Investment and capital structure of partially private regulated firms*

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Abstract

We develop a model that examines the capital structure and investment decisions of regulated firms in a setting that incorporates two key institutional features of the public utilities sector in many countries: firms are partially owned by the state and regulators are not necessarily independent. Among other things, we show that regulated firms issue more debt, invest more, and enjoy higher regulated prices when they face more independent regulators, are more privatized, and when regulators are more pro-firm. Moreover, regulatory independence, higher degree of privatization, and pro-firm regulatory climate are associated with higher social welfare.

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1 Introduction

Since the early 1990's, many countries around the world have substantially reformed their public utilities sector through large scale privatization and by establishing Independent Regulatory Agencies (IRAs) to regulate the newly privatized utilities. These reforms were intended to improve the efficiency and service quality of utilities and boost their investments. The structural reforms, however, were accompanied by a substantial increase in the financial leverage of regulated utilities.[1] This trend, coined the "dash for debt," is widespread across countries and across sectors and has raised substantial concerns among policy markers. For instance, a joint study of the UK Department of Trade and Industry (DTI) and the HM Treasury argues that the "dash for debt" within the UK utilities sector from the mid-late 1990's "could imply greater risks of financial distress, transferring risk to consumers and taxpayers and threatening the future financeability of investment requirements" (DTI and HM Treasury, 2004, p. 6). Likewise, the Italian energy regulatory agency, AEEG, has recently expressed its concern that excessive financial leverage could lead to financial distresses which in turn could cause service interruptions (AEEG 2008, paragraph 22.13). The AEEG has also announced its intention to start monitoring the financial leverage of Italian energy utilities in order to discourage speculative behavior that might jeopardize their financial stability (see AEEG, 2007, paragraph 17.40 and AEEG, 2009, paragraph 11.8).

To put the concerns about the dash for debt phenomenon in perspective, it is worth noting that the investments of public utilities in infrastructure account for a significant fraction of GDP. For example, Table 1 in the Appendix shows that in the EU14 states, the average rate of gross fixed capital formation in the energy sector (electricity and gas), telecommunications, water supply, and transportation, was 15.24% of GDP in 2008. Given the sheer size of investments at stake and the overall importance of the public utilities sector for the economy at large, it is clearly important to understand the determinants of the investments and financial decisions of regulated firms and study how these decisions affect social welfare.

[1] See Bortolotti et al. (2011) for evidence on the EU14 states and Da Silva et al. (2006) for evidence on Latin America and Asia.

Earlier literature on this topic (e.g., Taggart 1981 and 1985; Dasgupta and Nanda, 1993; Spiegel and Spulber, 1994 and 1997; and Spiegel, 1994 and 1996) has shown that regulated firms may have an incentive to strategically issue debt in order to induce regulators to set a relatively high price in order to minimize the risk that the firm will become financially distressed.[2] This literature however implicitly assumed that the regulated firm is privately owned and regulators are independent.[3] While these assumptions reflect the institutional setting in the U.S. and more recently in the UK, in many other countries around the world, including the EU, Latin America, and Asia, central or local governments still hold significant ownership stakes (often controlling stakes) in many public utilities (see e.g., Bortolotti and Faccio, 2008; Boubakri and Cosset, 1998; and Boubakri et al., 2004), and IRAs do not exist in all sectors.[4] Indeed, the large scale privatization process that started in the 1990's seems to have led to a new form of "state capitalism," whereby governments choose to remain partial owners of large firms, rather than try to completely sell their stakes to private investors (The Economist, 2012).[5] This phenomenon is widespread for example in Europe, where many large telecoms and energy utilities are partially held by the state, as well as in emerging markets.[6] The purpose of this paper is to develop a tractable model that will allow

[2] Jaimison and Sappington (2013) examine how regulators can prevent excessive leverage by imposing penalties on the firm should it experience financial distress.

[3] Moreover, with the exception of Spiegel (1994), this literature has only considered the interaction between capital structure and regulated prices, holding the firm's invetment level constant.

[4] For instance, fully or partially state-owned enterprises in the OECD area are valued at over 2 trillion USD and employ over 6 million people. Half of these firms by value operate in the network industries (telecoms, electricity and gas, transportation and postal services). See http://www.oecd.org/daf/ca/oecddatasetonthesizeandcompositionofnationalstate-ownedenterprisesectors.htm

As for regulation, IRAs were established and are fully operational in the EU only in the telecommunications and energy sectors, but in other sectors, like transportation and water, most utilities are still regulated directly by ministries, governmental committees, or local governments (see Bortolotti et al. 2011).

[5] According to this report, the combined market value of state owned companies is over 2 trillion USD and total employment is around 6 million.

[6] To illustrate, as of the end of 2013, France Telecom-Orange is 23.2% held by the French Government, Deutsche Telekom is 31.9% held by the German Government, TeliaSonera is 37% held by the Swedish Government and 13.2% by the Finnish Government, and Telekom Austria is 28% held by the Austrian Government. Likewise, in the energy sector, the French Government holds a 84.5% stake in EDF, while the

us to study how (partial) state ownership and regulatory independence affect the capital structure and investments of the regulated firm, regulated prices, and welfare.

Our model considers the strategic interaction between the managers of a regulated firm, who need to decide how much to invest and how to finance this investment, and a regulator, who needs to set the regulated price. A main assumption in our model is that the firm's cost is subject to random shocks. Hence, when the firm is leveraged, a sufficiently negative cost shock may result in a costly financial distress. The regulator therefore faces a trade off between setting a low price, which benefits consumers, and a high price, which minimizes the probability of financial distress.

There is no general agreement in the literature on how to model the objective of the management of a partially state owned firm. We follow two main strands in the literature and assume the firm's management chooses the firm's actions to maximize the expected profit of the firm, but in doing so, the management discounts to some extent the firm's costs. According to Sappington and Sidak (2003, 2004), the managers of partially state-owned firms are concerned not only with profit, but also with revenue, and the weight assigned to revenue increases with the state's stake in the firm. As a result, the firm's managers effectively discount the firm's cost, and more so when the state's stake in the firm is large.[7] Alternatively, according to the soft budget constraint approach, partially state owned firms are more likely to be bailed out by the state in case of financial distress, especially when the state's stake in the firm is large. Hence, the cost of financial distress from the perspective of the managers is decreasing with the state's stake in the firm. Since the regulator sets a regulated price that takes the firm's objective into account, he sets a higher price when the firm is more privatized and internalizes a larger fraction of its cost. The higher regulated

Italian Government holds a 32% stake in Enel and 30% stake in Eni, and the Austrian Government holds a 70% stake in Verbund. According to the Economist report on state capitalism (the Economist 2012), the share of national/state-controlled companies in the MSCI emerging-market index is over 65% in energy, around 55% in utilities, and around 35% in telecommunication services.

[7] If managers maximize a weighted average of revenue and profit, then they maximize the expression $\delta R + (1-\delta)(R-C)$, where R is revenue, C is cost, and δ is the state's stake in the firm. This expression is equivalent to $R-(1-\delta)C$, so the managers discount the firm's cost to a larger extent when the firm is less privatized (i.e., δ is high).

price, in turn, allows the firm to issue more debt and induces it to increase its investment. To model regulatory independence, we follow the literature on central bank independence (see e.g., Cukierman, 1992) and assume that more independent regulators are more committed to the regulatory rule used to determine the regulated price, while less independent regulators are more likely to behave opportunistically and deviate from their preannounced regulatory rule. Consequently, more regulatory independence leads to a higher regulated price and hence induces the firm to issue more debt and raise its investment level.

Altogether then, our model implies that regulated firms that face more independent regulators and are more privatized will be more leveraged, will invest more, and will enjoy higher regulated prices. In addition, our results show that higher degrees of regulatory independence and privatization, as well as more pro-firm regulatory climate (the regulator assigns more weight the firm's payoff in setting the regulated price), are all associated with higher social welfare. These results suggest that the "dash for debt" phenomenon mentioned above is a natural outcome of the privatization process and the establishment of IRAs, and moreover, these processes are welfare improving.

The rest of the paper is organized as follows. Section 2 presents the model. Section 3 characterizes the equilibrium regulated price for given combinations of debt and investment. In Sections 4 and 5, we solve for the equilibrium choice of capital structure and investment and study how these choices are affected by the main exogenous parameters of the model, namely the degree regulatory independence, the extent of privatization (i.e., the state's stake in the regulated firm), and the regulatory climate. 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 examine the implications of our model for social welfare. Concluding remarks are in Section 7. All proofs are in the Appendix.

2 The model

Consider a regulated firm, which is partially owned by the state (at the national or the local level). For simplicity (but without a serious loss of insights), we assume that the firm faces a unit demand function. The willingness of consumers to pay depends on the firm's investment, k, and is given by a twice differentiable, increasing, and concave function $V(k)$. That is, k can be interpreted as investment in the "quality" of the firm's services. Using p to denote the regulated price, consumers' surplus is given by $V(k) - p$.

2.1 The capital structure of the firm and its expected cost

The firm's cost of production is subject to random cost shocks (e.g., fluctuating energy prices) and is given by a random variable, c, distributed uniformly over the interval $[0, \overline{c}]$, where $\overline{c} < V(0)$. 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 D in full, it incurs a fixed cost T due to financial distress.[8] Using $\phi(p, D)$ to denote the probability of financial distress, the total expected cost of the firm is

$$C = \frac{\overline{c}}{2} + \phi(p, D) T,$$

where

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

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

2.2 The regulated firm's objective

Let δ denote the state's stake in the firm's equity. As mentioned in the Introduction, there is no generally agreed upon way to model the effect of δ on the objective of the firm's manage-

[8] Financial distress does not necessarily mean formal bankruptcy: it could refer to any financial problem that the firm may face when it cannot pay its debt in full and needs to reorganize it. For instance, financial distress may make it harder for the firm to deal with customers and suppliers and raise capital for investment, and it also diverts managerial attention away from normal operations.

ment. Our modeling approach follows two main strands in the literature: the managerially-oriented public enterprise (MPE) approach, due to Sappington and Sidak (2003, 2004), and the soft-budget constraint (SBC) approach introduced by Kornai (1986).

