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Abstract

The quality of goods provided by public utilities depends on infrastructure features and operational inputs. I compare the economic efficiency that results from price ceilings and minimum quality standards (i.e., compliance with environmental, chemical, and performance standards and norms) imposed by a benevolent regulator to a Coasean bargaining solution between a median consumer and a monopolist. When quality is non-excludable and non-rival, rate-of-return regulation yields higher economic efficiency than price cap regulation.

JEL Classification: H41, H54, L15, L43, L51

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Quality is a major concern in infrastructure-based public services, which are often regulated monopolies. The quality of regulated goods refers to compliance with sector-specific environmental, chemical, and performance standards, norms, and requirements.[1] The sought-after quality and the cost of delivering that quality target determine investments in regulated utilities and public infrastructure. Thus, quality standards are not an output variable, but significant input variables. In this paper, I analyze quality as a decision variable in regulated goods. I show that in particular cases price–quality regulation may hinder the optimal provision of quality, and that rate-of-return regulation bargaining yield efficient allocations when quality has public good attributes.

Section 1 presents a review of the economic literature on quality of regulated goods and the contribution of the paper to the literature body. Section 2 introduces the agents, decision variables, informational structure, contractual frictions, and timing of the game. Section 3 is devoted to the analysis of quality of infrastructure-based goods as an externality and the application of Coase theorem to the quality of regulated goods. Section 4 provides a discussion on the efficiency and social implications of regulations. Section 5 exposes the scope and limitation of infrastructure regulation. Section 6 concludes with policy recommendations.

1 Relation to the Literature

In the first half of the 20th century, there was a vivid debate on the pricing of decreasing-average-cost industries (i.e., natural monopolies), whose two most prominent representatives where Harold Hotelling and Ronald H. Coase (Frischmann and Hogendorn 2015). Hotelling (1938) advocated for a government subsidy of the fixed cost component that would enable marginal cost pricing for industries with high fixed and low marginal cost; Coase (1946)—who arguably succeeded in this debate considering today's applied industry standards—favored a two-part tariff system. While the profession consensus was that marginal cost pricing leads

[1] Quality of public goods is regulated legally in bills or contractually between public authorities (e.g., municipalities, regulatory agencies) and utility operators. The following are examples of quality regulation items by sector:
(a) Public transportation: routes, frequency of connections, and timetables.
(b) Waste disposal: frequency and times of waste collection, safety, and hygiene.
(c) Electricity: annual cumulative time of constant outages (planned and unplanned) per consumer.
(d) Fresh water: organoleptic, bacteriologic, and physiochemical factors.

to efficient allocation and the debate focused on the pricing and financing of fixed costs, investment outlays—which determine not only fixed costs, but to a large extend quality output—were taken as given.

The research on the demand and regulation of quality in regulated goods is quite recent. In a classical paper, Spence (1975) showed that an unregulated monopolist is unlikely to supply the optimal level of quality, given that the monopolist bases his decision on the marginal valuation of quality by consumers, whereas the socially optimal decision should instead be based on average valuation of quality. Since then, the existing literature has examined the interplay of market structure, regulation, and the provision of quality (Sappington 2005).

Early works were related to the American Prospective Payment System (PPS) mechanisms for rewarding hospitals: Johnson (1984) and Broyles and Rosko (1985) studied the incentives for providing high-quality medical services. Stiglitz (1987) described the consumer's perception of quality from price signals in markets with incomplete information and showed that, in standard economic theory, price depends on quality; but when quality is unobservable, perceived quality depends on price. Gwartney, Studenmund, and Stroup (1987) claimed that it is easier to regulate price than quality in natural monopolies. Lewis and Sappington (1991) examined the effect of optimal regulations when quality is contractible. Holmström and Milgrom (1991) formally developed the idea that economic agents with multiple objectives (e.g., high quality at low cost) put more effort into those objectives that are best rewarded. Laffont and Tirole (1993) presented two models for regulating quality: one in which quality is observable *ex ante* and another in which quality is observable only *ex post*. They concluded that incomplete information about the producer leads to a decrease in quality and further analyzed how incentives to increase quality affect demand and supply functions. Along these lines, Auriol (1998) studied the effect of competition on quality demand when quality is verifiable and non-verifiable, and stated that quality has features of public goods.

