UniS

University of Surrey

Discussion Papers in Economics

# PRICE REGULATION AND THE COMMITMENT PROBLEM: CAN LIMITED CAPTURE BE BENEFICIAL?

By

Paul Levine
(University of Surrey)

Neil Rickman
(University of Surrey)

&

Francesc Trillas
(Universitat Autonoma de Barcelona)

DP 01/06

Department of Economics
University of Surrey
Guildford
Surrey GU2 7XH, UK
Telephone +44 (0)1483 689380
Facsimile +44 (0)1483 689548
Web www.econ.surrey.ac.uk
ISSN: 1749-5075

# Price Regulation and the Commitment Problem: Can Limited Capture be Beneficial?*

Paul Levine[†]
University of Surrey

Neil Rickman
University of Surrey,
and CEPR

Francesc Trillas
Universitat Autonoma de Barcelona

February 23, 2006

**Abstract**

We consider two aspects of the commitment problem in price regulation with lobbying: the ratchet effect and the hold-up problem. We set out a dynamic model of price regulation with asymmetric information where the regulated firm can 'buy influence' in a lobbying equilibrium. Firms can sink non-contractible, cost-reducing investment but regulators cannot commit to future price levels. We fully characterize the perfect Bayesian equilibrium and show that the lobbying equilibrium can both ameliorate the ratchet effect and improve investment incentives by credibly offering the firm future rent. Simulations indicate significant welfare gains are possible from these two effects and that a range of lobbying outcomes can achieve this result.

JEL Classification: L51

Keywords: price regulation, commitment problem, ratchet effect, under-investment

*We would like to thank David Currie and participants at the CEPR IO Workshop on Regulation for helpful comments and discussion. Remaining errors are ours.

[†]Corresponding author: Department of Economics, University of Surrey, Guildford GU2 7XH, UK; e-mail: p.levine@surrey.ac.uk.

# Contents

# 1 Introduction

In this paper, we address two problems faced by regulators. These relate to potential commitment problems and the opportunities these present for capture by interest groups (Laffont and Tirole (1993), chs 9, 13; Dixit (1996)). While each of these may often be regarded as having negative impacts on regulatory outcomes, we suggest that this need not be the case: in particular, we investigate the extent to which lobbying to influence a regulated firm can compensate for the absence of a commitment mechanism and address the incentive problems when commitment is not present. For concreteness, we consider this issue in the case of privatised (and now regulated) industries.

Commitment problems can arise because regulatory policies tend to require intermittent revision (to take account of new circumstances), or because the identity of the regulator can change over time. Thus, in the UK (for example), independent regulators of privatised utilities undertake price reviews every five years or so, while decisions on pricing and investment may subsequently be changed.[1] The change of stance brought about by new regulators can be illustrated by the descriptions of Tom Winsor when he was announced as the UK's new rail regulator in 1999: "a 'hawkish' lawyer [appointed] to toughen up rail regulation and make life more difficult for the train operating companies."[2] The inability to commit in such settings generates cost inefficiencies via the familiar ratchet effect and through difficulties in encouraging long-term capital investments (the 'hold-up problem'). Levy and Spiller (1994), Lyon (1995) and Newbery (1999) all present evidence to confirm the empirical relevance of these problems.[3]

Capture of regulated industries has been a concern since Stigler (1971). However, as Dixit (1996) and Faure-Grimaud and Martimort (2003) make clear, independent regulators present especially fertile ground for successful lobbying because, by definition, the 'independence' implies that the regulator enjoys considerable discretion, ruling out a rule-based solution to the commitment problem. In principle, such lobbying may come from consumer or industry groups: Grossman and Helpman (2001), p. 3, cite research iden-

[1] For example, the electricity regulator (OFFER) was criticised for a lack of commitment following post-review price-cap alterations in 1995: see EIA (1997).

[2] Daily Telegraph, 24 March, 1999; see also Daily Telegraph, 28 May, 1999.

[3] Even without a commitment problem, under-investment can occur if investment is irreversible and there is exogenous uncertainty; see Dobbs (2004).

tifying over 3,900 "trade, business and commercial" special interest groups. In addition, its practical manifestation may be varied, ranging from side-payments to the regulator to offers of future employment (so-called "revolving doors": Che (1995); Salant (1995)). The nature of such practices can make them hard to detect yet the presence of capture in regulatory settings has recently been well documented (e.g. Guasch (2004); Guasch *et al.* (2005); Straub (2005)).

We consider a dynamic, non-commitment, model where the firm's costs comprise an exogenous productivity parameter, cost-reducing effort and investment that is costly in period 1 but reduces costs in period 2. The regulator observes total costs in a given period but not any individual components. The presence of asymmetric information means that welfare costs arise from suboptimal investment and the ratchet effect. As in Grossman and Helpman (1994), the regulated firm is able to invest in lobbying the regulator for favourable contracts in the first period. It does this by offering the regulator a fraction of any information rent it receives under the regulatory mechanism. We ask whether this makes the regulator less averse to the firm's rent and, thus, reduces under-investment and the ratchet effect. As discussed below, this method of modelling regulatory capture differs from other literature in this area. In addition to the capture aspect, we extend the theoretical literature on regulation in two ways: (i) situations where the regulator observes neither investment nor the other components of cost have received little attention yet, for some types of activity, are clearly appropriate; (ii) we examine the problem in the context of optimal (subject to asymmetric information) price regulation, where the regulator is prevented from making lump-sum transfers to the firm. Both of these reflect much regulatory practice.

Our main result is that capture can, indeed, help to overcome the dual effects of non-commitment on effort and investment. As such, it can lower prices and raise social welfare.[4] The effects of capture on investment result from its effects on the marginal benefit and cost of investment. The marginal benefit of investment arises from its positive effects on period 2 rents (since investment lowers these costs) and, as such, is influenced

[4]This result gives support to the intuitive discussion in Armstrong and Vickers (1996): in the context of transition economies, "a degree of capture might enhance the credibility of commitment to allow an adequate return on investment." (p. 303). Interestingly, this view refers only to the 'marginal benefit effect' we refer to below, and not to the 'marginal cost effect' that we also uncover.

by the degree of capture. More subtly, the marginal cost of investment is determined by the cost of the effort needed in period 1 to keep costs down when investment is first sunk; since the degree of capture affects the power of the period 1 contracts, it therefore affects the marginal cost of investment (since effort costs are increasing and convex). Investment is determined when these marginal effects are equal.

Our analysis identifies some interesting implications of capture. First, because the relative magnitudes of the effects of capture on the marginal costs and benefits are generally different, there are a number of possible equilibria, each of them unique, as the degree of capture changes. These can result in different investment levels, depending on the unobserved productivity level of the firm. Second, there are equilibria where over-investment, as well as under-investment occurs. Third, we demonstrate the possibility that there is an optimal degree of capture: beyond this, the firm's lobbying of the regulator generates investment and effort but at the expense of excessive consumer prices. Kessides (2004) identifies such concerns when discussing a backlash against privatisation in Latin America (most dramatically, in Bolivia and Argentina). Thus, as well as demonstrating potential gains from capture, our paper also identifies an important trade-off underlying this result and several key factors that determine when the gains might be offset.

A number of other authors have considered issues relating to independent regulation, capture and, separately, investment by a regulated firm. Laffont and Tirole (1993) and Laffont (2000) set out a general model of capture, without investment and with lump-sum transfers as opposed to price regulation. The regulator is delegated the task of collecting information about the regulated firm's performance by a principal ('Congress') who, otherwise, has incomplete information about this. Congress ultimately designs the revelation mechanism for the firm. Here, capture involves biasing the regulator's feedback to Congress in return for a share of the information rents arising from the latter's subsequent asymmetric information problem. Although popular in the literature, this model of capture differs from ours in that we assume that the regulator determines pricing and investment policy and, therefore, designs the firm's contracts. As such, the firm directly lobbies the regulator for favourable contract terms, as in Grossman and Helpman (1994, 1996)'s analysis of lobbying for trade policy.[5] Our approach reflects institutional arrangements such

[5]For other examples, see Dixit (1996)—tax policy—Aidt (1998) and Fredriksson and Gaston (2000)—environmental regulation, Trillas (2000)—privatization—and Baldwin and Robert-Micoud (2001)—support

as those in the UK, where regulators act independently to set price and investment policy in 'price reviews' (see Armstrong *et al.* (1994); Laffont (2005), pp. 198–200). Laffont and Martimort (1998) discuss the general circumstances in which it is optimal to delegate such decisions to an independent agent and, as such, under which our model of regulatory capture is appropriate.

Martimort (1999) explicitly models problems that can arise when an independent regulator is captured in a setting with lump-sum transfers and no investment. In his model, the regulator and the firm interact repeatedly over time and this leads to regulatory 'drift' in the sense that it becomes increasingly difficult for Congress to design collusion-proof contracts for the firm with the degree of 'familiarity' between firm and regulator increasing over time. One solution to such problems, is the separation of regulatory powers between several regulators (Olsen and Torsvick (1993); Laffont and Martimort (1999)). Here, capture is rendered a less effective policy for firms because they are less able to influence the web of policies by which they are regulated. Laffont (2005) makes a powerful case for such a strategy in developing countries. As noted earlier, our paper considers possible benefits from capture and, thus, does not consider separation of powers. The mechanism we identify would operate in qualitatively the same way in a setting like Martimort's.

We are not alone in conjecturing that capture may be beneficial in regulatory settings. Faure-Grimaud and Martimort (2003) assume that the governing principal in Congress can change identity between periods while the regulator does not, and contracts are static (one-period) ones. In this setting, capture lends stability to the regulatory process because it tends to pull the regulator towards the firm and away from changing political priorities. If the benefits of this stability offset the costs of the information rent it produces, capture can improve welfare.[6] Che (1995) considers the effects of 'revolving door' arrangements, where regulators can expect employment within the regulated industry upon completion of their terms of office (see also Salant (1995)). The model assumes that regulators (not firms) make effort choices (they can improve their industry-specific knowledge) and the prospects of subsequent employment are shown to enhance this. The information set-up is simpler than our combination of moral hazard and adverse selection and the firm's capital investment decision is not modelled, but Che conjectures that investment prospects may

to declining industries. See, more generally, Grossman and Helpman (2001).

