Investment, Dynamic Consistency and the Sectoral Regulator's Objective*

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Abstract

We explore the separation of powers between the legislative and the executive branch of government as a way of overcoming the dynamic consistency problem of regulatory policy towards investment. We model the industry as a regulated duopoly. The incumbent is a vertically integrated firm that owns a wholesaler and a retailer. The entrant owns a retailer. Either retailer needs access to the input produced by the wholesaler to operate. The incumbent can make an investment that improves the quality of the input produced by the wholesaler. The regulator sets the access price and is unable to commit. The legislator sets the regulator's objective function and is able to commit. We derive general conditions under which having the legislator distort the regulator's objective function away from social welfare allows increasing the range of parameter values for which it is possible to induce socially desirable investment.

Keywords: Investment, Dynamic Consistency, Regulator's Objective.

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1 Introduction

In many regulated industries, incumbents are required to make large investments. This implies that the regulatory policy must balance the conflicting goals of reducing the incumbents' market power, namely on the wholesale market, and giving incumbents incentives to invest. In other words, regulatory policy must trade-off static and dynamic efficiency.

This trade-off may generate a dynamic consistency problem. The regulation of access prices is an important area where this may occur. Before investment, it is socially optimal to set a high access price to promote investment. However, after investment is made, it is socially optimal to set a low access price to promote competition in the retail market. This dynamic consistency problem affects investment negatively. The incumbent anticipates that it will be expropriated from the incremental profit, and reduces investment.

If the regulator can commit to a policy, the dynamic consistency problem can be overcome. However, typically, it is only feasible for the regulator to commit for a policy for short periods, while the investment cycle in these industries can be very long.

Another possible solution to the dynamic consistency problem consists of distorting the regulator's objective function away from social welfare in a fashion that ensures that its optimal policy after investment is the same as the one of a regulator able to commit to a policy before investment. This requires two conditions. First, the regulator's objective function must be set by a third party. Second, the third party must be immune to the dynamic consistency problem, at least for the period of the investment cycle.

In many legislatures these two conditions are potentially fulfilled. First, usually the separation of powers between the legislative and the executive branch of government implies that the legislator enacts the law that governs sectoral regulation and, in particular, defines the regulator's objective function. Then, the regulator carries out its mandate by, namely, setting the access price to the incumbent's wholesale services. Second, the legislative decision process takes much longer than the regulatory decision process. This gives the legislator the chance to commit to a regulatory policy for a longer period than the regulator, and perhaps for a period longer than the investment cycle.

In this article, we explore the separation of powers between the legislative and the executive branch of the government as a way of overcoming the dynamic consistency problem of regulatory policy towards investment. We derive general, intuitive and easy to check conditions, under which, having the legislator distort the regulator's objective function allows increasing the range of parameter values for which it is possible to induce socially desirable investment. These general conditions encompass various modes of competition, types of investment, and forms of regulation, and amount to: **(i)** the incumbent's profit increasing with the access price, and **(ii)** the consumer surplus decreasing with the access price.

We model the industry as a regulated duopoly. The incumbent is a vertically integrated firm that owns a wholesaler and a retailer. The entrant owns a retailer. Either retailer needs access to the input produced by the wholesaler to operate. We refer to the price of the input as the *access price*. First, the legislator sets the weights of the regulator's objective function for: **(i)** consumer surplus, **(ii)** the incumbent's profit, and **(iii)** the entrant's profit. These weights depend on the incumbent's investment decision, which is observed by the regulator. Second, the incumbent makes its investment decision. The investment may either increase the quality of the retail services, or reduce marginal costs. Third, the regulator sets the access price. Fourth, the entrant decides whether to enter the industry. The timing of the game reflects the assumptions that the legislator can commit to a legislative policy, whereas the regulator cannot commit to a regulatory policy.

We refer to the access price that maximizes social welfare, given that the incumbent has made its investment decision, as the *first-best* access price.

If consumer surplus has more weight than the firms' profits in the regulator's objective function, the regulator sets the access price below the first-best level. A low access price implies a low marginal cost for the entrant and a low wholesale margin for the incumbent, both of which lead to low retail prices, thereby increasing consumer surplus and decreasing the incumbent's profit. Similarly, if the incumbent's profit has more weight than consumer surplus and the entrant's profit, the regulator sets the access price above the first-best level.

The access price has two opposing effects on welfare. First, a higher access price if there is investment, given the access price if there is no investment, increases the incumbent's incentives to invest, which is positive. Second, a higher access price leads to higher retail prices, which is negative. When choosing the weights of the regulator's objective function, the legislator has to trade-off these two effects.

If the investment cost is low, the legislator gives the same weight to the payoffs of all parties if there is investment, and gives relatively more weight to consumer surplus if there is no investment. Under these conditions, the incumbent invests to avoid the low access price that would emerge under no-investment, and the regulator sets the access price of the upgraded network at the first-best level. If the investment cost takes intermediate values, the legislator gives relatively more weight to the incumbent's profit if there is investment, and gives relatively more weight to consumer surplus if there is no investment. Under these circumstances, the incumbent invests and the regulator sets the access price above the first-best level. Now the threat of a low access price if there is no investment is not enough to induce investment. The regulator also has to reward the incumbent with a high access price if there is investment. Hence, investment comes at the expense of distorting the retail market. If the investment cost is high, the legislator gives the same weight to the payoffs of all parties, both if there is investment or no investment. Under these circumstances, the incumbent does not invest and the regulator sets the access price at the first-best level. In this case the legislator chooses not to distort the regulator's preferences because, either the distortions in the retail market necessary to induce investment are excessively high, or, it is simply impossible for the regulator to induce investment.

We also consider three extensions of the basic model. First, we analyze the case of over-investment, which may occur when investment has incomplete spillovers. In this context, if the investment cost is high, the legislator's optimal policy is to give relatively more weight to consumer surplus if there is investment. Second, we analyze the case where the legislator cannot set weights conditional on the incumbent's investment decision. Under these circumstances, the legislator's optimal policy achieves a lower welfare level, and investment only occurs for smaller values of the investment cost since the distortions required to induce investment are higher. Third, we discuss the case of retail price regulation. All of our results also hold in this context.

The remainder of the article is organized as follows. In section 2, we review the literature. In section 3, we present the model. In section 4, we characterize the equilibrium of the game. In section 5, we analyze three extensions to the model. Finally, in Section 6, we discuss the policy implications and conclude.

2 Literature Review

The dynamic consistency problem of regulatory policy towards investment was discussed by Levy and Spiller (1996) and Newbery (2000), in general terms, and by Brito et al. (2010), Gans and King (2004), Grajek and Röller (2009) and Vareda (2010), with a focus on access regulation.[1] Vareda (2010) shows that the lower the regulator's commitment capacity, the lower the investment of a network operator will be, both on cost reduction and on quality upgrades. Grajek and Röller (2009) find that whereas access regulation is unaffected by entrants' investment, access regulation makes entry easier, the higher the level of the incumbent's infrastructure investment is. According to these authors, this suggests that the

[1] See Guthrie (2006) for a discussion about the regulators inability to commit to a regulatory policy.

regulatory environment in Europe has a commitment problem, which reduces incumbents' incentives to invest. Brito et al. (2010) analyze if two-part access tariffs solve the dynamic consistency problem of the regulation of new networks, and show that if the regulator cannot commit to a policy, it can induce investment only when the investment cost is low, and the entrant makes large payments to the incumbent. Gans and King (2004) show that when investment returns are uncertain and the regulator is unable to commit to an access price, welfare increases if the regulator commits to a regulatory moratorium.

Several articles analyze the idea of distorting the regulator's objective function away from social welfare to compensate for some sort of market imperfection. Vogelsang (2010) argues that if a regulator is unable to commit to a regulatory policy, soft regulation may provide better investment incentives than tight regulation, where tight regulation refers to a low regulated access price. Armstrong and Vickers (1996) argue that although the danger of regulatory capture might argue against industry-oriented regulators, some degree of industry-orientation might enhance the credibility of commitment to allow an adequate return on investment.[2] Other studies which convey the idea of the existence of an optimal, positive, degree of industry-orientation, in the presence of other market imperfections, include Che (1995), De Figueiredo et al. (1999), Grossman and Helpman (2001), Salant (1995), Sloof (2000), Spiller (1990) and Spulber and Besanko (1992). There are also studies, for instance, by Fridolfsson (2005), Lyons (2001) and Neven and Roller (2007), that propose, in the context of mergers, a consumer surplus standard to be used strategically by the competition authorities as a means of ultimately achieving greater social welfare.

