\underline{\theta}^2(2-2\nu+\nu^2)$$

$$\mathrm{Min}\Bigg[\frac{\bar{\theta}(4\underline{\theta}^2\nu^2-2\underline{\theta}\bar{\theta}\nu(3+\nu)+\bar{\theta}^2(3+\nu^2))}{8\underline{\theta}\bar{\theta}\nu-4\underline{\theta}^2\nu^2-2\bar{\theta}^2(2+\underline{\theta}(-1+\nu)\nu)+\bar{\theta}^3(-1+\nu)},$$

$$(-8(-2+\underline{\theta})\underline{\theta}^4\nu^4+\bar{\theta}^6(-1+\nu)^2(-5+\nu^2)+$$

$$(-48+\underline{\theta}^2\nu(5+3\nu)-4\underline{\theta}(-5-10\nu+\nu^2))+\underline{\theta}\bar{\theta}^3\nu$$

$$(-64+\underline{\theta}^2\nu(13+4\nu+7\nu^2)-8\underline{\theta}(-2-15\nu+\nu^3))-$$

$$2\bar{\theta}^4(-8+4\underline{\theta}\nu(8-3\nu-2\nu^2)+\underline{\theta}^2\nu(7-6\nu+6\nu^2+\nu^3+$$

$$\bar{\theta}^5(8_16\nu-8\nu^2+\underline{\theta}(6-15\nu^2+16\nu^3-3\nu^4)))\Big/$$

$$-16\underline{\theta}^3(4+\underline{\theta})\bar{\theta}\nu^3+4\underline{\theta}^4(+\underline{\theta})\nu^4+$$

$$\bar{\theta}^6(-1+\nu)^3(1+\nu)+2\underline{\theta}^2\bar{\theta}^2\nu^2(48+\underline{\theta}^2(-1+\nu)\nu+2\underline{\theta}(7-4\nu+3\nu^2))-$$

$$\underline{\theta}\bar{\theta}^3\nu(64+\underline{\theta}^2\nu(-5+4\nu+\nu^2)+8\underline{\theta}(3-4\nu+2\nu^2+\nu^3))-$$

$$\bar{\theta}^5(-1+\nu)(8\nu+\underline{\theta}(2+2\nu-5\nu^2+3\nu^3))+$$

$$2\bar{\theta}^4(8+\underline{\theta}^2\nu(-3+4\nu-2\nu^2+\nu^3)+\underline{\theta}(4-8\nu-2\nu^2+8\nu^3)))\Bigg]\Bigg)\Bigg), \tag{5.1}$$

$$\nu\left(\frac{2-\underline{\theta}}{4+\underline{\theta}}\right)+(1-\nu)\left(\frac{2-\bar{\theta}}{4+\bar{\theta}}\right). \tag{5.2}$$

The result that expected average cost is greater under COS Regulation than under PC Regulation is due to the fact that the manager is making the utility-maximizing choice of effort under COS Regulation. This effort is actually at a level that is greater than what is shown to be optimal under PC Regulation, which is contrary to what is found in the existing literature. The existing literature shows PC Regulation to be optimal in terms of productive efficiency as the manager is offered the proper incentives for cost reduction, while under COS Regulation, there are not any incentives in place for cost reduction. Separating the firm's management from the ownership of the firm allows the manager to make the only utility-maximizing decision in the model. Since she will be offered the salary, $t(\theta)$, which increases with effort level to $t^*(\theta) = \frac{4(1+\theta)^2}{(4+\theta)^2}$, she has an incentive to overexert effort in the interest of receiving a higher salary. Since a higher salary directly increases the firm's fixed cost, average cost also increases as a result of the overexertion of effort. Under PC Regulation, however, the rationality and incentive compatibility constraints force an inefficient manager to just achieve zero utility while an efficient manager will receive only a small information rent. This results a lower salary being paid to the manager, leaving average cost at an efficient level.

Our results show that COS Regulation can, in fact, induce effort on the part of the manager, which does not occur in the literature to date. The manager's effort level, however, turns out to be too high, resulting in an inefficiently high salary, average cost and regulated price.

5.2 Consumer Surplus

The regulator's optimal choice of regime will be the one that offers the greatest expected consumer surplus after taking into account the appropriate constraints.