Quality can either be observable *ex ante* or *ex post* consumption; furthermore, quality is verifiable if it is costlessly describable *ex ante* in a contract and enforceable *ex post* in court (Laffont and Tirole 1991). Regarding the observability and verifiability of quality, goods can be classified as (Tirole 1988):

(a) Search goods, whose quality is observable before consumption (Nelson 1970);

(b) Experience goods, whose quality is observable only after consumption (Nelson 1970);

(c) Credence goods, whose quality is hardly verifiable even after consumption (Arrow 1963; Darby and Karni 1973).

Regulated goods are largely experience goods—i.e., their quality is not observable *ex ante*.[2] If quality were observable *ex ante* (search goods), the regulator would deftly enforce the appropriate level of quality.[3] The key issue with experience goods is information: How consumers learn about quality and what incentives companies have to produce goods at a given level of quality. The better *ex ante* informed consumers are about quality, the more the producer is motivated to produce high quality goods (Tirole 1988). Although Tirole did not spell this explicitly, his remarks refer only to goods with close substitutes. Should the good be indispensable and unsubstitutable, the revenue and reputation incentives would play no role for the producer as there is no alternative for the consumer but to purchase the necessary good at the provided level of quality.

Laffont and Tirole (1991) proposed to analyze the regulation of verifiable quality analogously to the regulation of a multi-product firm, where the quality level of a given product may be treated as the quantity of another, "fictitious product." Similarly, Varian (1992) analyzed the quality in general as a good *per se* with a production cost. According to him, the increase in quality can be decomposed in two effects: an upward shift of the demand curve and a change of the demand curve tilt. Whereas the profit-maximizing monopoly always produces less in quantity than under free competition, the level of quality produced by the monopoly is ambiguous: It depends on the cost and demand functions. Analogously, the welfare effect of quality change is also ambiguous.

The puzzle with quality rests, however, in the fact that it is not a "product," but an entity contingent upon the existence of a certain product or service. Quality is difficult to capture or measure. There is no "price for quality," either, but rather price for a good of a certain quality. Therefore, generalizations are flawed and each type of good should be modelled individually. For example, Fabbri and Fraquelli (2000) analyzed hedonic cost functions in the water sector.

[2] Most goods partly share characteristics of more than one type. For example, regulated goods such as water supply and waste management can be partially regarded as *credence goods* because of the uncertainty about their ultimate effect on health and the environment.

[3] Laffont and Tirole (1991) evoke revenue as a sufficient incentive to provide the desirable quality level, but this only holds for goods which are price elastic.

They showed that the quality of water is a basic problem of the production process and thus of production costs. They treated the production of water as a process that "changes the location (in place and time) of water and improves its quality" (Feigenbaum and Teeples 1983). Each company from this sector operates in different environmental conditions that affect the cost structure of water production. In this case, quality is a "cost" of production.

There are objective and subjective problems in quality measurement[4] and, thus, in determining the "appropriate" level of output quality for the consumer and for the producer. In consumer goods markets, competing companies produce goods of various quality and price levels, and consumers reveal their preferences by making choices. In the case of regulated goods, there are local monopolies. If goods were procured in a simple tender to the lowest bidder, the winner of the tendering contract would supply the lowest possible quality at average cost pricing (Viscusi, Vernon, and Harrington 2000). Yet this combination of "low price–low quality" may not be preferred by consumers.[5]

Posner (1972) proposed a mechanism with an "open season," during which all franchise bidders would offer their products to consumers. This would not be just a non-bidding presentation; franchise bidders would try to secure real orders from potential consumers. At the end of this period, the orders collected by franchise bidders would be compared and the franchise would be given to the bidder who secured the highest revenue. In this way, consumer preferences would be inferred from their willingness to pay, and the winner would be the bidder who, in free competition, would be preferred by the majority of consumers. To secure fair competition, each candidate would commit to provide the price and level of quality they offered. If they failed, the franchise would be withdrawn and a new "open season" announced.

The pre-contract offering prevents the regulator from imposing an *a priori* level of quality and facilitates choice among various price–quality combinations; but—although ingenious—it is not practicable (Williamson 1985). First, it assumes that consumers are able to make an abstract evaluation of price–quality packages and that they have the time and willingness

[4] For example, it is difficult to continually measure water pressure along the whole pipeline or infer consumers' preferences.