Evans et al. (2008) and Levine and Rickman (2002) analyze problems similar to ours but in the context of particular models. The first article proposes, as a solution to the under-investment by a monopolist resulting from the regulator's inability to commit, that the government chooses a particular type of regulator, pro-industry or anti-industry, over a period longer than the electoral cycle.[3] The authors show that when voters are well informed and the regulator sets retail prices, a pro-industry regulator may induce first-best investment. The second article analyzes the under-investment problem in the context of a dynamic relationship between a regulator and a regulated monopolist, where the former

[2] Besley and Coate (2003) test a model where regulators that are directly elected by the voters are pro-consumer. They show that in the US, prices are lower in those states that elect their regulator than in those where the regulator is appointed by politicians. They also show that investment is higher in states that appoint the regulator.

[3] This solution follows the proposal by Rogoff (1985) which consists on a second-best commitment mechanism in which the pricing decision is delegated to an independent regulator whose preferences do not necessarily coincide with those of the government.

is unable to commit. They assume that the regulator cannot observe whether investment has taken place, but can observe the firm's total costs. They show that a pro-industry regulator can overcome the ratchet effect. Our article generalizes these results to a broader context, which encompass various modes of competition, types of investment, and forms of regulation. In addition, we allow the legislator to set the regulator's objective function conditional on the incumbent's investment decision.

3 Model

3.1 Environment

Consider a regulated duopoly that includes four players: the incumbent, the entrant, the regulator, and the legislator. The *incumbent*, firm i, is vertically integrated and owns a bottleneck input and can invest. The *entrant*, firm e, only operates in the retail market, and has to buy access to the incumbent's bottleneck input. We refer to the price of the bottleneck input as *access price*, and denote it by α. We index firms with subscript $j = i, e$. The *sectoral regulator* sets the access price. The *legislator* chooses the regulator's objective function.

The game has four stages, which unfold as follows. In stage 1, the legislator sets the weights of the regulator's objective function. In stage 2, the incumbent decides whether to invest. In stage 3, the sectoral regulator sets the access price. In stage 4, the entrant decides if it enters the market or not. Afterwards, the firms play some market game.

To keep the model as general as possible, we do not model explicitly the market game. Instead, we assume that the market game has a unique equilibrium, yielding reduced form profit functions with respect to which we make assumptions directly. Later, in sections 4.7 and 5, we will provide examples of specific market games that meet our assumptions.

All relevant information becomes common knowledge as the game unfolds.

3.2 Firms

It might be useful to think of the incumbent's bottleneck input as a network, e.g., a telecommunications network, an electricity network, or a railway network. At cost k on $(0, +\infty)$, the incumbent can make an investment, which either upgrades the network, or deploys a new and more advanced network. Also for the sake of concreteness, it might be useful to think of the investment as increasing the quality of retail services. However, all of our results also apply if, instead, the investment decreases the marginal cost of retail services. We will use superscript $v = n, o$ to denote whether there was investment or not, respectively.

Denote by χ^v, a parameter that measures the quality of the incumbent's bottleneck input, given v. Parameter χ^v takes value 0 if $v = o$, and value Ω on $(0, +\infty)$ if $v = n$.

Denote by $\Pi_j(\alpha^v, \chi^v)$, the gross profit of firm $j = i, e$. If there is no entry and the industry is a monopoly, the incumbent's gross profit is $\pi^M(\chi^v)$. If there is entry and the industry is a duopoly, firm j's gross profit is $\pi_j^D(\alpha^v, \chi^v)$.

3.3 Sectoral Regulator

The regulator is unable to commit to a regulatory policy, i.e., to an access price. Hence, it makes its choice after observing the incumbent's investment decision, as in Brito et al. (2010).

Denote by $CS(\alpha^v, \chi^v)$, the consumer surplus. If there is no entry, consumer surplus is $cs^M(\chi^v)$. If there is entry, consumer surplus is $cs^D(\alpha^v, \chi^v)$.

Social welfare is:

$$W(\alpha^v, \chi^v) := \Pi_i(\alpha^v, \chi^v) + \Pi_e(\alpha^v, \chi^v) + CS(\alpha^v, \chi^v).$$

If there is no entry, social welfare is $w^M(\chi^v) := \pi^M(\chi^v) + cs^M(\chi^v)$. If the there is entry, social welfare is $w^D(\alpha^v, \chi^v) := \pi_i^D(\alpha^v, \chi^v) + \pi_e^D(\alpha^v, \chi^v) + cs^D(\alpha^v, \chi^v)$.

The regulator's objective function is a weighted sum of consumer surplus and the firms' profits:

$$\Gamma(\theta_i^v, \theta_c^v, \alpha^v, \chi^v) = \theta_i^v \Pi_i(\alpha^v, \chi^v) + \Pi_e(\alpha^v, \chi^v) + \theta_c^v CS(\alpha^v, \chi^v); \tag{1}$$

where θ_i^v and θ_c^v are the weights of the incumbent's profit and consumer surplus, respectively, with $\min\{\theta_i^v, \theta_c^v\} = 1$.[4] Let $\boldsymbol{\theta}^v := (\theta_i^v, \theta_c^v)$. Note that $\Gamma(1, 1, \alpha^v, \chi^v) = W(\alpha^v, \chi^v)$.

The regulator sets the access price to maximize $\Gamma(\theta_i^v, \theta_c^v, \alpha^v, \chi^v)$, subject to the incumbent's participation constraint:

$$\Pi_i(\alpha^v, \chi^v) \geq 0. \tag{2}$$

[4] Given our assumptions about payoffs, introduced in section 3.5, there is no need to give a weight higher than 1 to the entrant's profit. The legislator can obtain a similar effect by adjusting the weights to the other parties's payoffs.

3.4 Legislator

Unlike the regulator, the legislator can commit to a legislative decision, perhaps because the legislative decision process takes longer than the regulatory decision process, and long enough for the investment cycle.[5] Hence, the legislator makes its choice before investment.

In addition, the legislator sets weights depending on whether there was investment or not. This assumption is justifiable because the regulator only chooses the access price after observing whether the incumbent has invested or not. However, it requires that the legislator is able to write complex laws. In section 5, we consider alternative assumptions.

The legislator's objective function is the net social welfare: $W(\alpha^v, \chi^v) - k$.

3.5 Assumptions about Payoffs

Throughout the remainder of the article we make the following assumptions about payoffs.

(A1) **(a)** There is an $\overline{\alpha}^v$ on $(-\infty, +\infty)$ such that: $\pi_e^D(\alpha, \chi^v) < 0$, if and only if, $\alpha > \overline{\alpha}^v$. **(b)** There is an $\underline{\alpha}^v$ on $(-\infty, +\infty)$ such that: $\pi_i^D(\alpha, \chi^v) < 0$, if and only if, $\alpha < \underline{\alpha}^v$. **(c)** $\underline{\alpha}^v < \overline{\alpha}^v$. **(d)** Functions $\pi_i^D(\cdot)$, $\pi_e^D(\cdot)$ and $cs^D(\cdot)$ are continuously differentiable in α^v, for all α^v on $[\underline{\alpha}^v, \overline{\alpha}^v]$. ■

(A2) Functions $w^D(\cdot)$ and $w^M(\cdot)$ are increasing in χ^v. ■

(A3) For all $\alpha^v > \underline{\alpha}^v$: $\pi_i^D(\cdot)$ is increasing in α^v and $\pi_i^D(\overline{\alpha}^v, \chi^v) \leq \pi_i^M(\chi^v)$. ■

(A4) For all $\alpha^v > \underline{\alpha}^v$: $cs^D(\cdot)$ is decreasing in α^v and $cs^D(\overline{\alpha}^v, \chi^v) \geq cs^M(\chi^v)$. ■

(A1) and (A2) are technical assumptions intended to avoid triviality. (A1) states that for a sufficiently high access price the entrant's profit becomes negative, and that for a sufficiently low access price, possibly negative, the incumbent's profit becomes negative. In addition, there are access prices such that both firms have positive profits. (A2) states that the investment improves welfare, all else constant.

(A3) and (A4) are the substantive assumptions of our approach. (A3) states that the incumbent's profit is increasing in the access price, and can be justified as follows. An

[5] According to Spulber and Besanko (1992), typically, administrative regulators are established before the economic parameters that affect regulatory outcomes are observed. Hence, statutory constraints provide a means of commitment for the legislature that restricts future regulatory decisions.

increase in the access price increases the incumbent's cost advantage over its rival and the incumbent's wholesale margin. However, increasing the access price has the negative effect of decreasing the number of units sold by the entrant. We assume the latter effect is always weaker than the sum of the two former effects, so that the incumbent's profit increases with the access price. (A4) states that consumer surplus is decreasing in the access price, and can be justified as follows. The higher the access price, the higher the entrant's marginal cost is, and thus the higher the retail price it charges. In addition, the incumbent is less worried about loosing subscribers to the entrant because the increase in the wholesale revenues compensate for this. As a result, the prices of both firms increase, thereby decreasing consumer surplus.