Proposition 4. *Expected consumer surplus is greater under PC Regulation than* *under COS Regulation.*

Proposition 4 is shown numerically in Section A.2 as a comparison of the following two prices for PC and COS Regulation, respectively:

$$
\begin{aligned}
&-\frac{8(1+\bar{\theta})^2(\bar{\theta}-\underline{\theta}\nu)^4}{(8\underline{\theta}\bar{\theta}\nu-4\underline{\theta}^2\nu^2-2\bar{\theta}^2(2+\underline{\theta}(-1+\nu)\nu)+\bar{\theta}^3(-1+\nu^2))^2}+\\
&\frac{1}{2}\nu\Bigg(-1+\mathrm{Min}\Bigg[\frac{\bar{\theta}(4\underline{\theta}^2\nu^2-2\underline{\theta}\bar{\theta}\nu(3+\nu)+\bar{\theta}^2(3+\nu^2))}{8\underline{\theta}\bar{\theta}\nu-4\underline{\theta}^2\nu^2-2\bar{\theta}^2(2+\underline{\theta}(-1+\nu)\nu)+\bar{\theta}^3(-1+\nu^2)},\\
&-8(-2+\underline{\theta})\underline{\theta}^4\nu^4+\bar{\theta}^6(-1+\nu)^2(-5+\nu^2)+\\
&4\underline{\theta}^3\bar{\theta}\nu^3(-16+\underline{\theta}^2\nu+4\underline{\theta}(2+\nu))-\\
&2\underline{\theta}^2\bar{\theta}^2\nu^2(-48+\underline{\theta}^2\nu(5+3\nu)-4\underline{\theta}(-5-10\nu+\nu^2))+\\
&\underline{\theta}\bar{\theta}^3\nu(-64+\underline{\theta}^2\nu(13+4\nu+7\nu^2)-8\underline{\theta}(-2-15\nu+\nu^3))-\\
&2\bar{\theta}^4(-8+4\underline{\theta}\nu(8+3\nu-2\nu^2)+\underline{\theta}^2\nu(7-6\nu+6\nu^2+\nu^3))+\\
&\bar{\theta}^5(8+16\nu-8\nu^2+\underline{\theta}(6-15\nu^2+16\nu^3-3\nu^4)))\Big/\\
&(-16\underline{\theta}^3(4+\underline{\theta})\bar{\theta}\nu^3+4\underline{\theta}^4(4+\underline{\theta})\nu^4+\bar{\theta}^6(-1+\nu)^3(1+\nu)+\\
&2\underline{\theta}^2\bar{\theta}^2\nu^2(48+\underline{\theta}^2(-1+\nu)\nu+2\underline{\theta}(7-4\nu+3\nu^2))-\\
&\underline{\theta}\bar{\theta}^3\nu(64+\underline{\theta}^2\nu(-5+4\nu-\nu^2)+8\underline{\theta}(3-4\nu+2\nu^2+\nu^3))\\
&\bar{\theta}^5(-1+\nu)(8\nu+\underline{\theta}(2+2\nu-5\nu^2+3\nu^3))+2\bar{\theta}^4\\
&(8+\underline{\theta}^2\nu(-3+4\nu-2\nu^3+\nu^3)+\underline{\theta}(4-8\nu^2+8\nu^3)))\Bigg]\Bigg)^2,
\end{aligned}
\tag{5.3}
$$

$$
-\frac{2(1+\bar{\theta})^2(-1+\nu)}{(4+\bar{\theta})^2}+\frac{2(1+\underline{\theta})^2\nu}{(4+\underline{\theta})^2}. \tag{5.4}
$$

The expected price under COS Regulation is always greater than that under PC Regulation, which leads to the conclusion that PC Regulation is the expected consumer surplus enhancing solution to the regulatory problem in the context of a three-player hierarchy. As was the case in the previous section, this is directly related to the effort put forth by the manager. Chapter 4 showed that it is in the manager's best interest, under COS Regulation, to overexert her effort in exchange for a higher salary, $t(\theta)$. Given that this directly increases the firm's fixed costs, the COS regulated price must be inflated to such a point where, even though the firm just breaks even, PC Regulation is the more efficient solution. In the previous section, it was shown that the expected average cost under COS Regulation was greater than that under PC Regulation. By showing that expected consumer surplus is greater under PC Regulation than under COS Regulation, we can see that the information rent offered to the efficient manager under PC Regulation is less than the difference between the two expected average costs. In other words, PC Regulation is a Pareto improvement over COS Regulation in the current regulatory model.

