Investment and capital structure of partially private regulated firms[*]

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January 28, 2015

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.

[*]We thank seminar participants at the 2009 EARIE Conference in Ljubljana, the 2010 "International Conference on Infrastructure Economics and Development" in Toulouse, the 2011 "Industrial Organization: Theory, Empirics and Experiments" workshop in Otranto, the 2011 CRESSE Conference in Rhodes, the 2012 Conference on the Economics of the Public-Private Partnerships in Barcelona, FEEM in Milano, IAE in Paris, LUISS in Rome and University of Melbourne. Yossi Spiegel thanks the Henry Crown Institute of Business Research in Israel for financial assistance and Carlo Cambini gratefully acknowledges financial support from the Italian Ministry of Education (No. 20089PYFHY_004).

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JEL Classification: G32, L33, L51

Keywords: regulation, debt, investment, government ownership, regulatory independence, regulatory climate

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.[1] In the EU for example, the structural reforms were prompted by the European Commission through a series of Directives, and were intended to enhance cost efficiency and service quality, open the market to competition where technologically feasible, and boost investments in infrastructure.[2] The decision whether to privatize state-owned monopolies was left however entirely in the hands of national governments.[3] The implementation of market reforms varies considerably across EU states and across sectors. Reforms are most advanced in the telecommunications industry, where IRAs were established in virtually all member states and most telecoms have been, at least partially, privatized. Reforms are also advanced in the energy sector, where the majority of electric and gas utilities are now regulated by IRAs. However, many natural gas utilities, and to a lesser extent electric utilities, are still controlled by the government, especially in France, Germany, Italy and Portugal. Structural reforms, however, are still lagging behind in water supply and transportation infrastructure (docks and ports, airports and freight motorways): with the exception of the UK, France, Germany, and Italy, most water and transportation utilities are still controlled by central and local governments and are still subject to regulation by ministries or other branches of the government rather than by independent regulatory agencies.

While for the most part, the structural reforms have significantly improved infrastructure performance (see e.g., Kessides, 2004, p. 9-15), they were also accompanied by a substantial increase in the financial leverage of regulated utilities.[4] 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

[1] For a comprehensive review of the structural reforms, see Kessides (2004).

[2] For more detail about the structural reforms in the EU, see Cambini, Rondi, and Spiegel (2012).

[3] Indeed, the establishment of IRA typically precedes privatization, see Bortolotti et al. (2011) and Zhang, Parker, Kirkpatrick (2005).

[4] See Bortolotti et al. (2011) for evidence on the EU-15 states and Da Silva, Estache, and Järvelä (2006) for evidence on Latin America and Asia.

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 regulated network industries account for around 7.5% of the EU-15's total value added, and 5.4% of the total workforce in the EU-25 states.(European Commission, 2007).[5] Moreover, the investment levels in these industries account for a significant fraction of GDP: for example, Table 1 in the Appendix shows that in the EU-15 states, the average rate of gross fixed capital formation in the energy sector (electricity and gas), telecommunications, water supply, and transportation, ranges between 14.6% and 15.9% of GDP in the period 2005-2009.[6] Given the sheer size of investments at stake, their high market value, and the overall importance of the public utilities sector (telecommunications, energy, transportation, and water) for the economy and consumers 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.

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 to induce regulators to set a relatively high price in order to minimize the risk that the firm will become financially distressed.[7] This literature however implicitly assumed that the regulated firm is privately

[5] Moreover, of the 30 companies with the largest market capitalization in the European Industrial Sector, 10 are telecoms or energy utilities (Bortolotti, Cambini and Rondi, 2013).

[6] The table is based on OECD data. Currently, 2009 is the most recent year for which the data is available.

[7] Jamison, Mandy, and Sappington (2014) show that regulators can prevent firms from issuing excessive

owned and regulators are independent.[8] 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, Cosset, and Guedhami, 2004), and IRAs do not exist in all sectors.[9] 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 (The Economist, 2012).[10]

The purpose of this paper is to develop a tractable model that will allow us to study how (partial) state ownership and regulatory independence affect the capital structure and investments of the regulated firm, regulated prices, and welfare. To this end, we consider 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 (e.g., an unexpected surge of energy prices, or extra costs due to natural disasters). Hence, when the firm is leveraged, a sufficiently negative cost shock may result in a costly

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debt if they can impose substantial penalties if the firm becomes financially distressed.

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

[9] 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. About 50% of these firms by value and over 60% by employment operate in network industries, including telecommunications, electricity and gas, transportation, and postal services (OECD, 2014, p. 10-11). And, as we mentioned above, in the EU, IRAs were established and are fully operational 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.