According to the MPE approach, the managers of the (partially) state-owned firm are concerned not only with the firm's profit, $R - C$, where R is revenue and C is cost, but also with the firm's revenue, R, and their objective function, after investment is already sunk, is given by[9]

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

This objective function reflects the idea that the managers of state-owned enterprises often have considerable interest in expanding the scale or scope of their activities and expand the firm's budget for political reasons. Alternatively, the manager's of partially state-owned firms are less exposed to the disciplining forces of the capital market and to takeover threats, and hence find it easier to expand the firm's budget in order to pursue their own private agenda. Noting that $C = \frac{\overline{c}}{2} + \phi(p, D)T$ and recalling that since we have a unit demand function, $R = p$, the ex post payoff of the firm's managers under the MPE approach can be written as

$$\delta R + (1 - \delta)(R - C) = R - (1 - \delta)C = p - (1 - \delta)\frac{\overline{c}}{2} - (1 - \delta)\phi(p, D)T. \tag{2}$$

As for the SBC approach, some authors (e.g., Schmidt, 1996, and Maskin and Xu, 2001) argue that public ownership is a major cause of SBC. According to this view, state-owned firms are more likely to be bailed-out by the state in case they become financially distressed. Using b to denote the probability of a bailout, and assuming for simplicity that the firm does not bear any cost of distress if it is bailed out (this assumption can be easily relaxed so long as the cost of distress is smaller under a bailout), the ex post payoff of the firm's managers under the SBC approach is given by

$$R - \frac{\overline{c}}{2} - (1 - b)\phi(p, D)T = p - \frac{\overline{c}}{2} - (1 - b)\phi(p, D)T. \tag{3}$$

[9] For related papers which model the effect of state ownership by modifying the firm's objective function, see for example, Bös and Peters (1988), De Fraja and Delbono (1989), Fershtman (1990), Cremer, Marchand and Thisse (1989, 1991), and Lee and Hwang (2003).

There is evidence that suggests that the probability of a bailout, b, increases with the state's stake in the firm δ. For instance, Glowicka (2006) finds that distressed public firms are more likely to receive long-term government assistance ("restructuring aid"), while distressed private firms are more likely to receive only short-term "rescue aid," which is intended to keep them in operation until a restructuring plan is in place. Borisova et al. (2011) examine stock purchases in publicly traded companies by governments or state-owned investors and find strong support for the notion that debtholders view government ownership as an implicit assurance of repayment and protection against bankruptcy. Similarly, Borisova and Megginson (2012) examine corporate bonds of fully and partially privatized firms and show that on average, a one-percentage-point increase in government ownership is associated with a decrease in the credit spread of roughly three-quarters of a basis point.

If we take b to be linear in δ, the payoff of the firm's managers under the SBC approach coincides with their payoff under the MPE approach, except for the coefficient of $\frac{\overline{c}}{2}$, which is equal to $1-\delta$ under the MPE approach, and is equal to 1 under the SBC approach. Hence, we can capture both approaches with the following (ex post) payoff function:

$$p - \beta\frac{\overline{c}}{2} - (1-\delta)\,\phi\,(p, D)\,T, \tag{4}$$

where $\beta = 1-\delta$ under the MPE approach and $\beta = 1$ under the SBC approach. Importantly, under both approaches, the managers of a partially state-owned regulated firm effectively behave as if they ignore a fraction δ of the firm's expected cost of financial distress. Ex ante, before k is sunk, the objective of the firm's managers is given by the same expression minus k.

2.3 The rate setting process, regulatory independence, and regulatory climate

Following Besanko and Spulber (1992), Dasgupta and Nanda (1993), and Spiegel and Spulber (1997), we assume that the regulator sets the regulated price, p, in order to maximize a welfare function defined over consumers' surplus, $V(k)-p$, and the firm's objective function:[10]

$$(V(k)-p)^{\gamma}\,(p-\beta\frac{\overline{c}}{2}-(1-\delta)\,\phi\,(p,D)\,T-k)^{1-\gamma}. \tag{5}$$

The parameter $\gamma\in(0,1)$ captures the regulatory climate: the higher γ, the more pro-consumer the regulator is. The resulting regulated price allocates the expected surplus according to the asymmetric Nash bargaining solution for the regulatory process. Under this interpretation, the parameters γ and $1-\gamma$ reflect the bargaining powers of consumers and the firm. Our approach is therefore consistent with models that view the regulatory process as a bargaining problem between consumers and investors (Spulber, 1988 and 1989). Alternatively, the welfare function (5) could represent a reduced form for the regulator's own payoff from being involved in some political economy game.

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 2002 and 2005, and the discussion in Edwards and Waverman, 2006).[11] In line with this argument, we will assume that the regulator is committed to the regulatory rule given by (5) only with probability ρ. With probability $1-\rho$, the regulator happens to be opportunistic, and after k is sunk, he sets a lower regulated price. The parameter $\rho\in(0,1)$ then reflects the regulator's ability to make long-term commitments to the regulatory rule

[10] Our approach is consistent with the observation that in practice, regulators set prices to balance the interests of consumers and firms. For example, according to the U.S. Supreme Court, price regulation "involves a balancing of the investor's and the consumers' interests" that should result in rates "within a range of reasonableness" (see *Federal Power Comm. v. Hope Natural Gas Co.*, 320 U.S. 591, 603 (1944)). Similiarly, Ofwat, the water and sewerage regulatory agency in England and Wales states that "...it is our role to protect the interests of consumers while enabling efficient companies to carry out and finance their functions. This is a delicate balancing act. On the one hand, we must be sure that customers continue to receive the services that they expect – at a price they are willing to pay – now and over the long term. On the other, we must ensure that the companies have sufficient resources to deliver services efficiently and remain attractive to investors..." (see Ofwat, 2010, p. 3).

[11] Guasch, Laffont, and Straub (2008) provide empirical support for this argument by showing that the presence of an IRA lowered the probability of renegotiation of contracts for the provision of utilities services by $5\%-7.3\%$. This effect is significant given that the average probability of renegotiation of any individual contract at any point in time is around 1%. The better ability of IRAs to make long-term commitments suggests that IRAs are less opportunistic than non-independent regulators.

and therefore serves as our measure of regulatory independence, with higher values of ρ indicating a greater degree of independence.[12]

Specifically, we will assume that while a committed regulator always sets a the price p to to maximize (5), an opportunistic regulator takes advantage of the fact that p is set after k is already sunk, and hence sets p to maximize an ex post objective function that ignores k:

$$(V(k) - p)^{\gamma} (p - \beta\frac{\overline{c}}{2} - (1-\delta)\,\phi(p, D)\,T)^{1-\gamma}. \tag{6}$$

Again, the probability that the regulator is committed is ρ while the probability that the regulator is opportunistic is $1-\rho$. In a technical Appendix, we show that the main results of the paper remain virtually the same if we adopt an alternative approach and assume that an opportunistic regulator uses a more pro-consumer rule when setting p (i.e., uses a higher γ for setting p) rather than ignore k when setting the regulated price.[13]

2.4 The sequence of events

The strategic interaction between the firm's managers and the regulator evolves in two stages. In stage 1, the firm's managers choose k and issues debt with face value D in a competitive capital market.[14] If the funds raised by issuing D exceed k, the firm pays the excess funds as a dividend. If the funds raised by issuing D fall short of k, the firm raises additional funds by issuing equity; to simplify matters, we assume that in this case the state participates in

[12] A similar appoach is used in the literature on central banks independence, where a greater degree of independence is modeled by assuming that the public assigns a larger probability to the event that the central banker is committed to his preannounced level of inflation. By contrast, an opportunistic central banker chooses ex post an actual level of inflation which may differ from the one that he announced. See for example Cukierman (1992).

[13] For details, see http://www.tau.ac.il/~spiegel/papers/CS-appendix-july-4-2012-gamma.pdf

[14] Our approach differs from De Fraja and Stones (2004) and Stones (2007) where the regulator, rather than the firm, chooses the capital structure of the firm. These papers also assume that the regulator must set p to ensure that the firm never goes bankrupt and shareholders earn their required rate of return. Our approach also differs from Lewis and Sappington (1995) who examine the optimal design of capital structure in the context of an agency model that involves a risk-averse regulator (a principal) and a risk-neutral regulated firm (an agent) under alternative assumptions regarding the principal's ability to control the agent's capital structure.

the equity issue to maintain its original stake δ.[15] In stage 2, given k and D, the regulator sets the regulated price p. As mentioned earlier, the regulator is committed to set p in order to maximize (5) with probability ρ, but with probability $1-\rho$, the regulator happens to be opportunistic and sets p in order to maximize (6).[16] Finally, the firm's cost c is realized, output is produced, and payoffs are realized. Our sequence of events (the firm makes its choices before the regulated price is set) is consistent with the empirical finding in Bortolotti et al. (2011) and Cambini and Rondi (2012) that leverage Granger causes regulated prices, but not vice versa.

3 The regulated price

In stage 2 of the game, the regulator sets p to maximize the ex ante objective function (5) with probability ρ and the ex post objective function (6) with probability $1-\rho$. Since the two functions differ only with respect to k, we can rewrite the regulator's objective function compactly as

$$(V(k)-p)^{\gamma}\,(p-\beta\frac{\overline{c}}{2}-(1-\delta)\,\phi\,(p,D)\,T-Ik)^{1-\gamma}, \tag{7}$$

where I is an indicator function which equals 1 with probability ρ (the regulator keeps his commitment to the regulatory rule) and equals 0 with probability $1-\rho$ (the regulator behaves opportunistically and ignores k when setting p). It should be noted that at the extreme when $\gamma=1$, the regulator cares only about consumers and hence sets a "cost-based" price that simply covers the firm's expected costs. At the opposite extreme when $\gamma=0$, the regulator cares only about the firm and sets $p=V(k)$; this price is independent of the firm's cost. In general then, the lower γ is, the more responsive is the regulated price to the firm's cost.

Using (7), we can now solve the problems of both committed and opportunistic regu-

[15] 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.