5.3 Conclusion

This analysis has shown the decision process that must be carried out if an additional stage is added to the beginning of the games in Chapters 3 and 4. In this stage, the regulator uses only the given values of $\underline{\theta}$, $\bar{\theta}$ and ν to determine which of the two regimes is optimal before carrying out one of the processes outlined in Chapters 3 and 4. In this chapter, we have shown that PC Regulation is the more efficient solution in terms of both allocative and productive efficiency. Both of these conclusions follow directly from the fact that the manager under COS Regulation is given the opportunity to make a utility maximizing choice of effort. Because of this, effort is overexerted and the firm's fixed costs become inefficiently high. This also results in a higher than efficient regulated price set by the regulator in the first stage in the game. The results of this analysis show that the regulator's optimal choice of regulatory regime in the first stage is PC Regulation.

Appendix A

Numerical Proofs

A.1 Numerical Proof of Proposition 3

		θ									
		-1	-0.9	-0.8	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1
$\underline{\theta}$	-1	1 1									
	-0.9	0.987491 0.993548	0.870968 0.935484								
	-0.8	0.976411 0.9875	0.86161 0.929435	0.75 0.875							
	-0.7	0.966489 0.981818	0.851155 0.923754	0.741244 0.869318	0.636364 0.818182						
	-0.6	0.957522 0.976471	0.841459 0.918406	0.732475 0.863971	0.628171 0.812834	0.529412 0.764706					
	-0.5	0.949351 0.971429	0.832616 0.913364	0.723527 0.858929	0.619956 0.807792	0.521747 0.759664	0.428571 0.714286				
	-0.4	0.941851 0.966667	0.824491 0.908602	0.71479 0.854167	0.61172 0.80303	0.514048 0.754902	0.421402 0.709524	0.333333 0.666667			
	-0.3	0.934923 0.962162	0.816973 0.904098	0.706701 0.849662	0.603462 0.798526	0.506316 0.750397	0.414181 0.705019	0.326627 0.662162	0.243243 0.621622		
	-0.2	0.928487 0.957895	0.809976 0.89983	0.699165 0.845395	0.595356 0.794258	0.498551 0.74613	0.40691 0.700752	0.319843 0.657895	0.236965 0.617354	0.157895 0.578947	
	-0.1	0.922477 0.953846	0.80343 0.895782	0.692106 0.841346	0.587804 0.79021	0.490753 0.742081	0.399591 0.696703	0.312986 0.653846	0.230569 0.613306	0.152 0.574899	0.0769231 0.538462
	0	0.91684 0.95	0.797278 0.891935	0.685463 0.8375	0.580692 0.786364	0.482924 0.738235	0.392225 0.692857	0.30606 0.65	0.224064 0.609459	0.145913 0.571053	0.0713125 0.534615

Table A.1: Expected average cost for PC and COS Regulation, respectively, when $\nu = .1$

		θ									
		-1	-0.9	-0.8	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1
$\underline{\theta}$	-1	1 1									
	-0.9	0.937159 0.967742	0.870968 0.935484								
	-0.8	0.8802 0.9375	0.813757 0.905242	0.75 0.875							
	-0.7	0.827463 0.909091	0.761368 0.876833	0.697818 0.846591	0.636364 0.818182						
	-0.6	0.778029 0.882353	0.712466 0.850095	0.64948 0.819853	0.58867 0.791444	0.529412 0.764706					
	-0.5	0.731343 0.857143	0.666333 0.824885	0.603959 0.794643	0.543899 0.766234	0.48571 0.739496	0.428571 0.714286				
	-0.4	0.687042 0.833333	0.622548 0.801075	0.560731 0.770833	0.501332 0.742424	0.44404 0.715686	0.38839 0.690476	0.333333 0.666667			
	-0.3	0.64487 0.810811	0.58084 0.778553	0.519501 0.748311	0.460634 0.719902	0.404013 0.693164	0.349356 0.667954	0.296197 0.644144	0.243243 0.621622		
	-0.2	0.604637 0.789474	0.541017 0.757216	0.480079 0.726974	0.421631 0.698565	0.365488 0.671827	0.311456 0.646617	0.259303 0.622807	0.208619 0.600284	0.157895 0.578947	
	-0.1	0.566193 0.769231	0.502935 0.736973	0.442335 0.706731	0.384212 0.678322	0.328403 0.651584	0.27475 0.626374	0.223104 0.602564	0.173295 0.580042	0.125057 0.558704	0.0769231 0.538462
	0	0.529412 0.75	0.466477 0.717742	0.406162 0.6875	0.348296 0.659091	0.29272 0.632353	0.239289 0.607143	0.187871 0.583333	0.138342 0.560811	0.0905884 0.539474	0.0445069 0.519231