3.6 Equilibrium Concept

The sub-game perfect Nash equilibrium is: **(i)** a set of weights to the regulator's objective function, **(ii)** an investment decision, **(iii)** an access price to the network $v = n, o$, and **(iv)** a decision of whether to enter the market, such that:

(E1) the decision to enter the market maximizes the entrant's profits, given the set of weights to the regulator's objective function, the investment decision, and the access prices.

(E2) the access price for network $v = n, o$ maximizes the regulator's objective function, given the set of weights to the regulator's objective function, the investment decision, and the optimal entry decision.

(E3) the investment decision maximizes the incumbent's profits, given the set of weights to the regulator's objective function, the optimal access prices, and the optimal entry decision.

(E4) the set of weights to the regulator's objective function maximizes social welfare, given the optimal investment decision, the optimal access prices, and the optimal entry decision.

4 Equilibrium of Game

In this Section, we characterize the equilibrium of the game, which we construct by working backwards.

4.1 Stage 4: Entry Decision

Next, we determine the entrant's optimal decision of whether to enter the market.

When indifferent between entering and not entering, the entrant chooses the former.

Given (A1):(a), the entrant chooses not to enter, and the market is a monopoly, if and only if the regulator sets $\alpha^v > \overline{\alpha}^v$. Hence, the incumbent's gross profit is given by:

$$\Pi_i(\alpha^v, \chi^v) = \begin{cases} \pi_i^D(\alpha^v, \chi^v) & \text{if} \quad \alpha^v \leq \overline{\alpha}^v \\ \pi^M(\chi^v) & \text{if} \quad \alpha^v > \overline{\alpha}^v; \end{cases}$$

the entrant's profit by:

$$\Pi_e(\alpha^v, \chi^v) = \begin{cases} \pi_e^D(\alpha^v, \chi^v) & \text{if} \quad \alpha^v \leq \overline{\alpha}^v \\ 0 & \text{if} \quad \alpha^v > \overline{\alpha}^v; \end{cases}$$

consumer surplus by:

$$CS(\alpha^v, \chi^v) = \begin{cases} cs^D(\alpha^v, \chi^v) & \text{if} \quad \alpha^v \leq \overline{\alpha}^v \\ cs^M(\chi^v) & \text{if} \quad \alpha^v > \overline{\alpha}^v; \end{cases}$$

and social welfare by:

$$W(\alpha^v, \chi^v) = \begin{cases} w^D(\alpha^v, \chi^v) & \text{if} \quad \alpha^v \leq \overline{\alpha}^v \\ w^M(\chi^v) & \text{if} \quad \alpha^v > \overline{\alpha}^v. \end{cases}$$

4.2 Stage 3: Regulation of the Access Price

Next, we characterize the regulator's optimal access price choice.

First, we define the socially optimal access price.

For $\alpha^v < \underline{\alpha}^v$, the incumbent's participation constraint (2) is violated. For $\alpha^v > \overline{\alpha}^v$, there is no entry and α^v becomes irrelevant. Hence, the market is a duopoly if:

$$\alpha^v \text{ is on } \left[\underline{\alpha}^v, \overline{\alpha}^v\right]. \tag{3}$$

Denote by α_D^v, the access price that maximizes welfare, given that there is entry and that the incumbent has made its investment decision, i.e.,

$$\alpha_D^v := argmax_{\alpha^v} \left\{ w^D\left(\alpha^v, \chi^v\right) \mid \alpha^v \text{ on } \left[\underline{\alpha}^v, \overline{\alpha}^v\right] \right\}.$$

Assume that α_D^v is unique.[6]

It simplifies exposition to denote by α_M^v, an arbitrary element of $(\overline{\alpha}^v, +\infty)$.

Denote by α_ω^v, the *first-best* access price, i.e.,

$$\alpha_\omega^v := argmax_{\alpha^v} \left\{ W\left(\alpha^v, \chi^v\right) \mid \alpha^v \text{ on } \left[\underline{\alpha}^v, +\infty\right) \right\}.$$

[6]Value α_D^v exists because $w^D\left(\cdot\right)$ is continuous on $[\underline{\alpha}^v, \overline{\alpha}^v]$.

Obviously, $\alpha_\omega^v = \alpha_D^v$, if $w^D(\alpha_D^v, \chi^v) \geq w^M(\chi^v)$, and $\alpha_\omega^v = \alpha_M^v$, otherwise. In the later case it is socially optimal to impose no access obligations.

By definition, $\alpha^v \neq \alpha_\omega^v$ involves a welfare loss. We do not model explicitly the market game until section 4.7. However, to interpret some of our results in section 4, it is useful to keep in mind that these welfare losses are caused by the distortions in the retail market. E.g., $\alpha^v > \alpha_\omega^v$ increases retail prices and thereby the deadweight loss above the socially optimum.

Given the entrant's optimal entry decision, the regulator's objective function is:

$$\Gamma\left(\theta_i^v, \theta_c^v, \alpha^v, \chi^v\right) = \begin{cases} \gamma^D := \theta_i^v \pi_i^D(\alpha^v, \chi^v) + \pi_e^D(\alpha^v, \chi^v) + \theta_c^v cs^D(\alpha^v, \chi^v) & \text{if} \quad \alpha^v \leq \overline{\alpha}^v \\ \gamma^M := \theta_i^v \pi_i^M(\chi^v) + \theta_c^v cs^M(\chi^v) & \text{if} \quad \alpha^v > \overline{\alpha}^v. \end{cases}$$

The incumbent's participation constraint (2) is equivalent to:

$$\alpha^v \text{ is on } \left[\underline{\alpha}^v, +\infty\right).$$

Denote by $\alpha_r^v(\boldsymbol{\theta})$, the regulator's optimal decision.[7] For $\alpha_r^v(\boldsymbol{\theta})$ on $(\underline{\alpha}^v, \overline{\alpha}^v)$, the following first-order condition holds:

$$\frac{\partial \gamma^D}{\partial \alpha^v} = \theta_i^v \frac{\partial \pi_i^D(\alpha_r^v(\boldsymbol{\theta}), \chi^v)}{\partial \alpha^v} + \frac{\partial \pi_e^D(\alpha_r^v(\boldsymbol{\theta}), \chi^v)}{\partial \alpha^v} + \theta_c^v \frac{\partial cs^D(\alpha_r^v(\boldsymbol{\theta}), \chi^v)}{\partial \alpha^v} = 0. \tag{4}$$

The next Lemma describes how the regulator's optimal access price varies with the weights for consumer surplus and the incumbent's profit.

Lemma 1: *Value $\alpha_r^v(\boldsymbol{\theta}^v)$ is non-decreasing in θ_i^v and non-increasing in θ_c^v.*

Proof: Let $\alpha_r^v(\boldsymbol{\theta}^v) \in (\underline{\alpha}^v, \overline{\alpha}^v)$. It follows from the definition of interior maximum and the implicit function theorem that:

$$\begin{aligned} sgn\left\{\frac{\partial \alpha_r^v(\boldsymbol{\theta}^v)}{\partial \theta_i^v}\right\} &= sgn\left\{\frac{\partial^2 \gamma^D}{\partial \theta_i^v \partial \alpha^v}\right\} = sgn\left\{\frac{\partial \pi_i^D(\alpha_r^v(\boldsymbol{\theta}^v), \chi^v)}{\partial \alpha^v}\right\} \\ sgn\left\{\frac{\partial \alpha_r^v(\boldsymbol{\theta}^v)}{\partial \theta_C^v}\right\} &= sgn\left\{\frac{\partial^2 \gamma^D}{\partial \theta_c^v \partial \alpha^v}\right\} = sgn\left\{\frac{\partial cs^D(\alpha_r^v(\boldsymbol{\theta}^v), \chi^v)}{\partial \alpha^v}\right\}. \end{aligned}$$

Then (A3) and (A4) imply that: $\frac{\partial \alpha_r^v(\boldsymbol{\theta}^v)}{\partial \theta_c^v} < 0 < \frac{\partial \alpha_r^v(\boldsymbol{\theta}^v)}{\partial \theta_i^v}$. Let $\alpha_r^v(\boldsymbol{\theta}^v) = \alpha_M^v$ or $\alpha_r^v(\boldsymbol{\theta}^v) = \underline{\alpha}^v$. Under these conditions, $\alpha_r^v(\boldsymbol{\theta}^v)$ can only decrease (increase), and only if θ_c^v (θ_i^v) increases. When $\alpha_r^v(\boldsymbol{\theta}^v) = \overline{\alpha}^v$, $\alpha_r^v(\boldsymbol{\theta}^v)$ may decrease or increase if θ_c^v or θ_i^v increases, respectively. ■

If the legislator gives the same weight to the payoffs of all parties in the regulator's objective function, the regulator maximizes social welfare, and sets the access price at the

[7] We assume that the legislator provides the regulator with a tie-breaking rule (e.g., choose the lowest value, or the highest value), such that the optimal access price is unique.

first-best level. If the legislator gives sufficiently more weight to consumer surplus than to firms' profits, $\theta_c^v > 1 = \theta_i^v$, the regulator sets the access price below the *first-best* level, $\alpha_r^v(1, \theta_c^v) < \alpha_r^v(1,1) = \alpha_\omega^v$, provided that $\alpha_\omega^v > \underline{\alpha}^v$. For a sufficiently high weight to consumer surplus, the incumbent's participation constraint becomes binding.[8] Finally, if the legislator gives sufficiently more weight to the incumbent's profit than to the other parties' payoffs, $\theta_i^v > 1 = \theta_c^v$, the regulator sets the access price above the *first-best* level, $\alpha_r^v(\theta_i^v, 1) > \alpha_\omega^v$, provided that $\alpha_\omega^v < \alpha_M^v$. Again, for a sufficiently high weight to the incumbent's profit, the entrant's participation constraint is violated and the regulator sets α_M^v, or equivalently, does not impose any open access obligations.

