Essays in Regulatory Economics

Selvin Hari Thanacoody

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School of Economics and Centre for Competition Policy
University of East Anglia

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To the memory of my dad

Abstract

This thesis is a collection of four essays related to the economics of regulation. The first chapter presents a theoretical analysis of a water utility's choice of network water retention and service quality when it is constrained by either price cap or rate of return regulation. Under price cap, when demand is inelastic enough, there is a trade-off between water retention and quality provision. A similar trade-off appears under rate of return regulation, but only for low levels of the rate of return. These predictions are tested in the second essay by fitting linear models of water retention and service quality to Eastern European water utility data. We find evidence that higher prices lead to lower water retention rates but to higher quality, while higher rates of return, in the form of higher costs of capital, lead to higher water retention rates but reduce quality provision. We also find that firms under price cap regulation retain less water in their network but provide higher service quality. Considering regulated industries in the broader sense, chapter 3 explores how incentives to reduce costs are affected when a monopolist is regulated by multiple regulators/principals. We use a common agency framework that allows the regulators to have different valuations for the firm's rent and different regulatory costs. When regulators move simultaneously, they grant too high-powered incentives to the firm, but they extract the firm's rent when they move sequentially. In chapter 4, we perform a meta-analysis on the effect of regulation and deregulation on consumer prices based on empirical IO papers covering a wide range of industries. We conduct linear regressions on price reductions in percentage. We find a systematic price reduction of at least 20% associated with economic deregulation. Interestingly, we find mild evidence of a higher price effect associated with social deregulation compared to social regulation.

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Introduction

Public utility and infrastructure services are essential for everyday life but investments and efficiency in the concerned sectors depend highly on how the industry is regulated (Stern and Holder, 1999). This is especially true for the water industry. Part of the literature related to network water retention has characterised the optimal level of water losses exclusively from the firm's cost function (Pearson and Trow, 2005; Wyatt, 2010). We add to this literature by incorporating demand forces and a regulatory framework when deriving the optimal level of water retention under price cap or rate of return regulation in chapter 1. Another part of the literature considers water supply and water losses as two decision variables from the regulator or the regulated water utility (Garcia and Thomas, 2001, 2003). But in practice, the water industry faces additional challenges such as the continuity of the service (IBRD, 2015; Klien and Salvetti, 2019). We contribute to this line of research by incorporating service quality into the analysis.

Chapter 1 provides a theoretical analysis of the water firm's incentives to augment water retention when it can also choose the level of service quality considering the regulatory environment it operates in. Under price cap regulation, the firm first chooses its three inputs – capital, labour and water retention rate, in a cost minimising way subject to a Cobb-Douglas technology. Then, the monopolist sets quantity and quality to maximise profits subject to the price cap. We find that, at the optimum, water retention is decreasing in the price cap if demand is inelastic enough as a higher revenue increases the opportunity cost of engaging in water retention. Quality provision is always increasing in the price, as the firm can extract more consumer surplus. The rate of return regulation model is adapted from Averch and Johnson (1962)'s approach, to which we add a quality component. In this setup, the firm chooses inputs and quality simultaneously, and the comparative statics are interpreted with respect to the rate of return. Quality is always decreasing in the rate of return, but water retention increases in the rate of return for small values of the rate of return, suggesting that a trade-off between quality and water retention arises in that case. While we do not compare water retention rate and quality provision between the two modes of regulation, we give insights on what should be the superior type of regulation from a consumer welfare perspective.

Following the findings in chapter 1, chapter 2 empirically tests the comparative statics of firm behaviour using accounting data from water utilities in Eastern Europe[1]. The dataset is compiled for every utility in every country worldwide by the World Bank under the International Benchmarking of Water and Sanitation Utilities (IBNET) program. We complement this dataset with information on the type of economic regulation implemented, namely price cap and rate of return. Since economic regulation is performed at the national level, all utilities within a given country face the same regulatory mode. In contrast to chapter 1, chapter 2 does not estimate welfare for each type of regulation but instead compares water retention and service quality between price cap and rate of return regulation. By doing so, we complement the existing empirical literature related to water retention and other performance criteria (IBRD, 2015; Garcia and Thomas, 2001, 2003; van den Berg, 2014). These works have either identified the effect of European Union membership and regulator independence or focused on water losses without considering service quality.

The panel of water utilities used for the analysis is drawn from eleven Eastern European countries over a 20-year period. The empirical exercise consists of estimating linear regression models mapped from the firm's first order conditions with respect to water retention and quality derived in chapter 1, where water retention rate and the number complaints received by the utility –a proxy for service quality, are the dependent variables. The main regressors are the average water price, the cost of capital and a dummy identifying price cap or rate of return regulation, but we also control for utilities' operational cost as well as demographics such as population served and gross national income. Among the estimation methods used, only the IV regressions show a significant effect of the price. The results partially confirm the theoretical findings. We find that the regulator is faced with a trade-off between achieving performance targets when allowing the price to change. We also find a significant difference in the water utilities' performances between price cap and rate of return regulation.

The remaining part of the thesis focuses on regulated industries by and large. In general, infrastructure industries are regulated by multiple bodies because of the multiple objectives the public utility must meet. Multi-regulation can take several forms (Laffont, 2005). For instance, it can be geographical with a national authority and a supranational regulator, or it can be multi-functional where an environmental regulator specifically set pollution levels. This fosters a fertile ground for complex interactions between the various players with multiple principals having conflicting interests (Kassim and Waddams Price, 2005). Consequently, the firm's incentives to invest or increase efficiency can be distorted or expanded. Chapter 3 attempts at analysing such implications. While the literature on multiple regulators has

[1] Chapter 2 was accepted for presentation at the 49$^{\text{th}}$ Annual Conference of the European Association for Research in Industrial Economics (EARIE) and at the *XXXVI Jornadas de Economía Industrial*.

been extensively studied under adverse selection, analysis with a moral hazard framework has remained scarce to our knowledge.

We extend a strict moral hazard model developed by Armstrong and Sappington (2007) to a two-principal one agent model in chapter 3. In this setup, there are two states of the world. In the desirable state, the firm charges a low price and welfare is high. In the bad state, the price is high and welfare is low. The firm can exert a privately known cost reducing effort. An efficient firm charges a low consumer price and thus can achieve the desirable state. Regulators grant a monetary transfer to the firm upon observing the desirable state of the world but incur a political cost for doing so as they redistribute money between consumers and the firm. The game is analysed when regulators move simultaneously and when they move sequentially. The model also allows the regulators to have asymmetric valuations for the firm's rent or costs. In the simultaneous game, in contrast to the existing literature, having two symmetric regulators leads to more transfers because it is less costly for each regulator to incentivise the firm to exert effort. This is not necessarily the case when regulators are asymmetric. In the sequential game, total transfers are lower than in the unique regulator game partly because of the first mover's freeriding behaviour. Freeriding is not systematic in this game. The first mover transfers more than the second mover if the gain in welfare across states is sufficiently small when valuations are asymmetric. The chapter finishes with welfare comparisons between multi-regulation and single regulation games.

While chapters 1 to 3 consider regulation to promote efficiency and benefit consumers, in practice the regulatory process has at times been justified on grounds other than the natural monopoly reason. In many cases, regulation was suspected to deter entry to allow incumbent firms to assert their market power by increasing consumer prices (Joskow and Rose, 1989). The subsequent deregulation waves in the West have in most cases reduced the problems caused by regulation, especially in industries where technological progress allowed the introduction of competition. Yet, if competition has facilitated the reduction of market power of incumbent firms, too much competition can come at the cost of failing to internalise other market failures such as pollution, consumer protection, risks or information asymmetry. This is the study of chapter 4. This project is a joint work with Stephen Davies and Sean Ennis, and mainly contributes to the meta-regression literature on price overcharges under collusion (Connor and Bolotova, 2006; Boyer and Kotchoni, 2015) and on deregulation of water utilities (Bel et al., 2010; Carvalho et al., 2012).

Chapter 4 performs a meta-analysis of numerous empirical IO studies to measure the price effects of regulation or deregulation. The dataset has been compiled by the OECD from academic journals, working papers and reports from government or public institutions. It puts together price decreases or increases following a change in the regulatory policy at a point in time for a given market or state but also accounts for price differences between a regulated industry and an unregulated counterpart. We have extended this dataset by identifying the nature of the policy (regulation or deregulation) and the type of the policy – economic or social. We are then able to perform linear regressions on the price effect by controlling for the policy, the purpose of regulation, the type of industry and the type of competition distortion. The papers included in the database cover a wide range of industries, which allows us to obtain a thorough picture of price variations associated to deregulation. From the analysis we have learnt that the magnitude of the price change is different across policy nature and type, with economic deregulation being the source of the highest price reductions in the sample. Price decreases under social deregulation tend to be bigger than price increases following social regulation. The study finishes by raising an important point. Economic deregulation can deliver lower prices by reducing barriers to entry while social regulation is designed to let firms meet safety and quality requirements in the most efficient manner.

Chapter 1

Price cap and rate of return regulation in the water industry

We develop a model of firm behaviour subject to price cap or rate of return regulation, where network water retention is an input choice and quality is an endogenous sunk cost. Lower price caps induce the firm to increase water retention when demand is inelastic enough, while higher rates of return lead the firm to reduce water retention only from high levels of the rate of return. Quality provision is always reduced following price cap reductions, whereas the opposite is true when the rate of return decreases. From a consumer surplus perspective, the regulator prefers a price cap when the cost of capital is not too high as the firm is efficient enough to supply at a low price and can sometimes provide some level of quality. Otherwise, the regulator chooses rate of return regulation to encourage supply by shielding the firm from high costs.

1.1 Introduction

The amount of water retained through a transmission network and the quality of the service to consumers are important performance aspects of any water industry. We study how economic regulation, in the form of price cap and rate of return, affect network water retention rate and service quality in the water utility industry. Water industries, especially in Eastern European countries, face several performance challenges due to important political and economic changes. Despite a general trend in increasing revenues and limiting operating cost increases, water losses in Eastern Europe range from 15% to 60%[1] and remain well above good practice levels. In general, implementation of water retention programs is weak due to the lack of incentives to take such initiatives (Kingdom et al., 2006; González-Gómez et al., 2011). Customer satisfaction levels about the quality of the service is reported to be low and varies considerably between countries. In this context, economic regulation can potentially create or mitigate incentives towards water retention and service quality.

We analyse separately the effect of price cap and rate of return regulation on network water retention and service quality. We perform a theoretical analysis on how the firm's optimal water retention rate and quality provision is affected by changes in the price cap or the rate of return. These regulated outcomes are also compared with the unregulated setup. We also assess implications on consumer welfare, which is obtained by deriving the optimal price cap or rate of return set by a regulator who seeks to maximise consumer welfare. The resulting consumer welfare levels are then compared across regulatory schemes.

The firm's equilibrium water retention and quality are characterised as functions of demand intercept, demand elasticity and costs. The comparative statics are as follows. Under price cap, the effect of regulation on water retention depends on demand elasticity. When demand is inelastic enough a higher price cap decreases water retention rate. Quality is always increasing in the price cap. Under rate of return regulation, higher rates lead to more water retention for low levels of the rate of return, and reduce water retention otherwise. Quality is monotonically decreasing in the rate of return. Moreover, consumer price is affected by the rate of return. It is decreasing in the rate of return when providing quality is not too costly but is increasing in the rate of return otherwise.

Finally, we compare the two modes of regulation in terms of achieved welfare. We find that consumers are better-off under a price cap regime when the cost of capital is low enough but rate of return fares better otherwise.

This paper's main contribution is a theoretical framework allowing for the analysis of the interaction between water retention rate and service quality, which are considered as inputs because of the firm's decision to dedicate resources to repair leakages. A few attempts have

[1] See IBRD (2015).

been made to derive a theoretical framework of water losses. In a regulatory concession contract model, Garcia and Thomas (2003) model water losses as an output which affects welfare. They recover optimal water losses from estimates of a cost function and an environmental damage function which are influenced the utility's inefficiency parameter. In Brea-Solis et al. (2017), water loss is modelled as an input in an input distance function that mirrors the firm's efficiency. In their analysis, water losses incentives are affected by the shadow price of water and the price cap allowed by the regulator. While these results are based on a single regulatory mode, our paper compares the firm's behaviour across two different regulatory modes, namely price cap and rate of return. Some papers find that returns from reducing losses are diminishing. For instance, Wyatt (2010) provides a financial modelling of water losses and derives an optimal amount of water losses for the firm. The graphical illustration of the economic leakage level put forward by Pearson and Trow (2005) shows that a minimal cost of water production is implied by a positive amount of leakage. We add to this literature on water market by analysing how market forces and regulation affect the firm's behaviour.

A literature survey from Sappington (2005) points out that stringent price regulation can lead the firm to reduce quality provision. However, if regulated prices reflect realised costs, the firm can have incentives to increase quality. The survey also highlights that regulation entails a trade-off between output expansion and quality provision. Our results show that a trade-off can instead take place between input choice and quality provision. The seminal works of Spence (1975) and Sheshinski (1976) have compared output and quality levels under regulation and no regulation but also across different regulatory modes for a given level of surplus and profit. An interesting point raised by the former is that rate of return regulation can increase quality provision if it is capital intensive but reduce it otherwise. We contribute to this literature by comparing consumer welfare levels obtained under price cap and rate of return regulation. When quality is unverifiable, Lewis and Sappington (1988) show that the regulator's imperfect demand information affect the optimal regulatory scheme, while Laffont and Tirole (1993) show how the power of the incentive regulatory scheme is affected by quality concerns. Their analysis is extended by Dalen (1997) in a dynamic setting. Not only do we suggest which mode of regulation is best for consumer welfare, we look at how the cost of quality affects the firm's input mix.

More recently, Fraja and Iozzi (2008) study the effect of a quality-adjusted RPI-X price cap on quality provision by extending Vogelsang and Finsinger (1979)'s model of price regulation, and highlight a trade-off between prices and quality. They argue that such price caps reduce incentives for cost reduction in the short run but induce the firm to practice socially optimal prices and quality in the long run. We instead compare two radically different types of regulation.

Section 1.2 introduces the setup. Section 1.3 presents a model of firm behaviour with respect to water retention rate and quality under the absence of regulation, price cap regulation and rate of return regulation. Section 1.4 compares consumer welfare between the two regulatory schemes. Section 1.5 concludes.

1.2 Setup

We analyse the water monopoly's behaviour under two different modes of regulation: price cap and rate of return. As a benchmark, we first derive the unconstrained optimal behaviour of the water supplier and we compare this outcome with the optimal solutions obtained under price cap regulation and rate of return regulation. We make the following assumptions.

Production technology. The production technology is defined by a Cobb-Douglas production function[2]: $k^{\alpha_k} l^{\alpha_l} v^{\alpha_v} = q$, with $\alpha_k, \alpha_l, \alpha_v \in [0,1]$ and $\alpha_k + \alpha_l + \alpha_v = \alpha$. The quantity of water q is the amount *delivered* to final consumers; k, l are respectively capital and labour, and the water retention rate $v \in [0,1]$ and is such that engaging in water retention efforts increases the water delivered to consumers for a given amount of k and l. Water retention enters the production technology in a similar way to Dawson and Lingard (1982)'s Cobb-Douglas production function which includes a management input in addition to labour and machinery costs. This input captures the entrepreneurial initiatives of the manager to increase productivity[3].

Quality. The level of quality is denoted by x. The cost of providing quality is $\mu \frac{x^2}{2}$ where μ is the marginal cost of quality. We define quality as either the quality of water or the quality of the service such as service coverage, supply continuity or the number of complaints received by the utility (van den Berg and Danilenko, 2011, p. 139; Haider et al.; 2013; p. 9-10). Quality enhancing investments are not affected by changes in the quantity supplied. For instance quality depends on the installation of a water softening plant or the replacement of filters which cannot be considered as a marginal cost of production because they do not affect quantity (Turvey, 1976, p. 159). Service continuity depends on a higher pipe diameter, which yields a higher construction cost (Abu-Madi and Trifunovic, 2013; Cronk and Bartram, 2018). Coverage costs or system expansion to new customers costs are constant while customer service attention costs increase with the number of new customers rather than with the quantity of water delivered (Griffin, 2006, p. 329-331; Waddams Price et al.; 2008).

Consumer demand. Consumer demand for water is given by the inverse demand function $p(q, x) = a - bq + x$, where b is the inverse demand slope and the quality level x shifts the demand curve upwards.

[2] The Cobb-Douglas functional form allows for the derivation of closed-form solutions when one analyses the firm's behaviour from an optimisation approach. See Wolak (1994), Brocas et al. (2006) and Philipps (2013) for applications in water industries.

[3] In the water industry, water loss reduction initiatives comes from the manager's and engineers' incentives to repair leaks (Kingdom et al., 2006; Lise and Bakker, 2005).

Price cap regulation. The regulator sets a maximal price at which the product can be sold, whatever quantity and quality chosen by the firm. In other words, if the firm were to choose q, x such that $\bar{p} < p(q, x)$, the firm would still not be able to sell at more than $\bar{p}$. Since price cap regulation is known to affect quality and quantity but not the allocation of inputs, it is reasonable to assume that the firm's behaviour is in two stages. First, at the production level, the firm optimises the choice of inputs to minimise production costs. Second, at the market level, the firm chooses the optimal quantity and quality for any $\bar{p}$.

Rate of return regulation. Under rate of return, the regulator sets rate of return $s \geq 0$ on each unit of capital such that the revenue generated by the firm is just enough to cover the total cost of supplying water and the cost of quality provision. Formally, the rate of return constraint is $p(k, l, v, x)k^{\alpha_k} l^{\alpha_l} v^{\alpha_v} \leq wL + mv + \mu\frac{x^2}{2} + sk$ as in Averch and Johnson (1962) but with a quality component. Since rate of return regulation affects the firm at the input choice stage, we assume that where k, l, v, x are chosen simultaneously[4]. Note that the price charged by the firm is then induced by its optimal policy. Finally, the firm's behaviour is framed in a single stage where the optimal inputs are determined simultaneously.

1.3 Positive analysis

1.3.1 Production cost function

We begin by characterising the firm's optimal mix of inputs. The total cost function of the firm consists of the production cost and the cost of quality provision. The production cost function is a long-run cost function where all the inputs are variable. Since the analysis focuses on Eastern European water systems, where the infrastructure has experienced major changes in size, we assume that capital is variable. Under price cap, the firm first chooses its input to minimise production expenses given the production technology. The production cost function is thus characterised by solving the following optimisation program[5]:

$$\min_{k,l,v} \quad C(k, l, v) = rk + wl + mv$$
$$\text{s.t.} \quad k^{\alpha_k} l^{\alpha_l} v^{\alpha_v} = q$$

[4] In practice, firms make all their decision simultaneously. Defining a two-stage process in the price cap environment simplifies the mathematical analysis.

[5] We do not make a distinction between the behaviour of the public and a private firm. Day to day operations are similar between public and private firms (Sappington and Stiglitz, 1987). In either public or private firms, politicians or shareholders delegate the firm's operations to a manager who has detailed knowledge about the industry and can have similar incentives across ownership types. Furthermore, because of public service obligations it maximises output whereas the private firm chooses inputs in a cost minimisation way. Duality theory shows that economic efficiency is equivalent between cost minimisation and maximising output from a given use of resources (Ferguson, 1969). Empirically, DiCosmo (2013) finds no evidence of efficiency difference between public and private firms in the Italian water industry and Aubert and Reynaud (2005) highlight that most studies do not document which type of ownership is more efficient.

where r, w and m are the corresponding input prices. The price of water retention rate m accounts for the opportunity cost of allocating input in reducing losses in terms of maintenance and managerial effort dedicated in augmenting the retention of water through the distribution system. Engaging in loss reduction is not the most preferred option for the firm as it requires pipe fixing and repairs, night work, constant dedication and funding (Kingdom et al., 2006).

Lemma 1.1. *The firm's optimal choice of water retention rate v^* increases in the cost of capital, the wage rate and output q and decreases in its own cost m.*

$$v^* = A_v w^{\frac{\alpha_k}{\alpha_v}} r^{\frac{\alpha_l}{\alpha}} m^{-\frac{\alpha_l+\alpha_k}{\alpha}} q^{\frac{1}{\alpha}} \tag{1.1}$$

$$l^* = A_l w^{-\frac{\alpha_k+\alpha_v}{\alpha}} r^{\frac{\alpha_k}{\alpha_v}} m^{\frac{\alpha_v}{\alpha}} q^{\frac{1}{\alpha}} \tag{1.2}$$

$$k^* = A_k w^{\frac{\alpha_l}{\alpha}} r^{-\frac{\alpha_l+\alpha_v}{\alpha}} m^{-\frac{\alpha_l}{\alpha_v}} q^{\frac{1}{\alpha}} \tag{1.3}$$

See proof in Appendix 1.A.1

By characterising total expenses and the production technology in this manner, we are able to express the optimal water retention rate as a function of input prices. The water retention rate is increasing in capital and labour input costs as higher costs lead the firm to save more water but decreasing in the cost of water retention as illustrated by network repairs and managerial capacity. The total cost function is then derived by inserting the optimal values into the total expenses expression gives[6]:

$$c(r, w, q) = \theta w^{\frac{\alpha_l}{\alpha}} r^{\frac{\alpha_k}{\alpha}} m^{\frac{\alpha_v}{\alpha}} q^{\frac{1}{\alpha}}$$

where $\theta = A_k + A_l + A_v$. Denoting $c = \theta w^{\frac{\alpha_l}{\alpha}} r^{\frac{\alpha_k}{\alpha}} m^{\frac{\alpha_v}{\alpha}}$, the final production cost expression can then be written $cq^{\frac{1}{\alpha}}$, where c is the average production cost of water in the case of constant returns to scale ($\alpha = 1$).

1.3.2 Unconstrained behaviour

As a benchmark, we characterise the firm's optimal policy under no regulation. Assuming constant returns to scale, the firm's objective can be written as[7]:

$$\max_{q,\, x} \quad \pi(q, x) = [a - bq + x]q - cq - \mu\frac{x^2}{2} \tag{1.4}$$

[6]We provide the full expressions for A_K, A_L and A_E in appendix 1.A.1.

[7]The properties of the first order conditions are analysed in the appendix in the case of non-decreasing returns to scale.

Proposition 1.1. *The optimal quantity $\hat{q}(.)$, water retention rate $\hat{v}(.)$ and quality $\hat{x}(.)$ chosen by the unregulated monopolist are interior solutions and are given by:*

$$\hat{q}(.) = \frac{\mu(a-c)}{2b\mu - 1} \tag{1.5}$$

$$\hat{v}(.) = A_v w^{\frac{\alpha_k}{\alpha_v}} r^{\frac{\alpha_l}{\alpha}} m^{-\frac{\alpha_k+\alpha_l}{\alpha}} \left(\frac{\mu(a-c)}{2b\mu-1}\right) \tag{1.6}$$

$$\hat{x}(.) = \frac{a-c}{2b\mu - 1} \tag{1.7}$$

See proof in Appendix 1.A.2.

As expected, the quantity produced increases with the value that consumers have for water. Since demand shifts upwards, the firm finds it more profitable to supply more water. The more the firm is inefficient, that is the higher the cost of production, the less it supplies. However, the unconstrained monopolist will not necessarily pass on any cost increase to consumers. Indeed, the firm charges a price $\hat{p}(\hat{q}, \hat{x}) = \frac{b(a+c)\mu - c}{2b\mu - 1}$. This expression shows that the firm will pass on any cost increase to consumers if demand is inelastic enough since the price increases in the unit cost if $b\mu > 1$.

Given that water retention rate increases in quantity delivered, the firm improves network efficiency with higher demand. When demand for water is high, the opportunity cost from losing water is high and hence the firm has an incentive to incur more effort in reducing network losses. Rearranging (1.6), water retention can be re-expressed as a concave function of the average cost c: $\frac{A_v \mu c(a-c) w^{\left(\frac{\alpha_k}{\alpha_v} - \frac{\alpha_l}{\alpha}\right)} r^{\left(\frac{\alpha_l - \alpha_k}{\alpha}\right)}}{\theta(2b\mu-1)m}$. Water retention first increases in the cost as the firm engages in network loss reduction to save costs, but then the cost effect of water retention initiative outweighs the cost savings effect. It becomes too costly for the firm to retain more water through the network.

Equation (1.7) shows that the less costly is water production and supply, the higher is the quality provided. As it is costly for the firm to increase quality, any savings made from reducing the unit production cost can be offset by increasing quality. However, as in the standard model of quality provision by a monopolist, the profitability of the firm crucially depends on the demand side. The higher the willingness to pay of consumers, the higher service quality as the firm can pass on any cost increments due to quality enhancements. The inverse demand slope b is negatively related to quality. This is counter-intuitive as one would expect that a more inelastic demand would drive more quality as a higher price would lead to less distortions in sales. However, a higher perceived quality shifts the demand curve upwards. The flatter the demand curve, the higher the increase in price from such a shift.

1.3.3 Price cap regulation

Price cap regulation occurs at the market level where the regulator sets a price ceiling $\bar{p}$ that the firm cannot exceed when maximising profits. Having chosen its input mix in the first stage, the firm now chooses output and quality level based on the price cap set by the regulator by solving:

$$\begin{aligned} \max_{q,\,x} \quad & \pi(q,x) = [a - bq + x]q - cq - \mu\frac{x^2}{2} \\ \text{s.t.} \quad & \bar{p} \leq a - bq + x \end{aligned}$$

Lemma 1.2. *The price cap set by the regulator is binding for the firm and implies a solution pair $\{q^*(.), x^*(.)\}$ that is different from the unconstrained problem.*

See proof in appendix 1.A.3.

The regulator does not set a price cap $\bar{p}$ such that $a - bq + x \leq \bar{p}$. By doing so, the regulator can implement a loose price cap such that $\bar{p} \geq \hat{p}$. Then, it is as if the firm is still unconstrained in its pricing policy and will choose the unconstrained profit maximising levels of quantity $\hat{q}$, water retention rate $\hat{v}$ and quality $\hat{x}$. When $\bar{p} \leq a - bq + x$, the cap is set at an affordable level for consumers and the firm's ability to extract consumer surplus is limited.

In most Eastern European countries, it is reasonable to expect that the price will be set below the demand intercept as prices are kept artificially low due to political pressures (IBRD, 2015). When the regulator implements a stringent price cap ($\bar{p} \leq \hat{p}$), the firm's ability to extract consumer surplus is now limited but the optimal level of quality no longer satisfies the condition that an incremental upward shift in demand should equal the marginal cost of providing an additional level of quality[8].

In this case the firm would set the lowest level of quality such that $\bar{p} = a - bq + x$ or $x = \bar{p} - a + bq$. The firm then solves[9].

$$\max_{q} \pi(q) = \bar{p}q - cq - \mu\frac{(\bar{p} - a + bq)^2}{2}$$

The following proposition characterises the solution to this problem.

Proposition 1.2. *Under price cap regulation, when the constraint is binding, the optimal water retention rate increases in the price if demand is elastic enough ($\frac{1}{b} \geq \mu$). Otherwise, the optimal water retention rate decreases in the price. The optimal quality is monotonically*

[8]Even if the price cap is lower than the marginal cost of production, the firm can provide a strictly positive amount of quality because of implicit incentives stemming from workers' pleasure to work (Dalen, 1997).

[9]In the rate of return model the slope of the demand curve is normalised to one to make the analysis tractable. We don't make this normalisation in the case of price cap to keep the results as general as possible.

increasing in the price. These quantities are given by

$$v^*(.) = A_v w^{\frac{\alpha_k}{\alpha_v}} r^{\frac{\alpha_l}{\alpha}} m^{-\frac{\alpha_k+\alpha_l}{\alpha}} \left(\frac{b\mu(a-\bar{p})+\bar{p}-c}{b^2\mu}\right), \tag{1.8}$$

$$x^*(.) = \frac{\bar{p}-c}{b\mu} \tag{1.9}$$

$$q^*(.) = \frac{b(a-\bar{p})\mu+\bar{p}-c}{b^2\mu}. \tag{1.10}$$

See proof in appendix 1.A.3.

The effect of price cap regulation on quantity and thus on the water retention rate depends on the slope of the demand curve b. Note that, when the constraint is binding, $v^*(.)$ increases in $\bar{p}$ when $b < \frac{1}{\mu}$ and decreases as $\bar{p}$ increases when $b > \frac{1}{\mu}$. When demand is elastic, an increase in the price decreases sales more than proportionally for the firm. The firm compensates this revenue loss with cost savings through higher network water retention. Conversely, when demand is inelastic a higher price cap will generate a higher revenue. This higher revenue reduces the opportunity cost of maintaining leakages. Put differently, the monopolist has less incentives to augment water retention to save costs because of the higher revenues generated. By the law of demand and provided that when the regulated price is lower than the unregulated price and greater than the cost of production, the firm increases the quantity of water delivered with respect to the unconstrained setting. Thus a stringent price cap incentivises the firm to increase water retention rate as its market power is limited by the price cap.

The optimal quantity $q^*(.)$ can be rewritten $\frac{a-\bar{p}}{b} + \frac{x^*}{b}$. From this expression, $q^*(.)$ increases as the level of quality $x^*(.)$ gets higher. By equation (1.8), the same comparative statics apply to the retention rate $v^*(.)$. The level of quality shifts the demand curve upwards as consumers are willing to pay more for the same amount of water. As quantity supplied increases, the growing opportunity cost from network losses leads the firm to increase the retention rate $v^*(.)$.

It is not sufficient to reduce the price cap to encourage water retention. Comparing (1.6) and (1.8), water retention is higher under price cap than under no regulation if the cost of production is low enough. In other words, regulation can lead to a better outcome if the firm is sufficiently efficient as it can earn profits even from a low price cap.

When the price cap is equal to the unregulated monopoly price, the firm is indifferent between $\hat{x}$ and $\bar{x}$ and thus provides the same level of quality. Since $x^*(.)$ is increasing in $\bar{p}$, the firm chooses a lower level of quality if the regulator implements $\bar{p} < \hat{p} = \frac{b(a+c)\mu-c}{2b\mu-1}$. Within the price cap regulation setting, it is clear that the firm reduces the level of quality following a tightening of the price ceiling. This is an expected result since it is costly for the firm to provide quality. The firm increases quality as long as the marginal benefit of doing so is greater than its marginal cost of quality provision. The cost parameter μ decreases the level of quality of the firm. In other words, the higher the pace of quality cost increases, the less profitable it is to increase quality which thereby reduces the firm's incentives to enhance quality. The level of quality also decreases with c. Less efficient firms are unable to generate enough rent to invest in more service quality. Again, the higher is the slope of b, the more demand is inelastic, the less the firm provides quality because the increase of revenue following a demand shift is reduced when demand is more inelastic.

1.3.4 Rate of return regulation

We now analyse the firm's behaviour under rate of return regulation, which is an alternative scheme used in Eastern European countries. Under rate of return regulation, following the approach of Averch and Johnson (1962), the price is instantaneously adjusted by the firm's output through the demand function $a - bf(k, l, v) + x$. The firm is allowed a fair rate of return s on each unit of capital used and is such that the profit is upper-bounded. Taking into account the cost of quality, the rate of return constraint can be rewritten as

$$\frac{p(f(k, l, v, x))f(k, l, v) - wl - mv - \mu\frac{x^2}{2}}{k} \leq s$$

As explained in section 1.2, rate of return affects the firm's behaviour at the input choice level and thus implies a simultaneous choice of inputs. Expressing the firm's profit in terms of inputs, the firm's problem writes:

$$\begin{aligned} \max_{k,l,v,x} \quad & \pi(k, l, v, x) = (a - bk^{\alpha_k}l^{\alpha_l}v^{\alpha_v} + x)k^{\alpha_k}l^{\alpha_l}v^{\alpha_v} - rk - wl - mv - \mu\frac{x^2}{2} \\ \text{s.t.} \quad & (a - bk^{\alpha_k}l^{\alpha_l}v^{\alpha_v} + x)k^{\alpha_k}l^{\alpha_l}v^{\alpha_v} - wl - mv - \mu\frac{x^2}{2} \leq sk \end{aligned} \tag{1.11}$$

Due to the nature of the constraint and the Cobb-Douglas specification, it has proved difficult to obtain a tractable solution of this optimisation problem. To make the problem analytically tractable, we set $\alpha_k = \frac{1}{2}, \alpha_l = \frac{1}{4}, \alpha_v = \frac{1}{4}$ and normalise $b = 1, w = 1, m = 1$, which we define as the *normalised economy*. While there has not been a clear consensus about the relative values of output elasticities in the academic literature, Teeples and Glyer (1987) and Zhang et al. (2017) find that the output elasticity of capital is higher than that of the other inputs for the water industry. This confirms the capital-intensive nature of water industries where the highest cost share lie within the water transportation part (OFWAT, 2007). Hence, it is reasonable to assume that $\alpha_k > \alpha_l, \alpha_v$. Besides, we are interested in the comparative statics of the optimal behaviour with respect to the intensity of regulation.

Intuitively, if the firm was solving this optimisation problem freely, that is as a non-regulated monopolist, it would earn an unconstrained rate of return $\hat{s}(r)$ that would be higher than the regulated rate of return, since there would not be a need for regulating the firm otherwise. As stated by the following lemma, the regulated rate of return should be binding for the firm.

Lemma 1.3. *Consider the normalised economy. Under rate of return regulation, the constraint is binding if the regulated rate of return s is lower than the unregulated monopoly rate of return $\hat{s}(r)$.*

The intuition of the statement is straightforward: the goal of rate of return regulation is to constrain the firm's profit, and the regulator will determine a rate of return and a revenue requirement such that the firm is not residual claimant of any profits above what is authorised. In the unconstrained monopoly case, the rate of return is induced by the firm's behaviour. If the choice of inputs to produce the unregulated monopoly output generates a rate of return such that it is lower than the regulated rate s, the regulatory constraint does not need to bind and regulation becomes irrelevant. The outcome would then be the firm's behaviour under the unconstrained environment.

Determining a fair rate of return protects the firm against positive cost shocks. The output elasticity of capital is smaller than one and thus implies that the returns on capital are diminishing. Hence, for some level of r high enough, the unregulated firm cannot break-even and would exit the market. To ensure that the firm continues to serve consumers when the cost of capital is very high, the regulator thus guaranties a *fair* rate of return which such that $\hat{s} > s \geq r$.

Because the firm is able to shift demand upwards through its choice of quality, the level of the rate of return can mitigate or amplify the Averch-Johnson effect of over-capitalisation. This is stated in the following proposition.

Proposition 1.3. *Consider the normalised economy. Under rate of return regulation, the optimal water retention rate increases in the rate of return for low levels of the rate of return but decreases otherwise. The optimal quality always decreases in the rate of return. These quantities are given by:*

$$\tilde{v}(.) = \tilde{l}(.) = \frac{2s\mu(a^2 - 8s)}{a^2(2\mu - 1)}, \tag{1.12}$$

$$\tilde{x}(.) = \frac{(a^2 - 8s)}{a(2\mu - 1)}. \tag{1.13}$$

Moreover, capital, output and price are respectively given by:

$$\tilde{k}(.) = \frac{\mu(a^2 - 8s)}{2s(2\mu - 1)}, \tag{1.14}$$

$$\tilde{q}(.) = \frac{\mu(a^2 - 8s)}{a(2\mu - 1)}, \tag{1.15}$$

$$\tilde{p}(.) = \frac{a^2\mu + 8(\mu - 1)s}{a(2\mu - 1)}. \tag{1.16}$$

The price is non-increasing in the rate of return if $\mu \in \left[\frac{1}{2}, 1\right]$ *and increases in the rate of return if* $\mu > 1$.

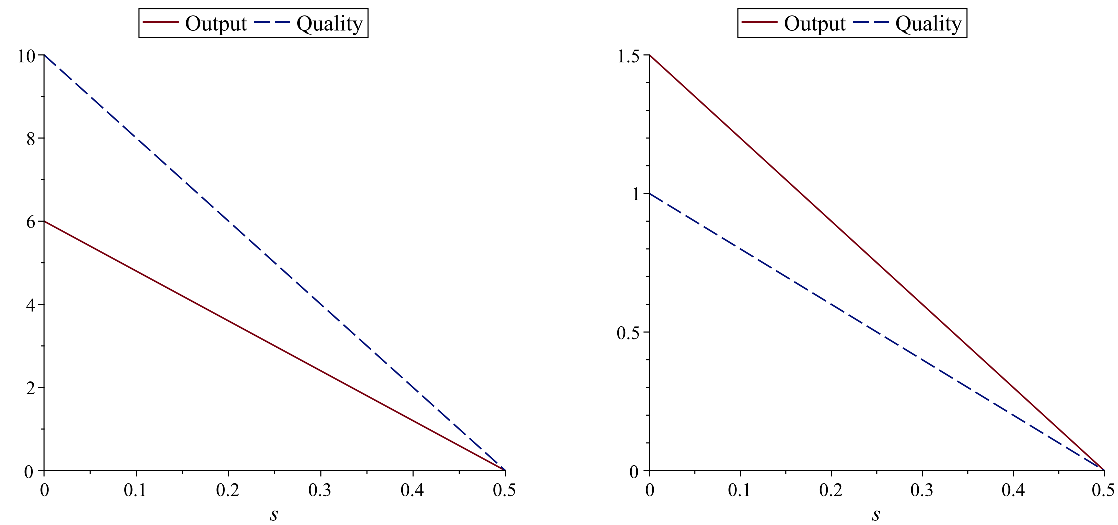
See proof in appendix 1.A.5.

Under rate of return regulation, when $s \in \left[0, \frac{a^2}{16}\right]$, quality and water retention are substitutes as they are moving in opposite directions with respect to the rate of return s. Water retention first increases in the rate of return as the firm is able to cover for higher water retention costs. The decreasing effect from higher levels of the rate of return parallels the effect found in price cap regulation. When the rate of return is too high, the higher revenue earned increases the opportunity cost of retaining more water and thereby reduces incentives to rehabilitate the network. The level of quality provision decreases in the rate of return because the firm does not earn any extra profit from the higher demand resulting from quality improvements.

In addition, a fair return on capital makes the firm more inefficient because it artificially increases capital costs. Therefore, a higher rate of return reduces the firm's incentives to provide service quality. A higher return on capital disincentivises the firm to invest in capital since it will earn more for each unit of capital while being bounded by the revenue requirement constraint.

Note that the optimal capital stock $\tilde{k}(s)$ is a decreasing function of s, which is consistent with the Averch-Johnson effect. The firm increases quantity and quality in order to increase the revenue requirement when the regulator shrinks the rate of return. An increase in the allowed rate of return s from small levels highlights a trade-off between capital expansion and water retention efforts as the firm substitutes water retention for infrastructure extension. As capital cost is increased, the firm uses more of other inputs. In the current setup, the comparative statics of the optimal labour force is similar to the comparative statics of water retention efforts. Indeed, as engineers and technicians are required to perform water loss reduction programs, their productivity would increase water retention (Kingdom et al., 2006).

Quantity and quality are complements and this has some interesting implications on the variation of price with respect to the rate of return. When μ is high enough ($\mu \geq 1$), the price is positively affected by the rate of return. As the firm becomes more inefficient through a higher rate of return, the firm chooses to reduce output more than quality. The firm then



(a) Effect of the rate of return s on output and quality for $\mu = 0.6$.

(b) Effect of the rate of return s on output and quality for $\mu = 1.5$.

Figure 1.1: Comparative statics of output and quality under rate of return regulation.

passes this higher inefficiency on consumers through a higher price. This higher price in turn allows the firm to mitigate quality distortion. Put differently, when the firm has a high marginal cost of quality, a lower rate of return reduces the firm's cost of capital and thus decreases the price. Figure 1.1 depicts how output (solid lines) and quality (dashed lines) change when the rate of return increases for different values of μ and $a = 2$. For instance, when $\mu = 1.5$, the output effect dominates the quality effect, as can be seen in panel 1.1b.

For $\mu \in \left[\frac{1}{2}, 1\right)$, the price is inversely related to s. In this case, a reduction in s considerably expands the firm's revenues as the price increases due to a sharp increase in quality provision. Since the marginal cost of quality is not too high, the firm compensates any reduction of the rate of return by over-investing in capital and quality to increase the price. As returns to scale are constant, the firm can then increase the average cost. By doing so, the price increases as well as the firm's revenue due to the cost reimbursement nature of rate of return regulation. As illustrated by panel 1.1a, when μ is low enough, an increase in the rate of return reduces quality more than output. Finally, from equation (1.16), the price drops as μ goes up. That is, when the cost of quality is high, the firm reduces quality and thus decreases the price.

Note that water retention under rate of return is higher than under no regulation if $s \leq \frac{(\sqrt{2}\sqrt{r}a-4r-4)a^2}{32}$ and quality under rate of return is higher than the unregulated quality if $s \leq \frac{\sqrt{\frac{1}{2}\sqrt{r}}}{2}$. When the firm is unregulated, the rate of return earned does not provide enough incentives for quality provision and distorts output downwards. Because the rate of return applied by the regulator is lower than the unregulated rate of return, regulation can yield a better outcome if the regulator wishes to encourage the firm to increase water retention and quality. However from a consumer welfare viewpoint, a low s can be costly because the firm might over-invest or provide more quality than what consumers value.

1.4 Consumer welfare analysis

We now analyse the impact of both types of regulation on welfare. The above analysis shows that the firm's optimal levels of water retention rate and quality both depend on either the price cap or the rate of return, which were considered exogenous in the firm's behaviour. In principle, the regulator's duty is to ensure that the service is affordable to consumers while complying with cost recovery principles. Thus, it is reasonable to assume that the regulatory instruments are set in a consumer welfare maximising way such that the firm is not making losses.

1.4.1 Price cap

Since the firm's behaviour under price cap regulation, as stated in proposition 1.2, is a function of the price cap, the regulator's welfare is a function of $\bar{p}$. The price is itself chosen by the regulator who anticipates the firm's behaviour for any given price cap. Using expressions (1.9) and (1.10), the regulator solves:

$$\begin{aligned}
\max_{\bar{p}} \quad & \int_0^{q(\bar{p})} (a - bq + x^*(\bar{p}))\, dq - \bar{p}q^*(\bar{p}). \\
\text{s.t.} \quad & x^*(\bar{p}) = \frac{\bar{p} - c}{b\mu}, \\
& q^*(\bar{p}) = \frac{b(a-\bar{p})\mu - c + \bar{p}}{b^2\mu}, \\
& \bar{p}q^*(\bar{p}) - cq^*(\bar{p}) - \mu\frac{(x^*(\bar{p}))^2}{2} \geq 0.
\end{aligned} \tag{1.17}$$

This problem can be reduced to a consumer welfare objective that depends on $\bar{p}$:[10]

$$\begin{aligned}
\max_{\bar{p}} \quad & CS(p) = \frac{(a-\bar{p})\mu - c + \bar{p})^2}{2\mu^2} \\
\text{s.t.} \quad & \bar{p}q^*(\bar{p}) - cq^*(\bar{p}) - \mu\frac{(x^*(\bar{p}))^2}{2} \geq 0
\end{aligned} \tag{1.18}$$

The consumer surplus function is convex in $\bar{p}$. First it decreases because of the negative direct effect of price on consumer welfare. Second, quality has a positive effect on welfare. Thus, consumer welfare starts to rise with the price cap as the quality effect dominates the

[10] In the normalised economy, the unit cost of the firm under price cap regulation is $c = 4\sqrt{\frac{1}{2}}\sqrt{r}$. In this subsection we keep c for notation convenience.

direct effect. Hence, there can be more than one solution to the regulator's problem. The regulator can choose as low a price as possible or the highest possible price. The lowest price set by the regulator is such that the firm earns zero profit and the highest price corresponds to the unconstrained monopoly price. The price decided is thus the one that generates the highest consumer welfare.

The prices for which the firm's profit equals zero are $\{\bar{p_1}, \bar{p_2}\} = \left\{\frac{2a\mu - c}{2\mu - 1}, c\right\}$. Alternatively, the profit maximising price is given by $\hat{p} = \frac{(a+c)b\mu - c}{2b\mu - 1}$. To make welfare comparable between regulatory modes, we derive the results in the normalised economy. The value of consumer welfare at the socially optimal prices depends on the value of μ, as stated in the following proposition.