[5] For example, low price–low quality package A preferred by 40% of consumers wins over high price–high quality packages B, C, D, and E chosen by 15% of consumers each. Can we conclude that A is socially preferred?

to do so, which poses the problem of bounded rationality. Second, the pre-contract offering causes the aggregation of preferences in a rather arbitrary way.

Whereas the aforementioned literature has considered the provision and regulation of quality in a monopoly setting from an industrial organization standpoint—i.e., with focus on asymmetric information, incentives, and incomplete contracting—the contention of this paper is to show the applicability of the Coase theorem to quality of public goods. Costless verifiability and bargaining over quality provide a benchmark for policy recommendations when these assumptions vanish and regulation comes into play.

2 A Model of Quality Provision of Public Goods

Consider an economy with two goods: a public good x of variable quality q provided by a monopoly, and the *numéraire*. Quantity demand x is fixed (e.g., miles of railroad tracks or pipelines) and quality supply q depends largely on infrastructure features (e.g., construction materials used). The representative consumer has welfare w and quasi-linear preferences $u = v(x, q) + (w - p \cdot x)$, where the second term is the volume *numéraire* left to the consumer to buy other commodities. The monopoly maximizes profit $\pi = p \cdot x - TC(x, q)$. Output quality q is known by the monopoly, but only estimated by the consumer.

At time zero, a benevolent regulator roughly gauges the consumer's preferences and—on her behalf—bargains with the monopoly over quality and price. The regulator sets minimum quality standards q_{min} and maximum price p_{max}, and the investor invests large, non-redeployable, non-observable, and hardly verifiable I to meet these quality standards (i.e., I depends on q_{min}).

Although avowed administrative, quality regulation is consensual. Specifically, the regulator balances the inter-temporal trade-offs of costly quality provision, public acceptance, profit incentives, and contract termination. On the one hand, the regulator does not have complete information about consumer's preferences nor producer's costs; therefore, even though the regulator is benevolent, p_{max} and q_{min} can end at a suboptimal level. On the other hand, large and non-redeployable I lowers profit through depreciation and financial expenses, thus the investor has an incentive to shirk and lower output quality.

At time one, the utility produces and the consumer buys quantity x of the public good with quality q, and profit and consumer surplus are realized. The demand curve is such that the consumer is a price-and-quality taker: Since she has no substitutes for the public good provided, high prices and low quality realize in lower consumer surplus.

At time two, after experiencing the good the consumer learns more about output quality. The regulator, then, reassesses the price–quality policy, and eventually terminates the contract if quality standards were not met.

The central (and longer) stage of the game is time one: The monopoly has an informational advantage to cope with the consumer's preferences more promptly than regulatory policy updating, should the monopoly has the ability and willingness to do so.

3 The Coase Theorem Applied to Quality

The Coase theorem (Coase 1960) states that, assuming away transaction costs, the efficient level of demand for and supply of an externality does not depend on the allocation of the initial endowment and property rights of the agents (i.e., the quality of regulated goods does not depend on the bargaining power of the utility and the regulator). Defining a Coasean unambiguous quality optimum would be of particular importance in regulating monopolies.[6]

The quality of goods and services provided by network utilities (e.g., tap water) depends on the quality of infrastructure (e.g., endurance of pipes) and operational inputs (e.g., chemical treatment). Inasmuch as operators can arguably discriminate users on operational treats, the quality of infrastructure—e.g., power grid, water and sewage pipes, railroad tracks, etc.—bears features of a (local) public good: congestion aside, the consumption of quality by one user does not diminish the consumption of quality by other users (*non-rivalrous*) and quality discrimination is technically unfeasible (*non-excludable*).[7]

Moreover, infrastructure quality can be described as an externality: enjoyable for the

[6] Tirole (1988), discussing quality, information, and public policy, used a meaningful heading "Failure of the Coase Theorem and Product Liability." Tirole's aim was to prove that the intervention of a regulator is necessary to achieve an efficient level of quality production. He argued that there are always externalities on third parties and transaction costs. Therefore, in his opinion, the Coase theorem does not have any application and the intervention of the regulator is purposeful and desirable.