[6]See also Faure-Grimaud and Martimort (2005).

be enhanced by giving the regulator an interest in the future recovery of sunk costs by her future employer. Finally, de Figueiredo *et al.* (1999), Epstein and O'Halloran (1995) and Sloof (2000) note positive informational externalities arising from capture: for example, lobbies may provide (biased) information on regulated firms or on regulators.

Time inconsistency problems in regulatory settings are studied in Laffont and Tirole (1993) and applied to investment incentives under complete and asymmetric information assumptions. With complete information, Salant and Woroch (1992) and Newbery (1999) (ch. 2) show how optimal investment can be sustained in a reputational equilibrium provided the regulator is sufficiently far-sighted.[7] Besanko and Spulber (1992) (and Urbiztondo (1994)) and by Dalen (1995) assume asymmetric information. All three of these papers assume that the regulator makes lump-sum transfers to the firm (rather than using price regulation). Besanko and Spulber abstract from the ratchet effect and focus on investment incentives in a dynamic non-commitment setting with observable investment but unobservable fixed costs. They show that under-investment can be avoided in sequential equilibrium because the firm can use its (observable) investment decision to signal its fixed cost to the regulator. Dalen shows how contractible investment reduces the ratchet effect by inducing more first-period separation. When investment is non-contractible, under-investment occurs. By allowing for price regulation and unobservable cost-reducing effort and unobservable investment (as well as capture), our paper adds significantly to this literature. The effect is to increase the range of possible (unique) equilibria and to introduce the possibilities of over- and under-investment.

The paper proceeds as follows. In the next section, we set out the model and the full-information benchmark. Section 3 then introduces asymmetric information for the regulator but in the presence of commitment. Section 4 relaxes the commitment assumption and introduces a lobbying stage to the game. It fully characterises the perfect Bayesian equilibria and investigates the effects of capture on investment. Section 5 examines the effects of capture on welfare and demonstrates the potential existence of an optimal degree of capture. Section 6 discusses our results.

[7] In a complete information set-up, Levine *et al.* (2005) draw comparisons between this and commitment problems in monetary policy. They also identify some drawbacks with a reputational solution to the hold-up problem as opposed to the lobbying solution of the current paper.

# 2 Full Information and the Ramsey Optimum

## 2.1 The Model and Payoffs

First, we set out the basic elements of the model in the absence of lobbying by the firm. In period $t = 1, 2$, the firm produces a quantity $q_t$ of a homogeneous good at cost

$$C_t = C(q_t, e_t, \beta_t) = \beta_t - e_t + cq_t; \quad \beta_1 = \beta + i; \quad \beta_2 = \beta - f(i) \tag{1}$$

where $e_t$ is total cost-reducing effort of which an amount $i$, 'investment', is devoted to reducing fixed costs in the second period by an amount $f(i)$.[8] Marginal costs are fixed and given by $c$. We make the standard assumptions $f' > 0, f'' < 0,\ f(0) = 0, f'(0) = \infty$. If we put $f(i) \equiv 0$, then $i = 0$ and there is no investment hold-up problem, but there is a ratchet effect. We also assume that the efficiency parameter is sufficiently large to ensure that fixed costs are never negative; i.e., $\beta_t - e_t \geq 0$. The good is sold at a price $p_t = \phi(q_t)$ where $\phi(\cdot)$ is the inverse demand curve. The combined inclusion of $e_t$, $i$ and $\phi(\cdot)$ distinguishes our set-up from other regulatory models.

Both the firm and regulator maximize a two-period welfare function with the same discount factor $\delta$ and with single-period payoffs given respectively by

$$U_t = U(q_t, e_t, \beta_t) = R(q_t) - C_t - \psi(e_t) \tag{2}$$

$$W_t = W(q_t, e_t, \beta_t) = S(q_t) - R(q_t) + U_t \tag{3}$$

In (2), $\psi(e_t)$ is the disutility of effort and again we make standard assumptions: $\psi', \psi'' > 0$ for $e_t > 0$, $\psi(e_t) = 0$ otherwise. In (3), $S(q_t)$ is the gross consumer surplus of the industry, $R(q_t) = p_t q_t$ is the revenue, $S(q_t) - R(q_t)$ is the net consumer surplus, so the regulator maximizes the sum of net consumer and producer surpluses.

## 2.2 The Ramsey Optimum (RO)

We first solve for the 'Ramsey Optimum' (RO); that is the social optimum subject to a two-period individual rationality constraint for the firm in the absence of lobbying.[9]

[8] The assumption that effort only reduces fixed and not variable costs can be relaxed but at considerable cost in terms of tractability. For example, we could assume two types of imperfectly substitutable effort with managers dividing their total effort in each period between reducing fixed and variable costs. Laffont and Tirole (1993) consider situations where all effort is devoted to reducing variable costs.

[9] We use the term 'Ramsey-Optimal' because the pricing formula involves a (Ramsey) inverse elasticity mark-up to cover fixed costs. Notice that the *unconstrained* social optimum would have $p_t = c$ and would

This provides a full information benchmark for later results. Suppose that the social planner adopts the single-period social welfare function (3). Then the RO is found by the maximization of the intertemporal social welfare function $\Omega = W_1 + \delta W_2$ with respect to $(q_t,\ e_t)$, $t = 1, 2$ and $i$, where $W_t$ is given by (3) subject to a two-period individual rationality constraint

$$IR : U_1 + \delta U_2 \geq 0$$

To solve this maximization problem define a Lagrangian $\mathcal{L} = \Omega + \mu(U_1 + \delta U_1)$ where $\mu$ is a Lagrangian multiplier. The Kuhn-Tucker first-order and complementary slackness (CS) conditions are

$$e_t \quad : \quad \psi'(e_t) = 1; \quad t = 1, 2 \tag{4}$$

$$i \quad : \quad \delta f'(i) = 1 \tag{5}$$

$$q_t \quad : \quad S'(q_t) + +\mu R'(q_t) = (1 + \mu)c; \quad t = 1, 2 \tag{6}$$

$$CS \quad : \quad \mu(U_1 + \delta U_2) = 0$$

Using the standard result $S'(q_t) = p_t$, (6) can be written

$$L_t = \frac{p_t - c}{p_t} = \frac{\mu}{(\mu + 1)\eta(q_t)} \tag{7}$$

where $L_t$ is the Lerner index and $\eta(q_t) = -p_t q_t'/q_t$ is the elasticity of demand. It follows from (7) that the price in each period is the same. Furthermore, since fixed costs can never be negative by assumption, this common price must exceed the marginal cost, otherwise the IR constraint cannot be satisfied; thus $L_t > 0$. It follows from (7) that $\mu > 0$, and the IR condition therefore binds, iff

$$L_t = \frac{p_t - c}{p_t} \geq 0$$

which always holds.

From (7) Ramsey prices $p_1 = p_2 = p^{RO}$ and hence output $q_1 = q_2 = q^{RO}$ are equal in the two periods, but not yet determined. Denote by $e^{RO}$ and $i^{RO}$ the Ramsey-optimal levels of $e$ and $i$ given by (4) and (5) respectively. Substituting back into the binding IR constraint then determines the Ramsey-optimal output $q^{RO}$ and hence the price $p^{RO} = \phi(q^{RO})$, completing the social planner's problem.[10]

---

require investment to be subsidized from lump-sum taxation.

[10] With commitment plus full information about total costs and demand, the RO can be implemented

# 3 Asymmetric Information with Commitment

We continue to assume there is no lobbying and seek to establish the nature of the commitment problem in our model that leads to both the ratchet effect and the hold-up problem. First, we present results for the case where commitment is feasible, then we explain how these break down when the regulator cannot commit to a contract with the firm.

In contrast with the previous section, suppose that neither effort nor the productivity parameter $\beta$ are observed by the regulator so she faces both an adverse selection and moral hazard problem. The regulator observes total cost and knows that $\beta$ belongs to a two-point support: $\beta = \underline{\beta}$ and $\beta = \overline{\beta}$ ($\overline{\beta} > \underline{\beta} > 0$), over which she holds priors $\nu_1$ and $1-\nu_1$ respectively at the beginning of period 1. Investment does not need to be contractible, nor indeed observable for our results to hold.

Asymmetric information now introduces dynamics through the process of learning about the firm's type. Following Laffont and Tirole (1993), the regulator must now design contracts $(\underline{p}_t, \underline{C}_t)$, $(\overline{p}_t, \overline{C}_t), t = 1, 2$ for the efficient and inefficient firms respectively. In doing so, she must recognise the incentive compatibility constraints introduced by asymmetric information: each firm can mimic the other's costs by suitable choice of unobservable effort. Letting $\underline{p}_1^C = \underline{p}_2^C = \underline{p}^C$, $\overline{p}_1^C = \overline{p}_2^C = \overline{p}^C$, etc., denote the solution to this problem is[11]

**Proposition 1 (Commitment Equilibrium).** *Assume fixed costs are always positive. Then for the two-period contract under commitment we have that:*

*(i)* $\underline{e}^C = e^{RO}$; $\overline{e}^C < e^{RO}$.

*(ii)* $\underline{i}^C = \overline{i}^C = i^{RO}$.

*(iii) If the elasticity* $\eta(q_t)$ *is non-increasing in* $q_t$, $\overline{p}^C > \underline{p}^C$.