Proposition 1.4. *Consider the normalised economy. Under price cap regulation, the welfare maximising price is* $\bar{p_1} = \frac{2a\mu - c}{2\mu - 1}$ *if and only if* $\mu < 1$ *and consumer surplus is* $CS^{PC} = \frac{(a-c)^2}{2(\mu-1)^2}$. *Otherwise,* $\bar{p_2} = c$ *and consumer welfare is given by* $CS^{PC} = \frac{(a-c)^2}{2(2\mu-1)}$. *The unregulated consumer welfare* $CS^U = \frac{\mu^2(a-c)^2}{2(2\mu-1)}$ *is lower than consumer welfare under any regulated price.*

See proof in appendix 1.A.6.

Although, one of the price caps is increasing in the marginal cost of quality, any regulated price caps lead to a higher consumer welfare than an unregulated price regardless of the value of μ. The direct negative effect associated with a higher price is stronger than a higher welfare resulting from a higher quality. This is consistent with many cases of public owned utilities where the regulator sets the price cap such that firm's profit is null. When μ is low enough, the regulator chooses the price cap $\bar{p_1}$, which is higher than $\bar{p_2}$. Allowing a higher price when the marginal cost of quality is low enough enables the firm to provide more quality and therefore obtain a higher welfare. Conversely, a high enough marginal cost of quality leads the regulator to choose the lower regulated price $\bar{p_2}$. Indeed, a higher price ($\bar{p_1}$) does not induce the firm to increase quality substantially because it is costly. As a result, the direct negative effect of price on welfare dominates the indirect quality effect of price.

1.4.2 Rate of return

Under rate of return regulation, the regulator chooses s by considering the firm's behaviour for any given level of the rate of return as described in proposition 1.3. Since the regulator allows a fair rate of return to the firm, the latter earns a positive profit. Before stating the regulator's objective, we re-express the rate of return constraint as a function of the amount of capital. Subtracting rk from both sides of the revenue requirement constraint in problem (1.11), the firm's profit can be expressed as:

$$(a - b + \tilde{x}(s))\,\tilde{q}(s) - r\tilde{k}(s) - w\tilde{l}(s) - m\tilde{v}(s) - \mu\frac{\tilde{x}(s)^2}{2} = (s - r)\tilde{k}(s).$$

Considering the firm's policy for any given rate of return, as defined in expressions (1.13) to (1.16), the regulator's problem is expressed as:

$$\begin{aligned}
\max_{s} \quad & \int_0^{q(s)} (a - bq + x)dq - \tilde{p}(s)\tilde{q}(s) \\
\text{s.t.} \quad & (s-r)\tilde{k}(s) \geq 0, \\
& \tilde{x}(s) = \frac{(a^2 - 8s)}{a(2\mu - 1)}, \\
& \tilde{k}(s) = \frac{\mu(a^2 - 8s)}{2s(2\mu - 1)}, \\
& \tilde{q}(s) = \frac{\mu(a^2 - 8s)}{a(2\mu - 1)}, \\
& \tilde{p}(s) = \frac{a^2\mu + 8(\mu - 1)s}{a(2\mu - 1)}.
\end{aligned} \tag{1.19}$$

Because a fair rate of return is such that $s > r$ and the revenue requirement is determined by a cost reimbursement rule, the profit constraint of this problem is satisfied with strict inequality, as, following proposition 1.3, the firm's optimal behaviour is such that s and is higher than r, $\forall r \in \left[0, \frac{a^2}{8}\right]$. Put differently, when (1.13), (1.14), (1.15) and (1.16) are binding, the rate of return constraint is slack. Note that if the regulator wanted to make this constraint binding, this would be possible only if $s = \frac{a^2}{8}$. But then, this implies that consumer welfare is also equal to zero. Therefore, in the normalised economy, the regulator's problem is as follows:

$$\begin{aligned}
\max_{s} \quad & = \frac{\mu^2(a^2 - 8s)^2}{2a^2(2\mu - 1)^2} \\
\text{s.t.} \quad & (s-r)\tilde{k}(s) > 0
\end{aligned} \tag{1.20}$$

The consumer welfare function is decreasing in s, $\forall s \in \left[0, \frac{a^2}{8}\right]$. Hence, the regulator will choose the smallest possible s such that the constraint is satisfied.

Proposition 1.5. *Consider the normalised economy. The firm produces a positive level of output and quality if and only if* $r < \frac{a^2}{8}$. *The regulator sets* $s^* \cong r$ *and consumer welfare is positive and given by* $CS^{RR} \equiv \frac{\mu^2(a^2-8r)^2}{2a^2(2\mu-1)^2}$. *Otherwise, the firm does not produce and* $CS^{RR} = 0$. *Furthermore,* CS^{RR} *is bigger than the unregulated consumer welfare* CS^U *if the marginal cost of quality is low enough* $\left(\mu \leq \frac{(a^2-8r)^2}{2a^2\left(a-4\sqrt{\frac{1}{2}\sqrt{r}}\right)} + 1\right)$.

Proof. See proof in appendix 1.A.7. □

When r is small enough, the regulator has enough room to allow revenues to cover costs. The firm is then able to produce a positive level of output and quality without extracting too much consumer welfare. For instance, the regulator can do better by setting $s = \frac{a^2}{16}$.

Following proposition 1.3, this leads the firm to maximise water retention and labour while still inducing positive levels of quality and consumer welfare. If the regulator chooses an s lower than $\frac{a^2}{16}$, the firm does not maximise water retention but can increase output through a higher deployment of capital while enhancing service quality. This in turn increases welfare. When the cost of capital is high enough, the regulator cannot induce the firm to provide positive levels of output and quality under a rate of return scheme because it is too costly and demand is not high enough to sustain sufficient revenues to cover the firm's costs.

If the marginal cost of quality is too high, higher quality requirements will entail a bigger revenue requirement. This can be too costly for consumers in the sense that the direct effect of a higher price on consumer welfare dominates the positive effect of better quality. In contrast, an unregulated monopoly will quality downwards if it is too costly. This is less harmful to consumers as the negative effect of lower quality is attenuated by a lower price.

1.4.3 Consumer surplus comparison

We now compare the highest levels of consumer welfare across both regulatory environments. When $\mu < 1$, we compare the price cap consumer surplus obtained from $\bar{p_1}$ with CS^{RR}. When $\mu \geq 1$ price cap consumer surplus obtained with p_2 is compared to CS^{RR}. The comparison is made for $r \in \left[0, \frac{a^2}{8}\right)$ and is formally stated in the following proposition.

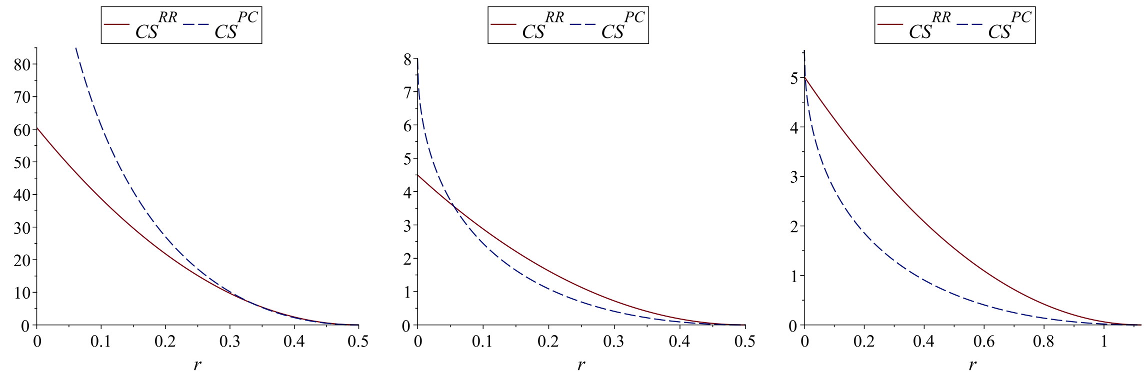
Proposition 1.6. *Consider the normalised economy. Let the conditions for which consumer welfare under rate of return is defined hold. If r or μ is low enough $\left(r < \frac{a^2(\mu-1)^2}{8\mu^2}\right)$, consumer welfare under price cap is higher than welfare under rate of return. Otherwise, consumer welfare under rate of return is higher.*

See proof in appendix 1.A.8. Table 1.1 provides a summary of the main results and conditions of the chapter.

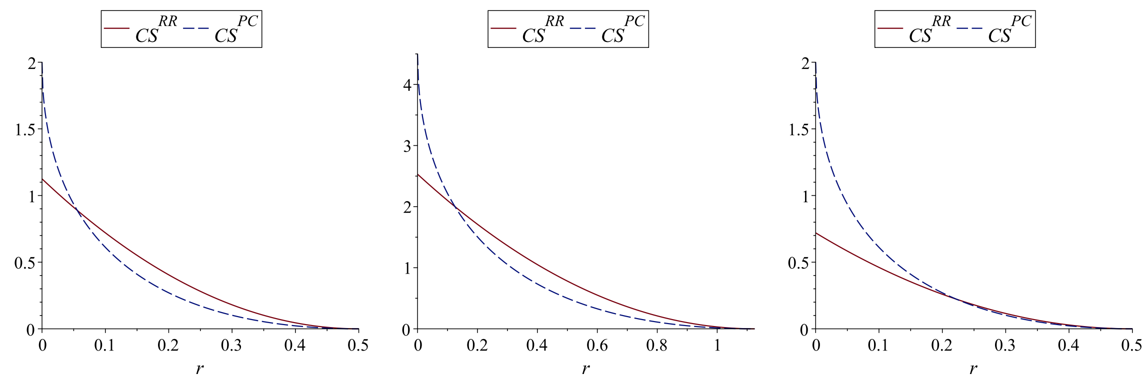
From a capital cost perspective, a lower input price through a low r is passed on to consumers under a price cap scheme and thus entails a higher welfare. Alternatively, when the cost of capital is too high, a price cap does not incentivise the firm to supply because it is bearing more the risk of costs increases. This is not the case under rate of return regulation because the firm is guaranteed a net rate of return for any cost of capital increase up to $\frac{a^2}{2}$, and is thus willing to serve consumers.

Figure 1.2 plots the value functions of consumer welfare under price cap (dashed line) and rate of return (solid line) for $r \in \left[0, \frac{a^2}{8}\right]$ and various values of a and μ. In the the first three plots, consumer welfare under price cap is calculated for $\bar{p_1}$ and in the last three graphs, consumer welfare under price cap is obtained with $\bar{p_2}$. For intermediate levels r the difference between consumer surplus across regimes is expanding. The rapid decrease of consumer surplus under price cap shows that the firm reduces output considerably more than under rate of return in order to stabilise profits when the cost of capital increases. For the highest

Figure 1.2: Consumer welfare comparison.



(a) $a = 2, \mu = 0.55$ (b) $a = 2, \mu = 0.75$ (c) $a = 3, \mu = 0.95$



(d) $a = 2, \mu = 1.5$ (e) $a = 3, \mu = 1.5$ (f) $a = 2, \mu = 3$

Note: Consumer welfare under rate of return $\left(CS^{RR}\right)$ and under price cap $\left(CS^{PC}\right)$ are respectively represented by the solid and dashed lines. The price cap consumer welfare curves in the top panels are obtained with $\bar{p_1}$ and the ones in the bottom panels are obtained with $\bar{p_2}$.

levels of the cost of capital, the difference is reduced. This convergence can be explained by a higher burden of capital cost variation risks on consumers under rate of return (Alexander and Irwin, 1996), which dominates the positive benefit of more supply.

Since the rate of return scheme is based on the cost reimbursement principle, a higher provision of quality will be covered by a higher price. Although a high level of quality benefits consumers, it is over optimal and thus too costly as the prices rises to cover this quality increase. In contrast, price cap regulation varies less with cost increases and is less concerned with quality provision. As stated by proposition 1.4, when $\mu > 1$, a regulator using a price cap regime does not find it worth to increase the price to cover extra costs from higher service quality. Consumers face an under provision of quality but this welfare loss is outweighed by the effect of a lower price on welfare.

When $\mu \leq 1$, the regulator allows price cap $\bar{p_1}$ to cover quality improvements as long as

Table 1.1: Summary of the main conditions and results

	Condition	**Result**
Price cap		
	• Demand elastic enough	Water retention increases in the price cap
	• -	Quality always increases in the price cap
Rate of return		
	• Low rate of return levels	Water retention increases in rate of return
	• -	Quality always decreases in the rate of return
Welfare		
	• r or μ low enough	Consumer welfare under price cap higher than consumer welfare under rate of return

it is not too costly. Since $\bar{p_1}$ is increasing in μ, any increase in the marginal cost of quality will reduce welfare. Concerning rate of return, the consumer price is decreasing in μ. Hence welfare losses from quality reductions for a high μ is compensated by welfare gains from a lower price. Thereby, rate of return regulation is superior to price cap regulation. This is the case when the optimal price cap accounts for the cost of quality ($\bar{p_1}$), as illustrated in charts 1.2a, 1.2b and 1.2c, where a higher μ reduces the set of r for which consumer surplus under price cap is higher.

When the socially optimal price cap ($\bar{p_1} = c$) is independent from the marginal cost of quality (charts 1.2d, 1.2e and 1.2f), a higher μ increases the set of r for which consumer surplus under price cap is higher. In this case, a higher μ decreases consumer welfare under under rate of return more since the price cap is not influenced by changes in the marginal cost of quality because a marginal quality enhancement is valued less than μ.

This highlights a classic trade-off in the regulatory literature between lower prices and higher quality investments. In the case of water, the value of quality is not likely to vary much beyond the need of having water on a continuous basis for daily usage. Therefore, investments can easily be too high from consumer welfare perspective. For instance, a substantial price rise due to increasing investments has raised a concern for affordability issues in Romania where rate of return regulation is applied and annual investment per capita is already high (IBRD, 2015).

1.5 Conclusion

In this paper, we analyse the impact of price cap or rate of return regulation on a water utility's network water retention and quality of service by adopting a profit maximisation problem under the corresponding regulatory constraint. In price cap regulation, the cap is set by the regulator and the firm is residual claimant of any profit or loss incurred. Higher price caps lead to more service quality provision because it is profitable to do so. The effect of higher price caps on water retention depends on demand responsiveness. If demand is inelastic enough, higher price caps lead the firm to reduce the water retention of the transmission system. A higher price cap does not considerably reduce quantity demanded which results in higher revenues for the firm. This increase in revenue inflates the opportunity cost of water retention as higher revenue disincentivises the firm to save more water. When demand is elastic enough, a higher price cap entails a drop in the firm's revenue. As this increases the opportunity cost of water loss, the firm wants to save more water.

Rate of return regulation is analysed in a normalised economy. The rate of return earned by the firm ensures profit stability for any value of the cost of capital within a defined range. At the optimum, higher rates of return reduce investments in capital and quality provision, which is consistent with the Averch-Johnson effect. A higher rate of return consolidates the firm's market power who then has less incentives to raise output and quality, since a higher rate of return ensures a higher profit to the firm. However, higher rates of return increase water retention for low levels of the rate of return. For higher levels of the rate of return, water retention instead drops as the rate of return goes up. A higher rate of return allows the firm to earn a higher profit per unit of capital who can then afford to cover most cost increases associated to higher water retention levels. However, increasing the rate of return from high levels reduces the opportunity cost of water losses. This disincentivises the firm to retain more water since the guaranteed profit is already very high. The induced price increases with the rate of return when the marginal cost of quality is high enough. As output and quality are complements, output is distorted downwards and leads to a price increase. Otherwise, the price decreases in the rate of return as the firm drastically reduces quality.

The welfare analysis shows that price cap is superior to rate of return regulation if the cost of capital is low enough. The optimal price cap is set at a level which is such that the firm is willing to supply while encouraging some level of quality provision. In contrast, rate of return regulation leads the firm to over-invest in capital and quality at the expense of consumers. However, when the cost of capital or the cost of quality is too high, price cap regulation is not concerned with quality provision. Instead, rate of return regulation entails higher consumer welfare by providing positive quality and capital investment levels.

1.A Appendix

1.A.1 Proof of lemma 1.1

Proof. The Lagrangian of the cost minimisation problem is:

$$\mathcal{L} = rk + wl + mv + \lambda\left[q - k^{\alpha_k} l^{\alpha_l} v^{\alpha_v}\right]$$

Optimising the above expression and using $m = rw$ yields the following first order conditions:

$$\begin{aligned}
\frac{\partial \mathcal{L}}{\partial l} &= w - \lambda \alpha_l k^{\alpha_k} l^{(\alpha_l - 1)} v^{\alpha_v} = 0 \\
\frac{\partial \mathcal{L}}{\partial k} &= r - \lambda \alpha_k k^{(\alpha_k - 1)} l^{\alpha_l} v^{\alpha_v} = 0 \\
\frac{\partial \mathcal{L}}{\partial v} &= m - \lambda \alpha_v k^{\alpha_k} l^{\alpha_l} v^{(\alpha_v - 1)} = 0 \\
\frac{\partial \mathcal{L}}{\partial \lambda} &= q - k^{\alpha_k} l^{\alpha_l} v^{\alpha_v} = 0.
\end{aligned}$$

Assuming the constraint is binding ($\lambda > 0$) and solving the above system for k, l and v, we obtain the optimal levels of capital k^*, labour l^* and v^*:

$$\begin{aligned}
v =& A_v w^{\frac{\alpha_K}{\alpha_E}} r^{\frac{\alpha_L}{\alpha}} m^{-\frac{\alpha_L + \alpha_K}{\alpha}} q^{\frac{1}{\alpha}} \\
l =& A_l w^{-\frac{\alpha_K + \alpha_E}{\alpha}} r^{\frac{\alpha_K}{\alpha_E}} m^{\frac{\alpha_E}{\alpha}} q^{\frac{1}{\alpha}} \\
k =& A_k w^{\frac{\alpha_L}{\alpha}} r^{-\frac{\alpha_L + \alpha_E}{\alpha}} m^{-\frac{\alpha_L}{\alpha_E}} q^{\frac{1}{\alpha}}
\end{aligned}$$

where $A_l = \left(\frac{\alpha_l}{\alpha_k}\right)^{\frac{\alpha_k}{\alpha}} \left(\frac{\alpha_l}{\alpha_v}\right)^{\frac{\alpha_v}{\alpha}}$, $A_k = \left(\frac{\alpha_k}{\alpha_l}\right)^{\frac{\alpha_l}{\alpha}} \left(\frac{\alpha_k}{\alpha_v}\right)^{\frac{\alpha_v}{\alpha}}$, $A_v = \left(\frac{\alpha_v}{\alpha_k}\right)^{\frac{\alpha_k}{\alpha}} \left(\frac{\alpha_v}{\alpha_l}\right)^{\frac{\alpha_l}{\alpha}}$. □

1.A.2 Proof of proposition 1.1

Unconstrained behaviour. Since the profit function is concave in q and x, an interior solution is obtained by solving the system of FOCs for q and x:

$$\begin{aligned}
\frac{\partial \pi}{\partial q} &= -2bq + a - c + x = 0 \\
\frac{\partial \pi}{\partial x} &= -\mu x + q = 0
\end{aligned}$$

which yields $\hat{q}(.) = \frac{\mu(a-c)}{2b\mu - 1}$ and $\hat{x}(.) = \frac{a-c}{2b\mu - 1}$. □

1.A.3 Proof of lemma 1.2

. The proof is in two steps. First we analyse the outcome when a loose price cap is implemented and in the second step we derive the solution when a tight price cap is implemented.

1. **Loose price cap**
   Under a loose price cap, the firm cannot implement a price higher than $\bar{p}$. Thus the Lagrangian writes:

$$\mathcal{L} = [a - bq + x]q - cq - \mu\frac{x^2}{2} - \lambda[a - bq + x - \bar{p}]$$

   The first order conditions are:

$$\frac{\partial \mathcal{L}}{\partial q} = a - 2bq + x - c + b\lambda = 0$$
$$\frac{\partial \mathcal{L}}{\partial x} = q - \mu x - \lambda = 0$$
$$\frac{\partial \mathcal{L}}{\partial \lambda} = \bar{p} - a + bq - x = 0$$

   - case 1: $a - bq + x - \bar{p} = 0$, $\lambda > 0$:
     solving for λ and rearranging the above system reduces to:

$$\frac{a}{b} - q + \frac{x}{b} - \frac{c}{q} - \mu x = 0$$
$$a - bq + x = \bar{p}$$

     Solving for q and x yields the solutions in (1.10) and (1.9): $\left\{q^*(.) = \frac{b(a-\bar{p})\mu - c + \bar{p}}{b^2\mu}, x^*(.) = \frac{\bar{p}-c}{b\mu}\right\}$.
   - case 2: $a - bq + x - \bar{p} < 0$, $\lambda = 0$:
     the FOCs are rewritten:

$$a - 2bq + x - c = 0$$
$$q - \mu x = 0$$

     which yield the same solutions (1.5) (1.7) as in the unconstrained problem.

2. **Tight price cap**
   Under a tight price cap, when $\bar{p}$ is low enough, the firm solves:

$$\max_{q,x} = \bar{p}q - cq - \mu\frac{x^2}{2} \qquad a - bq + x \geq \bar{p}$$

Clearly, the firm's problem is not concave in q. Since $\frac{\partial C(q,x)}{\partial x} = \mu x > 0$, the firm chooses the lowest level of quality making the constraint binding, that is $x(q) = \bar{p} - a + bq$. Inserting this lower bound in the objective function, we can rewrite the firm's profit as:

$$\pi(q) = \bar{p}q - cq - \mu\frac{(\bar{p} - a + bq)^2}{2}$$

The profit maximising levels of quantity and quality are then

$$q' = \frac{b(a - \bar{p})\mu - c + \bar{p}}{b^2\mu}$$
$$x'(q') = \frac{p - c}{b\mu}$$

which are the solutions obtained in (1.9) and (1.10). Inserting these values in the inverse demand and the profit function gives respectively expressions $p^*(q^*, x^*) = \bar{p}$ and $\pi^*(q^*, x^*) = \frac{(p-c)[b(a-p)\mu+1/2(p-c)]}{b^2\mu}$.

□

1.A.4 Proof of proposition 1.2

. By lemma 1.2, the optimal $q^*(.)$ and $x^*(.)$ are characterised as well as $p^*(q^*, x^*)$ and $\pi^*(q^*, x^*)$. Thus, it is straightforward to see that $x^*(.)$ increases in $\bar{p}$. □

1.A.5 Proof of proposition 1.3

. The Lagrangian of problem (1.11) writes:

$$\mathcal{L} = (a - bk^{\alpha_k}l^{\alpha_l}v^{\alpha_v} + x)k^{\alpha_k}l^{\alpha_l}v^{\alpha_v} - rk - wl - mv - \mu\frac{x^2}{2}$$
$$- \lambda\left[(a - bk^{\alpha_k}l^{\alpha_l}v^{\alpha_v} + x)k^{\alpha_k}l^{\alpha_l}v^{\alpha_v} - wl - mv - \mu\frac{x^2}{2} - sK\right] \quad (1.21)$$

FOC:

$$\frac{\partial \mathcal{L}}{\partial K} = 2\alpha L^{2\alpha_l}v^{2\alpha_v}b(\lambda - 1)k^{2\alpha_k - 1} - \alpha_k l^{\alpha_l}v^{\alpha_v}(a + x)(\lambda - 1)K^{\alpha_k - 1} + \lambda s - r = 0 \quad (1.22)$$
$$\frac{\partial \mathcal{L}}{\partial l} = -(-2\alpha_l l^{2\alpha_l}k^{2\alpha_k}bv^{2\alpha_v} - l^{\alpha_l - 1}v^{\alpha_v}(a + x)(\lambda - 1)k_k^{\alpha} - w)(\lambda - 1) = 0 \quad (1.23)$$
$$\frac{\partial \mathcal{L}}{\partial v} = -(-2\alpha_v l^{2\alpha_l}k^{2\alpha_k}bv^{2\alpha_v - 1} - l^{\alpha_l}v^{\alpha_v - 1}(a + x)(\lambda - 1)K^{\alpha} - m)(\lambda - 1) = 0 \quad (1.24)$$
$$\frac{\partial \mathcal{L}}{\partial x} = (1 - \lambda)(k^{\alpha_k}l^{\alpha_l}v^{\alpha_v} - \mu x) = 0 \quad (1.25)$$
$$\frac{\partial \mathcal{L}}{\partial \lambda} = (a - bk^{\alpha_k}l^{\alpha_l}v^{\alpha_v} + x)k^{\alpha_k}l^{\alpha_l}v^{\alpha_v} - wl - mv - \mu\frac{x^2}{2} - sk \leq 0, \qquad \lambda \geq 0 \quad (1.26)$$

Condition (1.22) can be rearranged as follows

$$\lambda = \frac{2l^{2\alpha_l}E2\alpha_v K^{2\alpha_k}\alpha_k b - l^{\alpha_l}v^{\alpha_v}k^{\alpha_k}a\alpha_k - l^{\alpha_l}v^{\alpha_v}k^{\alpha_k}\alpha_k x + rk}{2l^{2\alpha_l}E2\alpha_v K^{2\alpha_k}\alpha_k b - l^{\alpha_l}v^{\alpha_v}k^{\alpha_k}a\alpha_k - l^{\alpha_l}v^{\alpha_v}k^{\alpha_k}\alpha_k x + sk} \tag{1.27}$$

Hence, it is clear that, when $s = r$, $\lambda = 1$, a contradiction since a fair rate of return implies $s > r$. Note that when $r = s$, there is no unique solution as any solution that satisfies the constraints is a solution. From condition (1.22), it is straightforward to see that $r < s$ implies $0 < \lambda < 1$. Setting the exogenous parameters value as follows: $b = 1, w = 1, m = 1, \alpha_k = \frac{1}{2}, \alpha_l = \frac{1}{4}, \alpha_v = \frac{1}{4}$, and having $-(\lambda - 1) \neq 0$ the system of FOCs simplifies as

$$\frac{\partial \mathcal{L}}{\partial k} = l^{\frac{1}{2}}v^{\frac{1}{2}}(\lambda - 1) - \frac{1}{2}l^{\frac{1}{4}}v^{\frac{1}{4}}(a + x)(\lambda - 1)k^{-\frac{1}{2}} + \lambda s - r = 0 \tag{1.28}$$

$$\frac{\partial \mathcal{L}}{\partial l} = -\frac{1}{2}l^{-\frac{1}{2}}kv^{\frac{1}{2}} - l^{-\frac{3}{4}}v^{\frac{1}{4}}(a + x)(\lambda - 1)k^{\frac{1}{2}} - 1 = 0 \tag{1.29}$$

$$\frac{\partial \mathcal{L}}{\partial v} = -\frac{1}{2}l^{\frac{1}{2}}kv^{-\frac{1}{2}} - l^{\frac{1}{4}}v^{-\frac{3}{4}}(a + x)(\lambda - 1)K^{\frac{1}{2}} - 1 = 0 \tag{1.30}$$

$$\frac{\partial \mathcal{L}}{\partial x} = k^{\frac{1}{2}}l^{\frac{1}{4}}v^{\frac{1}{4}} - \mu x = 0 \tag{1.31}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = (a - k^{\frac{1}{2}}l^{\frac{1}{4}}v^{\frac{1}{4}} + x)k^{\frac{1}{2}}l^{\frac{1}{4}}v^{\frac{1}{4}} - l - v - \mu\frac{x^2}{2} - sk = 0 \tag{1.32}$$

The solution solves the system of first order conditions, and are given by:

$$\left\{\tilde{k}(.) = \frac{\mu(a^2 + 8s)}{2\mu - 1}, \tilde{l}(.) = \tilde{v}(.) = -\frac{2\mu s(a^2 + 8s)}{2\mu - 1}, \tilde{x}(.) = \frac{a^2 + 8s}{(2\mu - 1)a}\right\},$$

$$\left\{\tilde{k}(.) = \frac{\mu(a^2 - 8s)}{2\mu - 1}, \tilde{l}(.) = \tilde{v}(.) = \frac{2s\mu(a^2 - 8s)}{(2\mu - 1)a^2}, \tilde{x}(.) = \frac{a^2 - 8s}{(2\mu - 1)a}\right\}$$

The first set of solutions implies that either $k, x < 0$ and $l, v > 0$, or $k, x > 0$ and $l, v < 0$. To see this, suppose $\mu < \frac{1}{2}$. Then $K, x > 0$ and $L, E < 0$. Hence, only the second set of solutions holds true. This yields an output $\tilde{q}(s) = \frac{\mu(a^2-8s)}{(2\mu-1)a}$ and a price $\tilde{p}(s) = \frac{a^2\mu+8(\mu-1)s}{(2\mu-1)a}$. □

1.A.6 Proof of proposition 1.4

. Since consumer welfare in convex in the price cap, the highest welfare can be achieved by setting a price cap such that the firm's profit is null or by letting the firm to choose the unconstrained monopoly maximising profit price. In the former, the price is such that:

$$\bar{p}q^*(\bar{p}) - cq^*(\bar{p}) - \frac{\mu}{2}\left(\frac{\bar{p} - c}{\mu}\right)^2 = 0.$$

The solutions of this condition are $\left\{c, \frac{2a\mu - c}{2\mu-1}\right\}$. Substituting these expressions in the consumer welfare function yields respectively $CS^c = \frac{(a-c)^2}{2}$ and $CS^p = \frac{(a-c)^2}{2(2\mu-1)^2}$. The unconstrained monopoly maximising price is given by solving:

$$\max_p \pi(p) = pq^*(p) - cq^*(p) - \mu\frac{(x^*(p))^2}{2}.$$

This gives a price equal to $\frac{b(a+c)\mu - c}{2b\mu-1}$, which is exactly the price obtained in the unconstrained monopoly section. The resulting consumer welfare is $CS^m = \frac{(a-c)^2\mu^2}{(2(2\mu-1)^2}$.

We now compare consumer welfare under the three different prices. The following holds true: $CS^c \geq CS^U$ if $\mu \leq \frac{1}{3}$ or $\mu \geq 1$, $CS^c \geq CS^p$ if and only if $\mu \geq 1$, and $CS^p \geq CS^U$ if and only if $\mu \leq 1$.

□

1.A.7 Proof of proposition 1.5

. Since CS^{RR} is decreasing in s, $\forall s \in \left[0, \frac{a^2}{8}\right]$, the regulator chooses the smallest s such that the revenue $(s-r)\tilde{k}(s) > 0$ is satisfied. It is straightforward to see that the regulator will choose $s^* \cong r$. Consumer surplus is then $CS^{RR} \equiv \frac{\mu^2(a^2-8r)^2}{2a^2(2\mu-1)^2}$.

Next we compare consumer surplus under regulation and consumer surplus without regulation. Rate of return regulation is superior to no regulation if $CS^{RR} \geq CS^U$, or $\frac{\mu^2(a^2-8r)^2}{2a^2(2\mu-1)^2} \geq \frac{\mu^2(a-c)^2}{2(2\mu-1)}$. This is true if $\mu \leq 1 + \frac{(a^2-8r)^2}{2a^2\left(a-4\sqrt{\frac{1}{2}}\sqrt{r}\right)}$. □

1.A.8 Proof of proposition 1.6

. We compare consumer welfare for different values of μ. By proposition 1.4, consumer welfare under price cap is $CS(\bar{p_1}) = \frac{(a-c)^2}{2(2\mu-1)^2}$ when $\mu \leq 1$. Consumer welfare under price cap is greater if

$$CS(\bar{p_1}) \geq CS^{RR}$$
$$\frac{(a-c)^2}{2(2\mu-1)^2} \geq \frac{\mu^2(a-c)^2}{2(2\mu-1)^2}$$

There are three roots for which this condition is satisfied as an equality: $r = \left\{\frac{a^2(\mu-1)^2}{8\mu^2}, \frac{a^2(\mu+1)^2}{8\mu^2}, \frac{a^2}{8}\right\}$, where $\frac{a^2(\mu-1)^2}{8\mu^2} < \frac{a^2}{8} < \frac{a^2(\mu+1)^2}{8\mu^2}$. By proposition 1.5, only roots in $0\left[\frac{a^2}{8}\right)$ are admissible. In addition $CS(\bar{p_1}) = CS^{RR} = 0\ \forall r \geq \frac{a^2}{8}$. Therefore, only $\frac{a^2(\mu-1)^2}{8\mu^2}$ is a feasible threshold.

If $\mu > 1$, consumer welfare under price cap is $CS(\bar{p_2}) = \frac{(a-c)^2}{2}$. This is greater than consumer welfare under rate of return if

$$CS(\bar{p_2}) \geq CS^{RR}$$
$$\frac{(a-c)^2}{2} \geq \frac{\mu^2(a-c)^2}{2(2\mu-1)^2}$$
$$\frac{(a-c)^2}{2} - \frac{\mu^2(a-c)^2}{2(2\mu-1)^2} \geq 0$$

This condition is satisfied with equality for $r = \left\{\frac{a^2(\mu-1)^2}{8\mu^2}, \frac{a^2(3\mu-1)^2}{8\mu^2}, \frac{a^2}{8}\right\}$, where $\frac{a^2(3\mu-1)^2}{8\mu^2} \geq \frac{a^2}{8}$ if $\mu \leq \frac{1}{4}$ or $\mu \geq \frac{1}{2}$; $\frac{a^2(\mu-1)^2}{8\mu^2} > \frac{a^2}{8}$ if $\mu < \frac{1}{2}$; and $\frac{a^2(\mu-1)^2}{8\mu^2} < \frac{a^2(3\mu-1)^2}{8\mu^2}$ if $\mu > 1$. Given proposition 1.3 and proposition 1.5, positive input levels are only possible if $\mu > \frac{1}{2}$ and if $r < \frac{a^2}{8}$. Therefore, only $\frac{a^2(\mu-1)^2}{8\mu^2}$ is a feasible root. $\square$

Chapter 2

Regulating service quality and water retention: the Case of Eastern European water industries

This paper analyses how economic regulation affects water utilities' performance in terms of network water retention and service quality by empirically modelling the interaction between a sector regulator and water utilities who are confronted to either price cap or rate of return regulation. We estimate an equation of network water retention and an equation of quality of service with accounting data from a panel of 505 water utilities in 11 Eastern Europe countries from 1996 to 2015. The results show a trade-off between water retention and service quality with respect to economic regulation. Namely, price cap regulation entails less water retention but leads to better quality of service than rate of return. Regardless of the regulation type, a lower price incentivises the firm to more water retention but less quality when price is instrumented. In addition, the adoption of the cost recovery principle through European Union accession acts as an incentive to increase scale efficiency in an attempt to reduce prices.

2.1 Introduction

The purpose of this paper is to compare the impact of different forms of economic regulation on quality and water transmission efficiency and to test propositions from the first chapter using a case study of the water sectors in selected countries of Central and Eastern Europe. To do this, we specify a static linear model of water retention rate and consumer complaints in which price and the type of regulation are the main explanatory variables. The model is estimated using a firm-level dataset of Eastern Europe water industries obtained from the World Bank (International Benchmarking Network - IBNET).

The countries of Eastern Europe provide a fruitful testing ground for the theory. While the countries all share a common feature of economic system transition, they adopted different forms of regulation: in some, it took the form of rate of return, while in others price caps or revenue caps were preferred. Our dataset comprises a panel of 505 monopolistic water firms from 11 countries over a 20-year period and contains firm and macroeconomic data. Moreover, within the observed sample period, three countries switched from the former to the latter. By complementing the data with information on the type of regulation, we allow our estimation to compare the impact of price cap and rate of return regulation on water retention and quality.

The main findings are as follows. Lower prices imply increased incentives for water retention but entail more complaints. Economic regulation comes with a similar trade-off. Specifically, implementing price cap regulation leads to less water retention but more quality than rate of return regulation. A higher cost of capital drives the firm to more water retention but leads to more complaints. An independent regulator is more driven towards customer satisfaction but induce less water retention.

The econometric model is built from firm behaviour in propositions 1.2 and 1.3 in the previous chapter. These results show how a higher price cap or rate of return affects the firm's water retention and quality but they don't compare the firm's behaviour between these two regulatory schemes. Since rate of return values are not observed in the dataset, only water price and a proxy of the cost of capital can be used to test the propositions. However, price is endogenous. First, the price is a consequence of the firm's choice of water retention and quality levels in a rate of return environment. Second, the regulator sets the price cap as a function of demand and cost factors. To account for the simultaneity problem endorsed by the price variable, we perform a two-stage least square estimation where the first stage estimation is a linear price model.

Besides regulatory policy, Eastern European countries have other institutional differences that potentially affect performance in the water sector. For instance, there has been a trend towards more independence of regulators, especially in countries with regional utilities. All regulators formally determine tariffs, often alongside government authorities. Since we observe when a country has established an independent regulator, we investigate whether the independence of the regulator impacts on water retention and complaints. Furthermore, the accession to the European Union meant the adoption of the EU Water Framework Directives (WFD) on water and wastewater services, which pushes for cost recovery pricing and more rigorous water quality and environmental standards. We control for EU membership status by identifying utilities in EU countries and in non-EU ones.

Some of the International Bank for Reconstruction and Development (IBRD)'s descriptive conclusions provide a useful background for the current paper (IBRD, 2015). The results of this study will be discussed more fully below but it should be noted at the outset that it does not study the effect of economic regulation on utilities' performance.

The present paper sheds further light on the persistent issues of water supply in the region by identifying econometrically the role of economic regulation on water utilities performance. Section 2.2 surveys the literature. Section 2.3 describes the water industry and the data. Section 2.4 presents the empirical modelling and the variables. Section 2.5 discusses the results. Section 2.6 concludes.

2.2 Related literature

Our study is closest to the IBRD (2015)'s analysis[1] under the Danube Water Program. The Danube Water Program was launched in 2013 as a partnership between the World Bank and the International Association of Water Supply Companies in the Danube River Catchment Area (IAWD) aiming to address the challenges faced by the water industry in Danube countries. As part of its work, it produced a briefing document reporting an in-depth analysis of the water sector in the region. This included an introductory econometric analysis on the performance of water utilities in the region based on the IBNET database (IBRD, 2015). The analysis is based on the estimation of a log-linear model that quantifies the relationship between water tariffs and performance[2][3]. The results show that higher performing utilities tend to charge higher tariffs. However, management efficiency is negatively correlated with tariffs, which potentially shows that more efficient utilities can benefit consumers through lower tariffs. The study finds that the overall performance of utilities is found to grow over time and utilities in EU member countries have a higher

[1]The 2019 report mentions an econometric analysis on water utility cost efficiency which has not been published.

[2]Tariffs are calculated by dividing total revenue over the number of consumers.

[3]Utility performance is measured by the Water Utility Performance Index (WUPI) which is calculated by assigning a score between 0 and 10 according to the performance achieved for a certain criterion and averaging this score over the number of criteria used. An overall WUPI is calculated as well as three sub-WUPIs based on the main axis of water utility performance, namely service coverage, quality and management efficiency. The management efficiency component is calculated from labour, cash collection and water losses performance scores. In the first model, tariff is endogenous and the WUPI components are the regressors along with country and year effects. In a second model, the WUPI is regressed against institutional and industry regressors.

WUPI than their non-EU counterparts but have a slower performance improvement. However, the introduction of a regulatory agency is not associated with higher performance levels. We contribute to this literature by assessing the effects of water price on water retention while accounting for different modes of economic regulation.

The impact of different modes of regulation on water utility efficiency is analysed by Aubert and Reynaud (2005). They assess how price cap or rate of return affects effort to minimise costs in Wisconsin water utilities. They find that water utilities under rate of return regulation are more efficient than utilities under either a hybrid form of rate of return regulation or a form of price cap regulation. Lise and Bakker (2005) instead analyse the impact of a loosening of regulation on UK water utilities. Their game theoretical analysis shows that the regulator sets a high price cap while the firm chooses low levels of capital investment but high levels of operation expenditure for the maintenance of the distribution network. We contribute to this literature by making use of a wider dataset that accounts of various geographical and political differences. Other empirical studies on efficiency adopt classical approaches. Filippini et al. (2008), Philipps (2013) and Nourali et al. (2014) analyse water utility efficiency in Slovenia, Japan and Iran respectively by employing either Stochastic Frontier Analysis or Data Envelopment Analysis but do not identify the effect of different economic regulation modes on efficiency levels.

The literature has also devoted a particular attention to water losses. The seminal work of Garcia and Thomas (2001) estimate the cost function of Bordeaux water utilities by treating water losses as a bad output. They highlight a possible trade-off from the utilities' perspective between increasing production and reducing water losses when the price of electricity rises. Garcia and Thomas (2003) extend the analysis of the Bordeaux water utilities by introducing private information on the firm's efficiency. They stress that the regulator faces a trade-off between granting the information rent and allowing water losses and conclude that the regulator allows the firm to incur more losses when the firm is more inefficient. Martins et al. (2012) estimate a quadratic cost function on Portuguese water firms by also considering water losses as a bad output. Their results show that lower water losses reduce marginal cost as water utilities face diseconomies of scope from the joint production of water sold and water losses. By contrast, this paper considers water losses as an input.

Other studies focus on the drivers of water losses. van den Berg (2014) empirically assesses the determinants of non-revenue water using the IBNET database over 69 countries with a log-log model. Like the IBRD's study, she finds that the water utility's revenue per consumer is negatively correlated with water losses. Her results also shows that energy costs, wage, connection density and household size positively affect water losses. Unlike this paper, she does not control for different regulatory modes. In a recent analysis of water losses in England and Wales, Brea-Solis et al. (2017) calculate the shadow price of water by estimating an input distance function. They conclude that, unlike water only firms, water and sewerage firms have been given strong incentives to reduce losses by being allowed to charge a consumer price higher than the shadow price of water. While this study is performed in the context of a single regulatory regime, our analysis compares the performance of water utilities under various types of regulation.

The effect of economic regulation on service quality performance in the water industry is an emerging area. A survey of water regulators from Marques, Simões and Pires (2011) documents the effectiveness of benchmarking approaches to regulate the quality of service by comparing utilities. From examples in several countries, they argue that the combination of economic regulation and benchmarking techniques can help improve water utility performance. A similar conclusion is drawn by Ananda and Pawsey (2019) whose estimation of a bootstrap Data Envelopment Analysis in the Australian water industry finds that benchmarking has led to productivity and service quality improvements. They conclude that price changes should be linked to changes in service quality. The most recent analysis that we know of assesses the impact of price cap regulation on quality in the Danish water industry (Bjørner et al., 2021). In their study, water leakage is considered a quality component. Using a difference in difference approach, they show that price cap regulation leads to higher quality.

2.3 Data and industry background

2.3.1 Statistical description

The water sector in Eastern Europe has been characterised by substantial changes since the 1990s (IBRD, 2015). The shift to a market-based economy led to decentralisation of services and more private and international involvement, as well as a modernisation of the infrastructure and an increased attention of economic efficiency. The (potential) accession to the European Union of Eastern European countries meant the adoption of the EU Water Framework Directives (WFD) on water and wastewater services, which pushes for the introduction of cost recovery principle and more rigorous water quality and environmental standards. Before these important mutations, these countries had experienced strong industrialisation and urbanisation, but the necessary development of the water supply infrastructure came with deterioration of water quality standards and efficiency.

The dataset obtained from the World Bank's IBNET data on water utilities consists of an unbalanced panel of 505 water companies from 1996 to 2015 but most of the variables used in the regressions are observed from year 2000. These firms are all monopolies in the areas they supply water[4]. The data cover 11 countries of the Danube River Catchment Area and two countries outside the area, namely Poland and Lithuania. The variables are indexed by firm i

[4] Most utilities are owned by the State or municipalities. In countries like The Czech Republic or Poland, there are private concessions in the capital cities taken by multi-nationals. In many of the countries, one water utility can serve multiple regions as a result of consolidating small utilities.

and year t. Data on water produced and sold as well as labour costs and electricity expenses were recorded by the IBNET. In addition there is information on the value of total assets, the number of complaints, operating costs and revenues and the population served. The monetary variables used in this analysis have been converted into US dollars by dividing the variables expressed in local currencies by the exchange rate provided in the dataset, except for the Gross National Income (GNI) which is already measured in US dollars. All financial data are in nominal values. The data is collected from water utilities through questionnaire filling. To limit measurements errors, we have removed observations for which values of revenues, costs and assets are negative or null.

