Investment and capital structure of partially private regulated firms

Carlo Cambini*

Politecnico di Torino

Laura Rondi†

Politecnico di Torino and CERIS-CNR

Yossi Spiegel‡

Tel Aviv University and CEPR

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Abstract

Since the early 1990's, regulated utilities in the EU have substantially increased their debt levels. In this paper we develop a theoretical model that sheds light on this trend. The model examines the capital structure and investment decisions of regulated utilities and explicitly takes into account two key institutional features of the public utilities sector in the EU: partial ownership of the state in the regulated firm and regulation by agencies with various degrees of independence. The main goal is to derive testable hypotheses about the effects of these features on capital structure, regulated prices, and investment decisions.

JEL Classification:

*Politecnico di Torino, DISPEA, Corso Duca degli Abruzzi, 24, 10129 Torino, Italy. Tel: + 39-0115647292, email: *carlo.cambini @polito.it.*

†Politecnico di Torino, DISPEA, Corso Duca degli Abruzzi, 24, 10129 Torino, Italy and CERIS-CNR. Tel: +39-0115647232, email: *laura.rondi@polito.it, http://www.ceris.cnr.it/Rondi.htm*

‡Recanati Graduate School of Business Administration, Tel Aviv University, Ramat Aviv, Tel Aviv, 69978, Israel, email: *spiegel@post.tau.ac.il, http://www.tau.ac.il/~spiegel*

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1 Introduction

Since the early 1990's, the public utilities sector in the European Union has gone through substantial structural reforms that included large privatizations of state-owned utilities and the establishment of independent agencies to regulate public utilities. The reforms were promoted by the European Commission in an attempt to improve the efficiency and service quality of EU utilities and boost their investments. The extent of the reforms however varies considerably across member states and across industries. The reforms are most advanced in the telecommunications and energy sectors where independent regulatory agencies (IRA's) have been established in virtually all member states in the last 20 years and most of the companies are (at least partially) privatized. The reforms are also advanced in the energy sector where electric and gas utilities are subject to regulation by IRA's in most member states, though large utilities in some states are still controlled by the state especially in the natural gas industry. By contrast, the structural reforms in the water and transportation sectors are still in early stages; with the exception of the U.K., most water and transportaton utilities are still controled by central and local governments and utilities are still subject to regulation by ministries or other branches of the government rather than by an independent regulatory agencies (IRA).

The role of ownership and the degree of regulatory independence play a fundamental role in utilities and especially in utilities' investment decisions. The uncertainty in the regulatory framework and rules could deprive utilities' incentive to invest, especially when investments are both irreversible and risky (Guthrie, 2006). When regulators cannot commit to long-term regulated prices, they may have an incentive to cut prices, once the firm's investments are sunk, in order to benefit consumers at the expense of the firm's owners.

Public ownership could, at least in principle, alleviate the regulatory opportunism through the direct control of the firm, but it could also exacerbate it especially when the government's agenda changes over time for (typically short-term) political purposes. Economic literature[1] has deeply analysed the time-inconsistency problem in regulation (the so called hold up problem). As shown by Sappington and Stiglitz (1987), both privatization

[1]See for example Newbery (1999; ch. 2) and the survey by Armstrong and Sappington (2007).

and independent regulation enhance the commitment powers of regulators rendering more credible the policy maker's interventions. The institutional and political framework also affects the regulatory commitment power. Laffont and Tirole (1991) show that under state ownership, the government could force the regulator to use assets for policy purpose (i.e. extending the universal service obbligation or providing the service in non commercial areas) instead of for profit and this choice could generate a serious commitment problem. On the contrary, if the utility is privately owned the double control by shareholders, on one side, and by the regulator, on the other side, provide the manager an incentive to properly invest.

Firms' behaviour could also affect regulatory decisions. Since the possibility of capture is a well recognized feature of regulated utilities, firms could lobby regulators in order to limit their ex post opportunism (Evans *et al.*, 2008). However, and this is the issue of this paper, firms could also use *financial* variables to affects regulatory outcomes and limits regulatory opportunism. High leverage can shield regulated firms against regulatory opportunism because then regulators may wish to keep prices relatively high in order to minimize the risk of financial distress (see e.g., Taggart 1981, Spiegel and Spulber, 1994 and 1997, and Spiegel, 1994 and 1996). Hence, debt financing may lead to higher regulated prices and may therefore encourage regulated firms to increase their investment levels. The relevance of the problem has been recently recognized also by governamental institutions. In the U.K., a joint study of the Department of Trade and Industry (DTI) and the HM Treasury (DTI-HM, 2004) has expressed a concern about the high leverage of U.K. utilities and argued that it "could imply greater risks of financial distress, transferring risk to consumers and taxpayers and threatening the future financeability of investment requirements" (DTI-HM, 2004, p. 6).[2] Similarly, Ofgem (2008) expresses concerns on the increase in leverage by transport electric utilities and start investigating how to intervene in case of finanancial distress.

The high leverage of privately-owned regulated utilities is a well-known and well-documented phenomenon in the U.S., where large utilities were always privately owned and subject to rate regulation by state and by federal regulatory commissions since the 1910's.[3] It is therefore not surprising to see a similar trend in Europe. Yet, the European

[2]For a related report, see Ofwat and Ofgem (2006).

[3]See for example, Bowen, Daly and Huber (1982), Bradley, Jarrell, and Kim (1984), and Barclay, Marx,

context differs from that in the U.S. because many European utilities are still owned, at least partially, by central or local governments, and because, as mentioned above, many European utilities are not yet subject to regulation by IRAs. Notwithstanding these institutional differences, existing theory was established under the implicit assumption that regulated firms are privately owned and subject to regulation by IRAs. The question is whether the theory carries over to the case where firms are at least partially owned by the government and subject to regulation by non independent regulators. Recent empirical evidence (Bortolotti *et al.*, 2008) indeed suggests that the interaction between capital structure and regulation critically depends on two factors: (i) regulatory framework, i.e., whether firms are subject to regulation by an IRA or not, and (ii) the ownership structure, i.e., whether firms are privately- or state-controlled. The purpose of this paper is to theoretically analyse how these two factors affect the interaction between capital structure and investments of regulated firms.

To this end, we modify the Spiegel (1994) and Spiegel and Spulber (1997) models on the interaction between price regulation, capital structure, and investment to account for partial ownership of the regulated firm by the state and for the presence of regulation by a non independent regulatory agency. More specifically, we formalize the state intervention using the so called *managerially-oriented public enterprise* (MPE) approach, due to Sappington and Sidak's (2003, 2004), and, as suggested in Levy and Spiller (1994), we assume that an higher degree of regulatory independence improves the regulators' ability to make long-term commitments to regulatory policies and therefore that ex post the sunk investment is less likely expropriated through a cut in retail prices. In addition, we analyse firm's leverage, i.e. on the ratio between debt and debt plus equity, and how it is affected by the degree of regulatory independence, the ownership status and the regulatory climate.

Our results could be summarized as follows. First, as expected, the utility invests more when the regulator is independent, i.e. he has a greater commitment ability, but it invests less than the social optimal level. Interestingly, however, this positive effect of regulatory independence on investment is present only if the degree of independence is above some threshold level, while for low levels of independence the firm's incentive to invest

and Smith (2003).

is independent of the degree of regulatory independence. Therefore, when the degree of independence is very small, there is a complete lack of credibility in the regulator's behavior and the firm investment's decisions are thus independent from his choice. The equilibrium level of investment is also decreasing with the state's ownership stake and with a measure of regulatory clmate, i.e. the regulator's propensity of being more pro-consumers than pro-firm: the higher is the government's stake (and similary the regulatory climate), the lower is the regulated price and this in turn reduces the incentive to invest.

Second, the firm's debt level and the regulated price are also affected by ownership and regulatory independence. Both variables (debt and regulated price) are higher when the regulator is independent and they are both decreasing with state's ownership and with the measure of regulatory climate. The results on regulated price - that is higher when the regulator is independent - is conterintuitive, since an independent regulator is supposed to have a greater ability to commit to certain level of price. However, precisely for this reason, the regulated firm issues debt with larger face value when the regulator is independent (but not fully committed) in order to induce the regulator to raise the regulated price. On the other hand, when the regulator is not independent, the firm issues debt with smaller face value which induces the regulator to set a regulated price which is never updates. The regulated firm will issue less debt the larger is the state's stake in the firm and the more pro-consumer the regulator is: When the state's stake in the firm is larger, the firm behaves as if it ignores a larger fraction of its costs; consequently, the regulated price is lower at each level of debt. Moreover, the effects of the state's ownership stake and the regulatory climate on the firm's debt are larger when the firm is subject to regulation by an independent regulator. These results imply that (i) privately-controlled regulated firms should issue more debt than state-controlled firms, and this is particularly true if they are subject to regulation by an independent regulator, and (ii) regulated firms that operate in more pro-firm environment should issue more debt than otherwise similar firms operating in more hostile regulatory environment, especially when facing an independent regulator.

The rest of the paper is organized as follows. Section 2 presents the model. The rate setting process is considered in Section 3 and the equilibrium regulated price is characterized. In Section 4 we solve for the equilibrium choice of capital structure and study how it is affected by the main exogenous parameters of the model, namely the degree regulatory independence, the state's stake in the regulated firm and the measure of regulatory climate (how pro-consumers or pro-firm the regulator is). In Section 5 we consider the firm's investment decision and study how it is affected by the main exogenous parameters of the model. In Section 6 we analyse the equilibrium firm's leverage and its interaction with firm ownership and the degree of regulatory independence. Concluding remarks are in Section 7.