Denote by $\overline{\theta}_c^v$, the lowest value of the weight of consumer surplus, such that the incumbent's participation constraint is binding, i.e., $\alpha_r^v(1, \overline{\theta}_c^v) \equiv \underline{\alpha}^v$, and denote by $\overline{\theta}_i^v$ the lowest weight of the incumbent's profit, such that the regulator sets α_M^v.

4.3 Stage 2: Investment Decision

Next, we characterize the incumbent's optimal investment decision.

Denote the incremental profit of investment gross of investment costs, by:

$$\Delta\Pi_i(\boldsymbol{\theta}^n, \boldsymbol{\theta}^o) := \Pi_i(\alpha_r^n(\boldsymbol{\theta}^n), \Omega) - \Pi_i(\alpha_r^o(\boldsymbol{\theta}^o), 0) \tag{5}$$

The incumbent invests if the incremental profit of the investment is no smaller than the investment cost:

$$\Delta\Pi_i(\boldsymbol{\theta}^n, \boldsymbol{\theta}^o) \geq k. \tag{6}$$

Investment has two effects. First, it has a direct effect over the incumbent's profit. Second, it has an indirect effect of inducing a change in the access price.

The next Lemma describes how the incremental profit of investment varies with the weights of consumer surplus and the incumbent's profit in the regulator's objective function.

Lemma 2: *Value $\Delta\Pi_i(\boldsymbol{\theta}^n, \boldsymbol{\theta}^o)$ is non-decreasing in θ_i^n and θ_c^o, and non-increasing in θ_i^o and θ_c^n.*

Proof: Follows from (A3) and Lemma 1. ■

From equation (5), the incremental profit of investment is increasing in $\alpha_r^n(\boldsymbol{\theta}^n)$ and decreasing in $\alpha_r^o(\boldsymbol{\theta}^o)$. From Lemma 1, $\alpha_r^v(\boldsymbol{\theta}^v)$ is non-decreasing in θ_i^v and non-increasing in

[8] It is also possible that $\alpha_\omega^v = \underline{\alpha}^v$, in which case a higher weight to consumer surplus would make the regulator's optimal access price equal to the first-best.

θ_c^v. Hence, by setting high values for θ_i^n and θ_c^o, or by setting high values for θ_i^o and θ_c^n, the legislator can, respectively, encourage or discourage investment.

Given Lemma 2, it follows that:

$$\max_{\{\boldsymbol{\theta}^n,\boldsymbol{\theta}^o\}} \Delta\Pi_i(\boldsymbol{\theta}^n,\boldsymbol{\theta}^o) = \pi_i^M(\Omega).$$

Hence, it is possible to induce the incumbent to invest, only if k is on $\left(0, \pi_i^M(\Omega)\right]$.

4.4 Stage 1: Weights of Regulator's Objective Function

Next we characterize the legislator's optimal weight choice decision.

We start by defining some important thresholds.

Denote by $\Delta W(\boldsymbol{\theta}^n) := W(\alpha_r^n(\boldsymbol{\theta}^n),\Omega) - W(\alpha_\omega^o, 0)$, the incremental social welfare of investment. The legislator, when setting the weights of the regulator's objective function, chooses indirectly the access prices. In doing so it faces a trade-off. On the one hand, from (A3), the incentives to invest are higher, the higher α^n is compared to α^o. On the other hand, for $\alpha^n \neq \alpha_\omega^n$ there is a welfare loss caused by the distortions in the retail market.

Denote by K_ω*,* the highest level of the investment cost for which investment increases welfare, given that the regulator's objective function is not distorted if there is investment, i.e., given $\boldsymbol{\theta}^n = (1,1)$:

$$\Delta W(1,1) - K_\omega \equiv 0.$$

(A2) implies: K_ω is on $(0,+\infty)$. We will say that investment is *first-best* if it increases social welfare evaluated at the *first-best* access prices, i.e. $\Delta W(1,1) > k$, and that investment is *socially desirable* if, given the access prices set by the regulator, it increases social welfare, i.e. $\Delta W(\boldsymbol{\theta}^n) > k$. Naturally, for k on $(K_\omega,+\infty)$ the legislator does not want to induce investment.

Denote by K_0*,* the highest level of the investment cost for which the incumbent invests, given that the regulator's objective function is not distorted, i.e., $\boldsymbol{\theta}^n = \boldsymbol{\theta}^o = (1,1)$:

$$\max\{0, \Delta\Pi_i(1,1,1,1)\} - K_0 \equiv 0.$$

Value K_0 may be equal to zero if the incumbent's profit, gross of the investment cost, does not increase with investment for $\boldsymbol{\theta}^n = \boldsymbol{\theta}^o = (1,1)$.[9]

We will say that there is *under-investment* if the incumbent does not invest when investment is *first-best*, and that there is *over-investment* if the incumbent invests when investment is not a *first-best.*

[9] This is the case of the Hotelling model presented in section 4.7.1 and the symmetric Cournot model presented in section 4.7.2.

In the absence of distortions of the regulator's objective function, if $K_0 < K_\omega$, there may be *under-investment*, and if $K_\omega < K_0$, there may be *over-investment*. The following assumption states under which conditions there may be *under-investment*, (A5):(a), and *over-investment*, (A5):(b), respectively.

(A5) (a) Let: $\Delta\Pi_i(1,1,1,1) \leq \Delta W(1,1)$.

(b) Let: $\Delta\Pi_i(1,1,1,1) > \Delta W(1,1)$. ■

In the remainder of the article, except in section 5.1, we assume that (A5):(a) holds.

For k on $(0, K_0]$, the legislator can set the regulator's objective function to be equal to social welfare. For k on $(K_0, +\infty)$, the legislator can only induce investment by distorting the regulator's objective function away from social welfare, at least in the no-investment case.

Denote by K_1, the highest level of the investment cost for which the incumbent invests, given $\boldsymbol{\theta}^n = (1,1)$ and $\boldsymbol{\theta}^o = (1, \overline{\theta}_c^o)$:

$$\max\left\{0, \Delta\Pi_i(1,1,1,\overline{\theta}_c^o)\right\} - K_1 \equiv 0.$$

From Lemma 2, K_1 is on $\left[K_0, \pi_i^M(\Omega)\right]$. For k on $(K_0, K_1]$, investment occurs without any distortion in the retail market, i.e., occurs with $\boldsymbol{\theta}^n = (1,1)$ and $\boldsymbol{\theta}^o = (1, \overline{\theta}_c^o)$, or alternatively, with $\alpha_r^n = \alpha_\omega^n$ and $\alpha_r^o \leq \alpha_\omega^o$. All that is required is that the legislator sets weights for the regulator's objective function such that the incumbent's participation constraint is binding if there is no-investment.

If $K_\omega \leq K_1$, the legislator is able to induce *first-best* investment without distortions, just by threatening the incumbent with a higher weight on consumer surplus if there is no investment. The following assumption states under which conditions this may or may not occur, respectively.

(A6) (a) Let: $\Delta W(1,1) \leq \Pi_i(\alpha_\omega^n, \Omega)$.

(b) Let: $\Delta W(1,1) > \Pi_i(\alpha_\omega^n, \Omega)$. ■

The next Lemma summarizes the legislator's optimal decision when it is possible to induce *first-best* investment without distortions.

Lemma 3: *Let **(A1)** to **(A4)**, **(A5):(a)** and **(A6):(a)** hold.*

(i) if k is on $(0, K_\omega]$, the legislator sets the weights $\boldsymbol{\theta}^n = (1,1)$ and $\boldsymbol{\theta}^o = (1, \overline{\theta}_c^o)$;

(ii) if k is on $(K_\omega, +\infty)$, the legislator sets the weights $\boldsymbol{\theta}^n = (1,1)$ and $\boldsymbol{\theta}^o = (1,1)$. ■

Next we consider the case where (A6):(b) holds. We start by determining the best way, from the legislator's perspective, of inducing investment.

For k on $(K_0, K_1]$, investment occurs without any distortion in the retail market, as explained above.