*(iv) For both types of firm, rent is less in the first period than the second. For the inefficient firm, rent is negative in the first period and positive in the second.*

Parts (i) and (iii) of this proposition reflect the single-period trade-off between effort

if the regulator faces only moral hazard ($\beta$ but not $e$ or $i$ observable) or adverse selection ($e$ and $i$ but not $\beta$ observable). In the former case, she commits to a two-period contract specifying only $p^{RO}$ and rent maximizing managers choose $e^{RO}$ and $i^{RO}$. In the latter case, the regulator can calculate $\beta$ from observable cost, demand, effort and investment.

[11] See Levine and Rickman (2001) for a proof of the case where investment is contractible. Proof of the non-contractible and non-observable result is available from the authors.

and rent that typifies such incentive contracts (see Laffont and Tirole (1993)). However, (ii) tells us that the regulator's ability to commit assures the firm of sufficient second-period rent (see (iv)) to encourage Ramsey-optimal investment.

Having examined the nature of the commitment solution in the presence of asymmetric information, now suppose that such commitment is *not feasible*. In this case, the contracts described in Proposition 1 are *time-inconsistent*: although they are optimal *ex ante*, *ex post* in period 2 they cease to be optimal and there exists a temptation for the regulator to re-optimize. This temptation exists for two reasons. First, the contract is a revelation mechanism that reveals the type of firm. In the second period an optimizing regulator will offer a new contract at a lower price that removes any information rent to the efficient firm. This is the familiar 'ratchet effect' which, when anticipated by the efficient firm, requires higher information rent in the first period to satisfy the first-period incentive-compatibility constraint. Second, the first-period investment is a sunk-cost. The *ex ante* contract sees negative rent in the first period and positive rent in the second period for both types. However, in the absence of a binding commitment, *ex post* an optimizing regulator will renege on the promise of positive rent and offer a new contract at a lower price just sufficient to satisfy the second-period individual rationality constraint. Anticipating this opportunistic behaviour, in the absence of commitment both firms will under-invest in the first period. We now move to a formal analysis of the non-commitment case in order to show how the extent, or indeed the existence, of both these problems can be influenced by the existence of lobbying.

# 4 Asymmetric Information without Commitment

## 4.1 The Lobbying Game

Consider a two-period, two-type lobbying game with the same structure and information assumptions as section 3, but with the assumption that the regulator cannot commit to a two-period price contract. The main contribution of the paper is to investigate whether lobbying for influence by the firm can compensate for the absence of a commitment mechanism. The sequence of events for the lobbying game is given by:

1. The firm makes a long-term commitment to a *lobbying fund*, proportional to and

contingent on profits (whatever they turn out to be), $\ell U_t$; $\ell \in [0,1)$; $t = 1, 2$.

2. Lobbying by the firm occurs and results in a monetary benefit $\kappa\ell U_t$; $\kappa > 0$ to the regulator modifying the single period utility (3) which now becomes

$$W_t = W(q_t, e_t, \beta_t, \alpha) = S(q_t) - R(q_t) + \alpha U_t \tag{8}$$

where $\kappa$ is a measure of the effectiveness of the lobby and $\alpha = 1 + \kappa\ell$ measures the overall degree to which the regulator is captured, which may result from a larger fund ($\ell$) and/or more effective lobbying ($\kappa$).[12,13]

3. The firm's cost parameters $\beta = \overline{\beta}$, $\underline{\beta}$ are realized and observed by the firm.

4. The regulator offers a choice of two first-period price contracts from which the firm chooses one or neither.

5. First-period effort $e_1$ and investment $i$ are applied by the firm, the cost $C_1$ is realized and observed by regulator.

6. The regulator updates her prior $\nu_1$ to $\nu_2$.

7. The regulator offers a choice of two second-period contracts from which the firm chooses one or neither.

8. Second-period effort $e_2$ is applied by the firm, the cost $C_2$ is realized and observed by regulator.

[12] We discuss possible determinants of $\kappa$ in the Conclusions. Note that our concentration on lobbying by the firm is largely for convenience: effectively, we assume consumers are too atomized to conduct an effective lobby in their favour. In fact, in many countries, consumer groups have emerged to lobby regulators of privatised firms. We could readily model this development by writing $\alpha = 1 + \kappa^F\ell^F - \kappa^C\ell^C$, where the subscripts refer to Firm and Consumer lobbies respectively. We could endogenise $\ell^C$ in similar fashion to the approach used below—with consumers offering the regulator some share in the rent she saves them from paying.

[13] The result that with lobbying a regulator would maximize a modified utility function that gives more weight to the utility of the lobbying party (the firm), is also a feature of the 'buying of influence model' of Grossman and Helpman (2001), chapter 7. In their complete information set-up, period-by-period choice of the lobbying fund and joint efficiency gives rise to this result. By making the firm commit to a lobbying fund contingent on profits, whatever they turn out to be, our set-up rules out the regulator learning about the type of firm as a result of observing the lobbying process at stage 3.

The capture parameter $\alpha \geq 1$ is crucial in our analysis and measures the size, $\ell$, and the effectiveness $\kappa$ of the lobbying fund. Capture, in effect, changes the preferences of the regulator in a 'pro-industry' direction. Consider the solution to the game given $\alpha$; i.e., in the sub-game from stage 4 onwards. In the first period, given $\nu_1$, the regulator designs contracts $(\underline{p}_1, \underline{C}_1)$ and $(\overline{p}_1, \overline{C}_1)$. In general we must consider equilibria in which the efficient firm may mimic the inefficient and *vice versa*. When the efficient firm chooses the low cost contract it chooses output $\underline{q}_1 = \phi^{-1}(\underline{p}_1)$ and effort $(\underline{e}_1, \underline{i})$ such that observed cost $\underline{C}_1 = \underline{\beta} - \underline{e}_1 + \underline{i} + c\underline{q}_1$. Similarly when the inefficient firm chooses the high cost contract it chooses output $\overline{q}_1 = \phi^{-1}(\overline{p}_1)$ and effort $(\overline{e}_1, \overline{i})$ such that observed cost $\overline{C}_1 = \overline{\beta} - \overline{e}_1 + \overline{i} + c\overline{q}_1$. Denote mimicking effort for the efficient and inefficient firms by $(\tilde{\underline{e}}_1, \tilde{\underline{i}})$ and $(\tilde{\overline{e}}_1, \tilde{\overline{i}})$ and $\Delta\beta \equiv \overline{\beta} - \underline{\beta}$.[14] In order to realize the appropriate observed costs, these mimicking efforts must satisfy

$$\tilde{\underline{e}}_1 = \overline{e}_1 - \Delta\beta + \tilde{\underline{i}} - \overline{i}; \quad \tilde{\overline{e}}_1 = \underline{e}_1 + \Delta\beta + \tilde{\overline{i}} - \underline{i} \tag{9}$$

Suppose that the efficient firm chooses the low cost contract with probability $x$ and the high cost contract with probability $1-x$. Similarly suppose that the inefficient firm chooses the high cost contract with probability $y$ and the low cost contract with probability $1-y$. The appropriate equilibrium concept for this game is a perfect Bayesian equilibrium (PBE) found by backward induction starting at stage 8. We define the regulator's information sets at this point as follows: **H** (resp. **L**) if $(\overline{p}_1, \overline{C}_1)$ (resp. $(\underline{p}_1, \underline{C}_1)$) was accepted in period 1.

## 4.2 The Second-Period Contract

At **L** and **H**, the regulator designs contracts $(\underline{p}_2, \underline{C}_2)$, and $(\overline{p}_2, \overline{C}_2)$ for low and high cost types respectively, given the (updated) probabilities $\nu_2(\mathbf{L})$ and $\nu_2(\mathbf{H})$ that the firm is efficient. At **L** we have that $\underline{\beta}_2 = \underline{\beta} - f(\underline{i})$ and $\overline{\beta}_2 = \overline{\beta} - f(\tilde{\overline{i}})$. Similarly at **H**, $\underline{\beta}_2 = \underline{\beta} - f(\tilde{\underline{i}})$ and $\overline{\beta}_2 = \overline{\beta} - f(\overline{i})$. Contracts must be designed to satisfy the following incentive

[14] We adopt the following notation: $\tilde{\underline{z}}$ is some outcome for the efficient firm who mimics the inefficient firm and $\tilde{\overline{z}}$ is the corresponding outcome for the inefficient firm who mimics the efficient firm.

compatibility (IC) and individual rationality (IR) constraints for each firm:

$$\begin{aligned}
\underline{IC}_2: &\quad \underline{U}_2 \geq \tilde{\underline{U}}_2 = \overline{U}_2 + \Phi(\overline{e}_2) \\
\overline{IC}_2: &\quad \overline{U}_2 \geq \tilde{\overline{U}}_2 = \underline{U}_2 - \Phi(\underline{e}_2 + \Delta\beta_2) \\
\overline{IR}_2: &\quad \overline{U}_2 \geq 0 \\
\underline{IR}_2: &\quad \underline{U}_2 \geq 0
\end{aligned}$$

where $\Phi(\overline{e}_2) = \psi(\overline{e}_2) - \psi(\overline{e}_2 - \Delta\beta_2)$ and $\Phi(\underline{e}_2 + \Delta\beta_2) = \psi(\underline{e}_2 + \Delta\beta_2) - \psi(\underline{e}_2)$ are the firms' information rents. Because $\underline{IC}_2 + \overline{IR}_2 \Rightarrow \underline{IR}_2$, we can drop the latter constraint.

