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# Incentives, Efficiency and Quality in Regulated Monopolies under Customer Ownership

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# Incentives, Efficiency and Quality in Regulated Monopolies under Customer Ownership

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**Abstract**

We extend the theory of monopoly regulation under imperfect information to the case of customer, rather than investor, ownership. The firm's manager can exert two types of effort – a contractible effort to reduce costs, and a non-contractible effort to increase quality. The former decreases expected costs and increases expected profits, while the latter increases expected demand, costs and consumer surplus. We show that the manager faces a conflict between pursuing cost reductions and quality when his or her net marginal disutility of cost-reducing effort is sufficiently increased by quality-enhancing effort. We further show that this conflict can arise even without an effort substitution effect. Thus stronger incentives (i.e. a higher managerial profit share) induce greater cost-reducing effort, but lower quality-enhancing effort. Since customer owners value consumer surplus as well as profits, they optimally provide the manager with weaker incentives than investor owners – who only value profits – for a given regulated price. This implies higher quality but lower efficiency under customer ownership, given price. A customer-owned firm is optimally set a *tighter* price cap than an investor-owned firm if its profits are less price-sensitive than is relative consumer surplus. This can result in quality differences being reduced between ownership types, but with ambiguous impacts on efficiency differences. Failure to account for ownership-related differences in objective functions gives rise to regulatory distortions.

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# 1 Introduction

The modern theory of regulation and incentives examines how best to regulate a profit-maximizing firm when the regulator has imperfect information (e.g. Baron and Myerson (1982), Laffont and Tirole (1986, 1993)). Such a focus is justified for investor-owned firms, since profit-maximization can reasonably be assumed.[1] However, conflicts between the pursuit of efficiency and quality can arise when firms maximize profits. As Joskow (2006, p. 8) puts it: "Clearly if a regulatory mechanism focuses only on reducing costs [i.e. increasing efficiency] and ignores quality it will lead [a profit maximizing] firm to provide too little quality." For certain monopolies, such as transmission networks for electricity, gas, telecommunications, water and wastewater, quality is a critical dimension of firm output. Thus the practice of modern regulation has evolved to allow for tradeoffs between both of these goals.[2]

However, many monopolies are customer-owned, in which case different firm objectives arise, with both profits and consumer surplus being valued. Since consumer surplus in general depends on quality as well as price, the tradeoff between quality provision and efficiency can be expected to differ between customer- and investor-owned firms.[3] A regulator confronted with firms of either ownership type should therefore account for such a difference when optimally regulating monopoly prices.

This paper extends the theory of regulation and incentives by examining how customer ownership changes the optimal price regulation of monopolies under imperfect information. It does so in a context in which the monopoly's manager faces a conflict between the pursuit of quality on the one hand, and cost reductions (i.e. efficiency) on the other. We show that this conflict arises when the manager's net marginal disutility of cost-reducing effort is sufficiently increased by quality-enhancing effort. This is because if the manager's quality- or efficiency-enhancing efforts are not contractible, then the firm's owners can only indirectly induce effort from the manager by offering high-powered incentives, such as through profit-sharing. However, for a positive choice of incentive power (i.e. managerial profit share) the manager will wish to maximize his or her private payoff by pursuing efficiency, rather than reduce it by pursuing quality. Since investor owners care only about profits, while customer owners value both profits and consumer surplus (hence quality to a greater degree), we predict that customer owners will optimally choose a weaker incentive power than investor owners for a given regulated price. This provides one explanation for the limited available evidence showing that customer-owned firms tend to set either no or very low-powered managerial incentives.[4] It also sheds light on the

[1] The theory of corporate finance would substitute shareholder wealth maximization for profit maximization (e.g. Brealey et al. (2011)). Setting aside issues of intertemporal profit manipulation, and assuming economic rather than accounting-based profits, profit maximization should serve as a reasonable proxy.

[2] For example, early $RPI - X$ regulation sought to induce efficiency gains, but later evolved into $RPI - X + Q$ regulation allowing also for quality standards. See Joskow (2006) and Ajodhia and Hakvoort (2005) for discussions in the electricity context.

[3] For an early analysis of the impact of different objectives on quality provision, though without incentive problems or a conflict between quality and efficiency, see Spence (1975) and Tirole (1988).

[4] See, for example, the survey in Kopel and Marini (2012).

ambiguous conclusions of empirical studies of utility efficiency under different ownership types.[5]

Given this difference in optimal incentive power between customer- and investor-owned firms, for a given price we predict that customer-owned firms will be less efficient but produce higher quality than comparable investor-owned firms. Moreover, this difference also changes the mechanisms by which a regulator can use its price choice to influence both owners' optimal incentives choices, and managers' optimal efficiency and quality choices. In particular, investor owners optimally choose managerial incentive power to maximize profits. If the regulator attempts to use price to influence managerial effort choices, it can only do so directly, and not via influencing incentive power (since maximized profits are invariant to marginal changes in incentive power). By contrast, customer owners choose incentive power to trade off consumer surplus and profits, with the result that maximized profits are optimally increasing in incentive power. This provides the regulator with an additional, indirect channel via which its price choice can affect managerial effort choices under customer ownership. Moreover, both the regulator's price choice, and the owners' choice of incentive power, have the capacity to alter the nature of the manager's tradeoffs when choosing each effort type. In particular, the regulator and owners can influence whether each effort type is complementary or conflicting from the manager's perspective.

As a result, we establish conditions under which a regulator optimally sets a *lower* price (i.e. tighter price cap) under customer ownership than under investor ownership, despite customer owners having less incentive to over-price, or to under-provide quality. In such circumstances we show that the regulator's price choice can serve to reduce the quality differences between ownership types, but can have an ambiguous impact on efficiency differences. These findings suggest that a failure to account for different efficiency-quality tradeoffs and associated incentive power differences between ownership types, could lead to distortionary price regulation.

Our main contribution is to add to the literature formally addressing optimal monopoly regulation when both efficiency and quality are of concern. Shestalova (2002) and Mikkers and Shestalova (2003) extend the theory of yardstick competition to allow for quality in electricity distribution, while Tangeras (2002) does so in healthcare. Sappington (2005) and Sheshinski (1976) also show that price regulation can adversely affect quality provision under monopoly. Despite such theoretical contributions, Growitsch et al. (2009, p. 2556) observe that "a formal treatment of [quality] from an industrial organization point of view and/or as an integrated part of regulatory analysis has been widely neglected." Furthermore, none of these studies examine how customer ownership affects the optimal regulation of both efficiency and quality, which is the focus of our research. Other related research includes studies on the impact of different objective functions on quality (e.g. Spence (1975), Tirole (1988)), which we extend by introducing both incentive problems and multitasking. We also extend research on the choice of quality under customer ownership (e.g. Herbst and Pruefer (2005)), by allowing for multitasking.[6]

[5] See the discussion in Soderberg (2011).

[6] A separate literature addresses the choice of quality in firms that are supplier- rather than customer-owned, such as agricultural cooperatives – e.g. see Hoffmann (2005).

Notably, our results extend the well-known result in the literature on multitasking under moral hazard that it can be optimal to reduce or even eliminate incentive power when a manager's effort on one, contractible task increases his or her private effort cost in relation to another, non-contractible task (Holmstrom and Milgrom (1991)). We show that it can remain optimal to reduce or eliminate incentive power even without this "effort substitution effect" in terms of the manager's private effort costs. Instead we show that it is sufficient for each effort type to have conflicting effects on the manager's private payoffs for this result to obtain. This arises when the manager's net marginal disutility of cost-reducing effort is sufficiently increased by quality-enhancing effort. Thus we identify a novel mechanism giving rise to such a tradeoff in incentive power choice, which is relevant to the literature on managerial incentives when the industries concerned involve costly quality provision.[7]

Two other literatures related to ours include models of decision-making under customer ownership, and of agency costs under customer ownership. The former includes studies such as Hart and Moore (1996, 1998), and Hendrikse (1998), which examine how control differences peculiar to customer ownership – e.g. democratic voting, or multiple decision stages – affect outcomes in customer-owned firms. The latter literature includes studies such as those surveyed in Sexton and Iskow (1993), focusing on how features of customer ownership such as limited share tradability give rise to particular agency cost problems in customer-owned firms. We abstract from either set of considerations and instead focus on how differences in owners' objectives under each ownership type can rationally result in weaker managerial incentives under customer ownership.

Finally, our research relates to three-tier regulatory incentives models such as those in Laffont and Tirole (1993), Demski and Sappington (1987) and Spiller (1990). Spiller (1990) considers incentive issues in the context of politicians and interest groups competing to influence the effort choice of a regulator. The other two studies involve a principal, regulator and firm, focusing on the provision of incentives to the regulator (with the possibility of regulatory capture in Laffont and Tirole (1993)). None of these studies considers our question of how different forms of ownership affect the interaction between regulation and managerial incentives, and to our knowledge there is currently no other formal research on this question.

Our paper is structured as follows. Section 2 discusses the prevalence and regulation of customer-owned monopolies. Section 3 describes our setup, while Section 4 sets out our findings regarding how optimal managerial incentives – and hence tradeoffs between quality and efficiency – differ between investor- and customer-owned monopolies. It goes on to discuss the implications of optimal price regulation for expected efficiency and quality. Section 5 concludes.

[7] Aside from utility industries which are the focus of this study, other possible applications include healthcare, education, broadcasting and banking, though with public ownership objectives in place of customer owner objectives, and allowing also for competition in supply.

Table 1: Significance of Customer-Owned Electric Utilities in the US (2010)

| | *Investor-Owned* | *Publicly-Owned* | *Customer-Owned* |
|---|---|---|---|
| No. Organizations | 200 | 2,000 | 912 |
| No. Customers (million) | 104 | 21 | 18.5 |
| Revenue (US$billion) | 273 | 53 | 40 |
| Share of Distribution Lines Length | 50% | 7% | 43% |
| Customers/Line Mile (i.e. density) | 34 | 48 | 7.4 |
| Distribution Assets/Customer (US$) | 2,798 | 2,740 | 3,290 |

# 2 Prevalence and Regulation of Customer-Owned Monopolies

Table 1 presents summary statistics for US electric utilities, highlighting the dominance of investor-owned firms.[8] It also shows that rural electric cooperatives (i.e. customer-owned firms) are almost as significant as publicly-owned (i.e. municipal) firms in terms of customers and sales, and rival even investor-owned firms in terms of network size (i.e. line length). Conversely, customer-owned firms dominate in terms of distribution assets per customer, reflecting their relatively lower customer density. Notably, the 912 customer-owned electric utilities can be found in 47 US states, with networks servicing 75% of the US landmass, generating annual revenues in the order of US$40 billion from assets worth US$140 billion (NRECA (2012)).

Customer ownership of electricity distribution firms is also significant in parts of Europe (Italy and Spain), Latin America (Argentina, Bolivia, Brazil and Chile), and Asia (India, the Philippines and Bangladesh) (NRECA International (2010)). It is the dominant form of ownership in the New Zealand electricity distribution sector (Talosaga and Howell (2012)). Similarly, customer cooperatives are important providers of telecommunications and water services in the rural US (Deller et al. (2009)). For example, 260 telephone cooperatives supply just 5% of subscribers, but have networks servicing more than 40% of the US landmass. Water cooperatives are also common in rural parts of New South Wales and Tasmania in Australia (ACIL Tasman (2005)), and also in certain horticultural regions of New Zealand (Le Prou (2007)). They are also common in Finland, as are energy cooperatives.[9] Finally, aside from their importance in developed countries, customer-owned firms and other forms of cooperatives are regarded as important for development in less-developed countries.[10] In particular customer-owned firms have played important roles in rural electrification in Bangladesh, Costa Rica, Kenya, the Philippines, and other developing countries (Barnes and Foley (2004), Kirubi et al. (2009), NRECA International (2010)).

[8]Based on 2010 data from NRECA (2012).

[9]Finland had 938 water cooperatives and 74 energy cooperatives as at December 2008, from www.pallervo.fi (accessed September 2010).

[10]In 2010 the UN General Assembly declared 2012 to be the International Year of Cooperatives, in recognition of the contribution of cooperatives to socioeconomic development.

Importantly, there is a diversity of regulatory treatment for customer-owned utilities. While investor-owned electricity distribution firms in the US are subject to price regulation, customer-owned electricity firms are regulated in just 16 of the 47 states in which they feature (NRECA International (2010)). Likewise, customer-owned US telephone firms are often not subject to price regulation, unlike their investor-owned counterparts, while customer-owned US water firms are not price regulated (Deller et al. (2009)).[11] In New Zealand, 12 out of 29 electricity distribution firms satisfy a high threshold of customer ownership entitling them to opt out of price-quality regulation (Commerce Commission (2013)). Such firms directly return profits to customers, via either rebates on power bills, distributions such as dividends, or through reduced lines charges.

The fact that many customer-owned electricity and telephone firms (and all such water firms) in the US are unregulated is attributed to them being operated as "not for profits" – instead, existing to provide "service at cost". It is also because they are customer-controlled and hence in a large part "self-regulating" (Deller et al. (2009), NRECA International (2010)). However, all such firms must be run profitably in order to remain viable and to fund required investments, so in practice they accumulate "margins" – an excess of revenues over costs, i.e. profits (Deller et al. (2009)).[12] Margins that are not needed for investments are eventually returned to customer owners in the form of "capital credits" (akin to dividends), in proportion to their patronage of the relevant firm, usually via a credit on their bill. Such returns amount to some US$600 million annually just for US electricity cooperatives (NRECA (2012)).[13]

Given the prevalence and scale of such customer-owned, imperfectly competitive firms, the question of how they should be regulated is potentially of considerable economic importance. Since it can be expected that investor- and customer-owned firms will make different tradeoffs between quality and efficiency, it can also be expected that the optimal regulation of such firms should differ. In the next section we present a model addressing these questions.

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[11] Relatedly, credit unions – a form of depositor cooperative – were exempted from the interest rate ceilings that applied to investor-owned banks in the US for many years (Hansmann (1996)).

[12] Indeed, customer-owned US electric utilities can be required to covenant in their loan contracts to charge output tariffs that are sufficient to enable them to repay their lenders (NRECA International (2010)). While the influence of debt financing on the interaction between regulation and incentives for customer-owned firms is not the focus of this research, lending considerations further underscore that customer owners will act to ensure that their firm's remain profitable, and thus value profits.