The econometric analysis of this paper aims at understanding the role of price and various forms of regulation in affecting water utilities' performance. To this end, we complement the IBNET industry variables with regulatory variables constructed from other sources. Table 2.1 gives an overview of the variables that are used for the empirical strategy and table 2.2 below reports summary statistics of these variables. Except for *Gross National Income* which is measured at country level, all the economic variables are observed at firm level. As for the regulatory variables - price cap, regulator and the EU membership status dummies, they are captured at country level. The first dependent variable of the analysis is the water retention rate *per connection*, which is the ratio of water sold to water produced per connection. This ratio can be interpreted as an inverse of water loss index[5]. Because the water produced flows through the distribution network and can therefore potentially leak out of the system, it reflects how much water reaches the final consumer. This paper focuses only on the consumption water service of the utility and not the sewerage activity.

The volume of water sold is the total quantity supplied across households, firms and institutions. In some countries, water prices (tariffs) are different for households and non-households but such data are missing for most observations. Only the water utility's total revenues are observed thoroughly.

The dependent variable used to measure service quality is the number of complaints per population served by the utility. Not only is the level of complaints a function of the firm's effort, it can also be influenced by factors that encourage consumers to make a complaint. For instance, raising complaints have been made less costly for consumers through surveys conducted by water utilities and through customer complaints mechanisms that utilities are required to set in certain countries. However, these aspects are not captured in the data.

Price. We use an average water price as a proxy for *price* by dividing total revenues by total quantity of water sold. Average water price is used in Nauges and Thomas (2000)

[5]In van den Berg and Danilenko (2011) water loss=water produced - water billed. Thereby the water loss rate would be water loss = water produced - water billed/water produced and hence water retention rate = water billed/water produced. However, González-Gómez et al. (2011) points out that this measure is influenced by the volume of consumption and thus suggest normalising the indicator by the number of connections or the network length.

Table 2.1: Overview of variables used in the model

Variable	Description
Water retention rate	Quantity of water sold per quantity of water produced per connection
Complaints per capita	Number of complaints received by the utility per population served
Average water price	Ratio of water utility total revenue over water sold
Price cap	= 1 if utility i is regulated by a price cap
Regulator	= 1 if utility i is regulated by an independent regulator
Wage rate	Ratio of total labour costs over number of employees
Electricity unit cost	Electricity expenses per length of network
Capital cost proxy	Asset value per length of network
Gross National Income	Gross National Income per capita in purchasing power parity
Water interruption	Hour duration of water cut
Population per connection	Number of individuals served per water connection
EU member	= 1 if utility i's country is an European Union member
EU candidate	= 1 if utility i's country is an European Union candidate
No EU affiliation	= 1 if utility i's country has no EU affiliation

Note: Description of the accounting variables used for the empirical analysis.

to estimate water demand in France. In Eastern Europe, water consumption has decreased due to tariff and individual metering (IBRD, 2015, 2019). This suggests that consumers are informed about their consumption and respond to tariff changes. Furthermore, since we have yearly data, it can be assumed that consumers acquire information about the price they pay within a given year. Thus it is reasonable to use average price as a proxy.

Input prices. We use proxies to capture production costs. To measure the *cost of capital proxy* of firm i at year t we calculate a ratio[6]. Electricity expenses are reported in the dataset but not the amount of electricity consumed. Following Brocas et al. (2006), we calculate a proxy for *electricity unit cost* by dividing the total electricity expenses over the amount of capital. Labour cost is represented by a *wage rate* defined as total labour cost over the total workforce.

Other characteristics. We calculate a variable capturing the size of household as *population per connection* which is the population served by the utility over the number of connections

[6]Many empirical studies dealing with the cost of capital highlight the inability of accurately measuring such variable. Different approaches can be used to derive those variables which makes it impossible to get the true value of the cost of capital. For instance, some use the discount rate to calculate depreciation of assets (Comisari et al., 2011), while others take into account the age and lifespan of equipment (Göerzig, 2007; PSC, 2014). When the rate of return is observable, it can be used to calculate the cost of capital (Jorgenson, 1989; Wolak, 1994)

Table 2.2: Tabulation of price cap dummy

Variable	Mean	Std. Dev.	N
Water retention rate	.0002697	.0008031	3475
Complaints per capita	0.006	0.012	1784
Average water price ($)	0.42	0.34	3123
Regulatory agency dummy	0.594	0.491	3539
Wage rate ($)	7754.02	10211.625	3187
Electricity unit cost proxy ($)	1151.28	1513.463	3200
Capital cost proxy	50516.261	303642.92	2951
Water connections	19763.717	30553.778	3475
Gross National Income ($)	5761.344	4589.529	3539
Water supply interruption (hours)	3.978	6.763	3529
Population per connection	6.939	12.483	3472
EU member	0.333	0.471	3539
EU candidate	0.27	0.444	3539
No EU affiliation	0.398	0.489	3539

of the utility. Note that GNI is constant across all firms within a given country for a given year. The dataset also provides information on the hour duration of daily water supply which we use to calculate the hours of supply interruption by subtracting the supply hours from 24.

2.3.2 Water utility heterogeneity

There are several water utilities within a given country and each firm serve a given area. The empirical analysis will require the use of fixed effects as their performance is partly explained by unobserved heterogeneity. For instance, water retention is explained by factors inherent to the utility such as geographical characteristics (Skipworth et al, 1999) and governance (Gonzales et al, 2011) which are unobserved either by the econometrician or the regulator. From the IBRD (2015)'s analysis, bigger utilities perform better than smaller ones in terms of WUPI and even charge higher prices. Table 2.11 in the appendix shows this heterogeneity by summarising the distribution of firms by size (quantity of water produced) and by country as well as the number of utilities regulated by an independent regulatory agency.

From the mid-2000s, small utilities have started to merge to form regional entities in order to benefit from economies of scale, initiate cross-subsidies and receive funding mainly

Table 2.3: Tabulation of the values of the Price cap dummy for observed values of water retention rate

Variable	**Freq**	**Percentage**
Price cap = 0	2,809	80.83
Price cap = 1	666	19.17
Total	3,475	100.00

Table 2.4: Tabulation of the values of the Price cap dummy for observed values of complaints

Variable	**Freq**	**Percentage**
Price cap = 0	1,279	71.69
Price cap = 1	505	28.31
Total	1,784	100.00

from the UE. For instance, in Albania, the number of firms in the sample over the period is 65 but by 2015, there were 58 utilities. The dataset does not contain information for all utilities. In Lithuania, there are 74 water firms but the data covers for only 41 firms[7]. Figure 2.4 in appendix 2.A.1 displays the value of the average variable cost of producing one cubic meter of water with respect to the quantity of water produced[8] and shows a downward trend of the average variable cost with respect to the utility output size. This suggests that the water industry exhibits some degree of economies of scale and that bigger firms, by being more efficient, would be able to cover the cost related to increasing water retention or service quality.

Firms can feature specific governance aspects as most of these small utilities are owned by local governments. However, water utilities still need the approval of either the central government or regulator for tariff setting. In some countries, local government owned utilities tend to be regional providers (Romania, Slovakia) but central government ownership is also possible amongst regional utilities (Bulgaria and Kosovo). In Poland, full public management and public-private partnerships are common at the municipal level (Szmigiel-Rawska and Lukomska, 2020) but are still regulated by the local government. Even though these small utilities are generally owned by local governments, the legal status, accounts and personnel of the former are separated from the latter. Hence, despite the existing heterogeneity, most utilities share some common corporate features which are affected by their interaction with

[7] There was no evidence on the number of firms regulated by the regulator. Therefore it is considered as N.A.

[8] The plot is obtained by simply dividing total operational cost by the quantity of water produced.

the regulator. For instance, they can make revenue requirement proposals, operate within a set of performance targets, perform benchmarking exercises and survey customers about their opinions.

2.3.3 Regulatory environment

The data present cross-section variation in the form of regulation and temporal variation in the type of regulator despite having common structural trajectory of their economies. Table 2.5 highlights the main regulatory events that occurred during the sample period for each country by compiling information for various sources including national regulators (WWRO, 2011; WRA, 2013), association of regulators (WAREG, 2017, 2019) and institutions (KPC, 2019; IBRD, 2015; Vucijak, 2019; OECD, 2015, 2019*a*,*b*).

The regulation scheme, the agency independence and the EU status are implemented at country level and are treated in a binary manner for the purpose of the econometric analysis. The variation in regulation is between countries rather than intertemporal. Bulgaria and Moldova are the only two countries for which regulation changes from rate of return to price cap over time. Serbia and Slovakia have price cap regulation throughout the sample period and the remaining countries are identified with rate of return regulation. Regulator independence changes over time in four countries, namely Bulgaria, Kosovo, Moldova and Romania. Albania and Slovakia have also established independent regulator during the sample period but data for these countries are not observed at the time of the change of regulator status.

Economic regulation

There are different ways in implementing a type of regulation. For instance, Albania and Kosovo adopt a rate of return regulation but incorporate target achievement of key performance indicators in their water tariff readjustment process. In Kosovo, prior to 2009 tariffs were determined by previous financial records and there had been no consideration for incentives in promoting efficiency. In Slovakia, the regulator adopts price cap regulation but ensures that compensation payments are made to consumers if standards are not met[13]. Regarding countries where there is no clear tariff setting methodology[14], we make an

[9] Bulgaria and Romania endorsed the Accession Partnership in March 1998. The 1998 - 2004 period corresponds to the period in which these two countries are considered as EU candidates in the IBRD (2015) report.

[10] The Czech Republic formerly applied to join the EU in 1996 (See `https://europa.eu/european-union/about-eu/history/1990-1999/1996_en`). The 1996 - 2004 period corresponds to the period in which the Czech Republic is considered as a candidate by the IBRD (2015).

[11] `https://europa.eu/european-union/about-eu/history/1990-1999/1998_en`

[12] `https://europa.eu/european-union/about-eu/history/1990-1999/1998_en`

[13] Slovakia implemented price cap regulation in 2001 but data is not available before 2005, and thus outside the sample period for Slovakia.

[14] The case where tariff regulation is defined as cost-plus is considered as rate of return in this paper (WAREG, 2019).

Table 2.5: Regulatory environment by country

Country	EU membership	Regulation	Regulator type
Albania	Candidate in 2014	Rate of Return regulation. Inclusion of KPIs in tariff setting since 2012	Independent regulator since 1998. Power to set tariffs
Bulgaria	Candidate[9] between 1998 and 2007. Member state since 2007.	Rate of return until 2009. Price cap since 2009. Inclusion of KPIs since 2009.	Independent regulator since 2005. Power to set tariffs.
Czech Republic	Candidate[10] between 1996 and 2004. Member state since 2004.	Rate of return. Tariffs based on justified costs.	Regulated by government.
Kosovo	Potential candidate in 2003	Rate of return regulation. Prior to 2009 tariffs were determined by historical reasons. Inclusion of KPIs in tariff setting since 2009.	Regulator established in 2004. Power to set final tariff.
Lithuania	Candidate between 1998 and 2004[11]. Member state since 2004	Rate of return. Tariff setting based on KPIs since 2006.	Independent regulator in 2015
North Macedonia	Candidate in 2005	Rate of return since 2005. Tariffs based on cost recovery and political considerations	Regulatory independence established through the energy regulator in 2017. Does not have power to decide on the final tariffs.
Moldova	Neither member nor candidate (signed an association agreement in 2014)	Rate of return regulation. Since 2015, implementation of new tariff methodology.	Independent regulator established in 2014.
Poland	Candidate since 1998. Member state since 2004	Rate of return. Received substantial funding from the EU. Lower tariffs in rural areas	No independent regulator. Tariff regulated at the municipal level.
Romania	Candidate between 1998 and 2007. Member state since 2007	Rate of return without incentives for efficiency but tariffs can increase based on projected expenditures	Independent regulator since 2004. Power to approve final tariffs.
Serbia	Candidate since 2012	Tariffs increases only based on inflation and are capped. Incentives to limit tariff increases through transfers.	Tariffs are regulated by local governments.
Slovakia	Candidate between 1995 and 2004[12]. Member state since 2004.	Price cap set every 5 years and based on justified costs	Independent since 2001. Regulates quality standards and compensation payments to consumers if non-compliance of standards.

assumption on the economic regulation form adopted. In Serbia, although increases in water price are capped by considering targeted inflation, they carry political and social considerations independently from the firm's operation and investment requirements.

Independent regulator

The establishment of independent economic regulators is not a requirement for accessing the EU but, following a survey from regulators, it appears that the main reason for their establishment was to protect the public interest (OECD, 2015)[15]. The appointment of regulators has been also a part of a broader reform process in the sector and to make water utilities more accountable or verifying that they meet their universal service obligations duties[16]. Further, the establishment of regulatory agencies was encouraged by the lack regulatory capacity (expertise) in the sector. Many agencies were established along the derivation of a new water tariff methodology to ensure that the regulator enforces the agreed tariffs as in the case of Moldova (OECD, 2019*a*) but also to monitor firms' KPIs and collect technical and economic data (WAREG, 2017). All regulators play a formal role in setting the price by reviewing and signing-off tariffs previously approved by local governments. In most countries, utilities generally comply with the regulatory mechanism except in Moldova (before 2014), Macedonia and Serbia where the regulatory mechanism is enforced when local governments and the firm agree on the price (IBRD, 2015).

European Union membership

There are many levels of EU membership status. The sample contains countries who are EU members or EU candidates except for Moldova who is not in the process of integrating the EU. During the sample period, some countries start as candidates and end up as members whereas others start without any EU integration and switch to the candidate status. Prior to becoming a member, any country becomes a candidate to EU accession where they start transposing EU directives such as the Water Framework Directive into national legislation while EU members should already comply with the directives. Thus, in every country in the sample, legislation has defined a set of performance indicators to ensure that water suppliers deliver the required water quality and efficiency standards (WAREG, 2017). The economic regulation aspect of the WFD is the cost recovery principle pricing which stipulates that water prices should be high enough to recover water utilities costs.

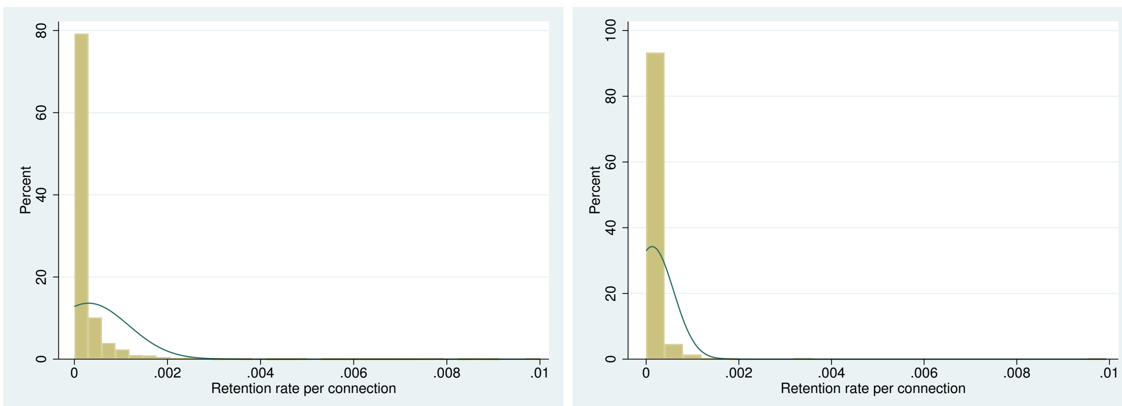
2.3.4 Visual analysis of water utility performance

A first comparison between regulatory policies on performance effects is shown in figures 2.1 and 2.2 respectively for water retention rate and complaints. The left hand side panels of these

[15]The concerned Eastern European regulators participating to the survey were from Albania, Bulgaria, Kosovo and Romania.

[16]See WWRO (2011).

figures illustrate the distribution, expressed in percentage, of these performance measures under rate of return regulation, and the right hand side panels replicate the distributions under price cap. A normal distribution curve is fitted to the different histograms. Figure 2.1 gives a first indication that higher levels of water retention is associated to rate of return. The distribution of water retention is flatter under rate of return and suggests that higher values of water retention are observed more under rate of return than under price cap, which features a distribution that is seemingly more right-skewed. The difference in terms of complaints per capita is less sharp between the two forms of regulation but the distribution under rate of return appears to be more concentrated around the smallest interval, as shown in the charts of figure 2.2.

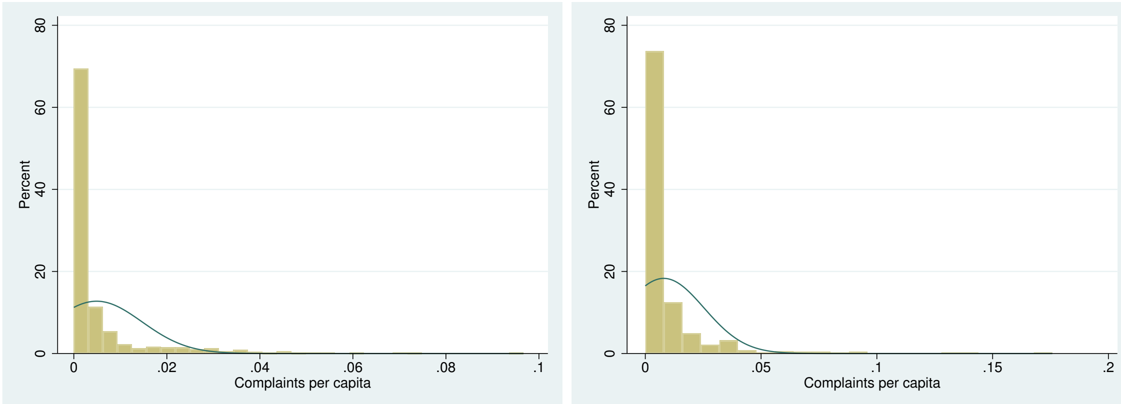


(a) Rate of return (b) Price cap

Figure 2.1: Water retention by regulation.

Note: the distributions are expressed in percentage.

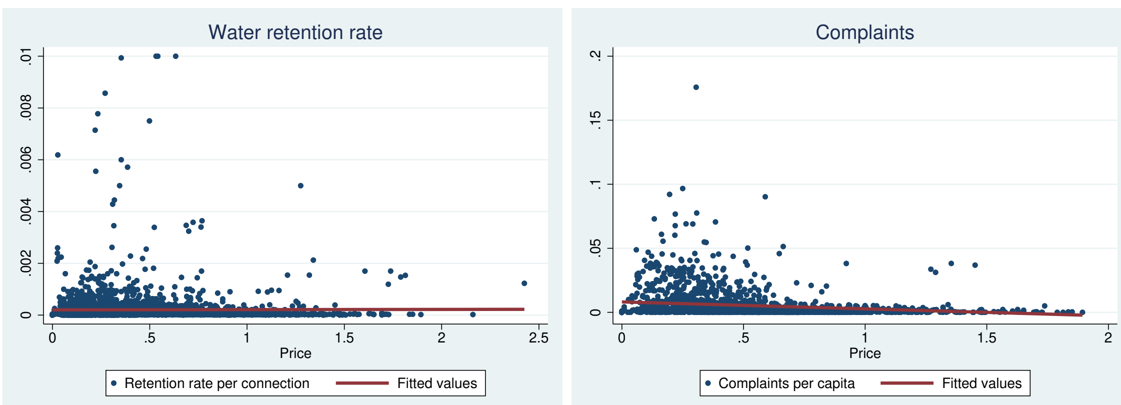
The performance trends with respect to the price is represented in figure 2.3. The left panel shows a scatter plot of water retention rate per connection against price along with a fitted regression line and the right panel corresponds to complaints per capita. The left panel is not suggestive of a clear correlation between reducing water leakage and price. The complaints diagram does not display a definite trend. There is a tendency of increasing complaints with respect to price for low levels of complaints, which is then reversed as prices continue to go up. The fitted regression line has a downward slope but is quite flat. Nonetheless, the slopes of the fitted lines indicate that improving the service comes at the expense of consumers, which is the basic trade-off faced by regulation.



(a) Rate of return (b) Price cap

Figure 2.2: Complaints distribution by regulation.

Note: the distributions are expressed in percentage.



(a) Water retention rate (b) Complaints

Figure 2.3: Water retention rate and complaints trends with respect to price.

Note: scatter plots and fitted regression lines for water retention rate per connection (left panel) and complaints per capita (right panel).

2.4 Model specification and estimation

2.4.1 Firm behaviour specification

We partly test propositions 1.2 and 1.3 of the previous chapter that specify the firm's optimal water retention and quality under a price cap and rate of return respectively. These propositions analyse the comparative statics of water retention and quality with respect to the regulatory tightness under each regulation mode. Under price cap, tighter regulation translates into lower price caps while under rate of return it corresponds to lower allowed rates of return[17].

Under price cap, water utility i solves at each year t:

$$\begin{aligned} \max_{q_{it},\, x_{it}} \quad & (a_{it} - b_{it}q_{it} + x_{it})q_{it} - c_{it}q_{it} - \mu_{it}\frac{x_{it}^2}{2} \\ \text{s.t.} \quad & \bar{p}_{it} \leq (a_{it} - b_{it}q_{it} + x_{it}) \end{aligned}$$

From the first order conditions (FOCs), the optimal water retention (1.8) and quality (1.9) are rewritten for firm i at year t:

$$\begin{aligned} v_{it}^* &= A_{it} w_{it}^{\frac{\alpha_k}{\alpha_v}} r_{it}^{\frac{\alpha_l}{\alpha}} m_{it}^{-\frac{\alpha_l+\alpha_k}{\alpha}} \left(\frac{b_{it}\mu_{it}a_{it} + (1 - b_{it}\mu_{it})\bar{p}_{it} - c_{it}}{b_{it}^2\mu_{it}} \right), \\ x_{it}^* &= \frac{\bar{p}_{it} - c_{it}}{b_{it}\mu_{it}}. \end{aligned} \tag{2.1}$$

Under rate of return, water utility i sets inputs and quality simultaneously as follows:

$$\begin{aligned} \max_{k_{it},\, l_{it},\, v_{it},\, x_{it}} \quad & (a_{it} - b_{it}q_{it} + x_{it})q_{it} - r_{it}k_{it} - w_{it}l_{it} - m_{it}v_{it} - \mu_{it}\frac{x_{it}^2}{2} \\ \text{s.t.} \quad & (a_{it} - b_{it}q_{it} + x_{it})q_{it} - r_{it}k_{it} - w_{it}l_{it} - m_{it}v_{it} - \mu_{it}\frac{x_{it}^2}{2} \leq s_{it}k_{it}, \\ & q_{it} = k_{it}^{\alpha_{kit}} l_{it}^{\alpha_{lit}} v_{it}^{\alpha_{vit}} \end{aligned}$$

Following optimisation, the solutions (1.12) and (1.13) for utility i at year t are rewritten:

$$\begin{aligned} \tilde{v}_{it} &= \frac{2s_{it}\mu_{it}(a_{it}^2 - 8s_{it})}{a_{it}^2(2\mu_{it} - 1)}, \\ \tilde{x}_{it} &= \frac{(a_{it}^2 - 8s_{it})}{a_{it}(2\mu_{it} - 1)}. \end{aligned} \tag{2.2}$$

According to the theoretical price cap environment, water retention and quality linearly depend on price. While quality always increases with price, the direction of the water retention effect depends on the demand slope and the marginal cost of quality. If the marginal cost of quality is lower than the price elasticity of demand, the firm's retention rate level decreases with lower price caps as the revenue loss reduces the firm's incentives to make network rehabilitation efforts. If instead the marginal cost of quality is higher than the price elasticity of demand, a price reduction leads to lower revenues for the firm who then invests in repairs to reduce leaks. In addition, the theory shows that water retention increases in the demand intercept whereas quality does not depend on this parameter. Finally, higher average production costs reduces quality whereas wage rate and capital cost

[17] The mathematical notations are the same as in the previous chapter.

increase water retention.

The rate of return framework is analysed under a scenario where the regulator sets the rate of return higher than the cost of capital. In this setting, quality is a linear decreasing function of the rate of return but water retention is not monotonic in the regulation tightness. Increasing the rate of return from a low level leads to increases in water retention. If instead the rate of return is increased from a high level, incentives for water retention are reduced.

The empirical model is derived from solutions (2.1) and (2.2). The dependent variables of the econometric models are water retention rate per connection and complaints per capita, and the main explanatory variable is the average water price. As rate of return data are not available, price or the capital cost proxy are used instead to directly identify the comparative statics derived by the theory on rate of return regulation. In practice, regulators can adjust water prices to achieve the determined rate of return (Reynaud and Thomas, 2012). Furthermore, the price as a regulatory tool in a rate of return policy is also considered in academic work (Brocas et al., 2006; Wolak, 1994).

The gross national income per capita (GNI) is used as a proxy for the demand intercept in the water retention equation. Put differently, higher living standards, which is expected to increase with the countries' economic development, would increase the need for water (Reynaud et al., 2016)[18]. The input prices that are included are the wage rate, the cost of capital and the unit electricity cost proxy. Note that, since the rate of return depends on the cost of capital, the firm's behaviour indirectly depends on the cost of capital.

The variable *Population per connection* can have two purposes. On the one hand, it is a proxy for household size and can have a positive effect on price. Following Worthington and Hoffman (2008), household size should be correlated with water consumption and the literature survey in Arbués et al. (2010) reports that bigger households tend to have higher water demand. In addition, urban regions are more densely populated than rural areas and are also richer and cross-subsidisation can explain why prices are higher in urban areas and thus among bigger households. On the other hand, population per connection (Skipworth et al., 1999; van den Berg, 2014) affects the efficiency of the system because bigger households put a higher pressure on the system and thus can increase leakage. Population per connection is thus used as the demand intercept proxy in the quality model and as a control in the water retention model.

We include other controls which specifically affect water retention or quality. Water interruption hours is included in the quality equation since it reflects the service quality perceived from consumers (Ananda and Pawsey, 2019). Following Clements (2004) and Sappington (2003), we include year specific dummies to capture industry wide, socio-economic and political aspects that can affect service quality over time like

[18]Roibas et al. (2007) and Reynaud et al. (2016) use average income per household and income per capita at the district level respectively but our data for GNI are aggregated at the national level.

technological change and (non-economic) state regulation.

The models used for the analysis are assessed by pooled-sample regressions and include dummies to capture changes in the regulatory environment. The regulatory variables are characterised based on the description in table 2.5. The form of regulation takes the value of 1 if the firm is regulated by price cap at time t and 0 if regulated by a rate of return policy. Likewise, the independent regulator dummy takes the value of 1 if the firm is regulated by an independent regulator at time t and 0 otherwise. The regulatory environment is assumed to be the same for every utility within a country. The empirical specifications of (2.1) and (2.2) takes the form of two linear equations $k = v, x$, along with a price equation in the following econometric model:

$$\begin{aligned} v_{it} &= \beta p_{it} + \gamma_e G_{it} + \delta_v C_{v_{it}} + \varphi_{v_i} + \theta_{v_{it}} + \epsilon_{v_{it}} \\ x_{it} &= \delta p_{it} + \gamma_x G_{it} + \delta_x C_{x_{it}} + \varphi_{x_i} + \theta_{x_{it}} + \epsilon_{x_{it}} \\ p_{it} &= \eta n_{it} + \iota EU_{it} + \gamma_p G_{it} + \delta_p C_{k_{it}} + \varphi_{p_{it}} + \theta_{p_{it}} + \epsilon_{p_{it}}, \end{aligned} \tag{2.3}$$

where $v_{it} \in [0, 1]$ is water retention rate per connection and calculated as the ratio of quantity sold to quantity produced, x_{it} is the number of complaints per capita, p_{it} is the average water price, G is a vector of regulatory dummies and C is a vector that include cost variables and other controls. The terms φ_{v_i}, φ_{x_i}, and $\theta_{v_{it}}$, $\theta_{x_{it}}$ are respectively the firm fixed effects and error terms in each equation. The error terms are $\epsilon_{v_{it}}$, $\epsilon_{x_{it}}$. We assume that unobserved firm characteristics are uncorrelated across firms. In the price equation, n_{it} is the number of water connections, EU_{it} is a vector containing two dummies respectively reflecting for EU membership and EU candidacy, φ_{p_i} and $\theta_{p_{it}}$ are respectively the firm fixed effect and the time dummies, and $\epsilon_{p_{it}}$ is the error term. The EU vector also includes a default dummy illustrating non-EU membership to account for countries that are neither EU members nor EU candidates at a given point in time. Moreover, these dummies are mutually exclusive in that a firm belongs to a country that is either an EU member or an EU candidate or a non EU member.

2.4.2 Identification and exclusion restriction

The empirical model inherits a theoretical model of firm behaviour but the theory also characterises the price cap and and the rate of return as results of the regulator's behaviour. In practice, the regulator takes into account the affordability of consumers and several performance criteria to set the level of prices and rates of return as summarised in table 2.5. Further, the water price variable is a function of quantity sold and can therefore be correlated with the error term of the water retention equation. The following discussion informs the choice of instruments for the price variable.

Water prices can also be influenced by institutional factors. According to the IBRD

(2015), water prices are higher in EU member countries than in non-EU members. Aspiring EU members and EU members strive for the implementation of the Water Framework Directives (WFD) which stipulates that water prices be based on cost recovery principles, water consumption and on the polluter pays principle. However, the WFD does not specify performance targets for utilities[19]. Thus, it is reasonable to assume that the EU membership status has an influence on price but not on water retention. Since the sample contains EU members, EU candidates and non EU candidates[20], the first set of instruments consists of an EU member dummy, and an EU candidate dummy.

Although EU integration can influence drinking quality standards through the Drinking Water Directive (DWD), it does not set any specific standards for service quality (IBRD, 2015). The IBNET dataset does not provide information about the source of complaints and thus customers could complain because of water supply interruption. Ananda and Pawsey (2019) stress that water quality and service quality are two different aspects of quality. And because service quality reflects how the business is interacting with customers (response to interruption or customer complaint), EU dummies potentially satisfy exclusion restriction as instruments for price in the complaints equation.

Connections can have an impact on the price. As discussed in a technical report by the EEA (2013), if the customer base shrinks following a declining population, the price for the remaining customers will increase as the capital used must be amortised over the remaining households and businesses. This is supported by Nauges and van den Berg (2008), who find evidence of economies of customer density in Moldova, Romania and Vietnam, using the number of connections as a proxy for population. In other words, an increase in the number of water produced and the number of connections reduce average variable costs. van den Berg (2014) adds that water connection density, as measured by the ratio of connection to network length, is outside the control of the utility as is it determined by urbanisation and land settlement patterns.

Finally, as discussed in section 2.3.2, prices are likely to be different across regions within a country because of heterogeneous wealth distribution and scale and density economies. To capture this unobserved heterogeneity, the price equation is estimated with firm fixed effects. This equation is estimated in the first stage of a 2SLS estimation procedure to capture the endogeneity of the price variable.

The regulation dummy variable *Price cap* is potentially endogenous because regulatory mode can change due to industry performance concerns. In the US power market, the implementation of price or revenue caps have been driven by efficiency and political

[19] Although the White Paper on the integration of Central and Eastern European countries to the common market mentions sectors like transportation, energy and telecommunications and stresses the importance of competition policy, it does not provide specific requirements regarding the efficiency of the water industry (EC, 1995).

[20] Kosovo and Moldova in our sample.

concerns (Guerriero, 2013), while in the telecommunications sector, rate of return is presumably preferred to tackle quality issues (Clements, 2004). Since these studies are in the US, they exploit the variation of regulation across firms within different states. In contrast, regulation is homogeneously applied at the national level in our context. Given the lack of information on the political characteristics or the variation of demographics surrounding each water utility, finding suitable instruments for the regulation dummy is challenging. However, the change in regulation happens at most only once, and for most countries no change occurs. Nonetheless, some specifications include country dummies to capture possible endogeneity of regulation.

2.4.3 Choice of estimator

For a first set of results, the water retention and the complaints equations are estimated separately by OLS. This is possible by assuming that the set of regressors for both specifications are identical. Because the first order conditions with respect to quantity, quality and water retention are inter-dependent in the firm's optimisation problem, we also use Zellner's seemingly unrelated regressions (SUR) model. Moreover, the dependent variables can be correlated due to unobserved firm specific effects when estimating firm behaviour equations (Baltagi, 2008; Berndt, 1991),

The SUR model has the convenience of treating each equation as unrelated to the other and at the same time allows for correlations between the error terms (Wooldridge, 2002). For instance, firms can have different priorities in terms of water retention and service quality and thus can choose to allocate their revenue and inputs differently. These differences in managerial quality and decision processes are not observed in the data. The GLS estimator used to perform seemingly unrelated regressions is equivalent to OLS if the set of regressors are identical across equations or if the set of regressors of one equation is the subset of the other (Revankar, 1974), and can be a more efficient estimator than OLS even for moderate size samples (Wooldridge, 2002).

Because $v_{it} \in [0, 1]$, fractional regression analysis can be an alternative empirical strategy. Fractional regression can yield the same predictions as OLS and the estimates can as efficient. Furthermore, fractional regression has the advantage of deriving predicted values which lie in the interval of the actual values. Since we are only interested in the impact of price and regulation on the firm's performance, and not the predicted values, linear regression will suffice for the current analysis.

We use the STATA software to perform the regressions. Since the software uses the GLS estimator to run seemingly unrelated regressions and to ensure that GLS is asymptotically more efficient than OLS, different controls are added or removed from each equation. The theoretical discussion helps to choose the set of regressors for each equation. For instance, GNI is included in the water retention only and electricity unit cost and water interruption hours are added only to the complaints equation. To account for heteroskdasticity, the standard errors are clustered at firm level.

Following the discussion in the previous sections, it is natural to apply instrumental variable regressions to obtain a second set of results. Olmstead (2009)'s survey of the water demand literature highlights a trend for IV estimation when water price is endogenous before estimating her own water demand with endogenous price with IV model and structural demand equation estimations. Her Monte Carlo simulation shows that the latter model can result in more efficient price elasticity estimates but the reduced-form IV procedure has on average lower bias parameters. In a further attempt at estimating the effect of average price on water consumption by using IV models, Szabó (2015) shows considerable sensitivity in the estimates to the choice of instruments and controls because the instruments used - nonlinear tariff schedules - are not likely to satisfy exclusion restriction. We do not use this variable as an instrument but rather the variables discussed in section 2.4.2. Besides, while the limits of IV are acknowledged in estimating price elasticity of demand, our analysis is rather focused on the game between the regulator and the water utility to understand how the firm responds to changes in the allowed price per unit of water supplied in the form of higher average revenue.

2.5 Results

The results of OLS and seemingly unrelated regressions are displayed in table 2.6. Columns 1 and 2 show the respective OLS results for the water retention rate and complaints per capita equations estimated separately, and column 1a replicates the OLS estimation of the water retention model on the same sample as the complaints OLS model. Columns 3 and 4 show the results of the SUR model with firm fixed effects. Columns 5 and 6 replicate the estimation by using country fixed effects and clustering standard errors at country level instead.

The effects of price and the independent regulator dummy are sensitive to the specification for water retention as the effect is significant only in the SUR estimations. For the complaints equations, the effect of price is not conclusive. Under price cap, price increases lead to more water retention when demand is elastic enough because the drop in sales incentivises the firm to reduce network losses. Under rate of return, for low levels of the rate of return, a higher rate of return induces more water retention because the firm can better recoup network rehabilitation investment efforts. The sign of the price effect on quality, although not significant, is in line with the literature (Sappington, 2005; Ananda and Pawsey, 2019) as the higher the price the more the firm is able to cover the extra costs associated to quality provision efforts. The effect of price cap is robust and significant in the water retention equation only and suggests that water retention is lower under price cap than under rate of return regulation, which is consistent with Aubert and Reynaud (2005) who explain that the over-capitalisation induced by rate of return regulation entails more variable cost savings.

The first stage results of the 2SLS estimation are shown in table 2.7[21]. Columns 1 to 4 are the first stage results for the water retention rate equation and columns 5 to 8 show the results for the complaints equation. Columns 4 and 8 show results where country fixed effects are used and standard errors are clustered at country level to account for similarities in political and development paths that the countries have encountered. The F-test of joint significance of instruments reflects the joint significance of the instruments only. In all specifications, price cap regulation leads to a lower price than rate of return regulation. First, since rate of return regulation is based on the cost reimbursement principle, it is more sensitive to cost variations which have had a positive trend in the water industry. This increasing trend can also be compounded by a lack of incentives to reduce allocative inefficiency. Second, price cap regulation is known to induce more cost efficiency incentives than rate of return regulation with the idea of passing on these gains to consumers through lower prices.

[21]For robustness checks, table 2.12 in the appendix provide results where price and price cap are instrumented. The signs of price remains unchanged with respect to the IV regression results presented in this section for the water retention rate specifications but the sign of price cap changes for complaints specifications. Both variables are not significant.

Table 2.6: OLS and SUR regression results of retention rate and complaints equations

	OLS			SUR		SUR	
	(1)	(1a)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Retention rate	Retention rate	Complaints	Retention rate	Complaints	Retention rate	Complaints
Price	0.000103	4.75e-05	-0.00160	5.75e-05***	-0.00161	0.000285***	-0.00157
	(7.34e-05)	(4.77e-05)	(0.00128)	(1.62e-05)	(0.00112)	(5.48e-05)	(0.00126)
Price cap	-0.000160**	-4.54e-05**	0.00099	-4.58e-05***	-0.00103	-0.000196**	0.00118
	(6.29e-05)	(2.25e-05)	(0.00164)	(1.79e-05)	(0.00129)	(9.27e-05)	(0.00216)
Regulator	7.55e-05*	-6.14e-06	0.000323	-9.44e-06	-0.00033	4.53e-05	0.0006
	(3.89e-05)	(7.14e-06)	(0.00186)	(1.36e-05)	(0.000978)	(7.71e-05)	(0.00181)
Wage	5.43e-10*	-3.80e-10	-1.94e-08	-3.04e-10		-1.06e-09	
	(3.24e-10)	(4.28e-10)	(5.18e-08)	(4.43e-10)		(1.64e-09)	
Electricity cost	-1.74e-09	-6.19e-09	2.38e-06**		2.38e-06***		1.21e-07
	(1.10e-08)	(5.04e-09)	(1.26e-06)		(3.95e-07)		(3.67e-07)
Capital cost proxy	1.32e-11***	2.18e-11***	-1.46e-10**	2.13e-11 ***	-1.40e-10	2.16e-11	-1.72e-11
	(3.51e-12)	(2.04e-12)	(7.19e-11)	(4.70e-12)	(3.37e-10)	(2.62e-11)	(6.18e-10)
Gross National Income	3.54e-08**	-1.24e-09		3.19e-10		-1.75e-08*	
	(1.56e-08)	(1.92e-09)		(2.52e-09)		(1.31e-08)	
Population per connection	1.97e-05*	7.25e-06***	1.64e-05		2.14e-05		4.82e-05***
	(1.10e-05)	(2.76e-07)	(2.17e-05)		(2.38e-05)		(1.52e-05)
Interruption (hrs)			0.000252**		0.000249***		4.55e-05
			(0.000115)		(8.15e-05)		(0.000103)
Constant	9.94e-05	0.000127***	0.00800***	0.000157	0.0495***	0.000152	0.001702
	(0.000103)	(1.01e-05)	(0.00307)	(5.54e-05)	(0.000)	(0.000105)	(0.00246)
Observations	2,413	1,360	1,360	1,360	1,360	1,360	1,360
R-squared	0.127	0.397	0.068	0.976	0.801	0.218	0.213
Number of id	405	289	289				
Firm FE	Yes	Yes	Yes	Yes	Yes	No	No
Country FE	No	No	No	No	No	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: From columns 1 to 4, standard errors are clustered at firm level. In colums 5 and 6, standard errors are clustered at country level.

An independent regulator is associated with lower prices (see table 2.7). This does not support the standpoint that independent regulatory agencies have a higher preference for the firm's welfare. Regulatory agencies were set-up to protect consumers, provide regulatory expertise and collect information on the water industry. This subsequent reduction of asymmetric information allows the regulator to implement lower prices[22].

The coefficient estimates associated to the cost of capital proxy are the most robust for the water retention subset. The highly significant results across all specifications suggest that price is strongly influenced by the cost of capital as it is expected in a highly capital intensive industry. The demand shifter variables Gross National Income (GNI) and *Population per connection* have the expected impact. As predicted by the theory, the demand intercept proxies shift water demand upwards and would inflate the price.

A perhaps more interesting result is the effect of the EU status dummies on price. The negative impact of these dummies contradicts the assumption that more European Union integration should lead to higher water prices because of the requirement of the cost recovery pricing principle. But in fact, high prices would be politically costly to implement and countries have implemented reforms to merge small utilities into big regional firms in the context of EU integration to benefit from economies of scale and to facilitate the absorption of EU funding into utilities and thus making cost recovery pricing more feasible. Indeed, utilities of EU countries have higher efficiency[23]. The regulator then passes on any efficiency gains to consumers by adjusting the price, every other thing being equal. Because EU member countries have higher GDP per capita (IBRD, 2005, p. 64 figure 62) and prices have increased mainly because of cost increases and economic development (IBRD, 2015, p. 56), both of which effects are captured in the econometric model, water prices would appear higher in EU member countries from a descriptive perspective.

[22]One can think that countries with an independent regulator could have invested to reduce average cost which would have resulted in lower prices. However, investments have led to higher prices. For instance, EU countries without an independent regulator like Poland and the Czech Republic, which have invested substantially in the water industries, have higher water prices than the rest of the sample countries.

[23]EU member countries have higher labour productivity and water retention than the remaining countries while the gap in affordability of water services between EU members, EU candidates and non EU members is very small. In addition, Moldova, a non EU country, have relatively high water tariffs. See figures 58 and 61 in IBRD (2015, p. 58 - 63).

Table 2.7: First stage regressions

	Retention rate				Complaints			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	Price	Price	Price	Price	Price	Price	Price	Price
Price cap	-0.0785***	-0.105***	-0.106***	-0.106**	-0.114***	-0.114***	-0.114***	-0.114**
	(0.0186)	(0.0194)	(0.0195)	(0.0354)	(0.0234)	(0.0233)	(0.0232)	(0.0376)
Regulator	-0.160***	-0.141***	-0.129***	-0.129***	-0.118***	-0.101***	-0.101***	-0.101
	(0.0229)	(0.0233)	(0.0247)	(0.0339)	(0.0305)	(0.0327)	(0.0328)	(0.0554)
Wage rate	6.26e-07	6.70e-07	6.91e-07	6.91e-07	1.72e-06	1.85e-06	1.86e-06	1.85e-06
	4.74e-07	4.96e-07	5.09e-07	4.22e-07	(1.19e-06)	(1.21e-06)	(1.21e-06)	(1.16e-06)
Electricity unit cost	1.00e-05	9.04e-06	8.51e-06	8.51e-06	1.05e-05	6.22e-06	6.30e-06	6.22e-06
	(7.48e-06)	(7.49e-06)	(7.27e-06)	(8.25e-06)	(1.38e-05)	(1.44e-05)	(1.45e-05)	(2.07e-05)
Capital cost proxy	1.83e-08***	1.82e-08***	1.83e-08***	1.83e-08***	2.54e-08***	2.57e-08***	2.57e-08***	2.57e-08***
	(2.72e-09)	(2.72e-09)	(2.78e-09)	(1.97e-09)	(2.06e-09)	(2.11e-09)	(2.12e-09)	(1.43e-09)
Gross National Income	2.30e-05***	2.40e-05***	2.36e-05***	2.36e-05**				
	(4.44e-06)	(4.42e-06)	(4.44e-06)	(9.92e-06)				
Connections			-1.61e-06**	-1.61e-06		-2.17e-06**	-2.27e-06**	-2.17e-06
			(6.71e-07)	(9.54e-07)		(9.49e-07)	(9.45e-07)	(1.25e-06)
Population per connection	0.000525**	0.000680***	0.000575**	0.000575*	0.000869***	0.000790***		0.000790**
	(0.000226)	(0.000230)	(0.000235)	(0.000273)	(0.000231)	(0.000187)		(0.000334)
EUM		-0.0884***	-0.0846***	-0.0846***	-0.146***	-0.143***	-0.140***	-0.143***
		(0.0210)	(0.0208)	(0.0207)	(0.0334)	(0.0335)	(0.0335)	(0.0323)
EUC	-0.0295**	-0.0696***	-0.0704***	-0.0704**	-0.123***	-0.126***	-0.126***	-0.126***
	(0.0115)	(0.0155)	(0.0156)	(0.0245)	(0.0222)	(0.0225)	(0.0225)	(0.0145)
Constant	0.0648**	0.0692**	0.0837***	0.0837	0.155***	0.189***	0.202***	0.189*
	(0.0292)	(0.0294)	(0.0293)	(0.0536)	(0.0399)	(0.0423)	(0.0408)	(0.0985)
Observations	2,413	2,413	2,413	2,413	1,360	1,360	1,360	1,360
F-test	6.56	11.03	8.04	5.78	15.44	11.88	12.04	41.00
R-squared	0.573	0.576	0.577	0.577	0.510	0.511	0.511	0.511
Number of id	405	405	405	405	289	289	289	289
Firm FE	Yes	Yes	Yes	No	Yes	Yes	Yes	No
Country FE	No	No	No	Yes	No	No	No	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Columns 1 to 4 show first stage results for the water retention specification. First stage results for the complaints equation are shown in columns 5 to 8.