[16] More formally, one can think about the game as having three stages: Nature chooses the regulator's type (committed or opportunitic) in stage 1, the firm's managers chooses k and D in stage 2 wiithout observing nature's choice, and in stage 3, the regulator sets p given his type.

lators by simply maximizing (7) with respect to p. Using the same steps as in Spiegel (1994), the solution to the maximization problem is given by

$$p^*(D,k,I) = \begin{cases} D_1(k,I) + \bar{c} & D \le D_1(k,I), \\ D + \bar{c} & D_1(k,I) < D \le D_2(k,I), \\ D_1(k,I) + \bar{c} + M(D,I) & D_2(k,I) < D \le D_3(k,I), \\ D_1(k,I) + \bar{c} + \gamma(1-\delta)T & D > D_3(k,I), \end{cases} \tag{8}$$

where

$$D_1(k,I) \equiv (1-\gamma)V(k) + \gamma\beta\frac{\bar{c}}{2} - \bar{c} + \gamma I k, \tag{9}$$

$$M(D,I) \equiv \frac{\gamma(1-\delta)\frac{T}{\bar{c}}\left(D + (2-\beta)\frac{\bar{c}}{2} - Ik\right)}{1+(1-\delta)\frac{T}{\bar{c}}}, \tag{10}$$

$$D_2(k,I) \equiv \frac{(1-\gamma)\left(1+(1-\delta)\frac{T}{\bar{c}}\right)V(k) + \gamma\beta\frac{\bar{c}}{2} + \gamma I k}{1+(1-\gamma)(1-\delta)\frac{T}{\bar{c}}} - \bar{c}, \tag{11}$$

and $D_3(k,I)$ is smaller than the value of D for which $D_1(k,I) + \bar{c} + M(D,I) = D$. This solution is obtained under the assumption that $\gamma < \frac{V(0)-\bar{c}}{V(0)-\beta\frac{\bar{c}}{2}}$ (the regulator is not too pro-consumer). If this assumption is violated, then $D_1(k,0) = 0$, though none of our results is affected. The regulated price is illustrated in the following figure:

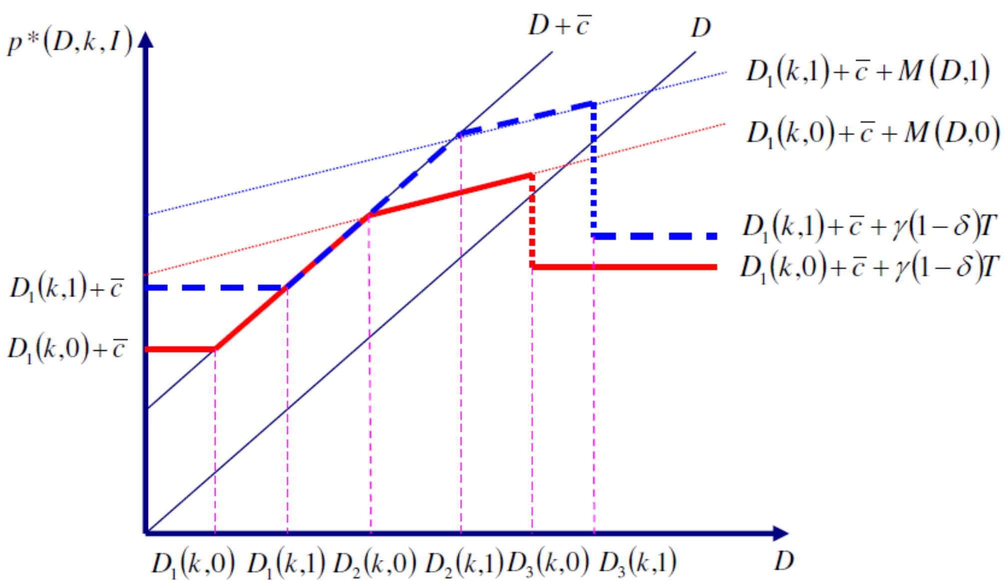

Figure 1: Illustrating the regulated price as a function of D for $I = 0$ (the solid red line) and $I = 1$ (the dashed blue line), holding k fixed

To interpret Figure 1, note that if we ignore financial distress, i.e., assume that $\phi(p,D)=0$, then the price that maximizes (7) is given by $D_1(k,I)+\bar{c}$. So long as $D \leq D_1(k,I)$, this price covers the firm's cost plus its debt obligation even in the worst state of nature.[17] Hence, $\phi(p,D)$ is indeed equal to 0 for all $D \leq D_1(k,I)$. However, once $D > D_1(k,I)$, a price of $D_1(k,I)+\bar{c}$ leaves the firm susceptible to financial distress. So long as D does not exceed $D_1(k,I)$ by too much, the regulator finds it optimal to set $p = D + \bar{c}$ to keep $\phi(p,D)$ just equal to 0. However, when $D > D_2(k,I)$, this strategy is no longer optimal for the regulator because the resulting marginal loss in consumers' surplus becomes too large relative to the benefit of preventing financial distress. The regulator now allows the firm to charge a price premium, given by $M(D,I)$, to lower the probability that the firm becomes financially distressed. Although the price premium $M(D,I)$ is increasing with D, its slope is less than 1; hence p is now smaller than $D+\bar{c}$, and as a result, $\phi(p,D)>0$. When $D > D_3(k,I)$, it is no longer optimal for the regulator to offset the effect of debt on the likelihood of financial distress. Consequently, $\phi(p,D)=1$, so p is now constant and equals $D_1(k,I)+\bar{c}+(1-\delta)T$.

It is easy to see from equations (9) and (11) that $D_1(k,1) > D_1(k,0)$ and $D_2(k,1) > D_2(k,0)$, and moreover, it is easy to check from (8) that $p^*(D,k,1) \geq p^*(D,k,0)$: the regulated price set by a committed regulator (who takes k into account) is weakly higher than price set by an opportunistic regulator (who ignores k). To limit the number of different cases that can arise, we make the following assumption:

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

Assumption 1 ensures that the parameters of the model are such that there exists an interval of D for which $p^*(D,k,1) = p^*(D,k,0)$.[18] A sufficient condition for Assumption 1 to hold is that the social surplus absent financial distress is sufficiently large:

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

[17]As mentioned above, if γ is relatively large, then $D_1(k,I)=0$ and the regulator cannot ignore the possibility of financial distress, no matter how small D is.

[18]Absent Assumption 1, $p^*(D,k,1) > p^*(D,k,0)$ for all D, although none of our main results is affected.

Assumption 1, together with the fact that $D_2(k,0) < D_2(k,1)$, implies that, as Figure 1 shows,

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

4 The choice of capital structure

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, $p - C$, net of the sunk cost of investment, k, must accrue to the original equityholders.

To write down the firm's objective function, let $\phi^*(D,k,I) \equiv \phi^*(p^*(D,k,I),D)$ be the probability of financial distress, which is obtained by substituting $p^*(D,k,I)$ into equation (1). Now, recall that with probability ρ, the regulator is committed to take k into account, in which case the regulated price is $p^*(D,k,1)$ and the probability of financial distress is $\phi^*(D,k,1)$. With probability $1-\rho$, the regulator is opportunistic, so the regulated price and probability of financial distress are $p^*(D,k,0)$ and $\phi^*(D,k,0)$. Using these expressions and equation (4), the expected payoff of the firm's managers is given by

$$\begin{aligned} Y(D,k) &= \rho\left[p^*(D,k,1) - \beta\frac{\overline{c}}{2} - (1-\delta)\phi^*(D,k,1)T - k\right] \\ &\quad + (1-\rho)\left[p^*(D,k,0) - \beta\frac{\overline{c}}{2} - (1-\delta)\phi^*(D,k,0)T - k\right]. \end{aligned} \tag{12}$$

The firm's managers choose the firm's debt level, D, and investment, k, to maximize $Y(D,k)$. The following proposition characterizes the equilibrium choice of debt. The proof, as well as all other proofs, is in the Appendix.

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*

$$\rho^* \equiv \frac{(1-\gamma)(1-\delta)\frac{T}{\overline{c}}}{1+(1-\gamma)(1-\delta)\frac{T}{\overline{c}}}. \tag{13}$$

Proposition 1 shows that the capital structure of the firm depends on ρ, which reflects the degree of regulatory independence. In what follows, we will say that the regulator is “independent” if $\rho > \rho^*$ (the regulator’s ability to commit to take k into account is relatively high) and “non independent” if $\rho < \rho^*$ (the regulator’s ability to commit is relatively low). Proposition 1 shows that the firm issues more debt when it faces an independent regulator. Note from (13) that the threshold ρ^* above which we consider the regulator as “independent” is decreasing with both γ and δ: other things equal, a more pro-consumer regulator (a higher γ) who faces a less privatized firm (a higher δ) is considered “independent” for a larger range of values of ρ.

We now establish two corollaries to Proposition 1.

Corollary 1: *When the regulator is non independent ($\rho < \rho^*$), the regulated price is equal to $D_2(k, 0) + \overline{c}$ with probability 1. When the regulator is independent ($\rho > \rho^*$), the regulated price is equal to $D_2(k, 1) + \overline{c}$ with probability ρ and $D_1(k, 0) + \overline{c} + M(D_2(k, 1), 0)$ with probability $1 - \rho$, where $D_2(k, 1) + \overline{c} > D_1(k, 0) + \overline{c} + M(D_2(k, 1), 0)$. The expected regulated price when $\rho > \rho^*$ is therefore*

$$Ep^*(k) = \rho D_2(k, 1) + (1 - \rho)(D_1(k, 0) + M(D_2(k, 1), 0)) + \overline{c}. \tag{14}$$

Corollary 1 shows that the regulated price is be fully anticipated when the regulator is non-independent ($\rho < \rho^*$), but not when the regulator is independent. This result may seem surprising because an independent regulator has a greater ability to commit to the regulatory rule and determine the regulated price. However, precisely for this reason, the regulated firm is able to issue in this case debt with a larger face value. This debt level in turn induces an opportunistic regulator to set a lower price than the price set by a committed regulator.