[13] The fact that customer-owned electric utilities in the US distribute such large annual amounts to their customer-owners highlights that their oft-used "not-for-profit" label might cause confusion. As explained in Hansmann (1996), traditionally this term is used for voluntary (e.g. charitable) organizations which rely on donor contributions to fund their activities. Even in that context such organizations must remain profitable in order to remain viable – instead the "not-for-profit" status refers to the fact that their operating surpluses cannot be distributed (so as to protect donors' interests). In the present context, "not-for-profit" status is relevant for US tax purposes, in that US customer-owned utilities typically qualify for tax exemptions along the lines of those enjoyed by more traditional "not-for-profit" organizations (Deller et al. (2009)). Such tax advantages are not always available in other jurisdictions, as in New Zealand for example (Evans and Meade (2005)).

# 3 Setup

## 3.1 Setting

We consider a price-regulated monopoly producing a single service such as the transportation of electricity, gas or water/wastewater on a local distribution network. Consumers of the firm's services are assumed to care not only about supply price, but also about the quality at which the firm provides its services. For example, quality can take the form of network reliability – i.e. the extent to which materiel (i.e. electricity, gas, etc) is conveyed without interruption – or safety (e.g. absence of leaks). In the case of electricity distribution, it can also take the form of visual amenity, such as undergrounded cables instead of unsightly power lines and poles (which also present hazards to road users). Quality is assumed to increase both demand and consumer surplus. However, it is privately costly for the manager to produce, both directly and in terms of how it affects the manager's private disutility of achieving cost-reductions.

The firm's costs are assumed to be fixed, in the sense that they do not vary with the quantity of transportation services that the firm supplies.[14] However, the level of these fixed costs can be reduced if the firm's manager exerts cost-reducing effort, which is assumed to be observable and contractible.[15] On the other hand, the firm's fixed costs are assumed to increase with the level of quality at which its services are supplied. That quality is positively related to the manager's quality-enhancing effort, which is unobservable and non-contractible.[16]

Specifically, we assume that quality depends on both "nature" as well as the manager's effort. For example, network reliability can reflect the combined effects of managerial effort and severe weather events, unforeseeable equipment failures, traffic or other accidents involving network assets, etc. Indeed, quality can involve dimensions over and above just reliability, not all of which can be accurately measured. Hence it is assumed infeasible for the firm's owners (or the regulator) to accurately infer the manager's quality-enhancing effort even ex post. Furthermore, since quality is uncertain, so too are the firm's costs and profits.

As a consequence, if the manager is incentivized via profit-sharing, this means the manager's wage – net of private effort costs – is also ex ante uncertain. Assuming risk-neutral firm owners, but a risk-averse manager, those owners are confronted with the problem of optimally choosing the manager's profit share under moral hazard. Customer owners do so to maximize the sum of consumer surplus and expected profits, while investor owners do so to maximize just expected profits.

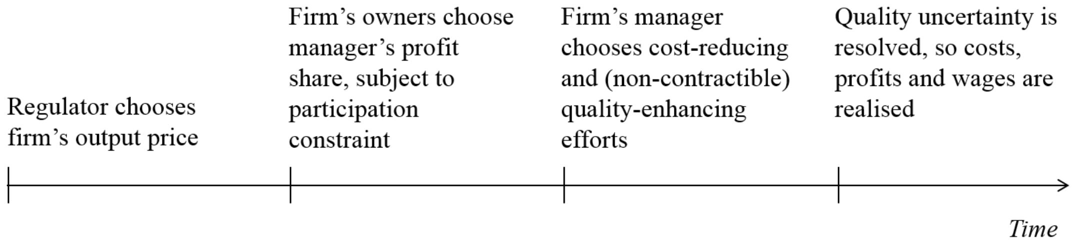
Finally, the regulator is also assumed to be risk neutral, and to value both consumer surplus and profits. The former depends on quality, while profits depend on both quality

[14]Kumbhakar and Hjalmarsson (1998) report that labour costs in electricity distribution firms, which costs are largely fixed and relate more to capacity than output per se, constitute up to 50% of total supply-related costs.

[15]For example, the manager might introduce improved work practices.

[16]We assume there is no clear correlation between effort types allowing one to be inferred from the other.

Figure 1: Timing




and efficiency. While customer owners are assumed to fully value both consumer surplus and profits, following the usual analysis of regulatory problems the regulator is assumed to value only a fraction of profits in addition to consumer surplus.[17]

The timing of the game is illustrated in Figure 1, and is as follows:

1. Anticipating the incentive parameter choices of the firm's owners and the effort choices of the firm's manager, the regulator chooses the firm's output price.

2. Taking the regulator's price choice as given, and anticipating the manager's optimal effort choice, the firm's owners choose the manager's profit share – i.e. incentive power – subject to meeting the manager's reservation wage (i.e. his or her participation constraint).[18]

3. Given the regulator's price choice and owners' choice of profit share, the manager chooses cost-reducing and quality-enhancing efforts to maximize the expected utility of wages net of private effort costs.

4. Finally, quality uncertainty is resolved, at which point the firm's costs and profits, and the manager's wage, are realized.

This timing is natural on several grounds. Regulated prices are typically chosen to apply over regulatory periods often spanning several years.[19] Conversely, a manager's incentive arrangements are often set more frequently, such as annually. In turn, a manager's effort choices can be varied on an intra-day basis. Hence, while our model is essentially static, these considerations support the assumed timing.

Also note that this assumed timing simplifies the nature of the managerial incentive problem confronting owners and the regulator. Specifically, since we assume that the manager makes his or her effort choices facing the same quality uncertainty as owners and the regulator, this means that the only information asymmetry between the manager on

[17] As in Armstrong and Sappington (2007), for example.

[18] By choosing incentive power in anticipation of the manager's optimal effort choices, the owners in effect condition that choice on the manager's incentive compatibility constraint – namely that the manager will be choosing his or her private utility-maximizing efforts, given that incentive power.

[19] In practice this is because regulated firms often make long-lived investments, or require a reasonable time-frame over which to benefit from efficiency gains. Either could be prejudiced by more frequent regulatory reviews.

the one hand, and the firms' owners and regulator on the other, relates to the manager's effort choices. As such we have a situation of pure moral hazard.[20]

We adopt the Linear-Exponential-Normal (LEN) framework as often used in moral hazard analyzes. The manager is assumed to have CARA preferences with risk-aversion parameter $\rho > 0$, and uncertainty is assumed to be normally distributed. The manager's wage contract is assumed to be linear in profits – i.e. comprising a fixed wage plus some share of realized profits.[21] The LEN approach simplifies analysis of the owners' optimal incentive choice,[22] and restricting attention to linear contracts in this framework involves no loss of generality.[23] Furthermore, linear wage contracts are often observed in practice. In the case of customer-owed firms – and also for unlisted investor-owned firms – reliance on linear contracts can be further justified in terms of the costs of specifying non-linear contract terms, such as share options, when the firm's share price is not observable.

The above setting is now described more formally, and then solved in Section 4.

## 3.2 The Firm

Conditional on the manager's quality-enhancing effort $e_s$, the firm's output of quality is $s \sim f(s \mid e_s)$, with the support of $s$ independent of $e_s$. We assume that expected quality conditional on $e_s$, $\overline{s}(e_s) = \int_s x f(x \mid e_s)dx$, is increasing in $e_s$, i.e. that $\overline{s}'_s \equiv \frac{\partial \overline{s}(.)}{\partial e_s} > 0$. Furthermore, while $s$ cannot be observed ex ante, its conditional density $f(.)$ is assumed to be common knowledge. Thus, in particular, consumers form their demand for the firm's services based on expected quality, given $e_s$.[24] Hence demand for the firm's services is $q\left(p, \overline{s}(e_s)\right)$.[25] While $s$ is uncertain, its conditional mean $\overline{s}\left(e_s\right)$ is

[20] Conversely, if the manager was assumed to observe quality uncertainty prior to choosing his or her efforts, this would introduce an informational advantage for the manager relative to the owners and regulator. Since the manager could then condition his or her effort choice on such information, while the owners and regulator could not, this would introduce an additional adverse selection dimension to the model, which we do not analyze.

[21] In effect we allow for the manager's wage to be a two-part tariff, including fixed and variable components. However, for consistency with related studies, and to emphasize that we are not allowing for fully general, non-linear wages, we refer to the manager's wage contract here as being linear.

[22] In particular, we can safely adopt the first order approach in which the manager's incentive compatibility constraint in the owners' problem can be replaced with the first order condition from the manager's problem. See, for example, Bolton and Dewatripont (2005).

[23] See, for example, Holmstrom and Milgrom (1987).

[24] Unlike the usual experience good setting, we abstract from considerations of quality signaling and consumers' expectational errors. In the present setting consumers are assumed to use the firm's services irrespective of any such errors. Furthermore, the firm does not need to signal its quality in order to attract consumers since it is a monopoly provider of "essential" services.

[25] Formally, since demand for the firm's services is derived from consumers' demand for a transported good (e.g. electricity, gas, water, etc), the firm's demand could be written as $q(p+\tilde{p}, \overline{s}(e_s))$ where $\tilde{p}$ is the price of that good. We assume that local distribution monopolies have been unbundled from producers or retailers of the transported good, and that $\tilde{p}$ is exogenous to the firm. So without loss of generality we assume that $\tilde{p} \equiv 0$, and write demand in terms of only the firm's regulated price and conditionally expected quality. Furthermore, we abstract from considerations such as non-linear pricing for the firm's services by assuming that the regulator sets only a per-unit supply price, or that it is the firm's revenues that are regulated and $p$ is the resulting implied price per unit.

not, so $q(p, \overline{s}(e_s))$ is also not uncertain. As usual $q'_p \equiv \frac{\partial q(.)}{\partial p} < 0$, while $q(.)$ is increasing in $\overline{s}(e_s)$. For notational simplicity we henceforth write demand in its reduced form as $q(p, e_s)$, on the understanding that the dependance of demand on $e_s$ is via its impact on $\overline{s}(e_s)$. Furthermore, given $\overline{s}'_s > 0$, we have that $q'_s \equiv \frac{\partial q(.)}{\partial e_s} > 0$. The firm's revenues, which are also not uncertain, are thus $pq(p, e_s)$.

The firm's pre-wage costs of supplying output $q(p, e_s)$ at quality $s(e_s)$ are assumed to be conditional on the manager's cost-reducing effort $e_q$, written as $c(s(e_s)|e_q)$. Since quality is uncertain, so too are costs, with the firm's pre-wage conditionally expected costs of supply and quality being $\overline{c}(e_s, e_q) = \int_s c(x|e_q) f(x \mid e_s)\, dx$. Notice that these costs are independent of $q(p, e_s)$. This is natural for network monopolies in which costs are essentially fixed, at least over the short to medium term, because they relate more to peak transportation capacity than to the level of transportation services supplied. The firm's conditionally expected costs are denoted in their reduced form as $\overline{c}(e_q, e_s)$, on the understanding that their dependence on $e_s$ arises via their dependence on quality $s(e_s)$.

We assume that $\overline{c}'_q \equiv \frac{\partial \overline{c}(.)}{\partial e_q} < 0$ and $\overline{c}''_{qq} \equiv \frac{\partial^2 \overline{c}(.)}{\partial e_q^2} > 0$, while $\overline{c}'_s \equiv \frac{\partial \overline{c}(.)}{\partial e_s} > 0$ and $\overline{c}''_{ss} \equiv \frac{\partial^2 \overline{c}(.)}{\partial e_s^2} > 0$. Thus the manager's cost-reducing effort reduces the firm's expected costs but at a decreasing rate, while quality-enhancing effort increases expected costs at an increasing rate. Later we discuss restrictions on $\overline{c}''_{qs} \equiv \frac{\partial^2 \overline{c}(.)}{\partial e_s \partial e_q}$, but for now simply note that in general this cross derivative may be non-zero.[26]

Consistent with the usual LEN approach, we assume that $c(s(e_s)|e_q)$ is distributed normally with conditional mean $\overline{c}(e_q, e_s)$ and variance $\sigma_c^2$:

$$c(s(e_s)|e_q) \sim N\left(\overline{c}(e_q, e_s), \sigma_c^2\right)$$

Given these specifications, the firm's pre-wage profits are also normally distributed, with variance $\sigma_c^2$ and conditional mean:

$$\overline{\Pi}(p, e_q, e_s) = pq(p, e_s) - \overline{c}(e_q, e_s) \tag{1}$$

## 3.3 The Manager

Profits are contractible even though quality is not, so the firm's owners are assumed to induce the manager to exert cost-reducing and quality-enhancing efforts by offering him or her a linear wage contract $(t, \beta)$ comprising fixed wage $t$ and profit share (i.e. incentive power) $\beta$, where $0 \leq \beta \leq 1$. They do so subject to ensuring that in expected utility terms the manager achieves his or her reservation wage $w_0$ (i.e. subject to satisfying the manager's participation constraint), with $w_0 = 0$ assumed.[27]

Given $p$ and wage contract $(t, \beta)$, the manager's uncertain wage, conditional on $e_q$ and $e_s$, has expected value:

$$\overline{w}(p, t, \beta, e_q, e_s) = t + \beta\overline{\Pi}(p, e_q, e_s) = t + \beta\left[pq(p, e_s) - c(e_q, e_s)\right] \tag{2}$$

[26] Later, in Lemma 1, we show that the relationship between this cross derivative and that of the manager's private effort cost function will play a key role in our analysis.

[27] In effect it is assumed that the manager is made a take-it-or-leave-it offer by the owners, but since the manager's participation constraint is satisfied, he or she will always accept that offer.

In exerting cost-reducing and quality-enhancing efforts $e_q$ and $e_s$, the manager incurs private effort costs $\psi(e_q, e_s)$ where $\psi'_i \equiv \frac{\partial\psi(.)}{\partial e_i} > 0$ and $\psi''_{ii} \equiv \frac{\partial^2\psi(.)}{\partial e_i^2} > 0$ for $i \in \{q, s\}$. Furthermore, we place no a priori restriction on the sign of $\psi''_{qs} \equiv \frac{\partial^2\psi(.)}{\partial e_s \partial e_q}$, meaning that the manager's private marginal cost of exerting one type of effort could be either increasing or non-increasing as he or she exerts the other type of effort. Imposing $\psi''_{qs} > 0$ was the source of the effort substitution effect in Holmstrom and Milgrom (1991). This explained why owners might optimally reduce the manager's incentive power for a contractible task (here, cost reduction) so as to induce greater effort on a non-contractible task (here, quality enhancement). As we will see, this results can also obtain in our setup with $\psi''_{qs} \leq 0$, meaning we have a new mechanism giving rise to this tradeoff.