The IV estimates of water retention and complaints are shown respectively in tables 2.8 and 2.9 and the last column of each table shows coefficient estimates where country fixed effects are included instead of firm fixed effects and standard errors clustered at country level. The columns in table 2.8 are the second stage specifications corresponding respectively to first stage estimations in columns 1 to 4 in table 2.7, and the columns in table 2.9 are the second stage specifications of the complaints model corresponding to first stage estimations in columns 5 to 8 of table 2.7.

The effect of price cap regulation compared to rate of return is confirmed. Price cap entails less water retention possibly because of the lack of capitalisation under this form of regulation but also from the more stringent monitoring of the firm's information under rate of return that enables the regulator to closely monitor the firms' behaviour (Aubert and Reynaud, 2005). Since the age of the infrastructure is one of the reasons for water leakage (van den Berg and Danilenko, 2011), the effect of the price cap dummy may reflect the capital intensity of conducting rehabilitation of old systems that is accounted for in the rate of return setting. This is also reflected in the capital cost proxy, which reflects a higher rate of return. This allows the firm to cover the costs associated with network rehabilitation. On the other hand, under price cap, higher water retention can achieve a lower average cost since it is possible to deliver a higher level of output with a given amount of inputs. Hence, an increasing cost of capital leads the firm to reduce costs by augmenting water retention (equation (1.8)).

Based on the theory, the effect of price on water retention is interpreted as follows. Under price cap, water retention decreases with the price when water demand is inelastic enough. The sign of the coefficient associated with price suggests that this is the case. When demand is inelastic enough, higher prices do not substantially reduce the firm's revenue. The higher profit generated by a higher price thereby disincentivises the firm to augment water retention since it decreases the associated opportunity cost. The result is also in line with empirical findings (IBRD, 2015; van den Berg, 2014). The ambiguous effect of price on water retention across our estimation procedures can be explained by van den Berg (2014) who stresses that higher prices can cover costs associated water loss reduction and thus encourage more water retention but can also reduce such incentives if the firm is already earning high sales revenues.

The presence of an independent regulator appears to make the firm reduce water retention but the associated effect is in most cases not significant at the 5% level. The sign of the effect suggests two mechanisms. First, regulators are more able to obtain information from the water industry and benchmark firms, thereby reducing informational asymmetries. Extracting more informational rent from water utilities could reduce incentives for water retention. Second, the highest performing utilities are located in countries without an independent regulator. Countries without a regulator often rely on public-private partnerships which are regulated by a concession contract. The basic form of concession contract regulation model does not require a regulator as all the rules are explicated in the law (OECD, 2015) and exists in the

Czech Republic and Poland. Both the Czech Republic and Poland joined the EU at the same time and most likely benefit from substantial funding and expertise which could have helped these countries improve the state of their water systems. As the theory predicts, the demand intercept GNI leads to more water retention. The coefficient estimate associated to population per connection, despite not being significant, seems to support that bigger households are associated to higher water demand instead of increased pressure on the network.

Table 2.8: Water retention IV regressions

VARIABLES	(1) Retention rate	(2) Retention rate	(3) Retention rate	(4) Retention rate
Price	-0.00120	-0.00154***	-0.00164**	-0.00164***
	(0.000856)	(0.000597)	(0.000706)	(0.000481)
Price cap	-0.000240**	-0.000262**	-0.000267**	-0.000267***
	(0.000110)	(0.000103)	(0.000110)	(2.56e-05)
Regulator	-0.000121	-0.000174*	-0.000188*	-0.000188**
	(0.000139)	(9.61e-05)	(0.000104)	(8.03e-05)
Wage rate	1.38e-09	1.60e-09	1.66e-09	1.66e-09**
	(9.66e-10)	(1.06e-09)	(1.13e-09)	(7.70e-10)
Electricity cost	1.12e-08	1.46e-08	1.55e-08	1.55e-08
	(1.69e-08)	(1.72e-08)	(1.87e-08)	(1.86e-08)
Capital cost	3.67e-11**	4.30e-11***	4.46e-11***	4.46e-11***
	(1.79e-11)	(1.39e-11)	(1.62e-11)	(7.76e-12)
Gross National Income	6.79e-08**	7.65e-08**	7.88e-08**	7.88e-08***
	(3.32e-08)	(3.00e-08)	(3.44e-08)	(1.43e-08)
Population per connection	2.03e-05*	2.05e-05*	2.06e-05*	2.06e-05
	(1.08e-05)	(1.09e-05)	(1.10e-05)	(1.39e-05)
Constant	0.000149	0.000162	0.000165	0.000165
	(0.000121)	(0.000116)	(0.000110)	(0.000197)
Observations	2,413	2,413	2,413	2,413
Number of id	405	405	405	405
Firm FE	Yes	Yes	Yes	No
Country FE	No	No	No	Yes
Year FE	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

As regards to the complaints specifications (see table 2.9), price cap regulation significantly improves the firm's level of service quality. This result potentially highlights a trade-off between increasing water retention and service quality. As the firm is residual claimant of its profit under price cap, a higher profit earned from a higher quality whereas rate of regulation constrains the firm to the same profit rate regardless of the amount of quality provision[24]. As explained by Bjørner et al. (2021), price cap regulation would drive firms to reduce unnecessary costs through better management practices in order to achieve quality standards. This suggests, in our case, that unnecessary costs can reflect low cash collection rates or low labour productivity. Note that these unnecessary costs may not refer to capital productivity since, according to our results, price cap entails lower water retention than rate of return. Higher capital costs increases water retention but reduces quality provision. This emphasises the trade-off between water retention and service quality highlighted under rate of return regulation.

Table 2.9: Complaints IV regressions

VARIABLES	(1) Complaints	(2) Complaints	(3) Complaints	(4) Complaints
Price	-0.0385***	-0.0393***	-0.0393***	-0.0393***
	(0.0121)	(0.0134)	(0.0134)	(0.0123)
Price cap	-0.00416**	-0.00423**	-0.00423**	-0.00423**
	(0.00200)	(0.00202)	(0.00202)	(0.00197)
Regulator	-0.00487*	-0.00497*	-0.00498*	-0.00497
	(0.00276)	(0.00299)	(0.00300)	(0.00324)
Wage rate	4.67e-08	4.81e-08	4.82e-08	4.81e-08
	(7.01e-08)	(7.09e-08)	(7.08e-08)	(7.18e-08)
Electricity cost	2.79e-06**	2.80e-06**	2.81e-06**	2.80e-06***
	(1.33e-06)	(1.37e-06)	(1.37e-06)	(9.35e-07)
Capital cost	7.79e-10***	7.99e-10**	7.97e-10**	7.99e-10***
	(2.96e-10)	(3.28e-10)	(3.30e-10)	(2.95e-10)
Interruption (hrs)	0.000521**	0.000527*	0.000527*	0.000527***
	(0.000262)	(0.000270)	(0.000270)	(0.000197)
Population per connection	1.33e-05	1.39e-05		1.39e-05
	(2.26e-05)	(1.96e-05)		(1.81e-05)
Constant	0.0107***	0.0107***	0.0109***	0.0107***
	(0.00363)	(0.00381)	(0.00368)	(0.00355)
Observations	1,360	1,360	1,360	1,360
Number of id	289	289	289	289
Firm FE	Yes	Yes	Yes	No
Country FE	No	No	No	Yes
Year FE	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

As predicted by the theory, higher prices allow water utilities to increase service quality, as

[24] This intuition is underlined in Laffont and Tirole (1993).

translated by fewer complaints. The signs of the coefficients associated to wage and electricity are consistent with the theory. We would expect that water utilities with higher costs find it more costly to enhance quality.

2.6 Conclusion

This paper compares the effect of rate of return and price cap on water retention and quality, and tests partly the theoretical predictions of the previous chapter. This is performed by estimating water retention and quality equations on a panel of 11 Eastern European countries over a 20-year period. The theoretical predictions are partly corroborated by the results. Although the analysis does not conclude which form of regulation is superior, it provides some insights on how water retention and service quality may be affected under different types of regulation.

One of the main findings of this paper sheds light on a trade-off between water retention and service quality improvements from economic regulation, which puts the regulator in front of a non-trivial decision. The comparison of the various forms of regulation shows that rate of return regulation fares better in improving the firm's water retention since the cost reimbursement rule of this scheme possibly allows the firm to bear less risk on its investments towards renovating the infrastructure. However, price cap entails better service quality as evidenced by less complaints because of possible efficiency gains that makes the cost of higher quality provision more affordable. The effect of price on water retention is ambiguous across estimators. On the one hand, the OLS results show that water utilities can achieve higher water retention rates through price increases because higher prices are able to cover the associated cost increases. On the other hand, the IV estimates suggest that allowing the firm to earn a higher price for each cubic metre of water sold reduces incentives to increase water retention because of a high enough revenue earned for each unit of water sold.

Our results also provide some insights into the benefits and downsides of having an independent regulatory agency. Although not strongly statistically significant, an independent regulator is associated with lower water retention but drives higher levels of quality provision, which confirms the importance given by independent agencies in addressing customer satisfaction. Finally, we find evidence that horizontal integration of utilities to achieve economies of scale and density is in line with a strategic response to the EU cost recovery pricing principle.

Given the limitations on the quality of the data at hand, our conclusions should be interpreted with care. Ideally, the analysis should be repeated on datasets from other countries with richer observations on quality indicators, water tariffs and finer definitions of the type of regulation enforced. Last, since the literature has highlighted the effectiveness of benchmarking techniques in influencing performance of water utilities (Marques, Simoes and

Pires, 2011; Ananda and Pawsey, 2019), a possible path of research could analyse water utilities' incentives by combining this approach with the traditional forms of economic regulation.

2.A Appendix

2.A.1 Firm output distribution

Table 2.10 gives the distribution of utilities by output volume from the overall sample and table 2.11 summarises the distribution of utility size by country over the sample period.

Table 2.10: Firm distribution - Pooled sample

Million m^3	No.	%	Cum
0	1.0	0.2	0.2
10	374	74.1	74.3
20	47	9.3	83.6
30	27	5.3	88.9
40	22	4.4	93.3
50	10	2.0	95.2
60	6	1.2	96.4
70	4	0.8	97.2
80	3	0.6	97.8
90	2	0.4	98.2
100	1	0.2	98.4
110	3	0.6	99.0
140	1	0.2	99.2
150	1	0.2	99.4
160	1	0.2	99.6
190	1	0.2	99.8
200	1	0.2	100.0
Total	505	100.0	

Table 2.11: Firm distribution by country

Albania

Firms regulated	58	
Output	Number	%
10	57	87.7
20	4	6.2
30	1	1.5
40	2	3.1
110	1	1.5
Total	65.0	100.0

Bulgaria

Firms regulated	64	
Output	Number	%
10	9	19.6
20	9	19.6
30	10	21.7
40	6	13.0
50	5	10.9
60	1	2.2
70	2	4.3
80	1	2.2
90	1	2.2
100	1	2.2
200	1	2.2
Total	46	100.0

The Czech Republic

Firms regulated	N.A	
Output	Number	%
10	11	45.8
20	6	25.0
30	1	4.2
40	2	8.3
50	1	4.2
80	1	4.2
90	1	4.2
140	1	4.2
Total	24	100.0

Kosovo

Firms regulated	7	
Output	Number	%
10	2	28.6
30	3	42.9
40	1	14.3
50	1	14.3
Total	7	100.0

Lithuania

Firms regulated	N.A	
Output	Number	%
10	35	92.1
20	1	2.6
30	1	2.6
40	1	2.6
Total	38	100.0

Macedonia

Firms regulated	N.A	
Output	Number	%
0	1	2.4
10	38	90.5
20	2	4.8
110	1	2.4
Total	42	100.0

Moldova

Firms regulated	40	
Output	Number	%
10	39	95.1
20	1	2.4
110	1	2.4
Total	41	100.0

Poland

Firms regulated	N.A	
Output	Number	%
10	22	55.0
20	5	12.5
30	5	12.5
40	3	7.5
50	1	2.5
60	2	5.0
70	1	2.5
150	1	2.5
Total	40	100.0

Romania

Firms regulated	42	
Output	Number	%
10	9	28.1
20	8	25.0
30	6	18.8
40	5	15.6
50	1	3.1
60	1	3.1
70	1	3.1
160	1	3.1
Total	32	100.0

Serbia

Firms regulated	N.A	
Output	Number	%
10	149	93.7
20	7	4.4
40	2	1.3
190	1	0.6
Total	159	100.0

Slovakia

Firms regulated	14	
Output	Number	%
10	3	27.3
20	4	36.4
50	1	9.1
60	2	18.2
80	1	9.1
Total	11.0	100.0

2.A.2 Economies of scale

Figure 2.4 plots the unit operational cost in US dollars against the amount of water produced for the whole sample.

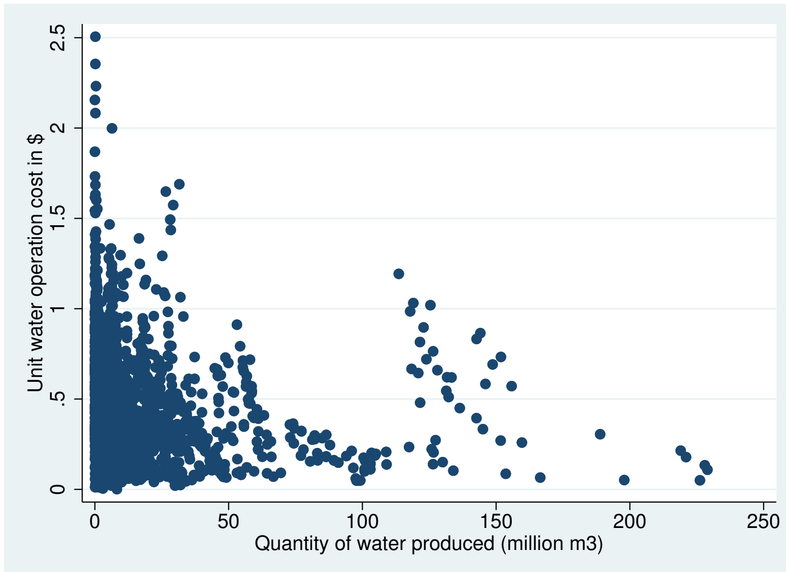


Figure 2.4: Unit operating cost by firm size

2.A.3 Regression results

Table 2.12 shows second stage regression results when the price cap dummy is instrumented using EUC, EUM and N.

Table 2.12: IV regression results with price cap instrumented

VARIABLES	(1) Retention rate	(2) Retention rate	(3) Retention rate	(4) Complaints	(5) Complaints	(6) Complaints
Price	-0.00246	-0.00220	-0.00220	-0.131	-0.113	-0.113
	(0.00217)	(0.00195)	(0.00194)	(0.168)	(0.136)	(0.0828)
Price cap	-3.43e-05	-9.36e-05	-9.36e-05	-0.00175	0.00179	0.00179
	(0.000572)	(0.000453)	(0.000565)	(0.0396)	(0.0405)	(0.0309)
Regulator	-0.000310	-0.000271	-0.000271	-0.0162	-0.0130	-0.0130
	(0.000322)	(0.000279)	(0.000272)	(0.0215)	(0.0166)	(0.0103)
Wage rate	2.19e-09	2.03e-09	2.03e-09	2.62e-07	2.33e-07	2.33e-07
	(2.07e-09)	(1.83e-09)	(1.72e-09)	(3.66e-07)	(3.10e-07)	(1.57e-07)
Electricity cost	2.37e-08	2.11e-08	2.11e-08	3.29e-06	3.72e-06	3.72e-06
	(3.19e-08)	(2.96e-08)	(3.85e-08)	(3.63e-06)	(3.78e-06)	(2.99e-06)
Capital cost	6.07e-11	5.57e-11	5.57e-11	3.01e-09	2.51e-09	2.51e-09
	(4.27e-11)	(3.97e-11)	(3.61e-11)	(4.23e-09)	(3.37e-09)	(2.01e-09)
Gross National Income	1.01e-07	9.44e-08	9.44e-08*	5.41e-06	4.53e-06	4.53e-06
	(6.49e-08)	(6.74e-08)	(5.25e-08)	(7.09e-06)	(5.59e-06)	(3.48e-06)
Population	2.10e-05*	2.09e-05*	2.09e-05			
	(1.11e-05)	(1.16e-05)	(1.47e-05)			
Water interruption (hrs)					0.00107	0.00107
					(0.00144)	(0.000829)
Constant	0.000164	0.000163	0.000163	0.0199*	0.0149**	0.0149***
	(0.000128)	(0.000120)	(0.000211)	(0.0113)	(0.00632)	(0.00487)
Observations	2,413	2,413	2,413	1,360	1,360	1,360
Number of id	405	405	405	289	289	289
Firm FE	Yes	Yes	No	Yes	Yes	No
Country FE	No	No	Yes	No	No	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Chapter 3

Multi-regulation and moral hazard

This paper analyses the interaction between two regulators and a natural monopoly in a strict moral hazard setting. The firm engages in a single cost reduction effort that can lead to the desirable state, and regulators motivate the firm in doing so through direct transfers. When regulators move simultaneously, incentives are stronger than in the unique regulator framework due to the sharing of regulatory cost burden. However these incentives are excessively strong from a welfare perspective if their valuation for the firm's rent is high enough. Due to the first mover's tendency to free-ride, sequential moves of regulators generate less incentives than any other setup, unless the regulators have asymmetric valuations or costs. In any case, the sequential game generates a higher welfare, which directs regulatory design towards this configuration.

3.1 Introduction

Public utilities are often regulated by several authorities and the design of these regulatory institutions is crucial to balance firms' incentives to invest and consumer affordability. The multiplicity of regulators can mitigate these problems or exacerbate them. In particular, multi-regulation can have non trivial effects on the firm's incentives to invest and on welfare when the regulators' moves are simultaneous or sequential. The present paper studies the impact of having multiple regulators on incentives and on welfare for various degrees of accountability or regulatory costs by taking a moral hazard approach.

While most of the literature has taken an adverse selection approach by focusing on the firm's superior information about its costs, this paper takes a common agency approach that analyses how the firm is incentivised to achieve performance targets.

Multi-regulation can take many forms but we focus on the regulation of a common industry by several authorities. In the European context, the European Investment Bank (EIB) or the European Bank for Reconstruction and Development (EBRD) are supranational agencies who provide funds to firms at the national level. In the UK, OFWAT and the CMA have determined different rates of return for water firms (OFWAT, 2020). In the Eastern Caribbean, a supranational telecommunications regulator, the Eastern Caribbean Telecommunications Authority (ECTEL), was established in 1998 to share information with national regulators and promote a wide range of regulatory policy measures including competition, fair pricing and technological progress (Kessides et al., 2010).

Despite these various institutional setups, the actual financing of infrastructure trend is inferior to the worldwide investment needs and the gap is likely to increase. According to Oxford Economics (2017), the amount spent globally on infrastructure investment rose from US $1.8 trillion in 2007 to US $2.3 trillion in 2015, whereas the amount needed for the 2016 - 2040 period equals US $94 trillion. In this context, regulatory governance and the design of regulatory institutions are essential to encourage private investment (Stern and Holder, 1999). These investments can increase efficiency and this paper aims at assessing how incentives to increase efficiency evolve under different parametric conditions of regulatory capture and costs.

In the present setup, the regulators seek to maximise expected welfare of a given country over two states of nature. They do so by incentivising the monopolist to reduce its cost through a transfer from the consumers in order to achieve welfare in the desirable state. The regulators have a valuation for the firm's rent and bear a regulatory (political) cost which is a function of their respective transfer. Since they do not necessarily operate in the exact same jurisdiction or because their mandate is not totally symmetric, we allow regulators to value the firm's rent differently and incur asymmetric regulatory costs.

The main findings are as follows. In the simultaneous two regulator setup, in contrast to the literature, incentives generated are too high-powered due to the savings incurred by the regulators through the sharing of regulatory costs. This configuration can thus be inferior to the unique regulator setup for high levels of the firm's rent valuation. The analysis also shows that higher regulatory cost of taxation leads to lower incentives. When the cost of regulation is asymmetric, the multiplicity of regulators has ambiguous results when this cost is either low or high. The regulatory cost sharing effect either outweighs the direct cost of taxation effect leading to stronger incentives or is outweighed by the direct cost of taxation effect, resulting thus in lower incentives.

The interaction between regulators is also analysed by means of a sequential game as the follower can adjust its strategy after having observed the first mover's action. In this setup, the Stackelberg leader freerides because of perfect foresight. Having observed the first mover's action, the second regulator can transfer an amount to the firm which is enough to motivate it to exert effort while being affordable to consumers. However, the sequential environment is superior to the single regulator game which directs the regulatory design towards sequential regulation. Alternatively, regulators can be suggested to move simultaneously if they are subject to high political interference (low valuation for firm's rent or high regulatory cost).

The paper is structured as follows. Section 3.2 surveys the related literature. Section 3.3 details the model and the different implications on incentives. Section 3.5 elaborate welfare implications. Section 3.6 discusses stylised facts in relation to the results. Section 3.7 concludes.

3.2 Related literature

The regulation literature has thoroughly analysed the relationship between regulators and firm under adverse selection with multi-principals and a single agent - common agency. Our paper is an extension of the strict moral hazard regulation model of Armstrong and Sappington (2007) to two principals and includes a political cost of regulation.

The first paper to consider common agency under moral hazard is the work of Bernheim and Whinston (1986) who construct a general framework of the interaction between multiply principals and one agent, while Martimort (1992) and Stole (1991) provide seminal work on a general framework of common agency under adverse selection.

A first common agency model with adverse selection applied to natural monopoly regulation dates back to Baron (1985), where a power producer is regulated by the Public Utility Commission (PUC) and an environmental regulator (EPA). The latter, being a Stackelberg leader, extracts more rent by setting more stringent abatement standards and forces the PUC to let the firm charge higher prices firm to encourage production. Martimort (1996) extends the analysis to a simultaneous game and non-benevolent regulators. Under a simultaneous setup, separation regulators results in lower incentives than a central regulator because each regulator free-rides. However, for certain values of the regulators' firm biases, separating regulators yields higher incentives and achieves a higher welfare. This literature focuses on industry specific regulators whereas our analysis is framed within a different context where regulators have a symmetric objective.

Multi-regulation is analysed within a three-tier hierarchy model. In Laffont (2005)'s adverse selection problem, the government pays two regulators to assess and report the firm's cost. There analysis shows that false reporting is reduced when transfers to a regulator depend on the quality of the other regulator's report. As each regulator creates a negative externality on the other, the inefficient firm's incentives are distorted whereas the efficient firm's rent is increased, leading to a higher welfare than when regulators are integrated. These findings are similar to Laffont and Martimort (1999) who instead consider an environmental regulator and an economic regulator in this three-tier hierarchy. They further show that when a regulator discloses his report on the firm first, the scope for collusion of the other regulator expands, leading to a lower welfare than when reports are disclosed simultaneously but to a higher welfare than with a single regulator. However, this literature considers the regulators as being themselves agents with a private information at the expense of the government. Our paper takes regulators as principals.

In a model of privatisation of a monopolist, Laffont and Tirole (1991) derive a model where the regulator and the firm's shareholders are different principals while the agent is the firm's manager. This multiplicity of principals leads to free-riding since each principal's decision benefits the other. They also show that incentives are inefficiently weak under privatisation since it is more costly to induce any given effort level. Olsen and Torsvik (1993) extends this privatisation model to a dynamic problem. They show that the weak static incentives created by privatisation mitigates the ratchet effect in subsequent periods because it is less costly for the principals to commit to give weak incentives in the future. This reduces the extent to which an efficient firm mimics an inefficient one. Common agency can then generate higher intertemporal welfare than single agency.

A part of the literature has focused on the regulation with adverse selection of multinational firms who are subject to regulation in their home country and regulation in the foreign market in which they operate. Based on Laffont and Tirole (1993) and Olsen and Osmundsen (2001)'s common agency model, Laffont and Pouyet (2004) develop a model of a firm undertaking projects in different countries and regulated by their respective authorities. They show that, when efforts to conduct the two activities are sufficiently substitutable, competition between non-benevolent national regulators provides too high-powered incentives which makes centralisation of the regulatory process socially more desirable. When regulators can be captured, decentralisation of regulators achieves a higher welfare as it reduces their discretionary power.

Calzolari (2004)'s multi-regulation of a multinational firm model has a similar setup to

Laffont and Pouyet (2004) but outputs between countries can to be either substitutes or complement and nonlinear schedules are used instead of direct mechanisms. With complementary outputs, incentives to produce are weaker. With substitutes and sufficiently large profit weights assigned by regulators, incentives to produce are also reduced. Biancini (2018) includes a competitor in the foreign market and accounts for technology correlation between the firms. When firms' technologies are uncorrelated, national regulators push efficient firms to produce too much by granting high informational rents. When costs are correlated, the regulators have a stronger signal about the firms' type and thus reduce their information rent. Our papers differs in that we do not analyse multimarkets but rather multi-regulation of a single market.

Some models in regulation economics make use of a mixed adverse selection and moral hazard setting. For instance, Carrasco (2010) models a single firm regulated by two regulators who contracts each the realisation of a project with the firm. Burnett and Carrasco (2011) analyse a model of cost padding regulation model where the firm can engage in cost reduction and self-dealing efforts. However such models are coined *false* moral hazard as the variable observed by the principal is a deterministic function of the agent's effort and thus "the agent does not have much freedom to choose the effort level when he has to chosen how much to produce" (Laffont and Martimort, 2002, p. 274), and thus such models end up being adverse selection models (Laffont and Martimort, 2002, p. 258). Our model is a pure moral hazard one.

Common agency models with strict moral hazard have been mainly used in political economy. The regulator is the agent and Congress and the regulated firm are the principals (Spiller, 1990), or at the constitutional level, the Congress and the President are the two principals with divergent objectives who can contract on the regulatory agency's effort with a lobby group to monitor the agency's productivity and report it to the principals upon receiving a payment (Spiller and Urbiztondo, 1991), or the lobby group is another principal (Dixit, 1996, 1997, 2002). Dixit et al. (1997) applies a model of common agency to a positive model of public finance in a general equilibrium setting, in which lobby groups are the principals and are allowed to maximise their own pay-offs by making transfers to the government who is the agent. Because of the context of regulation, our paper formulates a different problem in which the regulators are the principals.

3.3 Model

The model is based on the interaction between regulators and a natural monopolist. The game is a static principal-agent model where the regulators are the principals and the firm the agent. The later is regulated by receiving transfers from the former. There are two states, $k = l, h$ and gross welfare $w_k = s_k + \pi_k$ is such that $w_l > w_h$, where s_k is gross consumer surplus and π_k is gross firm surplus, which is the profit earned from sales. The firm makes a cost reduction effort e. In the desirable state l, the regulated firm is efficient and earns profit π_l, and consumers get s_l. In state h, the firm is inefficient and earns profit p_h and consumers get $s_h < s_l$. Total gross welfare in states l and h are $w_l = s_l + \pi_l$ and $w_h = s_h + \pi_h$ and $w_l - w_h = \Delta^W > 0$.

Each regulator offers a contract specifying the transfers allowed to the monopolist with respect to the realised state k. Namely, the regulators can motivate the firm to make effort e to attain the desirable state by granting transfers T_l and T_h if state l and h occur respectively. We follow the standard assumption of the incentive regulatory literature that the regulators can make direct transfers to the firm in addition to letting the firm earn revenues from sales (Baron and Myerson, 1982; Laffont and Tirole, 1986, 1993)[1].

In practice, regulators try to avoid the ratchet effect under price cap regulation when implementing the $RPI - X$ mechanism. That is, they don't allow the future price cap to drop to the same extent as the cost reduction between two periods so as not to reduce the firm's incentive to make the cost reducing effort. This allowed rent can thus be assimilated to the transfer in our model.

The first examples of performance based mechanism dates back to the 19$^{\text{th}}$ century. Joskow (2007) recalls a profit sharing mechanism put in place in the English gas sector that inversely linked prices to dividend rates of shareholders. If the prices increased above a base level, dividends would fall with respect to a sliding scale formula. A subsequent revision of the formula allowed the dividend rate to increase if gas prices fell below the base level. The moral hazard model of regulation presented below captures this idea. More recently, in the water industry, firms are subject to an allowance or a punishment mechanism defined by English water regulator for leakage reduction targets CMA (2020).

3.3.1 Single regulator game

In the different game descriptions, we first introduce the firm's objective before detailing the regulator's goal. We consider a risk neutral firm whose utility is $eR_l + (1-e)R_h - \psi(e)$, where $\psi(e)$ is the cost of effort. In the single regulator frame, the firm's rents across states l, h depend only on the single regulator's transfers, and are respectively

$$R_l = \pi_l + T_l \tag{3.1}$$

$$R_h = \pi_h + T_h \tag{3.2}$$

[1] Joskow (2005, p. 1312) argues that the transfer payments serve as a reimbursement of managers disutility of effort and shows that the allowed revenue and the transfer can be seen as equivalent to Ramsey-Boiteux prices.

Faced with an incentive regulatory contract (R_l, R_h), the firm's objective is

$$\arg\max_{e\in[0,1]} EU = eR_l + (1-e)R_h - \psi(e), \qquad (IC_1)$$

where the disutility of effort $\psi(e)$ is increasing and convex in e ($\psi' > 0$ and $\psi'' > 0$) with $\psi(0) = 0$.

The firm accepts the regulatory contract if its expected utility is non-negative from the solution to (IC_1)

$$EU(e) = eR_l + (1-e)R_h - \psi(e) \geq 0 \qquad (PC_1)$$

The regulator seeks to maximise welfare and his payoffs depend on consumer surplus. Net consumer surplus in state l and h writes

$$S_l = s_l - T_l$$
$$S_h = s_h - T_h$$

Further we assume that the regulator bears a political cost of regulation λ per unit of transfer when transferring money from consumers to the firm

$$\lambda \begin{cases} = 0 & \text{if } T \leq 0, \\ > 0 & \text{otherwise.} \end{cases} \qquad (3.3)$$

This political cost of regulation is a social cost that comes from the deadweight loss created when transfers are given to the firm[2]. This deadweight loss aspect of costs has been used by Laffont and Tirole as an illustration of the administrative costs to process the taxes raised by the regulator[3]. According to Armstrong and Sappington (2007), the social cost of taxation is strictly positive when a deadweight loss is created due to the distortion of efficient effort or wasteful effort to avoid paying taxes by taxpayers.

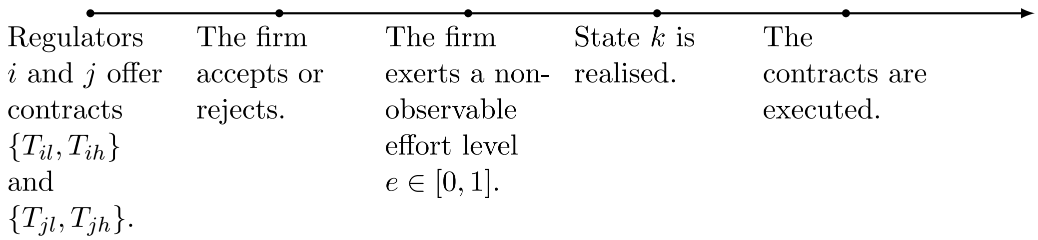
We assume that the cost of regulation is null when transfers are negative because it compensates the consumer welfare loss and the deadweight loss generated by the natural monopoly with respect to the competitive outcome. In addition, people are reluctant to pay taxes but seemingly don't have higher satisfaction when paying less taxes (The Economist, 2020).

We assume that the firm is faced with limited liability. In practice, the law specifies in

[2]According to Hahn and Hird (1991), there are two kinds of regulation costs, the transfer and the efficiency cost. The former is the transfer resulting from transferring money from consumers to producers while the latter represents a deadweight loss.

[3]For instance, US federal regulations costs more than $1,750 dollars for every taxpayer. A breakdown of regulatory cost estimates by Hopkins (1998) shows that costs associated to price and entry controls amounted to $218 billion and paperwork to $236 billion out of a total of $721 billion in 2000.

Figure 3.1: Timing of the game in the simultaneous two regulator game



many jurisdictions that a firm cannot bear losses

$$R_{k=l,h} \geq 0. \tag{LL}$$

In this case the regulator cannot leave the firm with a negative ex-post rent and will thus set a transfer in state h such that the firm's rent is non-positive[4]. With limited liability, the regulator sets $R_h = 0$ by choosing $T_h = -\pi_h$ so that (LL) is binding in state h. The pay-off in state h is then

$$\begin{aligned} W_h &= s_h - T_h + \alpha R_h \\ &= s_h + \pi_h = w_h \end{aligned}$$

where $\alpha \in [0, 1]$ is a valuation or weight attached to the firm's rent illustrating the extent of the regulatory capture by the industry (Martimort, 1996). The single regulator's objective (A) can be defined as setting the transfer to the firm in state l to maximise expected welfare across states l and h while ensuring the firm is willing to participate and make a positive effort

$$\begin{aligned} \max_{T_l} \quad & W^A = e(s_l - T_l + \alpha R_l - \lambda T_l) + (1-e)(w_h) - \alpha\psi(e) \\ \text{s.t.} \quad & (IC_1), \\ & (PC_1), \\ & (LL), \end{aligned} \tag{3.4}$$

where (IC_1) is binding and (LL) in state l and (PC_1) are satisfied.

3.3.2 Simultaneous two regulator game setup

In the two regulator game, there are two regulators i and j who simultaneously choose their transfer policy. We thus look for a Nash equilibrium. The timing of the game is depicted in figure 3.1.

[4]The regulator is confronted with the classic trade-off between incentives and rent extraction found in regulation under adverse selection. See Armstrong and Sappington (2007).

The firm's expected pay-off is $e(\pi_l + T_{il} - T_{jl}) + (1-e)(\pi_h + T_{ih} - T_{jh}) - \psi(e)$. In state h, limited liability induces each regulator to set $T_{ih} = T_{jh} = -\frac{\pi_h}{2}$. Suppose, for instance, that the firm receives an ex-post negative rent in state h. It can claim a compensation from regulators before the court such that $R_h \geq 0$. Hence, the court acts as a coordination mechanism between the regulators. We assume that the firm can only engage with both regulators. The participation constraint is thus

$$e(\pi_l + T_{il} + T_{jl}) - \psi(e) \geq 0, \tag{PC_2}$$

and the limited liability constraint in state l becomes

$$R_l = \pi_l + T_{il} + T_{jl} \geq 0. \tag{LL_2}$$

The monopolist then solves $\arg\max_e EU(T_{ik}, T_{jk}) = e(\pi_l + T_{il} + T_{jl}) - \psi(e)$, which is strictly concave in e. The first order condition of this program yields the local incentive compatibility constraint

$$R_l = \pi_l + T_{il} + T_{jl} = \psi'(e). \tag{IC_2}$$

We let the weight of the firm's rent and the regulatory cost differ between regulators. The regulator i's payoff now depends on his own transfer but also on regulator j's transfer and bears a regulatory cost $\lambda_i T_{ik}$ when transferring money from consumers to the firm. Similarly, regulator j bears his own regulatory cost $\lambda_j T_{jk}$. Using the fact that the firm's rent depends on the respective transfers of the regulators, the payoff of regulator i in state h is

$$\begin{aligned} W_{ih} &= S_h - \lambda_i T_{ih} + \alpha_i R_h \\ &= s_h - (1+\lambda_i)T_{ih} - T_{jh} + \alpha_i(\pi_h + T_{ih} + T_{jh}) \\ &= s_h - (1+\lambda_i - \alpha_i)T_{ih} - (1-\alpha_i)T_{jh} + \alpha_i \pi_h \end{aligned}$$

Following limited liability and condition (3.3), payoff in state h reduces to w_h. Regulator i's payoff in state l can be explicitly expressed in terms of T_{il}, T_{jl}

$$\begin{aligned} W_{il} &= S_l - \lambda_i T_{il} + \alpha R_l \\ &= s_l - (1+\lambda_i)T_{il} - T_{jl} + \alpha_i(\pi_l + T_{il} + T_{jl}) \\ &= s_l - (1+\lambda_i - \alpha_i)T_{il} - (1-\alpha_i)T_{jl} + \alpha_i \pi_l \end{aligned}$$

Figure 3.2: Timing of the game in the sequential two regulator game

Regulator i offers contract $\{T_{il}, T_{ih}\}$.	Regulator j offers contract $\{T_{jl}, T_{jh}\}$.	The firm accepts or rejects.	The firm exerts a non-observable effort level $e \in [0,1]$.	State k is realised.	The contracts are executed.

Denoting the simultaneous game by B, regulator i solves

$$\begin{aligned} \max_{T_{il}} \quad & W_i^B = e(s_l - (1+\lambda_i - \alpha_i)T_{i_l} - (1-\alpha_i)T_{j_l} + \alpha_i \pi_l) + (1-e)(w_h) - \alpha_i \psi(e) \\ \text{s.t.} \quad & (IC_2), \\ & (PC_2), \\ & (LL_2). \end{aligned} \tag{3.5}$$

3.3.3 Sequential two regulator game setup

In the sequential environment (C), one regulator sets transfers before the other. In this case, the first mover anticipates the response of the follower. The timing of the game is given in figure 3.2. As in a Stackelberg setup, we are looking for a subgame perfect Nash equilibrium. Suppose regulator i is the first mover. Then he will anticipate the behaviour of regulator j, which is the following

$$\begin{aligned} \max_{T_{jl}} \quad & W_j^C = e(s_l - T_{il} - T_{jl} + \alpha_j R_l - \lambda T_{jl}) + (1-e)(w_h) - \alpha_j \psi(e) \\ \text{s.t.} \quad & (IC_2), \\ & (PC_2), \\ & (LL_2). \end{aligned} \tag{3.6}$$

Denoting $T_{jl}^*(T_{il})$ the first order condition of problem (3.6), regulator i then solves

$$\begin{aligned} \max_{T_{il}} \quad & W_i^C = e(s_l - T_{il} - T_{jl} + \alpha_i R_l - \lambda T_{1l}) + (1-e)(w_h) - \alpha_i \psi(e) \\ \text{s.t.} \quad & e(\pi_l + T_{il} + T_{jl}^*(T_{il})) - \psi(e) \geq 0, \\ & \pi_l + T_{il} + T_{jl}^*(T_{il}) \geq 0, \\ & \arg\max_{e \in [0,1]} e(\pi_l + T_{il} + T_{jl}^*(T_{il})) - \psi(e), \end{aligned} \tag{3.7}$$

where T_{jl}^* is regulator's j best-response function.

In the remainder of the paper, we denote regulator i, j as $1, 2$.

3.4 Positive analysis

3.4.1 Single regulator game

Following limited liability, the regulator can motivate the firm to exert a cost reducing effort only with the rent in state l. The welfare maximising regulator's pay-off in state l is then

$$\begin{aligned} W_l &= S_l + \alpha R_l - \lambda T_l \\ &= s_l + \alpha \pi_l - (1 + \lambda - \alpha) T_l \end{aligned}$$

By strict concavity of the incentive constraint (IC_1) and setting $\psi(e) = \frac{e^2}{2}$, the necessary and sufficient condition of (IC_1) can be expressed as

$$R_l = \pi_l + T_l = \phi \tag{3.8}$$

where ϕ is the optimal effort chosen by the firm for any given transfer received in state l.

Program (3.4) is therefore rewritten

$$\begin{aligned} \max_{T_l} \quad & W^A = (\pi_l + T_l)\left(s_l - (1 + \lambda - \alpha) T_l + \alpha \pi_l\right) + (1 - \pi_l - T_l)(w_h) - \alpha \frac{(\pi_l + T_l)^2}{2} \\ \text{s.t.} \quad & (PC_1), \\ & (LL). \end{aligned} \tag{3.9}$$

Proposition 3.1. *Consider the single regulator game. The equilibrium entails:*

- *a transfer in state l which is positive and decreasing in the cost of regulation λ if the difference in gross welfare between states l and h is high enough $\Delta^W \geq (1 + \lambda - \alpha)\pi_l$. This transfer is given by*

$$T_l^A = \frac{\Delta^W - (1 + \lambda - \alpha)\pi_l}{2 + 2\lambda - \alpha}, \tag{3.10}$$

- *an effort which is decreasing in λ and given by*

$$\phi^A = \frac{\Delta^W + \lambda \pi_l}{2 + 2\lambda - \alpha}. \tag{3.11}$$

See proof in appendix 3.A.1.

At the optimum, as highlighted by Armstrong and Sappington (2007), an increase of α increases the rent granted in state l and increases the second best effort level given in expression (3.11)[5]. In other words, a regulator who values more the firm's rent gives stronger incentives to the firm to achieve state l, and can thus encourage investment (Spiller, 2013). This was for example the case in the Phillipines, where good relations between utilities shareholders' and the government have likely strengthened investment incentives (Esfahani, 1996). More generally, a pro-industry regulator can ensure the firm is rewarded for his investments and thus improve efficiency (Wren-Lewis, 2011).

When the regulator uses transfers to motivate the firm, it incurs a costly information rent due to the cost of regulation which makes the trade-off between incentives and rent extraction more favourable towards rent extraction. In the case where $\lambda = 0$ and when the regulator is fully sensitive to the firm's rent ($\alpha = 1$), the firm is given a franchise contract which makes him residual claimant of the total welfare gain Δ^W (Armstrong and Sappington, 2007). When regulation is costly ($\lambda > 0$), incentives from this franchise contract are distorted and reduced as this cost increases. Indeed, $\phi^A = \frac{\Delta^W + \lambda\pi_l}{1+2\lambda} < \Delta^W$ when Δ^W is high enough.

3.4.2 Simultaneous game equilibrium

3.4.2.1 Symmetric weight and regulatory cost

We start the two regulator simultaneous game analysis by considering the particular case of symmetric weight ($\alpha_1 = \alpha_2 = \alpha$) and regulatory cost ($\lambda_1 = \lambda_2 = \lambda$). We present only regulator 1's program. Rewriting the incentive compatibility constraint (IC_2) as $\phi = \pi_l + T_{1l} + T_{2l}$, regulator 1's program boils down to

$$\begin{aligned} \max_{T_{1l}} \quad & W_1^B = \phi\left(s_l - (1+\lambda-\alpha)T_{1l} - (1-\alpha)T_{2l} + \alpha\pi_l\right) + (1-\phi)\left(w_h\right) - \alpha\frac{\phi^2}{2} \\ \text{s.t.} \quad & (PC_2), \\ & (LL_2). \end{aligned} \tag{3.12}$$

Since this particular setup is perfectly symmetric, the respective objectives of the regulator can be very similar and it is possible to obtain multiple equilibria. The following lemma formalises the necessary condition under which it is possible to obtain a unique equilibrium contract.

Lemma 3.1. *Consider the simultaneous game with symmetric weights and symmetric regulatory costs.*

- *If Δ^W is high enough ($\Delta^W \geq (2+\lambda-\alpha)\pi_l$), there is a unique equilibrium of positive transfers $\left\{T_{1l}^B, T_{2l}^B\right\}$ such that the participation constraint (PC_2) and the limited liability constraint (LL_2) in state l are not binding.*

[5] The first best effort level, not defined in this paper, is characterised by the full information effort level.

- *Otherwise, any pair of transfers constitutes a Nash equilibrium.*

See proof in appendix 3.A.2.

When the regulators are symmetric, strict concavity of the objective function is not a sufficient condition to ensure uniqueness of equilibrium. Because transfers are negative when Δ^W is low enough, $\lambda = 0$ by condition (3.3). This implies that the best-response functions are superposed. Throughout the rest of the paper, the focus is restricted to the case in which there is a unique equilibrium.