The next corollary deals with financial distress. When the regulator is non independent ($\rho < \rho^*$), the firm issues debt with face value $D_2(k, 0)$. Since by Corollary 1, the resulting regulated price is $D_2(k, 0) + \overline{c}$, the firm is immune to financial distress even when the highest cost shock is realized. When the regulator is independent ($\rho > \rho^*$), the firm’s debt is $D_2(k, 1)$. By Corollary 1, the regulated price in this case is $D_2(k, 1) + \overline{c}$; with probability ρ, this price ensures once again that the firm never becomes financially distressed. With probability $1 - \rho$, though, the regulated price is $D_1(k, 0) + \overline{c} + M(D_2(k, 1), 0)$; since this price is below $D_2(k, 1) + \bar{c}$, the firm now becomes financially distressed when the cost shock is sufficiently large.

Corollary 2: *When the regulator is non independent ($\rho < \rho^*$), the firm is completely immune to financial distress. When the regulator is independent ($\rho > \rho^*$), the firm is immune to financial distress with probability ρ (the regulator is committed); with probability $1 - \rho$ (the regulator is opportunistic), the firm becomes financially distressed when $\bar{c}$ is sufficiently high.*

Corollary 2 shows another implication of Proposition 1: the regulated firm may become financially distressed only when the regulator is independent. As before, the reason is that in this case, the firm allows itself to issue debt with a higher face value. With probability $1 - \rho$, the regulator happens to be opportunistic, and sets a regulated price that leaves the firm susceptible to financial distress with a positive probability.

With Proposition 1 in place, we can now examine how the equilibrium debt level 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 examine how debt is affected by the other two main exogenous parameters: the state's stake in the regulated firm, δ, and the measure of regulatory climate (i.e., how pro-consumer the regulator is), γ.

Proposition 2: *Holding k fixed, the debt level of the regulated firm is higher the lower δ and γ are.*

Combined, Propositions 1 and 2 imply that if we consider a cross section of regulated firms that differ in terms of the degree to which they are privatized (the value of δ) and in terms of the regulatory environment they operate in (the values of ρ and γ), then other things equal, firms should be more leveraged when they are more privatized (δ is lower) and when they face more independent and more pro-firm regulators (ρ is higher and γ is lower). These predictions are consistent with Bortolotti et al. (2011) who study a comprehensive panel data of 92 publicly traded EU utilities over the period 1994–2005 and find that firms tend to be more leveraged if they are privately controlled (i.e., the state's stake in the firm is below 50% or below 30%) and regulated by an IRA.[19] Although Bortolotti et al. establish their results without controlling for investments, we show in Proposition 7 below that the predictions of Propositions 1 and 2 generalize to the case where k is determined endogenously.

To see the intuition for Proposition 2, note that in equilibrium, the firm issues the largest D that still ensures that if the regulator is committed, the firm will be completely immune to financial distress. Naturally then, the firm will issue a higher D if p is higher. When the state holds a smaller stake in the firm, the firm takes into account a larger fraction of its expected cost of financial distress, so the regulator, who sets p by taking into account the firm's objective function, will set a higher p. The reason why D is higher when γ is low is more subtle since now there are two opposing effects. On the one hand, other things being equal, p is higher when γ is low (the regulator is more pro-firm), so the firm has an incentive to issue more debt. But on the other hand, as noted above, a decrease in γ makes prices less responsive to the firm's cost; consequently, debt, has a weaker effect on the regulated price. It turns out that the first effect is always stronger, so a decrease in γ induces the firm to raise D. Finally, since other things being equal, p is higher when the regulator is independent, the firm will also issue a higher D when it faces an independent regulator.

Next, we examine how the regulated price is affected by δ and γ. As in the case of Proposition 2, for now we hold k fixed. In Section 5, we will show that our comparative statics results continue to hold even when k is determined endogenously.

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

The result that the regulated price is decreasing with the state's ownership stake is

[19] Bortolotti et al. (2011) do not have a direct measure of the regulatory climate and hence cannot study the effect of the regulatory climate on leverage and on prices. Their analysis shows however that firms have a lower leverage when the government is more right-wing. Cambini and Rondi (2012) find a similar result in a study that examines 15 EU Public Telcommunication Operators (PTOs) over the period 1994-2005. To the extent that right-wing governments are more pro-firm, this finding is inconsistent with Proposition 2.

consistent with Kwoka (2002) who shows that after controlling for cost differences, the prices of publicly owned electric utilities in the U.S. are 4.4% cheaper, on average, than the prices of investor owned utilities. Moreover, together with Proposition 2, Proposition 3 implies that if we hold k fixed, then any change in the parameters ρ, δ and γ shifts 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. This finding is consistent with Bortolotti et al. (2011) and with Cambini and Rondi (2012). The latter paper shows that the leverage of PTOs has a positive effect not only on regulated retail rates, but also on the wholesale access fees that PTOs charge alternative operators who wish to access the PTOs' networks.

Finally, recall from Corollary 2 that the firm never becomes distressed if $\rho < \rho^*$. When $\rho > \rho^*$, the firm becomes distressed only when the regulator is opportunistic and sets a price $p^*(D_2(k,1),k,0) = D_1(k,0) + \bar{c} + M(D_2(k,1),0)$. Since the probability of this event is $1-\rho$, the overall probability of financial distress when $\rho > \rho^*$ is $(1-\rho)\,\phi^I(k)$, where, using equation (1),

$$\begin{aligned}\phi^I(k) &\equiv \underbrace{1 - \frac{p^*(D_2(k,1),k,0) - D_2(k,1)}{\bar{c}}}_{\phi^*(D_2(k,1),k,0)} \\ &= \frac{D_2(k,1) - D_1(k,0) - M(D_2(k,1),0)}{\bar{c}} \\ &= \frac{\gamma k}{\bar{c}\left(1 + (1-\delta)\frac{T}{\bar{c}}\right)}.\end{aligned} \tag{15}$$

The following result is an immediate consequence of equation (15):

Proposition 4: *Holding k fixed, the probability of financial distress when an independent regulator happens to be opportunistic, $\phi^I(k)$, is increasing with δ, γ, and k and is independent of ρ. Under a non-independent regulator, the firm never becomes financially distressed.*

At a first glance, Proposition 4 seems counterintuitive since Proposition 2 implies that the firm issues less debt, D, when δ and γ are higher. Hence it might be thought that the firm would be less susceptible to financial distress. Yet, Proposition 3 shows that when δ and γ are higher, the regulated price, p, is also lower. It turns out that the decrease in p has a stronger effect on the probability of financial distress than the decrease in D, so overall, financial distress becomes more likely.

5 The equilibrium level of investment

Having characterized the equilibrium choice of debt, we next turn to the choice of investment. Consider first the case where $\rho < \rho^*$, and recall from Corollaries 1 and 2 that in this case, $D = D_2(k,0)$. The regulator in turn sets a price $D_2(k,0) + \bar{c}$, which ensures that the firm is completely immune to financial distress. By equation (12) then, the expected payoff of the firm is

$$Y^{NI}(k) \equiv Y(D_2(k,0), k) = D_2(k,0) + (2-\beta)\frac{\bar{c}}{2} - k. \tag{16}$$

When $\rho > \rho^*$, the firm issues debt with face value $D_2(k,1)$. Now, with probability ρ, the regulator is committed and sets a regulated price $p^*(D_2(k,1),k,1) = D_2(k,1) + \bar{c}$, which ensures that the firm never becomes financially distressed. With probability $1-\rho$, the regulator is opportunistic and sets a price $p^*(D_2(k,1),k,0) = D_1(k,0) + \bar{c} + M(D_2(k,1),0)$; with this price, the firm becomes financially distressed with probability $\phi^I(k)$. Substituting these expressions in equation (12), using the definition of $M(D_2(k,1),0)$, and rearranging terms (see the proof of Proposition 5 for details), the firm's expected payoff is

$$\begin{aligned} Y^I(k) \equiv\ & Y(D_2(k,1), k) = (1-\gamma(1-\rho^*))V(k) - (1-\gamma(\rho-\rho^*))k \\ & -\frac{\beta(1-\gamma)\left(1+(1-\delta)\frac{T}{\bar{c}}\right)\frac{\bar{c}}{2}}{1+(1-\gamma)(1-\delta)\frac{T}{\bar{c}}}. \end{aligned} \tag{17}$$

Using $Y^{NI}(k)$ and $Y^I(k)$ we establish the following result:

Proposition 5: *The equilibrium level of investment, k^*, is independent of the degree of regulatory independence, ρ, when $\rho < \rho^*$, but is increasing with ρ when $\rho > \rho^*$. Consequently, the firm invests more when the regulator is independent (i.e., $\rho > \rho^*$) than when the regulator is non independent (i.e., $\rho < \rho^*$).*

Since regulatory independence in our model is associated with a smaller degree of regulatory opportunism, Proposition 5 is consistent with Lyon and Mayo (2005) who show that a greater threat of regulatory opportunism leads firms to invest less.

Having fully characterized k^* and showed how it is affected by regulatory independence, we are now ready to examine how k^* is affected by the state's stake in the firm, δ, and by the regulatory climate, γ, which reflects the degree to which the regulator is pro-consumers.

Proposition 6: *The equilibrium level of investment, k^*, is decreasing with δ and γ. If in addition $\frac{V'(k)}{V''(k)}$ is nondecreasing, then the negative effects of δ and γ on k^* are larger when the regulator is independent, i.e., when $\rho > \rho^*$.*

To see the intuition for Proposition 6, recall from Proposition 2 that when δ and γ are higher, the regulator sets a lower regulated price. Consequently, the marginal benefit of investment falls and the firm invests less. Proposition 6 shows that these effects are stronger when the regulator is independent, i.e., when $\rho > \rho^*$.