The manager's conditionally expected wage net of private effort costs therefore writes as:

$$E(w - \psi) = \overline{w}(p, t, \beta, e_q, e_s) - \psi(e_q, e_s) = t + \beta\left[pq(p, e_s) - \overline{c}(e_q, e_s)\right] - \psi(e_q, e_s)$$

The conditional variance of that net wage arises from the cost uncertainty induced by quality uncertainty, and is thus:

$$V(w - \psi) = \beta^2\sigma_c^2$$

The manager chooses $(e_q, e_s)$ to maximize the expected utility of that net wage. Given exponential (i.e. CARA) preferences with risk aversion parameter $\rho$, this is equivalent to choosing those efforts so as to maximize the certainty equivalent of the net wage:[28]

$$\begin{aligned} CE(w - \psi) &= E(w - \psi) - \tfrac{\rho}{2}V(w - \psi) = \overline{w}(p, t, \beta, e_q, e_s) - \psi(e_q, e_s) - \tfrac{\rho}{2}\beta^2\sigma_c^2 \\ &= t + \beta\left[pq(p, e_s) - \overline{c}(e_q, e_s)\right] - \psi(e_q, e_s) - \tfrac{\rho}{2}\beta^2\sigma_c^2 \end{aligned} \tag{3}$$

In general this yields optimal efforts of the form $e_q(p, \beta)$ and $e_s(p, \beta)$.[29] The manager's problem is identical under either customer or investor ownership, although in general the optimal regulated price and wage contract parameters will differ under each ownership type.

We assume either that there is a single manager of the firm, or that managers capable of making cost-reducing or quality-enhancing effort choices do so in a unitary fashion. We therefore abstract from incentive issues within teams or intra-firm hierarchies.

[28]This exploits the fact that the moment generating function of a normal random variable $X$ with mean $\mu$ and variance $\sigma^2$ is known to be $E(exp(\tau X)) = exp\left(\mu\tau + \frac{1}{2}\tau^2\sigma^2\right)$ – e.g. see Mood et al. (1974, p. 541). With CARA utility of the form $U(x) = -exp(-\rho x)$, expected utility is $E(U(x)) = -E(exp(-\rho x))$, with $-\rho$ taking the place of $\tau$. The certainty equivalent of $x$ is found by factorization with respect to $\rho$, and we rely on the monotonicity of $exp(.)$ to justify the direct maximization of this certainty equivalent.

[29]In fact these optimal efforts could be written as functions of $t$ also. However, as shown below, $t$ can be expressed as a function of $p$ and $\beta$ using the manager's participation constraint. Furthermore, Holmstrom and Milgrom (1991) note that the fixed wage $t$ is simply a transfer that allocates the total available certainty equivalent between the owners and manager. Hence there is no loss of generality in writing optimal efforts as functions of $p$ and $\beta$ only.

### 3.4 The Owners

Both customer owners and investor owners choose the manager's fixed wage so that his or her participation constraint binds, which is equivalent to setting $CE(w-\psi) = CE(w_0) = w_0 = 0$. Thus from (3) we find:

$$t(p,\beta) = \psi\left(e_q(p,\beta), e_s(p,\beta)\right) + \frac{\rho}{2}\beta^2\sigma_c^2 - \beta\overline{\Pi}(p,\beta)$$

Since owners take $p$ as given by the regulator, substituting for $t$ in (2) yields expected wages as a function of price and incentive power, $\overline{w}(p,\beta) = \psi\left(e_q(p,\beta), e_s(p,\beta)\right) + \frac{\rho}{2}\beta^2\sigma_c^2$. So post-wage expected profits satisfying the manager's participation constraint are $\overline{\pi}(p,\beta) = \overline{\Pi}(p,\beta) - \overline{w}(p,\beta)$, with:[30]

$$\overline{\pi}(p,\beta) = \left[pq\left(p, e_s(p,\beta)\right) - \overline{c}\left(e_q(p,\beta), e_s(p,\beta)\right)\right] - \psi\left(e_q(p,\beta), e_s(p,\beta)\right) - \frac{\rho}{2}\beta^2\sigma_c^2 \quad (4)$$

Investor-owners are assumed to choose $\beta$ so as to maximize these expected post-wage profits.

By contrast, customer owners are assumed to choose $\beta$ so as to maximize *gross* consumer surplus net of expected costs and wages. This is equivalent to maximizing the sum of *net* consumer surplus and expected post-wage profits.[31] Net consumer surplus depends on both price and conditionally expected quality, writing as $CS\left(p, \overline{s}(e_s)\right)$.[32] As above we can write this in its reduced form as $CS(p, e_s)$, recognizing that the dependence on $e_s$ is via $\overline{s}(e_s)$. Thus, as usual, consumer surplus is decreasing in price, and is also increasing in expected quality, and hence in $e_s$. Formally, we write net consumer surplus as:

$$CS(p, e_s) = \int_p^\infty q(x, e_s)\, dx \quad (5)$$

with $CS_p' \equiv \frac{\partial CS(.)}{\partial p} < 0$ and $CS_s' \equiv \frac{\partial CS(.)}{\partial e_s} > 0$ as a consequence of $q_p' < 0$ and $q_s' > 0$. Since from the manager's problem $e_s$ will in general depend on $p$ and $\beta$ as above, we can write net consumer surplus as $CS(p,\beta) \equiv CS\left(p, e_s(p,\beta)\right)$. So, with expected post-wage

[30] In our setup expected wages will in general differ under each ownership type. This gives rise to questions of managerial selection which are beyond the scope of our model, but see Benabou and Tirole (2013) for a treatment of such issues.

[31] To see this, if gross consumer surplus is $S$, then customer owners receive $S$, for which they must pay $pq(.)$ to the firm. Thus they receive just net consumer surplus $CS(.) = S - pq(.)$. In turn those owners also receive the firm's expected post-wage profits, which are $pq(.) - \overline{c}(.) - \overline{w}(.)$. Adding net consumer surplus and expected profits leaves gross surplus net of expected costs and wages. If we allowed for company- and/or owner-level taxes on profits and distributions, customer owners would receive just a proportion of expected profits, where that proportion reflects cumulative taxes. Without loss of generality we abstract from such issues, for example assuming that customer-owned firms make non-taxable rebates to customers rather than taxable profit distributions, with the result that they also have no firm-level profits to be taxed. Thus customer owners maximize net consumer surplus and total expected post-wage profits.

[32] Recall that $s$ is uncertain, but its conditional mean $\overline{s}(e_s)$ is not. Thus, like demand and firm revenue, ex ante net consumer surplus is not uncertain.

profits also depending on $p$ and $\beta$ as above, the customer owners' objective function – to be maximized with respect to profit share $\beta$, taking $p$ as given – writes as:

$$CS(p,\beta)+\overline{\pi}(p,\beta)=\int_{p}^{\infty}q(x,e_s(x,\beta))\,dx+\left[pq(p,e_s(p,\beta))-\overline{c}(e_q(p,\beta),e_s(p,\beta))\right]$$
$$-\psi(e_q(p,\beta),e_s(p,\beta))-\frac{\rho}{2}\beta^2\sigma_c^2 \quad (6)$$

In either ownership case we assume owners operate in a unitary fashion, so we abstract from issues such as collective decision-making problems among either investor owners or customer owners.[33] Also, we take the firm's ownership structure as given,[34] and assume either full investor ownership or full customer ownership.[35]

## 3.5 The Regulator

The regulator is assumed to be risk-neutral, and as in Armstrong and Sappington (2007) maximizes net consumer surplus plus some fraction $\alpha$ of the firm's expected post-wage profits ($0<\alpha\leq 1$). The weighting $\alpha$ can be interpreted as either a political choice variable, or endogenously determined by the firm's break-even constraint, which in practice a regulator would need to respect when setting price.[36]

Given our timing, in general the owners' choices of profit share, and the manager's choice of efforts (directly, and via profit share $\beta$), will depend on $p$. Thus the regulator chooses the firm's price so as to maximize:

$$CS(p,\beta(p))+\alpha\overline{\pi}(p,\beta(p)) \quad (7)$$

# 4 Solution

As usual, we proceed by backward induction, using subgame perfection as the relevant equilibrium concept. We begin by solving for the manager's optimal effort choices, which will be the same under both ownership types. We then solve for optimal profit shares under investor and customer ownership using (4) and (6) respectively, showing how optimal incentive power varies with ownership type. Finally, we solve for the regulator's optimal

[33] See, for example, Hart and Moore (1996, 1998), Hendrikse (1998), or Sexton and Iskow (1993).

[34] For a model of quality provision with endogenous ownership choice – though not in a multitask setting as here – see Herbst and Pruefer (2005).

[35] It would be a simple extension to allow for partial customer ownership, in which case only some proportion of the firm's owners would value consumer surplus when determining the optimal wage contract. This would not fundamentally alter our results.

[36] Aside from potentially applying a profit weight that differs to that applied by customer owners, we make no assumption as to whether the regulator acts either with or without bias when seeking to serve the interests of the customers it is assumed to protect. Thus we abstract from other possible incentive issues as between regulators and either their appointers (e.g. politicians) or stakeholders (i.e. customers, managers, environmentalists, etc), as in Laffont and Tirole (1993), Demski and Sappington (1987) and Spiller (1990).

prices – showing how this too differs as a consequence of the differing incentive power chosen by each owner type – and discuss the implications of price regulation for differences between ownership types in terms of expected costs and quality.

## 4.1 Manager's Optimal Effort Choices

Assuming the relevant second order conditions are satisfied, the manager's optimal effort choices are defined implicitly by taking first order conditions for the manager's certainty equivalent of net wages (3) with respect to $e_q$ and $e_s$ respectively. These conditions write as:

$$\begin{gathered} -\beta\overline{c}'_q\left(e_q,e_s\right)-\psi'_q\left(e_q,e_s\right)=0 \\ \beta\left[pq'_s\left(p,e_s\right)-\overline{c}'_s\left(e_q,e_s\right)\right]-\psi'_s\left(e_q,e_s\right)=0 \end{gathered} \tag{8}$$

Since $\overline{c}'_q < 0$ and $\psi'_q > 0$ by assumption, the first of these conditions requires that $\beta > 0$. Furthermore, since $\psi'_s > 0$ by assumption also, the second condition ensures that expected pre-wage profits (the term in square brackets) are increasing in $e_s$.

In general these conditions yield optimal efforts of the form $e^*_q(p,\beta)$ and $e^*_s(p,\beta)$, where the dependence of $e^*_q$ on $p$ arises indirectly from its dependence on $e^*_s$ (which in turn depends directly on $p$ via the impact of $e_s$ on $q'_s$). Noting the dependence of optimal efforts on incentive power (i.e. managerial profit share) $\beta$, we obtain the sensitivity of optimal efforts to incentive power by totally differentiating these two conditions with respect to $\beta$, and simultaneously solving the resulting expressions for $e'_{q,\beta} \equiv \frac{\partial e_q(.)}{\partial\beta}$ and $e'_{s,\beta} \equiv \frac{\partial e_s(.)}{\partial\beta}$. Doing so leads to the following lemma.

**Lemma 1** (Necessary and sufficient conditions for manager's effort choices to diverge with respect to incentive power)

Jointly necessary and sufficient conditions for $e'_{q,\beta} > 0$ and $e'_{s,\beta} < 0$ are:

1. $0 < T^{min}_{qs} < \psi''_{qs} + \beta\overline{c}''_{qs} < T^{max}_{qs}$; and
2. $\psi''_{qq} + \beta\overline{c}''_{qq} < T^{max}_{qq}$;

where:

$$T^{min}_{qs} = -\frac{\left(\beta\overline{c}''_{qq}+\psi''_{qq}\right)\left(pq'_s-\overline{c}'_s\right)}{\overline{c}'_q}$$

$$T^{max}_{qs} = \frac{\left(\beta\left(pq''_{ss}-\overline{c}''_{ss}\right)-\psi''_{ss}\right)\overline{c}'_q}{pq'_s-\overline{c}'_s}$$

$$T^{max}_{qq} = -\frac{\left(\beta\left(pq''_{ss}-\overline{c}''_{ss}\right)-\psi''_{ss}\right)\left(\overline{c}'_q\right)^2}{\left(pq'_s-\overline{c}'_s\right)^2}$$

**Proof**: see Appendix A.

Under these two conditions, Lemma 1 states that cost-reducing effort $e_q$ will be increasing in incentive power $\beta$, while quality-enhancing effort $e_s$ will be decreasing in incentive power. The conditions involve two arguments: $\psi''_{qs} + \beta\overline{c}''_{qs}$ in the first case, and $\psi''_{qq} + \beta\overline{c}''_{qq}$ in the second. The first argument can be restated as:

$$\frac{\partial}{\partial e_s}\left(\underbrace{\frac{\partial\psi(.)}{\partial e_q}}_{+} + \underbrace{\frac{\partial\beta\overline{c}(.)}{\partial e_q}}_{-}\right)$$

Here the bracketed term is the manager's *net* marginal disutility from exerting extra cost-reducing effort $e_q$. It is a net marginal disutility since it comprises the manager's marginal private disutility from exerting $e_q$, namely $\frac{\partial\psi(.)}{\partial e_q} > 0$, but also adds the manager's private gain from such effort, namely profit share $\beta$ multiplied by the increase in expected pre-wage profits arising due to extra $e_q$, namely $\frac{\partial\beta\overline{c}(.)}{\partial e_q} < 0$. A reduction in expected costs from an increase in $e_q$ increases those expected profits and hence the manager's certainty equivalent wage, offsetting his or her private disutility of cost-reducing effort.

Thus for $e'_{q,\beta} > 0$ and $e'_{s,\beta} < 0$ simultaneously, the first condition in Lemma 1 requires that this net marginal disutility must be sufficiently (but not too) increasing in the manager's quality-enhancing effort $e_s$. In other words, for the manager to face a conflict regarding the impact of marginal changes in incentive power $\beta$ on cost-reducing and quality-enhancing efforts, we require that additional $e_s$ gives rise to (boundedly) higher net marginal disutility from additional $e_q$. This net marginal disutility is relevant because the manager's private effort costs in respect of increased $e_q$ are offset by his or her share of the resulting expected cost reductions. In turn, the resulting *net* marginal disutility of $e_q$ must be compared with the manager's marginal private benefits from his or her share of increased revenues, when increasing $e_s$, in order to determine whether effort types are diverging in incentive power.