Like in the single regulator problem, this unique equilibrium induces a positive level of effort and implies that the participation constraint and the limited liability constraint are not binding. Indeed, if each regulator wants to minimise transfers in state l such that (LL_2) is binding, they will end up giving no incentive to the firm to achieve state l[6]. Therefore, each regulator grants a transfer which is higher than the limited liability bound if they want the firm to exert a positive effort. The following proposition characterises this equilibrium contract.

Proposition 3.2. *Consider the simultaneous game with symmetric weights and symmetric regulatory costs. Let the parameter conditions be such that there exists a unique equilibrium* $\{T_{1l}^B, T_{2l}^B\}$*. Then, this equilibrium entails*

- *a total transfer given by*

$$T_l^B = T_{1l}^B + T_{2l}^B = \frac{2(\Delta^W - (2+\lambda-\alpha)\pi_l)}{4-3\lambda-2\alpha}, \tag{3.13}$$

- *an effort given by*

$$\phi = \frac{2\Delta^W + \lambda\pi_l}{4+3\lambda-2\alpha}, \tag{3.14}$$

  which is greater than the effort induced in the single regulator game.

See proof in appendix 3.A.3.

In the two regulator setting, the burden of the political cost of regulation is shared with the other regulator. Since each regulator saves an amount $\lambda\frac{T_l^A}{2}$, each can afford to give more rent to the firm. This result parallels Laffont (2005), who shows that, under adverse selection, the government saves on collusion-proof regulatory costs and thus can afford to grant more rent to the firm. However, the nature of the mechanism is different under moral hazard. Each regulator creates a positive externality on the other through this *dilution* of cost of transferring funds from consumers.

Having two regulators does not always generate higher incentives. When consumer surplus in state l is low enough, extending the game to a second regulator is equivalent to a central

[6] The regulators might even set a pair of transfers that violates (LL_2), knowing that a court of law will make them settle on an amount that binds (LL_2) and thus (PC_2).

regulator arrangement. Indeed, no regulator saves on regulatory costs since transfers in state l are negative. Therefore no regulator grants a higher transfer to the firm in state l since each regulator, anticipating that the other regulator already applies a negative transfer, does not attempt to give more rent to the firm so as not to appear unpopular.

3.4.2.2 Asymmetric weight and symmetric regulatory cost

We now let the regulators attribute different weights to the firm's rent. Let α_1 and α_2 be regulator 1's and regulator 2's respective valuations of the firm's rent, such that $\alpha_1 \neq \alpha_2$. We replace α by α_1 and α_2 in program (3.12). Because regulators value the firm's rent differently, the best-response functions are not superposed. However, parametric conditions are required to ensure that the best-response functions intersect to yield an equilibrium. This is formally stated in lemma 3.2.

Lemma 3.2 (Transfer equivalence)**.** *Consider two regulator game with asymmetric weight and symmetric regulatory cost. If* $\Delta^W > \max\left\{\frac{\lambda\pi_l(\lambda+(2-\alpha_1))}{\lambda+\alpha_1-\alpha_2}, \frac{\lambda\pi_l(\lambda+(2-\alpha_2))}{\lambda+\alpha_1-\alpha_2}\right\}$ *there is a unique equilibrium pair of positive transfers* $\left\{T^B_{1l}(\alpha_1,\alpha_2), T^B_{2l}(\alpha_1,\alpha_2)\right\}$*. Let the total transfer of this game be* $T^B_l(\alpha_1,\alpha_2) = T^B_{1l}(\alpha_1,\alpha_2) + T^B_{2l}(\alpha_1,\alpha_2)$*. The following holds true:*

- *If* $\alpha = \frac{\alpha_1+\alpha_2}{2}$*, then* $T^B_l(\alpha_1,\alpha_2) = T^B_l$
- *If* $\alpha < \frac{\alpha_1+\alpha_2}{2}$*, then* $T^B_l(\alpha_1,\alpha_2) > T^B_l$*.*
- *If* $\alpha > \frac{\alpha_1+\alpha_2}{2}$*, then* $T^B_l(\alpha_1,\alpha_2) < T^B_l$*.*

See proof in appendix 3.A.4.

Lemma 3.2 shows that total transfers are equal under symmetric and asymmetric weights when the symmetric weight assigned to the firm's rent game is equal to the average weight when regulators are asymmetric. In addition, a high enough average weight leads to higher transfers and vice-versa. Because regulators value the firm's rent more on average, they are more inclined to grant a higher transfer to the firm. This implies that, if one regulator is highly pro-consumer, it is possible to obtain at least a higher total transfer by introducing a pro-industry regulator. Conversely, if one regulator is highly pro-industry it is possible to limit the transfer burden on consumers by appointing a highly pro-consumer regulator. Consequently, it is sufficient to consider the case where biases are symmetric when regulators move simultaneously.

3.4.2.3 Symmetric weight and asymmetric regulatory cost

We now allow the cost of regulation to be different for each regulator. Let λ_1 and λ_2 be the respective political costs of regulator 1 and regulator 2, such that $\lambda_1 \neq \lambda_2$. In this case the first order conditions of the regulators satisfy

$$\frac{\partial W_1^B(T_{1l},T_{2l})}{\partial T_{1l}} = s_l - w_h - (2+2\lambda_1-\alpha)T_{1l}^* - (2+\lambda_1-\alpha)T_{2l}^* - (1+\lambda_1-\alpha)\pi_l = 0$$
$$\frac{\partial W_2^B(T_{1l},T_{2l})}{\partial T_{2l}} = s_l - w_h - (2+2\lambda_2-\alpha)T_{2l}^* - (2+\lambda_2-\alpha)T_{1l}^* - (1+\lambda_2-\alpha)\pi_l = 0.$$

From these expressions, the best-response functions do not have the same slope $\forall\lambda_1,\lambda_2 \in [0,1]$. Given the strict concavity of the objective functions and $\lambda_1 \neq \lambda_2$, the existence of a unique equilibrium is guaranteed. As in the previous subsection, it suffices to establish the condition of existence of the unique equilibrium in the perfectly symmetric case to compare transfers. This is formally stated in lemma 3.3. We also express our results in terms of a regulation cost index in the two regulator game define by

$$\Lambda = \frac{\lambda_1\lambda_2}{\bar{\lambda}}$$

where $\bar{\lambda} = \frac{\lambda_1+\lambda_2}{2}$.

Lemma 3.3. *Consider the simultaneous two regulator game with symmetric weight and asymmetric regulatory cost. Let $T_l^B(\lambda_1,\lambda_2) = T_{1l}^B(\lambda_1,\lambda_2) + T_{2l}^B(\lambda_1,\lambda_2)$ be the equilibrium total transfer and let the parameter conditions be such that there exists a unique equilibrium in the simultaneous two regulator game with symmetric weights and symmetric regulatory costs. Then:*

- $T_l^B(\lambda) \geq T_l^B(\lambda_1,\lambda_2)$ *if and only if* $\lambda \leq \Lambda$,
- $T_l^B(\lambda) < T_l^B(\lambda_1,\lambda_2)$ *otherwise.*

See proof in appendix 3.A.5

With different regulatory costs, the best-response functions are symmetric but not identical. The parametric condition on λ and Λ is a necessary and sufficient condition. By using the regulatory cost index Λ we are able to compare incentives when regulation costs are asymmetric between regulators and when they are symmetric. The interpretation is straightforward. When the regulatory cost index is lower than λ, transfer is higher than when regulators have a symmetric cost. Hence, having an efficient regulator alongside a highly inefficient regulator can increase the firm's incentives.

This also allows us to compare incentives under the simultaneous two regulator game when taxation costs are asymmetric and incentives under a single regulator as formalised in the next proposition.

Proposition 3.3. *Consider the simultaneous game with symmetric weights and asymmetric regulatory costs. The unique equilibrium is such that*

- *if* $\frac{4}{3}\lambda \leq \Lambda < \frac{2(2-\alpha)\lambda}{2-\alpha-\lambda}$*, the effort in the two regulator game is lower than in the single regulator game.*
- *Otherwise, the effort in the two regulator game can be either lower, equal or larger than under the single regulator game.*

See proof in appendix 3.A.6.

To understand the ambiguity of asymmetric regulatory costs, we need to emphasise the savings effect each regulator incurs from the regulatory cost dilution. If the cost of regulation is too low in the single regulator setup, the benefit from saving this cost under dual regulators will be low. Since each regulator does not benefit from substantial cost savings with respect to the unique regulator game, they can't afford to grant more rent to the firm. In this case the savings effect is not strong enough and each regulator grants less transfer to the firm which results in weaker aggregate incentives.

The other effect is simply attributed to a lower cost of regulation when the cost index is very low. In this case, the rent efficiency trade-off is more in favour of efficiency since granting a unit of transfer is cheaper to the regulators from a political perspective.

The same effects arise when the regulatory cost index is high enough but in a reversed way. When the regulatory cost index is high enough, there is a high scope for cost savings in the two-regulator game. The savings effect is in this case very high and thus induce the regulators to transfer more to the firm. For intermediate values of Λ, the regulatory cost savings are not high enough to compensate the direct cost of taxation and thus regulators cannot afford giving more rent to the firm.

3.4.3 Sequential game

3.4.3.1 Symmetric weight and regulatory cost

In this section we assume that the interaction between the two regulators is sequential. As one regulator sets transfers before the other, we look for a subgame perfect Nash equilibrium. For instance, in the UK the sector regulator OFWAT sets its regulatory policy first and is followed by the competition authority (CMA)'s policy upon the eventual appeal of water firms, which is assumed to be costless. In the case of supranational regulation, the regional regulator first makes recommendations and then national regulators define their policies.

Suppose regulator 1 is the first mover. Then, in the sequential game, regulator 1 maximises its objective function with respect to the firm's incentive compatibility constraint and regulator 2's best response strategy, which is explicitly expressed as the solution of problem (3.5):

$$T_{2l}^{*} = \frac{s_l - w_h + (\alpha - 2 - \lambda)T_{1l} + (\alpha - 1 - \lambda)\pi_l}{-\alpha + 2 + 2\lambda}. \tag{BR}$$

Rewriting incentive compatibility constraint (IC_2) as $\pi_l + T_{1l} + T_{2l}^* = \phi$, problem (3.7) simplifies to

$$\begin{aligned} \max_{T_{1l}} \quad & W_1^C = \phi(s_l - (1+\lambda-\alpha)T_{1l} - (1-\alpha)T_{2l}^* + \alpha\pi_l) + (1-\phi)w_h - \alpha\frac{\phi^2}{2} \\ \text{s.t.} \quad & \text{(BR)}, \\ & (PC_2), \\ & (LL_2). \end{aligned} \tag{3.15}$$

As in the simultaneous game, the participation constraint and the limited liability constraint in state l are not binding if regulator 1 wants to induce a positive level of effort.

Lemma 3.4. *Consider the sequential game with symmetric weights and symmetric regulatory costs.*

- *If* $\Delta^W > \max\left\{\frac{(-2\alpha^2+(4+2\lambda)\alpha-2\lambda-4)\pi_l}{\alpha-2}, \frac{\pi_l(4\lambda^2+(-6\alpha+9)\lambda+2(\alpha-2)(\alpha-1))}{2+2\lambda-\alpha}\right\}$, *there is a unique subgame perfect Nash equilibrium* $\left\{T_{1l}^C, T_{2l}^C\right\}$. *This equilibrium entails positive transfers and is such that the participation constraint* (PC_2) *and the limited liability constraint* (LL_2) *in state* l *are not binding.*
- *Otherwise, the subgame perfect Nash equilibrium is* $\left\{-\frac{\pi_l}{2}, -\frac{\pi_l}{2}\right\}$ *and* (PC_2) *and* (LL_2) *bind.*

See proof in appendix 3.A.7.

When $\lambda = 0$, strict concavity of the regulators' objective function is not guaranteed and thus the limited liability constraint ensures that a (corner) solution exists. If $\Delta^W \leq \frac{(-2\alpha^2+(4+2\lambda)\alpha-2\lambda-4)\pi_l}{\alpha-2}$, T_{1l}^C is non-positive and by condition (3.3), $\lambda = 0$. This in turn implies that the first mover's best response function is equal to zero for any $T_{1l}^C \leq 0$. If $\Delta^W \leq \frac{\pi_l(4\lambda^2+(-6\alpha+9)\lambda+2(\alpha-2)(\alpha-1))}{2\lambda-2\alpha+4}$, T_{2l}^C is non-positive which again implies that $\lambda = 0$ by condition (3.3). Since $T_{1l}^C(\lambda = 0) = -\infty$, regulator 1 can implement a strict free-riding strategy at least cost by setting an infinitely very small transfer. Because regulators have an identical cost ($\lambda = 0$) implied by a non-positive transfer, regulator 2's transfer is non-positive. In other words, it is not optimal for regulator 2 to set an infinitely high transfer because this will harm consumers. It is not worth either for regulator 2 to set a finite positive transfer as this will be costly without any incentive effect on the firm. However, as the firm is protected by limited liability, the court of law will make the regulators settle on the pair of transfers $\left\{-\frac{\pi_l}{2}, -\frac{\pi_l}{2}\right\}$. Therefore, the monopolist's rent in the desirable state will be $R_l = 0$.

Since the value of λ changes the concavity of the objective functions, we can deduce that the case of asymmetric weights and symmetric regulatory cost can lead to a similar type of equilibrium when $\lambda = 0$. However, making the participation constraint binding is not interesting as it induces no effort from the firm to achieve the desirable state. In the case of positive transfers, the participation and limited liability constraint are necessarily slack as effort incentives are provided to the firm. We thus focus only on positive equilibrium transfers in the remaining of the paper. As stated in the following proposition, regulator 1 free-rides in this type of equilibrium.

Proposition 3.4. *Consider the sequential game with symmetric weights and symmetric regulatory costs. Let the parametric conditions be such that there is a unique subgame perfect Nash equilibrium* $\{T_{1l}^C, T_{2l}^C\}$. *The transfer set by the first mover is lower than the transfer set by the second mover. This equilibrium entails a total transfer*

$$T_l^C = T_{1l}^C + T_{2l}^C = \frac{2\Delta^W - (7 + 4\lambda - 4\alpha)\pi_l}{6 + 4\lambda - 3\alpha}. \tag{3.16}$$

Moreover, this total transfer generates an effort given by

$$\phi^C = \frac{2\Delta^W - (1 - \alpha)\pi_l}{6 + 4\lambda - 3\alpha}, \tag{3.17}$$

which is weaker than the effort induced in the single regulator game and weaker than the effort induced in the simultaneous two regulator game with symmetric weight and symmetric cost.

See proof in appendix 3.A.8

When Δ^W is high enough, regulator 1 has a strong incentive to free-ride on regulator 2 because state l can be achieved at a lower cost for regulator 1. By moving first, regulator 1 knows that regulator 2 has a strong incentive to allow a transfer to the firm and thus reduces its own regulatory cost by decreasing the transfer to the firm. As a result regulator 2 is forced to transfer more. This result is reminiscent of previous literature which considers that each regulator has a different gross surplus and faces an adverse selection problem (Baron, 1985; Martimort, 1996) under a sequential environment.

In the strict free-riding equilibrium, the total transfer depends only on regulator 2's parameter. Weight asymmetry does not make a difference because the firm's rent depends only on the transfer of the last principal. This is similar to a single regulator-firm situation but with a further constraint on the rent allowed to the firm in the good state of nature. Put differently, regulator 1's behaviour acts as a constraint in regulator 2's optimal transfer.

The increased coordination induced by the sequential environment allows the regulators to extract more information rent from the firm with respect to the simultaneous and the single regulator setups, which results in a lower total transfer. When regulator 1 free-rides, regulator 2 is forced to transfer more to the firm only as long as the marginal benefit of a higher expected gain in welfare covers the marginal cost of transfer. Hence, if $\lambda > 0$, regulator 2 limits his own transfer, resulting in lesser incentives for the firm.

3.4.3.2 Asymmetric weight and symmetric regulatory cost

We replace α_1 and α_2 in problem (3.4). The objective function of regulator 1 is thus expressed in terms of α_1 and regulator 2's best response, derived from problem (3.5), is a function of α_2. The problem of regulator 1 is re-expressed as

$$\begin{aligned} \max_{T_{1l}} \quad & W_1^C = \phi(s_l - (1+\lambda-\alpha_1)T_{1l} - (1-\alpha_1)T'_{2l} + \alpha_1\pi_l) + (1-\phi)w_h - \alpha_1\frac{\phi^2}{2} \\ \text{s.t.} \quad & \pi_l + T_{1l} + T^*_{2l} = \phi, \\ & T^*_{2l} = \frac{s_l - w_h + (\alpha_2 - 2 - \lambda)T_{1l} + (\alpha_2 - 1 - \lambda)\pi_l}{-\alpha_2 + 2 + 2\lambda}, \\ & (PC_2), \\ & (LL_2). \end{aligned} \tag{3.18}$$

We consider only the subgame perfect equilibrium with positive transfers. This equilibrium exists under certain parametric conditions, as stated by lemma 3.5.

Lemma 3.5. *Consider the sequential game with asymmetric weights and symmetric regulatory costs. A necessary and sufficient condition for the existence of a unique subgame perfect equilibrium pair of positive transfers is*

$$\Delta^W > \Delta^{W'} = \frac{\left(4\lambda^2 + (9 - 5\alpha_2 - \alpha_1)\lambda + (\alpha_2 - 1)(\alpha_2 + \alpha_1 - 4)\right)\pi_l}{2 + 2\lambda - \alpha_1}.$$

Let $\{T^C_{1l}(\alpha_1,\alpha_2), T^C_{2l}(\alpha_1,\alpha_2)\}$ *be this unique equilibrium and let the total transfer* $T^C_l(\alpha_1,\alpha_2) = T^C_{1l}(\alpha_1,\alpha_2) + T^C_{2l}(\alpha_1,\alpha_2)$*. A sufficient condition for the total transfer in the symmetric case* T^C_l *to be strictly higher than* $T^C_l(\alpha_1,\alpha_2)$ *is*

- $\alpha \geq \frac{\alpha_1+2\alpha_2}{3}$ *or* $\alpha \leq \frac{4(1+\lambda)\alpha_2-\alpha_1}{4\lambda-3\alpha_1-\alpha_2+9}$ *when* $\alpha_1 > \alpha_2$
- $\alpha \leq \frac{\alpha_1+2\alpha_2}{3}$ *or* $\alpha \geq \frac{4(1+\lambda)\alpha_2-\alpha_1}{4\lambda-3\alpha_1-\alpha_2+9}$ *when* $\alpha_1 < \alpha_2$.

See proof in appendix 3.A.9.

When Δ^W is bigger than $\Delta^{W'}$, both regulators' transfers are positive. The respective first order conditions admit a unique solution due to λ being positive. Otherwise, transfers can be infinitely high or infinitely low. We focus on the equilibrium pair of positive transfers $\left\{T^C_{1l}(\alpha_1,\alpha_2), T^C_{2l}(\alpha_1,\alpha_2)\right\}$.

Contrary to the simultaneous setup, different rankings of α_1 and α_2 determine the pattern of incentives in the sequential environment. Note that the weighted average of the regulators' valuation of the firm's rent $\frac{\alpha_1+2\alpha_2}{3}$ is equal to $\frac{\alpha_1+\alpha_2}{2}$ only if $\alpha_1 = \alpha_2$. Thus there is no equivalence between T^C_l and $T^C_l(\alpha_1,\alpha_2)$. For a high enough α $\left(\alpha \geq \frac{\alpha_1+2\alpha_2}{3}\right)$, transfers in the single regulator game is higher. This is expected as a high α lead the regulators to grant a high transfer. However, this is also true for a low enough α when $\alpha_1 < \alpha_2$. The first mover anticipates that the second mover will be forced to transfer more to the firm and thereby free-rides even more. But the second regulator cannot commit to give more incentives to the firm because it is costly.

The implication of sequential moves of regulators with respect to the unique regulator environment is stated in proposition 3.5. The parametric conditions for which the effort in this sequential two regulator game is higher than in the single regulator game is compatible with the conditions under which there exists a unique equilibrium in the two regulator game with asymmetric weights.

Proposition 3.5. *Consider the sequential game with asymmetric weights and symmetric regulatory costs. Let the parametric conditions be such that there is a unique subgame perfect Nash equilibrium* $\left\{T_{1l}^C(\alpha_1,\alpha_2), T_{2l}^C(\alpha_1,\alpha_2)\right\}$. *This equilibrium entails an effort which is higher than under one regulator if* $\Delta^W \leq -\frac{\pi_l(4\lambda^2+(8-\alpha_1-4\alpha_2)\lambda+(\alpha_2-1)(\alpha-2))}{2\left(\alpha-\frac{\alpha_1}{2}-\alpha_2+1\right)}$. *This condition holds true if* $\alpha < \frac{\alpha_1}{2} + \alpha_2 - 1$ *with strict inequality. Otherwise, the effort is lower.*

See proof in appendix 3.A.10

This result shows that the first mover does not always free-ride on the follower. In contrast to the symmetric case where the sequential moves of regulators always entail lower incentives than the unique regulator, it is enough to have α small enough to ensure that incentives are higher with two regulators than with a single regulator. In the two-regulator game, by anticipating that regulator 2 will not grant enough transfer to the firm when Δ^W is low enough, regulator 1 transfers weakly more than regulator 2. Indeed, regulator 1 values the firm's rent highly enough and incentivises the firm accordingly.

3.4.3.3 Symmetric weight and asymmetric regulatory cost

The program of regulator 1 when his regulatory cost is different from the one of regulator 2 but with an identical weight writes:

$$\begin{aligned}
\max_{T_{1l}} \quad & W_1^C = \phi(s_l - (1+\lambda_1-\alpha)T_{1l} - (1-\alpha)T_{2l}^* + \alpha\pi_l) + (1-\phi)w_h - \alpha_1\frac{\phi^2}{2} \\
\text{s.t.} \quad & \pi_l + T_{1l} + T_{2l}^* = \phi, \\
& T_{2l}^* = \frac{s_l - w_h + (\alpha-2-\lambda_2)T_{1l} + (\alpha-1-\lambda_2)\pi_l}{-\alpha+2+2\lambda_2}, \\
& (PC_2), \\
& (LL_2).
\end{aligned} \tag{3.19}$$

To assess whether assigning different weights to regulators in the sequential game is relevant, it is necessary to compare whether transfers between the symmetric and asymmetric costs are equal or not when the average regulatory cost $\frac{\lambda_1+\lambda_2}{2}$ is equal to λ. This is formalised in the following lemma.

Lemma 3.6. *Consider the sequential game with symmetric weights and asymmetric regulatory costs, a unique subgame perfect equilibrium of positive transfers exists if Δ^W is high enough:*

$$\Delta^W > \underline{\Delta^W} \equiv \frac{(2-\alpha+4\lambda_1)\lambda_2^2+(7-5\alpha)\lambda_1\lambda_2+(\lambda_1+\lambda_2)(\alpha-1)(\alpha-2)}{(2-\alpha)\lambda_1+3\lambda_1\lambda_2-\lambda_2^2}.$$

Otherwise

- *when $\Delta^W > \frac{2(\alpha-1)\lambda_1-(\lambda_1+\lambda_2)(\alpha-1)(\alpha-2)}{(4-\alpha)\lambda_1-2\lambda_2^2}$, the equilibrium is the pair $\{-\frac{\pi_l}{2},-\frac{\pi_l}{2}\}$.*
- *Otherwise, an equilibrium does not exist.*

See proof in appendix 3.A.11.

In the case of asymmetric costs, the concavity of regulator 1's problem depends solely on λ_2 but the sign of the transfer depends on Δ^W. When $\Delta^W > \underline{\Delta^W}$, the transfer of the second mover is positive. This ensures that the first order condition of regulator 1 has a solution. Otherwise, regulator 2 sets the lowest possible transfer. Then, the sign of regulator 1's transfer determines the existence of an equilibrium. If Δ^W is high enough but not too high ($\Delta^W \leq \underline{\Delta^W}$), $T_{1l}^C(\lambda_1,\lambda_2)=\infty$. Regulator 1 sets the lowest possible transfer. From limited liability it follows that $T_{1l}^C(\lambda_1,\lambda_2), T_{2l}^C(\lambda_1,\lambda_2)=\{-\frac{\pi_l}{2},-\frac{\pi_l}{2}\}$. Otherwise we have $T_{1l}^{**}(\lambda_1,\lambda_2), T_{2l}^{**}(\lambda_1,\lambda_2)=\{\infty,-\infty\}$. We focus on the case of positive finite transfers.

Lemma 3.7. *Consider the sequential game with symmetric weights and asymmetric regulatory costs. Let $\{T_{1l}^C(\lambda_1,\lambda_2), T_{2l}^C(\lambda_1,\lambda_2)\}$ be the equilibrium pair of positive transfers and let $T^C(\lambda_1,\lambda_2)=T_{1l}^C(\lambda_1,\lambda_2)+T_{2l}^C(\lambda_1,\lambda_2)$. The following holds:*

- *when λ is larger than a threshold $\hat{\lambda}(\lambda_1,\lambda_2)$, $T_l^C(\lambda_1,\lambda_2) > T_l^C(\lambda)$. This threshold is*
  - *decreasing in λ_1,*
  - *increasing in λ_2 if $\lambda_1 > \frac{(\alpha-2)\left((\alpha-1)\pi_l-\Delta^W\right)}{4((\alpha-1)\pi_l+\Delta^W)}$.*
- *otherwise, $T_l^C(\lambda_1,\lambda_2) < T_l^C(\lambda)$.*

See proof in appendix 3.A.12

Lemma 3.7 shows the necessary condition under which incentives are higher or lower when the political cost of regulation is asymmetric. Transfers between the symmetric and the asymmetric case are not solely comparable on the basis of the average regulatory cost or the cost index Λ. A higher λ_1 reduces the threshold $\hat{\lambda}$ and therefore transfers can be higher in the asymmetric case even for small values of λ. A higher cost for regulator 1 does not affect the cost of regulator 2 who is pushed to transfer more. Hence, it is possible to generate higher-powered incentives when regulators have asymmetric costs even if the first mover is free-riding.

However, when the cost of regulator 1 is too high, transfers will depend on the second regulator's cost. Then, higher values of λ_2 reduces the set of λ for which transfers in the asymmetric case is higher. Put differently, transfers in the asymmetric case are higher less often than in the symmetric case.

The next proposition characterises the pattern of the necessary condition for which the effort in the single regulator game is higher than the effort in the two regulator game with asymmetric costs. Since the numerator of the threshold $\underline{\Delta^W}$ is strictly positive, the denominator can be either strictly positive or strictly negative and thus, the conditions for the existence of the unique equilibrium in the two-regulator game with asymmetric costs can be compatible with further conditions on Δ^W. For instance, we can have $(1-\alpha)\pi_l \geq \Delta^W > \underline{\Delta^W}$, as identified in the next proposition.

Proposition 3.6. *Consider the sequential two regulator game with symmetric weights and asymmetric regulatory costs. Let the parameter conditions be such that there is a unique subgame perfect equilibrium. Effort in the two regulator game is higher than in the single regulator game if λ is larger than a threshold $\tilde{\lambda}(\lambda_1, \lambda_2)$. Otherwise, the effort induced in the sequential two regulator game is weaker. This threshold is such that:*

- $\frac{\partial\tilde{\lambda}(\lambda_1,\lambda_2)}{\partial\lambda_1} \geq 0$, $\forall\lambda_2 \geq 0$,
- *when* $\Delta^W \geq (1-\alpha)\pi_l$
  - $\frac{\partial\tilde{\lambda}(\lambda_1,\lambda_2)}{\partial\lambda_2} > 0$ *if* $\lambda_1 > \frac{(2-\alpha)\big((1-\alpha)\pi_l+\Delta^W\big)}{4((\alpha-1)\pi_l+\Delta^W)}$
  - $\frac{\partial\tilde{\lambda}(\lambda_1,\lambda_2)}{\partial\lambda_2} \leq 0$ *otherwise,*
- *when* $\Delta^W < (1-\alpha)\pi_l$, $\frac{\partial\tilde{\lambda}(\lambda_1,\lambda_2)}{\partial\lambda_2} \geq 0$, $\forall\lambda_1 > 0$.

See proof in appendix 3.A.13

The proposition shows that the regulatory cost borne by the first mover is critical in determining the pattern of incentives. The first bullet point of the proposition shows that, regardless of the value of λ_2, the higher is λ_1 the higher is the threshold $\tilde{\lambda}$. Hence, for sufficiently small λ, incentives can be higher under single regulation because the propensity of regulator 1 to free-ride increases as his cost of regulation increases.

As illustrated by the second bullet point, the influence of the cost of regulator 2 depends on the value of the regulatory cost of regulator 1 when Δ^W is high enough, as suggested in proposition 3.4. When it is costly enough for regulator 1 to contribute, he has a higher tendency to free-ride. Therefore, when λ_2 increases, the set of λ for which incentives are stronger under two regulators is reduced as regulator 2 also cuts down on the rent given to the firm. Conversely, when λ_1 is low enough, incentivising the firm is less costly for regulator 1. By anticipating that regulator 2 is facing an increasing cost of regulating the firm, regulator 1 is willing to grant more rent to the firm which results in a reduction of the threshold. That is, incentives can be higher under multiple regulators even for low levels of λ.

In the last part of the result, when Δ^W is low enough, the pattern of incentives would depend mainly on regulator 2 since regulator 1 is more willing to contribute. When λ_2 increases, the set of λ for which incentives under multi-regulation is higher becomes smaller. Hence, when Δ^W is low enough, the increased cost of regulation through a higher λ_2 is not worth granting a higher rent to the monopoly and makes incentives under multi-regulation weaker.

3.5 Welfare

In this section, we perform welfare calculations under the different games. We first detail the welfare function of the different environments. Although regulators have different funding and powers in practice, welfare in two-regulator games is derived by keeping a symmetric weight and regulatory cost to keep the analysis tractable.

3.5.1 One regulator welfare

Under the single regulator framework, expected welfare at equilibrium is given by the sum of consumer surplus and producer rent in each state:

$$\begin{aligned} &= \phi^A(s_l - T_l^A + \pi_l + T_l^A - \lambda T_l^A) + (1-\phi^A)w_h - \frac{(\phi^A)^2}{2} \\ &= \phi^A(\Delta^W - \lambda T_l^A) + w_h - \frac{(\phi^A)^2}{2} \end{aligned} \tag{3.20}$$

where T_l^A and ϕ_l^A are respectively given by (3.10) and (3.11) in proposition 1.

3.5.2 Simultaneous regulation welfare

In the simultaneous two regulator game with symmetric weights and symmetric cost of regulation, welfare writes

$$\begin{aligned} &= \phi^B(s_l - T_l^B + \pi_l + T_l^B - \lambda T_l^B) + (1-\phi^B)w_h - \frac{(\phi^B)^2}{2} \\ &= \phi^B(\Delta^W - \lambda T_l^B) + w_h - \frac{(\phi^B)^2}{2} \end{aligned} \tag{3.21}$$

where T_l^B and ϕ^B are given in proposition 2. Because of transfer equivalence (lemma 3.2) we only calculate welfare when bias is symmetric in the two regulator game.

Taking $T_l^B = \phi^B - \pi_l$ and $T_l^A = \phi^A - \pi_l$, the two regulator design with identical bias and taxation cost entails a higher welfare if

$$\phi^B(\Delta^W - \lambda T_l^B) + w_h - \frac{(\phi^B)^2}{2} \geq \phi^A(\Delta^W - \lambda T_l^A) + w_h - \frac{(\phi^A)^2}{2} \tag{3.22}$$

$$\Delta^W \geq \left(\frac{1}{2} + \lambda\right)(\phi^B + \phi^A) - \lambda\pi_l \tag{3.23}$$

Replacing ϕ^A and ϕ^B by (3.11) and (3.14), condition (3.23) can be expressed as

$$\frac{\Delta^W - (\frac{1}{2} + \lambda)(5\lambda^2\pi_l + (-3\alpha\pi_l + 6\pi_l + 7\Delta^W)\lambda - 4(\alpha - 2)\Delta^W)}{\Gamma_1} + \lambda\pi_l > 0 \tag{3.24}$$

where $\Gamma_1 = \frac{1}{4(-2-\frac{3}{2}\lambda+\alpha)(-2-2\lambda+\alpha)} > 0$.

Proposition 3.7. *Consider the simultaneous game with symmetric weights and symmetric regulatory costs. Then*

- *if* $\alpha \in \left[\frac{3}{4}\lambda + \frac{3}{2} - \frac{\sqrt{17\lambda^2+16\lambda+4}}{4}, 1\right]$ *and* $\frac{\lambda\pi_l(-2\lambda^2-(11-8\alpha)\lambda-(4\alpha-5)(\alpha-2))}{-2\lambda^2-(6\alpha-5)\lambda+4(\alpha-1)(\alpha-2)} > \Delta^W$*, the two regulator design achieves a lower welfare.*

- *Otherwise, the two regulator design entails a higher welfare.*

See proof in appendix 3.A.14.

The condition on α ensures that the condition on Δ^W is compatible with the existence condition of the unique equilibrium of the simultaneous two regulator game stated in lemma 3.1. In other words, when $\alpha \in \left[\frac{3}{4}\lambda + \frac{3}{2} - \frac{\sqrt{17\lambda^2+16\lambda+4}}{4}, 1\right]$, the inequality $\frac{\lambda\pi_l(-2\lambda^2-(11-8\alpha)\lambda-(4\alpha-5)(\alpha-2))}{-2\lambda^2-(6\alpha-5)\lambda+4(\alpha-1)(\alpha-2)} > \Delta^W \geq (2 + \lambda - \alpha)\pi_l$ holds true.

When their valuation for the firm's rent is high, the sharing of the political cost of regulation lead them to grant too much rent to the firm but the welfare increment is too small. Consumers end up paying too much for the welfare increment across the two states. In this case, a single regulator configuration is superior because its preference for the firm's rent is countered by the cost incurred. The regulator then is able to motivate the firm without having to make the consumers paying too much for it.

When regulators' valuation is low, the trade-off between incentives and rent extraction is balanced in the sense that regulators' aversion to give a rent to the firm and the sharing of the regulatory cost counteract each other. The regulators motivate the firm to achieve state l while ensuring that consumers are able to afford it. When α is low, leaving the industry under the charge of a single regulator does not encourage the firm to invest enough to achieve the desirable outcome, especially since the single regulator bears all the cost of regulation.

3.5.3 Sequential regulation welfare

To obtain welfare of the sequential game, we substitute for ϕ^C in (3.21). Then, the sequential moves of regulators is superior to the single regulator environment if

$$\Delta^W \geq \left(\frac{1}{2}+\lambda\right)(\phi^C+\phi^A)-\lambda\pi_l \tag{3.25}$$

where ϕ^C is the equilibrium effort exerted by the firm in the sequential environment and expressed by (3.17). Hence, condition (3.25) writes

$$\Delta^W - \frac{(\frac{1}{2}+\lambda)(4\lambda^2\pi_l+(-\alpha\pi_l+8\Delta^W+4\pi_l)\lambda-5(\frac{1}{5}\alpha\pi_l+\Delta^W-\frac{1}{5}\pi_l)(\alpha-2))}{\Gamma_2}+\lambda\pi_l>0 \tag{3.26}$$

where $\Gamma_2 = 6\left(-\frac{4}{3}\lambda+\alpha-2\right)(-2-2\lambda+\alpha)>0$.

When bias is asymmetric, $\phi^C = \frac{2\Delta^W-(1-\alpha_2)\pi_l}{6+4\lambda-2\alpha_2-\alpha_1}$ and condition (3.25) is rewritten

$$\begin{aligned}&\Delta^W+\lambda\pi_l\\&-\frac{(\frac{1}{2}+\lambda)((-4\lambda^2+(\alpha_1-4)\lambda+(-1+\alpha_2)(\alpha-2))\pi_l+2\Delta^W(\alpha-4\lambda+\frac{\alpha_1}{2}+\alpha_2-5))}{\Gamma_3}>0\end{aligned} \tag{3.27}$$

where $\Gamma_3 = 2(-2-2\lambda+\alpha)(4\lambda-2\alpha_2-\alpha_1+6)<0$.

Proposition 3.8. *Consider the sequential game with symmetric regulatory costs. When weights on the firm's rent are symmetric or asymmetric, the two regulator design achieves a higher welfare than the single regulator design* $\forall\alpha,\lambda\in[0,1]$.

See proof in appendix 3.A.15.

As shown previously, transfers in the sequential game are lower than in the unique regulator game. Because of costly transfers and limited liability, a lower total transfer in the sequential environment loosens the burden on consumers. This savings effect is stronger than the incentive effect of increasing the firm's effort to achieve state l. Even when regulator 1 does not free-ride, the implicit coordination effect taking place under sequential duplication enables regulator 2 to adjust his own transfer. He gives just enough to the firm to achieve the desirable outcome. In this case the accountability measure becomes irrelevant.

Even when weights are asymmetric, regulator 1's free-riding behaviour limits the rent allowed to the firm as he anticipates the following regulator to grant more. Regulator 2 is expected to grant more because gross welfare in state l is high enough and worth investing in. However, the adjustment effect in the sequential environment and the cost of transfer lead the follower to restrict firm's rent, which results in a higher net welfare.

3.6 Discussion

The results in the previous sections can be interpreted in accordance with discussions in the literature and stylised facts. For instance, the interaction between a national regulator and a supranational authority can be illustrated by proposition 3.2. As changes in political power can lead to drastic changes in regulatory governance and reduce the commitment of a national regulator, the establishment of a regional authority can stabilise reforms already initiated because changes usually need the veto of all member states to be implemented (Kessides et al., 2010). There is thus less political pressure to expropriate the firm's rent, as illustrated by a lower political cost of regulation borne by each regulator.

In the UK water sector, there is a unique transfer whose level is decided by regulators in turn, and the intervention of a second regulator is made endogenous by the firms who decide to appeal the decision of the sector regulator before the competition authority. Although the present setup differs from the UK water case, some of the results are illustrative of the facts. The CMA allowed the firms to a higher rate of return than the one OFWAT had determined because of concerns to promote investment in the sector[7]. The CMA considers that a rate of return which is too low can be detrimental to the welfare of consumers but OFWAT's reasoning appears to corroborate proposition 3.8. OFWAT expressed concerns about the harm to consumers that a higher rate of return can do and stressed that a higher rate of return is not necessary to achieve the needed investments[8].

In the energy sector, the EIB intends to develop its lending policy once it knows national states' energy policy (EIB, 2019). The EIB thus acts as the follower and intends to support only projects with a high scope of reducing carbon emissions. This appears to be in line with proposition 3.4 which states that the second mover transfers more than the first mover if the gain in welfare is high enough.

In the Caribbean region, the establishment of the regional regulator ECTEL facilitated the liberalisation in the telecommunications industry that had been subject to the monopoly of Cable & Wireless (Kessides et al., 2010). The estimated benefit of the establishment of ECTEL amounts to EC$54 million per year in terms of consumer surplus. If we consider that the first mover is ECTEL, which regulatory initiatives aimed at fairer pricing, his willingness to extract more rent has led to a higher welfare as suggested by proposition 3.8.

[7]See CMA Provisional findings 2020 page 671 paragraph 9.667.

[8]From OFWAT's view, a higher rate of return allowed to firms would be costly to consumers without any short or long run benefit. This can be seen as a higher political cost that OFWAT would be willing to save upon. The Guardian even reports that Citizens Advice, a consumer group were disappointed towards the CMA's decision and argued that OFWAT could have been tougher towards firms in setting the rates. See `https://www.theguardian.com/money/2020/sep/29/competition-watchdog-sides-with-water-firms-in-row-over-plan-to-cut-household-bills`.

3.7 Conclusion

This paper provides an analytical framework of the interaction between two regulators making a decision on the amount of rent to grant to a public utility to perform a privately known cost reducing investment effort that would enhance consumer welfare. We have considered how the introduction of a second regulator can impact on incentives in a strict moral hazard setting. In the model, the regulators have symmetric powers in that they both use direct mechanisms.

The model can be extended to non-utility sectors. For instance, in the context of horizontal mergers, a potential trade-off arises between efficiency gains and lower wages (Shapiro, 2019). Mergers between hospitals led to labour market concentration that has reduced wages of skilled health workers (Prager and Schmitt, 2021). Hence, a regulator with a high valuation for the firm's rent may encourage mergers that could reduce labour costs whereas a regulator that weakly values the firm's rent, like the government, would generally want to keep wages from decreasing.

Although the model does not fully capture the complex reality of regulation, some of the results appear consistent with real world facts observed from different network industries across several countries.

The main results show that outcomes are different when the regulators move simultaneously or play a sequential game. In the simultaneous setup, incentives depend on the effect of the political cost of regulation. When more than one regulator are active, each regulator benefits from savings generated by the sharing of regulatory costs. These savings lead the regulators to grant higher-powered incentives than with a central regulator. From a welfare perspective, multi-regulation is inferior if their valuation of the firm's rent is high because incentives are too high-powered for the welfare gain in the desirable state.

In the sequential game with perfectly symmetric regulators, transfers are lower than in the single regulator game because the first mover free-rides and the second mover cannot compensate for this behaviour as it is too costly to do so. Welfare is higher under sequential duplication because incentives are just enough to motivate the firm to achieve the desirable state ex-ante. Nonetheless, a higher effort can be induced in the sequential environment when the regulatory cost differs between regulators. In this case, incentives can be higher if the regulatory cost in the single regulator design is high enough.

Given that no tractable welfare solution are obtained when weights or regulatory costs are asymmetric, the organisation of the regulatory system is based only on the case of symmetric weights and costs. Thus, a recommendation for designing the regulatory system is to have two regulators setting their respective policies sequentially. A simultaneous move configuration can also be preferred to the unique regulator setup if regulators do not value the firm's profits enough. These recommendations are more likely to be implemented in systems with a clear hierarchical structure.

A possible extension of this line of research would be assigning different powers to the regulators. In other words, a framework which allows the decision of a regulator to be overturned by the decision of a superior regulator as is the UK with the CMA and sector regulators, or more broadly when EU states national regulators decision are overruled by the European Commission.

3.A Appendix

3.A.1 Proof of proposition 3.1

Proof. The optimality conditions yield

$$\frac{\partial W^A}{\partial T_l} = s_l - w_h + (\alpha - 2\lambda - 2)T_l + (\alpha - \lambda - 1)\pi_l = 0 \tag{3.28}$$

$$\Leftrightarrow s_l + \pi_l - \pi_l - w_h + (\alpha - 2\lambda - 2)T_l + (\alpha - \lambda - 1)\pi_l \tag{3.29}$$

$$T_l^A = \frac{\Delta^W - (2 + \lambda - \alpha)\pi_l}{2 + 2\lambda - \alpha} \tag{3.30}$$

$$\phi^A = \pi_l + T_l^A = \frac{w_l - w_h + \lambda\pi_l}{2 + 2\lambda - \alpha} \tag{3.31}$$

Clearly, T_l^A is positive when $\Delta^W > (2 + \lambda - \alpha)\pi_l$. The comparative static of the optimal contract with respect to λ is

$$\frac{\partial T_l^A(.)}{\partial\lambda} = \frac{-2\Delta^W + (2 - \alpha)\pi_l}{(2 + 2\lambda - \alpha)^2}$$

which is negative when $\Delta^W \geq \left(\frac{2-\alpha}{2}\right)\pi_l$. □

3.A.2 Proof of lemma 3.1

Proof. In a first step, we derive the Nash equilibrium and in the second step we show that the best response of each regulator is positive when each regulator transfers half of the equilibrium transfer of the single regulator. In a second step we show that the (PC_2) and (LL_2) are not binding.