Propositions 5 and 6 imply that other things being equal, firms should invest more when they face an independent regulator, when they are more privatized (i.e., δ is lower), and when they face a more pro-firm regulator (i.e., γ is lower). These predictions are consistent with a number of empirical findings. Wallsten (2001) studies the investment of Telecoms in 30 African and Latin American countries from 1984 to 1997. Among other things, he finds that privatization combined with regulatory independence is positively correlated with investment in capacity and phone penetration. Privatization alone, however, is associated with few benefits, and is negatively correlated with interconnection capacity. Henisz and Zelner (2001) study data from 55 countries over 20 years and find that stronger constraints on executive discretion, which improves their ability to commit not to expropriate the property of privately owned regulated firms, leads to a faster deployment of basic telecommunications infrastructure. Gutiérrez (2003) examines how regulatory governance affected the performance of telecoms in 22 Latin American countries during the period 1980–1997 and finds that regulatory independence has a positive impact on network expansion and efficiency. Alesina et al. (2005) examine the aggregate levels of investment in the transport, telecommunications, and energy sectors in 21 OECD countries over the period 1975-1998. Among other things, they show that a larger ownership stake of the state is associated with lower levels of investment. Egert (2009) shows that incentive regulation implemented jointly with an independent sector regulator has a strong positive impact on investment in various network industries (electricity, gas, water supply, road, rail, air transportation, and telecommunications) in OECD member countries. Finally, Cambini and Rondi (2010) study a panel of 80 publicly traded EU telecoms, energy, transportation, and water utilities over the 1994-2004 period and find that utilities invest more when an IRA is in place; moreover, they find that conditional on the existence of an IRA, firms invest more when the IRA has a larger degree of formal independence.

Next, recall that Propositions 1-4 examined the effects of regulatory independence, privatization, and the regulatory climate on the firm's debt level, regulated price, and the probability of distress, holding k fixed. We now show that these results continue to hold even after the endogenous choice of k is taken into account.

Proposition 7: *Taking into account the endogenous choice of investment, the firm's debt 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 and the regulated price are both decreasing with the state's ownership stake δ, and with the measure of regulatory climate γ. The probability of financial distress when an independent regulator is opportunistic, $\phi^I(k^*)$, is increasing with the degree of regulatory independence, ρ. If in addition γ is sufficiently small to ensure that $\frac{V'(k^*)}{V''(k^*)k^*} + \frac{(1-\gamma)\left(1+(1-\gamma)(1-\delta)\frac{T}{\bar{c}}\right)}{\gamma} \geq 0$, then $\phi^I(k^*)$ is also increasing with the state's ownership stake, δ, and with the measure of regulatory climate, γ.*

The result that $\phi^I(k^*)$ is increasing with the degree of independence, ρ, is surprising given that an increase in ρ means that the regulator is less likely to be opportunistic (recall that financial distress occurs only when the regulator is opportunistic). The reason for this surprising result is that when the regulator is independent, an increase in ρ induces the firm to invest more and to issue more debt to finance its investment. Indeed, Proposition 4 shows that $\phi^I(k)$ is increasing with k and Proposition 5 shows that k^* is increasing with ρ. As a result, an increase in ρ makes the firm more susceptible to financial distress. Proposition 7 also shows that the result of Proposition 4 that the firm is more susceptible to financial distress as δ and γ increase continues to hold when k is endogenous, provided that γ is sufficiently low.

To get a better feel for the sufficient condition in the last part of Proposition 7, suppose that $V(k) = \log(a+k)$, where $a < 1$. Then, $\frac{V'(k^*)}{V''(k^*)k^*} = \frac{\frac{1}{a+k^*}}{-\frac{k^*}{(a+k^*)^2}} = -\left(1+\frac{a}{k^*}\right)$. In the proof of Proposition 8 below we show that $V'(k^*) > 1$. In the current example, this inequality implies that $\frac{1}{a+k^*} > 1$, or $k^* < 1-a$. Hence. $\frac{V'(k^*)}{V''(k^*)k^*} = -\left(1+\frac{a}{k^*}\right) < -\frac{1}{1-a}$. The sufficient condition then is more likely to hold as a gets smaller.

6 Social welfare

Having studied the firm's investment and financing decisions, we now turn to the implications of our model for social welfare. In particular, we are interested in finding out how regulatory independence, privatization, and the regulatory climate affect social welfare once the firm's and the regulator's decisions are taken into account. In our model, the expected value of social welfare is given by the difference between the willingness of consumers to pay and the expected cost of the firm, including its expected cost of financial distress and cost of investment:

$$W(k) = V(k) - \frac{\bar{c}}{2} - (1-\rho)\,\phi^*(D,k,I)\,T - k.$$

By Corollary 2, $\phi^*(D,k,I) = 0$ when the regulator is not independent. Hence, the expected social welfare, as a function of k, is given in this case by

$$W^{NI}(k) = V(k) - \frac{\bar{c}}{2} - k. \tag{18}$$

When the regulator is independent, equation (15) shows that $\phi^*(D,k,I) = \frac{\gamma k}{\bar{c}\left(1+(1-\delta)\frac{T}{\bar{c}}\right)}$. Hence, expected social welfare, as a function of k, is given by

$$W^{I}(k) = V(k) - \frac{\bar{c}}{2} - \frac{(1-\rho)\,\gamma k \frac{T}{\bar{c}}}{1+(1-\delta)\frac{T}{\bar{c}}} - k. \tag{19}$$

In the next proposition we compare the equilibrium level of investment, k^*, with the socially optimal level that maximizes $W^{NI}(k)$ and $W^{I}(k)$ and examine how social welfare is affected by regulatory independence, privatization, and the regulatory climate.

Proposition 8: *The equilibrium level of investment, k^*, is below the socially optimal level. Moreover, in equilibrium,*

(i) *social welfare is independent of the degree of regulatory independence, ρ, but is decreasing with the state's ownership stake δ, and with the measure of regulatory climate γ when the regulator is non-independent (i.e., when $\rho < \rho^*$);*

(ii) *assuming that $1 - \delta(1-\gamma)\frac{T}{\bar{c}} > 0$, social welfare is increasing with the degree of regulatory independence, ρ, and decreasing with the state's ownership stake δ, and with the measure of regulatory climate γ, when the regulator is independent (i.e., when $\rho > \rho^*$).*

Proposition 8 shows that when we take into account the endogenous determination of investment and capital structure, a higher degree of regulatory independence (a higher ρ), a larger extent of privatization (a decrease in the value of δ), and a more pro-firm regulatory climate (a lower value of γ), are all welfare-enhancing. The reason for this is that as Propositions 5-6 show, regulatory independence, privatization and pro-firm regulatory climate strengthen the firm's incentive to invest and, while the regulated price increases too, the increase in investment leads to an increase in the total surplus generated by the firm.

7 Conclusion

We studied the strategic interaction between capital structure, regulation, and investment, in a setting that features partial ownership by the state in the regulated firm and regulation by agencies with various degrees of independence. Both features are common in many countries around the world.

Our model shows that regulated firms issue more debt and enjoy higher regulated prices when they face more independent regulators, are more privatized, and when regulators are more pro-firm. At the same time, these factors also induce the firm to invest more and this increase in investment is overall welfare improving. These results indicate that the "dash for debt" phenomenon observed in many countries is a natural response of regulated utilities to the privatization process and the establishment of IRAs. Moreover, our results suggest while privatization and regulatory independence lead to a "dash for debt," these processes also lead to higher social surplus.

8 Appendix

Investment rate of utilities relative to GDP in the EU14 states:

The following table shows the rate of gross fixed capital formation in the energy sector (electricity and gas), water supply, transport, and telecommunications, as a share of GDP in 2008, using the OECD's STAN (Structural Analysis) Indicators database. This database provides annual sectorial indicators on the production and employment structures, labor productivity and costs, investments, R&D expenditures, and international trade patterns in each OECD country.

Table 1: Investment rate as % of GDP in 2008 in the EU14 states

State	Investment rate as % of GDP
Austria	13.94%
Belgium	15.57%
Denmark	18.80%
Finland	15.79%
France	9.84%
Germany	11.70%
Greece	14.59%
Ireland	19.00%
Italy	16.63%
Netherlands	9.66%
Portugal	20.24%
Spain	14.58%
Sweden	18.51%
UK	14.47%
Average EU14	15.24%

Proof of Proposition 1: Differentiating equation (12) yields

$$\begin{aligned} \frac{\partial Y(D,k)}{\partial D} &= \rho\left[\frac{\partial p^*(D,k,1)}{\partial D} - (1-\delta)\left(\frac{\partial \phi^*(D,k,1)}{\partial p^*}\frac{\partial p^*(D,k,1)}{\partial D} + \frac{\partial \phi^*(D,k,1)}{\partial D}\right)T\right] \\ &\quad + (1-\rho)\left[\frac{\partial p^*(D,k,0)}{\partial D} - (1-\delta)\left(\frac{\partial \phi^*(D,k,0)}{\partial p^*}\frac{\partial p^*(D,k,0)}{\partial D} + \frac{\partial \phi^*(D,k,0)}{\partial D}\right)T\right]. \end{aligned} \tag{20}$$

Note first that when $D \leq D_2(k,0)$, $\phi^*(D,k,0) = \phi^*(D,k,1) = 0$, while $\frac{\partial p^*(D,k,0)}{\partial D} \geq 0$ and $\frac{\partial p^*(D,k,1)}{\partial D} \geq 0$. Hence, $\frac{\partial Y(D,k)}{\partial D} \geq 0$ for all $D \leq D_2(k,0)$, implying that the firm's debt will be at least $D_2(k,0)$.

Second, consider the range where $D_2(k,1) < D < D_3(k,0)$. Here, $p^*(D,k,I) = D_1(k,I) + \overline{c} + M(D,I)$ and $\phi^*(D,k,I) = 1 - \frac{p^*(D,k,I)-D}{\overline{c}}$. Hence,

$$\frac{\partial p^*(D,k,I)}{\partial D} = \frac{\partial M(D,I)}{\partial D} = \frac{\gamma(1-\delta)\frac{T}{\overline{c}}}{1+(1-\delta)\frac{T}{\overline{c}}}, \tag{21}$$

and

$$\frac{\partial \phi^*(D,k,I)}{\partial p^*} = -\frac{\partial \phi^*(D,k,I)}{\partial D} = -\frac{1}{\overline{c}}. \tag{22}$$

Substituting in (20), yields

$$\begin{aligned} \frac{\partial Y(D,k)}{\partial D} &= \frac{\gamma(1-\delta)\frac{T}{\overline{c}}}{1+(1-\delta)\frac{T}{\overline{c}}} - (1-\delta)\left(1 - \frac{\gamma(1-\delta)\frac{T}{\overline{c}}}{1+(1-\delta)\frac{T}{\overline{c}}}\right)\frac{T}{\overline{c}} \\ &= -(1-\gamma)(1-\delta)\frac{T}{\overline{c}} < 0. \end{aligned}$$

Moreover, it is easy to see from equation (8) and Figure 1 that $p^*(D,k,I)$ jumps downward at $D = D_3(k,0)$ and is independent of D for all $D > D_3(k,0)$. Hence, $\frac{\partial Y(D,k)}{\partial D} < 0$ for all $D \geq D_2(k,1)$, implying that the firm will never issue debt with face value above $D_2(k,1)$.