For k on $\left(K_1, \pi_i^M(\Omega)\right]$, the legislator can only induce investment be distorting the retail market, i.e., with $\theta_i^n > 1$. Hence, to determine the best way of inducing investment, the legislator chooses $\boldsymbol{\theta}^n$ and $\boldsymbol{\theta}^o$ to maximize welfare, subject to the incumbent individual participation constraint (6). Hence, it should set $\boldsymbol{\theta}^o = (1, \overline{\theta}_c^o)$ to relax the constraint (6). Denote by $\widehat{\theta}_i^n(k)$, the lowest weight of the incumbent's profit that maximizes welfare, given that the incumbent invests:

$$\widehat{\theta}_i^n(k) = argmax_{\theta_i^n} \left\{ W(\alpha_r^n(\theta_i^n, 1), \Omega) \,\middle|\, \Delta\Pi_i(\theta_i^n, 1, 1, \overline{\theta}_c^o) \geq k \right\}.$$

Value $\widehat{\theta}_i^n(k)$ is higher than 1 and non-decreasing in k.[10] We now establish under which conditions inducing investment increases welfare.

Denote by K_2, the highest level of the investment cost for which it is possible to induce socially desirable investment, given that $\boldsymbol{\theta}^n = (\widehat{\theta}_i^n, 1)$:[11]

$$K_2 := max \left\{ k \,\middle|\, \Delta W(\widehat{\theta}_i^n(k), 1) \geq k \right\}.$$

Clearly, K_2 is on $\left(K_1, \min\left\{\pi_i^M(\Omega), K_\omega\right\}\right]$. In particular, we may have $\Delta W(\widehat{\theta}_i^n(k), 1) - k > 0$, for $k = \pi_i^M(\Omega)$, which implies that although investment is socially desirable for higher values of the investment cost, it is impossible to induce the incumbent to invest. In this case $K_2 = \pi_i^M(\Omega)$.

For k on $(K_1, K_2]$, it is possible to induce the incumbent to invest. Furthermore, investment is socially desirable, i.e., the welfare benefits of investment outweigh the welfare loss caused by the distortions in the retail market induced by $\alpha_r^n(\widehat{\theta}_i^n(k), 1) > \alpha_\omega^n$. Hence, the

[10] If the welfare function is decreasing in the access price for any $\alpha^n > \alpha_\omega^n$, the constraint $\Delta\Pi_i(\boldsymbol{\theta}^n, \boldsymbol{\theta}^o) \geq k$ is binding at $\widehat{\theta}_i^n(k)$, i.e., the legislator should choose the lowest weight on the incumbent's profit such that the incumbent invests. If, on the other hand, the welfare function is non-monotonic for $\alpha^n > \alpha_\omega^n$, we may have $\Delta\Pi_i(\boldsymbol{\theta}^n, \boldsymbol{\theta}^o) > k$ at $\widehat{\theta}_i^n(k)$. In this case, $\widehat{\theta}_i^n(k)$ is independent of k. The welfare function is decreasing in the case of Cournot competition and non-monotonic in the case of Hotelling model, both presented in section 4.7.

[11] Function $\Delta W(\widehat{\theta}_i^n(k), 1)$ is non-increasing in k : the higher is k, the stronger the constraint that leads the incumbent to invest.

legislator still prefers to induce investment and sets $\theta_i^n = \widehat{\theta}_i^n(k) > 1$. The weight given to the incumbent's profit may be such that the regulator induces a monopoly. This happens if, but not only if, k is on $\left(\pi_i^D(\overline{\alpha}^n, \Omega), \Delta W(\overline{\theta}_i^n)\right)$. In this case, the incumbent would never invest if there is a duopoly after investment, and the legislator would prefer a monopoly after investment to a duopoly without investment.

For k on $(K_2, K_\omega]$, it is either impossible to induce investment, or investment is socially undesirable, i.e., the value of $\alpha_r^n(\widehat{\theta}_i^n(k), 1)$ required to induce investment is so high that the welfare loss caused by the associated distortions in the retail market outweigh the welfare benefits of investment. Hence, the legislator does not want to induce investment, and gives equal weights to all parties' payoffs.

Lemma $3'$ sums up the legislator's optimal decision for the case where inducing *first-best* investment may involve distortions.

Lemma $3'$: *Let **(A1)** to **(A4)**, **(A5):(a)** and **(A6):(b)** hold.*

(i) if k is on $(0, K_1]$, the legislator sets the weights: $\boldsymbol{\theta}^n = (1, 1)$ and $\boldsymbol{\theta}^o = (1, \overline{\theta}_c^o)$;[12]

(ii) if k is on $(K_1, K_2]$, the legislator sets the weights: $\boldsymbol{\theta}^n = \left(\widehat{\theta}_i^n(k), 1\right)$ and $\boldsymbol{\theta}^o = (1, \overline{\theta}_c^o)$;

(iii) if k is on $(K_2, +\infty)$, the legislator sets the weights: $\boldsymbol{\theta}^n = (1, 1)$ and $\boldsymbol{\theta}^o = (1, 1)$. ■

The legislator's ability to distort the regulator's objective function away from social welfare, i.e., the ability of setting $\theta_l^v > 1$, $l = i, c$, allows inducing *first-best* investment for k on $(K_0, K_2]$, but not for k on $(K_2, K_\omega]$. Inducing investment for k on $(K_0, K_1]$ requires increasing the weight to consumer surplus if there is no-investment, θ_c^o. Inducing investment for k on $(K_1, K_2]$ requires both increasing the weight of consumer surplus if there is no-investment, θ_c^o, and increasing the weight of the incumbent's profit if there is investment, θ_i^n.

4.5 Equilibrium of the Whole Game

The next Proposition summarizes the equilibrium of the whole game.

Proposition 1. **(a)** *Let **(A1)** to **(A4)**, **(A5):(a)** and **(A6):(a)** hold.*

[12] In the case of k on $(0, K_0]$ the legislator could set weights such that the regulator would maximize social welfare in case of no-investment. However, for exposition convenience, and given the welfare equivalence, we assume that the legislator sets the weights as for the case of $(K_0, K_1]$.

(i) if k is on $(0, K_\omega]$, the legislator sets the weights $\theta^n = (1,1)$ and $\theta^o = (1, \overline{\theta}^o_c)$; the incumbent invests; and the regulator sets access price $\alpha^n = \alpha^n_\omega$;

(ii) if k is on $(K_\omega, +\infty)$, the legislator sets the weights $\boldsymbol{\theta}^n = (1,1)$ and $\boldsymbol{\theta}^o = (1,1)$; the incumbent does not invest; and the regulator sets access price $\alpha^o = \alpha^o_\omega$.

(b) *Let **(A1)** to **(A4)**, **(A5):(a)** and **(A6):(b)** hold.*

(i) if k is on $(0, K_1]$, the legislator sets the weights $\boldsymbol{\theta}^n = (1,1)$ and $\boldsymbol{\theta}^o = (1, \overline{\theta}^o_c)$; the incumbent invests; and the regulator sets access price $\alpha^n = \alpha^n_\omega$;

(ii) if k is on $(K_1, K_2]$, the legislator sets the weights $\boldsymbol{\theta}^n = \left(\widehat{\theta}^n_i(k), 1\right)$ and $\boldsymbol{\theta}^o = (1, \overline{\theta}^o_c)$; the incumbent invests; and the regulator sets access price $\alpha^n = \alpha^n_r(\widehat{\theta}^n_i(k), 1)$;

(iii) if k is on $(K_2, +\infty)$, the legislator sets the weights $\boldsymbol{\theta}^n = (1,1)$ and $\boldsymbol{\theta}^o = (1,1)$; the incumbent does not invest; and the regulator sets access price $\alpha^o = \alpha^o_\omega$.

Proof: Follows from Lemma 1, 2, 3 and 3′. ■

If (A6):(a) holds, the legislator is always able to induce *first-best* investment by threatening the incumbent with a low access price if there is no investment.

If (A6):(b) holds, when investment is a *first-best*, there are three types of equilibria, depending on the value of the investment cost. First, if the investment cost is low, i.e., if k is on $(0, K_1]$, the legislator gives the same weight to the payoffs of all parties if there is investment, and gives relatively more weight to consumer surplus if there is no-investment, $\theta^o_c > 1$. Setting $\theta^o_c > 1$ involves a credible out-of-the-equilibrium threat to the incumbent of facing a low access price if there is no investment: $\alpha^o < \alpha^o_\omega$. This induces the incumbent to invest. Second, if the investment cost takes intermediate values, i.e., if k is on $(K_1, K_2]$, the legislator gives relatively more weight to consumer surplus if there is no-investment, $\theta^o_c > 1$, and gives relatively more weight to the incumbent's profit if there is investment, $\theta^n_i > 1$. In other words, now the legislator not only threatens the incumbent with a low access price if there is no-investment, $\alpha^o < \alpha^o_\omega$, but also rewards the incumbent with a high access price if there is investment $\alpha^n > \alpha^n_\omega$. Again the incumbent invests. Third, if the investment cost is high, i.e., if k is on $(K_2, K_\omega]$, it is impossible to induce investment, or the distortions the legislator needs to impose to induce investment are too high. Hence, the legislator gives the same weight to the payoff of all parties, whether there is investment or not, and the incumbent does not invest.