Similarly, the $\psi''_{qq} + \beta\overline{c}''_{qq}$ term in condition two of the lemma represents the rate at which the manager's net marginal disutility from extra $e_q$ is changing with respect to $e_q$ (instead of $e_s$, as in condition (1)). Simply put, the condition requires that the manager's net marginal disutility from extra $e_q$ be either non-increasing, or not too increasing, in $e_q$, with the relevant threshold being $T^{max}_{qq}$. We interpret both this threshold, and the upper threshold in condition one of the lemma ($T^{max}_{qs}$), as feasibility constraints deriving from the concavity of the manager's programme. In particular, condition (2) ensures that $\psi''_{qs} + \beta\overline{c}''_{qs}$ can simultaneously be above $T^{min}_{qs}$ and below $T^{max}_{qs}$ when the manager's programme is well-defined.[37]

[37] We note that $e'_{q,\beta} > 0$ and $e'_{s,\beta} < 0$ can also arise simultaneously in our setup – under simpler conditions than in Lemma 1 – if the manager is assumed to enjoy intrinsic utility, in particular from quality-enhancing effort (see Benabou and Tirole (2013) for a model with such intrinsic utility). For example, if the manager's certainty equivalent of net wages included non-random intrinsic utility $\gamma e_s$ from $e_s$ (with $\gamma$ a positive constant), then it can be shown that sufficient conditions for $e'_{q,\beta} > 0$ and $e'_{s,\beta} < 0$ are that: (a) $\gamma > \psi'_s$; and (b) $\psi''_{qs} + \beta\overline{c}''_{qs} > 0$. Since the manager's first order condition with respect to $e_s$ writes as $pq'_s - \overline{c}'_s = \psi'_s - \gamma$ in that case, condition (a) ensures that expected profits are *decreasing* in $e_s$, whereas they are increasing in our setup. Conversely, (b) requires that the manager's net marginal disutility from $e_q$ be simply increasing in $e_s$, which is less restrictive than condition (1) in Lemma 1. Thus if higher $e_s$ decreases expected profits and hence wages, but increases the manager's net

The first condition in Lemma 1 is a variant on that responsible for the "effort substitution effect" identified by Holmstrom and Milgrom (1991, pp 32–33). Specifically, in their setup having $\psi''_{qs} > 0$ was sufficient to cause the manager's private marginal cost of one effort type to increase the private marginal cost of exerting the other effort type. Thus if only one of the manager's efforts was non-contractible, then offering high-powered incentives on the other would cause the manager to exert higher effort on the contractible effort type. In turn that would increase the manager's private marginal cost of the non-contractible effort, and thus lead to a reduction in that effort. So if the party contracting with the manager values both effort types, they should optimally trade off the positive impact of incentive power on the manager's contractible effort choice against its negative impact on the non-contractible effort type, with effort substitution at the heart of the tradeoff.

The conditions in Lemma 1 are necessarily more involved than $\psi''_{qs} > 0$ due to our setup being more general than Holmstrom and Milgrom's in terms of both revenues and costs. Specifically, they allow for the manager to be rewarded for both effort types, each of which increases the firm's profits linearly, and do not allow for firm-level costs. In contrast, we reward our manager in proportion to profits in which revenue is a general rather than linear function of $e_s$ (and is independent of $e_q$), and in which there are firm-level costs that are a general function of each effort type. On the other hand, Holmstrom and Milgrom are more general than us in allowing separate incentive parameters for the returns to each effort type, while we impose a single incentive parameter on profits. To see how the conditions in Lemma 1 change if we impose Holmstrom and Milgrom's assumptions – except that we continue to allow for a single incentive parameter $\beta$ – we set $\overline{c}'_q = \alpha_q$ and $\overline{c}'_s = \alpha_s$ for negative constants $\alpha_q$ and $\alpha_s$. That way our cost derivatives with respect to each effort type assume the role of Holmstrom and Milgrom's linear returns to efforts. We further impose $q'_s = q''_{ss} = 0$, and $\overline{c}''_{qq} = \overline{c}''_{qs} = \overline{c}''_{ss} = 0$. With these restrictions the conditions in Lemma 1 simplify to:

$$0 < \psi''_{qq} < \psi''_{qs} < \psi''_{ss}$$

$$\psi''_{qq} < \psi''_{ss}$$

These conditions remain more restrictive than Holmstrom and Milgrom's $\psi''_{qs} > 0$. This is a consequence of our imposition that the manager is rewarded via a single incentive parameter $\beta$ on total effort-related returns, rather than via separate incentive parameters for the returns from each effort type.

Notice that in our setup the first condition in Lemma 1 does not impose that $\psi''_{qs} > 0$. Indeed, it might conceivably be satisfied with $\psi''_{qs} \leq 0$ (i.e. even in the case of effort complementarity), provided $\beta\overline{c}''_{qs}$ is sufficiently (but not too) positive. Thus, even when the Holmstrom and Milgrom (1991) effort substitution effect is absent, it can still be

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marginal disutility from higher $e_q$, then increasing the manager's profit share $\beta$ will cause $e_s$ to decrease. Conversely, since cost reductions increase profits and wages, an increase in $\beta$ would cause the manager to increase $e_s$. In our setup we do not allow for such intrinsic utility, and mention its possibility simply to highlight that various mechanisms might cause $e_q$ and $e_s$ to diverge with respect to changes in incentive power.

optimal in our setup for contractible and non-contractible effort choices to diverge with respect to incentive power. Thus we have a new, more general mechanism giving rise to this divergence. However, just as in Holmstrom and Milgrom, our divergence between effort types with respect to incentive power is key to our findings below – in this case regarding relative optimal incentive power choices under customer and investor ownership.

## 4.2 Owners' Optimal Incentive Power Choices

Given the regulator's price choice, and anticipating the manager's optimal effort choices, the owners at this stage choose their optimal incentive power, $\beta$. Under customer ownership this is achieved by maximizing (6), which includes consumer surplus, while under investor ownership it requires maximization of (4), which does not. Substituting $e_q^*(p,\beta)$ and $e_s^*(p,\beta)$ from above for $e_q$ and $e_s$ in (6), and differentiating with respect to $\beta$, results in the following first order condition in the customer ownership case:

$$\int_p^\infty q_s'\left(x, e_s(x,\beta)\right) e_{s,\beta}' dx + p q_s'\left(p, e_s(p,\beta)\right) e_{s,\beta}' - \left(\overline{c}_q' e_{q,\beta}' + \overline{c}_s' e_{s,\beta}'\right)$$

$$- \left(\psi_q' e_{q,\beta}' + \psi_s' e_{s,\beta}'\right) - \rho\beta\sigma_c^2 = 0 \qquad (9)$$

This expression implicitly defines optimal incentive power $\beta_C^*(p)$ under customer ownership. In general, each of $q_s'$, $e_{q,\beta}'$, $e_{s,\beta}'$, $\overline{c}_q'$, $\overline{c}_s'$, $\psi_q'$ and $\psi_s'$ will be functions of $\beta_C^*(p)$. So as above, we find the sensitivity of incentive power to regulated price, $\beta_{C,p}' \equiv \frac{\partial \beta_C^*(p)}{\partial p}$, by totally differentiating this first order condition with respect to $p$ and then solving for $\beta_{C,p}'$.

Similarly, in the investor ownership case the relevant first order condition – implicitly yielding $\beta_I^*(p)$ – is given by (9) omitting the first term relating to consumer surplus, namely:

$$p q_s'\left(p, e_s(p,\beta)\right) e_{s,\beta}' - \left(\overline{c}_q' e_{q,\beta}' + \overline{c}_s' e_{s,\beta}'\right) - \left(\psi_q' e_{q,\beta}' + \psi_s' e_{s,\beta}'\right) - \rho\beta\sigma_c^2 = 0 \qquad (10)$$

That too can be totally differentiated with respect to $p$, yielding $\beta_{I,p}' \equiv \frac{\partial \beta_I^*(p)}{\partial p}$. This leads us to our first proposition.

**Proposition 1** (Optimal incentive power under customer and investor ownership)

Under the necessary and sufficient conditions in Lemma 1, and assuming that the owners' objective functions (4) and (6) each have a unique interior maximum:

1. $\beta_{I,p}' < \beta_{C,p}'$;
2. The owners' optimal incentive power is decreasing (non-decreasing) in price – i.e. $\beta_{I,p}' < \beta_{C,p}' < 0$ ($0 \leq \beta_{I,p}' < \beta_{C,p}'$) – if the price-responsiveness of the $e_s$-related terms in their first order conditions is less than (no less than) that of the $e_q$-related terms (see Appendix B.2 for precise details); and
3. $0 < \beta_C^*(p) < \beta_I^*(p)$.

**Proof**: see Appendix B for parts (1) and (2), and below for part (3).

The first part of the proposition follows directly from the difference between the customer owners' and investor owners' first order conditions with respect to $\beta$. These differ only in respect of the first term in (9), relating to the sensitivity of consumer surplus to incentive power. Total differentiation of this term with respect to $p$ yields $-q_s'(p, e_s(p, \beta_C^*(p)))\, e_{s,\beta}'(p, \beta_C^*(p)) > 0$ which does not involve $\beta_{C,p}'$. So when solving the total derivative of (9) for $\beta_{C,p}'$ we find an expression involving $q_s'(p, e_s(p, \beta_C^*(p)))\, e_{s,\beta}'(p, \beta_C^*(p))$ in the numerator, which is negative, and the denominator is identical to the investor owners' second order condition with respect to $\beta$, which is globally negative by assumption. Since $\beta_{I,p}'$ shares this negative denominator, and differs to $\beta_{C,p}'$ only by its omission of $q_s'(.)e_{s,\beta}' < 0$, we have that $\beta_{C,p}' > \beta_{I,p}'$ as required. The intuition for this result is that when price rises, this increases revenue (ceteris paribus) and thus optimally induces greater $e_s$ (i.e. lowers incentive power). This effect is shared under both ownership types. However, under customer ownership there is an additional and perfectly offsetting effect via the reduction in consumer surplus resulting from the rise in price. As a consequence customer owners optimally respond to a price increase by inducing a lower change in $e_s$, and hence increase incentive power by more than would investor owners.

The second part of the proposition can be seen by decomposing the numerator of $\beta_{C,p}'$, which determines the sign of $\beta_{C,p}'$, into terms arising from differentiation of the investor owners' first order condition with respect to each of $e_s$ and $e_q$, as shown in Appendix B.1. From doing so it can be seen that $\beta_{C,p}' < 0$ if the $e_s$-related terms are in aggregate less than the $e_q$-related terms. This can be interpreted as meaning that if $e_s$ responds less strongly than $e_q$ to an increase in price, then expected post-wage profits rise more than they fall. As a consequence, customer owners optimally respond by reducing incentive power, so as to induce lower $e_q$ but greater $e_s$ – i.e. $\beta_{C,p}' < 0$. Since we already have that $\beta_{C,p}' > \beta_{I,p}'$ by the first part of the proposition, it follows that $\beta_{I,p}' < 0$ in this case. When solving for the regulator's optimal price choices under each ownership type we will show that clear predictions as to relative price are possible when $\beta_{C,p}' < 0$.

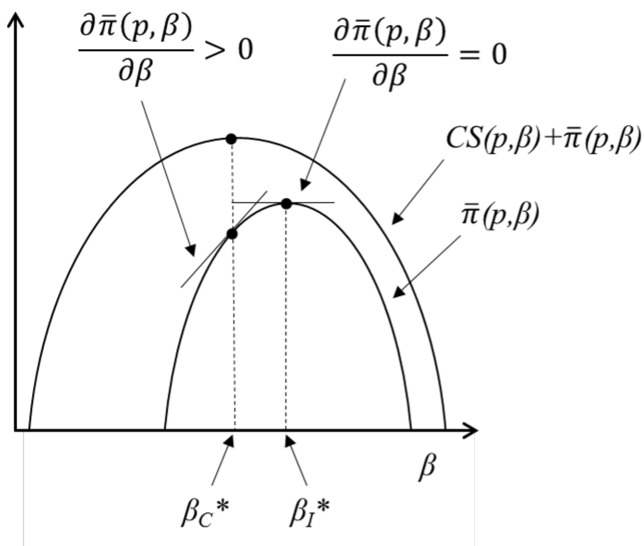
Regarding the third part of the proposition, the only difference between the customer owners' and investor owners' problems is the inclusion of $CS(p, e_s^*(\beta))$ in the former. Since $CS(.)$ is increasing in $e_s$, and by Lemma 1 $e_s(.)$ is decreasing in $\beta$, we have that $CS(.)$ is also decreasing in $\beta$. Specifically, differentiating the expression for $CS(p, e_s(p, \beta))$ in (5) with respect to $\beta$ yields:

$$\frac{d}{d\beta} CS(p, e_s(p, \beta)) = \int_p^{\infty} q_s'(x, e_s(x, \beta))\, e_{s,\beta}' dx < 0$$

The sign of the derivative follows from the assumption that $q_s' > 0$, while $e_{s,\beta}' < 0$ by Lemma 1. Assuming that both owner types' objective functions have a unique interior optimum, with $CS(.)$ decreasing in $\beta$, it follows that the customer owners' optimum occurs with $0 < \beta_C^* < \beta_I^*$. This is illustrated in Figure 2, and completes the proof of part (3) of Lemma 2.

Our finding that $\beta_C^* < \beta_I^*$ is key to our analysis below of how optimal regulation differs for customer- and investor-owned firms, and has the following intuition. By Lemma 1 we

Figure 2: Owners' Optimal Incentive Power Choices, given Price




know that the manager's optimal effort choices diverge with respect to incentive power $\beta$, with $e_q$ increasing but $e_s$ decreasing in $\beta$. Since customer owners value consumer surplus as well as expected profits, and consumer surplus is increasing in $e_s$ (via its impact on expected quality), those owners will wish to induce the manager to exert higher $e_s$ and lower $e_q$ than will investor owners. This is because investor owners care about quality only indirectly, via its impact on revenue, and not also directly via its impact on consumer surplus. Thus customer owners will optimally choose lower-powered incentives for the manager than will investor owners.