2 The model

Consider a regulated monopoly, which for simplicity (but without a serious loss of insights), faces a unit demand function. The willingness of consumers to pay depends on the firm's investment level, k, and is given by a twice differentiable, increasing, and concave function $V(k)$. That is, k can be interpreted as the "quality" of the firm's product or the range of its services. Using p to denote the regulated price, consumers' surplus is given by $S(k,p) = V(k) - p$.

2.1 The regulated firm's objective

The regulated firm is partially owned by the state (at the national or the local level). The state's stake in the firm's equity is δ. To capture the effect of δ on the firm's behavior, we adopt the managerially-oriented public enterprise (MPE) approach, due to Sappington and Sidak's (2003, 2004).[4] The key assumption in the MPE approach is that the (partially) state-owned firm is concerned not only with profits, π, but also with revenues, R, and its objective function, after its investment k is already sunk, is given by

$$\delta R + (1 - \delta)\,\pi.$$

Ex ante, before k is sunk, the firm is interested in maximizing the same objective function, net of the cost of investment k. Noting that $\pi = R - C$, where C denotes the

[4] For related papers in which the effect of state ownership is modelled by modifying the firm's objective function, see for example, Bös and Peters (1988), De Fraja and Delbono (1989), Fershtman (1990), and Cremer, Marchand and Thisse (1989, 1991).

firm's costs, the (ex post) objective function of the (partially) state-owned regulated firm can also be written as

$$\delta R + (1-\delta)(R-C) = R - (1-\delta)C = \pi + \delta C.$$

(Again, ex ante the firm has the same objective function minus the cost of investment k). That is, the firm effectively behaves as if ignores a fraction δ. This objective function reflects the idea that the managers of state-owned enterprises (and state officials who monitor them) often have considerable interest in expanding the scale or scope of their activities and expand the firm's budget and its labor force either for political reasons (e.g., cater to the needs of special interest groups), or because they wish to signal their ability to run large firms, or because of their desire to realize the power and prestige that often accompany expanded operations. Alternatively, the objective function can simply reflect managerial slack. While managers of fully private, profit-maximizing, firms may have similar interests, the discipline of capital markets, as well as takeover threats, limit their freedom to pursue private interests that do not maximize shareholder value. Of course, the managers of partially state-owned firms are also exposed to these forces but to a lesser extent; the objective function captures that idea that the larger is the state's stake in the firm, the lower is the disciplining force of capital markets, so the firm's cost is more heavily discounted.

2.2 The capital structure of the firm and the expected value of its profit

To model the firm's choice of capital structure, we assume that the firm's cost are subject to random cost shocks and are given by a random variable, c, distributed uniformly over the interval $[0, \widehat{c}]$, where $\widehat{c} < V(0)$. Let D denote the face value of the firm's debt, which the firm needs to cover from its operating income $p - c$. If the firm cannot pay its debt in full, then it incurs a fixed cost T due to financial distress. For a given debt obligation D and a regulated price p, the regulated firm can pay its debt in full if and only if $p - c \geq D$, or $c \leq p - D$. Since c is distributed uniformly on the interval $[0, \widehat{c}]$, the probability of financial distress is given by:

$$\phi(p,D) = \begin{cases} 0 & D + \hat{c} \le p, \\ 1 - \frac{p-D}{\hat{c}} & D \le p < \hat{c} + D, \\ 1 & p < D. \end{cases} \tag{1}$$

Intuitively, when $D + \hat{c} \le p$, the firm can always pay its debt in full so $\phi(p,D) = 0$. On the other hand, when $p < D$, the firm cannot pay its debt in full even when $c = 0$, so $\phi(p,D) = 1$. For intermediate levels of p between D and $\hat{c} + D$, $\phi(p,D) = 1 - \frac{p-D}{\hat{c}}$. Obviously, $\phi(p,D)$ is (weakly) increasing with D and (weakly) decreasing with p: the firm is more likely to be financially distressed when its debt is high and the regulated price is low.

Recalling that the (fixed) cost of financial distress is T, the total expected cost of the firm is $C = \hat{c}/2 + \phi(p,D)T$. Since the firm faces a unit demand function, its revenue is equal to the regulated price, p. Hence, the expected value of the firm's objective function can be written as:

$$\pi + \delta C = \underbrace{p - C}_{\pi} + \delta C = p - (1-\delta)\left[\frac{\hat{c}}{2} + \phi(p,D)T\right].$$

Substituting for $\pi(p,D)$ from equation (1) and rearranging, yields:

$$p - (1-\delta)C = \begin{cases} p - (1-\delta)\frac{\hat{c}}{2} & D + \hat{c} \le p, \\ p - (1-\delta)\frac{\hat{c}}{2} - (1-\delta)\frac{T(\hat{c}+D-p)}{\hat{c}} & D \le p < \hat{c} + D, \\ p - (1-\delta)\frac{\hat{c}}{2} - (1-\delta)T & p < D. \end{cases} \tag{2}$$

2.3 The rate setting process and regulatory independence

Following Spiegel and Spulber (1997), we assume that the regulator chooses the regulated price to maximize a social welfare function which is defined over consumers' surplus, $S(k,p)$, and the firm's objective function. It is often argued that a greater degree of regulatory independence improves the regulators' ability to make long-term commitments to regulatory policies (see e.g., Levy and Spiller, 1994, Gilardi 2005, and the discussion in Edwards and Waverman, 2006). In line with this argument, we capture the regulator's independence by assuming that although the regulator always sets the regulated price before the firm's investment, k, is sunk, he is able to commit to this price only with probability ρ. With probability $1-\rho$, the regulator behaves opportunistically and updates the regulated price after the firm's investment, k, is already sunk.[5] The parameter ρ is therefore our measure of regulatory independence, with a larger value of ρ indicating a larger ability to make long-term commitments and hence a greater degree of independence.

Specifically, we assume that before the firm invests, the regulator takes into account the ex ante objective function of the firm $\pi+\delta C-k$, and sets the regulated price to maximize the social welfare function

$$S(k,p)^{\gamma}(\pi+\delta C-k)^{1-\gamma}. \tag{3}$$

This price remains in effect only with probability ρ. With probability $1-\rho$, the regulator behaves opportunistically and updates the regulated price *after* the firm's investment, k, is already sunk. In that case, the regulator ignores the sunk cost of investment, k, and maximizes the social welfare function

$$S(k,p)^{\gamma}(\pi+\delta C)^{1-\gamma}. \tag{4}$$

The parameter $\gamma \in (0,1)$ captures the regulatory climate: the higher γ is, the more pro-consumer the regulator is. Notice that the regulatory climate and regulatory opportunism are two different parameters: an opportunistic regulator can be pro-firm while a committed regulator could be pro-consumers. Moreover, notice that ex post, it is socially optimal to ignore the sunk cost of investment k when setting rates. Ex ante however, the firm will invest less if it anticipates a higher probability that the regulated price will be updated. Hence, regulatory opportunism leads to lower investment ex ante, but for a given level of investment, it leads to a more efficient price ex post.

Notice that the prices that maximize the social welfare function (3) and (4) allocate the expected social surplus according to the asymmetric Nash bargaining solution for the regulatory process. Hence, our approach is consistent with models that view the rate-setting process as a bargaining problem between consumers and investors (Spulber, 1989; Besanko and Spulber, 1992). Alternatively, the social welfare functions (3) and (4) could represent a reduced form for the regulator's own payoff from being involved in some political economy game. It should also be noted that in our formulation, the government does not play any

[5] See Gausch, Laffont, and Straub (2008) for related work in which governments with lower quality institutions renegotiate concession contracts with higher probability.

direct role in the bargaining process between the firm and the regulator, even if the firm is at least partially owned by the state. The government's involvement with the regulated firm and the regulatory process is reflected only in the firm's objective function, which as mentioned above, is modelled along the MPE approach.[6]

2.4 The sequence of events

The strategic interaction between the firm and the regulator evolves in 3 stages. In stage 1, the regulator sets long-term prices in anticipation of the firm's investment and debt level. In stage 2, the firm chooses its investment level, k, and issues debt with face value D in a competitive capital market. If the funds raised by issuing D are insufficient to finance k, the firm raises additional funds by issuing equity; to simplify matters we assume that in this case the state participates in the equity issue to maintain its original stake δ.[7] In making its choices, the firm takes into account that the stage-1 price will remain valid only with probability ρ. With probability $1-\rho$, the stage-1 price is updated in stage 3 on the basis of k and D that the firm chose in stage 2. Finally, the firm's cost c is realized, output is produced, and payoffs are realized.

3 The regulated price

In stage 1, the regulator sets the regulated price with the objective of maximizing the social welfare function given by (3). Since the firm chooses its investment, k, and debt level, D, only in period 2, the stage-1 regulated price can be viewed as a contingent rule that specifies the regulated price for each pair of k and D that the firm will choose in stage 2. With

[6] In a more general model, the relative bargaining powers of consumers and the firm may also be affected by γ, due to the fact that if the government plays the dual role of a (partial) owner and a regulator, then it will advance the firm's goals at the expense of consumers. For instance, if the firm is fully state-owned, then it is plausible that γ will be much higher than if the firm is fully privatized.

[7] Without this assumption, there would be another link between the investment decision of the firm, its capital structure, and its ownership structure. However, taking this link into account would require a theory of public ownership (i.e., a theory that would endogenize the state's stake in the firm). Such a theory is beyond the scope of the current paper.

probability ρ, the regulator is committed to the stage-1 price and does not update it in stage 3. With probability $1-\rho$, the regulator behaves opportunistically in stage 3 and updates the stage-1 regulated price by maximizing the social welfare function given by (4), which ignores the sunk cost of investment, k.