Note that in any case, when k is on $(K_\omega, +\infty)$ investment is not a *first-best.* Hence, the legislator gives the same weigh to the payoffs of all parties, whether there is investment or not, to discourage investment.

Summing up, the legislator, by setting the weights to the regulator objective function, induces the regulator to choose an access price after investment equal to the one of an hypothetical regulator able to commit to an access price before investment.

4.6 Consumer Surplus

Next we determine if consumers are better off with the possibility of the regulator giving relatively more weight to the incumbent's profits than to the payoffs of the other parties.

According to Proposition 1, the legislator will only give relatively more weight to the incumbent's profit if (A6):(b) holds, and in particular, only for k on $(K_1, K_2]$. In this case, the legislator gives more weight to the incumbent's profit if there is investment to induce the regulator to set the access price above the *first-best* level.

Compared to a context where the weights given to the players' payoffs are all equal, it is optimal for consumers that the legislator gives relatively more weight to the incumbent's profit if:

$$\Delta CS\left(k\right) = CS\left(\alpha_r^n(\widehat{\theta}_i^n\left(k\right), 1), \Omega\right) - CS\left(\alpha_\omega^o, 0\right) \geq 0.$$

A necessary condition for the above to hold for k on $(K_1, K_2]$ is that consumers benefit from investment when the regulator maximizes the social welfare function and sets $\alpha^n = \alpha_\omega^n$, i.e., if $\Delta CS\left(K_1\right) > 0$. This motivates the next assumption.

(A7) Let $\Delta CS\left(K_1\right) > 0$. ■

Denote by K_c, the highest level of investment cost for which consumers are indifferent between buying services if there is investment when the legislator gives relatively more weight to the incumbent's profit, $\widehat{\theta}_i^n\left(k\right) > 1$, and buying services if there is no investment when the access price equals α_ω^o:

$$\Delta CS\left(K_c\right) \equiv 0.$$

The next Lemma presents the range of parameters for which consumers are better off with the policy of giving relatively more weight to the incumbent's profits to induce investment.

Lemma 4: *Let **(A1)** to **(A4)**, **(A5):(a)**, **(A6):(b)** and **(A7)** hold.*

(i) *if* $\Delta CS\left(K_2\right) \geq 0$, *consumer surplus does not decrease when the legislator sets* $\theta_i^n = \widehat{\theta}_i^n(k)$, *instead of* $\theta_i^n = 1$, *for all* k *on* $(K_1, K_2]$;

(ii) *if* $\Delta CS(K_2) < 0$, *consumer surplus does not decrease when the legislator sets* $\theta_i^n = \widehat{\theta}_i^n(k)$ *for* k *on* $(K_1, K_c]$, *and decreases for* k *on* $(K_c, K_2]$.

Proof: Given assumption (A4), and knowing, by Lemma 1, that $\alpha_r^n(\boldsymbol{\theta})$ is non-increasing in $\widehat{\theta}_i^n$, which is non-decreasing in k, we have: $\frac{d\Delta CS(k)}{dk} \leq 0$. Assuming that $\Delta CS(K_1) > 0$, then $\Delta CS(K_2) \geq 0$ implies $\Delta CS(k) \geq 0$, for all $k \in (K_1, K_2]$. If $\Delta CS(K_2) < 0$, there is a K_c such that $\Delta CS(K) < 0$, if and only if, $K > K_c$. ■

If $\Delta CS(K_2) \geq 0$, consumers will never be worse off if the regulator gives relatively more weight to the incumbent's profit. Otherwise, consumer surplus may decrease or increase. If the investment cost is low, the distortions in the access price resulting from the legislator setting a higher weight to the incumbent's profit to induce investment are also low. Hence, consumers are better off with this policy, despite having to pay higher retail prices, because they consume higher quality services. If the investment cost is high, the distortions required to induce investment are higher, and therefore retail prices are also higher, and consumers may be worse off despite the fact that they now have higher quality services available.

4.7 Examples

In this Section we present two models of the regulation literature that fulfill our assumptions on payoffs.

4.7.1 Hotelling with Negatively Sloped Demands

The first example we present is similar to the one of Biglaiser and DeGraba (2001) and Brito et al. (2010). This model assumes consumers are uniformly distributed along a Hotelling line, facing transportation costs tx to travel distance x. Each consumer has a demand function given by $q_j = (z + \chi^v) - p_j$, where q_j is the number of units purchased from firm $j = i, e$, p_j is the per unit price of the services of firm j, and z is a demand parameter, assumed to be sufficiently large. Moreover, assume the incumbent's wholesale marginal cost is constant and equal to c, while its retail activities have a zero marginal cost. The entrant has marginal costs α^v on $\{\alpha^o, \alpha^n\}$ if it uses network $v = o, n$. Firms charge consumers two-part *retail tariffs*.

This full-consumer participation model verifies our assumptions (A1) to (A4), (A5):(a) and (A7), and the entrant's profits are invariant to investment. The *first-best* access price is equal to marginal cost, for which the incumbent's profits, gross of investment cost, are positive but invariant to investment. Hence, if the legislator sets the regulator's objective function to be equal to social welfare, the incumbent will not invest for any k, i.e., $K_0 = 0$. When the legislator is able to set weights conditional on the investment decision, it must introduce distortions if there is investment when $k > K_1 = \frac{1}{2}t$. Investment is not a *first-best* for $k > K_\omega = \frac{1}{2}\Omega\left(2\left(z-c\right)+\Omega\right)$. Hence, (A6):(a) holds, if and only if, $t > \Omega\left(2\left(z-c\right)+\Omega\right)$.

The same base model can be used for an example of investment in cost reduction. In this case, we would have a reduction in the marginal cost c of $\chi^n = \Omega$ in the case of investment. Again, the *first-best* access price is equal to marginal cost, i.e., in case of no-investment $\alpha_\omega^o = c$, and in case of investment $\alpha_\omega^n = c - \Omega$. Hence, the incumbent's profits are invariant to investment at the *first-best* access price, i.e., $K_0 = 0$, and the legislator needs to punish the incumbent for not investing. For $k > K_1 = \frac{1}{2}t$ it must additionally reward the incumbent for investing. Again, (A6):(a) holds, if and only if, $t > \Omega\left(2\left(z-c\right)+\Omega\right)$.

4.7.2 Quantity Competition with Complete Spillovers

Consider now a model similar to the one presented in Foros (2004) and Kotakorpi (2006). Assume consumers have unit demands and are heterogeneous in their basic willingness to pay. This model is of partial consumer participation and gives origin to demand functions $p_j = z_j + \chi^v - q_j - q_{j'\neq j}$, where q_j is the number of units purchased from firm $j = i, e$, p_j is the per unit price of the services of firm $j = i, e$, z_j is the reservation price of firm $j = i, e$. The model in Foros (2004) assumes incomplete spillovers, but for now we will assume that spillovers are complete so that both demand functions increase by Ω with investment. Regarding the supply side, we make the same assumptions as in the example of section 4.7.1. Firms charge consumers linear *retail tariffs*.

This model verifies our assumptions (A1) to (A4), (A5):(a) and (A7). If firms are symmetric, i.e. $z_i = z_e = z$, then the *first-best* access price is such that the incumbent's participation constraint is binding, i.e. $\alpha_\omega^v = \underline{\alpha}^v$, and it is impossible for the regulator to punish the incumbent in the case of no-investment. This implies that $K_1 = K_0 = 0$. Thus (A6):(b) holds for all parameter values, and the legislator has necessarily to give a higher weight to the incumbent's profit in case of investment whenever it wants to induce investment. If, on the other hand, the incumbent has a sufficiently high initial quality advantage over the entrant, i.e. $z_i > z_e$, the *first-best* access price is such that the incumbent obtains positive profits, thus both K_0 and K_1 are positive. If the incumbent's advantage is sufficiently high, i.e. $z_i > z_e + \frac{z_e - c}{3}$, even when maximizing social welfare, the regulator prefers to induce a monopoly, i.e. $\alpha_\omega^v = \alpha_M^v$, thus $K_2 = K_1$.

Again, similar results hold for an investment in cost reduction.

5 Extensions

In this section we present three extensions to the model. In the first extension there may be over-investment. In the second extension the legislator is unable to set weights conditional on the investment decision of the incumbent. In the third extension the regulator sets retail prices, instead of access prices.

5.1 Over-investment

Next we will analyze the case of *over-investment*.