This result echoes the Holmstrom and Milgrom (1991) finding that an owner might optimally reduce a manager's incentive power regarding a contractible action. As discussed earlier, they do so if inducing that action causes the manager to reduce his or her effort on another, non-contractible action which the owner also values. However, while their finding rested on the detrimental impact of contractible effort on the manager's private marginal cost of the non-contractible effort (i.e. $\psi''_{qs} > 0$), our result can arise even when there is no such effort substitution effect in relation to the manager's effort costs (i.e. $\psi''_{qs} \leq 0$). The manager's efforts diverge with respect to incentive power on our setup when his or her net marginal disutility of $e_q$ is sufficiently increasing in $e_s$.

The third part of Proposition 1 is also explicable in terms of previous findings regarding quality provision under monopoly.[38] In particular, while a profit maximizing monopolist chooses quality based on the marginal consumer's willingness to pay for that quality, social welfare maximization requires consideration of consumer's average willingness to pay. In the present context, customer ownership involves the choice of incentive power to maximize an objective function analogous to that of a social planner, since it explicitly includes consumer surplus. By contrast, investor owners choose incentive power simply

[38]See, for example, Spence (1975), and Tirole (1988).

to maximize expected profits, in which case only marginal willingness to pay for quality is considered.

Finally, the third part of the proposition suggests an explanation for the finding that customer-owned firms in practice typically offer either no or only very low-powered incentives to their managers.[39] Due to their particular concern for quality, which might be compromised if the manager is incentivized to reduce costs, customer owners optimally offer relatively low-powered incentives.

By combining Lemma 1 and Proposition 1 we have the following Corollary:

**Corollary 1** (Relative expected costs, quality, revenue and profit, given price)

Under the necessary and sufficient conditions in Lemma 1, and assumptions of Proposition 1, for a given regulated price $p$:

1. Expected quality is higher under customer ownership than investor ownership – i.e. $\overline{s}\left(e_s(p,\beta_C^*(p))\right) > \overline{s}\left(e_s(p,\beta_I^*(p))\right)$;

2. Quantity and hence revenue is higher under customer ownership than investor ownership – i.e. $pq\left(p,e_s(p,\beta_C^*(p))\right) > pq\left(p,e_s(p,\beta_I^*(p))\right)$; and

3. Total expected costs are higher under customer ownership than investor ownership – i.e. $\overline{c}\left(e_q\left(p,\beta_C^*(p)\right),e_s\left(p,\beta_C^*(p)\right)\right) > \overline{c}\left(e_q\left(p,\beta_I^*(p)\right),e_s\left(p,\beta_I^*(p)\right)\right)$.

**Proof**: The first part of the corollary follows from the facts that $\beta_C^*(p) < \beta_I^*(p)$, $e'_{s,\beta} < 0$ and $\overline{s}'_s > 0$. The second part follows from the first, since $q'_s > 0$, and we take $p$ as given. The third part also follows from the first, since $\overline{c}'_s > 0$, and also from the facts that $\beta_C^*(p) < \beta_I^*(p)$, $e'_{q,\beta} > 0$ and $\overline{c}'_q < 0$. In other words, given price, weaker incentives under customer ownership result in higher quality-enhancing effort, which raises expected quality. At the same time they cause lower cost-reducing effort. Both of these effects raise expected costs.

Having determined the manager's and owners' optimal choices of efforts and incentive power respectively, we now determine the regulator's optimal price choices.

## 4.3 Regulator's Optimal Price Choices

Anticipating the optimal incentive power choices $\beta_j^*(p)$ of the firm's owners for $j \in \{C, I\}$ under customer ownership ($C$) and investor ownership ($I$) – and the manager's optimal effort choices $e_q(p,\beta_j^*(p))$ and $e_s(p,\beta_j^*(p))$ – the regulator chooses $p$ to maximize the sum of consumer surplus and fraction $\alpha$ of expected post-wage profits. Writing expected post-wage profits (4) and consumer surplus (5) respectively as:

$$\overline{\pi}_j = \overline{\pi}\left(p,\beta_j^*(p)\right)$$

$$CS_j = CS\left(p,\beta_j^*(p)\right) \equiv CS\left(p,e_s^*\left(p,\beta_j^*(p)\right)\right)$$

then the regulator's objective functions (7) for $j \in \{C, I\}$ write as:

[39] As surveyed in Kopel and Marini (2012).

$$CS_j + \alpha\bar{\pi}_j = CS_j\left(p, \beta_j^*(p)\right) + \alpha\bar{\pi}\left(p, \beta_j^*(p)\right) \tag{11}$$

Notice that $p$ affects the regulator's objective both directly and indirectly. The direct effects are from the impact of price on both consumer surplus and output. Conversely, price indirectly affects consumer surplus, expected costs and hence expected post-wage profits via its direct impact on $e_s$, as well as its indirect impact on $e_s$ via its impact on incentive power $\beta_j^*(p)$. Likewise, $e_q$ is also affected by price and incentive power, which in turn affects expected costs. Consequently, differences between ownership types in terms of both incentive power, and the sensitivity of incentive power to price, will be key in determining how the regulator sets price under each type.

Before proceeding to our proposition regarding the regulator's optimal price choices, it is convenient to present the following two lemmas.

**Lemma 2** (Relative consumer surplus and expected profits as functions of price)

Under the necessary and sufficient conditions in Lemma 1 and assumptions of Proposition 1, and denoting $CS'_{j,p} \equiv \frac{dCS_j}{dp}$ and $\bar{\pi}'_{j,p} \equiv \frac{d\bar{\pi}_j}{dp}$ for $j \in \{C, I\}$:

1. $0 \leq CS_I < CS_C$, while $CS'_{C,p} < CS'_{I,p} \leq 0$; and
2. $0 \leq \bar{\pi}_C < \bar{\pi}_I$, and $\bar{\pi}'_{C,p} < \bar{\pi}'_{I,p}$ ($\bar{\pi}'_{C,p} \geq \bar{\pi}'_{I,p}$) if $\beta'_{C,p} < 0$ ($\beta'_{C,p} \geq 0$).

**Proof**: By Proposition 1 we know that $\beta_C^*(p) < \beta_I^*(p)$, and hence by Corollary 1 that $e_s\left(p, \beta_C^*\left(p\right)\right) > e_s\left(p, \beta_I^*\left(p\right)\right)$. Since $CS'_s > 0$ by assumption, and $CS \geq 0$ by the definition of $CS$, we have that $0 \leq CS_I(p) < CS_C(p)$. Furthermore, by differentiation of (5) with respect to $p$ we have that $CS'_{C,p} = -q\left(p, e_s\left(p, \beta_C^*\left(p\right)\right)\right) \leq 0$ since $q(.) \geq 0$, and likewise for $CS'_{I,p}$. But since $e_s\left(p, \beta_C^*\left(p\right)\right) > e_s\left(p, \beta_I^*\left(p\right)\right)$ we also have that $q\left(p, e_s\left(p, \beta_C^*\left(p\right)\right)\right) > q\left(p, e_s\left(p, \beta_I^*\left(p\right)\right)\right)$, given $q'_s > 0$ by assumption. Thus $CS'_{C,p} < CS'_{I,p} \leq 0$. This completes the proof for the first part of the lemma.

The fact that $\bar{\pi}_C < \bar{\pi}_I$ when each owner type is optimally choosing incentive power can be seen from Figure 2. This follows from the fact that investor owners maximize expected post-wage profits when choosing their optimal incentive power, and hence choose $\beta_I^*$ such that $\frac{\partial\bar{\pi}}{\partial\beta} = 0$. Conversely, customer owners maximize the sum of consumer surplus and expected post-wage profits (which profits are an identical function of $\beta(p)$ under both ownership types).[40] Since this tradeoff between consumer surplus and profits inclines customer owners towards weaker incentive power, they do not maximize expected profits. Hence, for a given $p$ their profits are both lower than under investor ownership, and remain increasing in incentive power, at $\beta_C^*(p)$. Assuming that profit functions have an interior maximum further assures that $0 \leq \bar{\pi}_C < \bar{\pi}_I$. Note that since the owners' optimal incentive power was chosen for a given price $p$, this holds for all $p$.

Furthermore, the total derivative of each owner-type's profit function with respect to $p$ can be written as follows, given that $\frac{\partial\bar{\pi}}{\partial\beta} = 0$ at $\beta_I^*$:

$$\bar{\pi}'_{C,p} = \frac{\partial\bar{\pi}}{\partial p} + \frac{\partial\bar{\pi}\left(\beta = \beta_C^*\right)}{\partial\beta}\beta'_{C,p}$$

[40] Profit functions diverge under each ownership type when expressed as a function of optimal incentive power. In general, however, they are identical as a function of incentive power due to the manager's optimal effort choices being identical functions of $p$ and $\beta$ under each ownership type.

$$\bar{\pi}'_{I,p} = \frac{\partial \bar{\pi}}{\partial p}$$

Since we know that $\frac{\partial \bar{\pi}}{\partial \beta} > 0$ at $\beta^*_C$, this means that the relative slopes of $\bar{\pi}_C$ and $\bar{\pi}_I$ are determined by the sign of $\beta_{C,p}$, given $\frac{\partial \bar{\pi}}{\partial p}$ is identical under each ownership type. Thus $\bar{\pi}'_{C,p} < \bar{\pi}'_{I,p}$ if $\beta'_{C,p} < 0$ (and vice versa) as required. This completes the proof of the lemma.

The intuition for the first part of the lemma comes from demand, and hence consumer surplus, being increasing in expected quality, and because quality-enhancing effort is higher under customer ownership. This is due to customer owners placing higher weight on quality than investor owners, as reflected in the optimal choice of weaker incentives (i.e. lower $\beta^*_C(p)$). In turn, having higher consumer surplus for all prices because of this quality difference means that customer owners suffer a more serious loss of surplus than do investor owners as price rises.

The intuition for the second part of the lemma follows from the fact that profits are an identical function of $\beta$ under each ownership type, given $p$, since the manager's optimal effort choices are identical functions of $p$ and $\beta$ under each ownership type. Given that the customer owners' objective shares this profit function, but also includes consumer surplus which is decreasing in $\beta$, profits remain sensitive to (i.e. increasing in) incentive power under customer ownership but not investor ownership when incentive power is optimally chosen. As a consequence, $p$ affects $\bar{\pi}_C$ both directly and indirectly, while it affects $\bar{\pi}_I$ only directly and to a greater or lesser degree than $\bar{\pi}_C$ depending on the sign of $\beta'_{C,p}$.

From Lemma 2 it is clear that in general the regulator's objective function (11) under customer ownership may be either above or below that arising under investor ownership. For example, while consumer surplus is higher under the former, expected post-wage profits are higher under the latter if $\beta'_{C,p} < 0$. In general, the regulator will optimally choose a higher or lower regulated price under customer ownership than under investor ownership depending on the sign of the following difference between the *slopes* of the regulator's objective functions under each ownership type:

$$\Delta \equiv \left(CS'_{C,p} - CS'_{I,p}\right) + \alpha \left(\bar{\pi}'_{C,p} - \bar{\pi}'_{I,p}\right)$$

Using the fact that $CS'_{j,p} = -q\left(p, e^*_s\left(p, \beta^*_j\left(p\right)\right)\right)$, and that $\bar{\pi}'_{j,p}$ can be written as in the proof to Lemma 2, we have:

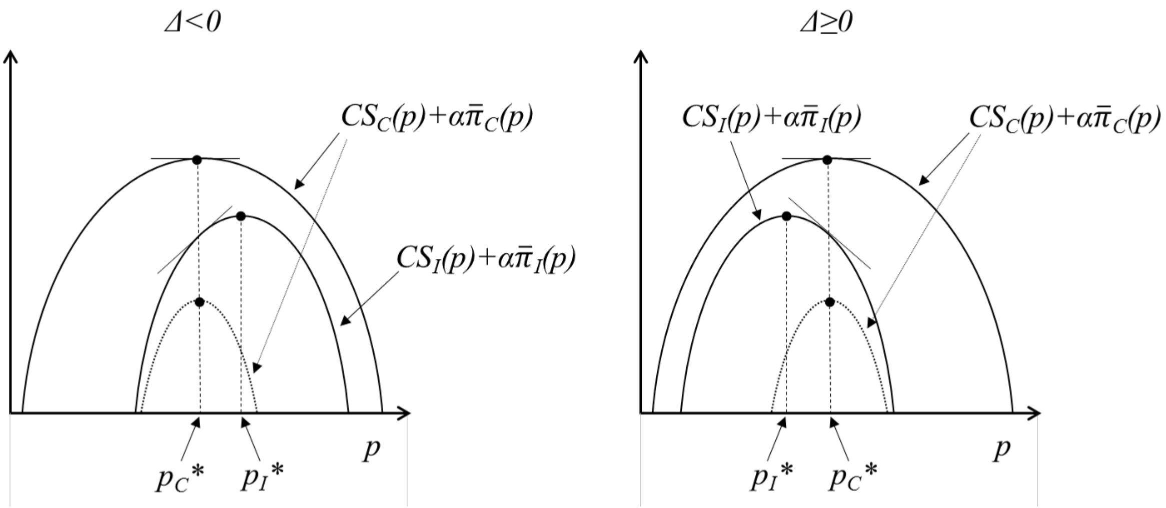
$$\Delta \lesseqgtr 0 \quad \Leftrightarrow \quad q\left(p, e^*_s\left(p, \beta^*_C\left(p\right)\right)\right) - q\left(p, e^*_s\left(p, \beta^*_I\left(p\right)\right)\right) \gtreqless \alpha \frac{\partial \bar{\pi}\left(\beta = \beta^*_C\right)}{\partial \beta} \beta'_{C,p} \tag{12}$$

This leads to the second of our two lemmas, following which we present our proposition regarding optimal price regulation.

**Lemma 3** (Optimal regulated prices under Customer Ownership and Investor Ownership)

Under the necessary and sufficient conditions in Lemma 1 and assumptions of Proposition 1, and assuming that the regulator's problem has a unique interior maximum under each ownership type:

Figure 3: Regulator's Optimal Price Choices




1. $p_C^* < p_I^*$ iff $\Delta < 0$; and

2. $p_C^* \geq p_I^*$ iff $\Delta \geq 0$.