Given that the social welfare functions in (3) and (4) differ only with respect to whether the regulator takes the firm's investment, k, into account or ignores it, we can rewrite them compactly as

$$S(k,p)^{\gamma}(\pi+\delta C-Ik)^{1-\gamma}, \tag{5}$$

where I is an indicator function which is equal to 1 if the regulator is committed to the stage-1 price and equal to 0 if the regulator behaves opportunistically in stage 3 and updates the stage-1 price. Using (5) we can therefore solve the problems of both committed and opportunistic regulators by simply maximizing (5) with respect to p. Setting $I=1$ will yield the stage-1 regulated price which remains in effect with probability ρ and setting $I=0$ will yield the updated regulated price which is set in stage-3 with probability $1-\rho$. Using the same steps as in Spiegel (1994), the solution to the maximization problem is given by[8]

$$p^{*}(D,k,I)=\begin{cases} D_1\left(k,I\right)+\hat{c} & D\leq D_1\left(k,I\right), \\ D+\hat{c} & D_1\left(k,I\right)<D\leq D_2\left(k,I\right), \\ D_1\left(k,I\right)+\hat{c}+M\left(D,I\right) & D_2\left(k,I\right)<D\leq D_3\left(k,I\right), \\ D_1(k,I)+\hat{c}+\gamma\left(1-\delta\right)T & D>D_3(k,I). \end{cases} \tag{6}$$

where

$$D_1(k,I)\equiv(1-\gamma)\,V(k)+\gamma\left(1-\delta\right)\frac{\hat{c}}{2}+\gamma Ik-\hat{c}, \tag{7}$$

$$M(D,I)\equiv\frac{\gamma\left(1-\delta\right)T\left(D+\frac{\hat{c}}{2}\left(1+\delta\right)-Ik\right)}{\hat{c}+\left(1-\delta\right)T}, \tag{8}$$

$$D_2(k,I)\equiv\frac{D_1\left(k,I\right)\left(\hat{c}+(1-\delta)T\right)+\gamma(1-\delta)T\left((1+\delta)\frac{\hat{c}}{2}-Ik\right)}{\hat{c}+(1-\gamma)(1-\delta)T}. \tag{9}$$

This solution is obtained under the assumption that $\gamma<\frac{V(0)-\hat{c}}{V(0)-(1-\delta)\frac{\hat{c}}{2}}$ (the regulator is not too pro-consumer). If this assumption is violated, then $D_1(k,0)=0$ though none of our results are effected. The regulated price is illustrated in the following figure:

[8] See Spiegel (1994) for a formal proof.

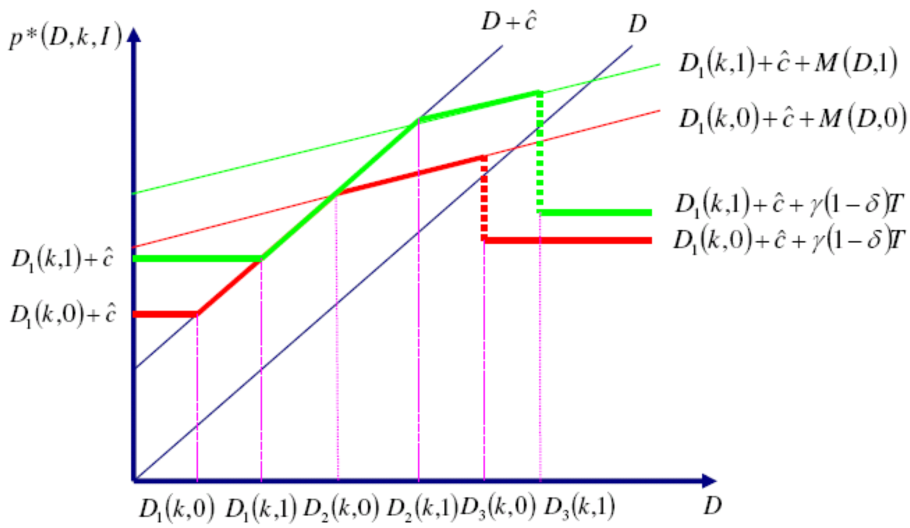

Figure 1: Illustrating the regulated price as a function of D
for I = 0 (in red) and I =1 (in green), holding k fixed

To interpret Figure 1, note that when the regulated price is above $D + \hat{c}$, the firm is immune to financial distress, and when it is below D, financial distress occurs with probability 1. For regulated prices between $D + \hat{c}$ and D, the probability of financial distress is positive but less than 1. Ignoring the possibility of financial distress (i.e., assuming that $\phi(p, D) = 0$), the price that maximizes (5) is given by $D_1(k, I) + \hat{c}$. This price covers the firm's cost plus its debt obligation even in the worst states of nature so long as $D_1(k, I) + \hat{c} \geq D + \hat{c}$, or $D \leq D_1(k, I)$. At this range of debt levels, the probability of financial distress is indeed 0. (As mentioned above, if γ is relatively large, then $D_1(k, I) = 0$). However, once D increases above $D_1(k, I)$, a regulated price of $D_1(k, I) + \hat{c}$ leaves the firm susceptible to financial distress. At this range of debt levels, the regulator finds it optimal to set the regulated price equal to $D + \hat{c}$ in order to keep the probability of financial distress equal to 0. However, when $D_2(k, I) < D < D_3(k, I)$, it is no longer optimal for the regulator to continue and raise the regulated price with D on a 1:1 basis because the resulting marginal loss in consumers' surplus is too large. Therefore, while the regulator continues to increase the regulated price with D, the slope is now less than 1 and consequently, now the firm faces a positive probability of financial distress. When $D > D_3(k, I)$, the firm's debt is so large that it is no longer optimal for the regulator to offset the effect of debt on the likelihood of financial distress. Consequently, financial distress is now inevitable, and hence the regulated price is now constant and equals $D_1(k, I) + \hat{c} + (1 - \delta)T$, where the last term reflects the discounted cost of financial distress (which is now a sure thing).

It is easy to see from equation (7) that $D_1(k, 1) > D_1(k, 0)$, and moreover, it is easy to check that $D_1(k, 1) + \hat{c} + M(D, 1) > D_1(k, 0) + \hat{c} + M(D, 0)$. Hence, the stage-1 regulated price, $p^*(D, k, 1)$, is weakly higher than the stage-3 updated regulated price, $p^*(D, k, 0)$. The reason why $p^*(D, k, 1)$ is not necessarily strictly higher than $p^*(D, k, 0)$ is that both are equal to $D + \hat{c}$ for all $D \in [D_1(k, 1), D_2(k, 0)]$ whenever this interval is non empty. To limit the number of different cases that can arise, we shall assume that the parameter values of the model are such that this interval is indeed non empty:

Assumption 1: $D_1(k, 1) < D_2(k, 0)$.

A sufficient condition for Assumption 1 to hold is that $V(k)$ is sufficiently large:

$$V(k) > \frac{\hat{c}k}{(1-\gamma)(1-\delta)T} + k + (1-\delta)\frac{\hat{c}}{2}.$$

It is now easy to verify that $D_2(k, 0) < D_2(k, 1)$. Together with Assumption 1, we have

$$D_1(k, 0) < D_1(k, 1) < D_2(k, 0) < D_2(k, 1),$$

as illustrated in the Figure 1.

4 The optimal capital structure of the firm

Assuming that the capital market is perfectly competitive, the market value of new equity and debt is exactly equal in equilibrium to their expected return. Hence, outside investors (debtholders and possibly new equityholders if the firm also issues new equity) must break even. This implies in turn that the entire expected profit of the firm, π, net of the sunk cost of investment, k, must accrue to the original equityholders.

Let $\phi^*(D, I) \equiv \phi^*(p^*(D, k, I), D)$ be the probability of financial distress which is obtained by substituting $p^*(D, k, I)$ into equation (1). Since the original equityholders ignore a fraction δ of the firm's cost, their expected payoff is equal to

$$\begin{aligned} Y(D,k) &= \rho\left[\underbrace{p^*(D,k,1)-\frac{\hat{c}}{2}-\phi^*(D,1)T}_{\pi}+\delta\underbrace{\left(\frac{\hat{c}}{2}+\phi^*(D,1)T\right)}_{C}-k\right] \\ &\quad +(1-\rho)\left[\underbrace{p^*(D,k,0)-\frac{\hat{c}}{2}-\phi^*(D,0)T}_{\pi}+\delta\underbrace{\left(\frac{\hat{c}}{2}+\phi^*(D,0)T\right)}_{C}-k\right] \quad (10) \\ &= \rho L(D,k,1)+(1-\rho)L(D,k,0)-(1-\delta)\frac{\hat{c}}{2}-k, \end{aligned}$$

where

$$L(D,k,I)\equiv p^*(D,k,I)-(1-\delta)\phi^*(D,I)T, \qquad I=0,1. \quad (11)$$

The firm chooses its debt level, D, and its investment level, k, to maximize $Y(D,k)$. The following proposition characterizes the equilibrium debt level.

Proposition 1: *In equilibrium, the regulated firm will issue debt with face value $D_2(k,0)$ if $\rho<\rho^*$, and will issue debt with face value $D_2(k,1)$ if $\rho>\rho^*$, where*

$$\rho^*\equiv\frac{(1-\gamma)(1-\delta)T}{\hat{c}+(1-\gamma)(1-\delta)T}.$$

Proof: First, note that $Y(D,k)$ is increasing with D for all $D\leq D_2(k,0)$ because at this range both $p^*(D,k,0)$ and $p^*(D,k,1)$ are (weakly) increasing with D, while $\phi^*(D,0)=\phi^*(D,1)=0$ for all $D\leq D_2(k,0)$. Hence, the firm's debt will be at least $D_2(k,0)$.