Finally, we need to consider the range where $D_2(k,0) \leq D \leq D_2(k,1)$. Figure 1 shows that in this range $p^*(D,k,1) = D + \overline{c}$, and $p^*(D,k,0) = D_1(k,0) + \overline{c} + M(D,0)$. Hence, $\phi^*(D,k,1) = 0$ and $\phi^*(D,k,0) = 1 - \frac{p^*(D,k,0)-D}{\overline{c}}$. Noting that $\frac{\partial p^*(D,k,1)}{\partial D} = 1$, and that

$\frac{\partial p^*(D,k,0)}{\partial D}$ and $\frac{\partial \phi^*(D,k,0)}{\partial p^*}$ are given by (21) and (22), and substituting in (20), yields

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

If $\rho < \rho^*$, then $\frac{\partial Y(D,k)}{\partial D} < 0$, so the firm will set $D = D_2(k,0)$. If $\rho > \rho^*$, then $\frac{\partial Y(D,k)}{\partial D} > 0$, so the firm will set $D = D_2(k,1)$. ■

Proof of Corollary 1: When $\rho < \rho^*$, the firm issues debt with fact value $D_2(k,0)$. By (8),

$$p^*(D,k,1) = p^*(D,k,0) = D_2(k,0) + \bar{c}.$$

That is, the regulated price is the same irrespective of whether the regulator is committed or opportunistic.

When $\rho > \rho^*$, the firm issues debt with face value $D = D_2(k,1)$. By (8), the regulated price under a committed regulator is

$$p^*(D_2(k,1),k,1) = D_2(k,1) + \bar{c},$$

while the price under an opportunistic regulator is

$$p^*(D_2(k,1),k,0) = D_1(k,0) + \bar{c} + M(D_2(k,1),0).$$

The expected price is then given by (14). Noting from Figure 1 that

$$D_2(k,1) + \bar{c} > D_1(k,0) + \bar{c} + M(D_2(k,1),0),$$

it follows that $p^*(D_2(k,1),k,1) > p^*(D_2(k,1),k,0)$: the price is higher when the regulator is committed. ■

Proof of Proposition 2: Differentiating $D_2(k,I)$ with respect to δ and γ, and recalling that $\beta = 1-\delta$ under the MPE approach and $\beta = 1$ under the SBC approach, yields:

$$\frac{\partial D_2(k,I)}{\partial \delta} = -\frac{\gamma(1-\gamma)\frac{T}{\bar{c}}\left(V(k) - \beta\frac{\bar{c}}{2} - Ik\right)}{\left(1+(1-\gamma)(1-\delta)\frac{T}{\bar{c}}\right)^2} + \frac{\gamma\frac{\bar{c}}{2}\frac{\partial \beta}{\partial \delta}}{1+(1-\gamma)(1-\delta)\frac{T}{\bar{c}}^2} < 0, \tag{23}$$

and

$$\frac{\partial D_2(k,I)}{\partial \gamma} = -\frac{\left(1+(1-\delta)\frac{T}{\bar{c}}\right)\left(V(k)-\beta\frac{\bar{c}}{2}-Ik\right)}{\left(1+(1-\gamma)(1-\delta)\frac{T}{\bar{c}}\right)^2} < 0, \tag{24}$$

where the inequalities follow since (7) implies that $V(k) \geq p \geq \beta\frac{\bar{c}}{2} + (1-\delta)\phi(p,D)T + Ik$, so $V(k) \geq \beta\frac{\bar{c}}{2} + Ik$. ■

Proof of Proposition 3: First, suppose that $\rho < \rho^*$. By Corollary 1, the regulated price is then $D_2(k,0)+\bar{c}$. Since Proposition 2 shows that $D_2(k,0)$ decreases with δ and γ, so does the regulated price.

Second, suppose that $\rho > \rho^*$. As Corollary 1 shows, the regulated price is then equal to $D_2(k,1)+\bar{c}$ with probability ρ and to $D_1(k,0)+\bar{c}+M(D_2(k,1),0)$ with probability $1-\rho$, and the expected regulated price, $Ep^*(k)$, is given by (14). It is easy to see from Figure 1 that

$$D_2(k,1)+\bar{c} > D_1(k,0)+\bar{c}+M(D_2(k,1),0) > D_2(k,0)+\bar{c}.$$

Hence, $Ep^*(k) > D_2(k,0)+\bar{c}$, implying that if we hold k fixed, the regulated price is higher in expectation when the regulator is independent than when he is not.

Using (14) along with equations (9) and (10), using (**??**) and (**??**), and recalling that $\beta = 1-\delta$ under the MPE approach and $\beta = 1$ under the SBC approach, yields

$$\begin{aligned}\frac{\partial Ep^*(k)}{\partial \delta} &= \left(\rho + (1-\rho)\underbrace{\frac{\gamma(1-\delta)\frac{T}{\bar{c}}}{1+(1-\delta)\frac{T}{\bar{c}}}}_{\frac{\partial M(D,0)}{\partial D}}\right)\frac{\partial D_2(k,1)}{\partial \delta} \\ &\quad -(1-\rho)\underbrace{\frac{\gamma\left(D_2(k,1)+(2-\beta)\frac{\bar{c}}{2}\right)\frac{T}{\bar{c}}}{\left(1+(1-\delta)\frac{T}{\bar{c}}\right)^2}}_{\frac{\partial M(D,0)}{\partial \delta}} + \underbrace{\frac{(1-\rho)\gamma\frac{\bar{c}}{2}}{1+(1-\delta)\frac{T}{\bar{c}}}}_{\frac{\partial D_1(k,0)}{\partial \beta}+\frac{\partial M(D,0)}{\partial \beta}}\frac{\partial \beta}{\partial \delta} < 0,\end{aligned}$$

and

$$
\begin{aligned}
\frac{\partial Ep^{*}(k)}{\partial \gamma} &= \left(\rho+(1-\rho)\underbrace{\frac{\gamma(1-\delta)\frac{T}{\bar{c}}}{1+(1-\delta)\frac{T}{\bar{c}}}}_{\frac{\partial M(D,0)}{\partial D}}\right)\frac{\partial D_2(k,1)}{\partial \gamma} \\
&\quad -(1-\rho)\underbrace{\frac{\left(V(k)-\bar{c}-D_2(k,1)\right)(1-\delta)\frac{T}{\bar{c}}+V(k)-\beta\frac{\bar{c}}{2}}{1+(1-\delta)\frac{T}{\bar{c}}}}_{\frac{\partial D_1(k,0)}{\partial \gamma}+\frac{\partial M(D,0)}{\partial \gamma}} \\
&= \left(\rho+(1-\rho)\frac{\gamma(1-\delta)\frac{T}{\bar{c}}}{1+(1-\delta)\frac{T}{\bar{c}}}\right)\frac{\partial D_2(k,1)}{\partial \gamma} \\
&\quad -(1-\rho)\frac{\left(V(k)-\beta\frac{\bar{c}}{2}-\gamma k\right)+\frac{\gamma k}{1+(1-\delta)\frac{T}{\bar{c}}}}{1+(1-\delta)(1-\gamma)\frac{T}{\bar{c}}} < 0,
\end{aligned}
$$

where the inequalities follow since (7) implies that $V(k) \geq p \geq \beta\frac{\bar{c}}{2}+(1-\delta)\phi(p,D)T+Ik$, so $V(k) \geq \beta\frac{\bar{c}}{2}+\gamma k$. This completes the proof. ■

Proof of Proposition 5: When $\rho < \rho^{*}$, the first order condition for k^{*} is given by

$$
\begin{aligned}
\frac{dY^{NI}(k)}{dk} &= \frac{\partial D_2(k,0)}{\partial k}-1 \\
&= \left(\frac{1+(1-\delta)\frac{T}{\bar{c}}}{1+(1-\delta)(1-\gamma)\frac{T}{\bar{c}}}\right)(1-\gamma)V'(k)-1 \qquad (25) \\
&= \left(1-\gamma\left(1-\rho^{*}\right)\right)V'(k)-1=0,
\end{aligned}
$$

where the last equality follows by using (13). Since $V''(k) < 0$, the first order condition is sufficient for a maximum.

As mentioned in the text, when $\rho > \rho^{*}$, the firm issues debt with face value $D_2(k,1)$. With probability ρ, the regulator is committed and sets a price $p^{*}\left(D_2(k,1),k,1\right) = D_2(k,1)+\bar{c}$, which ensures that the firm is immune to financial distress. With probability $1-\rho$, the regulator is opportunistic and sets a price $p^{*}\left(D_2(k,1),k,0\right) = D_1(k,0)+\bar{c}+M\left(D_2(k,1),0\right)$ which leaves the firm susceptible to financial distress with probability $\phi^{I}(k)$. Substituting $p^{*}\left(D_2(k,1),k,1\right)$ and $p^{*}\left(D_2(k,1),k,0\right)$ in equation (12), using equation (15), and rearranging terms, yields

$$
\begin{aligned}
Y^I(k) \equiv\ & Y(D_2(k,1),k) = \rho\left(\overbrace{D_2(k,1)+\bar{c}}^{p^*(D_2(k,1),k,1)}\right) + (1-\rho)\left[\overbrace{D_1(k,0)+\bar{c}+M(D_2(k,1),0)}^{p^*(D_2(k,1),k,0)}\right] \\
& -(1-\rho)(1-\delta)\phi^I(k)T - \beta\frac{\bar{c}}{2} - k \\
=\ & \left[\frac{\rho(1+(1-\gamma)(1-\delta)\frac{T}{\bar{c}}) + \gamma(1-\delta)\frac{T}{\bar{c}}}{1+(1-\delta)\frac{T}{\bar{c}}}\right] D_2(k,1) + (1-\rho)D_1(k,0) \\
& + \frac{\left(1+(1+\gamma(1-\rho))(1-\delta)\frac{T}{\bar{c}}\right)\left((2-\beta)\frac{\bar{c}}{2}-k\right)}{1+(1-\delta)\frac{T}{\bar{c}}}.
\end{aligned}
$$

Using the definitions of $D_1(k,0)$ and $D_2(k,1)$ and equation (13), yields equation (17) in the text. Differentiating this equation, yields the first order condition for k^*:

$$\frac{dY^I(k)}{dk} = (1-\gamma(1-\rho^*))V'(k) - (1-\gamma(\rho-\rho^*)) = 0. \tag{26}$$

Since $V''(k) < 0$, the first order condition is sufficient for a maximum.