It is convenient to formulate the regulator's problem in terms of the choice of output and effort levels bearing in mind that contracts are designed as prices, contingent on observed total costs. The regulator's problem, to be carried out at each information set characterized by the state variables given by the vector $s = [\nu_2, \underline{\beta}_2, \overline{\beta}_2]$, is now:

**Given $s = [\nu_2, \underline{\beta}_2, \overline{\beta}_2]$, choose $(\overline{q}_2, \overline{e}_2)$ and $(\underline{q}_2, \underline{e}_2)$ to maximize the expected welfare**

$$E[W_2] = \Omega_2 = \nu_2 W(\underline{q}_2, \underline{e}_2, \underline{\beta}_2, \alpha) + (1 - \nu_2) W(\overline{q}_2, \overline{e}_2, \overline{\beta}_2, \alpha) \tag{10}$$

**subject to $\underline{IC}_2$, $\overline{IC}_2$ and $\overline{IR}_2$.**

To solve this optimization problem, let $\mu_2 \geq 0$, $\zeta_2 \geq 0$ and $\xi_2 \geq 0$ be the Lagrangian multipliers associated with the $\underline{IC}_2$, $\overline{IC}_2$ and $\overline{IR}_2$ constraints respectively. Then defining the Lagrangian

$$\mathcal{L}_2 = \Omega_2 + \mu_2(\underline{U}_2 - \overline{U}_2 - \Phi(\overline{e}_2)) + \zeta_2(\overline{U}_2 - \underline{U}_2 + \Phi(\underline{e}_2 + \Delta\beta_2)) + \xi_2 \overline{U}_2$$

the first-order conditions are:

$$\begin{aligned}
\underline{L}_2 = \frac{\underline{p}_2 - c}{\underline{p}_2} &= \frac{\mu_2 - \zeta_2 + \nu_2(\alpha - 1)}{(\mu_2 - \zeta_2 + \nu_2\alpha)\eta(\underline{q}_2)} && (11) \\
\overline{L}_2 = \frac{\overline{p}_2 - c}{\overline{p}_2} &= \frac{\xi_2 - \mu_2 + \zeta_2 + (1 - \nu_2)(\alpha - 1)}{(\xi_2 - \mu_2 + \zeta_2 + (1 - \nu_2)\alpha)\eta(\overline{q}_2)} && (12)
\end{aligned}$$

$$\begin{aligned}
(\nu_2\alpha + \mu_2 - \zeta_2)(1 - \psi'(\underline{e}_2)) &= -\zeta_2 \Phi'(\underline{e}_2 + \Delta\beta_2) && (13) \\
((1 - \nu_2)\alpha + \xi_2 - \mu_2 + \zeta_2)(1 - \psi'(\overline{e}_2)) &= \mu_2 \Phi'(\overline{e}_2) && (14) \\
\mu_2(\underline{U}_2 - \overline{U}_2 - \Phi(\overline{e}_2)) &= 0 && (15) \\
\zeta_2(\overline{U}_2 - \underline{U}_2 + \Phi(\overline{e}_2 + \Delta\beta_2)) &= 0 && (16) \\
\xi_2 \overline{U}_2 &= 0 && (17)
\end{aligned}$$

To characterize the period 2 equilibrium and how it is affected by the degree of capture we need to examine the behaviour of the constraints as $\alpha$ increases. In Appendix A we characterize three second period equilibrium categories, depending on the value of $\alpha \geq 1$. In particular, there are threshold values $\overline{\alpha}_2 > \underline{\alpha}_2 > 1$ such that:

- $\alpha \in (1, \underline{\alpha}_2]$: $\underline{IC}_2$ and $\overline{IR}_2$ both bind. We call this *second-period equilibrium type b.*
- $\alpha \in (\underline{\alpha}_2, \overline{\alpha}_2]$: $\overline{IR}_2$ binds. We call this *second-period equilibrium type c.*
- $\alpha > \overline{\alpha}_2$: unconstrained. We call this *second-period equilibrium type d.*

Notice that, in principle, we could have a second-period equilibrium, type $a$ say, in which all three constraints $\underline{IC}_2$, $\overline{IC}_2$ and $\overline{IR}_2$ bind. A familiar one-period result for a utilitarian regulator ($\alpha = 1$) is that $\overline{IC}_2$ does not bind (see Laffont and Tirole (1993)) and therefore $\xi_2 = 0$. Since the effect of increasing $\alpha$ is to relax constraints, this means that equilibrium type $a$ does not exist in the second period for $\alpha > 1$ either. Equilibrium type $b$ is then the familiar result for a single-period model. As $\alpha$ increases (i.e. as the regulator becomes more captured), first $\underline{IC}_2$ ceases to bind ($\mu_2 = 0$) at $\alpha = \underline{\alpha}_2$ and then $\overline{IR}_2$ ceases to bind too ($\xi_2 = 0$), at $\alpha = \overline{\alpha}_2$.[15] We thus move from equilibrium type $b$ to $c$, then $d$ as the regulator becomes more captured.

The intuition is as follows. Since $\overline{p}_2 > \underline{p}_2$ there is no incentive for the inefficient type to mimic the efficient type. Therefore constraint $\overline{IC}_2$ does not bind. The following possibilities remain: $\underline{IC}_2$ and $\overline{IR}_2$ bind (i.e., equilibrium $b$), only $\underline{IC}_2$ binds, only $\overline{IR}_2$ binds, and no constraints bind. Of these, an equilibrium with only $\underline{IC}_2$ binding must be sub-optimal because it implies rent for the inefficient type which must also be passed on to the efficient type. As $\alpha$ increases, the progression between each equilibrium tells us that the increasingly generous regulator eventually supplies enough rent to the efficient firm to remove its incentive to mimic, and then allows the inefficient firm positive rent.

By setting the appropriate multipliers to zero in (11)–(17), and eliminating the rest, we can determine the nature of the second period contracts offered for different degrees of capture; see Appendix A. Thus for $\alpha \in (0, \overline{\alpha}_2]$ to offer a high-powered contract to the efficient firm ($\psi'(\underline{e}_2) = 1$) and one involving a measure of cost-sharing for the inefficient

[15] As can be confirmed from (14) to (17) this order for relaxing the constraints assumes $\eta'(q_2) \leq 0$ and $e^{RO} > \Delta\beta_2$. The first of these implies $\underline{p}_2 < \overline{p}_2$ (See Levine and Rickman (2001) for further details.)

one ($\psi'(\overline{e}_2) < 1$). More captured regulators ($\alpha > \overline{\alpha}_2$) offer high-powered contracts to both firms and secure Ramsey-optimal effort in either case. At the same time, the fact that more rent is available to both firms as $\alpha$ increases will provide investment incentives in period 1. We now turn to this investment decision.

### 4.3 The First-Period Investment Decision

Our analysis now moves to the first period where there are two decisions: the firm's investment decision and the regulator's contract offers. Beginning with the former, consider a firm of either type who has accepted a first-period contract specifying price and cost, $(p_1, C_1)$, and faces the prospect of a rent $U_2 = U(q_2, e_2, \beta_2)$ corresponding to one of the second-period equilibria $b, c$ or $d$ at **L** or **H**. From the second-period optimization we know that $(q_2, e_2)$ is a function of the state vector $s = [\nu_2, \underline{\beta}_2, \overline{\beta}_2]$ at the relevant information set. Thus we can write $U_2 = U_2(s)$. Then given $(p_1, C_1)$ and therefore $q_1 = \phi^{-1}(p_1)$, the firm chooses $i$ to maximize

$$U_1 + \delta U_2 = p_1 q_1 - C_1 - \psi(\beta + i + cq_1 - C_1) + \delta U_2(\beta_2(i)) \tag{18}$$

The first-order condition for a *local* maximum (we consider whether this is also global below) is

$$\psi'(\beta + i + cq_1 - C_1) = \psi'(e_1) = -\delta \frac{\partial U_2}{\partial \beta_2} f'(i) \tag{19}$$

using $\beta_2 = \beta - f(i)$, from which $\beta_2'(i) = -f'(i)$. This is the familiar condition that the marginal cost of investment ($\mathrm{MC}(e_1) \equiv \psi'(e_1)$) must equal its marginal benefit ($\mathrm{MB}(i) \equiv -\delta \frac{\partial U_2}{\partial \beta_2} f'(i)$). It is immediately apparent that the firm's investment decision depends on its first-period effort and anticipated second-period rent: the former offsets the effects of $i$ on costs; the latter funds the investment. Accordingly, the regulator can influence investment behaviour through the power of the first-period contract and the credibility of offers of future rent (i.e., prices). In particular, the position of the MB curve is determined by the capture parameter $\alpha$ since different second-period equilibrium categories ($b$, $c$, $d$) generate different $U_2$ and, thus, different $\frac{\partial U_2}{\partial \beta_2}$. Writing the solution to (19) as $i = i(e_1)$ and differentiating gives

$$\psi''(e_1) = -\delta \left[ \frac{\partial U_2}{\partial \beta_2} f''(i) - \frac{\partial^2 U_2}{\partial {\beta_2}^2} (f'(i))^2 \right] \frac{di}{de_1} \tag{20}$$

$$\Rightarrow \frac{di}{de_1} < 0 \text{ provided that } \left[\frac{\partial U_2}{\partial \beta_2} f''(i) - \frac{\partial^2 U_2}{\partial {\beta_2}^2}(f'(i))^2\right] > 0 \tag{21}$$

Stated differently, the condition in (21) is that MB($i$) is decreasing in $i$.[16] Recalling (5), (19) tells us that the firm's choice of investment is optimal ($i = i^{RO}$) when $\psi'(e_1) = \mid \frac{\partial U_2}{\partial \beta_2} \mid = 1$; i.e., the firm must get a one-for-one return on its investment in period 2. Equation (4) then tells us that optimal investment also requires $e = e^{RO}$.

Figure 1 illustrates our results; both parts show optimal MB and MC curves, along with a pair relating to a low-powered contract and a regulator who generates $\mid \frac{\partial U_2}{\partial \beta_2} \mid < 1$ (so that the firm's rent does not fully benefit from its investment). Here, the second-period prospects for lower rent and the low power of the first-period contract (which reduces the marginal cost of investment) work in opposite directions: the former lowering and the latter raising investment. Depending on which effect dominates we can have under- or over-investment (Figures 2a and b respectively). Thus the value of $\mid \frac{\partial U_2}{\partial \beta_2} \mid$ is crucial for the investment decision and Appendix B provides details of this expression for the second-period equilibrium categories $b$, $c$ and $d$.