1$^{\text{st}}$ step The optimality conditions for regulators 1 and 2 respectively yield

$$\frac{\partial W_1^B}{\partial T_{1l}} = s_l - w_h - (2 + 2\lambda - \alpha)T_{1l} - (2 + \lambda - \alpha)T_{2l} - (1 + \lambda - \alpha)\pi_l = 0 \tag{3.32}$$

$$\frac{\partial W_2^B}{\partial T_{2l}} = s_l - w_h - (2 + \lambda - \alpha)T_{1l} - (2 + 2\lambda - \alpha)T_{2l} - (1 + \lambda - \alpha)\pi_l = 0 \tag{3.33}$$

The problem of each regulator is strictly concave and the best response functions are downward sloping

$$BR_1 : T_{1l} = \frac{s_l - w_h - (2+\lambda-\alpha)T_{2l} - (1+\lambda-\alpha)\pi_l}{2+2\lambda-\alpha} \tag{3.34}$$
$$BR_2 : T_{2l} = \frac{s_l - w_h - (2+\lambda-\alpha)T_{1l} - (1+\lambda-\alpha)\pi_l}{2+2\lambda-\alpha} \tag{3.35}$$

Suppose $s_l \leq w_h + (1+\lambda-\alpha)\pi_l$. Then, T_{1l} and T_{2l} are negative. By assumption, $\lambda = 0$ when transfers are negative. The best response functions thereby simplify to

$$BR_1 : T_{1l} = \frac{s_l - w_h - (2-\alpha)T_{2l} - (1-\alpha)\pi_l}{2-\alpha} \tag{3.36}$$
$$BR_2 : T_{2l} = \frac{s_l - w_h - (2-\alpha)T_{1l} - (1-\alpha)\pi_l}{2-\alpha} \tag{3.37}$$

Since BR_1 and BR_2 have the same slope and the same intercept, they are equal for any pair of $\{T_{1l}, T_{2l}\}$.

2$^{\text{nd}}$ step Suppose (LL_2) is binding in state l. This implies implies that $R_l = 0$ and (PC_2) is binding. By condition (IC_2), this implies that the optimal effort $\phi = 0$, and the firm has not incentive to achieve any positive level of effort. Therefore, (LL_2) and (PC_2) are slack for a contract inducing effort. □

3.A.3 Proof of proposition 3.2

Proof. Solving for the Nash equilibrium we get

$$T_{1l}^B = T_{2l}^B = \frac{-s_l + w_h + (1+\lambda-\alpha)\pi_l}{2\alpha - 3\lambda - 4} \tag{3.38}$$
$$\phi = T_{1l}^B + T_{2l}^B + \pi_l = \frac{2(w_l - w_h) + \lambda\pi_l}{4+3\lambda-2\alpha} = \frac{2\Delta^W + \lambda\pi_l}{4+3\lambda-2\alpha} \tag{3.39}$$

Now, suppose that both regulators set $T_{1l}^B + T_{2l}^B = \frac{T_l^A}{2}$. Then replacing the expression for $\frac{T_l^A}{2}$ in 3.34 we obtain

$$\begin{aligned}
\frac{\partial W_1^B}{\partial T_{1l}}\left(T_{1l}^B = T_{2l}^B = \frac{T_l^{A*}}{2}\right) &= \frac{\pi_l(-1-\lambda+\alpha)}{2} + \frac{(2\alpha-2\lambda-4)(T_l^{A*}/2)}{2} + \frac{s_l - w_h}{2} \\
&= \lambda\frac{-s_l + w_h + (1+\lambda-\alpha)\pi_l}{2\alpha - 4\lambda - 4} \\
&= \lambda\frac{T_l^A}{2} > 0
\end{aligned}$$

□

3.A.4 Proof of lemma 3.2

Proof. In the two regulator setup, regulator i solves

$$\max_{T_{il}} W_i^B = (\pi_l + T_{1l} + T_{2l})\,(s_l - (1+\lambda-\alpha_i)T_{1l} - (1-\alpha_i)T_{2l} + \alpha_i \pi_l) \\ + (1 - (\pi_l + T_{1l} + T_{2l}))\,(w_h) - \alpha_i \frac{(\pi_l + T_{1l} + T_{2l})^2}{2} \quad (3.40)$$

The optimality conditions for regulators 1 and 2 respectively yield

$$\frac{\partial W_1^B}{\partial T_{1l}} = s_l - w_h - (2+2\lambda-\alpha_1)T_{1l} - (2+\lambda-\alpha_1)T_{2l} - (1+\lambda-\alpha_1)\pi_l = 0 \quad (3.41)$$

$$\frac{\partial W_2^B}{\partial T_{2l}} = s_l - w_h - (2+\lambda-\alpha_2)T_{1l} - (2+2\lambda-\alpha_2)T_{2l} - (1+\lambda-\alpha_1)\pi_l = 0 \quad (3.42)$$

The best responses are

$$BR_1 : T_{1l} = \frac{s_l - w_h - (2+\lambda-\alpha_1)T_{2l} - (1+\lambda-\alpha_1)\pi_l}{2+2\lambda-\alpha_1} \quad (3.43)$$

$$BR_2 : T_{2l} = \frac{s_l - w_h - (2+\lambda-\alpha_2)T_{1l} - (1+\lambda-\alpha_2)\pi_l}{2+2\lambda-\alpha_2} \quad (3.44)$$

Solving for the Nash equilibrium we get:

$$T_{1l}^B(\alpha_1,\alpha_2) = \frac{-\lambda^2\pi_l + ((\alpha_1-2)\pi_l + \Delta^W)\lambda + (\alpha_1-\alpha_2)\Delta^W}{\lambda(3\lambda-\alpha_1-\alpha_2+4)} \quad (3.45)$$

$$T_{2l}^B(\alpha_1,\alpha_2) = \frac{-\lambda^2\pi_l + ((\alpha_2-2)\pi_l + \Delta^W)\lambda + (\alpha_2-\alpha_1)\Delta^W}{\lambda(3\lambda-\alpha_1-\alpha_2+4)} \quad (3.46)$$

and $T_l^B(\alpha_1,\alpha_2) = T_{1l}^B(\alpha_1,\alpha_2) + T_{2l}^B(\alpha_1,\alpha_2) = \frac{(2\lambda-\alpha_1-\alpha_2-2)\pi_l-2s_l+2w_h}{-3\lambda+\alpha_1+\alpha_2-4}$. Following condition (3.3), there is a unique equilibrium if and only if $T_{1l}^B(\alpha_1,\alpha_2), T_{2l}^B(\alpha_1,\alpha_2) > 0$. Since the denominator is strictly positive, the sign of the transfers depend on the numerators. Hence (3.45) and (3.46) are positive if $\Delta^W > \frac{\lambda\pi_l(\lambda+(2-\alpha_1))}{\lambda+\alpha_1-\alpha_2}$ and $\Delta^W > \frac{\lambda\pi_l(\lambda+(2-\alpha_2))}{\lambda+\alpha_1-\alpha_2}$ respectively.

We now compare whether transfers are equivalent when two regulators have identical preferences, $T_l^B(\alpha)$ or not $T_l^B(\alpha_1,\alpha_2)$

$$T_l^B(\alpha_1,\alpha_2) - T_l^B(\alpha) = 0 \quad (3.47)$$

$$\frac{(-2\lambda+\alpha_1+\alpha_2-2)\pi_l + 2s_l - 2w_h}{(3\lambda-\alpha_1-\alpha_2+4)} - \frac{2(s_l - w_h - (1+\lambda-\alpha)\pi_l)}{(4+3\lambda-2\alpha)} = 0 \quad (3.48)$$

$$\frac{\overbrace{(\lambda\pi_l + 2\pi_l + 2s_l - 2w_h)}^{>0}(2\alpha-\alpha_1-\alpha_2)}{\underbrace{(3\lambda-\alpha_1-\alpha_2+4)(-4-3\lambda+2\alpha)}_{<0}} = 0 \quad (3.49)$$

which holds true for $\alpha = \frac{\alpha_1+\alpha_2}{2}$. Now suppose $\alpha \neq \frac{\alpha_1+\alpha_2}{2}$. The difference is positive if $2\alpha - \alpha_1 - \alpha_2 < 0$ or

$$\alpha < \frac{\alpha_1 + \alpha_2}{2}$$

similarly, it is clear than $T_l^B(\alpha_1, \alpha_2) < T_l^B(\alpha)$ if $\alpha > \frac{\alpha_1+\alpha_2}{2}$.

□

3.A.5 Proof of lemma 3.3

Proof. Regulator 1 then solves

$$\max_{T_{1l}} (\pi_l + T_{1l} + T_{2l}) \left(s_l - (1 + \lambda_1 - \alpha)T_{1l} - (1-\alpha)T_{2l} + \alpha\pi_l\right) + \left(1 - (\pi_l + T_{1l} + T_{2l})\right)(w_h) - \alpha\frac{(\pi_l + T_{1l} + T_{2l})^2}{2} \tag{3.50}$$

Solving for the Nash equilibrium we get

$$T_{1l}(\lambda_1, \lambda_2) = \frac{(\pi_l\lambda_2 + \Delta^W)\lambda_1 - \lambda_2(+2\Delta^W - \pi_l)}{(\alpha - 3\lambda_2 - 2)\lambda_1 + (\alpha - 2)\lambda_2} \tag{3.51}$$

$$T_{2l}(\lambda_1, \lambda_2) = \frac{(\pi_l\alpha + \pi_l\lambda_2 - 2s_l + 2w_h)\lambda_1 + \lambda_2(s_l - w_h + \pi_l)}{(\alpha - 3\lambda_2 - 2)\lambda_1 + (\alpha - 2)\lambda_2} \tag{3.52}$$

Clearly, since $\lambda_1 \neq \lambda_2$, a solution always exists.

$$T_l^B(\lambda_1, \lambda_2) = \frac{2\pi_l\lambda_1\lambda_2 + ((1-\alpha)\pi_l - s_l + w_h)(\lambda_1 + \lambda_2)}{(\alpha - 2)(\lambda_1 + \lambda_2) - 3\lambda_1\lambda_2}$$

We now compare the difference between $T_l^B(\lambda)$ and $T_l^B(\lambda_1, \lambda_2)$:

$$T_l^B(\lambda, .) - T_l^B(\lambda_1, \lambda_2, .) \geq 0 \tag{3.53}$$

$$\Leftrightarrow \frac{((2\alpha - 2\lambda - 2)\pi_l + 2s_l - 2w_h)}{(4 + 3\lambda - 2\alpha)} - \frac{2\pi_l\lambda_1\lambda_2 + ((1-\alpha)\pi_l - s_l + w_h)(\lambda_1 + \lambda_2)}{(\alpha - 2)(\lambda_1 + \lambda_2) - 3\lambda_1\lambda_2} \geq 0 \tag{3.54}$$

$$-\frac{((\alpha\pi_l + 3\Delta^W)(\lambda(\lambda_1 + \lambda_2) - 2\lambda_1\lambda_2)}{2\left(-2 - \frac{3}{2}\lambda + \alpha\right)((\alpha - 2)(\lambda_1 + \lambda_2) - 3\lambda_1\lambda_2)} \geq 0 \tag{3.55}$$

which holds true for $\lambda \leq \frac{2\lambda_1\lambda_2}{\lambda_1+\lambda_2} = \Lambda$. This is a necessary condition since all the other terms have a definite sign.

□

3.A.6 Proof of proposition 3.3

Proof. We now compare the single regulator transfer with the two regulator transfer with asymmetric regulatory cost of taxation. $T_l^B(\lambda_1, \lambda_2) \leq T_l^A$ if:

$$\frac{2\pi_l\lambda_1\lambda_2 + ((1-\alpha)\pi_l - s_l + w_h)(\lambda_1+\lambda_2)}{(\alpha-2)(\lambda_1+\lambda_2) - 3\lambda_1\lambda_2} - \frac{-s_l + w_h + (1+\lambda-\alpha)\pi_l}{\alpha - 2\lambda - 2} \leq 0 \tag{3.56}$$

$$\Leftrightarrow \frac{((1+\alpha+\lambda)\pi_l + 3(s_l - w_h))\lambda_1\lambda_2 - \lambda(\alpha\pi_l + 2(s_l - w_h))(\lambda_1+\lambda_2)}{\underbrace{(-2-2\lambda+\alpha)((\alpha-2)(\lambda_1+\lambda_2) - 3\lambda_1\lambda_2)}_{>0}} \leq 0 \tag{3.57}$$

Clearly, the sign of (3.57) depends on the sign of the numerator. Rearranging, the numerator is negative if

$$[2\lambda(\lambda_1+\lambda_2) - 3\lambda_1\lambda_2](s_l - w_h) \leq (1+\alpha+\lambda)\pi_l\lambda_1\lambda_2 - \alpha\pi_l\lambda(\lambda_1+\lambda_2).$$

Adding $[2\lambda(\lambda_1+\lambda_2) - 3\lambda_1\lambda_2]\pi_l$ on both sides, we obtain

$$[2\lambda(\lambda_1+\lambda_2) - 3\lambda_1\lambda_2]\Delta^W \leq -\pi_l[(2-\alpha-\lambda)\lambda_2\lambda_1 + (\alpha-2)\lambda(\lambda_1+\lambda_2)] \tag{3.58}$$

A sufficient condition for (3.58) to hold is to have:
$2\lambda(\lambda_1+\lambda_2) - 3\lambda_1\lambda_2 < 0$ and $(2-\alpha-\lambda)\lambda_2\lambda_1 + \alpha\lambda(\lambda_1+\lambda_2) - 2\lambda(\lambda_1+\lambda_2) < 0$.
Thereby:

1. $(2-\alpha-\lambda)\lambda_2\lambda_1 + \alpha\lambda(\lambda_1+\lambda_2) - 2\lambda(\lambda_1+\lambda_2) < 0$ if $\frac{\lambda_1\lambda_2}{\lambda_1+\lambda_2} < \frac{(2-\alpha)\lambda}{2-\alpha-\lambda}$ and
2. $2\lambda(\lambda_1+\lambda_2) - 3\lambda_1\lambda_2 < 0$ if $\frac{2}{3}\lambda < \frac{\lambda_1\lambda_2}{\lambda_1+\lambda_2}$.

Therefore it is straightforward to see that a sufficient condition for $T_l^B(\lambda_1, \lambda_2) \leq T_l^A$ to hold true is $\frac{2}{3}\lambda < \frac{\lambda_1\lambda_2}{\lambda_1+\lambda_2} < \frac{(2-\alpha)\lambda}{2-\alpha-\lambda}$. Multiplying each part by 2 yields $\frac{4}{3}\lambda < \Lambda < \frac{2(2-\alpha)\lambda}{2-\alpha-\lambda}$.

However, the converse is not true. Suppose $T_l^B(\lambda_1, \lambda_2) \geq T_l^A$. This holds if $\frac{2}{3}\lambda > \frac{(2-\alpha)\lambda}{2-\alpha-\lambda}$. This implies that $-2\lambda > 2 - \alpha$, which is impossible. This completes the proof. □

3.A.7 Proof of lemma 3.4

Proof. The proof is in two steps. In a first step, we show the conditions for which the respective transfers constitute a unique equilibrium. In a second step, we argue that this unique equilibrium implies that the participation and limited liability constraint are not binding.

Step 1

Regulator 1's problem is

$$\max_{T_{1l}}(\pi_l + T_{1l} + T'_{2l})\left(s_l - (1+\lambda_1-\alpha)T_{1l} - (1-\alpha)T'_{2l} + \alpha\pi_l\right) + (1-(\pi_l+T_{1l}+T'_{2l}))(w_h) - \alpha\frac{(\pi_l+T_{1l}+T'_{2l})^2}{2} \quad (3.59)$$

where T'_{2l} is regulator 2's best response function, for any given T_{1l}. Substituting the expression of T'_{2l} in the objective function, the first order condition and the optimal transfer for regulator 1 writes:

$$\frac{\lambda}{2(\alpha-2-2\lambda)^2}\left(-8T_1\lambda^2 + ((6T_1-4\pi_l)\alpha - 12T_1 + 4\pi_l)\lambda + (4\alpha^2\pi_l + (-2w_h - 10\pi_l + 2s_l)\alpha + 4w_h + 4\pi_l - 4s_l)\right) = 0 \quad (3.60)$$

$$\frac{(-2\alpha^2\pi_l + ((2\lambda+5)\pi_l - s_l + w_h)\alpha + \pi_l(-2-2\lambda) + 2s_l - 2w_h)}{\lambda(-4\lambda+3\alpha-6)} = T^C_{1l} \quad (3.61)$$

Clearly, an interior solution to (3.61) does not exist when $\lambda = 0$, which is true when $\{T^C_{1l}, T^C_{2l}\} \leq 0$. We now look at the conditions for which the equilibrium transfers are positive. We start with regulator 1's optimal transfer. Since the denominator is negative, T^C_{1l} is positive if

$$2\alpha^2\pi_l + ((2\lambda+5)\pi_l - s_l + w_h)\alpha - \pi_l(-2-2\lambda) + 2s_l - 2w_h) < 0 \quad (3.62)$$

$$\Leftrightarrow 2\alpha^2\pi_l - ((2\lambda+5)\pi_l - s_l + w_h)\alpha + \pi_l(-2-2\lambda) - 2\pi_l + 2\pi_l + 2s_l - 2w_h) < 0 \quad (3.63)$$

$$\frac{(-2\alpha^2 + (4+2\lambda)\alpha - 2\lambda - 4)\pi_l}{\alpha-2} < \Delta^W \quad (3.64)$$

Substituting for T^C_{1l} in regulator 2's best-response function, we obtain

$$T^C_{2l} = \frac{4\lambda^2\pi_l + (-6\alpha\pi_l + 7\pi_l - 2s_l + 2w_h)\lambda + (\alpha-2)(2\alpha\pi_l - \pi_l + s_l - w_h)}{\lambda(-4\lambda+3\alpha-6)}$$

$$-4\lambda^2\pi_l + (-6\alpha\pi_l + 7\pi_l - 2s_l + 2w_h)\lambda - (\alpha-2)(2\alpha\pi_l - \pi_l + s_l - w_h) > 0 \quad (3.65)$$

$$\Leftrightarrow -4\lambda^2\pi_l - (-6\alpha\pi_l + 7\pi_l - 2s_l + 2w_h)\lambda + (\alpha-2)(2\alpha\pi_l - \pi_l + -\pi_l + \pi_l + s_l - w_h) > 0 \quad (3.66)$$

$$\frac{(4\lambda^2 + (-6\alpha+9)\lambda + 2(\alpha-2)(\alpha-1))\pi_l}{2+2\lambda-\alpha} < \Delta^W \quad (3.67)$$

Note that when $\lambda = 0$, $\{T^C_{1l}, T^C_{2l}\} = \{-\infty, -\infty\}$.

Step 2 Suppose the unique equilibrium $\{T_{1l}^C, T_{2l}^C\}$ is such that the participation constraint and the limited liability constraint of the firm are binding. These constraints are binding if

$$T_{1l}^* + T_{2l}^*(T_{1l}^*) = -\pi_l.$$

This equality implies that least one of the two transfers is negative. A contradiction. Hence the unique equilibrium is such that (PC_2) and (LL_2) are not binding. □

3.A.8 Proof of proposition 3.4

Proof. The proof is in three steps. First we compare T_{1l}^C and T_{2l}^C. In the second step we compare the effort in the sequential game with the effort obtained in the single regulator setup, ϕ^A. In the third step we compare the effort obtained in the simultaneous game with symmetric weight and cost.

Step 1. We compare T_{1l}^C and T_{2l}^C. $T_{1l}^C - T_{2l}^C \leq 0$ if

$$\frac{(-2\alpha^2\pi_l + ((2\lambda+5)\pi_l - s_l + w_h)\alpha + \pi_l(-2-2\lambda) + 2s_l - 2w_h)}{\lambda(-4\lambda+3\alpha-6)} - \frac{4\lambda^2\pi_l + (-6\alpha\pi_l + 7\pi_l - 2s_l + 2w_h)\lambda + (\alpha-2)(2\alpha\pi_l - \pi_l + s_l - w_h)}{\lambda(-4\lambda+3\alpha-6)} \leq 0 \quad (3.68)$$

$$\Leftrightarrow \frac{-4\lambda^2\pi_l + (8\alpha\pi_l - 9\pi_l + 2s_l - 2w_h)\lambda - 2(\alpha-2)(2\alpha\pi_l - \pi_l + s_l - w_h)}{\underbrace{\lambda(-4\lambda+3\alpha-6)}_{<0}} \leq 0 \quad (3.69)$$

Since the denominator is negative, we look at the condition on s_l and w_h for which the numerator is positive. It is positive if

$$s_l - w_h \geq \frac{(4\lambda^2 + (-8\alpha+9)\lambda + 4\alpha^2 - 10\alpha + 4)\pi_l}{2(\lambda-\alpha+2)}$$

or, adding π_l on both sides

$$s_l + \pi_l - w_h \geq \frac{(4\lambda^2 + (-8\alpha+9)\lambda + 4\alpha^2 - 10\alpha + 4)\pi_l}{2(\lambda-\alpha+2)} + \pi_l \quad (3.70)$$

$$w_l - w_h = \Delta^W \geq \frac{4\pi_l(\lambda^2 + (-2\alpha + \frac{11}{4})\lambda + \alpha^2 - 3\alpha + 2)}{2\lambda - 2\alpha + 4} \quad (3.71)$$

Next, we check whether $T_{1l}^C > T_{2l}^C$ is feasible. This is implied by $\Delta^W < \frac{4\pi_l(\lambda^2+(-2\alpha+\frac{11}{4})\lambda+\alpha^2-3\alpha+2)}{2\lambda-2\alpha+4}$. Following lemma 3.4, this condition is compatible with the condition of existence of the unique equilibrium if $\frac{4\pi_l(\lambda^2+(-2\alpha+\frac{11}{4})\lambda+(\alpha-2)(\alpha-1))}{-2\alpha+2\lambda+4} - \frac{(4\lambda^2+(-6\alpha+9)\lambda+2(\alpha-2)(\alpha-1))\pi_l}{2+2\lambda-\alpha} > 0$. However, this difference simplifies to $\frac{\pi_l\lambda(-4\lambda+3\alpha-6)}{2(\alpha-\lambda-2)(\alpha-2\lambda-2)} < 0, \forall \alpha, \lambda \in [0,1]$. A contradiction.

It follows that the total transfer

$$T_l^C = T_{1l}^C + T_{2l}^C = \frac{2\Delta^W - (7+4\lambda-4\alpha)\pi_l}{6+4\lambda-3\alpha} \tag{3.72}$$

Step 2. We now compare the efforts between games. We proceed by contradiction. Suppose the effort in the single regulator game is higher. Then:

$$T_l^A + \pi_l - T_l^C + \pi_l \geq 0 \tag{3.73}$$

$$\frac{s_l - w_h - (1+\lambda-\alpha)\pi_l}{2+2\lambda-\alpha} - \frac{(-4\alpha+4\lambda+5)\pi_l - 2s_l + 2w_h}{-4\lambda+3\alpha-6} \geq 0 \tag{3.74}$$

$$\frac{\alpha^2\pi_l + ((-5\lambda-4)\pi_l - s_l + w_h)\alpha + 4(1+\lambda)^2\pi_l + 2s_l - 2w_h}{(\alpha-2-2\lambda)(-4\lambda+3\alpha-6)} \geq 0 \tag{3.75}$$

Since the denominator is strictly positive, it suffices to look at the signs of the numerator. It is positive if:

$$\alpha^2\pi_l + ((-5\lambda-4)\pi_l - s_l + w_h)\alpha + 4(1+\lambda)^2\pi_l + 2s_l - 2w_h \geq 0 \tag{3.76}$$

$$(\alpha^2 - (5\lambda+4)\alpha + 4(1+\lambda)^2)\pi_l > (\alpha-2)(s_l - w_h) \tag{3.77}$$

$$((\alpha-1)(\alpha-2) + (8-5\alpha)\lambda + 4\lambda^2)\pi_l > (\alpha-2)\Delta^W \tag{3.78}$$

which is always true since the right hand side is negative. Therefore, transfer in the two regulator sequential game is lower than the single regulator game transfer.

Step 3. We now compare T_l^B and T_l^C. $T_l^B > T_l^C$ if

$$\frac{2(s_l - w_h - (1+\lambda-\alpha)\pi_l}{(4+3\lambda-2\alpha)} - \frac{(-4\alpha+4\lambda+5)\pi_l - 2s_l + 2w_h}{(-4\lambda+3\alpha-6)} > 0 \tag{3.79}$$

$$\frac{4\lambda^2\pi_l + (-6\alpha\pi_l + 11\pi_l + 2s_l - 2w_h)\lambda - 2(\alpha-2)(-\alpha\pi_l + 2\pi_l + s_l - w_h)}{(-4-3\lambda+2\alpha)(-4\lambda+3\alpha-6)} > 0 \tag{3.80}$$

Since the denominator is strictly positive, we need the numerator to be positive, which is equivalent to:

$$(4\lambda^2 + (-6\alpha+11)\lambda + 2(\alpha-2)^2)\pi_l - 2(-\lambda+\alpha-2)(s_l - w_h) > 0 \tag{3.81}$$

$$(4\lambda^2 + (-6\alpha+11)\lambda + 2(\alpha-2)^2)\pi_l > 2(-\lambda+\alpha-2)(s_l - w_h) \tag{3.82}$$

adding $2(-\lambda+\alpha-2)\pi_l$ on both sides yields:

$$2\pi_l\left(2\lambda^2 + \left(-3\alpha + \frac{9}{2}\right)\lambda + (\alpha-1)(\alpha-2)\right) > (2(-\lambda+\alpha-2))\Delta^W,$$

which is always true since the left hand side is strictly positive and the right hand side strictly negative. □

3.A.9 Proof of lemma 3.5

Proof. Substituting for R_l and T'_{2l} in the objective function and taking the first order condition we get

$$\frac{\partial W_1^C}{\partial T_{1l}} = \frac{1}{2(-\alpha_2+2+2\lambda)^2}\big(-8T_1\lambda^3 + (2(T_1-2\pi_l)\alpha_2 + 2T_1\alpha_2 + 4\pi_l + 2(\alpha_1-6)T_1)\lambda^2 + \big(2\pi_l\alpha_2^2 + (2\alpha_1-10)\pi_l\alpha_2 + 4\pi_l + (-2\alpha_1+4)w_h + 2s_l(\alpha_1-2)\big)\lambda\big) = 0 \quad (3.83)$$

Solving for T_{1l}^C, regulator 1's optimal transfer when she moves first writes

$$T_{1l}^{CA} = \frac{(\alpha_2^2 + (-2\lambda+\alpha_1-5)\alpha_2 + 2\lambda+2)\pi_l + (\alpha_1-2)(s_l-w_h)}{\lambda(4\lambda-2\alpha_2-\alpha_1+6)},$$

which is positive if the numerator is positive, or

$$\Delta^W > \Delta^{W*} \equiv \frac{(-\alpha_2+2\lambda-\alpha_1+4)(\alpha_2-1)\pi_l}{\alpha_1-2}$$

and regulator 2's optimal behaviour as a follower is then

$$T_{2l}^{CA} = \frac{-4\lambda^2\pi_l + ((\alpha_1+5\alpha_2-7)\pi_l + 2s_l - 2w_h)\lambda + (-\alpha_1\alpha_2 - \alpha_2^2 + 5\alpha_2 - 2)\pi_l - (\alpha_1-2)(s_l-w_h)}{\lambda(4\lambda-2\alpha_2-\alpha_1+6)}.$$

This expression is positive if

$$\Delta^W > \Delta^{W'} \equiv \frac{\big(4\lambda^2 + (9-5\alpha_2-\alpha_1)\lambda + (\alpha_2-1)(\alpha_2+\alpha_1-4)\big)\pi_l}{2+2\lambda-\alpha_1}$$

To obtain a sufficient condition for which a unique equilibrium exists, we compare Δ^{W*} and $\Delta^{W'}$. We look at the sign of $\Delta^{W*} - \Delta^{W'}$:

$$\Delta^{W*} - \Delta^{W'} = \frac{-\pi_l\lambda(\alpha_1-\alpha_2-1)(4\lambda-\alpha_1-2\alpha_2+6)}{(\alpha_1-2)(2+2\lambda-\alpha_1)} < 0.$$

Hence, $\Delta^{W*} < \Delta^{W'}$ and $\Delta^W > \Delta^{W'}$ is a sufficient condition for the existence of a unique equilibrium.

Adding the respective transfers yields the total transfer

$$T_l^{CA} = T_{1l}^{CA} + T_{2l}^{CA} = \frac{(4\lambda-\alpha_1-3\alpha_2+5)\pi_l - 2s_l + 2w_h}{-4\lambda+2\alpha_2+\alpha_1-6} \quad (3.84)$$

Suppose $T^C(\alpha_1, \alpha_2) < T^C(\alpha)$. Then

$$\frac{(-4\lambda + \alpha_1 + 3\alpha_2 - 5)\pi_l + 2s_l - 2w_h}{(4\lambda - 2\alpha_2 - \alpha_1 + 6)} - \frac{(-4\alpha + 4\lambda + 5)\pi_l - 2s_l + 2w_h}{-4\lambda + 3\alpha - 6} < 0 \quad (3.85)$$

$$\frac{((4\lambda - \alpha_1 + \alpha_2 + 9)\alpha + (-4\lambda - 8)\alpha_2 - \alpha_1)\pi_l + 6(\alpha - \frac{\alpha_1}{3} - \frac{2\alpha_2}{3})(s_l - w_h)}{(-4\lambda + 3\alpha - 6)(4\lambda - 2\alpha_2 - \alpha_1 + 6)} < 0 \quad (3.86)$$

where $(-4\lambda + 3\alpha - 6)(4\lambda - 2\alpha_2 - \alpha_1 + 6) < 0$. For (3.86) to hold true, the numerator should be positive:

$$((4\lambda - \alpha_1 + \alpha_2 + 9)\alpha - (4\lambda + 8)\alpha_2 - \alpha_1)\pi_l + (6\alpha - 2\alpha_1 - 4\alpha_2)(s_l - w_h) > 0 \quad (3.87)$$

$$(6\alpha - 2\alpha_1 - 4\alpha_2)(s_l - w_h) > -((4\lambda - \alpha_1 + \alpha_2 + 9)\alpha - (4\lambda + 8)\alpha_2 - \alpha_1)\pi_l \quad (3.88)$$

adding $(6\alpha - 2\alpha_1 - 4\alpha_2)\pi_l$ on both sides yields

$$(6\alpha - 2\alpha_1 - 4\alpha_2)\Delta^W > -\pi_l((4\lambda - \alpha_1 + \alpha_2 + 3)\alpha - (1 + \lambda)\alpha_2 + \alpha_1) \quad (3.89)$$

$$\Delta^W > -\frac{\pi_l((4\lambda - \alpha_1 + \alpha_2 + 3)\alpha - (1 + \lambda)\alpha_2 + \alpha_1)}{6\alpha - 2\alpha_1 - 4\alpha_2} \quad (3.90)$$

Thus, a sufficient condition for (3.90) to hold true is to have the right hand side of (3.90) to be non-positive. We have the following two cases

1. $(4\lambda - \alpha_1 + \alpha_2 + 3)\alpha - (1 + \lambda)\alpha_2 + \alpha_1 \geq 0$ and $3\alpha - \alpha_1 - 2\alpha_2 \geq 0$, or

2. $(4\lambda - \alpha_1 + \alpha_2 + 3)\alpha - (1 + \lambda)\alpha_2 + \alpha_1 \leq 0$ and $3\alpha - \alpha_1 - 2\alpha_2 \leq 0$

Rearranging, case 1 holds if $\alpha > \alpha' \frac{4(1+\lambda)\alpha_2 - \alpha_1}{4\lambda - 3\alpha_1 + \alpha_2 + 9}$ and if $\alpha > \alpha'' \frac{\alpha_1 + 2\alpha_2}{3}$. Note that $\alpha'' > \alpha'$ if $\alpha_1 > \alpha_2$. Hence, if $\alpha_1 > \alpha_2$, $\alpha \geq \frac{\alpha_1 + 2\alpha_2}{3}$ is sufficient for (3.90) to hold true. Otherwise it is sufficient to have $\alpha \geq \frac{4(1+\lambda)\alpha_2 - \alpha_1}{4\lambda - 3\alpha_1 + \alpha_2 + 9}$. Similarly, case 2 holds if $\alpha \leq \frac{4(1+\lambda)\alpha_2 - \alpha_1}{4\lambda - 3\alpha_1 + \alpha_2 + 9}$ and if $\alpha \leq \frac{\alpha_1 + 2\alpha_2}{3}$. Hence, if $\alpha_1 < \alpha_2$, it is sufficient to have $\alpha \leq \frac{4(1+\lambda)\alpha_2 - \alpha_1}{4\lambda - 3\alpha_1 + \alpha_2 + 9}$. Otherwise it is sufficient to have $\alpha \leq \frac{\alpha_1 + 2\alpha_2}{3}$. □

3.A.10 Proof of proposition 3.5

Proof. We compare the effort induced in the sequential game with asymmetric weights and the effort generated in the single regulator. The former is greater than the latter if $\phi_l^C - \phi_l^A > 0$, or

$$\frac{2\Delta^W-(1-\alpha_2)\pi_l}{(4\lambda-2\alpha_2-\alpha_1+6)}-\frac{(\Delta^W+\lambda\pi_l)}{2+2\lambda-\alpha}>0 \tag{3.91}$$

$$\frac{\begin{array}{r}(-4\lambda^2+(4\alpha_2+\alpha_1-8)\lambda-(\alpha_2-1)(\alpha-2))\pi_l\\ -2\left(\alpha-\frac{\alpha_1}{2}-\alpha_2+1\right)\Delta^W\end{array}}{\underbrace{(4\lambda-2\alpha_2-\alpha_1+6)(2+2\lambda-\alpha)}_{>0}}>0 \tag{3.92}$$

After rearranging, the numerator is positive if

$$-\pi_l(4\lambda^2+(8-\alpha_1-4\alpha_2)\lambda+(\alpha_2-1)(\alpha-2))>2\left(\alpha-\frac{\alpha_1}{2}-\alpha_2+1\right)\Delta^W.$$

Since the left hand side is negative, this condition holds only if $\alpha-\frac{\alpha_1}{2}-\alpha_2+1<0$, or $\alpha<\frac{\alpha_1}{2}+\alpha_2-1$.

Now suppose $\phi^C<\phi^A$. Then it must be that

$$-\pi_l(4\lambda^2+(8-\alpha_1-4\alpha_2)\lambda+(\alpha_2-1)(\alpha-2))<2\left(\alpha-\frac{\alpha_1}{2}-\alpha_2+1\right)\Delta^W,$$

which is always true if $\alpha\geq\frac{\alpha_1}{2}+\alpha_2-1$.

To ensure that the threshold $\bar{\Delta^W}$ is compatible with the existence of the unique equilibrium, the threshold must verify $\bar{\Delta^W}-\Delta^{W'}>0$:

$$\bar{\Delta^W}-\Delta^{W'}=\frac{-\pi_l(4\lambda-\alpha_1-2\alpha_2+6)(\alpha+\lambda-\alpha_1-\alpha_2+2)(2\lambda-\alpha_2+1)}{(2\alpha-\alpha_1-2\alpha_2+2)(2+2\lambda-\alpha_1)}.$$

This difference is strictly positive if $\alpha<\frac{\alpha_1}{2}+\alpha_2-1$.

□

3.A.11 Proof of lemma 3.6

Proof. In a first step, we look at the condition under which an equilibrium exists. In a second step we assess the sign of regulator 1'a transfer.

Step 1. The first order condition in regulator 1's problem is given by:

$$\frac{\left((2T_{1l}^*-2(2+\lambda_1)T_{1l}^*+4\Delta^W)\lambda_2^2+(2\alpha\pi_l-(6+4\lambda_1)\alpha+4(\alpha-2)T_{1l}^*\lambda_1+8\pi_l-4\Delta^W\lambda_1)\lambda_2\right.}{2(\alpha-2-2\lambda_2)}$$
$$\frac{\left.+2(\pi_l\lambda_1\alpha+\lambda_1(s_l-w_h))(\alpha-2)\right)}{2(\alpha-2-2\lambda_2)}=0$$

The transfer of regulator 2 is thus

$$T_{2l}^*(T_{1l}^*) = \frac{1}{2\lambda_2\left(\left(\frac{\alpha}{2} - 2\lambda_1 - 1\right)\lambda_2 + (\alpha-2)\lambda_1\right)}((2-\alpha+4\lambda_1)\pi_l + \Delta^W)\lambda_2^2 + ((7-5\alpha)\pi_l)\lambda_1\lambda_2$$
$$+ (\lambda_1+\lambda_2)\pi_l(\alpha-1)(\alpha-2) - 3\Delta^W\lambda_1\lambda_2 + \lambda_1(\alpha-2)\Delta^W \quad (3.93)$$

Since the denominator is negative, this transfer is positive if the numerator is negative, or:

$$\frac{(2-\alpha+4\lambda_1)\pi_l\lambda_2^2 + (7-5\alpha)\pi_l\lambda_1\lambda_2 + (\lambda_1+\lambda_2)\pi_l(\alpha-1)(\alpha-2)}{(2-\alpha)\lambda_1 + 3\lambda_1\lambda_2 - \lambda_2^2} \leq \Delta^W.$$

If the inequality is reversed, then by assumption (3.3), $\lambda_2 = 0$, and the first order condition (3.93) admits no solution. □

Step 2. Solving for T_{1l}^* in (3.93) yields

$$T_{1l}^* = \frac{((4-\alpha)\lambda_1 - 2\lambda_2^2)\Delta^W - (2(1-\alpha)\lambda_1 - (\lambda_1+\lambda_2)(\alpha-1)(\alpha-2))\pi_l}{2\lambda_2\left(\left(\frac{\alpha}{2} - 2\lambda_1 - 1\right)\lambda_2 + (\alpha-2)\lambda_1\right)}$$

This expression is positive if $\Delta^W < \frac{2(\alpha-1)\lambda_1 - (\lambda_1+\lambda_2)(\alpha-1)(\alpha-2)}{(4-\alpha)\lambda_1 - 2\lambda_2^2}$.

3.A.12 Proof of lemma 3.7

Proof. We compare transfers with the symmetric case. The total transfer is given by $T^C(\lambda_1,\lambda_2) = \frac{((4\pi_l\lambda_2 + (-3\alpha+4)\pi_l - s_l + w_h)\lambda_1 - (\pi_l(\alpha-1) + s_l - w_h)\lambda_2)}{((2\alpha - 4\lambda_2 - 4)\lambda_1 + \lambda_2(\alpha-2))}$ and is bigger than T^C if

$$\frac{((4\pi_l\lambda_2 + (-3\alpha+4)\pi_l - s_l + w_h)\lambda_1 - (\pi_l(\alpha-1) + s_l - w_h)\lambda_2)}{((2\alpha - 4\lambda_2 - 4)\lambda_1 + \lambda_2(\alpha-2))}$$
$$- \frac{((-4\alpha + 4\lambda + 5)\pi_l - 2s_l + 2w_h}{-4\lambda + 3\alpha - 6} > 0 \quad (3.94)$$

After rearranging, this condition can be re-expressed as a threshold $\hat{\lambda}(\lambda_1,\lambda_2)$

$$\lambda \geq \hat{\lambda}(\lambda_1,\lambda_2) = \frac{((4\alpha\pi_l + 4\pi_l + 8s_l - 8w_h)\lambda_2 - (\alpha-2)(-\alpha\pi_l + 2\pi_l + s_l - w_h))\lambda_1 + \lambda_2(\alpha-2)(-\alpha\pi_l + 2\pi_l + s_l - w_h)}{(4\alpha\pi_l + 4s_l - 4w_h)\lambda_1 + 4\lambda_2(s_l - w_h + pi_l)} \quad (3.95)$$

The first derivatives of with respect to λ_1 and λ_2 are

$$\frac{\partial\hat{\lambda}}{\partial\lambda_1} = -\frac{((-\alpha^2 + 4\alpha - 4\lambda_2 - 4)\pi_l + (\alpha - 4\lambda_2 - 2)(s_l - w_h))\lambda_2((\frac{1+\alpha}{2})\pi_l + s_l - w_h)}{2((\alpha\lambda_1 + \lambda_2)\pi_l + (\lambda_1+\lambda_2)(s_l - w_h))^2}$$

which is positive if $\lambda_2 < \frac{(\alpha-2)\left((1-\alpha)\pi_l+\Delta^W\right)}{4\Delta^W}$. However, $\frac{(\alpha-2)\left((1-\alpha)\pi_l+\Delta^W\right)}{4\Delta^W} < 0$. Hence, $\frac{\partial\hat{\lambda}}{\partial\lambda_1} < 0$. And

$$\frac{\partial\hat{\lambda}}{\partial\lambda_2} = \frac{((4\alpha\lambda_1-(\alpha-2)^2)\pi_l+(\alpha+4\lambda_1-2)(s_l-w_h))\left(\left(\frac{\alpha+1}{2}\right)\pi_l+s_l-w_h\right)\lambda_1}{2((\alpha\lambda_1+\lambda_2)\pi_l+(\lambda_1+\lambda_2)(s_l-w_h))^2}$$

which is positive if $\lambda_1 > \frac{(\alpha-2)\left((\alpha-1)\pi_l-\Delta^W\right)}{4(\alpha\pi_l+s_l-w_h)}$. □

3.A.13 Proof of proposition 3.6

Proof. First we look at the condition for which on λ for which effort in the two regulator is higher than in the single regulator game. In a second step, we look at how does this condition changes with respect to increases in λ_1 and λ_2.

Step 1. Comparing efforts is equivalent to comparing transfer. Thus, $T_l^C > T_l^A$ if $T_l^C - T_l^A > 0$, or

$$\underbrace{\frac{1}{2(-2-2\lambda+\alpha)((\alpha-2\lambda_2-2)\lambda_1+\lambda_2\frac{(\alpha-2)}{2}}}_{>0}\times$$
$$(\lambda(((\alpha-4\lambda_1)\lambda_2+4\lambda_1(\alpha-1))\pi_l+2(s_l-w_h)(\lambda_1+\lambda_2))+$$
$$\lambda_1((-\alpha^2+4\alpha-4\lambda_2-4)\pi_l+(\alpha-4\lambda_2-2)(s_l-w_h))\big)>0$$

The second term is positive if

$$\lambda > \tilde{\lambda}(\lambda_1,\lambda_2) = -\frac{\lambda_1((-\alpha^2+4(\alpha-\lambda_2-1)\pi_l+(\alpha-4\lambda_2-2)(s_l-w_h))}{((\alpha-4\lambda_1)\lambda_2+4\lambda_1(\alpha-1))\pi_l+2(s_l-w_h)(\lambda_1+\lambda_2)} \tag{3.96}$$

We now take the first derivative with respect to λ_1:

$$\frac{\partial\tilde{\lambda}(\lambda_1,\lambda_2)}{\partial\lambda_1} = -\frac{\left(\frac{\alpha}{2}\pi_l+s_l-w_h\right)((-\alpha^2+4\alpha-4\lambda_2-4)\pi_l+(\alpha-4\lambda_2-2)(s_l-w_h))\lambda_2}{2\left(\left(\left(\frac{\alpha}{2}-2\lambda_1\right)\lambda_2+2\lambda_1(\alpha-1)\right)\pi_l+(s_l-w_h)(\lambda_1+\lambda_2)\right)^2}$$

The numerator is concave in λ_2 and is positive in the interval

$$\left[\underline{\lambda}_2 = \frac{(\alpha-2)((1-\alpha)\pi_l+\Delta^W)}{4\Delta^w} < 0; \qquad \bar{\lambda}_2 = 0\right]$$

Therefore, $\frac{\partial\tilde{\lambda}(\lambda_1,\lambda_2)}{\partial\lambda_1} > 0$ if $\lambda_2 > 0$ and non-positive otherwise.