**Proof**: If $\Delta < 0$, then the gradient of the regulator's objective function is lower under customer ownership than under investor ownership. Assuming that the regulator's objective function has an interior maximum, the situation is as illustrated in the first panel of Figure 3. As can be seen, irrespective of whether $CS_C + \alpha\overline{\pi}_C \lesseqgtr CS_I + \alpha\overline{\pi}_I$, having $\Delta < 0$ is sufficient to ensure that $p_C^* < p_I^*$.

Conversely, if $\Delta \geq 0$, then the gradient of the regulator's objective function is at least as great under customer ownership as under investor ownership. Assuming that the regulator's objective function has an interior maximum, the situation is as illustrated in the second panel of Figure 3. As can be seen, irrespective of whether $CS_C + \alpha\overline{\pi}_C \lesseqgtr CS_I + \alpha\overline{\pi}_I$, having $\Delta \geq 0$ is sufficient to ensure that $p_C^* \geq p_I^*$. This completes the proof of the lemma.

Condition (12) reflects the fact that since investor owners optimally choose incentive power to maximize profits, this removes a channel via which the regulator can indirectly affect such profits. While the regulator's price choice affects $\beta_I^*(p)$, and in turn $e_q$, $e_s$, $\overline{s}$, $\overline{c}$, $q$ and $CS_I$, investor-owners choose $\beta_I^*(p)$ such that profits are invariant to marginal changes in $\beta_I^*(p)$, and hence are not indirectly (i.e. via $\beta_I^*(p)$) affected by $p$, as in Figure 2. By contrast, customer-owners choose incentive power to maximize the sum of expected profits and consumer surplus, resulting in their expected profits being increasing in optimal incentive power, and hence in price. Thus, under customer ownership, an increase in $p$ affects both expected profits and consumer surplus directly and indirectly. Once again, varying $p$ results in owners changing incentive power, and thus affects $e_q$, $e_s$, $\overline{s}$, $\overline{c}$, $q$ and $CS_C$. However, under customer ownership the regulator's price choice also affects expected profits indirectly – in contrast to investor ownership – since $\frac{\partial \pi}{\partial \beta} > 0$ in this case.

Thus the indirect impact of $p$ on profits must also be taken into account under customer ownership.

As to intuition, the left-hand side of (12) measures the demand contraction and hence consumer surplus loss under customer ownership, relative to investor ownership, from a marginal increase in $p$. A price increase reduces demand and hence consumer surplus directly. It also affects each via the change in quality-enhancing effort that results when increased price changes incentives. Conversely, the right-hand side of the condition measures the extent to which $\alpha$-weighted profits indirectly increase, under customer ownership, as a consequence of the change in incentive power when $p$ rises. Since there is no corresponding indirect increase in profits under investor ownership when price changes, this change also measures the relative (to investor ownership) indirect increase in profits under customer ownership in response to a price change.

If the relative contraction in demand and hence consumer surplus is less than this (relative) profit increase (i.e. $\Delta > 0$), then the regulator optimally chooses $p_C^* > p_I^*$. This is because the regulator anticipates that setting $p_C^*$ higher than $p_I^*$ benefits (relative) $\alpha$-weighted profits more than it hurts relative consumer surplus. Conversely, if the relative demand contraction exceeds the (relative) profit increase (i.e. $\Delta < 0$), then the regulator anticipates that relative consumer surplus is more adversely impacted than (relative) profits are benefited by setting $p_C^* > p_I^*$, and so optimally it sets $p_C^* < p_I^*$. While in general condition (12) does not result in an unambiguous prediction as to the regulator's relative optimal price choices, the following proposition shows that a clear prediction arises when $\beta'_{C,p} < 0$.

**Proposition 2** (Tighter Price Cap under Customer Ownership when Incentive Power Decreasing in Price)

Under the conditions and assumptions in Lemma 3, a sufficient condition for $p_C^* < p_I^*$ is that $\beta'_{C,p} < 0$.

**Proof**: By Corollary 1 we know that the left-hand side of condition (12) is positive. Since $0 < \alpha \leq 1$ by assumption, and $\frac{\partial \overline{\pi}}{\partial \beta} > 0$ at $\beta_C^*$ from the proof of Lemma 2, the right-hand side of condition (12) is negative if $\beta'_{C,p} < 0$. This ensures that $\Delta < 0$ in this case, and hence by Lemma 3 we have that $p_C^* < p_I^*$. Indeed, with $\beta'_{C,p} < 0$ we know from Lemma 2 that $\overline{\pi}'_{C,p} < \overline{\pi}'_{I,p}$, and hence that $CS'_{C,p} + \alpha\overline{\pi}'_{C,p} < CS'_{I,p} + \alpha\overline{\pi}'_{I,p}$ in that case (since $CS'_{C,p} < CS'_{I,p} \leq 0$ by Lemma 2 also). Thus under the conditions and assumptions of Lemma 3 this is also sufficient to establish that $p_C^* < p_I^*$. This completes the proof of the proposition.

While $\beta'_{C,p} < 0$ is sufficient to ensure that the regulator optimally sets a tighter price cap under customer ownership than under investor ownership, it is not necessary. In particular, by Lemma 3 we see that this might also arise with $\beta'_{C,p} \geq 0$ provided we still have $\Delta < 0$. This is perhaps surprising, since intuitively customer ownership should present fewer regulatory concerns than investor ownership, and hence should require a looser price cap. The key here is that if relative consumer surplus is sufficiently price-sensitive, while profits are sufficiently price-insensitive – both directly and via cost-reducing and quality-enhancing efforts (and hence incentive power) – then the regulator optimally reduces $p_C^*$ to induce higher relative consumer surplus at the expense of relative profits. Because $\frac{\partial \overline{\pi}}{\partial \beta} > 0$

at $\beta_C^*$ but $\frac{\partial \overline{\pi}}{\partial \beta} = 0$ at $\beta_I^*$, the regulator confronts different tradeoffs under customer and investor ownership, with the result that a tighter price cap is justified under the former when $\Delta < 0$.

Finally, before proceeding to an analysis of the implications of price regulation, we first summarize how our predictions are changed if the conditions in Lemma 1 are not satisfied. It can be shown that the manager's second order conditions preclude $e'_{s,\beta} < 0$ and $e'_{q,\beta} < 0$ arising simultaneously.[41] On a priori grounds we consider the case with $e'_{s,\beta} > 0$ but $e'_{q,\beta} < 0$ to be implausible, since the quality-efficiency tradeoff highlighted in Section 1 suggests that firms prefer to achieve cost savings than to improve output quality. Hence if the conditions in Lemma 1 are not satisfied, then the leading alternative to consider is that in which both $e'_{s,\beta} > 0$ and $e'_{q,\beta} > 0$. The implications of this case are summarized in the following corollary:

**Corollary 2** (Predictions when $e'_{s,\beta} > 0$ and $e'_{q,\beta} > 0$)

Under the assumptions in Propositions 1, Corollary 1, and Lemmas 2 and 3, but now assuming that both $e'_{s,\beta} > 0$ and $e'_{q,\beta} > 0$:

1. Proposition 1(1) and 1(3) are reversed – i.e. $\beta'_{C,p} < \beta'_{I,p}$ and $\beta_C^*(p) > \beta_I^*(p) > 0$;
2. Corollary 1(1) and 1(2) are unchanged, but 1(3) is reversed – i.e. for a given price, expected quality, output and revenue remain higher – but expected costs are now lower – under customer ownership than under investor ownership;
3. Lemma 2 is unchanged except for the price derivatives of profits – i.e. now $\overline{\pi}'_{C,p} > \overline{\pi}'_{I,p}$ ($\overline{\pi}'_{C,p} \leq \overline{\pi}'_{I,p}$) if $\beta'_{C,p} < 0$ ($\beta'_{C,p} \geq 0$);
4. Lemma 3 is unchanged – i.e. $p_C^* < p_I^*$ iff $\Delta < 0$, while $p_C^* \geq p_I^*$ iff $\Delta \geq 0$; and
5. Proposition 2 now holds if the sign of $\beta'_{C,p}$ is reversed – i.e. a sufficient condition for $p_C^* < p_I^*$ is that $\beta'_{C,p} > 0$.

**Proof**: Details omitted since they follow the existing proofs. Showing that $\beta'_{C,p} < \beta'_{I,p}$ is clear on inspection of the final expression in Appendix B.1 with $e'_{s,\beta} > 0$. The key to establishing $\beta_C^*(p) > \beta_I^*(p)$ is that with $e'_{s,\beta} > 0$ we now have consumer surplus increasing rather than decreasing in $\beta$. Thus in Figure 2 the peak of $CS(p,\beta) + \overline{\pi}(p,\beta)$ now lies to the right of that for $\overline{\pi}(p,\beta)$. With both $e'_{s,\beta} > 0$ and $\beta_C^*(p) > \beta_I^*(p)$ we continue to predict that $e_s$ is higher under customer ownership, and hence so too is expected quality, and thus also output and firm revenue (given $p$). Conversely, while $e'_{q,\beta} > 0$ as before, we now have $\beta_C^*(p) > \beta_I^*(p)$, so $e_q$ is also higher under customer ownership, in contrast to before. Hence expected costs are now lower under customer ownership. Furthermore, since $e_s$ remains higher under customer ownership as before, assuming $e'_{q,\beta} > 0$ does not affect the rankings of $CS$ or its price derivative under each ownership type. Likewise, customer-owners continue to choose $\beta_C^*(p)$ such that it does not maximize profits – unlike investor owners when they choose $\beta_I^*(p)$ – thus expected profit rankings are also not affected by

[41] Specifically, this is a consequence of the requirement that $det(A) > 0$ using the notation in Appendix A.

assuming $e'_{q,\beta} > 0$. However, with $\beta^*_C(p) > \beta^*_I(p)$ we now have that $\frac{\partial\overline{\pi}(\beta=\beta^*_C)}{\partial\beta}$ is negative rather than positive, in contrast to the situation in Figure 2 (since the customer owners' objective now peaks to the right of the investor owners' objective). Thus the rankings of total derivatives of expected profits with respect to $p$ are now reversed. Since Lemma 3 was couched in general terms, its predictions are unchanged by assuming that $e'_{s,\beta} > 0$. Finally, since $e_s$ remains higher under customer ownership, we have that the left-hand side of (12) remains positive when $e'_{s,\beta} > 0$. However, due to $\frac{\partial\overline{\pi}(\beta=\beta^*_C)}{\partial\beta}$ now being positive, we require $\beta'_{C,p}$ to be positive, rather than negative, to ensure that the right-hand side of (12) is negative, which is sufficient for $\Delta < 0$ and hence $p^*_C < p^*_I$ by Lemma 3. This completes the proof of the corollary.

The relevance of Corollary 2 can be seen by the fact that the conditions in Lemma 1 (ensuring that the manager's optimal effort choices diverge in incentive power) depend on $\beta$ directly, but also on other terms which in general will depend on both $\beta$ and $p$. Thus, while the manager makes his or her optimal effort choices taking both $\beta$ and $p$ as given, in equilibrium both the firm's owners (via their $\beta$ choice) and the regulator (via its choice of $p$) have the capacity to affect the nature of the tradeoffs confronting the manager between the two effort types. Indeed, it may even be possible for either the owners or the regulator to cause the manager's effort choices to align rather than diverge in terms of incentive power. This highlights an additional channel via which regulation affects both efficiency and quality – by conceivably changing the manager's efficiency and quality choices from being substitutes to complements.

Importantly, if $e'_{s,\beta} > 0$ rather than as in Lemma 1, then we predict that customer-owned firms will optimally set stronger incentives than investor-owned firms. As mentioned previously, the limited available empirical evidence suggests that the contrary is true, which motivated the way in which Lemma 1 was framed. Of particular note is that customer-owned firms are still predicted, for a given $p$, to produce higher expected quality than investor-owned firms if $e'_{s,\beta} > 0$, though in that case they are now predicted to produce *lower* expected costs. This latter prediction is also at odds with available studies, which predict on theoretical grounds that customer-owned firms should be less efficient than investor-owned firms, or empirically find cost advantages for investor-owned firms.[42] This also motivated the way in which Lemma 1 was framed.

Notably, most of our predictions remain unchanged when $e'_{s,\beta} > 0$ is assumed. The assumption is important for explaining whether the manager's effort choices are substitutes or complements, and hence why differences arise in the owners' choice of incentive power under each firm type. However, it does not fundamentally alter the channels via which regulated price influences managerial effort choices and hence the firm's expected costs and quality, which we have shown to be mediated by differences in owners' objective functions.

[42] For example, see Sexton and Iskow (1993) and Soderberg (2011).

### 4.4 Implications of Price Regulation

We now consider how regulation affects expected costs and quality across each firm type under the conditions in Lemma 1. We begin by observing that if $\alpha = 1$, then the objective functions of the regulator and customer owners coincide in relation to price choice. In that case the customer owners' optimal unregulated price choice $p_C^U$ would coincide with the regulator's optimal price choice $p_C^*$. With $0 < \alpha < 1$, however, the regulator optimally chooses $p_C^* < p_C^U$. Indeed, in that case we have $CS_C + \alpha\overline{\pi}_C < CS_C + \overline{\pi}_C$ and hence that $CS'_{C,p} + \alpha\overline{\pi}'_{C,p} < CS'_{C,p} + \overline{\pi}'_{C,p}$.[43] Thus the regulator's objective function attains its maximum with respect to $p$ sooner than does the customer owners' objective function, assuming each has a unique interior maximum.

By contrast, investor owners will always optimally choose an unregulated price $p_I^U > p_I^*$, for all $\alpha$ in the assumed range. This is because the price choice maximizing $\overline{\pi}$ also maximizes $\alpha\overline{\pi}$ given $\alpha$ is a positive scalar. However, the regulator maximizes $CS_I(p) + \alpha\overline{\pi}(p)$, where we have shown that $CS_I(p)$ is decreasing in $p$. Thus the regulator's objective attains its maximum before the investor owners' objective, again assuming a unique interior maximum, implying that $p_I^* < p_I^U$.