As we have stated, (19) defines a local optimum. If the firm chooses to invest at all it will choose $i = i(e_1)$. However the firm may choose not to invest. Given the anticipated second-period regulated price (which depends on $\alpha$), $i = i(e_1)$ is preferable to no investment, $i = 0$, only if $-\psi(e_1) + \delta U_2(\beta_2(i)) > -\psi(e_1 - i) + \delta U_2(\beta_2(0))$; i.e.,

$$\delta[U_2(\beta_2(i)) - U_2(\beta_2(0))] > \psi(e_1) - \psi(e_1 - i) \tag{22}$$

This *investment condition* states that the second-period price must be sufficient for the future gain in rent to outweigh the current marginal cost of investing. Notice that if, in the second period, the constraint $\overline{IR}_2$ binds then $U_2(\beta_2(i)) = U_2(\beta_2(0) = 0$ and (22) cannot hold for $i > 0$. Only when the capture is such that $\alpha > \overline{\alpha}_2$ and we have a second-period equilibrium type $d$, can this condition hold for both the efficient and inefficient firm. However, the efficient firm may optimally invest, or over-invest, in second-period equilibrium categories $b$, $c$ and $d$ because of the existence of information rent. We summarize our results on the firm's investment decision in the following proposition:

[16] For small changes in $\underline{\beta}_2$ and $\overline{\beta}_2$ we can linearise $U_2(s)$ around $\underline{\beta}$ and $\overline{\beta}$, the second term in this condition can be ignored and the condition becomes $\frac{\partial U_2}{\partial \beta_2} f''(i) > 0$. Since $f'' < 0$ and $\frac{\partial U_2}{\partial \beta_2} < 0$ is necessary for any investment, the condition then holds. We are not able to show that the condition holds more generally, but numerical results indicate that this may be the case.

**Proposition 2 (The firm's investment decision).** *There is an investment-effort trade-off in the first period and more investment can only be secured at the expense of lower effort (i.e., a lower power contract) in the first period, provided* (22) *and the condition in* (21) *are satisfied. Over-investment or under-investment can occur.*

It is interesting that, in principle, the regulator's commitment problem can generate *over*-investment as well as under-investment. We now examine the regulator's first-period contract offer and confirm that both forms of investment behaviour can arise in equilibrium. We also examine how a sufficient degree of capture may achieve Ramsey-optimal investment.

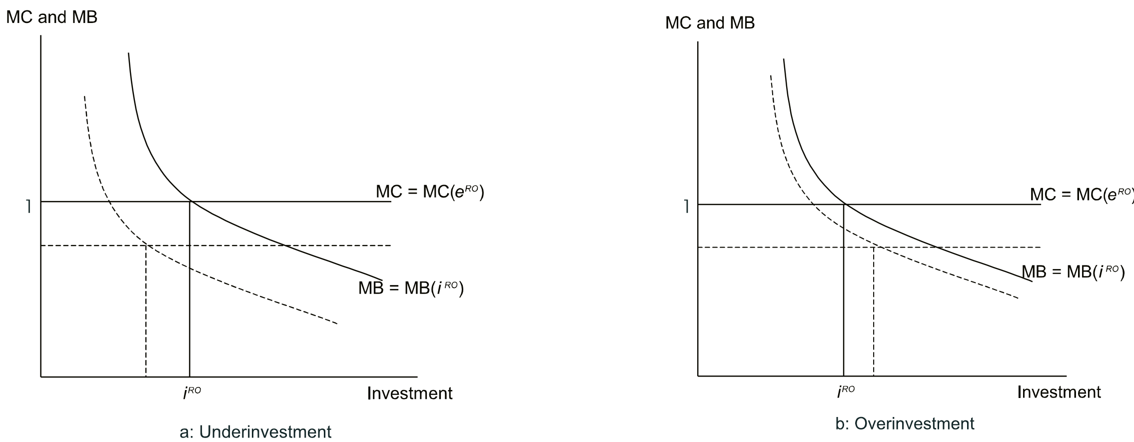


**Figure 1: Determinants of under/over-investment**

## 4.4 First-Period Contract

Now consider the design of contracts $(\underline{p}_1, \underline{C}_1)$ and $(\overline{p}_1, \overline{C}_1)$, given $\nu_1$. Since the efficient firm may mimic the inefficient firm with probability $1 - x$, and the inefficient may mimic the efficient firm with probability $1 - y$, the probabilities of arriving at $\mathbf{L}$ and $\mathbf{H}$ are $\Pr(\mathbf{L}) = \nu_1 x + (1 - \nu_1)(1 - y)$ and $\Pr(\mathbf{H}) = \nu_1(1 - x) + (1 - \nu_1)y$. Then by Bayes' Rule we have

$$\begin{aligned}
\nu_2(\mathbf{L}) &= \Pr(\text{firm is efficient} \mid \text{low cost contract has been accepted}) \\
&= \frac{\nu_1 x}{\Pr(\mathbf{L})} = \frac{\nu_1 x}{(\nu_1 x + (1-\nu_1)(1-y))} && (23) \\
\nu_2(\mathbf{H}) &= \Pr(\text{firm is efficient} \mid \text{high cost contract has been accepted}) \\
&= \frac{\nu_1(1-x)}{\Pr(\mathbf{H})} = \frac{\nu_1(1-x)}{(\nu_1(1-x) + (1-\nu_1)y)} && (24)
\end{aligned}$$

It is convenient to formulate the regulator's problem in terms of the choice of output and effort levels and the probabilities $x$ and $y$. With $E[W_2] = \Pr(\mathbf{L})E[W_2 \mid \mathbf{L}] + \Pr(\mathbf{H})E[W_2 \mid \mathbf{H}]$, the first-period optimization problem given $\alpha$ is:

**Given $\nu_1$, choose $x, y$, $(\overline{q}_1, \overline{e}_1)$ and $(\underline{q}_1, \underline{e}_1)$ to maximize**

$$\begin{aligned}
\Omega = E[W_1 + \delta W_2] &= \nu_1[xW(\underline{q}_1, \underline{e}_1, \underline{\beta} + i(\underline{e}_1), \alpha) + (1-x)W(\overline{q}_1, \tilde{\underline{e}}_1, \underline{\beta} + i(\tilde{\underline{e}}_1), \alpha)] \\
&+ (1-\nu_1)[yW(\overline{q}_1, \overline{e}_1, \overline{\beta} + i(\overline{e}_1), \alpha) + (1-y)W(\underline{q}_1, \tilde{\overline{e}}_1, \overline{\beta} + i(\tilde{\overline{e}}_1), \alpha)] \\
&+ \delta E[W_2] && (25)
\end{aligned}$$

**subject to $\underline{IC}_1$, $\overline{IC}_1$, $\underline{IR}_1$ and $\overline{IR}_1$.**

Let the rent obtained when each firm mimics the other be given by

$$\tilde{\underline{U}}_1 = \overline{U}_1 + \psi(\overline{e}_1) - \psi(\tilde{\underline{e}}_1)\,; \quad \tilde{\overline{U}}_1 = \underline{U}_1 + \psi(\underline{e}_1) - \psi(\tilde{\overline{e}}_1) \tag{26}$$

where from (9) and (19) we have that $\tilde{\underline{e}}_1 = \overline{e}_1 - \Delta\beta + i(\tilde{\underline{e}}_1) - i(\overline{e}_1)$ and $\tilde{\overline{e}}_1 = \underline{e}_1 + \Delta\beta + i(\tilde{\overline{e}}_1) - i(\underline{e}_1)$. Hence $\tilde{\underline{e}}_1 = \tilde{\underline{e}}_1(\overline{e}_1)$ and $\tilde{\overline{e}}_1 = \tilde{\overline{e}}_1(\underline{e}_1)$ and (26) can be written

$$\tilde{\underline{U}}_1 = \overline{U}_1 + \Theta(\overline{e}_1)\,; \quad \tilde{\overline{U}}_1 = \underline{U}_1 - \Gamma(\underline{e}_1)$$

Also, let $s(\mathbf{L})$ and $s(\mathbf{H})$ denote the state vectors at $\mathbf{L}$ and $\mathbf{H}$ respectively. Then the first-period incentive compatibility and individual rationality constraints are given by:

$$\begin{aligned}
\underline{IC}_1 : \underline{U}_1 + \delta\underline{U}_2(s(\mathbf{L})) &\geq \tilde{\underline{U}}_1 + \delta\underline{U}_2(s(\mathbf{H})) \\
\overline{IC}_1 : \overline{U}_1 + \delta\overline{U}_2(s(\mathbf{H})) &\geq \tilde{\overline{U}}_1 + \delta\overline{U}_2(s(\mathbf{L})) \\
\underline{IR}_1 : \underline{U}_1 + \delta\underline{U}_2(s(\mathbf{L})) &\geq 0 \\
\overline{IR}_1 : \overline{U}_1 + \delta\overline{U}_2(s(\mathbf{H})) &\geq 0
\end{aligned}$$

Once again, it is clear that $\underline{IC}_1 + \overline{IR}_1 \Rightarrow \underline{IR}_1$ so that we can ignore the latter. Also, since $\overline{U}_2 = 0$ in second-period equilibrium $b$ and $c$, and $\overline{U}_2$ is independent of $\mathbf{L}$ and $\mathbf{H}$

in equilibrium $d$, we must have that $\overline{U}_2(s(\mathbf{H})) = \overline{U}_2(s(\mathbf{L}))$. The $\overline{IC}_1$ constraint therefore simplifies to $\overline{U}_1 \geq \tilde{\overline{U}}_1$.