Table A.2: Expected average cost for PC and COS Regulation, respectively, when $\nu = .5$

		θ									
		-1	-0.9	-0.8	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1
$\underline{\theta}$	-1	1 1									
	-0.9	0.884899 0.941935	0.870968 0.935484								
	-0.8	0.77678 0.8875	0.764714 0.881048	0.75 0.875							
	-0.7	0.674886 0.836364	0.663488 0.829912	0.651546 0.823864	0.636364 0.818182						
	-0.6	0.578812 0.788235	0.567702 0.781784	0.556491 0.775735	0.544765 0.770053	0.529412 0.764706					
	-0.5	0.488132 0.742857	0.477173 0.736406	0.466245 0.730357	0.455247 0.724675	0.443807 0.719328	0.428571 0.714286				
	-0.4	0.402432 0.7	0.391568 0.693548	0.38078 0.6875	0.370039 0.681818	0.359267 0.676471	0.348161 0.671429	0.333333 0.666667			
	-0.3	0.321328 0.659459	0.310531 0.653008	0.299827 0.646959	0.289208 0.641278	0.278653 0.63593	0.268109 0.630888	0.257361 0.626126	0.243243 0.621622		
	-0.2	0.244471 0.621053	0.233724 0.614601	0.223078 0.608553	0.212529 0.602871	0.202072 0.597523	0.191695 0.592481	0.18137 0.587719	0.170975 0.583215	0.157895 0.578947	
	-0.1	0.171539 0.584615	0.160834 0.578164	0.150231 0.572115	0.13973 0.566434	0.129328 0.561086	0.119022 0.556044	0.108809 0.551282	0.0986782 0.546778	0.0885898 0.54251	0.0769231 0.538462
	0	0.102244 0.55	0.0915739 0.543548	0.0810064 0.5375	0.0705404 0.531818	0.0601745 0.526471	0.0499072 0.521429	0.039737 0.516667	0.0296626 0.512162	0.0196825 0.507895	0.0097954 0.503846

Table A.3: Expected average cost for PC and COS Regulation, respectively, when $\nu = .9$

Each cell in Tables A.10, A.11 and A.12 contains two values. The first is the expected average cost under PC Regulation and the second is that under COS Regulation. In each cell, we can see that the expected average cost is greater under COS Regulation than under PC Regulation.

A.2 Numerical Proof of Proposition 4

		θ									
		-1	-0.9	-0.8	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1
$\underline{\theta}$	-1	0 0									
	-0.9	0.000782 0.000208	0.008325 0.002081								
	-0.8	0.002782 0.000781	0.008325 0.002654	0.03125 0.007812							
	-0.7	0.005615 0.001652	0.009796 0.003525	0.031247 0.008684	0.066116 0.016528						
	-0.6	0.009022 0.002768	0.012167 0.004641	0.031239 0.009799	0.066109 0.017644	0.110727 0.027681					
	-0.5	0.012827 0.004081	0.015039 0.005954	0.032014 0.011112	0.066089 0.018957	0.110714 0.028995	0.163265 0.040816				
	-0.4	0.016906 0.005555	0.018272 0.007429	0.034437 0.012587	0.066058 0.020432	0.110667 0.030469	0.163243 0.042290	0.222222 0.055556			
	-0.3	0.021175 0.007158	0.021763 0.009032	0.037185 0.014190	0.066016 0.022035	0.110618 0.032072	0.163181 0.043893	0.222186 0.057159	0.28634 0.071585		
	-0.2	0.025571 0.008864	0.025442 0.010737	0.040175 0.015896	0.067107 0.023740	0.110541 0.033778	0.163083 0.045599	0.222085 0.058864	0.286281 0.073291	0.354571 0.088643	
	-0.1	0.030049 0.010650	0.029256 0.012524	0.04335 0.017682	0.06967 0.025527	0.110447 0.035564	0.162955 0.047386	0.22193 0.060651	0.28612 0.075078	0.354467 0.090429	0.426036 0.106509
	0	0.034578 0.0125	0.033167 0.014373	0.046664 0.019531	0.07241 0.027376	0.110337 0.037414	0.1628 0.049235	0.221729 0.0625	0.285877 0.076927	0.354198 0.092278	0.425817 0.108358

Table A.4: Expected consumer surplus for PC and COS Regulation, respectively, when $\nu = .1$.