Consider the model of section 3 and assume that (A5):(b) holds, i.e., that $K_0 > K_\omega$. In this case, (A6):(a) necessarily holds since $K_1 \geq K_0$.

As we argued before, under these circumstances, and whenever k is on $(K_\omega, K_0]$, for the *first-best* access prices, $(\alpha_\omega^n, \alpha_\omega^o)$, there is *over-investment*. Hence, the legislator should dissuade the incumbent from investing.

Following the same reasoning as before, the legislator discourages the incumbent to invest with the threat of a low access price if there is investment.

The next Lemma summarizes the legislator's optimal policy.

Lemma 5: *Let **(A5):(b)** hold, and assume k is on $(0, K_0]$:*

(i) If k is on $(0, K_\omega]$, the legislator sets the weights $\boldsymbol{\theta}^n = (1,1)$ and $\boldsymbol{\theta}^o = (1,1)$, the incumbent invests, and the regulator sets access price $\alpha^n = \alpha_\omega^n$.

(ii) If k is on $(K_\omega, K_0]$, the legislator sets the weights $\boldsymbol{\theta}^n = \left(1, \overline{\theta}_c^n\right)$ and $\boldsymbol{\theta}^o = (1,1)$, the incumbent does not invest, and the regulator sets access price $\alpha^o = \alpha_\omega^o$. ■

If the investment cost is high, the legislator gives more weight to the consumer surplus if there is investment, $\theta_c^n = \overline{\theta}_c^n > 1$, threatening with a low access price: $\alpha^n < \alpha_\omega^n$. This dissuades the incumbent from investing.

Example: Quantity Competition with Incomplete Spillovers

Over-investment generally occurs if the business stealing effect of investment is very strong. This is the case if investment has incomplete spillovers, i.e., if investment benefits more the quality of the incumbent's services than the quality of the entrant's services.

Consider the same model as in section 4.7.2, but now assume that the incumbent's investment increases its demand by Ω, but only increases the entrant's demand by $\beta\Omega$, with

$0 < \beta < \frac{3\Omega-(z-c)}{4\Omega} < 1$ and $\Omega > \frac{z-c}{3}$. In this case, investment allows the incumbent to become a monopolist. In fact, investment not only allows the incumbent to win a quality advantage over the entrant, but it also leads the *first-best* access price to be such that the entrant does not enter the market. This happens because, since the incumbent now has a quality advantage, it is socially preferable to have more consumers buying services from the incumbent than from the entrant.

Since without investment the *first-best* access price is such that the incumbent earns zero profits, while after investment it is such that it becomes a monopolist, the incentives to invest by the incumbent are very high. On the contrary, the social gains of investment, although positive, are not very high since investment induces the entrant to stay out of the market. Therefore, for k on $\left(\frac{3\Omega(2(z-c)+\Omega)-(z-c)^2}{8}, \frac{(z+\Omega-c)^2}{4}\right]$, the incumbent invests for the *first-best* access prices, but investment is not a *first-best*. Hence, the legislator should dissuade the incumbent from investing by giving more weight to the consumer surplus.

5.2 Investment Independent Weights

Next, we consider the case where the legislator is constrained to write simple laws. More specifically, the legislator is unable to set the weights of the regulator's objective function conditional on the incumbent's investment decision.

Consider the model of section 3 except that the legislator is unable to set the weights of regulator's objective function conditional on the incumbent's investment decision. The equilibrium of the two last stages of the game remains unchanged. Hence, we will only analyze the first two stages of the game.

5.2.1 Investment Decision

In this case the legislator's choice variables available are: $\boldsymbol{\theta} := (\theta_i, \theta_c)$. The incremental profit of the investment, gross of the investment cost, is then given by:

$$\Delta\widetilde{\Pi}_i(\boldsymbol{\theta}) := \Pi_i(\alpha_r^n(\boldsymbol{\theta}), \Omega) - \Pi_i(\alpha_r^o(\boldsymbol{\theta}), 0) \tag{7}$$

Investment occurs if:

$$\Delta\widetilde{\Pi}_i(\boldsymbol{\theta}) \geq k.$$

Contrary to the scenario where the legislator sets weights conditional on the investment decision, the relationship between the incremental profit of investment and the weights of the regulator's objective function is not straightforward. In fact, the higher the weight for consumer surplus (incumbent's profit) set by the legislator, the lower (higher) the access price the regulator will set both to network v and o.

The next Lemma describes how the incremental profit of investment varies with the weights for consumer surplus and the incumbent's profit.

Lemma 6: *Given $\boldsymbol{\theta}$, value $\Delta\Pi_i(\boldsymbol{\theta})$ is **(i)** non-decreasing in θ_i, if and only if,*

$$g(\alpha, \boldsymbol{\theta}) := \frac{\frac{\partial \Pi_i(\alpha,\Omega)}{\partial \alpha}}{\frac{\partial \Pi_i(\alpha,0)}{\partial \alpha}} - \frac{\frac{\partial \alpha_r^o(\boldsymbol{\theta})}{\partial \theta_i}}{\frac{\partial \alpha_r^n(\boldsymbol{\theta})}{\partial \theta_i}} \geq 0;$$

*and, **(ii)** is non-decreasing in θ_c, if and only if,*

$$f(\alpha, \boldsymbol{\theta}) := \frac{\frac{\partial \Pi_i(\alpha,\Omega)}{\partial \alpha}}{\frac{\partial \Pi_i(\alpha,0)}{\partial \alpha}} - \frac{\frac{\partial \alpha_r^o(\boldsymbol{\theta})}{\partial \theta_c}}{\frac{\partial \alpha_r^n(\boldsymbol{\theta})}{\partial \theta_c}} \leq 0.$$

Proof: Follows immediately from the derivative of (7), assumption (A3) and Lemma 1. ■

Since investment implies a higher number of units sold by the incumbent's wholesale unit, we expect the impact of an increase in the access price on the incumbent's profit to be larger if there is investment than if there is no investment, i.e. $\frac{\partial \Pi_i(\alpha,\Omega)}{\partial \alpha} \geq \frac{\partial \Pi_i(\alpha,0)}{\partial \alpha}$. Assuming this condition holds, which is true for both models of section 4.7, if the increase in the access price caused by a higher weight for the incumbent's profit is higher if there is investment, the incentives to invest are higher if the legislator sets a higher θ_i. On the other hand, a negative $f(\alpha, \boldsymbol{\theta})$ can only be possible if $\left|\frac{\partial \alpha_r^o(\boldsymbol{\theta})}{\partial \theta_c}\right|$ is sufficiently higher than $\left|\frac{\partial \alpha_r^n(\boldsymbol{\theta})}{\partial \theta_c}\right|$. If, on the contrary, $\left|\frac{\partial \alpha_r^o(\boldsymbol{\theta})}{\partial \theta_c}\right| < \left|\frac{\partial \alpha_r^n(\boldsymbol{\theta})}{\partial \theta_c}\right|$, then $f(\alpha, \boldsymbol{\theta}) \geq 0$, i.e., whenever the negative impact of a higher weight for consumer surplus in the access price is higher if there is investment, the incentives to invest are lower if the legislator sets a higher θ_c.

5.2.2 Legislator's Decision

Denote by $\Delta\widetilde{W}(\boldsymbol{\theta}) := W(\alpha_r^n(\boldsymbol{\theta}), \Omega) - W(\alpha_\omega^o, 0)$, the incremental social welfare of investment, given $\boldsymbol{\theta}$. Denote by $\widetilde{K}_\omega$, the highest level of the investment cost for which investment increases welfare, given $\boldsymbol{\theta} = (1,1)$:

$$\Delta\widetilde{W}(1,1) - \widetilde{K}_\omega \equiv 0.$$

and denote by $\widetilde{K}_0$, the highest level of the investment cost for which the incumbent invests, given $\boldsymbol{\theta} = (1,1)$:

$$\max\left\{0, \Delta\widetilde{\Pi}_i(1,1)\right\} - \widetilde{K}_0 \equiv 0.$$

Note that $\widetilde{K}_\omega = K_\omega$ and $\widetilde{K}_0 = K_0$ since $\Delta\widetilde{W}(1,1) = \Delta W(1,1)$ and $\Delta\widetilde{\Pi}_i(1,1) = \Delta\Pi_i(1,1,1,1)$.

The legislator can induce investment with no distortions if k is on $\left(0, \widetilde{K}_0\right]$, i.e., if the investment cost is sufficiently low compared to the incremental revenue of investment at the *first-best* access prices. Hence, it will only need to distort the weights of the regulator's objective function to induce investment for k on $\left(\widetilde{K}_0, +\infty\right)$.