As before, to solve this optimization problem, we let $\mu_1 \geq 0$, $\zeta_1 \geq 0$ and $\xi_1 \geq 0$ be the Lagrangian multipliers associated with the $\underline{IC}_1$, $\overline{IC}_1$ and $\overline{IR}_1$ constraints respectively. Then the Lagrangian and first-order conditions are given by:

$$\mathcal{L}_1 = \Omega + \mu_1[\underline{U}_1 - \tilde{\underline{U}}_1 + \delta(\underline{U}_2(s(\mathbf{L})) - \underline{U}_2(s(\mathbf{H}))] + \zeta_1[\overline{U}_1 - \tilde{\overline{U}}_1] + \xi_1[\overline{U}_1 + \delta\overline{U}_2(s(\mathbf{H}))]$$

$$\underline{L}_1 = \frac{\underline{p}_1 - c}{\underline{p}_1} = \frac{\mu_1 - \zeta_1 + (\nu_1 x + (1-\nu_1)(1-y))(\alpha - 1)}{[\mu_1 - \zeta_1 + (\nu_1 x + (1-\nu_1)(1-y))\alpha]\eta(\underline{q}_1)} \tag{27}$$

$$\overline{L}_1 = \frac{\overline{p}_1 - c}{\overline{p}_1} = \frac{\xi_1 - \mu_1 + \zeta_1 + (\nu_1(1-x) + (1-\nu_1)y)(\alpha - 1)}{[\xi_1 - \mu_1 + \zeta_1 + (\nu_1(1-x) + (1-\nu_1)y))\alpha]\eta(\overline{q}_1)} \tag{28}$$

$$\begin{aligned} & (\alpha\nu_1 x + \mu_1 - \zeta_1)(1 - \psi'(\underline{e}_1)) + \zeta_1\Gamma'(\underline{e}_1) \\ - & [\alpha\nu_1 x(1 - \delta f'(\underline{i})) + \mu_1(1 - \psi'(\underline{e}_1)) - \zeta_1]i'(\underline{e}_1) \\ - & \alpha(1-\nu_1)(1-y)(1 - \delta f'(\tilde{\bar{i}}))i'(\tilde{\overline{e}}_1)\tilde{\overline{e}}_1'(\underline{e}_1) = 0 \end{aligned} \tag{29}$$

$$\begin{aligned} & (\alpha(1-\nu_1)y + \xi_1 - \mu_1 + \zeta_1)(1 - \psi'(\overline{e}_1)) - \mu_1\Theta'(\overline{e}_1) \\ - & [\alpha(1-\nu_1)y(1 - \delta f'(\bar{i})) + \xi_1(1 - \psi'(\overline{e}_1)) - \mu_1 + \zeta_1]i'(\overline{e}_1)) \\ - & [\alpha\nu_1(1-x)(1 - \delta f'(\tilde{\underline{i}})) + \mu_1\psi'(\tilde{\underline{e}}_1)]i'(\tilde{\underline{e}}_1)\tilde{\underline{e}}_1'(\overline{e}_1) = 0 \end{aligned} \tag{30}$$

$$\mu_1(\underline{U}_1 - \tilde{\underline{U}}_1 - \delta(\underline{U}_2(s(\mathbf{H})) - \underline{U}_2(s(\mathbf{L}))) = 0 \tag{31}$$

$$\zeta_1(\overline{U}_1 - \tilde{\overline{U}}_1) = 0 \tag{32}$$

$$\xi_1(\overline{U}_1 + \delta\overline{U}_2(s(\mathbf{H}))) = 0 \tag{33}$$

In period 1, unlike period 2 the $\overline{IC}_1$ constraint can bind. The reason for this is the ratchet effect: the higher rent required by the efficient type to prevent it from mimicking and thus enjoying information rent in the second period is also attractive to the inefficient firm. The ratchet effect increases with the discount factor $\delta$ (and disappears as $\delta \to 0$ where the set-up in effect is static). As the weight $\alpha$ increases in period 2, second-period equilibrium categories $c$ then $d$ emerge, offering the $\underline{\beta}$-firm second-period rent even when it reveals its type in period 1. This in turn reduces the ratchet effect and constraints $\overline{IC}_1, \underline{IC}_1$ and $\overline{IR}_1$ cease to bind in that order giving four first-period equilibrium categories: 'type

$a$' where all bind, 'type $b$' where $\underline{IC}_1$ and $\overline{IR}_1$ bind, 'type $c$' where only $\overline{IR}_1$ binds and 'type $d$' the unconstrained case. The intuition is the same as that set out for the second period.

### 4.5 The Lobbying Decision

The equilibrium is now completed with the choice of the lobbying fund by the firm at the beginning of the game. In general the rents of the firm will depend on the lobbying effort, the realization of the cost parameters and the type of equilibria that result, in particular on whether the IR constraints bind or not in a particular period. Given our sequencing the important feature of this choice is that it is made before the realization of the cost parameter $\beta$ and is therefore the same for both types of firm.

At the beginning of the game the rents are functions of the size of the lobbying fund $\ell$; i.e., $U_t = U_t(\ell)$ and the firm maximizes $(1-\ell)E[U_1(\ell) + \delta U_2(\ell)]$. The first order condition for a local maximum is

$$E\left[\frac{\partial U_1}{\partial \ell} + \delta \frac{\partial U_2}{\partial \ell} = U_1(\ell) + \delta U_2(\ell)\right] \tag{34}$$

In (34) expectations are formed over the realizations of the parameter $\beta$ and the relationships $U_t(\ell)$ must take into account which equilibrium is appropriate given the choice of $\ell$. The firm will need to choose a global maximum over $\ell$. Although in general this is a complicated calculation, its main feature is intuitive: the size of the lobbying fund will depend on its effectiveness at buying influence and this in turn is measured by the size of the parameter $\kappa$ defining $\alpha = 1 + \kappa\ell$ in (8). As $\kappa \to 0$ then lobbying becomes totally ineffective and the firm will choose $\ell = 0$. As $\kappa$ increases so does the incentive to invest in a lobbying fund; ie., $\ell = \ell(\kappa)$; $\ell(0) = 0$, $l' > 0$.

### 4.6 The Two-Period Equilibrium

Taking the second and first-period contracts together, we now have a number of possible outcomes, depending on the cost and demand conditions and, in particular, the degree of capture, $\alpha$. Each configuration of parameters determines which $IC$ and $IR$ constraints bind in each period. Table 1 sets out the possibilities. Each row describes a particular combination of first-period constraints. The columns describe second-period constraints and depend on whether a low cost (**L**) or high cost (**H**) first-period contract has been observed.[17] The degree of capture, $\alpha$, is particularly crucial for determining which equilibrium type applies. As with the second-period contract, each of these outcomes can be characterized by setting the relevant multipliers to zero in (27)–(32) and solving the resulting simplified first-order conditions: see Appendix B.

| | $\underline{IC}_{2\mathbf{L}}, \overline{IR}_{2\mathbf{L}}$ | $\overline{IR}_{2\mathbf{L}}$ | None | $\underline{IC}_{2\mathbf{H}}, \overline{IR}_{2\mathbf{H}}$ | $\overline{IR}_{2\mathbf{H}}$ | None |
|---|---|---|---|---|---|---|
| $\underline{IC}_1, \overline{IC}_1, \overline{IR}_1$ | $(a, b_{\mathbf{L}})$ | $(a, c_{\mathbf{L}})$ | $(a, d_{\mathbf{L}})$ | $(a, b_{\mathbf{H}})$ | $(a, c_{\mathbf{H}})$ | $(a, d_{\mathbf{H}})$ |
| $\underline{IC}_1, \overline{IR}_1$ | $(b, b_{\mathbf{L}})$ | $(b, c_{\mathbf{L}})$ | $(b, d_{\mathbf{L}})$ | $(b, b_{\mathbf{H}})$ | $(b, c_{\mathbf{H}})$ | $(b, d_{\mathbf{H}})$ |
| $\overline{IR}_1$ | $(c, b_{\mathbf{L}})$ | $(c, c_{\mathbf{L}})$ | $(c, d_{\mathbf{L}})$ | $(c, b_{\mathbf{H}})$ | $(c, c_{\mathbf{H}})$ | $(c, d_{\mathbf{H}})$ |
| None | $(d, b_{\mathbf{L}})$ | $(d, c_{\mathbf{L}})$ | $(d, d_{\mathbf{L}})$ | $(d, b_{\mathbf{H}})$ | $(d, c_{\mathbf{H}})$ | $(d, d_{\mathbf{H}})$ |

**Table 1. The Two-Period Equilibrium**

In fact we can rule out some of the outcomes in Table 1. The ratchet effect means that first-period constraints $\overline{IC}_1$ and $\underline{IC}_1$ must bind before their second-period counterparts. Similarly $\overline{IR}_1$ must bind before $\overline{IR}_2$; otherwise the contracts offer rent to the inefficient type in the first period, but not the second; yet the only reasons for offering the inefficient type rent would be a captured regulator who sufficiently favours rent, in which case she would offer it in both periods (equilibrium $(d, d)$), or a regulator who wishes to encourage investment, in which case rent is offered in the second-period only. These considerations imply that as $\alpha$ increases above unity, second-period constraints cease before their first-period counterparts, ruling out the lower-diagonal equilibrium categories $(c, b_{\mathbf{L}}), (d, b_{\mathbf{L}})$, $(d, c_{\mathbf{L}})$ and $(c, b_{\mathbf{H}}), (d, b_{\mathbf{H}})$, $(d, c_{\mathbf{H}})$.