We now look at the effect of λ_2 on $\tilde{\lambda}(\lambda_1,\lambda_2)$. The first derivative with respect to λ_2 writes

$$\frac{\partial\tilde{\lambda}(\lambda_1,\lambda_2)}{\partial\lambda_2}=\frac{\left(\frac{\pi_l\alpha}{2}+s_l-w_h\right)\lambda_1((-4-\alpha^2+(4\lambda_1+4)\alpha)\pi_l+(\alpha+4\lambda_1-2)(s_l-w_h))}{2\left(\left(\left(2\lambda_1+\frac{\lambda_2}{2}\right)\alpha-2\lambda_1(\lambda_2+1)\right)\pi_l+(s_l-w_h)(\lambda_1+\lambda_2)\right)^2}$$

Clearly the sign of $\frac{\partial\tilde{\lambda}(\lambda_1,\lambda_2)}{\partial\lambda_2}$ depends on the sign of the numerator which is convex in λ_1. Hence it is negative in the interval

$$\left[\lambda_1^*=0, \qquad \lambda_1'=-\frac{\overbrace{(\alpha-2)\left((1-\alpha)\pi_l+\Delta^W\right)}^{<0}}{4((\alpha-1)\pi_l+\Delta^W))}\right]$$

Hence, $\frac{\partial\tilde{\lambda}(\lambda_1,\lambda_2)}{\partial\lambda_2}\geq 0\forall\lambda_1>0$ if

$$\lambda_1'<0 \tag{3.97}$$

$$(1-\alpha)\pi_l>\Delta^W \tag{3.98}$$

Last, to verify whether the conditions for the existence of the unique equilibrium is compatible with $(1-\alpha)\pi_l>\Delta^W$, we check whether $(1-\alpha)\pi_l>\underline{\Delta^W}$. Equivalently, we have $(1-\alpha)\pi_l-\underline{\Delta^W}>0$, or

$$\frac{\pi_l\lambda_2((4+4\lambda_2-2\alpha)\lambda_1+(3-2\alpha)\lambda_2+(\alpha-2)(\alpha-1)}{(\alpha-3\lambda_2-2)\lambda_1+\lambda_2^2}>0.$$

This inequality holds if and only if $(\alpha-3\lambda_2-2)\lambda_1+\lambda_2^2>0$, or after rearranging $\alpha<2+3\lambda_2-\frac{\lambda_2^2}{\lambda_1}$. □

3.A.14 Proof of proposition 3.7

Proof. Substituting for ϕ^B and ϕ^A in (3.23) and rearranging yields

$$\frac{2\lambda^3\pi_l+((11-8\alpha)\pi_l-2\Delta^W)\lambda^2+(\pi_l(4\alpha-5)(\alpha-2)+(-6\alpha+5)\Delta^W)\lambda+4(\alpha-1)(\alpha-2)\Delta^W}{\Gamma_1}$$

where $\Gamma_1>0$. Suppose condition (3.23) is true. Then the above condition holds if the numerator is positive, or if, after rearrangement,

$$\frac{\lambda\pi_l(-2\lambda^2-(11-8\alpha)\lambda-(4\alpha-5)(\alpha-2))}{-2\lambda^2-(6\alpha-5)\lambda+4(\alpha-1)(\alpha-2)}\leq\Delta^W \tag{3.99}$$

Since by assumption $\Delta^W > 0$, a sufficient condition for (3.99) to hold is for the left hand side to be non positive. Since the numerator in the left hand side of (3.99) is negative, we must have $-2\lambda^2 - (6\alpha - 5)\lambda + 4(\alpha - 1)(\alpha - 2) \geq 0$. This expression is convex in α and the roots are

$$\left\{ \tilde{\alpha} = \frac{3}{4}\lambda + \frac{3}{2} - \frac{\sqrt{17\lambda^2 + 16\lambda + 4}}{4}, \qquad \hat{\alpha} = \frac{3}{4}\lambda + \frac{3}{2} + \frac{\sqrt{17\lambda^2 + 16\lambda + 4}}{4} \right\}$$

The denominator is non positive for $\alpha \in [\tilde{\alpha}, \hat{\alpha}]$. Since $\hat{\alpha} > 1$, condition (3.99) and thus condition (3.23) hold if $\alpha \in [0, \tilde{\alpha}]$.

Finally, we check that condition (3.99) is compatible with the existence of the unique equilibrium in the two regulator game. This is true if $\frac{\lambda\pi_l(-2\lambda^2-(11-8\alpha)\lambda-(4\alpha-5)(\alpha-2))}{-2\lambda^2-(6\alpha-5)\lambda+4(\alpha-1)(\alpha-2)} > \Delta^W \geq (2 + \lambda - a)\pi_l$, or $\frac{\lambda\pi_l(-2\lambda^2-(11-8\alpha)\lambda-(4\alpha-5)(\alpha-2))}{-2\lambda^2-(6\alpha-5)\lambda+4(\alpha-1)(\alpha-2)} - (2 + \lambda - a)\pi_l > 0$, which reduces to

$$\frac{4(\alpha - 1)\pi_l(\alpha - 2\lambda - 2)\left(\alpha - \frac{3\lambda}{2} - 2\right)}{-2\lambda^2 - (6\alpha - 5)\lambda + 4(\alpha - 1)(\alpha - 2)} > 0$$

This condition holds true if and only if $\alpha \in [\tilde{\alpha}, \hat{\alpha}]$. □

3.A.15 Proof of proposition 3.8

Proof. In a first step we look at the parametric condition for which welfare in the sequential game is higher than welfare in the single regulator game. In a second step we reiterate the procedure with asymmetric bias.

Step 1.

Rearranging (3.26) yields

$$\frac{1}{\Gamma_2} \times \big((8\lambda^3 + (-18\alpha + 28)\lambda^2 + (8\alpha^2 - 29\alpha + 24)\lambda + \alpha^2 - 3\alpha + 2)\pi_l + (-10\alpha + 2)\lambda + \alpha^2 - 19\alpha + 14)\Delta^W\big) > 0 \quad (3.100)$$

Since $\Gamma_2 > 0$, condition (3.100) holds if the numerator is positive, or if, after rearranging,

$$\frac{-\pi_l(8\lambda^3 + (28 - 18\alpha)\lambda^2 + (8\alpha^2 - 29\alpha + 24)\lambda + (\alpha - 1)(\alpha - 2))}{(6\alpha^2 + (12 - 10\alpha)\lambda - 19\alpha + 14)} \leq \Delta^W \quad (3.101)$$

A sufficient for condition (3.101) to hold is that the left hand side is non-positive. Clearly, the numerator of the left hand side of (3.101) is negative for $\alpha, \lambda \neq 0$ and the denominator is convex in α. The roots are:

$$\left[\alpha' = \frac{5}{6}\lambda + \frac{19}{12} - \frac{\sqrt{100\lambda^2 + 92\lambda + 25}}{12}, \alpha'' = \frac{5}{6}\lambda + \frac{19}{12} + \frac{\sqrt{100\lambda^2 + 92\lambda + 25}}{12}\right]$$

Therefore the denominator in the left hand side of (3.101) is positive if $\alpha < \alpha'$ or $\alpha > \alpha''$ and non positive $\forall \alpha \in [\alpha', \alpha'']$. But since $1 < \alpha' < \alpha''$ $\forall \lambda \in [0,1]$, the left hand side of (3.101) is non positive $\forall \alpha$. Thus condition (3.101) and thus condition (3.25) are always true.

Step 2.

We now look at the case where bias is asymmetric ($\alpha_1 \neq \alpha_2$). Condition (3.27) is now expressed as:

$$\frac{1}{\Gamma_3} \times \left(-8\lambda^3\pi_l + 8\left(\alpha + \frac{\alpha_1}{4} + \alpha_2 - \frac{7}{2}\right)\pi_l\lambda^2 + \left(((-2\alpha_1 - 6\alpha_2 + 14)\alpha + 3\alpha_1 + 12\alpha_2 - 24)\pi_l + 4\Delta^W\left(\alpha + \frac{\alpha_1}{2} + \alpha_2 - 3\right)\right)\lambda - (-1+\alpha_2)(\alpha-2)\pi_l - 2\Delta^W\left((\alpha_1 + 2\alpha_2 - 5)\alpha - \frac{3}{2}\alpha_1 - 3\alpha_2 + 7\right)\right) > 0 \quad (3.102)$$

Since $\Gamma_3 < 0$, condition (3.25) holds if the second term of (3.102) is negative.

Clearly, after rearranging, the second term of (3.102) is negative if:

$$\frac{-8\lambda^3\pi_l + 8\left(\alpha + \frac{\alpha_1}{4} + \alpha_2 - \frac{7}{2}\right)\pi_l\lambda^2 + (((-2\alpha_1 - 6\alpha_2 + 14)\alpha + 3\alpha_1 + 12\alpha_2 - 24)\pi_l)\lambda - (-1+\alpha_2)(\alpha-2)\pi_l}{2\left((\alpha_1 + 2\alpha_2 - 5)\alpha - \frac{3}{2}\alpha_1 - 3\alpha_2 + 7\right) - 4\left(\alpha + \frac{\alpha_1}{2} + \alpha_2 - 3\right)\lambda} < \Delta^W \quad (3.103)$$

A sufficient condition for which (3.103) holds true is for the left hand side to be non positive. The numerator is positive if

$$\alpha_1 \leq \bar{\alpha_1} = -\frac{-8\lambda^3 + \overbrace{(8\alpha + 8\alpha_2 - 28)\lambda^2}^{<0} + \overbrace{((-6\alpha_2 + 14)\alpha + 12\alpha_2 - 24)\lambda}^{<0} \overbrace{-(\alpha_2 - 1)(\alpha - 2)}^{\leq 0}}{\underbrace{\lambda(-2\lambda + 2\alpha - 3)}_{<0}} < 0,$$

a contradiction. The denominator is positive if

$$\alpha_1 > \underline{\alpha_1} = \frac{2(2\alpha\lambda - 2\alpha\alpha_2 + 2\lambda\alpha_2 + 5\alpha - 6\lambda + 3\alpha_2 - 7)}{-2\lambda + 2\alpha - 3}$$

In addition, $\bar{\alpha_1} - \underline{\alpha_1} = \frac{(1+2\lambda)^2(2\lambda+1-\alpha_2)(-2-2\lambda+\alpha)}{\lambda(-2\lambda+2\alpha-3)} \geq 0$ which implies that $\underline{\alpha_1} \leq \bar{\alpha_1} < 0$. Hence, condition (3.103) and thus condition (3.101) always hold true.

□

Chapter 4

The benefits of regulation and deregulation: A meta-analysis

Stephen Davies*, Sean Ennis† and Selvin Thanacoody‡

Following the wave of deregulation that took place in the western world, a rich literature has assessed the impact of deregulation on prices. However, the empirical evidence on the effectiveness of deregulation regarding price reduction is mixed. This paper investigates the effect of economic and social deregulation on price by conducting a meta-regression analysis of the empirical literature examining the effects of regulation or deregulation on consumer prices. We find that deregulation has generally been successful as prices are on average 22 percent lower in deregulated markets. Although price effects associated to social deregulation are stronger than the effects of social regulation, the regression results from the academic journal subsample do not suggest a genuine price effect difference. We conclude that competition advocacy can play a key role to achieve the social goals of regulation without higher prices.

*School of Economics & Centre for Competition Policy, University of East Anglia
†Norwich Business School & Centre for Competition Policy, University of East Anglia
‡School of Economics & Centre for Competition Policy, University of East Anglia

4.1 Introduction

Our aim in this paper is to assess the price effect of various forms of regulation and deregulation through a meta-analysis of mainly empirical studies measuring the impact of such policies on consumer prices. The database used for this study contains price reduction estimates derived from moving towards a more competitive market environment, along with descriptive information on whether deregulation or regulation makes the market more or less competitive. By estimating a model of price reduction estimates, we are able to measure the magnitude of the benefits or downsides of regulation and deregulation. Most of the studies included in the database cover US industries and were conducted in the 1970s and 1980s after the wave of deregulation. This literature has led to various magnitudes of the price effect but also to mixed conclusions as to the nature of the effect.

Surprisingly, despite an abundant literature treating the price effects of regulation or deregulation, the debate on these works has been limited to study reviews (Joskow and Rose, 1989; Winston, 1993; Kwoka, 2008; Estache and Wren-Lewis, 2009). Meta-analyses or review of studies in the field of industrial organisation focus on competition policy matters such as cartel overcharge (Connor and Bolotova, 2006; Connor and Lande, 2008; Boyer and Kotchoni, 2015), the efficiency effect of privatisation or regulation of public utilities (Bel and Warner, 2008; Bel et al., 2010; Carvalho et al., 2012), or the dynamic price effects of mergers (Mariuzzo and Ormosi, 2019). The work on overcharge or regulation typically control for study characteristics like the year, method, type of service, method employed, country or type of publication. By using further information from the papers used in the database, we are able to control for the type of industry, the regulation motive and the nature of competition distortion.

To better apprehend the price effects of deregulation, it is necessary to recall the rationale for regulation. The first reason for regulation is *economic*: entry in natural monopoly industries is limited in order to ensure efficient production scale, and price and rates of return are controlled to prevent firms from capturing monopoly rents (Breyer and MacAvoy, 2016). Economic regulation can also be implemented in competitive markets where firms are deemed to earn excessive rents. In other cases, like in the US trucking, railroads, airlines or banking sector, regulation of price and entry was implemented on the grounds of *destructive* competition (Nelson, 1965; Joskow and Rose, 1989). Regulation also extends to other markets that require safety and quality certifications because prices do not reflect the social cost of providing goods. This type of regulation, also qualified as *social*, aims to limit the risks for society by, for instance, setting pollution or product safety standards (Breyer and MacAvoy, 2016; Viscusi et al., 2018).

However, regulation can be imperfect because it is costly to enforce and regulators are unlikely to be perfectly informed (Joskow and Rose, 1989). In the sectors where competition is presumably destructive, economic regulation could have been motivated to protect industry interests as it enabled the industry to earn rents, whereas in natural monopoly industries regulation did not significantly constrain prices (Viscusi et al., 2018). Based on these findings, the theories on the effect of deregulation predicted higher firm efficiency and subsequently lower consumer prices due to accrued competition (Winston, 1993). The early social regulatory policies were mainly based on meeting technological standards by adopting a command and control approach without considering the economic incentives of consumers and industry (Viscusi et al., 2018). While consumer prices increased as a result, the effectiveness of such policies on reducing risks have not been substantial.

Historically, deregulation primarily translated into the introduction of competition in sectors that had been kept as a regulated monopoly. The regulation paradigm differed across nations (Breyer, 2016). In the US, these former monopolies were subject to sector regulation. In Europe and Asia, these sectors were public-owned.

The meta-regressions performed in this paper are done by OLS estimation over the whole sample and a subsample of academic journals. Our results show that, on average, regulated industries charge prices 22 percent on average higher than their unregulated counterparts. Because the sample does not only contain before and after effects of regulation or deregulation, we do not only gauge the effect of policy on price reduction, but we assess whether price reductions are stronger under deregulation. In addition, since we are able to distinguish between economic and social policy types, we compare price reductions between economic and social regulation and deregulation. Overall, price reductions under economic deregulation appear stronger than under social deregulation. Price reductions from social deregulation are potentially 8 percentage points higher than price increases following social regulation possibly because of the difference in the intensity of regulation, the time it takes for regulation to impact on prices, or market specific effects. However, this price effect difference is reduced to an average of 3 percentage points and is not significant when estimations are conducted at academic journal sample level.

The results do not suggest that markets should be completely deregulated. While economic deregulation should be accompanied with effective competition policy, public intervention for health and safety or environment purposes remain essential. Yet, these social goals can be achieved without higher prices if social regulation adopts market-based mechanisms and reduces barriers to entry.

The paper is organised as follows. Section 4.2 surveys the literature related to our research. Section 4.3 describes the database and key variables. In section 4.4 we provide descriptive statistics. Section 4.5 defines the econometric model and the estimation methodology. Section 4.6 presents the regression results. Section 4.7 discusses the key role that competition advocacy can play. Section 4.8 concludes.

4.2 Literature review

In this section, we provide an insight on the different empirical magnitudes that regulation or deregulation can have on prices, which is essentially based on the US experience. An early reflection on industry regulation by Joskow and Rose (1989) states that the effects of regulation depends on a range of factors related to the nature and the instruments of regulation, the motivation for regulation but also on industry characteristics and the institutional environment. Moreover, the effect of regulation on price and other outcomes can reflect the interaction between various interest groups and the prevailing economic conditions surrounding the industry.

4.2.1 Price effect of natural monopoly regulation

Economic regulation is considered to be efficient mainly in the case of natural monopolies. According to Joskow and Rose (1989), regulating entry is desirable if it allows the monopoly to achieve scale economies and prices are constrained so that firms don't earn excessive or insufficient profits and tariff structures are efficient for individual consumers.

The early literature on electric utility regulation shows that regulation affects prices negatively. Using demand and cost data, Smiley and Greene (1983) and Greene and Smiley (1984) show that unregulated monopoly prices in the electricity industry is 20-50% higher than regulated prices. Obtaining marginal profits through the estimation of the firm's optimal choice of capital and a shareholder's value function, Baron and Taggart (1977) conclude that regulated prices in the electricity industry is lower than unconstrained monopoly prices. Joskow (1974) finds that regulatory constraints tend to bind following increases in costs as regulators attempt to limit price increases.

The effects of regulation can differ across industries and time. For instance, Breyer and MacAvoy (1974) find no considerable effects of regulation on natural gas prices prior to 1974 but the subsequent related literature cited by Joskow and Rose (1989) conclude that the tight price regulation implemented in the late 1970s led to an increase in the price of unregulated categories of gas, which was amplified by the oil price shock.

The literature on the effect of regulation on prices is sparse in the telecommunications industry, possibly because it has been regulated with either one form of regulation or another. Indeed, the stream of studies on the sector compare prices and industry performance between price cap and rate of return schemes (Ai and Sappington, 2002). Yet the US experience can give some indication on the effect of the degree of regulation. In retrospect, regulation of the natural monopoly AT&T would not have ensured lower prices than under a regulated competition configuration (Viscusi et al., 2018). The services provided by AT&T were deemed substitutes to those of competitors, without reasonable grounds of predatory pricing behaviour. In the US cable TV industry, the cross-sectional analysis from Zupan (1989) shows that unregulated operators charged \$3.82 more than regulated firms for basic services. Operators who committed to freeze rates reduced rates of basic services by \$1.37. Others find no effect on prices. After deregulation of the sector in 1984-1992, the reintroduction of rate regulation led to nominal price drops but at the expense of consumer welfare through lower output and no apparent quality-adjusted prices reduction (Hazlett, 1991).

When regulation was designed to serve the interests of the industry, it's effect on price in the rail freight transport sector was inconsistent. The creation of the sector regulator Interstate Commerce Commission (ICC) led to higher prices in rail transportation in the late 1880s but a century later, the ICC kept rail rates artificially low to shield the sector from competing with the trucking industry Viscusi et al. (2018). By comparing estimates of rate of return values or cost of capital replacement from Levin (1981) under marginal cost pricing and under ICC regulation, Joskow and Rose (1989) suggest that average rail prices were lower under regulation than under no regulation.

4.2.2 Price effect of regulation in other industries

Sometimes, regulation is justified on grounds of excessive competition in an unregulated environment like banking and trucking, but these arguments were unconvincing (Nelson, 1965; Joskow and Rose, 1989). Regulation can thus protect industries that are not natural monopolies from the threat of competition, resulting in inefficient pricing. Entry regulation in the road haulage industry resulted in higher rates (Joskow and Rose, 1989). In the US, the regulated prices allowed operators to earn substantial profits that could have shrank through free entry (Viscusi et al., 2018). But entry was allowed by the ICC only on the basis of a compelling need to provide the service (Nelson, 1965). Evidence of higher prices under regulation is found by estimating the value of operating certificates under regulation through structural or reduce-form equations of certificate price or rate of return (Breen, 1977; Frew, 1981; Moore, 1978). Since these certificates have no value without regulation, the positive values reflect higher trucking rates.

In the US airline industry, a cross-sectional analysis from Douglas and Miller (1975) shows that regulated prices are higher than unregulated fares, but also provide evidence that regulation led to higher than socially optimal prices because of too much quality provision. At the multi-country level, Gönenç and Nicoletti (2000) analyse the impact of bilateral restrictions of international air transportation in 27 OECD countries by performing cross-sectional reduced form regressions at country and route level during the 1996/1997 air travel season. They find evidence of higher fares due to these restrictions. Doove et al. (2001) extends this empirical exercise to 35 OECD countries and her results confirms that such restrictions significantly raises air fares. In a comparative study, Simat, Helliesen and

Eichner, Inc (1977) show that regulated interstate air fares in California were 39.4 to 92.9 percent higher than unregulated intrastate fares across various haul distances in 1972.

The effects of regulation is also considered in non-network industries. Results from the insurance industry are not found to be conclusive (Joskow and Rose, 1989). In the milk market, regulation of milk supply has also led to higher prices. By estimating demand for raw milk, Ippolito and Masson (1978) find that price discrimination regulation led to an overall price increase of 3.7 percent. A later study on the related topic found that regulation increased the price of raw milk by almost 6% in Boston (Dhar and Cotterill, 2002). Entry restriction is found to increase prices in the professional services sector. For instance, Shepard (1978)'s cross-sectional analysis find that dental fees are 12-15 percent higher in states without reciprocity restrictions and find dental prices to be 4-4.7% higher in states with multiple entry restrictions. By studying the effect of commercial practices restrictions in the optometry industry. The double-log cross-section regression model of Haas-Wilson (1986) finds that prices are 5.5 percent higher in regulated states. The price differential regression model of Benham (1972) produces estimates for regulated states that are 25 to more than 100 percent than unregulated states in eyeglasses prices. In an attempt to estimate price differences between additional regulatory measures, Benham and Benham (1975) estimate a two equation model consisting of a price and a demand equation. They find that states with greater commercial restrictions have 25 to 40 percent higher prices for eyeglasses.

Studies undertaken in the 2000s in the professional services corroborate the positive price impacts of restrictions. Further econometric studies on US occupational licenses find that entry regulation or work safety regulation positively affect professional's fees (Kleiner and Todd, 2009; Kleiner and Kudrle, 2000; Kleiner and Krueger, 2008). Smith et al. (2018)'s literature survey argues that the effect of licensing laws on quality in the US healthcare sector is not conclusive, but asserts that such regulation restricts labour supply and thus increases health practitioners' fees. In the funeral services specifically, Sutter (2005) concludes that the regulated price of caskets in Oklahoma is 68 percent higher than prices found on the internet. A later econometric study by Chevalier and Morton (2008) shows that consumers pay less for a casket bought online than in several other US states that impose restrictions in this market.

Regarding other countries, Nguyen-Hong (2000) estimates a reduce-form model of price-cost margins to find that restriction increase prices charged by engineering services in Austria, Mexico, Malaysia, Indonesia and Germany by 10 - 15%. Similar effects are found in Japan. Kinoshita (2000) finds that prices for legal services in Japan are almost 14 to 100% higher than in countries without regulation. In the Tokyo housing market, the hedonic model of condominium price and the architect supply model estimated by Kawaguchi et al. (2014) shows that a stricter quality standards regulation concerning new condominiums increased the price of existing condominiums by 15 percent. Furthermore, the obligation of retaining the services of a certified architect to review certain buildings could have increased their fees, without any increase in their hours work.

A recent empirical analysis by Chambers et al. (2019) on a wide range of consumer groups treats regulation as a continuous variable by means of an index. Their GMM estimation of a price growth rate model shows that a 10% increase in social regulation increases consumer prices by 1.285%. They also show that regulation affects mostly lower income groups.

4.2.3 Price effect of deregulation

Given the wave of deregulation experience in the US, the literature on deregulation is essentially economic. The telecommunications sector is a showcase example as technological changes made competition feasible and accelerated the deregulation process. The rates reduction for interstate and international calls reported by the Trends in Telephone Service[1] amounted to almost 77 percent percent in rates between 1984 and 2007, and more than an 88 percent decline for access charges over the roughly the same period.

The academic literature is more abundant regarding transportation industries. The comparative approach used in the literature cited by Joskow and Rose (1989) suggests that price reduction following price and entry deregulation accounts for 7-36 percent in the Canadian, US and European trucking industries. Time series studies report price declines after the deregulation in the late 1970s and early 1980s, with notably a decline of 14% of trucking rates in Florida induced by interstate deregulation (Blair et al., 1986). Ying and Keeler (1991) use a translog price and cost functions to estimate the impact of deregulation in the trucking industry. Their results show a rate increase estimate of 3% in the first year of the reform but afterwards yield rate reductions of 15-20 percent by 1983 and of 25-35 percent by 1985.

In the rail sector, many studies conclude that deregulation led to rates reduction. However, Boyer (1987) observes that most of the effect is due to freight composition. By controlling for years in his linear regression model, he finds that deregulation has actually led a 2% increase in rates between 1980 and 1985. In the same line, Wilson (1994) shows the price effect of deregulation depends on freight composition through a reduced form model of rail prices with a before-and-after deregulation dummy. His results show that rail rates for forest products fell by 13 percent, while for coal, paper and concrete rates increased by 5 to 6 percent just after deregulation. Rail rates for transporting farm products shrank by 8.5 percent. Over time, the cumulative effect of deregulation on price reduction amounted to a 30 percent by 1988. Interestingly, the effect of deregulation is sensitive to time. After an initial increase of rates shortly after deregulation, rates declined by 30 percent in 1988. It is worth noting that the rail rates of certain products that were exempted from regulation the mid-1950s fell (Snow, 1984). For instance, rates declined by 19 percent for fruits and 33 percent for poultry.

[1] See Industry Analysis and Technology Division, Wireline Competition Bureau (2010).

In the airline industry, most studies perform before and after econometric analyses (see literature cited by Joskow and Rose (1989), p. 1470). These works show that fares after deregulation would be lower than they would have under regulation. Using air fares in 1977, Morrison and Winston (1986) find that deregulated coach fares are on average 10 percent higher but discount fares would be 15 percent lower under deregulation. Like in the surface transportation, the effect of deregulation is sensitive to time. Indeed, Morrison and Winston (1999) conclude that prices are 20 percent lower than they would under regulation. Despite fare reductions associated to the deregulation period, Moore (1986)'s regression analysis does not systematically find significant price reductions following deregulation, but points out that fares are 41 percent lower for a flight of 368 miles in large metropolitan markets when at least five carriers are operating. The cross sectional analyses from Graham et al. (1983) shows that fares in markets served by new entrants were 19 percent lower in 1980 and 26 percent lower in 1981. In New Zealand, entry of new airlines induced Air New Zealand to reduce its price by 7% and Qantas by by 17% (Ennis and Ghosal, 2010).

The effect of deregulation in the electricity industry is mixed. Using price-cost margin series from 1995 to 2002, Bertram and Twaddle (2005) show that the removal of regulation in the New Zealand electricity industry has increased consumer prices since costs decreased over the same period. In Norway, following deregulation in 1990, the time series plot of prices in Bye and Hope (2005) show that end-user real prices increase by roughly 30 percent between 1993 and 1997 and thereafter decrease between 30 and 35 percent until 2000. In the US, a review of studies from Kwoka (2008) concludes that the literature has not identified the price effects of restructuring. A later paper by Kury (2013) finds that industry restructuring reduces retail prices by 4.8 percent in the first two years but becomes insignificant afterwards. The very recent work from MacKay and Mercadal (2021) extend this literature with the use of data from 42 US states between 1994 and 2016. Their difference-in-differences matching estimator shows that retail electricity prices of deregulated utilities were 16 percent higher than their regulated counterparts.

Given that the literature on social regulation focuses mainly on policy effects on risks, the availability of price effect if sparse. However, some studies are worth citing. Milyo and Waldfogel (1999) show that prices of advertised products are reduced by 20 percent lower in stores that advertise alcohol after a ban on advertisement was removed in Rhode Island. Prior to the deregulation, the prices at stores that advertised in newspapers were 7.71 percent lower than stores that did not advertise.

Command and control social regulation have increasingly adopted market-based principles. Emissions trading scheme has reduced abatement costs of coal-fired electric utilities by 25 to 35 percent (Winston, 2006). A report the U.S Environmental Protection Agency (2010) shows that since the adoption of the cap and trade system in 1995, electricity prices has declined by 8 percent. Regarding health and safety, hazard information regulation can be more efficient than banning a product because it influence the consumer's behaviour in manipulating dangerous products without much distortions to the market (Viscusi et al., 2018). The US occupational safety and health (OSHA) regulation for grain handling comes with several alternative options that gives firms the opportunity to select the most cost-effective solution (Viscusi et al., 2018).

4.3 Description of the database

4.3.1 General description

The dataset is a collection of 488 papers which identify the effect of regulation or deregulation on price, cost or output. The sample includes academic journals, government reports, OECD reports, book chapters and unpublished working papers. One observation corresponds to a single effect identified. Thus, a study can have more than one observation if it contains several effects. The database also contains information on the starting year and the ending year of the price data used in each study. Furthermore, the countries analysed by each paper are identified. Most of these variables are used as regressors for the meta-analysis model. The papers gathered in the database are from the field of economics, especially industrial organisation.

The studies collected cover a wide range of sectors including mainly network industries, professional services, distribution, the pharmaceutical industry, and food industry. Network industries comprise of airlines, railroads, telecommunications, electricity, and gas. Occupational licences sectors cover activities like health practice (doctors, nurses, dentists), law, architects and engineers, and funeral services.

The database reports a price, cost or output effect value, which is the figure directly extracted from the paper as well as the page number from which the effect is taken. In addition, a price reduction under a more competitive environment is included. When the paper report a price effect following a pro-competitive policy, the price reduction is simply equal to the effect expressed in the paper. The price reduction under a more competitive scenario is also derived for cases reporting a price effect following the implementation of an anti-competitive policy. The dependent variable chosen for the empirical strategy is then the price reduction expressed in percentage.

The price effect is observed for both pro and anti-competitive cases. Some papers estimate the effect of policy change only on output or cost. These papers were not removed since they do not have an observed value for the final price and thus do not affect the empirical strategy. A few papers about occupational licenses estimate an income effect and were treated as a price effect because higher wages in the concerned sectors means that the consumer pays a higher price (Pazderka and Muzondo, 2011; Pagliero, 2011; Kleiner, 2000; Kleiner et al., 2016; The Yale Law Journal, 1974; Mourre, 1995; Hotz and Kilburn, 1995; Hazilla and Kopp, 1990;

OECD, 1999; Ryan, 2012). For instance, higher income for lawyers and dentists generally entail higher fees for clients[2].

Most price effect values are obtained from econometric analysis, which are obtained either from a before-and-after or a cross-section approach. Other studies, generally institution reports, also adopt one of these approaches. Cross-section comparison consists of benchmarking the price of a regulated state or country with the price of an unregulated counterpart for a given industry. The cross-section estimates can be performed on a firm basis. For example, Morrison and Winston (1997) compare air fares between regulated and unregulated airports in the US.

The econometric studies generally specify demand or supply models and the price effect corresponds to an estimated coefficient (or the average of many estimates). These studies mainly apply a difference-in-differences methodology on linear models of price. Typical models control for quality factors, input costs and demographics. For before-and-after analyses, the price effect is captured with a dummy equal to one after the policy change is effected, and zero otherwise. For cross-section analyses, the main effect comes instead from a dummy variable differentiating between a regulated and an unregulated entity. Some studies use more sophisticated difference-in-differences to identify the effect of policy on a specific product. For instance, Genakos et al. (2018) use the interaction of a dummy capturing specific products affected by regulation and a dummy indicating deregulation.

Some of the working papers have been published in academic journals since they were first incorporated in the dataset. Subsequently the citation, publishing year and the document type have been updated. The price effect value has been updated if the value of the published version changed from the working paper version. These changes are summarised in table 4.1. Values are the same for half of the papers reported in the table while it is only higher for one case. Two working papers that have been published could not be updated because the interpretation of the price reduction differ in the published versions (Ros, 2011; Chevalier and Morton, 2008)[3][4].

Many observations are taken from Japanese government Cabinet Office reports (Cabinet Office, 2003, 2007, 2010) which provide estimates of price changes following deregulation in several industries. Part of the observations evaluate price changes between 1990 and 2005 (Cabinet Office, 2003, 2007), and part reports changes between 1996 and 2008 for the same industries (Cabinet Office, 2010). To remove redundancy and the likely effect of the 2007 financially crisis, the observations for which a price increase is recorded are excluded.

[2]The price reduction in percentage were assigned when the price reduction in a more competitive scenario is available.

[3]Ros (2011) gives the price impact of deregulation in the Mexican airline industry on air fares separately for two incumbent airlines whereas the working paper version gives an estimate of average price reduction in the whole industry.

[4]Chevalier and Morton (2008) do not provide a straightforward estimate of the price reduction following the impact of online sales of caskets on prices.

Table 4.1: Working papers published

Paper	Publication year	Journal	Unpublished price effect	Published price effect
Park (2010)	2011	The Journal of Industrial Economics	-0.042	-0.042
Suzuki (2012)	2013	International Economic Review	-0.038	-0.038
Kawaguchi et al. (2013)	2014	Journal of Law and Economics	-0.13	-0.13
Genakos et al. (2014)	2018	The Journal of Industrial Economics	-0.075	-0.06
Pagliero (2005)	2011	International Journal of Industrial Organization	-0.19	-0.46
Kleiner et al. (2012)	2016	Journal of Law and Economics	-0.087	-0.087

The earliest year of study in the database is 1932 from a paper by Barrett (2004) which discusses the distortion of competition in the Irish bus service sector since the implementation of the Transports Act in 1932. The latest year of analysis in the database is from Genakos et al. (2018) who study the effect of the abolition, in 2011, of mark-up regulation in the fresh fruit and vegetable market[5].

The database provides a classification of the competition restriction resulting from (generally) an anti-competitive policy for each case. These restrictions come in four categories: A, B, C and D and are defined in table 4.2. Category A and B are related to lesser competition due to market power through supply restrictions whereas category D restrictions are due to demand features. Finally, Category C captures competition distortion due to collusion.

4.3.2 Description of policy variables

4.3.2.1 Policy types

Identifying the type of policy for some cases requires judgement because, as mentioned earlier, the market failure that the regulatory policy means to correct is sometimes unclear. Nonetheless, we have identified four types of policies based on the description from the literature (Breyer and MacAvoy, 2016; Stern and Holder, 1999; Smith et al., 2018). These are highlighted in table 4.2. The studies in the database fall into these four policy categories.

Social regulation are all the rules that are in place to deal with market failures other than market power such as environmental, congestion, health and safety regulations. Observations identifying the intertemporal effects of occupational licenses, carbon emissions, traffic regulation, exclusive territory regulation of alcohol sales are classified as social regulation. This definition includes zoning regulation, and import restricting regulation to protect local industries (i.e. Folster et al., 1997), construction regulation of schools and advertisement of private healthcare services. The line between economic and social regulation can be blurred. Advertising is considered as economic regulation by Viscusi et al.

[5]Other essential products, including bread, meat and pharmaceutical products, were subject to this regulation.

Table 4.2: OECD competition restriction categories, policy types and purposes, and sample characteristics

	Definition
OECD Category	
A	Limits the number or range of suppliers
B	Limits the ability of suppliers to compete
C	Reduces the incentive of suppliers to compete
D	Limits the choices and information available to customers
Policy variables	
	Economic regulation
	Social regulation
	Economic deregulation
	Social deregulation
Regulatory purpose	
	Natural monopoly (NM)
	Universal Services Obligations (USO)
	Industry protection (Ipro)
	Congestion (Con)
	Environment (Env)
	Intellectual Property Rights (IPR)
	Financial protection (Finpro)
	Health (H)
	Food & commodity security (FCS)
	Safety & quality (SQ)
Start year	
Start 1	Period of study starts before 1971
Start 2	Period of study starts between 1971 and 1980
Start 3	Period of study starts between 1981 and 1990
Start 4	Period of study starts between 1991 and 2000
Start 5	Period of study starts after 2000
Country	=1 if observation is from the US market

(2018) but recognise that advertisement restriction for unhealthy products like cigarettes are a social regulation because it can correct failures. On economic grounds, they stress that these reasons do not justify advertising bans for optometry services. However, the official reason of the regulation eyeglass advertising was made in the interest of public health and safety (see Benham, 1972, p. 340). Thus Benham (1972) is classified as social regulation. Social regulation is assigned to cases that only identify the before and after effect of such policy.

Social deregulation refers to cases where industries having seen a removal of regulation or parts of regulation for social purposes defined above, irrespective of whether they have been put in place at a given time or in a given country/state. As such, observations identifying the before and after or cross-section effects of full or part removal of such regulations are classified social deregulation. Particular cases are also included. Taxicab operating licenses regulation is identified as social regulation in the UK and Australia because it aims to tackle congestion and ensure quality of service (Beesley, 1973; Ennis and Ghosal, 2010). In New Zealand and the US regulation of the taxicab industry is classified as economic regulation because it is thought to be a natural monopoly (Gaunt, 1995; Moore and Rose, 1998).

Economic regulation refers to the regulation of price or rate of return on capital and entry of primarily network industries (Stern and Holder, 1999; Viscusi et al., 2018). Thus it encompasses all the cases covering network industries like electricity, telecommunications, water and transportation but also other industries where regulation is implemented to regulated prices or firms market entry. For instance, in the telecommunications industry, Galbi (2001) analyses the effect of a reduction of provider switching price on consumer price. This is interpreted as more economic regulation. Other industries where the industry is protected from destructive competition are categorised as economically regulated like road haulage, the pharmaceutical industry, or the banking sector. We also classify cases treating monopsony power as economic regulation.

Economic deregulation accounts for previously economically regulated industries or segments of industries that have been open to competition because of their contestable nature. For instance, the airline industry and parts of the electricity, telecommunications and transport industries in the most advanced economies were liberalised in the late 1970s and the 1980s in the US and the UK, and later in the 1990s in Europe. Economic deregulation also refers to cross country / state comparison where the deregulated industry is compared to the regulated one. Finally, papers explicitly referring to economic deregulation or removal of economic regulation are classified as economic deregulation. Papers that do not contain any effect of any type of policy have been removed.

4.3.2.2 Classification of regulation purposes

Many of these industries are regulated by government or governmental agencies to serve social goals. These regulatory purposes are listed in table 4.2. Some of regulatory purposes classification deserve some explanation.

An industry can be regulated for several reasons. Public utilities are regulated because of their natural monopoly aspect but also serve universal service obligations (USO) purposes as they provide many of the goods and services essential for daily life (Stern and Holder, 1999; Laffont, 2005). However, if a paper specifically studies a particular regulatory purpose, then only the concerned purpose is assigned. For instance, electric utilities are generally economically and environmentally regulated. But if a case specifically measures the effect of environmental regulation on electricity prices, the related cases are thus assigned the purpose *Environment* only.

A given industry can be regulated for different reasons depending on the state or country. As seen previously, the taxicab industry is regulated for natural monopoly reasons in some cases but it is regulated for safety and quality purposes in others. The other transportation sectors are more complex and thus identifying the purpose of regulation is made on a case by case basis.

The airline industry features a wide range of regulations. The primary regulation purpose is safety (Blöndal and Pilat, 1997), but other regulatory policies are also covered like natural monopoly and congestion (slot controls). In Europe, states regulate their airlines to protect them because they are state-owned. Domestic flights are further regulated to achieve USO. When a case does not mention the purpose of regulations, we assign it the purposes highlighted in Blöndal and Pilat (1997).

Railroads feature aspects of natural monopoly due to the rail network and rates and entry are regulated. In addition, European railroads serve USO goals while US railroads engage in contracts with food and other commodities producers. Road haulage was regulated to protect industry from destructive competition and to ensure railways could provide freight services (Blöndal and Pilat, 1997; McKinnon, 1996). In other cases, road freight is regulated to maintain road safety, environment and limit congestion (Boylaud, 2000).

Food & commodity security consists of regulations to ensure society has access to necessary commodities like food or housing. In the distribution sector, retail firms are regulated for food security and to limit congestion (zoning regulation). As an example, the regulation purposes in Folster and Peltzman (1997) are *food & commodity security, Congestion* and *Industry protection* as the paper states that regulations in place serve to overcome shortages of supply in housing, protect industries against international competition. Entry at the retail level was restricted due to zoning regulation. Regulation can also be imposed for food security and quality purposes and not necessarily for congestion containment purposes (Genakos et al., 2018).

The cases identified as *Health* are regulated either because the good or service enhance or deteriorates the health of the user. For instance, pharmaceutical products must be certified safe and effective before they are released into the market. while the consumption of alcoholic drinks generates a negative externality (Viscusi et al., 2018).

4.4 Statistical description

The purpose of this meta-analysis is to identify the impact of regulation or deregulation on price reduction. To do this, we have trimmed observations based on two criteria. First, redundant observations were dropped: price effect observations from the same paper were repeated because they represented several OECD categories. The repetitions were consequently dropped. Multiple observations from the same paper that captured non-linear pricing were reduced to one by taking the average price reduction[6]. Second, cases identifying price reduction as a result of antitrust policy or aspects other than regulation or deregulation were dropped. Also, cases that compared one type of economic regulation with another were dropped.

Table 4.3: Price reductions in the more competitive scenario

Reform	**Cases**	**Median**	**Mean**
General	313	-0.156	-0.204
Economic regulation	8	-.074	-.07525
Economic deregulation	185	-0.19	-.2332393
Social deregulation	67	-0.17	-.2065552
Social regulation	53	-0.089	-.1179726
Total cases	313		
With regulation			
Category A	178	-0.1495	-0.19504
Category B	79	-0.167	-0.2167
Category C	33	-0.125	-0.1974
Category D	23	-0.16	-0.2388
Total cases	313		
Without regulation			
Category A	147	-0.17	-0.2152
Category B	63	-0.2	-0.2434
Category C	25	-0.13	-0.2052
Category D	20	-0.19	-0.2684
Total cases	255		

[6] Genakos et al. (2018) gives an average effect as compared to the working paper version which provide several estimates. In that case, the number of observations has been updated according to the published version.

The variable $Price\_fect$ is a continuous variable that expresses a percentage price change from moving towards a more competitive environment following a regulatory or deregulation policy. This would generally entail a negative value. Observations for which regulation or deregulation led to a less competitive situation generally result in a price increase. For such cases, prices were standardised for shifting to more competitive states. Price effect with the lowest value at -0.9 and the highest value at 0.205.

Except for regulatory purposes, the other dummies are mutually exclusive within their respective clusters. Because an industry can be regulated to achieve different goals, more than one regulatory purposes dummy can take the value of one for a given case. Most cases cover instances of economic deregulation which represent over 60% of the total observations. Nearly 25% of the cases are based on the transport industry and approximately 32% of cases are regulated for safety and quality purposes or for natural monopoly goals.

Most studies on deregulation were conducted in the US with 50% of cases. Time dummies measure decades, except for the dummies covering the earliest and latest periods. Studies using data starting in the 1991 - 2000 period represent 39% of the observations. Most of the cases were collected from academic journal articles which amount to roughly 36% of the total cases followed by government documents which account for nearly 35% of the cases.

Table 4.3 provides the mean and median of price reduction over the whole sample and also by policy type and by OECD category. The price reduction medians from economic and social deregulation are respectively 19% and 17%. These values are close to price overcharge estimates from the literature on cartel industries[7]. The mean and median of price effect are reproduced by OECD category on a sample without the regulation cases. The total number of observations for price effect for this deregulation sample amounts to 255. Category A covers most cases and together with category B accounts for around 82% of the cases. The means of category A and category B are higher whereas it decreases for C and D.

The interpretation of price effect under deregulation cases is straightforward as deregulation policies generally make markets more competitive. Since all cases of social regulation make the market less competitive, the price effect should be interpreted as a price reduction *without* social regulation. Economic regulation can make markets more or less competitive. Thus, price can increase or decrease following implementation.

The density of price effect over the whole sample is displayed figure 4.1. It is slightly skewed to the left as most values are negative after deregulation. The peak of the distribution

[7]Connor and Bolotova (2006) estimate an overcharge mean of 29% from their sample and the median is 19% which is equivalent to our estimated price reduction median from economic deregulation. Estimates from an OECD (2002) report a median between 15% and 20% for overcharges from 14 cases. Connor and Lande (2008) estimate a price overcharge median of 18% while Oxera et al. (2009) estimate a median of 20% from the peer-reviewed academic articles and chapters in published books subsample of the same dataset. More recently, the meta-analysis conducted by Boyer and Kotchoni (2015) finds overcharge median and mean of nearly 15.5% and 16% after accounting for estimation bias.

is reached at a price effect of -20% which is observed for 15 cases[8]. The distribution shows that deregulation appears to reduce firms' market power by eliminating competition restrictions. Indeed, the lognormal distribution of the price effect displayed in figure 4.2 shows that most of the mass occurs between 3 and 4. That is, most of the price reduction magnitudes range between 20.1% and 54.6% in absolute terms. The heavy lower tail of the distribution is due to a positive price effect after the economic deregulation of bus services in the UK[9]. The case shows an average price increase of 13% in real terms of bus services after economic deregulation.