Second, notice from equation (6) that for all $D_2(k,I)<D\leq D_3(k,I)$, $p^*(D,k,I)=D_1(k,I)+\hat{c}+M(D,I)$. Substituting this expression in (11) and rearranging terms, yields

$$L(D,k,I)=(1-\gamma)\frac{V(k)(\hat{c}+(1-\delta)T)-(\hat{c}+D)(1-\delta)T}{\hat{c}}+\gamma\left((1-\delta)\frac{\hat{c}}{2}+Ik\right). \quad (12)$$

This expression decreases with D. Moreover, it is easy to see from equation (6) and Figure 1 that the regulated price jumps downward when $D>D_3(k,I)$. Hence, $Y(D,k)$ is decreasing with D for all $D>D_2(k,1)$ implying that the firm will never issue debt with face value above $D_2(k,1)$.

Finally, we need to consider intermediate debt levels between $D_2(k,0)$ and $D_2(k,1)$. Since by Assumption 1, $D_1(k,1) \leq D_2(k,0)$, it follows that at this range, $L(D,k,1) = D + \hat{c}$, and $L(D,k,0)$ is given by the expression in (11) when it is evaluated at $I = 0$. Hence,

$$\begin{aligned}
\frac{\partial Y(D,k)}{\partial D} &= \rho - (1-\rho)\frac{(1-\gamma)(1-\delta)T}{\hat{c}} \\
&= \frac{\hat{c} + (1-\gamma)(1-\delta)T}{\hat{c}}\left[\rho - \underbrace{\frac{(1-\gamma)(1-\delta)T}{\hat{c} + (1-\gamma)(1-\delta)T}}_{\rho^*}\right].
\end{aligned}$$

If $\rho < \rho^*$, then $Y(D,k)$ is decreasing with D in the relevant range, implying that the firm will choose the minimal debt level in the relevant range, namely $D_2(k,0)$. On the other hand, if $\rho > \rho^*$, then $Y(D,k)$ is increasing with D in the relevant range, implying firm will choose the maximal debt level in the relevant range, namely $D_2(k,1)$. ■

Proposition 1 shows that the capital structure of the firm depends on the value of ρ, which, as mentioned above, reflects the degree of regulatory independence. In what follows we will say that the regulator is "independent" if $\rho > \rho^*$ and will say that the regulator is non independent if $\rho < \rho^*$. Proposition 1 shows that the firm will issue more debt when the regulator is independent than when the regulator is non independent. In both cases, if the amount raised by issuing debt is insufficient to cover the cost of investment, the firm will issue new equity (again, we assume that in this case the state participates in the equity issue so as to retain its ownership stake δ which we treat throughout as an exogenous parameter).

It is easy to notice from Figure 1 that at $D = D_2(k,0)$, the regulated price is equal to $D_2(k,0) + \hat{c}$ both when $I = 0$ and when $I = 1$. This price ensures that the firm never becomes financially distressed. On the other hand, at $D = D_2(k,1)$, the regulated price is equal to $D_2(k,1) + \hat{c}$, when $I = 1$, but is below $D_2(k,1) + \hat{c}$ when $I = 0$. Hence, the firm is now immune to financial distress only when $I = 1$, but is susceptible to financial distress when $I = 0$. Moreover, noting the regulated price is independent of the whether $I = 0$ or $I = 1$ at $D = D_2(k,0)$, but is lower when $I = 0$ than it is when $I = 1$ at $D = D_2(k,1)$, we obtain the following corollary to Proposition 1.

Corollary 1: *The stage-1 regulated price is updated downward in stage 3 with probability*

$1-\rho$ if $\rho > \rho^*$ (the regulator is independent), but it is never updated downward in stage 3 if $\rho < \rho^*$ (the regulator is non independent).

Corollary 1 shows that, counterintuitively, the regulated price is updated downward in stage 3 when the regulator is independent but not when the regulator is non independent. This result is counterintuitive because an independent regulator has a greater ability to commit to the stage-1 regulated price. However, precisely for this reason, the regulated firm issues debt with larger face value when the regulator is independent, and at this debt level, the regulated price is updated in stage 3 with probability $1-\rho$. On the other hand, when the regulator is non independent, the firm issues debt with smaller face value which induces the regulator to set a regulated price which is never updates in stage 3.

Using Proposition 1, we can now examine how the debt level that the firm issues in equilibrium is affected by the main exogenous parameters of the model, holding the firm's investment level, k, fixed. Proposition 1 already shows that the firm will issue more debt when the regulator is independent ($\rho > \rho^*$) than when the regulator is non independent ($\rho < \rho^*$). In the next proposition we shall therefore examine how debt is affected by the other main exogenous parameters which are δ (the state's stake in the regulated firm) and γ (the measure of regulatory climate which reflects how pro-consumer the regulator is).

Proposition 2: *Holding the firm's investment, k, constant, the equilibrium level of the regulated firm's debt is decreasing with both the state's ownership stake δ, and with the measure of regulatory climate γ. Both negative effects are stronger when the regulator is non independent than when the regulator is independent.*

Proof: Differentiating $D_2(k,I)$ with respect to δ and with respect to γ, yields:

$$\frac{\partial D_2(k,I)}{\partial \delta} = -\frac{\gamma \hat{c}\left((1-\gamma)(V(k)-Ik)+\frac{\hat{c}^2}{2}\right)}{\left(\hat{c}+(1-\gamma)(1-\delta)T\right)^2} < 0,$$

and

$$\frac{\partial D_2(k,I)}{\partial \gamma} = -\frac{\hat{c}\left(\hat{c}+(1-\delta)T\right)\left(V(k)-Ik-(1-\delta)\frac{\hat{c}}{2}\right)}{\left(\hat{c}+(1-\gamma)(1-\delta)T\right)^2} < 0.$$

The inequalities follow because, as we show in Proposition 4 below, $V'(k) > 1$; since $V(\cdot)$ is increasing and concave, this implies in turn that $V(k) > k$. Recalling that $I = 1$ when the regulator is independent, $I = 0$ when he is not, it is easy to see that $\left|\frac{\partial D_2(k,1)}{\partial \delta}\right| < \left|\frac{\partial D_2(k,0)}{\partial \delta}\right|$ and $\left|\frac{\partial D_2(k,1)}{\partial \gamma}\right| < \left|\frac{\partial D_2(k,0)}{\partial \gamma}\right|$: the negative effects of δ and γ on leverage are stronger when the regulator is non independent. ■

Proposition 2 shows that the regulated firm will issue less debt the larger is the state's stake in the firm and the more pro-consumer the regulator is. Moreover, the effects of the state's ownership stake and the regulatory climate on the firm's debt are larger when the firm is subject to regulation by an independent regulator. In particular, these results imply that (i) privately-controlled regulated firms should issue more debt than state-controlled firms, and this is particularly true if they are subject to regulation by an independent regulator, and (ii) regulated firms that operate in more pro-firm environment should issue more debt than otherwise similar firms operating in more hostile regulatory environment, especially when facing an independent regulator.

To see the intuition for these results, note that the firm issues debt in order to induce the regulator to raise the regulated price. However, when the state's stake in the firm is larger, the firm behaves as if it ignores a larger fraction of its costs. Consequently, the regulated price is lower at each level of debt. Likewise, given the firm's debt level, the regulated price is lower when the regulator is more pro-consumer. In both cases, the marginal effect of debt on the regulated price is lower. Since the marginal cost of debt (the likelihood of financial distress) is not affected by δ and γ, the firm issues less debt in equilibrium. This trade off is affected by regulatory independence because under regulatory independence, the regulated price is higher, and hence, at each level of debt, the likelihood of financial distress and thereby the marginal cost of debt are lower. Hence, the firm can issue more debt when it faces an independent regulator.

Next, we examine how the regulated price is affected by the main exogenous parameters of the model, for a given level of investment, k. To this end, recall from Proposition 1 that when $\rho < \rho^*$ (the regulator is non independent), the firm issues debt with face value $D_2(k,0)$. Equation (6) shows in turn that the regulated price is equal in this case to $D_2(k,0) + \hat{c}$. When $\rho > \rho^*$ (the regulator is independent), the firm issue debt with face value $D_2(k,1)$. Now equation (6) shows that the regulated price is equal to $D_2(k,1) + \hat{c}$

with probability ρ (the probability that $I = 1$) and to $D_1(k,0) + \hat{c} + M(D_2(k,1),0)$ with probability $1-\rho$ (the probability that $I = 0$). The expected regulated price when $\rho > \rho^*$ is therefore equal to

$$Ep^*\left(D_2\left(k,1\right),k\right) = \rho\left(\hat{c} + D_2\left(k,1\right)\right) + \left(1-\rho\right)\left(D_1\left(k,0\right) + \hat{c} + M\left(D_2\left(k,1\right),0\right)\right). \quad (13)$$

It is easy to see from Figure 1 that $D_2(k,1) + \hat{c} > D_1(k,0) + \hat{c} + M(D_2(k,1),0) > D_2(k,0) + \hat{c}$. Hence, $Ep^*(D_2(k,1),k) > D_2(k,0) + \hat{c}$, implying that if we hold investment fixed, the regulated price is higher when the regulator is independent than when the regulator is non independent. We report this result in the next proposition and also examine how the regulated price is affected by the parameters δ (the state's stake in the regulated firm) and γ (the measure of regulatory climate which reflects how pro-consumer the regulator is).