Table 1 provides the main insights into the effects of a particular degree of capture; once lobbying has determined $\alpha$, the type of equilibrium follows immediately. It is clear that only equilibrium categories $(*, d)$ can generate investment by the inefficient firm since $\overline{U}_2 > 0$ only when $\overline{IR}_2$ slackens. Similarly, as we move from $(b, *)$ to $(c, *)$, increasingly credible promises of future rent gradually overcome the ratchet effect ($\underline{IC}$ ceases to bind) and $\underline{e}_1$ and $\overline{e}_1$ can both equal $e^{RO}$ (see Appendix B)—a necessary condition for $i = i^{RO}$.

[17] Laffont and Tirole (1993), chapter 9, derive a non-commitment PBE equilibrium for a procurement problem where contracts are transfers conditional on cost, there is no capture ($\alpha = \alpha_s = 1$), and no investment. What they call types III and I equilibria correspond to our equilibrium categories $(a, b)$ and $(b, b)$ respectively.

Of course, because removing the ratchet effect reduces rents, prices can fall when this happens.

Focusing more closely on investment behaviour, and first period effort consider Figures 2 and 3. These provide a numerical example of how investment and first period effort respectively are affected by the degree of capture and can be explained using Table 1.[18] Note that Figure 3 excludes $\underline{e}_1$ $(= e^{RO} = 1)$ for simplicity. For our choices of functional forms and parameter values $(a, *)$ equilibrium categories do not occur, but if they did we find in Appendix C the possibility of all efforts and investment being greater or less than the Ramsey optimum.[19]

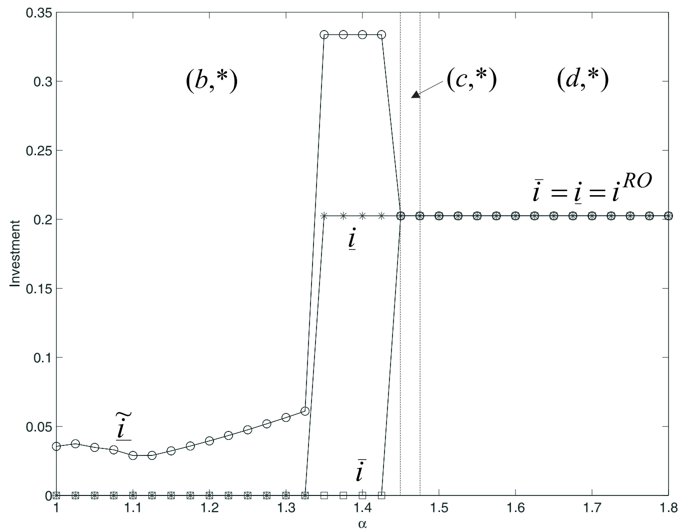


**Figure 2: Capture and Investment**

[18]We choose functional forms: $\psi(e) = \frac{\gamma}{2}(\max(0, e))^2$, $q = \phi(p) = Ap^{-\eta}$ , $\eta > 1$ and $f(i) = Bi^{\theta}$; $\theta \in (0, 1)$, and parameters: $\underline{\beta} = 2$, $\overline{\beta} = 2.5$, $c = \gamma = B = 1$, $A = 10$, $\eta = 1.5$, $\nu_1 = \theta = 0.5$, $\delta = 0.9$ and $\alpha = \alpha_s = 1$ (no capture). With these choices we have $e^{RO} = 1/\gamma = 1$ and $i^{RO} = (\delta\theta B)^{\frac{1}{1-\theta}} = 0.2025$

[19]For the $(b, *)$ type equilibrium categories, which do occur, the optimal incentive mechanism is found by maximizing the social welfare function over $x \in [0, 1]$, where, we recall, $x$ is the probability that the efficient firm mimics the inefficient firm in period 1. However here we avoid the complications arising from $x$ changing with every parameter combination and present results for an exogenously chosen $x = 0.5$. Thus, we actually underestimate the potential welfare gains from limited capture reported in section 5. All numerical results are obtained using programs written in MATLAB. These are available to the reader on request.

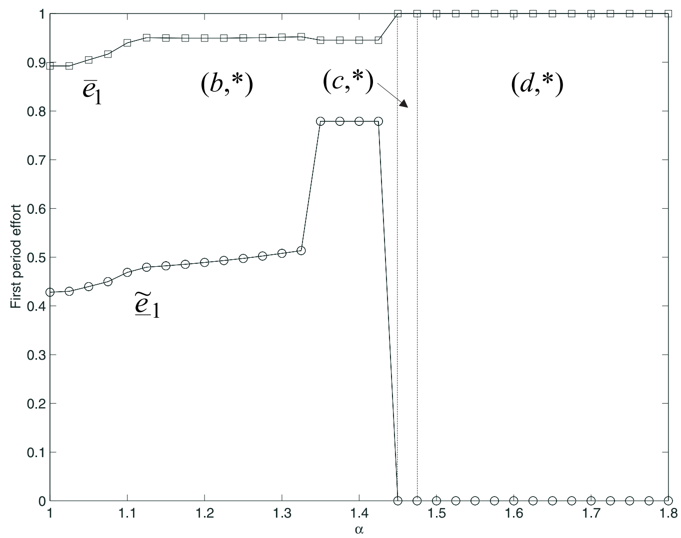


**Figure 3: Capture and first-period effort**

To begin with, the degree of capture is such as to produce equilibrium type $(b, b)$. Using Appendices B and C and Figure 2, we can characterize investment for this type as follows. First, since $\overline{IR}_2$ binds, $\overline{i} = 0$. Next, suppose the efficient firm does not mimic the inefficient one (i.e. $(b, b_{\mathbf{L}})$). From Appendix B, $\underline{e}_1 = e^{RO}$ (since $\overline{IC}_1$ does not bind); from Appendix B, we have $\mid \frac{\partial U_2}{\partial \beta_2} \mid < 1$ and therefore from (19) $\text{MB}(i) = \delta \mid \frac{\partial U_2}{\partial \beta_2} \mid f'(i) < \delta f'(i)$. Referring back to Figure 1, we thus have $0 < \underline{i} < i^{RO}$—assuming (22) holds (otherwise $\underline{i} = 0$). Thus, under-investment or, as in Figure 3, no investment occurs. Now suppose that the efficient firm mimics (i.e. $(b, b_{\mathbf{H}})$). We now have $\tilde{\underline{e}}_1 < e^{RO}$ (see Figure 3 and Appendix C) along with $\text{MB}(i) < \delta f'(i)$. From Figure 1 (and assuming (22) holds) the lower marginal cost and marginal benefit of investment lead to $\tilde{\underline{i}} \gtreqless i^{RO}$; in our example the net effect is under-investment.

With a higher degree of capture (higher $\alpha$) we move through the various $(b, *)$ equilibrium categories and at around $\alpha = 1.32$ the regulator is sufficiently pro-rent as to generate equilibrium type $(b, c)$ and then, as $\alpha$ increases, $(b, d)$. When the latter is reached, we know that both the efficient and inefficient firm may now invest since $\overline{IR}_2$ slackens, and indeed, the inefficient firm can *over-invest* if $\overline{e}_1 < e^{RO}$. However the investment condition (22) must also be satisfied. Since the inefficient firm receives no information rent in the second period this condition is only satisfied at higher values of $\alpha$ than for the efficient firm. In Figure 2 this does not happen and in equilibrium categories $(b, c)$ and $(b, d)$ the inefficient firm does not invest at all.

For the efficient firm, when $(b, c)$ is reached, non-mimicking investment is Ramsey-optimal as can be confirmed from Appendix C (no mimicking so $\overline{e}_1 = e^{RO}$) and Appendix B (MB$(i) = -1$). However its mimicking investment involves over-investment; see Figure 2. This is because its marginal cost of investment is low ($\underline{\tilde{e}}_1 < e^{RO}$) while its MB$(i)$ is optimal. Thus, as noted in Proposition 2, we have the interesting prospect of the regulator's commitment problem creating *over*-investment.

Still more captured regulators move us towards the bottom righthand corner of the table (through $(c, *)$ equilibrium categories for $\alpha \in [1.45, 1.47]$), then $(d, *)$, as $\underline{IC}_1$, and $\overline{IR}_1$ cease to bind in turn. Now $\underline{e}_1 = \overline{e}_1 = e^{RO}$ and Ramsey-optimal investment by both efficient and inefficient firms can take place if the investment condition (22) holds, as is the case in Figure 2. Then the marginal cost of investment is Ramsey-optimal and the regulator is sufficiently captured that the marginal benefit of investment is similarly optimal (Appendices B and C).

It is also possible to confirm (see Levine and Rickman (2001)) that as the $(b, d)$ equilibrium type is entered, the regulator is offering sufficient second-period rent to prevent the ratchet effect from taking place. Thus, at this point, regulated prices fall as they no longer take account of the extra information rent required by the efficient firm.