Tirole's argumentation does not impair the theorem, only its practical application by refuting its assumptions. Coase himself, however, did not claim that there are no transaction costs; on the contrary, he claimed that they exist and that they are significant. The theorem is a benchmark for analysis.

[7] E.g., the richest passenger will suffer from defective railroad tracks as the poorest passenger.

consumer ($\partial u/\partial q > 0$) and costly for the producer ($\partial TC/\partial q > 0$). Equating the first-order conditions of utility and profit maximization with respect to q, we obtain:

$$\frac{\partial u(x,q)}{\partial q} = \frac{\partial TC(x,q)}{\partial q} \tag{1}$$

The set of points $\{p,q\} \in \Re^{+}$ for which the marginal utility of the public good equals its marginal cost plots the price–quality contract curve. Equilibria on this curve are Pareto optimal. Notably, optimum quality q^{*} does not depend on the price of the public good nor on the initial endowments of the agents. Thus, the Coase theorem holds for the quality of infrastructure-based public goods.[8]

The contract curve with respect to quality of a public good and the disposable income is flat. I illustrate this result using a modified Edgeworth box (see Figure 1), adapted from Hurwicz (1995).[9] On the horizontal axis, the price of the public good p rises from right to left and the consumer's disposable income after the purchase of the public good $w - x \cdot p$ rises from left to right. The vertical axis shows quality q, which is enjoyable for the user and costly for the monopoly. Curves $u_{1,2,...}$ are the user's indifference curves such that $u_1 < u_2 < u_3 < u_4$. Analogously, curves $\pi_{1,2,...}$ are isoprofit curves of the monopoly such that $\pi_1 < \pi_2 < \pi_3 < \pi_4$.

The location of the equilibrium price–quality set along the contract curve depends on the bargaining power of the agents (i.e., the monopoly aiming at maximizing profit and the regulator aiming at maximizing welfare).

Hurwicz (1995) proved that quasi-linear utility functions are not only a sufficient, but also a necessary condition for the Coase theorem to hold and showed that all other utility functions classes do not lead to the horizontal contract curve.

4 Efficiency and Welfare Implications of Quality Regulation

There are two potential second-best policy strategies for the benevolent regulator of network infrastructure: (i) price cap regulation, i.e., independent set of maximum price p_{max} and a minimum quantity q_{min}; and (ii) rate-of-return regulation (price–quality combinations along

[8] With quasi-linear utility functions, there is no income effect related to the non-*numéraire* good (Hurwicz 1995). For a particular good, quality and quantity conform to a family of indifference curves. A quality change (unless caused by a technological shock) yields an equilibrium along the same indifference curve.

[9] Hurwicz (1995) credited Newbery (1989) and Eggertsson (1990). Eggertsson, on the other hand, attributed this interpretation to Haddock and Spiegel (1984).