Proposition 3: *Holding the firm's investment, k, constant, the expected regulated price is higher when $\rho > \rho^*$ (the regulator is independent) than it is when $\rho < \rho^*$ (the regulator is non independent). Moreover, the expected regulated price is decreasing with both the state's ownership stake δ, and with the measure of regulatory climate γ.*

Proof: First, consider the case where $\rho < \rho^*$. In that case, the regulated price is equal to $D_2(k,0)+\hat{c}$. Proposition 2 shows that $D_2(k,0)$ decreases with δ and γ. Hence, the regulated price will also decrease with δ and γ.

Second, consider the case where $\rho > \rho^*$. The expected regulated price in this case is given by $Ep^*(D_2(k,1),k)$. Differentiating this expression with respect to δ and γ and using equations (8) and (7), yields

$$\begin{aligned}\frac{\partial Ep^*\left(D_2\left(k,1\right),k\right)}{\partial\delta} &= \left(\rho + \left(1-\rho\right)\frac{\gamma\left(1-\delta\right)T}{\hat{c} + \left(1-\delta\right)T}\right)\frac{\partial D_2\left(k,1\right)}{\partial\delta} \\ &\quad - \left(1-\rho\right)\frac{\gamma\hat{c}\left(\frac{\hat{c}^2}{2} + \left(\hat{c} + D_2\left(k,1\right)\right)T\right)}{\left(\hat{c} + \left(1-\delta\right)T\right)^2},\end{aligned}$$

and

$$\begin{aligned}\frac{\partial Ep^*\left(D_2\left(k,1\right),k\right)}{\partial\gamma} &= \left(\rho + \left(1-\rho\right)\frac{\gamma\left(1-\delta\right)T}{\hat{c} + \left(1-\delta\right)T}\right)\frac{\partial D_2\left(k,1\right)}{\partial\gamma} \\ &\quad - \left(1-\rho\right)\frac{\left(V(k) - \hat{c} - D_2\left(k,1\right)\right)\left(1-\delta\right)T + \hat{c}\left(V(k) - \left(1-\delta\right)\frac{\hat{c}}{2}\right)}{\hat{c} + \left(1-\delta\right)T}.\end{aligned}$$

Both derivatives are negative because Proposition 2 implies that $\frac{\partial D_2(k,1)}{\partial \delta} < 0$ and $\frac{\partial D_2(k,1)}{\partial \gamma} < 0$. ■

Proposition 3 implies that if we hold the firm's investment, k, fixed, then any change in the parameters ρ, δ and γ will shift the firm's debt and the regulated price in the same direction. This implies in turn that in a sample of regulated firms that differ from each other only in terms of ρ, δ and γ, the firm's debt and regulated price should be positively correlated.

5 The equilibrium investment level of the firm

Having characterized the optimal debt level of the firm, we next turn to the choice of investment. To this end, note that if $\rho < \rho^*$, the firm issues debt with face value $D_2(k, 0)$. At this debt level, $\phi^*(D, 0) = 0$, so equation (11) implies that $L(D, k, 0) = D_2(k, 0) + \hat{c}$. Substituting in equation (10) and rearranging terms, yields

$$Y(k,0) \equiv Y(D_2(k,0), k) = D_2(k,0) + (1+\delta)\frac{\hat{c}}{2} - k,$$

The equilibrium level of investment, k^*, is implicitly defined in this case by the following first order condition:

$$\begin{aligned} \frac{dY(k,0)}{dk} &= \frac{\partial D_2(k,0)}{\partial k} - 1 \\ &= \frac{(1-\gamma)(\hat{c}+(1-\delta)T)V'(k)}{\hat{c}+(1-\delta)(1-\gamma)T} - 1 \\ &= (1-\gamma(1-\rho^*))V'(k) - 1 = 0, \end{aligned} \tag{14}$$

where ρ^* is defined in Proposition 1.

On the other hand, if $\rho > \rho^*$, then the firm issues debt with face value $D_2(k, 1)$. At this debt level, $\phi^*(D, 1) = 0$, so equation (11) implies that as before, $L(D, k, 1) = D_2(k, 1) + \hat{c}$. On the other hand, since $D_2(k, 1) > D_2(k, 0)$, $L(D, k, 0)$ is given by equation (12) when it is evaluated at $D = D_2(k, 1)$. Substituting these expressions in equation (10) and rearranging terms, yields

$$\begin{aligned}Y(k,1) &\equiv Y\left(D_2\left(k,1\right),k\right)=\rho\left(\hat{c}+D_2\left(k,1\right)\right)\\&+\left(1-\rho\right)\left(1-\gamma\right)\frac{V\left(k\right)\left(\hat{c}+\left(1-\delta\right)T\right)-\left(\hat{c}+D_2\left(k,1\right)\right)\left(1-\delta\right)T}{\hat{c}}\\&-\left(1-\delta\right)\left(1-\gamma\left(1-\rho\right)\right)\frac{\hat{c}}{2}-k,\end{aligned}$$

where $D_2(k,1)$ is given by equation (9), evaluated at $I=1$. The equilibrium level of investment, k^*, is now implicitly defined by the first order condition

$$\begin{aligned}\frac{dY\left(k,1\right)}{dk} &= \left(\rho-\frac{\left(1-\rho\right)\left(1-\gamma\right)\left(1-\delta\right)T}{\hat{c}}\right)\frac{\partial D_2\left(k,1\right)}{\partial k}\\&+\frac{\left(1-\rho\right)\left(1-\gamma\right)\left(\hat{c}+\left(1-\delta\right)T\right)V'(k)}{\hat{c}}-1\\&=\frac{\left(1-\gamma\right)\left(\hat{c}+\left(1-\delta\right)T\right)V'\left(k\right)}{\hat{c}+\left(1-\gamma\right)\left(1-\delta\right)T}+\gamma\left(\rho-\rho^*\right)-1\\&=\left(1-\gamma\left(1-\rho^*\right)\right)V'(k)+\gamma\left(\rho-\rho^*\right)-1=0,\end{aligned} \tag{15}$$

where ρ^* is defined in Proposition 1.

We obtain the following:

Proposition 4: *The equilibrium level of investment, k^*, is independent of the degree of regulatory independence, measured by ρ, when $\rho<\rho^*$, but is increasing with ρ when $\rho>\rho^*$. Consequently, the firm invests more when the regulator is independent (i.e., when $\rho>\rho^*$). The regulated firm however underinvests for all values of ρ in the sense that $V'(k^*)>1$ (the marginal benefit to consumers exceeds the marginal cost of investment).*

Proof: Equation (14) shows that k^* is independent of ρ when $\rho^*<\rho$. When $\rho>\rho^*$, k^* is implicitly defined by (15). Fully differentiating these equations with respect to k and ρ:

$$\frac{\partial k^*}{\partial\rho}=-\frac{\gamma}{\left(1-\gamma\left(1-\rho^*\right)\right)V''(k)}>0,$$

where the inequality follows because $V(\cdot)$ is concave, so $V''(k)<0$.

To establish that the firm underinvests, note from equation (14) that

$$V'(k^*)=\frac{1}{1-\gamma\left(1-\rho^*\right)}>1, \tag{16}$$

and from equation (15) that

$$V'(k^*) = \frac{1-\gamma(\rho-\rho^*)}{1-\gamma(1-\rho^*)} > 1. \tag{17}$$

This completes the proof. ■

Proposition 4 shows that as one might expect, an increase in regulatory independence strengthens the incentives of regulated firms to invest. Interestingly however, this positive effect of regulatory independence in investment is present only if the degree of independence is above some threshold. For low levels of independence, the firm's incentive to invest is independent of the degree of regulatory independence.

Having fully characterized the equilibrium investment level of the firm and having showed how it is affected by regulatory independence, we are now ready to examine how the equilibrium investment level is affected by the state's stake in the firm and by the regulatory climate.

Proposition 5: *The equilibrium level of investment, k^*, is decreasing with the state's ownership stake, δ, and with the measure of regulatory climate γ. The negative effects of δ and γ on k^* are larger when the regulator is independent, i.e., when $\rho > \rho^*$.*

Proof: When $\rho < \rho^*$, the firm's investment level k^* is implicitly defined by equation (16). Totally differentiating this equation with respect to k and δ and then substituting for $V'(k^*)$, yields

$$\begin{aligned}\frac{\partial k^*}{\partial \delta} &= -\frac{\gamma \frac{\partial \rho^*}{\partial \delta} V'(k^*)}{(1-\gamma(1-\rho^*))\, V''(k^*)} \\ &= -\frac{\gamma \frac{\partial \rho^*}{\partial \delta}}{(1-\gamma(1-\rho^*))^2\, V''(k^*)},\end{aligned} \tag{18}$$

where

$$\frac{\partial \rho^*}{\partial \delta} = -\frac{\hat{c}(1-\gamma)T}{(\hat{c}+(1-\gamma)(1-\delta)T)^2} < 0.$$

Recalling that $V(\cdot)$ is concave, $V''(\cdot) < 0$, so $\partial k^*/\partial \delta < 0$. Similarly, totally differentiating the equation (16) with respect to k and γ, and then substituting for $V'(k^*)$, yields

$$\begin{aligned} \frac{\partial k^*}{\partial \gamma} &= -\frac{\left(-(1-\rho^*)+\gamma \frac{\partial \rho^*}{\partial \gamma}\right) V'(k^*)}{(1-\gamma(1-\rho^*))\, V''(k^*)} \\ &= \frac{(1-\rho^*)-\gamma \frac{\partial \rho^*}{\partial \gamma}}{(1-\gamma(1-\rho^*))^2\, V''(k^*)}, \end{aligned} \tag{19}$$

where

$$\frac{\partial \rho^*}{\partial \gamma} = -\frac{\hat{c}(1-\delta)\,T}{(\hat{c}+(1-\gamma)(1-\delta)\,T)^2} < 0.$$

Once again, $V''(\cdot) < 0$ implies that $\frac{\partial k^*}{\partial \gamma} < 0$.