Notably, it is not assured that $p_C^U < p_I^U$. This is because $\overline{\pi}'_{C,p} \geq \overline{\pi}'_{I,p}$ if $\beta'_{C,p} \geq 0$ as in Lemma 2. Thus, even though $CS_C + \overline{\pi}_C$ reaches its maximum with respect to $p$ sooner than does $\overline{\pi}_C$, the latter reaches its maximum possibly for a higher $p$ than does $\overline{\pi}_I$. Thus in general we have that $p_C^U \lesseqgtr p_I^U$. However, a sufficient condition for $p_C^U < p_I^U$ is that $\beta'_{C,p} < 0$, since by Lemma 2 $\overline{\pi}'_{C,p} < \overline{\pi}'_{I,p}$ and $CS'_{C,p} < 0$ in that case, and hence $CS'_{C,p} + \overline{\pi}'_{C,p} < CS'_{I,p} + \overline{\pi}'_{I,p}$.

Thus the introduction of optimal price regulation is predicted to reduce $p$ for investor-owned firms. Conversely, it is predicted to either leave price unchanged for customer-owned firms (if $\alpha = 1$), or to reduce that price (if $0 < \alpha < 1$). Since in general $p_C^U \lesseqgtr p_I^U$ and $p_C^* \lesseqgtr p_I^*$, it is not possible to say in general whether regulation will reduce $p$ for customer-owned firms more or less than for investor-owned firms. This remains true even when $\beta'_{C,p} < 0$, in which case both $p_C^U < p_I^U$ and $p_C^* < p_I^*$.

Despite these ambiguities, it is possible to derive conditions under which predictions can be made regarding the impact of optimal price regulation on expected quality, although ambiguity remains regarding its impact on expected costs. To see this, denote expected costs and quality for $j \in \{C, I\}$ as:

$$\overline{c}_j = \overline{c}(p_j^*) \equiv \overline{c}\left(e_q\left(p_j^*, \beta_j^*(p_j^*)\right), e_s\left(p_j^*, \beta_j^*(p_j^*)\right)\right)$$

$$\overline{s}_j = \overline{s}(p_j^*) \equiv \overline{s}\left(e_s\left(p_j^*, \beta_j^*(p_j^*)\right)\right)$$

Suppressing asterisks for convenience, denoting $e'_{i,p} \equiv \frac{\partial e_i(p,\beta(p))}{\partial p}$ for $i \in \{q, s\}$, and further denoting $\overline{c}'_{j,p} \equiv \frac{d\overline{c}_j}{dp}$ and $\overline{s}'_{j,p} \equiv \frac{d\overline{s}_j}{dp}$ for $j \in \{C, I\}$, we have that at the regulator's optimal prices:

$$\overline{c}'_{j,p} = \overline{c}'_q\left(e'_{q,p} + e'_{q,\beta}\beta'_{j,p}\right) + \overline{c}'_s\left(e'_{s,p} + e'_{s,\beta}\beta'_{j,p}\right) \tag{13}$$

[43] By Lemma 2 we know that $CS'_{C,p} < 0$, so by the regulator's first order condition with respect to $p$ we have that $\overline{\pi}'_{C,p} > 0$.

$$\overline{s}'_{j,p} = \overline{s}'_s \left(e'_{s,p} + e'_{s,\beta}\beta'_{j,p}\right) \tag{14}$$

$$\overline{c}'_{C,p} - \overline{c}'_{I,p} = \left(\overline{c}'_q e'_{q,\beta} + \overline{c}'_s e'_{s,\beta}\right)\left(\beta'_{C,p} - \beta'_{I,p}\right) < 0 \tag{15}$$

$$\overline{s}'_{C,p} - \overline{s}'_{I,p} = \overline{s}'_s e'_{s,\beta}\left(\beta'_{C,p} - \beta'_{I,p}\right) < 0 \tag{16}$$

Notably, the inequalities in (15) and (16) remain true irrespective of whether $e'_{s,\beta} \lesseqgtr 0$, since the sign of $\beta'_{C,p} - \beta'_{I,p}$ reverses when that of $e'_{s,\beta}$ reverses (as in Corollary 2). So as well as clearly predicting that $p^*_C < p^U_C$ and $p^*_I < p^U_I$, we can clearly predict that both expected quality and expected cost will be more price-responsive under investor ownership than customer ownership.

However, the signs of $\overline{c}'_{j,p}$ and $\overline{s}'_{j,p}$ are not as easily determined. Recalling that $\overline{s}'_s > 0$ by assumption and $e'_{s,\beta} < 0$ under the conditions in Lemma 1, and that $\beta'_{I,p} < 0$ if $\beta'_{C,p} < 0$ by Proposition 1, then it is necessary and sufficient for $\overline{s}'_{I,p} > 0$ in this case that $e'_{s,p}$ is "not too negative". Specifically, we require that $e'_{s,p} > -e'_{s,\beta}\beta'_{I,p}$.[44] If the introduction of regulation is assumed not to materially affect the customer-owned firm's price (e.g. because $\alpha = 1$), then irrespective of the sign of $\overline{s}'_{C,p}$ we can predict that regulation should leave expected quality for the customer-owned firm unchanged. By contrast, if $e'_{s,p}$ is "not too negative" as above, then $\overline{s}'_{I,p} > 0$, and so with the regulator setting $p^*_I > p^*_C = p^U_C$, the quality differences predicted in Corollary 1 for each ownership type should be reduced by regulation. That is, while the investor-owned firm should have lower expected quality than a comparable customer-owned firm at a given price, with $p^*_I > p^*_C = p^U_C$ and $\overline{s}'_{I,p} > 0$ this quality difference should be reduced (or possibly reversed).

By contrast, even if $e'_{s,p}$ is "not too negative" in the sense as above – thus ensuring that the second term in (13) is positive (recalling that $\overline{c}'_s > 0$ by assumption) – $\overline{c}'_{I,p}$ could be either positive or negative depending on $e'_{q,p}$ (recalling further that $\overline{c}'_q < 0$ by assumption and $e'_{q,\beta} > 0$ under the conditions in Lemma 1). Hence, even if regulation results in $p^*_I > p^*_C = p^U_C$, and $\overline{s}'_{I,p} > 0$, it is possible in this case that $\overline{c}'_{I,p} \lesseqgtr 0$. Thus it is possible that the introduction of regulation either accentuates or reduces the efficiency differences predicted in Corollary 1 for each ownership type, even when it reduces those differences in terms of expected quality.

Table 2 summarizes cases in which the predicted cost and quality differences between customer-owned and investor-owned firms, for a given price, are reduced or possibly even reversed when $p^U_C = p^*_C < p^*_I$. As above, this requires $\overline{s}'_{j,p} > 0$ and $\overline{c}'_{j,p} > 0$. The table also shows cases in which this result is not assured due to $\overline{c}'_{j,p} \lesseqgtr 0$.

In conclusion, in general it is not possible to make unambiguous predictions regarding the impact of optimal price regulation on expected efficiency and quality differences between ownership types. Even in the specific cases discussed above only limited predictions can be made (relating just to regulated versus unregulated prices, and to expected quality, but not to expected efficiency). Hence future theoretical or empirical work is required to further explore these questions.

[44] In principle $e'_{q,p}$ and $e'_{s,p}$ can be found by totally differentiating the manager's first order conditions (8) with respect to $p$ and solving for $e'_{q,p}$ and $e'_{s,p}$, following the same approach as used when deriving $e'_{q,\beta}$ and $e'_{s,\beta}$ (as in the proof of Lemma 1 in Appendix A). In practice, however, it is not possible to make general statements regarding their magnitudes or signs.

Table 2: Cases in which $p_C^U = p_C^* < p_I^*$ Reduces or Reverses Corollary 1 Quality and Cost Difference Predictions

| $e'_{q,\beta}$ | $e'_{s,\beta}$ | $\beta'_{j,p}$ | $e'_{s,p} = 0$ | $e'_{s,p} = e'_{q,p} = 0$ | $e'_{s,p} > -e'_{s,\beta}\beta'_{j,p}$ $e'_{q,p} < -e'_{q,\beta}\beta'_{j,p}$ |
|---|---|---|---|---|---|
| + | − | − | n.a.* | $\overline{s}'_{j,p} > 0$, $\overline{c}'_{j,p} > 0$ | $\overline{s}'_{j,p} > 0$, $\overline{c}'_{j,p} > 0$ |
| + | + | + | n.a.* | n.a.* | $\overline{s}'_{j,p} > 0$, $\overline{c}'_{j,p} > 0$ |

* While $\overline{s}'_{j,p} > 0$ for these cases, they result in $\overline{c}'_{j,p} \lesseqgtr 0$.

Finally, we summarise the clear predictions from this discussion in the following proposition:

**Proposition 3** (Regulated and Unregulated Prices, and Relative Price Derivatives of Expected Costs and Quality)

1. Under the conditions in Lemma 1 ($e'_{s,\beta} < 0$):
   (a) $p_C^* \leq p_C^U$, with $p_C^* = p_C^U$ when $\alpha = 1$;
   (b) $p_I^* < p_I^U$;
   (c) A sufficient condition for $p_C^U < p_I^U$ is that $\beta'_{C,p} < 0$.
2. Irrespective of the sign of $e'_{s,\beta}$:
   (a) $\overline{c}'_{C,p} < \overline{c}'_{I,p}$; and
   (b) $\overline{s}'_{C,p} < \overline{s}'_{I,p}$.

# 5 Conclusions

In this paper we presented a model of monopoly regulation in which the manager of the regulated firm exerts efforts on both quality-enhancement and cost-reduction (i.e. efficiency) in a situation of moral hazard. We highlighted how the regulator faces different channels through which to use price to affect efficiency and quality, and hence different tradeoffs when setting price under customer and investor ownership. At the heart of these differences lies the tradeoffs made by each owner type when inducing the manager to exert each effort type, in situations where the manager faces conflicting incentives regarding the pursuit of efficiency and quality. Notably, our results arise even in the absence of effort substitution (as assumed in Holmstrom and Milgrom (1991)), or intrinsic motivation (as analyzed in Benabou and Tirole (2013)). They also do not hinge on assuming differences in decision-making processes or agency costs under each ownership type (as in Hart and Moore (1996, 1998) and Hendrikse (1998) in respect of the former, and Sexton and Iskow (1993) regarding the latter).

Our principal contribution has been to highlight that regulation under imperfect information – even when it accounts for quality as well as efficiency – must be adapted when managerial incentives cannot be assumed to be chosen so as to maximize profits. In particular, under customer ownership managerial incentive power is chosen to maximize the sum of both consumer surplus and profits, in our setup optimally resulting in weaker managerial incentives than under investor ownership at a given price. Further given price, both expected costs and quality are predicted to be higher under customer ownership as a consequence of this difference in incentive power, reflecting differences in objectives under each ownership type.

Importantly, this difference in objectives results in the regulator having an additional channel under customer ownership via which to use price to influence managerial effort choices. While the regulator can directly use price to influence effort choices under investor ownership, it can also do so indirectly under customer ownership. This is because customer owners' tradeoffs when choosing optimal managerial incentive power result in profits being increasing in incentive power, and hence in price. By contrast, profits are invariant to optimal incentive power under investor ownership. Moreover, we highlight how the price choice of the regulator, and owners' incentive power choice, each have the capacity to change the nature of the tradeoffs confronting the manager when choosing quality-enhancing and cost-reducing efforts. In our setup we focus on the case in which the manager has conflicting incentives in terms of these two effort types. However, we also discuss the implications of these efforts being complementary, highlighting how optimal incentive power and regulation change in that case.

Due to differences between customer- and investor-owned firms, we show that the regulator should in general choose a different price under each ownership type. Moreover, if a customer-owned firm's profits are sufficiently price-insensitive, or its consumer surplus sufficiently price-sensitive (relative to that arising under investor ownership), then regulated price is optimally *lower* under customer ownership than investor ownership. In that case price regulation can serve to reduce the predicted quality differences between firm types. However, even in that case it is not possible to make unambiguous predictions regarding the impact of regulation on expected efficiency differences.

These findings further highlight the complexity of the regulatory problem under asymmetric information. In particular, ownership mediates the effects of price regulation on managerial effort choice, and so different ownership types will in general warrant different regulatory treatments. Furthermore, when managers' efforts on different tasks are differentially affected by regulated price, this creates tradeoffs which further complicate the regulator's price choice. Failure to account for these tradeoffs, and in particular how they are affected by ownership choice, risks introducing regulatory distortions.

These complexities possibly explain why existing studies of the relative efficiency of utilities under investor and customer (or public) ownership are often contradictory or ambiguous.[45] By shedding light on these complexities our research should help to inform future empirical work. Moreover, while the focus of this paper has been on monopolistic network utilities such as those often found in electricity, gas and water distribution, and

[45] See, for example, the survey and discussion in Soderberg (2011), which also highlights that techniques commonly used for measuring firm efficiency assume that firms are profit maximizers. For an early survey of the wider cooperative efficiency debate see Sexton and Iskow (1993).

wastewater services, our findings suggest other rich areas of future research. These include, for example, the impact of customer ownership on optimal regulation in industries such as banking, or of public ownership in healthcare, education and broadcasting. Finally, other useful extensions to our work include modeling managerial selection issues (as in Benabou and Tirole (2013)), and endogenous ownership choice (as in Herbst and Pruefer (2005)). These extensions are left to future work.