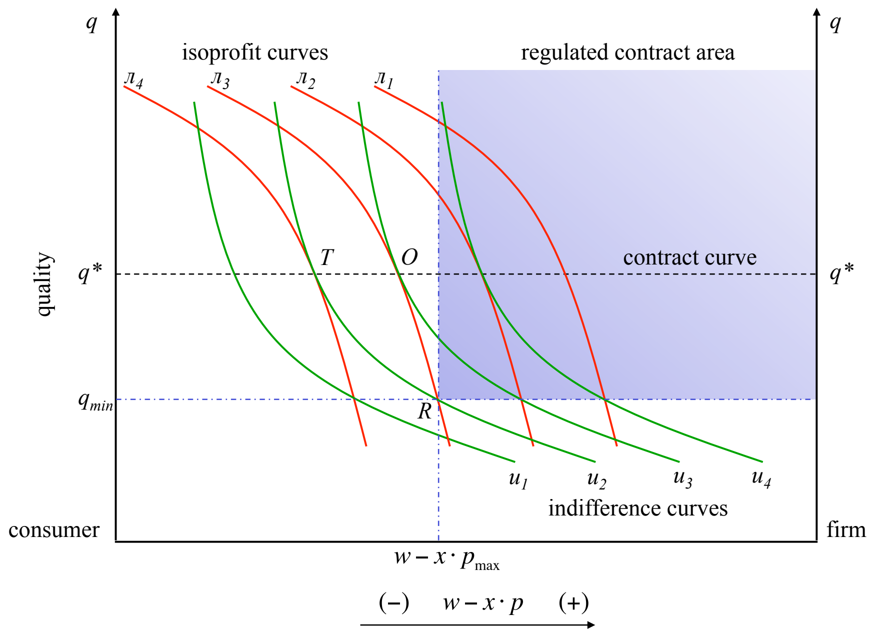

Figure 1: This figure presents indifference curves, isoprofit curves, and the resulting contract curve and regulated contract area. The chart is adapted from Hurwicz (1995). It is composed of two charts: the consumer's indifference curves are read from left to right and the firm's isoprofit curves are read from right to left. On the horizontal axis, the price of the public regulated good p rises from right to left and the consumer's disposable income after the purchase of the public good $w - x \cdot p$ rises from left to right. The vertical axis shows quality q, which is enjoyable for the consumer and costly for the monopoly. Curves $u_{1,2,...}$ are the consumer's indifference curves such that $u_1 < u_2 < u_3 < u_4$. Analogously, curves $\pi_{1,2,...}$ are isoprofit curves of the monopoly such that $\pi_1 < \pi_2 < \pi_3 < \pi_4$. The area below maximum price p_{max} and above minimum quality q_{min} is the regulated contract area. The line joining the points where indifference curves and isoprofits are tangent is the contract curve that defines Pareto efficient allocations.

a fixed isoprofit π).

If maximum price and minimum quality are set independently—e.g., by municipalities and the Ministry of Environment, correspondingly—the monopoly will aim towards the edge of the regulated contract area (i.e., to the price–quality set R in Figure 1), where it maximizes profit.

If the regulated set R is not on the contract line, price–quality regulation leads to Pareto inefficient allocations. For example, if the minimum quality q_{min} is set below the optimal level q^*, the monopoly could shift along the same isoprofit curve (π_3 in Figure 1) from price–quality set R to price–quality set O on the contract curve. Price–quality set O is preferred by the consumer to price–quality set R ($u_2 < u_3$). The shift from R to O is not possible, however, due to maximum price regulation. Likewise, if minimum quality q_{min} is set above the optimal level q^*, Pareto optimal contracting cannot occur either—the regulator conceivably wants "too good" for the consumer, who would prefer lower quality at a lower price, without a decrease in the monopoly's profit.

Alternatively, price–quality sets can be analyzed from the perspective of improving the monopoly's profitability without changing the consumer's utility (e.g., from price–quality set R to price–quality set T), or improving the outcome for both the consumer and the monopoly (i.e., price–quality sets between points O and T). It is worth noticing that Pareto improving set OT is always out the regulated contract area delimited by price cap and minimum quality regulation.

Under independent price cap and minimum quality standards, therefore, the regulators face a hard task: setting the maximum price and the minimum quality so that the resulting set is on the contract curve.[10] Paradoxically, regulation might obstruct the achievement of Pareto efficient contracts on regulated goods. Even though the regulators are benevolent, minimum quality standards and maximum price might be set endogenously at a suboptimal level, because the regulators do not have *ex ante* full information about the consumers' preferences nor the producers' costs.

A quality standard simplifies the bargaining to price, but it achieves efficiency only in the case that it lays on the contracting curve. If quality standards were univocally specifiable, the planner could simply finance the infrastructure and then outsource competitively its operations, in line with Hotelling's (1938) proposal.

Rate-of-return regulation gives the investor certainty about profit and solves the regulator's price–quality conundrum. For it to work, it should not be combined with maximum price regulation. Otherwise, from the perspective of economic efficiency, it would narrow the contract area to inefficient sets (i.e., left bound of the contract area in Figure 1).