[10] According to the Economist, the share of national/state-controlled companies in the MSCI emerging-market index is over 65% in energy, and around 55% in utilities and 35% in telecommunication services. This phenomenon is also widespread in Europe. For example, 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, the Italian Government holds a 32% stake in Enel and 30% stake in Eni, and the Austrian Government holds a 70% stake in Verbund.

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. According to the managerially-oriented public enterprise (MPE) approach, due 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.[11] According to the soft budget constraint (SBC) approach introduced by Kornai (1986), 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, under both approaches, the cost of financial distress from the firm's perspective 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. A higher regulated 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 increase its debt and to invest more.

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

[11] 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 more when the firm is less privatized (i.e., δ is high).

assigns more weight to the firm's payoff in setting the regulated price), are all welfare enhancing. 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, may be associated with higher social welfare.

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 of 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 and is given by a random variable, c, distributed uniformly over the interval $[0, \bar{c}]$, where $\bar{c} < V(0)$. The random cost shock could represent an unexpected surge of energy prices,[12] or extra costs due to natural

[12] For example, the sharp increase in electricity wholesale prices in California from April 2000 to December 2000 due to drought, delays in approval of new power plants, and market manipulation, eventually forced Pacific Gas and Electric Company into bankruptcy and forced Southern California Edison into near bankruptcy.

disasters like earthquakes, floods, and tsunamis, or terrorism and wars.[13]

Since costs are random, the firm may be unable to pay its debt in full when c is high. Using D to denote the face value of the firm's debt, the firm can fully pay its debt only if $D \leq p - c$. If $D > p - c$, the firm incurs a fixed cost T due to financial distress.[14] Hence, the total expected cost of the firm is

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

where $\phi\left(p, D\right)$ is the probability of financial distress given by

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

Intuitively, when $D + \overline{c} \leq p$, the firm can always pay D in full so $\phi\left(p, D\right) = 0$. On the other hand, when $p < D$, the firm cannot pay D in full even when $c = 0$, so $\phi\left(p, D\right) = 1$. For intermediate cases, $\phi\left(p, D\right) = 1 - \frac{p-D}{\overline{c}}$. Obviously, $\phi\left(p, D\right)$ 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.

Likewise, an expected surge in energy prices can hurt transportation companies: for instance, following the Italian government's decision to raised the price of electricity paid by railways in July 2014, the cost per km has unexpectedly increased by 10%.and raised the cost of the incumbent Trenitalia by 120 million Euros and the cost of the new entrant NTV by 20 million Euros. NTV claims that the cost increase forces it to fire 30% of its employees (see e.g., http://www.repubblica.it/economia/2014/09/02/news/ntv_a_rischio-94850698/)

[13]For instance, Tokyo Electric Power Co.'s sustained a 1.25 trillion yen ($15 billion) loss due to the Fukushima nuclear crisis (see e.g., http://www.bloomberg.com/news/2011-05-20/tepco-president-resigns-after-utility-reports-record-15-billion-loss.html) while the Thai telecommunications sector sustained losses and damages of almost 3.85 billion Bhat following the 2012 floods in Thailand (see e.g., https://www.itu.int/ITU-D/asp/CMS/Events/2012/emergencyworkshop/Nokeo_Ratanavong.pdf

[14]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.

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 management. 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 profit, $R - C$, where R is revenue and C is cost, but also with revenue, R, and their objective function, after investment is already sunk, is given by[15]

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

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.[16] This implies that a state-owned firm is less concerned about the extra cost it incurs when expanding its output. The greater the firm's focus on revenues rather than profits, the more the firm discounts its costs. Alternatively, the managers of partially state-owned firms are less exposed to the disciplining forces of the capital market and to takeover threats, and hence may find it easier to expand the firm's budget in order to pursue their own private agenda.[17] Another possibility is that state-owned firms, which are shielded from competitive pressures, are more prone to X-inefficiencies, so their managers effectively discount, to some extent, the firm's cost.[18] At any rate, noting

[15] 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).

[16] For example, telecoms, Cable TV operators, and postal services in the U.S. and in Europe are required to the provide a universal service even in areas where the cost of service exceeds the associated revenue. Likewise, state-owned firms may expand their labor force to avoid an increase in unemployment.

[17] The MPE approach then is in the spirit of the managerial discretion hypothesis, due to Baumol (1959) and Williamson (1964), which states that managers may pursue goals other than profit maximization (see Marris and Mueller, 1980, for a survey). The MPE approach essentially says that in state-owned firms managers have even more discretion than in private firms.