Equation (25) shows that k^* is independent of ρ when $\rho^* < \rho$. Fully differentiating equation (26) with respect to k and ρ shows that when $\rho > \rho^*$,

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

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

Proof of Proposition 6: First, note from (13) that

$$\frac{\partial \rho^*}{\partial \delta} = -(1-\gamma)(1-\rho^*)^2\frac{T}{\bar{c}} < 0, \qquad \frac{\partial \rho^*}{\partial \gamma} = -\frac{\rho^*(1-\rho^*)}{1-\gamma} < 0. \tag{27}$$

When $\rho < \rho^*$, k^* is implicitly defined by equation (25). Totally differentiating this equation with respect to k and δ, and recalling that $V''(\cdot) < 0 < V'(\cdot)$, yields

$$\frac{\partial k^*}{\partial \delta} = -\frac{\gamma\frac{\partial \rho^*}{\partial \delta}V'(k^*)}{(1-\gamma(1-\rho^*))V''(k^*)} < 0. \tag{28}$$

Similarly, totally differentiating equation (25) with respect to k and γ,

$$\frac{\partial k^*}{\partial \gamma} = -\frac{\left(\gamma\frac{\partial \rho^*}{\partial \gamma} - (1-\rho^*)\right)V'(k^*)}{(1-\gamma(1-\rho^*))V''(k^*)} < 0. \tag{29}$$

Next, suppose that $\rho > \rho^*$. Then k^* is defined by (26). Totally differentiating this equation and noting from (36) that $V'(k^*) > 1$,

$$\frac{\partial k^*}{\partial \delta} = -\frac{\gamma \frac{\partial \rho^*}{\partial \delta}\left(V'(k^*) - 1\right)}{\left(1 - \gamma\left(1 - \rho^*\right)\right) V''(k^*)} < 0, \tag{30}$$

and

$$\begin{aligned} \frac{\partial k^*}{\partial \gamma} &= -\frac{-\left(1-\rho^*\right) V'(k^*) + \left(\rho - \rho^*\right) + \gamma \frac{\partial \rho^*}{\partial \gamma}\left(V'(k^*) - 1\right)}{\left(1 - \gamma\left(1 - \rho^*\right)\right) V''(k^*)} \\ &= -\frac{\left(\gamma \frac{\partial \rho^*}{\partial \gamma} - \left(1 - \rho^*\right)\right)\left(V'(k^*) - 1\right) - (1 - \rho)}{\left(1 - \gamma\left(1 - \rho^*\right)\right) V''(k^*)} < 0. \end{aligned} \tag{31}$$

Finally, to examine the effect of ρ on $\frac{\partial k^*}{\partial \delta}$ and $\frac{\partial k^*}{\partial \gamma}$, we need to compare equation (28) with equation (30) and equation (29) with equation (31). To this end, let k^{NI} and k^I be the investment levels determined by (25) and (26). Then,

$$\begin{aligned} \underbrace{-\frac{\gamma \frac{\partial \rho^*}{\partial \delta}\left(V'(k^I) - 1\right)}{\left(1 - \gamma\left(1 - \rho^*\right)\right) V''(k^I)}}_{\text{R.H.S. of equation (30)}} &> -\frac{\gamma \frac{\partial \rho^*}{\partial \delta} V'(k^I)}{\left(1 - \gamma\left(1 - \rho^*\right)\right) V''(k^I)} \\ &> \underbrace{-\frac{\gamma \frac{\partial \rho^*}{\partial \delta} V'(k^{NI})}{\left(1 - \gamma\left(1 - \rho^*\right)\right) V''(k^{NI})}}_{\text{R.H.S. of equation (28)}}, \end{aligned}$$

where the first inequality follows since $\frac{\partial \rho^*}{\partial \delta} < 0$, and the second follows since $\frac{V'(k)}{V''(k)}$ is nondecreasing and since Proposition 5 implies that $k^I > k^{NI}$. Similarly,

$$\begin{aligned} \underbrace{-\frac{\left(\gamma \frac{\partial \rho^*}{\partial \gamma} - \left(1 - \rho^*\right)\right)\left(V'(k^I) - 1\right) - (1 - \rho)}{\left(1 - \gamma\left(1 - \rho^*\right)\right) V''(k^I)}}_{\text{R.H.S. of equation (31)}} &> -\frac{\left(\gamma \frac{\partial \rho^*}{\partial \gamma} - \left(1 - \rho^*\right)\right) V'(k^I)}{\left(1 - \gamma\left(1 - \rho^*\right)\right) V''(k^I)} \\ &> \underbrace{-\frac{\left(\gamma \frac{\partial \rho^*}{\partial \gamma} - \left(1 - \rho^*\right)\right) V'(k^{NI})}{\left(1 - \gamma\left(1 - \rho^*\right)\right) V''(k^{NI})}}_{\text{R.H.S. of equation (29)}}, \end{aligned}$$

where the first inequality follows since $\rho > \rho^*$ when the regulator is independent and since $\frac{\partial \rho^*}{\partial \gamma} < 0$, and the second inequality follows since $\frac{V'(k)}{V''(k)}$ is nondecreasing and since $k^I > k^{NI}$.
■

Proof of Proposition 7: In equilibrium, $D = D_2(k^*, 0)$ if $\rho < \rho^*$ and $D = D_2(k^*, 1)$ if $\rho > \rho^*$. Equation (11) shows that $D_2(k^*, I)$ is affected by ρ only through the choice of k, but not directly. Using equations (9) and (11) and the definition of ρ^* in Proposition 1,

$$\begin{aligned}\frac{dD_2(k^*,I)}{dk} &= \frac{(1-\gamma)\left(1+(1-\delta)\frac{T}{\overline{c}}\right)V'(k)+\gamma I}{1+(1-\gamma)(1-\delta)\frac{T}{\overline{c}}} \\ &= (1-\gamma(1-\rho^*))V'(k^*)+\gamma I(1-\rho^*)>0. \end{aligned} \tag{32}$$

Hence, both $D_2(k^*,0)$ and $D_2(k^*,1)$ are increasing with k. As in the proof of Proposition 6, let k^{NI} and k^I denote the equilibrium levels of investment when the regulator is non independent ($\rho<\rho^*$) and when he is independent ($\rho>\rho^*$) and recall that $k^I>k^{NI}$ by Proposition 4. Then,

$$D_2\left(k^{NI},0\right)<D_2\left(k^I,0\right)<D_2\left(k^I,1\right),$$

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

Next, we consider the effects of δ and γ on the firm's debt. Proposition 2 shows that holding k fixed, δ and γ have a negative direct effect on debt. Equation (32), together with Proposition 6, implies 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 k is taken into account.

As for the regulated price, recall from Corollary 1 that it is given by $D_2(k^*,0)+\overline{c}$ 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

$$D_2\left(k^{NI},0\right)+\overline{c}<D_2\left(k^I,0\right)+\overline{c}<Ep^*\left(D_2\left(k^I,1\right),k^I\right),$$

where the right inequality follows by Proposition 3 which states that if we hold k fixed, the expected price is higher when the regulator is independent. Therefore, the regulated price is higher when $\rho>\rho^*$ than when $\rho<\rho^*$.

Since $D_2(k^*,0)$ is decreasing with δ and γ, the regulated price is also decreasing with δ and γ for all $\rho<\rho^*$. When $\rho>\rho^*$, equation (14) implies that

$$\frac{dEp^*(k^*)}{dk}=\rho\frac{dD_2(k^*,1)}{dk}+(1-\rho)\left(\frac{dD_1(k^*,0)}{dk}+\frac{\partial M(D_2(k,1),0)}{\partial D}\frac{dD_2(k^*,1)}{dk}\right)>0, \tag{33}$$

where the inequality follows since $\frac{dD_2(k^*,1)}{dk}>0$ by (32), since $\frac{dD_1(k,0)}{dk}=(1-\gamma)V'(k)>0$, and since $\frac{\partial M(D_2(k,1),0)}{\partial D}>0$ by equation (10). Together with Proposition 6, it follows that δ

and γ have a negative indirect effect on $Ep^*(k^*)$. Proposition 2 in turn shows that holding k fixed, the direct effect is also negative. Hence, the regulated price is decreasing with δ and γ when n $\rho > \rho^*$.

Finally, recall that when $\rho > \rho^*$, the probability of financial distress is $\phi^I(k^*)$, where $\phi^I(k)$ is given by (15). Since $\frac{\partial k^*}{\partial \rho} > 0$ by Proposition 5, $\phi^I(k^*)$ is increasing with ρ.