[10] Setting price–quality on the contract curve by the regulator is strenuous not only for quasi-linear preferences, but also for other utility function classes. For a proof, let us assume any contract curve $p = f(q)$ such that $\partial p/\partial q \geq 0$. For $\partial p/\partial q = 0$, the case has been made in Section 3 with the applicability of the Coase theorem. For $\partial p/\partial q > 0$, if the corner solution $\{p_{max}, q_{min}\}$ is above the contract curve $p = f(q)$, efficient contracting is not achievable (too costly for the utility company to provide); if $\{p_{max}, q_{min}\}$ is below $p = f(q)$, the corner solution will not be Pareto efficient; lastly, if $\{p_{max}, q_{min}\}$ lays on $p = f(q)$, the solution is Pareto efficient. Whereas with quasi-linear preferences it suffices that the regulator sets only $q_{min} = q^*$, with other utility function classes the regulator has to know the functional description of $p = f(q)$.

5 Scope and Limitation of Infrastructure Regulation

A literal reading of the Coase theorem presents a bilateral view of externalities and a skeptical opinion about government regulation (i.e., a critique of Pigou 1920). It supposes that there are no transaction costs. As transaction costs and contract incompleteness problems are introduced, quality becomes non-contractible due to low enforceability. Free-riding and hold-up problems exacerbate inefficiencies (Hart, Shleifer, and Vishny 1997). Moreover, asymmetric information arising from the fact that public utilities produce experience goods impedes efficient bargaining (Myerson and Satterthwaite 1983): Consumers are not able to signal their preferences to the regulator and the regulator is not able to set the optimal quality level.

The Coase theorem is neither a tautological statement nor false:[11] It is a reference point that shows the scope of regulation besides capture and political economy arguments (Stigler 1971). It compares litigation to liability and proposes to assign property rights to where they would end up *if* there were no transaction costs. Under this normative approach regulation is deemed dispensable.

Shleifer (2010) presents four normative arguments supporting regulation:

1. Bankruptcy and the judgment-proof problem: Consumers might be unable to pay for vital minimum quality and/or small utilities to cover liability costs; therefore, it is better to prevent catastrophes with regulation before they occur.
2. Transaction costs of enforcement: Litigation is expensive, especially in cases of negligence. If the problem is widespread, it is cheaper to regulate.
3. Incentives and corruptibility of enforcers: Judges are assumed to be impartial, fair, and less politically driven. Whereas judges are lazier, less expert, or cheaper to influence than regulators, there is a progressive case for regulation.
4. Activity levels: Fines affect activity levels. When activity levels are too low, litigation may discourage activity because of large fines (e.g., malpractice). Regulation will then be preferred.

Social control across activities might also be explanatory of regulation. There is a big variation of regulatory regimes across countries that must be reconciled with theory. In

[11] See, for example, Halpin (2007), Stigler (1977), and Usher (1998).

a cross section of countries, Aghion, Algan, Cahuc, and Shleifer (2010) documented that regulation is strongly negatively correlated with measures of trust. The causality is two-directional: Distrust breeds demand for regulation, while regulation breeds underinvestment in social capital and distrust.

To achieve price–quality allocations close to the Coasean optimum q^*, the regulator should become a "trust buffer" whose role is to: (a) anticipate and incorporate technological changes into quality policy (i.e., set q_{min} where it would end if there were no regulation), (b) shorten lag times between quality consumption and re-assessment of consumers' preferences (with termination and reallocation of contract, if necessary), and (c) keep record and process the monopoly's performance and consumers' preferences (isoprofits $\pi_{1,2,3,4,...}$ and utility functions $u_{1,2,3,4,...}$ in Figure 1, correspondingly) to facilitate bargaining between the regulator and the monopoly.

In a multiple-consumer setup with heterogeneous quasi-linear preferences, there will be a family of parallel contract curves. The monopoly regulated by rate of return and subject to inter-temporal revision and plausible contract termination will choose a quality output that maximizes social welfare: i.e, the median-consumer contract curve.

6 Conclusions

This paper compares the economic efficiency that results from price and quality regulations (i.e., price ceilings and minimum quality standards) imposed by a benevolent regulator faced with asymmetric information to a Coasean bargaining solution between a median consumer and a monopolist. I argue that rate-of-return regulation yields higher efficiency due to quality externalities of infrastructure-based utilities.

When regulated quality has public good attributes, inverting the regulatory focus—i.e., fixing the monopoly's rate of return and enabling bargaining on quality—enables achieving Pareto optimal allocations: The monopoly is indifferent to the quality output and bargaining can bring quality closer to the socially desirable Coasean optimum.

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