[18] Indeed, a series of empirical papers, summarized in Meggison and Netter (2001), shows that state-owned

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; Maskin and Xu, 2001; and Kornai, Maskin, and Roland 2003) 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

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

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 (2011) 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,

firms are generally less efficient than private ones, and that following privatization, firms become more efficienct, particularly in the presence of substantial industry competition and independent regulators. See also Armstrong and Sappington (2006; p. 337).

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 managers' objective 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, to maximize a welfare function defined over consumers' surplus, $V(k)-p$, and the firm's objective function:

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

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, (5) could represent a reduced form for the regulator's own payoff from being involved in some political economy game. Under both interpretations, the regulated price is set to balance the interests of consumers and firms, which is consistent with how regulated prices are set in practice.[19,20]

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, Edwards and Waverman, 2006).[21] The reason is that independent regulators are more insulated from short-run political pressures, which may induce the government to deviate from past promises, especially when a new government is elected (Spiller, 2004, Hanretty, Larouche, and Reindl, 2012).[22] Gilardi and Maggetti (2011) argue that regulatory independence has both formal determinants such as the length of the term of office, whether officials can be dismissed, whether their appointment is renewable, whether independence is formally stated, the conditions under which decisions can be over-

[19] 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)). Similarly, 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).

[20] In principle, the regulator might also give the firm a subsidy S if this is legally possible (in the EU for example, subsidies are generally prohibited by Article 107(1) of the EU Treaty on the Functioning of the European Union, with exceptions only in very special circumstances). The subsidy however would lower consumer surplus by S and would raise the firm's profit by S and hence (5) would now depend on $p+S$, meaning that setting $S=0$ entails no loss of generality. In fact, if raising public funds is costly, then subsidies would lower consumer surplus by $(1+\lambda)S$, where $\lambda>0$ is the shadow cost of public funds. In this case, the regulator is better off setting $S=0$ and relying only on the regulated price to compensate the firm.

[21] 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.

[22] Of course, it is also possible that even independent regulators may be "captured" by firms (see e.g., Stigler, 1971) and may fail to mazimize social welfare. However, it is plausible that regulatory capture is an even bigger problem when the regulator is part of the government. In any event, our model abstracts from the possibility of regulatory capture.

turned, and the financial and organizational independence of the agency, as well as informal determinants such as the frequency of revolving doors, political influence on budget and on internal organization, and partisanship of nominations.

In line with this argument, we follow the literature on central bank independence (see e.g., Cukierman, 1992), and 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 and therefore serves as our measure of regulatory independence, with higher values of ρ indicating a greater degree of independence.[23]

Specifically, we will assume that while a committed regulator always sets the price p 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 $1-\rho$.[24] 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.[25]

Although the parameters δ, γ, and ρ might be correlated (e.g., a more pro-firm regulator may be more committed or a larger stake in the firm may induce the state to lean on the regulator to pursue more pro-firm policies), a-priori we will not impose any restrictions on their relative sizes.

[23] A common way to model the degree of central bank independence is to assume 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 has announced. See Cukierman (1992).

[24] It is plausible that in developed countries regulatory agencies would be more independent and would therefore have higher values of ρ than agencies in developing countries.

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

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.[26] 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 the equity issue to maintain its original stake δ.[27] 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 to maximize (6).[28] 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 Bortolotti et al. (2011) and Cambini and Rondi (2012) which find 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

[26] 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 study the optimal design of capital structure in a 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.

[27] Without this assumption, there is another link between investments, capital structure, and ownership structure. Taking this link into account requires a theory of public ownership which endogenizes the state's stake in the firm. Such a theory is beyond the scope of the current paper.

[28] More formally, one can think about the game as having three stages: Nature chooses the regulator's type (committed or opportunistic) in stage 1, the firm's managers chooses k and D in stage 2 without observing nature's choice, and in stage 3, the regulator sets p given his type.

compactly as

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

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 regulated price is more responsive to cost as γ decreases.