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# Appendix

## A Proof of Lemma 1

The manager's first order conditions with respect to $e_q$ and $e_s$ are as in (8), noting explicitly as in the text that each of $e_q$ and $e_s$ will in general depend on $(p, \beta)$:

$$-\beta\overline{c}_q'\left(e_q(p,\beta), e_s(p,\beta)\right) - \psi_q'\left(e_q(p,\beta), e_s(p,\beta)\right) = 0$$

$$\beta\left[pq_s'(p, e_s(p,\beta)) - \overline{c}_s'\left(e_q(p,\beta), e_s(p,\beta)\right)\right] - \psi_s'\left(e_q(p,\beta), e_s(p,\beta)\right) = 0$$

Totally differentiating these expressions with respect to $\beta$ and suppressing arguments for convenience yields:

$$-\overline{c}_q' - \beta\left(\overline{c}_{qq}''e_{q,\beta}' + \overline{c}_{qs}''e_{s,\beta}'\right) - \left(\psi_{qq}''e_{q,\beta}' + \psi_{qs}''e_{s,\beta}'\right) = 0$$

$$pq_s' - \overline{c}_s' + \beta\left[pq_{ss}''e_{s,\beta}' - \left(\overline{c}_{sq}''e_{q,\beta}' + \overline{c}_{ss}''e_{s,\beta}'\right)\right] - \left(\psi_{sq}''e_{q,\beta}' + \psi_{ss}''e_{s,\beta}'\right) = 0$$

This is a $2 \times 2$ system of equations in unknowns $e_{q,\beta}'$ and $e_{s,\beta}'$, of the form $Ax = b$:

$$\begin{bmatrix} -\beta\overline{c}_{qq}'' - \psi_{qq}'' & -\beta\overline{c}_{qs}'' - \psi_{qs}'' \\ -\beta\overline{c}_{sq}'' - \psi_{sq}'' & \beta\left(pq_{ss}'' - \overline{c}_{ss}''\right) - \psi_{ss}'' \end{bmatrix}\begin{bmatrix} e_{q,\beta}' \\ e_{s,\beta}' \end{bmatrix} = \begin{bmatrix} \overline{c}_q' \\ -(pq_s' - \overline{c}_s') \end{bmatrix}$$

Denoting the entries of the coefficient matrix as $A = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix}$ with determinant $det(A)$, and observing that $A_{12} = A_{21}$, the above system solves as:

$$\begin{bmatrix} e_{q,\beta}' \\ e_{s,\beta}' \end{bmatrix} = \frac{1}{det(A)}\begin{bmatrix} A_{22} & -A_{12} \\ -A_{21} & A_{11} \end{bmatrix}\begin{bmatrix} \overline{c}_q' \\ -(pq_s' - \overline{c}_s') \end{bmatrix}$$

Thus:

$$e_{q,\beta}' = \tfrac{1}{det(A)}\left(A_{22}\overline{c}_q' + A_{12}\left(pq_s' - \overline{c}_s'\right)\right)$$

$$e_{s,\beta}' = \tfrac{1}{det(A)}\left(-A_{21}\overline{c}_q' - A_{11}\left(pq_s' - \overline{c}_s'\right)\right)$$

Assuming satisfaction of the manager's second order conditions for a maximum, we have that $A$ is negative definite, and thus that $A_{11} < 0$ and $A_{22} < 0$, while $det(A) > 0$.

Thus $e_{q,\beta}' > 0 \quad\Leftrightarrow\quad A_{22}\overline{c}_q' + A_{12}\left(pq_s' - \overline{c}_s'\right) > 0$, which requires that $A_{22}\overline{c}_q' > -A_{12}\left(pq_s' - \overline{c}_s'\right)$, where $pq_s' - \overline{c}_s' > 0$ is assured by the manager's first order condition with respect to $e_s$, since $\psi_s' > 0$ by assumption. Thus we have:

$$e_{q,\beta}' > 0 \quad\Leftrightarrow\quad A_{12} > -\frac{A_{22}\overline{c}_q'}{pq_s' - \overline{c}_s'} \equiv T_q < 0$$

The final inequality on threshold $T_q$ follows from the facts that $pq'_s - \overline{c}'_s > 0$ from the manager's first order conditions, $A_{22} < 0$ from his or her second order conditions, and because $\overline{c}'_q < 0$ by assumption.

Similarly, $e'_{s,\beta} < 0 \quad \Leftrightarrow \quad -A_{21}\overline{c}'_q - A_{11}\left(pq'_s - \overline{c}'_s\right) < 0$, which requires that $-A_{21}\overline{c}'_q < A_{11}\left(pq'_s - \overline{c}'_s\right)$. Again, we have that $pq'_s - \overline{c}'_s > 0$, $A_{11} < 0$ by the manager's second order conditions, and $\overline{c}'_q < 0$, so:

$$e'_{s,\beta} < 0 \quad \Leftrightarrow \quad A_{21} < -\frac{A_{11}\left(pq'_s - \overline{c}'_s\right)}{\overline{c}'_q} \equiv T_s < 0$$

These two conditions on $A_{12}$ $(= A_{21})$ can simultaneously be satisfied only if $T_s > T_q$, which requires that:

$$-\frac{A_{11}\left(pq'_s - \overline{c}'_s\right)}{\overline{c}'_q} > -\frac{A_{22}\overline{c}'_q}{pq'_s - \overline{c}'_s} \quad \Leftrightarrow \quad A_{11}\left(pq'_s - \overline{c}'_s\right)^2 > A_{22}\left(\overline{c}'_q\right)^2$$

$$\Leftrightarrow \quad A_{11} > \frac{A_{22}\left(\overline{c}'_q\right)^2}{\left(pq'_s - \overline{c}'_s\right)^2}$$

where the right-hand side is negative since $A_{22} < 0$. Finally, substituting for $A_{12}$, $A_{11}$ and $A_{22}$ from above into these three conditions, and reversing signs and inequalities, we have the form of the conditions specified in Lemma 1, namely:

$$0 < \underbrace{-\frac{\left(\beta\overline{c}''_{qq} + \psi''_{qq}\right)\left(pq'_s - \overline{c}'_s\right)}{\overline{c}'_q}}_{\equiv T^{min}_{qs}} < \psi''_{qs} + \beta\overline{c}''_{qs} < \underbrace{\frac{\left(\beta\left(pq''_{ss} - \overline{c}''_{ss}\right) - \psi''_{ss}\right)\overline{c}'_q}{pq'_s - \overline{c}'_s}}_{\equiv T^{max}_{qs}}$$

$$0 < \psi''_{qq} + \beta\overline{c}''_{qq} < \underbrace{-\frac{\left(\beta\left(pq''_{ss} - \overline{c}''_{ss}\right) - \psi''_{ss}\right)\left(\overline{c}'_q\right)^2}{\left(pq'_s - \overline{c}'_s\right)^2}}_{\equiv T^{max}_{qq}}$$

where we have $T^{max}_{qq} > 0$ because $A_{22} < 0$, and $\psi''_{qq} + \beta\overline{c}''_{qq} > 0$ since $\psi''_{qq} > 0$ and $\overline{c}''_{qq} > 0$ by assumption. This completes the proof of the lemma.

# B Proof of Parts 1 and 2 of Proposition 1

## B.1 Proof that $\beta'_{C,p} > \beta'_{I,p}$

From (9), maximization of the customer owners' objective function with respect to $\beta$ involves the following first order condition:

$$\int_p^\infty q'_s\left(x, e_s(x,\beta)\right)e'_{s,\beta}dx + pq'_s\left(p, e_s(p,\beta)\right)e'_{s,\beta} - \left(\overline{c}'_q e'_{q,\beta} + \overline{c}'_s e'_{s,\beta}\right) - \left(\psi'_q e'_{q,\beta} + \psi'_s e'_{s,\beta}\right) - \rho\beta\sigma^2_c = 0$$

As noted in the text, in general $\beta$ will depend on $p$, and in turn each of $q_s'$, $e_{q,\beta}'$, $e_{s,\beta}'$, $\overline{c}_q'$, $\overline{c}_s'$, $\psi_q'$ and $\psi_s'$ will be functions of both $p$ and $\beta(p)$. Thus, totally differentiating this first order condition with respect to $p$, and denoting $\beta_{j,p}' \equiv \frac{\partial \beta_j^*(p)}{\partial p}$ for $j \in \{C, I\}$, and $e_{i,\beta p}'' \equiv \frac{\partial e_{i,\beta}'}{\partial p}$ and $e_{i,\beta\beta}'' \equiv \frac{\partial e_{i,\beta}'}{\partial \beta}$ for $i \in \{q, s\}$, yields in the customer ownership case:

$$\begin{gathered}
-q_s'e_{s,\beta}' + q_s'e_{s,\beta}' + p\left\{\left[q_{sp}'' + q_{ss}''\left(e_{s,p}' + e_{s,\beta}'\beta_{C,p}'\right)\right]e_{s,\beta}' + q_s'\left(e_{s,\beta p}'' + e_{s,\beta\beta}''\beta_{C,p}'\right)\right\} \\
-\left\{\left[\overline{c}_{qq}''\left(e_{q,p}' + e_{q,\beta}'\beta_{C,p}'\right) + \overline{c}_{qs}''\left(e_{s,p}' + e_{s,\beta}'\beta_{C,p}'\right)\right]e_{q,\beta}' + \overline{c}_q'\left(e_{q,\beta p}'' + e_{q,\beta\beta}''\beta_{C,p}'\right)\right\} \\
-\left\{\left[\overline{c}_{sq}''\left(e_{q,p}' + e_{q,\beta}'\beta_{C,p}'\right) + \overline{c}_{ss}''\left(e_{s,p}' + e_{s,\beta}'\beta_{C,p}'\right)\right]e_{s,\beta}' + \overline{c}_s'\left(e_{s,\beta p}'' + e_{s,\beta\beta}''\beta_{C,p}'\right)\right\} \\
-\left\{\left[\psi_{qq}''\left(e_{q,p}' + e_{q,\beta}'\beta_{C,p}'\right) + \psi_{qs}''\left(e_{s,p}' + e_{s,\beta}'\beta_{C,p}'\right)\right]e_{q,\beta}' + \psi_q'\left(e_{q,\beta p}'' + e_{q,\beta\beta}''\beta_{C,p}'\right)\right\} \\
-\left\{\left[\psi_{sq}''\left(e_{q,p}' + e_{q,\beta}'\beta_{C,p}'\right) + \psi_{ss}''\left(e_{s,p}' + e_{s,\beta}'\beta_{C,p}'\right)\right]e_{s,\beta}' + \psi_s'\left(e_{s,\beta p}'' + e_{s,\beta\beta}''\beta_{C,p}'\right)\right\} \\
-\rho\beta_{C,p}'\sigma_c^2 = 0
\end{gathered}$$

Solving for $\beta_{C,p}'$ in this customer ownership case yields:

$$\beta_{C,p}' = -\frac{1}{SOC(\beta)}(B - C)$$

The terms $B$ and $C$ represent the terms in the above total derivative not associated with $\beta_{C,p}'$, but arising in respect of $e_s$-related terms and $e_q$-related terms respectively (associating cross-derivatives with $e_s$-related terms), being:

$$\begin{gathered}
B = p\left(\left(q_{sp}'' + q_{ss}''e_{s,p}'\right)e_{s,\beta}' + q_s'e_{s,\beta p}''\right) - \left(\overline{c}_{ss}'' + \psi_{ss}''\right)e_{s,p}'e_{s,\beta}' - \left(\overline{c}_s' + \psi_s'\right)e_{s,\beta p}'' \\
-\left(\overline{c}_{qs}'' + \psi_{qs}''\right)e_{s,p}'e_{q,\beta}' - \left(\overline{c}_{sq}'' + \psi_{sq}''\right)e_{q,p}'e_{s,\beta}' \\
C = \left(\overline{c}_{qq}'' + \psi_{qq}''\right)e_{q,p}'e_{q,\beta}' + \left(\overline{c}_q' + \psi_q'\right)e_{q,\beta p}''
\end{gathered}$$

The $SOC(\beta)$ term reflects the fact that the denominator of $\beta_{C,p}''$ is identical to the derivative with respect to $\beta$ of the investor owners' first order condition (10). Specifically, $SOC(\beta)$, which by assumption is negative, is in that case:

$$\begin{gathered}
SOC(\beta) = p\left(q_{ss}''\left(e_{s,\beta}'\right)^2 + q_s'e_{s,\beta\beta}''\right) - e_{q,\beta}'\left(e_{q,\beta}'\left(\overline{c}_{qq}'' + \psi_{qq}''\right) + 2e_{s,\beta}'\left(\overline{c}_{sq}'' + \psi_{sq}''\right)\right) \\
-\left(e_{s,\beta}'\right)^2\left(\overline{c}_{ss}'' + \psi_{ss}''\right) - e_{q,\beta\beta}''\left(\overline{c}_q' + \psi_q'\right) - e_{s,\beta\beta}''\left(\overline{c}_s' + \psi_s'\right) - \rho\sigma_c^2 < 0
\end{gathered}$$

Notice in the above total derivative of the customer owners' first order condition with respect to $p$ that the first two terms cancel. This is because the impact on the sensitivity of consumer surplus to $\beta$ of an increase in $p$, namely $-q_s'e_{s,\beta}'$, equals the negative of the impact on the sensitivity of firm revenue to $\beta$ of such a price increase. Under investor ownership the relevant first order condition is as above, absent the first term, relating to consumer surplus. Thus in the above total derivative, the $-q_s'e_{s,\beta}'$ term does not arise.

With $SOC(\beta)$ being the investor owners' second order condition as before, it can be shown that:

$$\beta'_{I,p} = -\frac{1}{SOC(\beta)}\left(q'_s e'_{s,\beta} + B - C\right)$$

That being the case, we have:

$$\beta'_{C,p} - \beta'_{I,p} = \frac{q'_s e'_{s,\beta}}{SOC(\beta)} > 0$$

where $\beta'_{C,p} > \beta'_{I,p}$ arises because $e'_{s,\beta} < 0$ by Lemma 1, while $q'_s > 0$ and $SOC(\beta) < 0$ by assumption. This establishes the first part of the proposition.

## B.2 Proof that $\beta'_{I,p} < \beta'_{C,p} < 0$ $(0 \leq \beta'_{I,p} < \beta'_{C,p})$

This follows from the decomposition of the numerator of $\beta'_{C,p}$ as above. Denote by $B$ those terms in the numerator of $\beta'_{C,p}$ measuring the sensitivity of $e_s$-related terms to changes in $p$, and by $C$ those terms measuring the sensitivity of $e_q$-related terms to changes in $p$, given that owners are optimally determining incentive power. Since the sign of $\beta'_{C,p}$ is determined by the sign of its numerator, we have that $\beta'_{C,p} < 0 \quad \Leftrightarrow \quad B < C$. Since $\beta'_{C,p} > \beta'_{I,p}$ from above, this condition also ensures that $\beta'_{I,p} < 0$.

Analogously, $0 \leq \beta'_{I,p} < \beta'_{C,p}$ can be shown by denoting as $q'_s e'_{s,\beta} + B$ those terms in the numerator of $\beta'_{I,p}$ measuring the sensitivity of $e_s$-related terms to changes in $p$, with $C$ defined as above. Since the sign of $\beta'_{I,p}$ is determined by the sign of its numerator, we have that $\beta'_{I,p} \geq 0 \quad \Leftrightarrow \quad q'_s e'_{s,\beta} + B \geq C$. Because $q'_s e'_{s,\beta} < 0$ while $SOC(\beta) < 0$, this condition also ensures that $\beta'_{C,p} > 0$.

This establishes the second part of the proposition.

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