Next, suppose that $\rho > \rho^*$. The regulated firm's investment, k^*, is now given by equation (17). Totally differentiating the equation with respect to k and δ, and with respect to k and γ, substituting for $V'(k^*)$, and recalling that $V''(\cdot) < 0$, yields

$$\begin{aligned} \frac{\partial k^*}{\partial \delta} &= -\frac{\gamma \frac{\partial \rho^*}{\partial \delta}\,(V'(k^*)-1)}{(1-\gamma(1-\rho^*))\, V''(k^*)} \\ &= -\frac{\gamma^2 (1-\rho) \frac{\partial \rho^*}{\partial \delta}}{(1-\gamma(1-\rho^*))^2\, V''(k^*)} < 0, \end{aligned} \tag{20}$$

and

$$\begin{aligned} \frac{\partial k^*}{\partial \gamma} &= -\frac{-(1-\rho^*)\, V'(k^*)+\gamma \frac{\partial \rho^*}{\partial \gamma}\,(V'(k^*)-1)}{(1-\gamma(1-\rho^*))\, V''(k^*)} \\ &= \frac{(1-\rho^*)(1-\gamma(\rho-\rho^*))-\gamma^2(1-\rho) \frac{\partial \rho^*}{\partial \gamma}}{(1-\gamma(1-\rho^*))^2\, V''(k^*)} < 0. \end{aligned} \tag{21}$$

Finally, we need to examine the effect of regulatory independence on $\frac{\partial k^*}{\partial \delta}$ and $\frac{\partial k^*}{\partial \gamma}$. To this end, we need to compare equation (18) with equation (20) and equation (19) with equation (21). Noting that $\gamma(1-\rho) < 1$, $\frac{\partial \rho^*}{\partial \delta} < 0$, and k^* is larger when $\rho > \rho^*$, it follows that if $-V''(\cdot)$ is nondecreasing, i.e., $V'''(\cdot) \leq 0$, then $\frac{\partial k^*}{\partial \delta}$ is smaller when $\rho > \rho^*$. Similar arguments imply that $\frac{\partial k^*}{\partial \gamma}$ is smaller when $\rho > \rho^*$. Since $\frac{\partial k^*}{\partial \delta}$ and $\frac{\partial k^*}{\partial \gamma}$ are both negative, their absolute values are larger when $\rho > \rho^*$. ■

Intuitively, increases in the state's ownership stake in the regulated firm and in the measure of regulatory climate induce the regulator to lower the regulated price and induce the firm to issue less debt. These changes in turn, lower the marginal benefit of investment and hence, induce the firm to invest less. Proposition 5 shows that these effects are more pronounced when the regulator is independent, i.e., when $\rho > \rho^*$. This implies that when the firm is privately owned nd when the regulator is independent we expect that the optimal level of investment is higher than the one of a (partially) state owned firm.

Next, recall that in Propositions 1-3 we showed that, holding the firm's investment level fixed, k, the firm's debt and regulated price are higher when the regulator is independent than when the regulator is non independent, but are decreasing with both the state's ownership stake, δ, and with the measure of regulatory climate γ. We will now show that these results continue to hold even after taking into account the endogenous choice of investment which provides another channel through which the parameters ρ, δ, and γ, affect the firm's debt and regulated price.

Proposition 6: *Taking into account the endogenous choice of investment, k, the firm's debt level and the regulated price are higher when $\rho > \rho^*$ (the regulator is independent) than they are when $\rho < \rho^*$ (the regulator is non independent). Moreover, the firm's debt level and the regulated price are both decreasing with the state's ownership stake δ, and with the measure of regulatory climate γ.*

Proof: In equilibrium, the firm's debt is $D_2(k^*, 0)$ if $\rho < \rho^*$ and $D_2(k^*, 1)$ if $\rho > \rho^*$. Equation (9) shows that $D_2(k^*, 0)$ and $D_2(k^*, 1)$ are affected by ρ only through the choice of investment, k, but not directly. Using equations (7) and (9), and recalling that $I = 0, 1$,

$$\begin{aligned}
\frac{dD_2\left(k^*, I\right)}{dk} &= \frac{\overbrace{\left(\left(1-\gamma\right)V'\left(k^*\right)+\gamma I\right)}^{\frac{\partial D_1(k^*,I)}{\partial k}}\left(\hat{c}+\left(1-\delta\right)T\right)-\gamma\left(1-\delta\right)TI}{\hat{c}+\left(1-\gamma\right)\left(1-\delta\right)T} \\
&= \frac{\left(1-\gamma\right)\left(\hat{c}+\left(1-\delta\right)T\right)V'\left(k^*\right)+\gamma I\hat{c}}{\hat{c}+\left(1-\gamma\right)\left(1-\delta\right)T} \\
&= \left[\overbrace{\frac{\left(1-\gamma\right)\hat{c}}{\hat{c}+\left(1-\gamma\right)\left(1-\delta\right)T}}^{(1-\gamma)(1-\rho^*)}+\overbrace{\frac{\left(1-\gamma\right)\left(1-\delta\right)T}{\hat{c}+\left(1-\gamma\right)\left(1-\delta\right)T}}^{\rho^*}\right]V'\left(k^*\right)+\gamma I\overbrace{\frac{\left(1-\gamma\right)\hat{c}}{\hat{c}+\left(1-\gamma\right)\left(1-\delta\right)T}}^{1-\rho^*} \\
&= \left(1-\gamma\left(1-\rho^*\right)\right)V'\left(k^*\right)+\gamma I\left(1-\rho^*\right) > 0.
\end{aligned} \tag{22}$$

Hence, $D_2(k^*, 0)$ and $D_2(k^*, 1)$ are both increasing with k. Proposition 4 in turn shows that the equilibrium level of investment, k^*, is independent of ρ when $\rho < \rho^*$, but is increasing with ρ when $\rho > \rho^*$. Expressing k^* as a function of ρ, it follows that for every $\rho_1 < \rho^* < \rho_2$,

$$D_2\left(k^*(\rho_1), 0\right) < D_2\left(k^*(\rho_2), 0\right) < D_2\left(k^*(\rho_2), 1\right),$$

where the second inequality follows because holding k fixed, $D_2(k, 0) < D_2(k, 1)$.

As for the regulated price, recall from Section 4 that it is given by $D_2(k^*, 0) + \hat{c}$ if $\rho < \rho^*$ and by $Ep^*(D_2(k^*, 1), k^*)$ if $\rho > \rho^*$. Given that k^* is independent of ρ when $\rho < \rho^*$, but is increasing with ρ when $\rho > \rho^*$, it follows that for every $\rho_1 < \rho^* < \rho_2$,

$$D_2\left(k^*(\rho_1), 0\right) + \hat{c} < D_2\left(k^*(\rho_2), 0\right) + \hat{c} < Ep^*\left(D_2\left(k^*(\rho_2), 1\right), k^*(\rho_2)\right),$$

where the second inequality follows because Proposition 3 implies that for a fixed k, $D_2(k, 0) + \hat{c} < Ep^*(D_2(k, 1), k)$. Therefore, the regulated price is higher when $\rho > \rho^*$ than when ρ when $\rho < \rho^*$.

Next, we consider the effects of δ and γ on the firm's debt level. Proposition 2 shows that holding k fixed, debt is decreasing with both δ and γ. Equation (22), together with Proposition 5, imply that the indirect effect is negative as well. Hence, the equilibrium level of debt is decreasing with δ and γ, even after the endogenous choice of investment is taken into account.

As for the regulated price, when $\rho < \rho^*$, it is given by $D_2(k^*, 0) + \hat{c}$. Since $D_2(k^*, 0)$ is decreasing with δ and γ, so does the regulated price. When $\rho > \rho^*$, the regulated price is given by $Ep^*(D_2(k^*, 1), k^*)$. Differentiating this expression with respect to k, using equation (22), and noting from equation (7) that $dD_1(k, 0)/dk > 0$, yields

$$\frac{dEp^*\left(D_2\left(k^*, 1\right), k^*\right)}{dk} = \rho\frac{dD_2\left(k^*, 1\right)}{dk} + (1-\rho)\left(\frac{dD_1\left(k^*, 0\right)}{dk} + \overbrace{\frac{\gamma\left(1-\delta\right)T}{\hat{c}+\left(1-\delta\right)T}}^{\frac{\partial M(D_2(k,1),0)}{\partial D}}\frac{dD_2\left(k^*, 1\right)}{dk}\right) > 0. \tag{23}$$

Together with Proposition 5, it follows that the indirect effects of δ and γ on $Ep^*(D_2(k^*, 1), k^*)$ is negative. Proposition 2 shows that holding k fixed, the direct effect of δ and γ on $Ep^*(D_2(k^*, 1), k^*)$ is negative as well. Hence, the regulated price is decreasing with δ and γ.
■

We now turn to the effects of ρ, δ and γ, on the total value of the firm. Since the capital market is perfectly competitive, the total value of the firm is simply equal to the expected profit of the firm. Given that the stage-1 regulated price remains in effect with probability ρ, but is updated in stage-3 with probability $1-\rho$, the later is given by

$$E\pi = \rho \left[p^* (D, k^*, 1) - \frac{\hat{c}}{2} - \phi^* (D, 1) T \right] + (1-\rho) \left[p^* (D, k^*, 0) - \frac{\hat{c}}{2} - \phi^* (D, 0) T \right]. \quad (24)$$

Recall from Section 4 that when $\rho < \rho^*$, the firm issues debt with face value $D_2(k^*, 0)$ and the regulator sets the regulated price equal to $D_2(k^*, 0) + \hat{c}$, which ensures that the firm never becomes financially distressed. Hence, for $\rho < \rho^*$,

$$E\pi^{NI} = D_2 (k^*, 0) - \frac{\hat{c}}{2}, \quad (25)$$

where the superscript "NI" stands for "non independent regulator."