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

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

where

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

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

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

and $D_3(k,I)$ is smaller than the value of D for which $D_1\left(k,I\right)+\overline{c}+M\left(D,I\right)=D$. This solution is obtained under the assumption that $\gamma<\frac{V(0)-\overline{c}}{V(0)-\beta\frac{\overline{c}}{2}}$ (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:

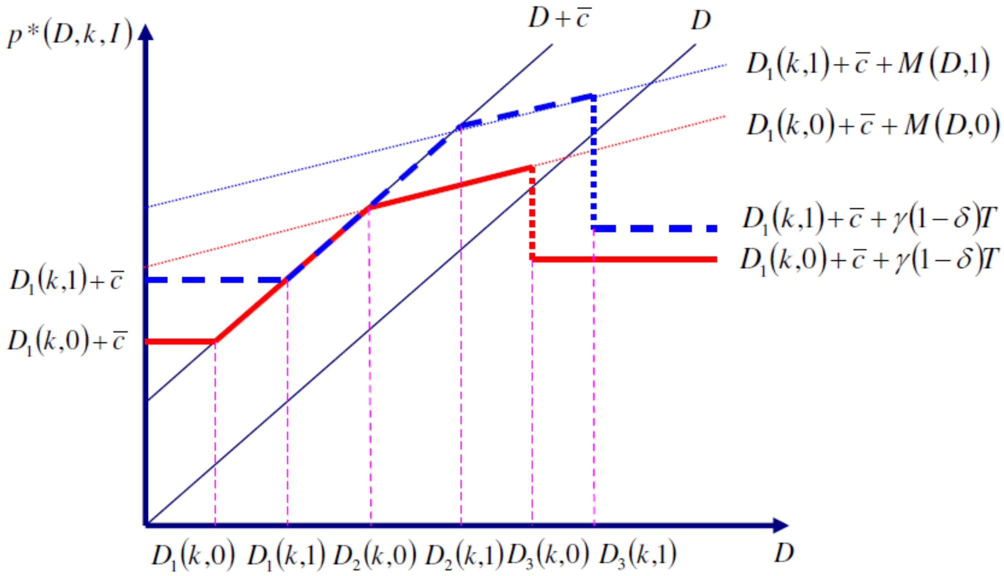

Figure 1: Illustrating the regulated price as a function of D for $I = 0$ (the solid red line) and $I = 1$ (the dashed blue line), holding k fixed

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.[29] Hence, indeed $\phi(p, D) = 0$ 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 $\phi(p, D) = 0$. 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 of financial distress. 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 $D_1(k, I) + \bar{c} + \gamma(1 - \delta)T$.

[29] 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.

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 $p^*(D,k,1) \geq p^*(D,k,0)$: a committed regulator (who takes k into account) sets a weakly higher price than 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 $p^*(D,k,1) = p^*(D,k,0)$.[30] A sufficient condition for Assumption 1 to hold is that the social surplus absent financial distress is sufficiently large:

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

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

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

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 firm's capital structure 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 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 act differently than 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 $D_2(k, 0) + \bar{c}$, 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 $D_2(k, 1)$. With probability ρ, the resulting regulated price is $D_2(k, 1) + \bar{c}$, which ensures once again that the firm never becomes financially distressed. But with probability $1 - \rho$, the regulated price is $D_1(k, 0) + \bar{c} + M(D_2(k, 1), 0)$; 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 under independent ($\rho > \rho^*$) than under 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 by and large 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. Moreover, using the same data set reveals that the market leverage of the 26 utilities that were privatized during the sample period increased by 14.6 percentage points on average after privatization (market leverage is defined as the book value of debt divided by the sum of the book value of debt and the market value of equity).[31] Although these results were established without controlling for investments, Proposition 7 below shows that Propositions 1 and 2 generalize to the case where k is determined endogenously.[32]

Intuitively, equation (4) shows that the firm discounts a larger fraction of the cost of financial distress when δ is higher either because the managers of (partially) state-owned firms care less about costs or due to the soft budget constraint. By implication then, firms with a lower δ face a higher cost of financial distress, so the regulator, who takes into account

[31] A number of papers, including Meggison, Nash and Randenborgh (1994), D'Souza and Meggison (1999), and Dewenter and Malatesta (2001) found the opposite result. These papers, however, examine privatized firms from all sectors, not just regulated firms. Bortolotti et al. (2002) examine a sample of privatized regulated telecoms and find that for the most part, privatization does not have a significant effect on leverage.

[32] 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.

the cost of distress, sets a higher regulated price, p. In equilibrium, the firm issues the largest D which still ensures that if the regulator is committed, the firm will be completely immune to financial distress. Consequently, more privatized firms with lower δ, enjoy a higher p, and are therefore able to issue a higher D in equilibrium.