Given (A5):(a), and assuming that $g(\alpha, \boldsymbol{\theta}) \geq 0$ and $f(\alpha, \boldsymbol{\theta}) \geq 0$, which holds, for instance, in the example presented in section 4.7.2, $\Delta\widetilde{\Pi}_i(\boldsymbol{\theta})$ is maximized at $\Delta\widetilde{\Pi}_i(\overline{\theta}_i^v, 1)$. Therefore, it is only possible to induce investment if k is on $\left(0, \Delta\widetilde{\Pi}_i(\overline{\theta}_i^v, 1)\right]$. Moreover, for a sufficiently high investment cost, the legislator must give relatively more weight to the incumbent's profit to induce investment. Hence, for k on $\left(0, \Delta\widetilde{\Pi}_i(\overline{\theta}_i^v, 1)\right]$ denote by $\widehat{\theta}_i(k)$ the lowest weight to the incumbent's profit that maximizes welfare, given that the incumbent invests:

$$\widehat{\theta}_i(k) = argmax_{\theta_i} \left\{ W(\alpha_r^n(\theta_i, 1), \Omega) \,\middle|\, \Delta\widetilde{\Pi}_i(\theta_i, 1) \geq k \right\}. \tag{8}$$

Finally, define $\widetilde{K}_2$ by:

$$\widetilde{K}_2 := max \left\{ k \,\middle|\, \Delta W(\widehat{\theta}_i(k), 1) \geq k \right\}.$$

For k on $\left(\widetilde{K}_0, \widetilde{K}_2\right]$, when trading-off the distortion in the retail market caused by a high access price and the benefits of investment, the legislator still prefers to induce investment. In this case, it sets a weight such that the regulator chooses a high access price. For k on $\left(\widetilde{K}_2, \widetilde{K}_\omega\right]$, the distortions caused by the high access price outweigh the social benefits of investment or investment is impossible to induce. Hence, the legislator does not encourage investment, and sets the regulator objective function to be equal to social welfare.

Proposition 2 presents the equilibrium of the whole game.

Proposition 2: *Let **(A1)** to **(A4)**, **(A5):(a)**, $g(\alpha, \boldsymbol{\theta}) \geq 0$ and $f(\alpha, \boldsymbol{\theta}) \geq 0$ hold. If the legislator cannot set weights conditional on investment:*

(i) if k is on $\left(0, \widetilde{K}_0\right]$, the legislator sets weights $\boldsymbol{\theta} = (1,1)$; the incumbent invests; and the regulator sets access price $\alpha^n = \alpha_\omega^n$;

(ii) if k is on $\left(\widetilde{K}_0, \widetilde{K}_2\right]$, the legislator sets weights $\boldsymbol{\theta} = \left(\widehat{\theta}_i(k), 1\right)$; the incumbent invests; and the regulator sets access price $\alpha^n = \alpha_r^n(\widehat{\theta}_i(k), 1)$.

(iii) if k is on $\left(\widetilde{K}_2, +\infty\right)$, the legislator sets weights $\boldsymbol{\theta} = (1,1)$; the incumbent does not invest; and the regulator sets access price $\alpha^o = \alpha_\omega^o$.

Proof: Follows from Lemmas 1 and 2 and the discussion above. ■

If $f(\alpha, \boldsymbol{\theta}) \leq 0$ for every $\boldsymbol{\theta}$, i.e., if increasing the weight for consumer surplus increases the marginal benefit of investment, it may, alternatively, be optimal for the legislator to give a higher weight to consumer surplus. If $g(\alpha, \boldsymbol{\theta}) \leq 0 \leq f(\alpha, \boldsymbol{\theta})$, for every $\boldsymbol{\theta}$, i.e., if increasing the weight for the incumbent's profits or for consumer surplus does not increase the incentives to invest, the legislator is unable to induce investment, for any k on $\left(\widetilde{K}_0, +\infty\right)$.

5.2.3 Comparison

Next we compare the scenarios where the legislator can set weights conditional on investment and where it cannot. To make the welfare comparison easier, we present in Figure 1 the equilibrium of the two scenarios for the case where (A6):(b), $f(\alpha, \boldsymbol{\theta}) \geq 0$ and $g(\alpha, \boldsymbol{\theta}) \geq 0$ hold.

$[Figure\ 1]$

Obviously, welfare is higher in the first scenario since the legislator has a higher number of instruments. In fact, while in the first scenario, if k is on $(K_0, K_1]$, the legislator can induce investment with no distortions, i.e., with an access price equal to α_ω^n, in the second scenario the incumbent only invests if the legislator gives a relatively higher weight to the incumbent's profit so that the regulator sets a higher access price. Moreover, we have $\widetilde{K}_2 \leq K_2$ and $\widehat{\theta}_i(k) \geq \widehat{\theta}_i^n(k)$. With investment-conditional weights the legislator can punish the incumbent with zero profits if there is no-investment, while with investment-independent weights it cannot. Hence, for a given k, the distortions introduced in the access price to induce investment are lower in the first scenario. This implies that when it is possible to set weights conditional on the investment decision, for a given k, the access price after investment will be lower and that inducing investment is the optimal policy for more values of k.

5.3 Retail Regulation

Until now, our analysis was all based on a model where the regulator sets the access price, i.e., regulates the wholesale market. This is presently the most common regulation policy adopted in western countries. However, when open access is not possible, and thus entry in the retail market not viable, the regulator may maximize its objective function by setting directly the retail price of the incumbent's services. In this case, the legislator induces a given retail price by choosing the weights in the regulator's objective function.

Given assumptions (A1) to (A7), our results still hold if α^v is interpreted as the retail price or a price cap on the retail price.

Example: Monopoly Regulation

Consider the model of a regulated monopolist with a demand is given by $Q(p, \chi^v)$ and marginal cost c. The monopolist's profit is then given by:

$$\pi = (p - c)\, Q(p, \chi^v),$$

and consumer surplus by $u(q, \chi^v) - pq$, with $\frac{\partial^2 u}{\partial q^2} < 0 < \frac{\partial u}{\partial q}$ and $\frac{\partial u}{\partial \chi^v} > 0$. Again, χ^v is a parameter that takes value 0 if $v = 0$ and takes value Ω on $(0, +\infty)$ if $v = n$.

This model verifies the assumptions (A1) to (A4), (A5):(a) and (A6):(b). The *first-best* retail price is equal to marginal cost, for which the monopolist obtains zero profits. Hence, $K_1 = K_0 = 0$, and the legislator has necessarily to give a higher weight to the incumbent's profit in case of investment whenever it wants to induce investment, as in Evans et al. (2008).

The same reasoning applies for an investment in cost reduction.

6 Concluding Remarks

In many regulated industries, the regulatory policy must trade-off static and dynamic efficiency. This trade-off generates a dynamic consistency problem, which in the absence of the ability to commit to a policy by the regulator, may reduce investment.

In this article we explore the separation of powers between the legislative and the executive branch of the government as a way of overcoming this dynamic consistency problem of regulatory policy towards investment. We derive general conditions under which, having the legislator distort the regulator's objective functions away from social welfare allows increasing the range of parameter values for which it is possible to induce socially desirable investment.

We conclude that, in the presence of a dynamic consistency problem of the regulatory policy towards investment, it may be socially optimal to give relatively more weight to the incumbent's profit in the regulator's objective function, if the incumbent invests, and relatively more weight to consumer surplus, if the incumbent does not invest. Such a policy allows inducing socially desirable investment in conditions under which it would not otherwise be possible. If the weights of the regulator's objective function cannot be set conditional on the incumbent's investment decision, the policy is less effective in terms of promoting investment, although it is still welfare improving to give relatively more weight to the incumbent's profit.

These results are in line with some recent decisions by various legislative bodies. For instance, the European Commission indicated that national regulators should add a risk premium to the access prices of Next Generation Networks (European Commission, 2010). This represents a deviation from the cost-oriention principle applied to the old copper networks. The new policy intends to signal to telecommunications firms that the returns to their investments in these networks will be protected. This type of policy has also been reported by Trillas and Staffiero (2007), who point to evidence that in many developing countries, and especially in Latin America, some degree of industry-orientation has been necessary to attract foreign capital in the utilities sector.

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Figures

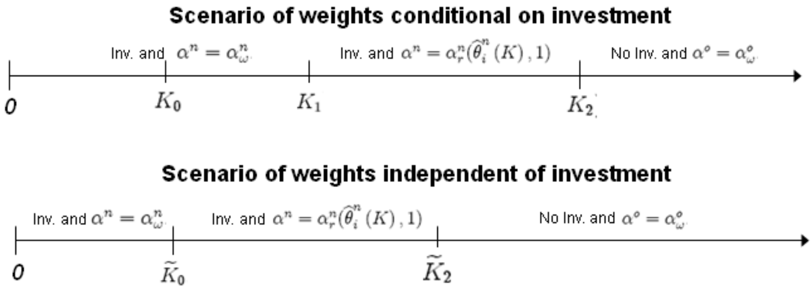

Figure 1: The equilibrium of the two scenarios for $f(\alpha, \boldsymbol{\theta}) \geq 0, g(\alpha, \boldsymbol{\theta}) \geq 0$.