Things are more complicated when $\rho > \rho^*$. Now the firm issues debt with face value $D_2(k^*, 1)$ and the resulting expected regulated price is $Ep^*(D_2(k^*, 1), k^*)$. Moreover, the firm is now susceptible to financial distress when $I = 0$; the probability of this event is $1-\rho$. Hence, now,

$$E\pi^{I} = Ep^* (D_2 (k^*, 1), k^*) - \frac{\hat{c}}{2} - (1-\rho) \phi^* (D_2 (k^*, 1), 0) T \quad (26)$$

where the superscript "I" stands for "independent regulator." Using equations (1), (6), and (9), we can write the probability of financial distress as

$$\phi^* (D_2 (k^*, 1), 0) = 1 - \frac{p^* (D_2 (k^*, 1), k, 0) - D_2 (k^*, 1)}{\hat{c}} = \frac{\gamma k^*}{\hat{c} + (1-\delta) T}.$$

Proposition 7: *Taking into account the endogenous choice of investment, k, the total value of the firm is always decreasing with the state's ownership stake δ, and with the measure of regulatory climate γ, whenever $\rho < \rho^*$ (the regulator is non independent). If $\rho > \rho^*$ (the regulator is independent), then a sufficient condition for the total value of the firm to be decreasing with the state's ownership stake δ, and with the measure of regulatory climate γ, is that the regulator is not too pro-consumer: $\gamma \leq \max \{2(1-\delta), 4\delta(1-\delta)\}$.*

Proof: Consider first the case where $\rho < \rho^*$. Then, the expected profit of the firm is given by $E\pi^{NI}$. Since $E\pi^{NI}$ is a linear function of the firm's debt level, it follows from Proposition

6, that $E\pi^{NI}$ is decreasing with the state's ownership stake δ, and with the measure of regulatory climate γ.

Next consider the case where $\rho > \rho^*$. The expected profit of the firm is then given by $E\pi^I$. Taking the derivative of $E\pi^I$ with respect to δ:

$$\frac{dE\pi^I}{d\delta} = \left[\frac{\partial Ep^*\left(D_2\left(k^*,1\right),k^*\right)}{\partial k} - \frac{\left(1-\rho\right)\gamma T}{\hat{c}+\left(1-\delta\right)T}\right]\frac{\partial k^*}{\partial \delta} + \frac{\partial Ep^*\left(D_2\left(k^*,1\right),k^*\right)}{\partial \delta} - \frac{\left(1-\rho\right)\gamma k^* T^2}{\left(\hat{c}+\left(1-\delta\right)T\right)^2}.$$

Proposition 6 shows that $\frac{\partial Ep^*(D_2(k^*,1),k^*)}{\partial \delta} < 0$ and Proposition 5 shows that $\frac{\partial k^*}{\partial \delta} < 0$. Hence, we can establish that $\frac{\partial E\pi^I}{\partial \delta} < 0$ by showing that the square bracketed term is positive. Using equation (23), this term is equal to

$$\overbrace{\rho\frac{dD_2\left(k^*,1\right)}{dk} + \left(1-\rho\right)\left(\frac{dD_1\left(k^*,0\right)}{dk} + \frac{\gamma\left(1-\delta\right)T}{\hat{c}+\left(1-\delta\right)T}\frac{dD_2\left(k^*,1\right)}{dk}\right)}^{\frac{dEp^*\left(D_2\left(k^*,1\right),k^*\right)}{dk}} - \frac{\left(1-\rho\right)\gamma T}{\hat{c}+\left(1-\delta\right)T}, \qquad (27)$$

where $\frac{dD_2(k^*,1)}{dk} = \left(1-\gamma\left(1-\rho^*\right)\right)V'\left(k^*\right) + \gamma\left(1-\rho^*\right) > 0$ by equation (22) and $\frac{\partial D_1(k^*,0)}{\partial k} = \left(1-\gamma\right)V'(k^*) > 0$ by equation (7). Using these expressions, noting from the proof of Proposition 4 that $V'(k^*) = \frac{1-\gamma(\rho-\rho^*)}{1-\gamma(1-\rho^*)}$, recalling that $\rho^* \equiv \frac{(1-\gamma)(1-\delta)T}{\hat{c}+(1-\gamma)(1-\delta)T}$, and rearranging terms, the square bracketed term becomes

$$\begin{aligned}
& \rho\left[\left(1-\gamma\left(1-\rho^*\right)\right)V'\left(k^*\right) + \gamma\left(1-\rho^*\right)\right] \\
& +\left(1-\rho\right)\left[\left(1-\gamma\right)V'(k^*) + \frac{\gamma\left(1-\delta\right)T}{\hat{c}+\left(1-\delta\right)T}\left(\left(1-\gamma\left(1-\rho^*\right)\right)V'\left(k^*\right)+\gamma\left(1-\rho^*\right)\right)\right] - \frac{\left(1-\rho\right)\gamma T}{\hat{c}+\left(1-\delta\right)T} \\
= & \left[\left(1-\gamma\left(1-\rho^*\right)\right)\left[\rho + \frac{\gamma\left(1-\delta\right)T}{\hat{c}+\left(1-\delta\right)T}\left(1-\rho\right)\right] + \left(1-\rho\right)\left(1-\gamma\right)\right]V'\left(k^*\right) \\
& +\gamma\left(1-\rho^*\right)\left[\rho + \frac{\gamma\left(1-\delta\right)T}{\hat{c}+\left(1-\delta\right)T}\left(1-\rho\right)\right] - \frac{\left(1-\rho\right)\gamma T}{\hat{c}+\left(1-\delta\right)T} \\
= & 1 - \frac{\delta\left(1-\rho\right)\gamma T}{\hat{c}+\left(1-\delta\right)T}.
\end{aligned}$$

The last expression is increasing with ρ. Since $\rho > \rho^*$,

$$\begin{aligned}
1 - \frac{\delta\left(1-\rho\right)\gamma T}{\hat{c}+\left(1-\delta\right)T} &> 1 - \frac{\delta\left(1-\rho^*\right)\gamma T}{\hat{c}+\left(1-\delta\right)T} \\
&= \frac{M\left(\hat{c}\right)}{\left(\hat{c}+\left(1-\delta\right)T\right)\left(\hat{c}+\left(1-\gamma\right)\left(1-\delta\right)T\right)},
\end{aligned}$$

where

$$M\left(\hat{c}\right) \equiv \hat{c}^2 + \left(2\left(1-\delta\right)-\gamma\right)\hat{c}T + \left(1-\gamma\right)\left(1-\delta\right)^2 T^2.$$

The sign of the expression depends on the sign of $M(\hat{c})$ which is a U-shaped function of $\hat{c}$. Note that $M(0) = (1-\gamma)(1-\delta)^2 T^2 > 0$ and $M'(\hat{c}) = 2(1-\delta) - \gamma$. If $\gamma \leq 2(1-\delta)$, then $M'(0) \geq 0$, and since $M(0) > 0$, then $M(\hat{c})$ is positive for all $\hat{c} \geq 0$ and we are done. If $\gamma > 2(1-\delta)$, then $M'(\hat{c}) < 0$ and hence it could be that $M(\hat{c}) < 0$ for some $\hat{c} \geq 0$. Now, note that

$$\min_{\hat{c}} M(\hat{c}) = \frac{\gamma(4\delta(1-\delta)-\gamma)T^2}{4}.$$

If $\gamma \leq 4\delta(1-\delta)$, then $\min_{\hat{c}} M(\hat{c}) \geq 0$ and hence once again, $M(\hat{c}) \geq 0$ for all $\hat{c} \geq 0$ and we are done. Hence, if $2(1-\delta) \leq 4\delta(1-\delta)$, then $M(\hat{c}) \geq 0$ for all $\hat{c} \geq 0$ whenever $\gamma \leq 4\delta(1-\delta)$. On the other hand, if $2(1-\delta) > 4\delta(1-\delta)$, then $M(\hat{c}) \geq 0$ for all $\hat{c} \geq 0$ whenever $\gamma \leq 2(1-\delta)$.

Now we need to take the derivative of $E\pi^I$ with respect to the measure of regulatory climate γ:

$$\frac{dE\pi^I}{d\gamma} = \left[\frac{\partial Ep^*(D_2(k^*,1),k^*)}{\partial k} - \frac{(1-\rho)\gamma T}{\hat{c}+(1-\delta)T}\right]\frac{\partial k^*}{\partial \gamma} + \frac{\partial Ep^*(D_2(k^*,1),k^*)}{\partial \gamma} - \frac{(1-\rho)k^* T}{\hat{c}+(1-\delta)T}.$$

Proposition 6 shows that $\frac{\partial Ep^*(D_2(k^*,1),k^*)}{\partial \gamma} < 0$ and Proposition 5 shows that $\frac{\partial k^*}{\partial \delta} < 0$. The above arguments show that a sufficient condition for the square bracketed term to be positive is $\gamma \leq \max\{2(1-\delta), 4\delta(1-\delta)\}$. ■

6 The equilibrium leverage ratio [preliminary]

Having fully characterized the equilibrium investment and debt levels, we are now ready to examine how leverage, defined as the ratio between debt and debt plus equity, is affected by the degree of regulatory independence, the ownership structure, and by the regulatory climate.