Using (30), (27), and (13),

$$\begin{aligned}
\frac{d\phi^I(k^*)}{d\delta} &= \frac{\gamma \frac{\partial k^*}{\partial \delta}}{\bar{c}\left(1+(1-\delta)\frac{T}{\bar{c}}\right)} + \frac{\gamma k^* T}{\bar{c}^2\left(1+(1-\delta)\frac{T}{\bar{c}}\right)^2} \\
&= \frac{\gamma T}{\bar{c}^2\left(1+(1-\delta)\frac{T}{\bar{c}}\right)}\left[\frac{\gamma(1-\gamma)(1-\rho^*)^2(V'(k^*)-1)}{(1-\gamma(1-\rho^*))V''(k^*)} + \frac{k^*}{1+(1-\delta)\frac{T}{\bar{c}}}\right] \\
&= \frac{\gamma^2(1-\gamma)(1-\rho^*)^2 T k^*}{\bar{c}^2\left(1+(1-\delta)\frac{T}{\bar{c}}\right)(1-\gamma(1-\rho^*))}\left[\frac{V'(k^*)-1}{V''(k^*)k^*} + \frac{(1-\gamma(1-\rho^*))}{\gamma(1-\gamma)(1-\rho^*)^2\left(1+(1-\delta)\frac{T}{\bar{c}}\right)}\right] \\
&= \frac{\gamma^2(1-\gamma)(1-\rho^*)^2 T k^*}{\bar{c}^2\left(1+(1-\delta)\frac{T}{\bar{c}}\right)(1-\gamma(1-\rho^*))}\left[\frac{V'(k^*)-1}{V''(k^*)k^*} + \frac{1+(1-\gamma)(1-\delta)\frac{T}{\bar{c}}}{\gamma}\right] \\
&> \frac{\gamma^2(1-\gamma)(1-\rho^*)^2 T k^*}{\bar{c}^2\left(1+(1-\delta)\frac{T}{\bar{c}}\right)(1-\gamma(1-\rho^*))}\left[\frac{V'(k^*)}{V''(k^*)k^*} + \frac{(1-\gamma)\left(1+(1-\gamma)(1-\delta)\frac{T}{\bar{c}}\right)}{\gamma}\right].
\end{aligned}$$

The condition in the proposition ensures that the square bracketed term, and hence the entire derivative, are positive.

Likewise, using (31), (27), and (13),

$$\begin{aligned}
\frac{d\phi^I(k^*)}{d\gamma} &= \frac{\gamma\frac{\partial k^*}{\partial \gamma} + k^*}{\bar{c}\left(1+(1-\delta)\frac{T}{\bar{c}}\right)} \\
&= \frac{k^*}{\bar{c}\left(1+(1-\delta)\frac{T}{\bar{c}}\right)}\left[\gamma\frac{\frac{1-\rho^*}{1-\gamma}(V'(k^*)-1) + \frac{1-\rho}{1-\gamma(1-\rho^*)}}{V''(k^*)k^*} + 1\right] \\
&> \frac{k^*}{\bar{c}\left(1+(1-\delta)\frac{T}{\bar{c}}\right)}\left[\gamma\frac{\frac{1-\rho^*}{1-\gamma}(V'(k^*)-1) + \frac{1-\rho^*}{1-\gamma}}{V''(k^*)k^*} + 1\right] \\
&> \frac{k^*}{\bar{c}\left(1+(1-\delta)\frac{T}{\bar{c}}\right)}\left[\frac{\gamma(1-\rho^*)}{1-\gamma}\frac{V'(k^*)}{V''(k^*)k^*} + 1\right] \\
&= \frac{k^*\frac{\gamma(1-\rho^*)}{1-\gamma}}{\bar{c}\left(1+(1-\delta)\frac{T}{\bar{c}}\right)}\left[\frac{V'(k^*)}{V''(k^*)k^*} + \frac{1-\gamma}{\gamma(1-\rho^*)}\right] \\
&= \frac{k^*\frac{\gamma(1-\rho^*)}{1-\gamma}}{\bar{c}\left(1+(1-\delta)\frac{T}{\bar{c}}\right)}\left[\frac{V'(k^*)}{V''(k^*)k^*} + \frac{(1-\gamma)\left(1+(1-\gamma)(1-\delta)\frac{T}{\bar{c}}\right)}{\gamma}\right],
\end{aligned}$$

where the first inequality follows because $V''(k^*) < 0$ and $\rho > \rho^*$ imply that $\frac{\frac{1-\rho^*}{1-\gamma}}{V''(k^*)k^*} >$

$\frac{\frac{1-\rho}{1-\gamma(1-\rho^*)}}{V''(k^*)k^*}$. The condition in the proposition ensures that the square bracketed term, and hence the entire derivative, are positive. ■

Proof of Proposition 8: We first compare the equilibrium level of investment, k^*, with the socially optimal level. To this end, note that when $\rho < \rho^*$, the first best level of investment maximizes $W^{NI}(k)$ and hence is implicitly defined by the first order condition $V'(k) = 1$. Since equation (25) implies that k^* is such that

$$V'(k^*) = \frac{1}{1-\gamma(1-\rho^*)} > 1, \tag{34}$$

the firm underinvests relative to the first best.

When $\rho > \rho^*$, the first best level of investment maximizes $W^I(k)$. Now, the first order condition for the first best level of investment is

$$V'(k) = 1 + \frac{\gamma(1-\rho)\frac{T}{\bar{c}}}{1+(1-\delta)\frac{T}{\bar{c}}} = \frac{1+(1-\delta)\frac{T}{\bar{c}}+\gamma(1-\rho)\frac{T}{\bar{c}}}{1+(1-\delta)\frac{T}{\bar{c}}}. \tag{35}$$

On the other hand, equation (26) implies that k^* is such that

$$V'(k^*) = \frac{1-\gamma(\rho-\rho^*)}{1-\gamma(1-\rho^*)} > 1. \tag{36}$$

Now notice that the right-hand side of (36) exceeds the right-hand side of (35):

$$\frac{1-\gamma(\rho-\rho^*)}{1-\gamma(1-\rho^*)} - \frac{1+(1-\delta)\frac{T}{\bar{c}}+\gamma(1-\rho)\frac{T}{\bar{c}}}{1+(1-\delta)\frac{T}{\bar{c}}} = \frac{\gamma(1-\rho)\left(1-(1-\gamma)(1-\rho^*)\frac{T}{\bar{c}}\right)}{1-\gamma(1-\rho^*)} > 0.$$

Since $V'(k)$ is decreasing, k^* is lower than the first best level of investment, so again, the firm underinvests relative to the first best.

Next, we turn to the comparative statics of welfare. When $\rho < \rho^*$, the equilibrium value of welfare is given by $W^{NI}(k^*)$. Differentiating with respect to $x = \rho, \delta, \gamma$, yields

$$\frac{\partial W^{NI}(k^*)}{\partial x} = [V'(k^*) - 1]\frac{dk^*}{dx}.$$

Since equation (34) implies that $V'(k^*) > 1$, and since Propositions 5-6 imply that when $\rho < \rho^*$, $\frac{dk^*}{d\rho} = 0$, $\frac{dk^*}{d\delta} < 0$, and $\frac{dk^*}{d\gamma} < 0$, we get $\frac{\partial W^{NI}(k^*)}{\partial \rho} = 0$, $\frac{\partial W^{NI}(k^*)}{\partial \delta} < 0$, and $\frac{\partial W^{NI}(k^*)}{\partial \gamma} < 0$.

When $\rho > \rho^*$, the equilibrium value of welfare is given by $W^I(k^*)$. Differentiating with respect to ρ, yields

$$\begin{aligned}\frac{\partial W^I(k^*)}{\partial \rho} &= \left[V'(k^*) - 1 - \frac{(1-\rho)\gamma \frac{T}{\bar{c}}}{1+(1-\delta)\frac{T}{\bar{c}}}\right]\frac{dk^*}{d\rho} + \frac{\gamma k^* \frac{T}{\bar{c}}}{1+(1-\delta)\frac{T}{\bar{c}}} \\ &= \left[\frac{\gamma(1-\rho)}{1-\gamma(1-\rho^*)} - \frac{(1-\rho)\gamma\frac{T}{\bar{c}}}{1+(1-\delta)\frac{T}{\bar{c}}}\right]\frac{dk^*}{d\rho} + \frac{\gamma k^*\frac{T}{\bar{c}}}{1+(1-\delta)\frac{T}{\bar{c}}} \\ &= \frac{(1-\rho)\gamma}{(1-\gamma)\left(1+(1-\delta)\frac{T}{\bar{c}}\right)}\left[1-\delta(1-\gamma)\frac{T}{\bar{c}}\right]\frac{dk^*}{d\rho} + \frac{\gamma k^*\frac{T}{\bar{c}}}{1+(1-\delta)\frac{T}{\bar{c}}},\end{aligned}$$

where the second equality follows by substituting for $V'(k^*)$ from (36) and the third equality follows by substituting for ρ^* from (13) and simplifying. By Proposition 5, $\frac{dk^*}{d\rho} > 0$. Hence, $1 - \delta(1-\gamma)\frac{T}{\bar{c}} > 0$ is sufficient for $\frac{\partial W^I(k^*)}{\partial \rho} > 0$.

Likewise, differentiating $W^I(k^*)$ with respect to δ and γ, using (36) and (13) and simplifying, yields

$$\frac{\partial W^I(k^*)}{\partial \delta} = \frac{(1-\rho)\gamma}{(1-\gamma)\left(1+(1-\delta)\frac{T}{\bar{c}}\right)}\left[1-\delta(1-\gamma)\frac{T}{\bar{c}}\right]\frac{dk^*}{d\delta} - \frac{(1-\rho)\gamma k^*\left(\frac{T}{\bar{c}}\right)^2}{\left(1+(1-\delta)\frac{T}{\bar{c}}\right)^2},$$

and

$$\frac{\partial W^I(k^*)}{\partial \gamma} = \frac{(1-\rho)\gamma}{(1-\gamma)\left(1+(1-\delta)\frac{T}{\bar{c}}\right)}\left[1-\delta(1-\gamma)\frac{T}{\bar{c}}\right]\frac{dk^*}{d\gamma} - \frac{(1-\rho)\gamma k\left(\frac{T}{\bar{c}}\right)^2}{\left(1+(1-\delta)\frac{T}{\bar{c}}\right)^2}.$$

Recalling from Proposition 6 that $\frac{dk^*}{d\delta} < 0$ and $\frac{dk^*}{d\gamma} < 0$, it follows that $1 - \delta(1-\gamma)\frac{T}{\bar{c}} > 0$ is sufficient for $\frac{\partial W^I(k^*)}{\partial \delta} < 0$ and $\frac{\partial W^I(k^*)}{\partial \gamma} < 0$. ■

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