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, $p^*(D, k, I)$ is higher when γ is low (the regulator is more pro-firm), so the firm has an incentive to raise D. But on the other hand, a decrease in γ makes $p^*(D, k, I)$ less responsive to cost and hence D has a weaker effect on $p^*(D, k, I)$. 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, $p^*(D, k, I)$ 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 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 p and D 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 Public Telecommunication Operators (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

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

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 $p^*(D_2(k,1), k, 1) = D_2(k,1) + \overline{c}$, which ensures that the firm never becomes financially distressed. With probability $1-\rho$, the regulator is opportunistic and sets a price $p^*(D_2(k,1), k, 0) = D_1(k,0) + \overline{c} + M(D_2(k,1), 0)$; 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

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

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 to less investment.

Having fully characterized k^* and shown 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 (2011) study a panel of 80 publicly traded EU telecoms, energy, transportation, and water utilities over the 1994-2004 period and find that they invest more when an IRA is in place, and when the IRA (when it exists) 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 $\frac{(1-\gamma)\left(1+(1-\gamma)(1-\delta)\frac{T}{\bar{c}}\right)}{\gamma} \geq -\frac{V'(k^*)}{V''(k^*)k^*}$, 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, $-\frac{V'(k^*)}{V''(k^*)k^*} = \frac{\frac{1}{a+k^*}}{\frac{k^*}{(a+k^*)^2}} = 1 + \frac{a}{k^*}$. As we will show in the proof of Proposition 8 below, $V'(k^*) > 1$, which is equivalent to $\frac{1}{a+k^*} > 1$, or $k^* < 1-a$ when $V(k) = \log(a+k)$. Using this inequality, $-\frac{V'(k^*)}{V''(k^*)k^*} = 1 + \frac{a}{k^*} > \frac{1}{1-a}$; hence the sufficient condition in the last part of Proposition 7 is more likely to hold when a is smaller.

6 Social welfare

In this section we consider the welfare implications of our model. In particular, we are interested to find 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:

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

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

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

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

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

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 $1-\delta(1-\gamma)\frac{T}{\overline{c}} > 0$, 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, more regulatory independence (a higher ρ), more privatization (a decrease in the value of δ), and more pro-firm regulatory climate (a lower value of

γ), all lead to higher welfare. 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 EU-15 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, 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. The table shows the data from 2005 to 2009 which is the last year for which the data is available (there is no data for Luxomburg).

Table 1: Investment rate as % of GDP in 2005-2009 in the EU-15 states

State	**Investment rate as % of GDP**				
	2005	*2006*	*2007*	*2008*	*2009*
Austria	17.30%	15.33%	15.72%	16.48%	15.01%
Belgium	16.69%	14.26%	14.13%	14.69%	16.33%
Denmark	15.55%	16.75%	17.67%	16.95%	18.01%
Finland	13.99%	14.07%	13.18%	14.84%	16.79%
France	8.56%	9.28%	9.74%	9.77%	9.67%
Germany	11.42%	12.37%	11.84%	11.59%	11.24%
Greece	18.38%	12.59%	17.35%	18.33%	21.56%
Ireland	18.18%	16.23%	19.42%	23.18%	-
Italy	16.89%	16.54%	16.77%	16.54%	16.74%
Netherlands	9.65%	10.13%	9.36%	9.66%	-
Portugal	20.40%	20.24%	18.1%	20.20%	-
Spain	14.35%	13.64%	13.86%	14.58%	15.19%
Sweden	18.46%	18.73%	18.19%	18.97%	19.29%
UK	13.76%	14.32%	14.25%	16.00%	-
Average EU-15	15.25%	14.60%	14.97%	15.84%	15.98%

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, $p^*(D,k,I)=D_1(k,I)+\bar{c}+M(D,I)$ and $\phi^*(D,k,I)=1-\frac{p^*(D,k,I)-D}{\bar{c}}$. Hence,

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

and

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

Substituting in (20), yields

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

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 $p^*(D,k,1)=D+\bar{c}$, and $p^*(D,k,0)=D_1(k,0)+\bar{c}+M(D,0)$. Hence, $\phi^*(D,k,1)=0$ and $\phi^*(D,k,0)=1-\frac{p^*(D,k,0)-D}{\bar{c}}$. 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:

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

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), given (23) and (24), 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

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

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

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

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

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 $p^{*}\left(D_2(k,1),k,1\right) = D_2(k,1) + \overline{c}$, which ensures that the firm is immune to financial distress. With probability $1-\rho$, the regulator is opportunistic and sets a price $p^{*}\left(D_2(k,1),k,0\right) = D_1(k,0) + \overline{c} + M\left(D_2(k,1),0\right)$ 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

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

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

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

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,

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

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 $D_2(k^*, 0) + \bar{c}$ 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

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

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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