Let $B(D)$ be the market value of debt, i.e., the amount that investors are willing to pay for the firm's debt, D, when it just issued, and let E be the market value of the firm's equity. We will assume that the firm issues debt and equity only in order to cover the cost of its investment, i.e., $k = B(D) + E$. Using this equality, leverage is defined as follows:

$$Lev = \frac{D}{D+E} = \frac{D}{D+k-B(D)}. \tag{28}$$

6.1 Leverage when the regulator is not independent

Recall that when the regulator is not independent ($\rho < \rho^*$), the equlibirum debt level is $D_2(k^*, 0)$ and the probability of financial distress is 0 in equilibrium. Therefore, $B(D) = D$, implying that the equilibrium leverage in this case is equal to

$$Lev^{NI} = \frac{D_2(k^*, 0)}{k^*}. \tag{29}$$

By Proposition 4, k^* is independent by ρ. Hence, Lev^{NI} is independent of ρ.

As for the ownership structure, note that

$$\frac{\partial Lev^{NI}}{\partial \delta} = \frac{\left(\frac{\partial D_2(k^*,0)}{\partial \delta} + \frac{\partial D_2(k^*,0)}{\partial k^*}\frac{\partial k^*}{\partial \delta}\right) k^* - \frac{\partial k^*}{\partial \delta} D_2(k^*, 0)}{(k^*)^2}.$$

By equation (22), $\frac{\partial D_2(k^*,0)}{\partial k^*} = (1 - \gamma(1 - \rho^*)) V'(k^*)$. Since equation (16) shows that $V'(k^*) = \frac{1}{1-\gamma(1-\rho^*)}$, it follows that $\frac{\partial D_2(k^*,0)}{\partial k^*} = 1$. Hence,

$$\begin{aligned}\frac{\partial Lev^{NI}}{\partial \delta} &= \frac{\left(\frac{\partial D_2(k^*,0)}{\partial \delta} + \frac{\partial k^*}{\partial \delta}\right) k^* - \frac{\partial k^*}{\partial \delta} D_2(k^*, 0)}{(k^*)^2} \\ &= \frac{\frac{\partial D_2(k^*,0)}{\partial \delta} + \frac{\partial k^*}{\partial \delta}\left(1 - Lev^{NI}\right)}{k^*}.\end{aligned}$$

Likewise,

$$\frac{\partial Lev^{NI}}{\partial \gamma} = \frac{\frac{\partial D_2(k^*,0)}{\partial \gamma} + \frac{\partial k^*}{\partial \gamma}\left(1 - Lev^{NI}\right)}{k^*}.$$

Since $\frac{\partial D_2(k^*,0)}{\partial \delta} < 0$ and $\frac{\partial D_2(k^*,0)}{\partial \gamma} < 0$, as long as $Lev^{NI} < 1$, then the equilibrium leverage ratio decreases both with the state ownership and the regulatory climate.

6.2 Leverage when the regulator is independent

Things are more complicated when the regulator is independent ($\rho > \rho^*$). At the equilibrium level of the debt, $D = D_2(k^*, 1)$, the equilibrium regulated price is $p^*(D_2(k^*, 1), k^*, 1) = D_2(k^*, 1) + \hat{c}$ and at this price the probability of financial distress is zero. However, this price could be lowered ex post by the regulator at $p^*(D_2(k^*, 1), k^*, 0) = D_1(k, 0) + \hat{c} + M(D_2(k, 1), 0)$, and this may happen with probability $1 - \rho$ (see equation (6). In this case, the firm could face financial problems; thus, the market value of debt $(B(D_2(k^*, 1)))$

differs from its face value, since it has to incorporate the potential cost of financial distress. Recall that, in equilibirum, the probability of financial distress is equal to $\phi^*\left(D_2\left(k^*,1\right),0\right) = \frac{\gamma k^*}{\hat{c}+(1-\delta)T}$. Hence, the ex post expected market value of debt becomes:

$$B(D_2\left(k^*,1\right)) = \rho D_2\left(k^*,1\right) + (1-\rho)\left[(1-\phi^*)D_2\left(k^*,1\right) + \phi^*(p^*\left(D_2\left(k^*,1\right),k^*,0\right) - \hat{c})\right].$$

The market value of debt is equal to the expected sum of the value of debt in different contingencies. The first term is given by the equilibrium face value of debt $(D_2\left(k^*,1\right))$ multiplied by the probability that the regulator does not lower ex post the regulated price and so firms does not suffer financial distress. The second term is the expected value of debt when the regulator decreases ex post the regulated price (with probability $1-\rho$), multiplied by $\phi^*\left(D_2\left(k^*,1\right),0\right)$, the probability of financial distress.

Then, the optimal leverage when the regulator is independent (denoted with Lev^I) has the following expression:

$$\begin{aligned} Lev^I &= \frac{D_2\left(k^*,1\right)}{D_2\left(k^*,1\right) + k^* - B(D_2\left(k^*,1\right))} \qquad (30) \\ &= \frac{D_2\left(k^*,1\right)}{k^* + \phi^*\left(1-\rho\right)\left[D_2\left(k^*,1\right) + \hat{c} - p^*\left(D_2\left(k^*,1\right),k^*,0\right)\right]}. \end{aligned}$$

Since $\phi^*\left(D_2\left(k^*,1\right),0\right) = 1 - \frac{p^*(D_2(k^*,1),k^*,0) - D_2(k^*,1)}{\hat{c}} = \frac{\gamma k^*}{\hat{c}+(1-\delta)T}$, then $D_2\left(k^*,1\right) + \hat{c} - p^*\left(D_2\left(k^*,1\right),k^*,0\right) = \hat{c}\phi^*$. Therefore, the equation (30) can be rewritten as:

$$\begin{aligned} Lev^I &= \frac{D_2\left(k^*,1\right)}{k^* + \phi^{*2}\left(1-\rho\right)\hat{c}} = \frac{D_2\left(k^*,1\right)}{k^* + \left(\frac{\gamma k^*}{\hat{c}+(1-\delta)T}\right)^2\left(1-\rho\right)\hat{c}} \qquad (31) \\ &= \frac{D_2\left(k^*,1\right)}{k^*\left[1 + \left(\frac{\gamma^2 k^*}{(\hat{c}+(1-\delta)T)^2}\right)\left(1-\rho\right)\hat{c}\right]} = \frac{D_2\left(k^*,1\right)\Lambda}{k^*}, \end{aligned}$$

where $\Lambda(\delta,\gamma,k^*) = \frac{(\hat{c}+(1-\delta)T)^2}{(\hat{c}+(1-\delta)T)^2 + \gamma^2 k^*(1-\rho)\hat{c}} < 1$. Note that when the degree of independence is high, say $\rho \longrightarrow 1$ then also $\Lambda(\delta,\gamma,k^*) \longrightarrow 1$.

As for the ownership structure, note that

$$\frac{\partial Lev^I}{\partial \delta} = \frac{\partial\left(\frac{D_2(k^*,1)}{k^*}\right)}{\partial \delta}\Lambda + \frac{\partial \Lambda}{\partial \delta}\frac{D_2\left(k^*,1\right)}{k^*},$$

where:

$$\frac{\partial\left(\frac{D_2(k^*,1)}{k^*}\right)}{\partial \delta} = \frac{\left(\frac{\partial D_2(k^*,1)}{\partial \delta} + \frac{\partial D_2(k^*,1)}{\partial k^*}\frac{\partial k^*}{\partial \delta}\right)k^* - \frac{\partial k^*}{\partial \delta}D_2(k^*,1)}{\left(k^*\right)^2}.$$

By equation (22), together with equation (17), it follows that in equilibrium $\frac{\partial D_2(k,1)}{\partial k} = 1 + \gamma(1-\rho)$. Hence,

$$\frac{\partial Lev^I}{\partial \delta} = \Lambda \left[\frac{\frac{\partial D_2(k^*,1)}{\partial \delta} + \frac{\partial k^*}{\partial \delta}\left(1 + \gamma(1-\rho) - Lev^I\right)}{k^*} \right] + \frac{\partial \Lambda}{\partial \delta} Lev^I,$$

where:

$$\frac{\partial \Lambda}{\partial \delta} = -\frac{\gamma^2 \left(1-\rho\right) \hat{c} \left(\hat{c} + \left(1-\delta\right) T\right) \left[2Tk^* + \frac{\partial k^*}{\partial \delta}\left(\hat{c} + \left(1-\delta\right) T\right)\right]}{\left[\left(\hat{c} + \left(1-\delta\right) T\right)^2 + \gamma^2 k^* \left(1-\rho\right) \hat{c}\right]^2}.$$

Likewise,

$$\frac{\partial Lev^I}{\partial \gamma} = \Lambda \left[\frac{\frac{\partial D_2(k^*,1)}{\partial \gamma} + \frac{\partial k^*}{\partial \gamma}\left(1 + \gamma(1-\rho) - Lev^I\right)}{k^*} \right] + \frac{\partial \Lambda}{\partial \gamma} Lev^I,$$

where

$$\frac{\partial \Lambda}{\partial \gamma} = -\frac{\gamma \left(1-\rho\right) \hat{c} (\hat{c} + \left(1-\delta\right) T)^2 \left[2k^* + \frac{\partial k^*}{\partial \gamma}\gamma\right]}{\left[\left(\hat{c} + \left(1-\delta\right) T\right)^2 + \gamma^2 k^* \left(1-\rho\right) \hat{c}\right]^2}.$$

`[To be continued]`

7 Conclusion

`[needs to be written]`

8 References

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