		$\bar{\theta}$									
		-1	-0.9	-0.8	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1
	-1	0 0									
	-0.9	0.003949 0.001041	0.008325 0.002081								
	-0.8	0.014352 0.003906	0.008277 0.004947	0.03125 0.007813							
$\underline{\theta}$	-0.7	0.029769 0.008264	0.016366 0.009305	0.031058 0.012171	0.066116 0.016529						
	-0.6	0.049271 0.013841	0.029873 0.014881	0.030634 0.017747	0.06568 0.022105	0.110727 0.027682					
	-0.5	0.072176 0.020408	0.047243 0.021449	0.037742 0.024314	0.064752 0.028673	0.109933 0.034249	0.163265 0.040816				
	-0.4	0.097943 0.027778	0.067893 0.028818	0.053218 0.031684	0.063662 0.036042	0.108324 0.041619	0.161977 0.048186	0.222222 0.055556			
	-0.3	0.126118 0.035793	0.091331 0.036833	0.07185 0.039699	0.065745 0.044057	0.106509 0.049633	0.159523 0.056201	0.22026 0.06357	0.28634 0.071585		
	-0.2	0.156312 0.044321	0.117132 0.045362	0.093186 0.048228	0.082575 0.052586	0.104729 0.058162	0.156898 0.06473	0.216835 0.072099	0.28346 0.080114	0.354571 0.088643	
	-0.1	0.188189 0.053254	0.144921 0.054295	0.116821 0.057161	0.102017 0.061519	0.103073 0.067095	0.154427 0.073663	0.213422 0.081032	0.279053 0.089047	0.35046 0.097576	0.426036 0.106509
	0	0.221453 0.0625	0.174371 0.063541	0.142394 0.066406	0.123681 0.070765	0.116615 0.076341	0.1522 0.082908	0.210373 0.090278	0.275076 0.098293	0.345421 0.106821	0.420626 0.115754

Table A.5: Expected consumer surplus for PC and COS Regulation, respectively, when $\nu = .5$.

		θ									
		-1	-0.9	-0.8	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1
$\underline{\theta}$	-1	0 0									
	-0.9	0.00736 0.001873	0.008325 0.002081								
	-0.8	0.027682 0.007031	0.008069 0.007239	0.03125 0.007813							
	-0.7	0.058721 0.014876	0.028089 0.015084	0.027291 0.015657	0.0661157 0.0165289						
	-0.6	0.098555 0.024914	0.057996 0.025122	0.029444 0.025695	0.0580605 0.0265664	0.110727 0.027682					
	-0.5	0.145561 0.036735	0.095818 0.036943	0.05789 0.037516	0.0536645 0.0383876	0.097893 0.039503	0.163265 0.040816				
	-0.4	0.198382 0.05	0.140049 0.050208	0.093446 0.050781	0.0582671 0.0516529	0.091632 0.052768	0.14557 0.054082	0.222222 0.055556			
	-0.3	0.255886 0.064427	0.189471 0.064635	0.134735 0.065208	0.0913508 0.0660795	0.088566 0.067195	0.138051 0.068508	0.200318 0.069982	0.28634 0.071585		
	-0.2	0.317125 0.079779	0.243078 0.079987	0.180672 0.08056	0.129576 0.081431	0.08947 0.0825466	0.134513 0.08386	0.192518 0.085334	0.261906 0.086937	0.354571 0.088643	
	-0.1	0.381304 0.095858	0.300031 0.096066	0.230367 0.096639	0.17198 0.097511	0.12455 0.0986262	0.132477 0.09994	0.189016 0.101414	0.255049 0.103016	0.330847 0.104722	0.426036 0.106509
	0	0.447758 0.1125	0.35963 0.112708	0.28308 0.113281	0.217779 0.114153	0.16341 0.115268	0.131156 0.116582	0.18704 0.118056	0.252135 0.119659	0.326168 0.121364	0.408875 0.123151

Table A.6: Expected consumer surplus for PC and COS Regulation, respectively, when $\nu = .9$.

Each cell in Table A.1, A.2 and A.3 shows first the value of expected consumer surplus under PC Regulation and then the value of that under COS Regulation for a given set of parameter values. Comparing these two values in each of the cells, we can easily see that the expected consumer surplus under PC Regulation will always exceed that under COS Regulation.

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