Figure 4.1: Price reduction density

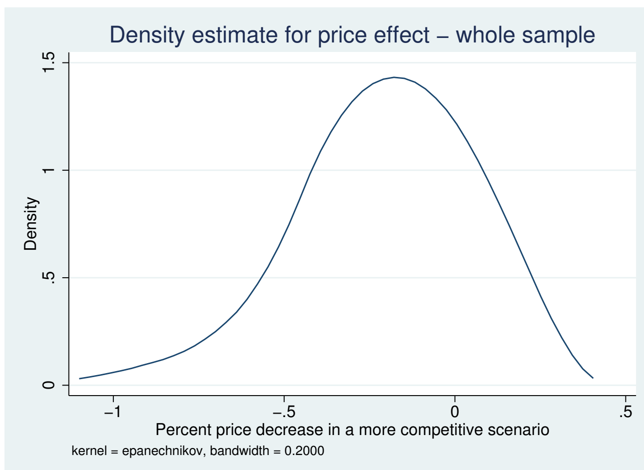
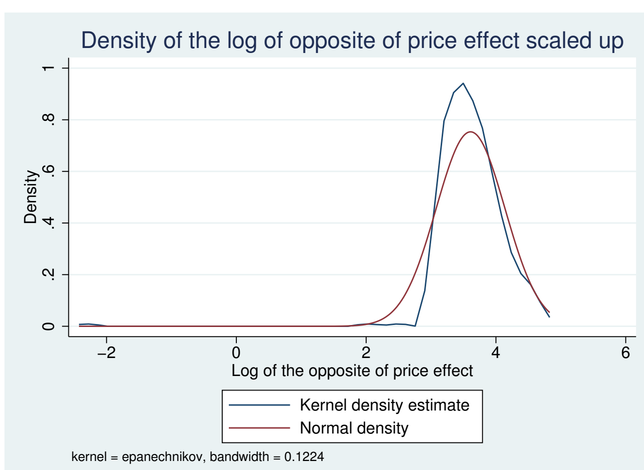


Figure 4.2: Lognormal density of price reduction



[8]This parallels Oxera (2009) who estimates that 93% of cases have positive overcharge values.
[9]Paper ID 108 - Nash (2008).

4.5 Model specification

The methodology of this paper consists of a meta-regression of price effect estimates by means of a linear specification. To analyse the effect of regulation and deregulation on price, we construct different sets of dummies to capture the nature and the type of the reform as well as the industries and the market failures those reforms aim at correcting. All the explanatory variables are binary variables taking the value of 1 or 0. The econometric model takes the following specification:

$$p_i = \alpha + \beta DR_i + \gamma F_i + \mu I_i + \delta C_i + \lambda T_i + \epsilon_i \tag{4.1}$$

where p_i is the percent price reduction for observation i in a more competitive environment[10], DR is a vector containing policy type dummies, F is the set of dummies of the regulatory purposes; the industry categories are captured by I; C is a vector containing the OECD categories of competition distortion; and T_i is a vector of time dummies is expressed in 10-year intervals.

Following the different price changes reported in the literature survey, distinguishing between regulation and deregulation by including DR allows us to assess whether deregulation is more conducive of price reduction than regulation. It also enables us to estimate whether the effect of deregulation is different according to the type (economic or social). Social regulation would tend to lead to higher prices whereas the effect of economic regulation is ambiguous.

By controlling for regulatory purposes, we can assess whether the effect of regulation of deregulation is sensitive to the market failure that is being corrected. From the earlier discussion, the effects of policies depend on the reason for regulation. For instance, regulating an industry to constrain market failure can have a different effect on price as compared to regulating to protect firms from destructive competition. The same applies when differentiating between economic and social policies.

We include industry dummies to capture potential variation in the degree of competition and technological change. For instance, technological change in the telecommunications industry has had profound implications on the efficient number of firms that can operate within an industry (ICN, 2002; Viscusi et al., 2018). In addition, we exploit information on the nature of the competition restriction available in the database to assess the possible impact that several restrictions can have on prices.

Finally, like other meta-regression exercises, we include sample characteristic dummy variables like the starting year of the study and a variable indicating that the observation studies a US industry, as defined in table 4.2. Because the effect of deregulation or

[10] This price reduction is referred to as $Price\_fect$ in the regression results tables.

regulation can be confounded with time, we include 5 year dummies that capture time periods in 10 year intervals. The years represents the time at which the data used in the papers start. Most observations are from the US and reforms have been widely tested (Bel and Warner, 2008). Moreover, the US regulated its industries differently than Europe or Asia (Breyer and MacAvoy, 2016).

We perform regressions on the whole sample and on the academic journal subsample. Replicating the analysis on an academic subsample can lead to more accurate coefficient estimates because journal articles go through the process of external review and are not sales-driven (Connor and Bolotova, 2006; Carvalho et al., 2012). On the other hand, repeating the empirical exercise on journal article sample can allow us to detect possible publication bias. Journal articles may suffer publication bias because referees tend to favour papers with statistically significant results which does not necessarily reflect the real effect (Stanley, 2005; 2007).

4.6 Results

The regression results for the whole sample are shown in table 4.4 for several variants of model (4.1). The first column contains only the types of regulation and deregulation dummies. In the subsequent columns, the regulatory purposes, the industry types and the OECD competition restriction classification dummies are added to the model. The last column shows the results of the general model which also includes country and the starting year dummies of the data. From column 2 to column 6, the F test is performed on all explanatory variables except the regulation and deregulation dummies and the p-value is the probability of erroneously rejecting the null hypothesis of the F test. In the whole sample, except for model 4 which has a p-value of 0.3767, we reject the null hypothesis of no joint significant impact on price reduction. Thus, when added alone, the OECD competition restriction classifications have no joint effect on price reduction. In the various specifications, the effect of social regulation is in the constant. The average price reduction associated with deregulation is around 22.6 percent[11].

Price reduction under economic deregulation is significantly stronger than the price effect following social regulation by 10.7 percentage points on average. The total effect of economic deregulation on price ranges from -17.6 (model 3) to -29 (model 4) percent[12]. Two reasons can explain this strong effect. First, the result indicates that part of industries that

[11]This average is obtained by calculating the average total effect of economic and social deregulation over all specifications in tables 4.4 and 4.5 respectively.

[12]Weighted regressions are also performed on the whole sample, where different weights are assigned to before-and-after observations and cross-section observations. These results can be found in tables 4.8 and 4.9 in appendix 4.A.3. Results from these weighted regressions are robust for the policy variables for columns 1 to 4.

were previously economically regulated did not feature natural monopoly characteristics as deregulation of the contestable parts of the industry has led to lower prices. This was experienced in many transportation sectors like trucking, railroads and airlines. Hence, even if economic regulation was effectively implemented, it did not incentivise firms to reduce their prices enough compared to an environment in which multiple firms compete.

Second, the result is consistent with regulatory capture. Put differently, economic regulation contributed to exacerbate the problems it was in theory meant to solve because it is a fertile ground for lobbying from industry groups who bend policies in their favour and at the expense of consumers (International Competition Network, 2002). One notable example is the US trucking industry where the economic regulator Interstate Commerce Commission (ICC) may have acted like a cartel rate-setter (Viscusi et al., 2018).

The effect of social deregulation on price reduction ranges between -15.6 (model 3) and -25.1 (model 4) percent. On the one hand, this reinforces the idea that social deregulation is associated with more competition through higher supply. For example, banning advertising restrictions or exclusive territories enhances the ability of suppliers to compete or increases the range of suppliers as evidenced in the optometry or the alcoholic drink sector. In both contexts, regulation aimed at limiting the risks on consumers. In the former, the rationale of regulation was to ensure quality of the optometry service while in the latter, the regulation aimed at curbing alcohol consumption[13]. In other instances like the airline and taxicab industries, congestion regulation has shrank the number of suppliers. On the other hand, social deregulation takes the form of more efficient social regulation - which consists of integrating market based mechanisms to regulation, is less restrictive to competition.

Social deregulation has a lower effect on price reduction than economic deregulation. This result can be attributed to certain product aspects that necessitate quality guarantees from the consumer's perspective. Indeed, even if regulations are not in place, the market, through consumers' purchase decision, can influence firms to keep minimum quality standards (Viscusi et al., 2018). For instance, air transport is one of the safest modes of transportation because consumers overestimate the associated risk. Even if consumers are not fully aware of the risks associated to the consumption of a product, the market does not necessarily supply sub-optimal safety levels. In fact, since economic deregulation, airline safety has increased in the US (Rose, 1992).

Since social regulation always lead to higher prices from the data, the effect of social regulation is interpreted as a price increase after the reform is implemented. In other words, social regulation significantly increases consumer prices by almost 12 percent (model 1)[14].

[13]It is argued that the alcoholic drinks ad restriction in Rhode Island was an excuse to help the industry keep prices high rather than temper alcohol consumption (Milyo and Waldfogel, 1999). In fact, the U.S Supreme Court dismissed the advertisement restriction, saying that alcohol consumption could have been curbed by taxes.

[14]In tables 4.6 and 4.7, the effect of economic regulation on price reduction is in the constant but is not

The coefficients associated to social deregulation shows that the price reduction from social deregulation is higher than the price increase following social regulation. This result suggests that markets which had a social regulation implemented already featured some degree of regulation or that a inter-temporal effect takes time to materialise. For instance, most social regulation cases cover the effect of further regulation in the professional services sectors (architects, medical practitioners, legal services), which are already complying with existing rules in a given state or country.

In socially regulated sectors, the extra cost associated to an accumulation of regulation can be borne by consumers (McLaughlin and Williams, 2014). For instance, consumers can pay a higher price for a good due to a new regulation only after already having paid a higher price for complying with existing regulation. Therefore, the lower effect of social regulation could come from capturing only the price effect of the incremental regulation. In contrast, social deregulation account for many cases comparing regulated and *unregulated* markets, and thus potentially captures greater regulatory differences. Indeed, regulations have been implemented in various intensities across US states (Joskow and Rose, 1989) while a before-and-after effect can only be seen in the long run (Milyo and Waldfogel, 1999).

Out of the ten regulatory purposes, financial protection is strongly significant whereas universal services obligation is significant in the more general specification. Studies of deregulation in the financial sector are more likely to report a price reduction following deregulation than studies in other sectors, while industries that were formerly regulated for USO purposes have seen a weakly significant increase in prices following deregulation. Regarding the industry type, papers on the telecommunications sector tend to report a price reduction by at least twenty percent after deregulation. This can be explained by more competition through technological progress that particularly affected the industry (International Competition Network, 2002).

The start year dummies are not significant; more recent studies do not seemingly find more price reductions than studies with older data time. Regarding the country, there is no statistical evidence that deregulation in the US lead to more price reductions than in other countries. Finally, except for the weak significance of the OECD categories in variant 5, the results do not show evidence of any impact of the type of competition distortion on price.

Table 4.4: Estimation results - whole sample

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Price_fect	Price_fect	Price_fect	Price_fect	Price_fect	Price_fect

significant. Nor is the effect of social regulation. As in the main results, the effect of social deregulation is significantly different than social regulation in the whole sample but not in the journal subsample.

Table 4.4 (continued)

VARIABLES	(1) Price_fect	(2) Price_fect	(3) Price_fect	(4) Price_fect	(5) Price_fect	(6) Price_fect
Economic deregulation	-0.115***	-0.0991***	-0.103**	-0.115***	-0.103**	-0.107**
	(-3.992)	(-2.661)	(-2.459)	(-3.961)	(-2.223)	(-2.127)
Social deregulation	-0.0886***	-0.0999***	-0.0830**	-0.0757**	-0.0656*	-0.0666*
	(-2.600)	(-2.926)	(-2.341)	(-2.159)	(-1.789)	(-1.714)
Con		0.0323	-0.000146		-0.00553	-0.0230
		(0.771)	(-0.00334)		(-0.123)	(-0.490)
Env		-0.0565	-0.0490		-0.0490	-0.0564
		(-1.286)	(-1.024)		(-1.007)	(-1.134)
FCS		0.00915	-0.0476		-0.0517	-0.0535
		(0.210)	(-0.940)		(-1.004)	(-1.020)
Finpro		-0.179***	-0.224***		-0.237***	-0.208**
		(-2.789)	(-2.950)		(-2.982)	(-2.541)
H		0.0249	-0.0556		-0.0480	-0.0587
		(0.629)	(-1.149)		(-0.930)	(-1.093)
IPR		-0.0369	-0.228**		-0.239**	-0.212*
		(-0.699)	(-2.062)		(-2.121)	(-1.814)
Ipro		-0.00603	0.0272		0.0282	0.0259
		(-0.155)	(0.621)		(0.641)	(0.542)
SQ		-0.00117	-0.0284		-0.0209	-0.0190
		(-0.0349)	(-0.700)		(-0.507)	(-0.450)
NM		-0.0401	0.0246		0.0315	0.0227
		(-1.271)	(0.658)		(0.742)	(0.513)
USO		0.0363	0.0881*		0.0961*	0.108*
		(0.793)	(1.660)		(1.769)	(1.949)
DummyA				0.0676	0.0856*	0.0814
				(1.501)	(1.891)	(1.560)
DummyB				0.0363	0.0902*	0.0851
				(0.772)	(1.823)	(1.489)
DummyC				0.0561	0.104*	0.0931
				(1.035)	(1.790)	(1.427)
Energy			-0.101		-0.114	-0.103
			(-1.327)		(-1.452)	(-1.272)
Telecoms			-0.206**		-0.207**	-0.203**

Table 4.4 (continued)

VARIABLES	(1) Price_fect	(2) Price_fect	(3) Price_fect	(4) Price_fect	(5) Price_fect	(6) Price_fect
			(-2.494)		(-2.465)	(-2.366)
Transport			-0.0659		-0.0748	-0.0639
			(-1.082)		(-1.209)	(-0.978)
Pharma			0.266*		0.254*	0.240
			(1.856)		(1.683)	(1.519)
Profession			-0.0164		-0.0286	-0.0306
			(-0.244)		(-0.415)	(-0.428)
Food			0.0141		0.00649	-0.0173
			(0.177)		(0.0787)	(-0.190)
Distribution			0.0923		0.0905	0.0948
			(1.399)		(1.314)	(1.329)
Country					-0.00393	-4.34e-05
					(-0.131)	(-0.00132)
Start2						0.0350
						(0.776)
Start3						-0.00281
						(-0.0688)
Start4						0.00176
						(0.0409)
Start5						0.0606
						(0.928)
Constant	-0.118***	-0.114***	-0.0730	-0.175***	-0.157**	-0.161*
	(-4.634)	(-2.897)	(-1.286)	(-3.441)	(-1.997)	(-1.775)
Observations	305	305	305	305	305	292
R-squared	0.050	0.109	0.167	0.060	0.180	0.177
F test:	7.97	1.93	2.36	1.04	2.11	1.67
p-value:	0.0004	0.0405	0.0021	0.3767	0.0036	0.0270

t-statistics in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Note: Regressions performed on the whole sample. The effect of social regulation is captured in the constant. The financial sector dummy is dropped due to collinearity with Finpro.

For robustness checks, the simulations are replicated on the academic journal subsample in table 4.5. The average price reduction effect across both types of deregulation is 21.4 percent. Again, we do not reject the null hypothesis of no joint significance of model 4. The R^2 of all specifications is bigger than in the whole sample. For instance, in models 5 and 6, the variation of the price reduction is explained at respectively 35.6% and 41.1% by the model. In the latter specification, the t-statistics of the policies, excluding the constant, are considerably bigger. This suggests that the effect of the various reforms can be sensitive to the period of the data.

From the academic publications sample, the coefficients associated to the policies, including the constant, are not always significant or higher than in the whole sample. The t-statistics are lower in the journal subsample for economic and social deregulation as compared to the whole sample. This has two meanings. First, higher t-statistics in absolute values from the bigger sample suggest a systematic empirical effect between the explanatory variables and the dependent variable (Bel et al., 2010), which implies that the effect of deregulation on price reduction is confirmed. Second, lower t-statistics in the other specifications do not suggest that the journal articles in the dataset suffer from publication bias.

The range of price effect deregulation is wider in the journal subsample (table 4.5). While the effect of economic deregulation lies from -15.5% to -34%, the price effect of social deregulation ranges between -9.8% and -26.4% and is not significantly different from the price effect associated to social regulation.

In this subsample, the profession dummy does not have a systematically strong significance across the different models. Put differently, studies about occupational licensing tend to find weakly more price reductions when the sector becomes more competitive through less regulation. The Intellectual Property Right (IPR) dummy is not always significant, which suggests that papers comparing industries with and without IPR regulation are not likely to find a strong price difference compared to other regulatory purposes. Finally, price reductions in the US are not higher than in the rest of the world.

Table 4.5: Academic journal subsample regressions excluding economic regulation cases

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Price_fect	Price_fect	Price_fect	Price_fect	Price_fect	Price_fect
Economic deregulation	-0.110***	-0.116	-0.0684	-0.103**	-0.0658	-0.0897
	(-2.667)	(-1.649)	(-0.875)	(-2.458)	(-0.810)	(-1.074)
Social deregulation	-0.0563	-0.0488	-0.0116	-0.0576	-0.00643	-0.0140
	(-1.340)	(-1.173)	(-0.260)	(-1.353)	(-0.139)	(-0.300)
Con		-0.0352	0.0270		0.00429	0.0170

Table 4.5 (continued)

VARIABLES	(1) Price_fect	(2) Price_fect	(3) Price_fect	(4) Price_fect	(5) Price_fect	(6) Price_fect
		(-0.315)	(0.203)		(0.0314)	(0.0933)
Env		-0.0443	0.00731		-0.00436	0.00791
		(-0.686)	(0.100)		(-0.0560)	(0.0949)
FCS		-0.0217	0.0157		-0.00131	-0.0616
		(-0.203)	(0.140)		(-0.0112)	(-0.542)
Finpro		-0.0910	-0.159		-0.121	0.0308
		(-0.901)	(-1.365)		(-0.972)	(0.212)
H		-0.0110	0.105		0.0743	0.104
		(-0.203)	(1.265)		(0.828)	(1.146)
IPR		-0.306***	-0.348*		-0.353*	-0.320**
		(-4.091)	(-1.800)		(-1.793)	(-2.522)
Ipro		0.139	0.0328		0.0419	-0.0160
		(1.313)	(0.245)		(0.310)	(-0.0731)
SQ		-0.0398	0.0845		0.0766	0.0868
		(-0.760)	(1.145)		(1.024)	(1.133)
NM		-0.00161	0.0155		0.0124	0.0146
		(-0.0272)	(0.241)		(0.181)	(0.200)
USO		-0.0203	0.0242		0.0353	0.0432
		(-0.255)	(0.257)		(0.368)	(0.449)
Category A				0.0306	0.0987	0.144
				(0.371)	(1.179)	(1.519)
Category B				0.0111	0.0812	0.152
				(0.133)	(0.944)	(1.557)
Category C				-0.0438	0.0336	0.0263
				(-0.494)	(0.349)	(0.235)
Energy			-0.134		-0.129	-0.0943
			(-1.253)		(-1.178)	(-0.776)
Telecoms			-0.0963		-0.0863	-0.0329
			(-0.716)		(-0.603)	(-0.220)
Transport			-0.187**		-0.183*	-0.124
			(-2.048)		(-1.964)	(-1.135)
Pharma			-0.362		-0.345	-0.401*
			(-1.349)		(-1.265)	(-1.879)

Table 4.5 (continued)

VARIABLES	(1) Price_fect	(2) Price_fect	(3) Price_fect	(4) Price_fect	(5) Price_fect	(6) Price_fect
Profession			-0.195**		-0.181*	-0.183*
			(-2.181)		(-1.921)	(-1.895)
Food			0.0460		0.0449	
			(0.255)		(0.247)	
Distribution			-0.101		-0.0658	-0.0757
			(-1.106)		(-0.689)	(-0.771)
Country					0.0172	-0.000764
					(0.342)	(-0.0155)
Start2						0.0230
						(0.441)
Start3						0.0517
						(0.965)
Start4						-0.0253
						(-0.377)
Start5						0.0878
						(1.139)
Constant	-0.140***	-0.104*	-0.0865	-0.152*	-0.179	-0.250*
	(-4.400)	(-1.812)	(-1.068)	(-1.753)	(-1.438)	(-1.748)
Observations	114	114	114	114	114	109
R-squared	0.061	0.255	0.336	0.082	0.356	0.411
F test:	3.59	2.63	2.30	0.83	1.96	2.00
p-value:	0.0308	0.0070	0.0059	0.4797	0.0154	0.0112

t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Regressions on academic journal subsample excluding economic regulation cases. The effect of social regulation is included in the constant. Food is dropped in the last regression due to collinearity.

4.7 Implication for advocacy

The results of the previous section is in line with the view that regulatory policies can have a considerable impact on competition. As deregulation has spurred competition by relaxing barriers to entry, competition advocacy should have a key role in how to constrain market power and mitigating risks to consumers. In this section we discuss the trade-offs that can arise in the context of economic and social policies and highlight examples where deregulation can lead to price reduction without compromising competition and health and safety. In fact, a recent OECD 2020 report on competition policy in the post-covid world concludes that advocacy would consist in clearly identifying the specific market failure that need to be corrected and assessing the effectiveness of a policy in correcting it. The examples given below provide support for competition advocacy in the context of deregulation.

4.7.1 The trade-off between cost efficiency and market power

The variety of magnitudes of the effects of deregulation on price reduction suggests that liberalising markets should be accompanied with a thorough understanding of market contestability and the degree of competition. In many network industries, economic deregulation entails a trade-off between efficient resources allocation and increased market power (Mackay and Mercadal, 2021). For economic deregulation to be fully effective it needs to be complemented by competition policy (Viscusi et al, 2018 p 665).

For instance, deregulation in the US telecommunications sector in the 1990s ensured that other suppliers than the incumbent monopolist AT&T, could supply telecommunications services. As a result of this increased competition, long-distance telephone rates dropped (Viscusi et al., 2018). In the EU, the liberalisation legislation allowed national regulators to grant access to networks where competitive pressure on dominant players is limited (ECB, 2005). The introduction of competition is shown to lead to a price reduction of 0.2% per extra entrant. In the UK electricity sector, prices fell by 5% after deregulation but a larger number of producers could have strengthened this price reduction (OECD, 1997).

4.7.2 The trade-off between efficiency and social goals

The results in previous section do not suggest that social regulation should be abandoned to satisfy the economic efficiency criteria. However, unlike economic deregulation which coincides with the removal of regulation, social deregulation signifies making social regulation more efficient by incorporating market based mechanisms in policy-making. For instance, the trade-off between efficiency and social goals can be eased by making regulation of airport slots more efficient. Market based solutions like auctions and congestion pricing can regulate congestion and can reduce passenger fares (Ros 2011; Morrison and Winston, 1997)[15].

In professional services, increasing mobility of certified workers across states or countries by recognising certifications can ensure consumers with the quality they want at a competitive

[15]For the Mexican market, Ros (2011) recommends a price cap that incorporates congestion costs to constrain monopoly pricing. He also suggests that grandfathering clauses that favour the incumbents' access to airport infrastructure should be removed.

price by maintaining high labour supply. Interestingly, relaxing licensing regulation does not necessarily alter care quality and even benefit consumers. Indeed, Kleiner et al. (2016) show that expanding the scope of nurses practice reduced the price of well-child visits by 3-16% and do not find evidence of changes in the rates of the most serious adverse medical outcomes.

Conversely, regulation in the healthcare service does not appear to have affected quality. Reviewing empirical studies conducted in the early 2000s on the effect of quality following regulatory policies implemented in the US and the UK during the 1980s and 1990s, a report from the Health Foundation (Sutherland and Leatherman, 2006) concludes that regulation has only an associative effect with quality instead of a causal one. However, across the various industries studied in this meta-analysis, not considering quality could have biased the size of the price effect upwards since a lower price generally comes with lower quality, as the latter is costly to maintain.

Environmental regulation can be achieved without being too costly for polluting firms. The cap and trade system replacing the command and control regulation of pollutant emission has enabled firms to abate sulfur dioxide at a lesser cost which can then be passed on to consumers through a lower price. Finally, informational regulation can be an effective approach to tackle risk failures as it can provide incentives to achieve efficient levels of safety without raising firms' costs (Viscusi et al., 2018).

4.8 Conclusion

The meta-analysis conducted in this paper allows us to quantitatively distinguish the effects of economic and social policies on price reduction. In addition, we obtain a range of effects when controlling for the regulatory motive, industries and competition restriction types. These controls can be viewed as proxies for the various degrees of competition, and thus extends the insight given by related study reviews on the influence of competition when assessing the effect of regulation or deregulation on consumer prices. Furthermore, we are able to control for the starting year of the data and the country.

Prices charged in regulated markets are on average 22 percent higher than prices charged in unregulated markets but this effect is slightly lower in the academic journal subsample. The magnitude of the impact depends on the type of deregulation. The effects of economic deregulation is stronger than social deregulation both over the whole sample and the academic journal subsample but are not always significantly different. The lower t-statistics of the coefficients associated with the deregulation dummies in the academic journal subsample are not suggestive of publication bias.

We find that price increases resulting from the implementation of social regulation is lower than the price reduction associated with social deregulation by 8 percentage points on average in the whole sample. However, this difference is lower and insignificant in the journal subsample.

For economic deregulation to effectively reduce price, it should be accompanied by competition policy. The challenge for social regulation aiming is to reduce risks without substantially increasing consumer prices. This can be achieved by making social regulation market-based oriented.

Intervention should be clearly justified by the market failure it is targeting. Following the pandemic, the importance of regulation relative to self-adjusting markets is essential, as prior crises have shown that relaxing the enforcement of competition law would delay recovery (OECD, 2020). Indeed, relaxing competition rules will diminish rivalry between firms and facilitate rent extraction from firms with market power at the expense of consumers and growth.

4.A Appendix

4.A.1 Sensitivity test

A sensitivity test has been attempted for the classification of economic and social regulation when performing trial regressions. Several classifications were tried for the different regulations and did not lead to considerable changes in the results. Furthermore, some results did not change when some observations were reclassified several times.

4.A.2 Further results

Table 4.6: Whole sample regressions including economic regulation cases

VARIABLES	(1) Price_fect	(2) Price_fect	(3) Price_fect	(4) Price_fect	(5) Price_fect	(6) Price_fect
Economic deregulation	-0.158**	-0.145**	-0.189***	-0.179***	-0.224***	-0.218***
	(-2.380)	(-2.113)	(-2.706)	(-2.632)	(-3.029)	(-2.914)
Social regulation	-0.0427	-0.0470	-0.0857	-0.0631	-0.120	-0.113
	(-0.613)	(-0.622)	(-1.069)	(-0.882)	(-1.460)	(-1.366)
Social deregulation	-0.131*	-0.147*	-0.167**	-0.140**	-0.185**	-0.178**
	(-1.909)	(-1.942)	(-2.087)	(-2.022)	(-2.276)	(-2.162)
Con		0.0332	2.70e-06		-0.00241	-0.0199
		(0.805)	(6.26e-05)		(-0.0548)	(-0.433)
Env		-0.0585	-0.0515		-0.0510	-0.0606
		(-1.346)	(-1.087)		(-1.059)	(-1.234)
FCS		0.000802	-0.0589		-0.0648	-0.0659
		(0.0188)	(-1.194)		(-1.292)	(-1.294)
Finpro		-0.181***	-0.231***		-0.245***	-0.217***
		(-2.854)	(-3.082)		(-3.114)	(-2.677)
H		0.0235	-0.0576		-0.0484	-0.0615
		(0.608)	(-1.214)		(-0.959)	(-1.174)
IPR		-0.0406	-0.239**		-0.252**	-0.221*
		(-0.795)	(-2.190)		(-2.261)	(-1.916)
Ipro		-0.0103	0.0225		0.0199	0.0175
		(-0.271)	(0.527)		(0.462)	(0.377)
SQ		0.00123	-0.0256		-0.0167	-0.0141
		(0.0373)	(-0.643)		(-0.410)	(-0.339)
NM		-0.0372	0.0293		0.0388	0.0276

Table 4.6 (continued)

VARIABLES	(1) Price_fect	(2) Price_fect	(3) Price_fect	(4) Price_fect	(5) Price_fect	(6) Price_fect
		(-1.198)	(0.804)		(0.945)	(0.643)
USO		0.0339	0.0852		0.0935*	0.104*
		(0.749)	(1.623)		(1.736)	(1.909)
Category A				0.0581	0.0789*	0.0727
				(1.361)	(1.822)	(1.451)
Category B				0.0251	0.0834*	0.0761
				(0.563)	(1.738)	(1.374)
Category C				0.0449	0.0951*	0.0840
				(0.870)	(1.723)	(1.343)
Energy			-0.108		-0.125	-0.110
			(-1.449)		(-1.620)	(-1.388)
Telecoms			-0.210**		-0.214***	-0.207**
			(-2.582)		(-2.596)	(-2.447)
Transport			-0.0707		-0.0831	-0.0709
			(-1.184)		(-1.364)	(-1.100)
Pharma			0.263*		0.255*	0.234
			(1.852)		(1.710)	(1.496)
Profession			-0.0240		-0.0392	-0.0395
			(-0.366)		(-0.580)	(-0.565)
Food			0.0196		0.0137	-0.0122
			(0.247)		(0.168)	(-0.136)
Distribution			0.0893		0.0845	0.0926
			(1.375)		(1.250)	(1.326)
Country					-0.00365	0.00277
					(-0.126)	(0.0874)
Start2						0.0287
						(0.649)
Start3						-0.0118
						(-0.299)
Start4						-0.00323
						(-0.0770)
Start5						0.0439
						(0.695)

Table 4.6 (continued)

VARIABLES	(1) Price_fect	(2) Price_fect	(3) Price_fect	(4) Price_fect	(5) Price_fect	(6) Price_fect
Constant	-0.0752	-0.0666	0.0188	-0.102	-0.0224	-0.0294
	(-1.158)	(-0.819)	(0.197)	(-1.452)	(-0.219)	(-0.256)
Observations	313	313	313	313	313	300
R-squared	0.061	0.119	0.177	0.070	0.188	0.186

t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Regressions performed on whole sample including economic regulation cases. The effect of economic regulation is included in the constant. The financial sector dummy is dropped due to collinearity with Finpro.

Table 4.7: OLS regression results over academic journal subsample

VARIABLES	(1) Price_fect	(2) Price_fect	(3) Price_fect	(4) Price_fect	(5) Price_fect	(6) Price_fect
Economic deregulation	-0.178**	-0.107	-0.197**	-0.173**	-0.221**	-0.319**
	(-2.553)	(-1.309)	(-2.039)	(-2.412)	(-2.130)	(-2.553)
Social regulation	-0.0680	-0.00198	-0.136	-0.0682	-0.164	-0.234*
	(-0.946)	(-0.0193)	(-1.085)	(-0.913)	(-1.261)	(-1.728)
Social deregulation	-0.124*	-0.0509	-0.147	-0.128*	-0.170	-0.245*
	(-1.772)	(-0.512)	(-1.172)	(-1.776)	(-1.314)	(-1.824)
Con		-0.0250	0.0119		0.0132	0.0495
		(-0.244)	(0.107)		(0.115)	(0.408)
Env		-0.0452	0.00505		-0.00213	0.0111
		(-0.713)	(0.0726)		(-0.0288)	(0.147)
FCS		-0.0688	-0.0158		-0.0237	-0.0796
		(-0.709)	(-0.156)		(-0.225)	(-0.782)
Finpro		-0.102	-0.171		-0.134	0.0218
		(-1.035)	(-1.519)		(-1.106)	(0.164)
H		-0.0114	0.108		0.0807	0.112
		(-0.213)	(1.352)		(0.937)	(1.328)
IPR		-0.310***	-0.369**		-0.386**	-0.732***

Table 4.7 (continued)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Price_fect	Price_fect	Price_fect	Price_fect	Price_fect	Price_fect
		(-4.201)	(-2.083)		(-2.128)	(-4.192)
Ipro		0.110	0.0365		0.0226	-0.0688
		(1.163)	(0.334)		(0.203)	(-0.512)
SQ		-0.0354	0.0902		0.0864	0.100
		(-0.684)	(1.284)		(1.212)	(1.456)
NM		0.00652	0.0166		0.0143	0.0173
		(0.112)	(0.267)		(0.216)	(0.245)
USO		-0.0192	0.0188		0.0343	0.0426
		(-0.250)	(0.207)		(0.372)	(0.472)
Category A				0.0104	0.0917	0.145
				(0.146)	(1.167)	(1.609)
Category B				-0.0132	0.0758	0.151
				(-0.182)	(0.929)	(1.615)
Category C				-0.0634	0.0325	0.0415
				(-0.814)	(0.359)	(0.393)
Energy			-0.139		-0.135	-0.0883
			(-1.341)		(-1.272)	(-0.750)
Telecoms			-0.103		-0.0884	-0.0196
			(-0.786)		(-0.635)	(-0.136)
Transport			-0.190**		-0.190**	-0.116
			(-2.178)		(-2.131)	(-1.122)
Pharma			-0.362		-0.335	
			(-1.396)		(-1.272)	
Profession			-0.203**		-0.188**	-0.187**
			(-2.358)		(-2.062)	(-2.029)
Food			0.0618		0.0781	0.428**
			(0.386)		(0.480)	(2.125)
Distribution			-0.107		-0.0733	-0.0739
			(-1.207)		(-0.790)	(-0.784)
Country					0.0204	0.00242
					(0.418)	(0.0506)
Start2						0.0211
						(0.419)

Table 4.7 (continued)

VARIABLES	(1) Price_fect	(2) Price_fect	(3) Price_fect	(4) Price_fect	(5) Price_fect	(6) Price_fect
Start3						0.0416
						(0.826)
Start4						-0.0358
						(-0.565)
Start5						0.0844
						(1.129)
Constant	-0.0717	-0.103	0.0536	-0.0619	-0.0123	-0.0267
	(-1.108)	(-0.928)	(0.393)	(-0.758)	(-0.0793)	(-0.165)
Observations	121	121	121	121	121	116
R-squared	0.088	0.263	0.359	0.109	0.377	0.429

t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Estimation results over the academic journal subsample including economic regulation cases. The effect of economic regulation is captured in the constant. The financial sector dummy is dropped due to collinearity with Finpro.

4.A.3 Weighed regressions

Table 4.8: Weighted OLS regression results over whole sample with weights 0.8365 and 0.1635 - excluding economic regulation cases

VARIABLES	(1) Price_fect	(2) Price_fect	(3) Price_fect	(4) Price_fect	(5) Price_fect	(6) Price_fect
Economic deregulation	-0.117***	-0.104**	-0.121**	-0.117***	-0.116*	-0.111*
	(-3.596)	(-2.391)	(-2.375)	(-3.570)	(-1.966)	(-1.780)
Social deregulation	-0.0870*	-0.0956**	-0.103**	-0.0751	-0.0872*	-0.0862
	(-1.892)	(-2.052)	(-2.083)	(-1.556)	(-1.676)	(-1.551)
Con		0.0444	-0.00623		-0.00724	-0.0285
		(0.899)	(-0.121)		(-0.134)	(-0.507)
Env		-0.0684	-0.0493		-0.0473	-0.0523
		(-1.348)	(-0.891)		(-0.835)	(-0.900)
FCS		-0.0123	-0.0546		-0.0507	-0.0516

Table 4.8 (continued)

VARIABLES	(1) Price_fect	(2) Price_fect	(3) Price_fect	(4) Price_fect	(5) Price_fect	(6) Price_fect
		(-0.235)	(-0.911)		(-0.827)	(-0.827)
Finpro		-0.193**	-0.217**		-0.241***	-0.218**
		(-2.571)	(-2.482)		(-2.603)	(-2.288)
H		-0.0117	-0.0947		-0.0795	-0.0943
		(-0.237)	(-1.562)		(-1.191)	(-1.374)
IPR		0.0102	-0.111		-0.1000	-0.0939
		(0.153)	(-0.742)		(-0.648)	(-0.605)
Ipro		-0.0256	-0.00409		-0.00553	0.00992
		(-0.538)	(-0.0758)		(-0.102)	(0.171)
SQ		-0.00452	-0.00104		0.00840	-0.00237
		(-0.108)	(-0.0209)		(0.165)	(-0.0459)
NM		-0.0387	0.0252		0.0240	0.0120
		(-1.049)	(0.582)		(0.463)	(0.223)
USO		0.0268	0.105		0.119*	0.140**
		(0.479)	(1.622)		(1.771)	(2.049)
DummyA				0.0374	0.0560	0.0793
				(0.665)	(0.983)	(1.242)
DummyB				0.00931	0.0632	0.0880
				(0.159)	(1.006)	(1.264)
DummyC				0.0400	0.0969	0.111
				(0.611)	(1.363)	(1.401)
Energy			-0.105		-0.115	-0.116
			(-1.185)		(-1.249)	(-1.212)
Telecoms			-0.213**		-0.213**	-0.218**
			(-2.220)		(-2.161)	(-2.167)
Transport			-0.0503		-0.0592	-0.0578
			(-0.700)		(-0.795)	(-0.751)
Pharma			0.146		0.0973	0.116
			(0.783)		(0.490)	(0.576)
Profession			-0.0307		-0.0445	-0.0402
			(-0.383)		(-0.531)	(-0.464)
Food			0.00559		-0.0150	-0.0128
			(0.0553)		(-0.142)	(-0.117)

Table 4.8 (continued)

VARIABLES	(1) Price_fect	(2) Price_fect	(3) Price_fect	(4) Price_fect	(5) Price_fect	(6) Price_fect
Distribution			0.128		0.117	0.123
			(1.598)		(1.384)	(1.413)
Country					0.00295	0.00272
					(0.0760)	(0.0634)
Start2						0.0365
						(0.595)
Start3						-0.000662
						(-0.0123)
Start4						-0.00951
						(-0.169)
Start5						0.0810
						(0.965)
Constant	-0.118***	-0.0964**	-0.0653	-0.148**	-0.130	-0.157
	(-4.134)	(-2.082)	(-1.007)	(-2.390)	(-1.386)	(-1.417)
Observations	222	222	222	222	222	215
R-squared	0.056	0.118	0.185	0.061	0.193	0.194

t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Estimation results over the whole sample excluding economic regulation cases. The before-and-after observations are assigned a weight of 0.8365 and the cross-section observations are assigned a weight of 0.1635. The effect of social regulation is captured in the constant. The financial sector dummy is dropped due to collinearity with Finpro.

Table 4.9: Weighted OLS regression results over whole sample with weights 0.6 and 0.4 - excluding economic regulation cases

VARIABLES	(1) Price_fect	(2) Price_fect	(3) Price_fect	(4) Price_fect	(5) Price_fect	(6) Price_fect
Economic deregulation	-0.116***	-0.101**	-0.108*	-0.116***	-0.107	-0.107
	(-3.065)	(-2.013)	(-1.872)	(-3.032)	(-1.638)	(-1.525)
Social deregulation	-0.0882*	-0.0991**	-0.0872*	-0.0755	-0.0702	-0.0710
	(-1.873)	(-2.071)	(-1.740)	(-1.546)	(-1.340)	(-1.270)

Table 4.9 (continued)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Price_fect	Price_fect	Price_fect	Price_fect	Price_fect	Price_fect
Con		0.0371	-0.00212		-0.00562	-0.0249
		(0.657)	(-0.0356)		(-0.0909)	(-0.383)
Env		-0.0604	-0.0484		-0.0478	-0.0543
		(-1.028)	(-0.747)		(-0.720)	(-0.796)
FCS		0.00164	-0.0497		-0.0510	-0.0523
		(0.0276)	(-0.719)		(-0.722)	(-0.724)
Finpro		-0.184**	-0.222**		-0.239**	-0.212*
		(-2.131)	(-2.167)		(-2.209)	(-1.894)
H		0.0123	-0.0685		-0.0578	-0.0697
		(0.226)	(-1.018)		(-0.793)	(-0.916)
IPR		-0.0199	-0.195		-0.199	-0.179
		(-0.272)	(-1.241)		(-1.233)	(-1.074)
Ipro		-0.0132	0.0178		0.0180	0.0211
		(-0.249)	(0.294)		(0.295)	(0.317)
SQ		-0.00261	-0.0205		-0.0122	-0.0136
		(-0.0567)	(-0.366)		(-0.212)	(-0.230)
NM		-0.0399	0.0248		0.0296	0.0193
		(-0.940)	(0.491)		(0.505)	(0.314)
USO		0.0334	0.0952		0.105	0.120
		(0.533)	(1.302)		(1.394)	(1.553)
DummyA				0.0563	0.0756	0.0809
				(0.915)	(1.192)	(1.111)
DummyB				0.0263	0.0822	0.0872
				(0.408)	(1.183)	(1.095)
DummyC				0.0504	0.102	0.101
				(0.689)	(1.274)	(1.107)
Energy			-0.104		-0.117	-0.109
			(-1.012)		(-1.092)	(-0.984)
Telecoms			-0.210*		-0.211*	-0.210*
			(-1.883)		(-1.845)	(-1.784)
Transport			-0.0614		-0.0708	-0.0632
			(-0.741)		(-0.831)	(-0.703)
Pharma			0.233		0.209	0.205

Table 4.9 (continued)

VARIABLES	(1) Price_fect	(2) Price_fect	(3) Price_fect	(4) Price_fect	(5) Price_fect	(6) Price_fect
			(1.158)		(0.977)	(0.917)
Profession			-0.0186		-0.0318	-0.0328
			(-0.203)		(-0.334)	(-0.330)
Food			0.0113		-0.00114	-0.0181
			(0.102)		(-0.00981)	(-0.143)
Distribution			0.104		0.0988	0.104
			(1.149)		(1.036)	(1.044)
Country					-0.00215	0.000189
					(-0.0508)	(0.00401)
Start2						0.0347
						(0.532)
Start3						-0.00366
						(-0.0628)
Start4						-0.00356
						(-0.0579)
Start5						0.0666
						(0.718)
Constant	-0.118***	-0.108**	-0.0713	-0.165**	-0.149	-0.160
	(-3.544)	(-2.035)	(-0.934)	(-2.398)	(-1.378)	(-1.259)
Observations	173	173	173	173	173	166
R-squared	0.052	0.111	0.171	0.060	0.181	0.180

t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Estimation results over the whole sample excluding economic regulation cases. The before-and-after observations are assigned a weight of 0.6 and the cross-section observations are assigned a weight of 0.4. The effect of social regulation is captured in the constant. The financial sector dummy is dropped due to collinearity with Finpro.

Conclusion

This thesis offers a collection of studies in the economic regulation of utility industries. A number of key trade-offs are reflected in the results.

The first two chapters formalise key trade-offs in the water industry across many countries from a theoretical and an empirical approach respectively. Chapter one provides a model that rationalises the trade-off between water retention and service quality. Under price cap, when demand is inelastic enough, there is a trade-off between increasing water retention and increasing quality. Under rate of return, such a trade-off appears for low levels of the rate of return. Comparing the two modes of regulation from a welfare perspective concludes that price cap regulation is superior for low costs of capital but rate of return is preferable otherwise. Modelling certain features of the water industry, like water retention is challenging and may require a richer model for future research.

The empirical tests for the comparative statics derived in chapter one are conducted in chapter two. This chapter indeed shows that some of the theoretical results are consistent with empirical observations in Eastern European water industries. A higher price leads to lower water retention but higher service quality, as translated by lower complaints. Results also show that price cap regulation leads to less water retention retention but less complaints than rate of return regulation.

The third chapter is motivated by common agency problems arising from the multi-regulation of utility industries by and large. As firms are regulated by several regulators, generating incentives to increase efficiency, and thus charge a low price, while protecting consumers becomes a more complex exercise especially when regulators have divergent objectives. In a simultaneous game with symmetric regulatory costs, multi-regulation is superior to single regulation only if the regulators' valuation for the firm's rent is low enough because their combined transfers are high enough to incentivise the firm to increase efficiency without substantially reducing consumer surplus. When regulators with identical costs move sequentially, a higher welfare can be achieved as compared to unique regulation because the second mover can adjust its transfer to the firm such that the latter receives enough incentives ex-ante while not extracting too much from consumers.

The fourth and last chapter questions the benevolence of regulation following the reasons of implementation of regulatory measures in developed countries' industries, especially the US. The meta-analysis conducted in this study shows that deregulation has significantly reduced prices and that economic deregulation is more effective than social deregulation in this respect. However, this work stresses that deregulation cannot be justified on prices alone. For instance, regulation for social goals are necessary as it reduces risks on consumers. Yet, the design of such regulatory policies should consider firms' costs and available technology to ensure that regulation does not considerably inflate costs and ultimately consumer prices.

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