Working through Table 1 in the above fashion gives us:

**Lemma 1.** *Any positive investment requires* (22) *to hold, otherwise investment is zero. Then the equilibrium categories exhibit the following first-period effort and investment behaviour:*

$$\left.\begin{array}{l} (a,b),(a,c)\ :\ \underline{\tilde{i}}, \underline{i} \gtreqless i^{RO}, \overline{i} = 0 \\ (a,d)\ :\ \underline{\tilde{i}}, \underline{i}, \overline{\tilde{i}}, \overline{i} \gtreqless i^{RO} \end{array}\right\} \underline{e}_1, \underline{\tilde{e}}_1, \overline{e}_1, \overline{\tilde{e}}_1 \gtreqless e^{RO}$$

$$\left.\begin{array}{l} (b,b)\ :\ \underline{\tilde{i}} \gtreqless i^{RO}, \underline{i} < i^{RO}, \overline{i} = 0 \\ (b,c)\ :\ \underline{\tilde{i}} > i^{RO}, \underline{i} = i^{RO}, \overline{i} = 0 \\ (b,d)\ :\ \underline{\tilde{i}}, \overline{i} > i^{RO},\ \underline{i} = i^{RO} \end{array}\right\} \underline{e}_1 = e^{RO}\ ;\ \overline{e}_1,\ \underline{\tilde{e}}_1 < e^{RO}$$

$$\left.\begin{array}{l} (c,c)\ :\ \underline{i} = i^{RO}, \overline{i} = 0 \\ (c,d),(d,d)\ :\ \underline{i} = \overline{i} = i^{RO} \end{array}\right\} \underline{e}_1 = \overline{e}_1 = e^{RO}$$

Bringing Lemma 1 together with the effect of $\alpha$ on the constraints yields the following result:

**Proposition 3 (Capture and investment).** *Unlike relatively utilitarian regulators, relatively captured ones are able to guarantee Ramsey-optimal investment (if sufficiently captured) by both firms. A necessary condition for Ramsey-optimal investment is* $\alpha > \overline{\alpha}_2$ *where* $\overline{\alpha}_2$ *is the regulator's weight on rent at which all second period IC and IR constraints cease to bind. The sufficient condition is that* $\alpha$ *must rise further to insure Ramsey-optimal investment is preferable to no investment and* (22) *is satisfied.*

It is clear that capture can help to address the regulator's commitment problem. This is a significant result and, as the intuitive arguments in Armstrong and Vickers (1996)—see Footnote (4)—suggest, it could have value in a variety of economies. As we have seen, however, matters are complicated by the fact that the marginal costs and benefits of investment are influenced by other policy concerns: the desires to encourage cost-reducing effort and to reveal information about the firm's productivity parameter ($\beta$). As such, a variety of investment outcomes are possible. Thus, we now move to the overall welfare effects of a captured regulator and the investment she may induce.

# 5 Capture and Welfare

We have seen that capture can result in a regulator with a capture parameter $\alpha$ that increases investment, reduce the ratchet effect and results in both lower prices, benefiting consumers, and higher rent: it can, in other words, be Pareto improving. This section investigates these welfare gains further, compares them with the welfare gain from full commitment and examines the scope for excessive capture that is welfare reducing. First consider the single-period social welfare:

$$W_t = S(p_t) - R(p_t) + \alpha_s U_t = W(p_t, U_t, \alpha_s)$$

where $\alpha_s < \alpha$ represents the weight on rent chosen by the social planner. In what follows, we assume a utilitarian loss function with $\alpha_s = 1$. Having obtained prices and rents in a

Perfect Bayesian Equilibrium given $\alpha$, we can write the two-period social welfare as

$$\begin{aligned}\Omega(\alpha,1) &= \nu_1[xW(\underline{p}_1(\alpha),\underline{U}_1(\alpha),1)+(1-x)W(\overline{p}_1(\alpha),\tilde{\underline{U}}_1(\alpha),1)]\\ &+ (1-\nu_1)[yW(\overline{p}_1(\alpha),\overline{U}_1(\alpha),1)+(1-y)W(\underline{p}_1(\alpha),\tilde{\overline{U}}_1(\alpha),1)]+E[W_2(\alpha,1)]\end{aligned}$$

where

$$\begin{aligned}E[W_2(\alpha,1)] &= (\nu_1 x+(1-\nu_1)(1-y))E[W_2|\mathbf{L})+(\nu_1(1-x)+(1-\nu_1)y)E[W_2|\mathbf{H}]\\ E[W_2|\mathbf{L}] &= \nu_{2\mathbf{L}}W(\underline{p}_{2\mathbf{L}}(\alpha),\underline{U}_{2\mathbf{L}}(\alpha),1)+(1-\nu_{2\mathbf{L}})W(\overline{p}_{2\mathbf{L}}(\alpha),\overline{U}_{2\mathbf{L}}(\alpha),1)\\ E[W_2|\mathbf{H}] &= \nu_{2\mathbf{H}}W(\underline{p}_{2\mathbf{H}}(\alpha),\underline{U}_{2\mathbf{H}}(\alpha),1)+(1-\nu_{2\mathbf{H}})W(\overline{p}_{2\mathbf{H}}(\alpha),\overline{U}_{2\mathbf{H}}(\alpha),1)\end{aligned}$$

We measure the welfare gain from capture, $G(\alpha)$, as follows. Let $\Omega^C=\Omega^C(\alpha_s)$ be the optimal two-period social welfare under commitment. Then

$$G(\alpha)=\frac{\Omega(\alpha,1)-\Omega(1,1)}{\Omega^C-\Omega(1,1)}\times 100$$

Thus $G(\alpha)\leq 100\%$ and measures the extent to which limited capture can substitute for full commitment.

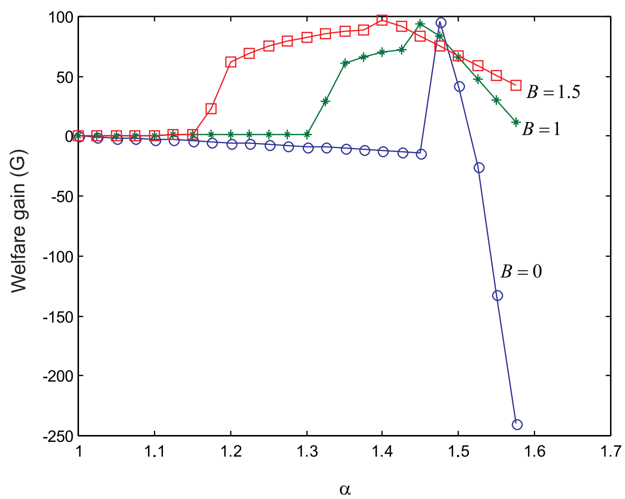


**Figure 4: Welfare gains from capture with zero, intermediate and high levels of investment**

Figure 4 plots $G(\alpha)$ against $\alpha$ for $B=\{0,1,1.5\}$. The case of $B=0$ shows the ability of limited capture to mitigate the ratchet effect on its own, without investment considerations. For $B>0$, the case with investment, these results demonstrate the possibility of significant welfare gains.[20] However without investment considerations a regulator who is only slightly too captured leads to a welfare loss: the negative welfare effects of increasing rent (i.e., prices) cut in quickly. The beneficial effect of capture is far more robust (and the range of beneficial outcomes is considerably wider) if investment is introduced, especially if its impact on costs is at the higher level of $B = 1.5$.

**Proposition 4 (Capture and Welfare).** *Numerical results demonstrate that welfare can be increased by limited capture, for which there is an optimal degree. As investment becomes more effective, a wider range of capture levels increases welfare.*

# 6 Conclusions and Future Research

The question of how to encourage investment (and effort) by regulated industries is a central one for regulators. Problems arise because despite the benefits of both inputs (lower costs), regulators *ex post* have an incentive to lower prices, which firms anticipate: a high price bias results. A number of authors have identified the resulting 'under-investment' in a variety of regulatory settings. The present paper considers a dynamic non-commitment problem and makes several contributions to the analysis of the under-investment problem. First, we show how a sufficient degree of capture can result in a pro-rent regulator and overcome the under-investment problem (as well as the ratchet effect that also arises in the model); as such, Pareto improvements are possible, with higher rents but lower prices emerging. In addition, our analysis takes place within a more detailed (and, we suggest for many regulatory environments, more satisfactory) model than has previously been studied. In particular, we focus on non-contractible investment in the presence of asymmetric information about other cost-reducing effort by the firm, and the regulator is prevented from using transfers in order to reimburse the firm. The full set of Perfect Bayesian Equilibria is characterised.

[20] It is clear from our numerical example that, given our choice of parameter values, there exists an 'optimal degree of capture'. It would be desirable to produce an analytical existence result, but this is precluded by the complexities of the set-up that includes two-period dynamics, moral hazard and adverse selection—all essential ingredients in the regulation game with investment. Our result is consistent with literature from Latin America, where capture concerns have lead to substantial public backlashes against privatised firms—see Kessides (2004).

Our results throw some light on how a regulatory regime might achieve effective regulation. This must achieve: (i) the freedom to respond to the latest information regarding the industry; i.e., it must involve discretion; (ii) socially optimal investment and effort, ruling out direct controls or 'rate-of-return' regulation and (iii) consumer benefits from higher investment through lower prices. Our paper shows that, with discretion, price regulation by a sufficiently, but not excessively, captured regulator will achieve these objectives.

This, in a sense, is a positive rather than normative result. If we observe good regulation it could be coming about through this mechanism. To derive normative conclusions we note that, in common with much of the strategic delegation literature, we have relocated the problem as one of having just the correct degree of capture, $\alpha$, but we have not addressed directly how this correct degree of capture could be engineered. Part of the answer here involves factors affecting the level of capture. We have modelled this as being determined by the size of the lobbying fund chosen by the regulated firm ($\ell$) and (for a given size of fund) by its degree of 'effectiveness' ($\kappa$). While the former is endogenous to the model, the latter reflects exogenous political and/or institutional elements of the economy. In this respect, our results are consistent with observations made by Laffont (2005). For example, high pay for regulators that increase the marginal cost of dismissal and rules that forbid revolving doors may both lower $\kappa$. This could harm, or improve, welfare. Of course, to the extent that 'mistakes' are possible here, Spulber and Besanko (1992)'s suggestion that legal rules can be helpful for implementing simple (but clear) policy objectives is relevant.[21]

Our analysis makes predictions about the effects of regulatory independence (along with the kinds of institutional factors mentioned above) on investment, costs and prices (see also Currie *et al.* (1999)). An important requirement for testing these predictions would be a suitable index of regulatory independence in various countries/industries in order to compare different regulatory regimes. Naturally, such an index would be complex to produce. However, to the extent that regulatory independence can be shown to have benefits in theory, such empirical work would provide important insights for policy makers in this area.

[21] It should also be noted that there is an equivalent mechanism for achieving our results; namely delegation to a regulator of a particular 'type' with preferences $\alpha > 1$ and instituting institutional arrangements that prevent further distortion of preferences by lobbying: see Currie *et al.* (1999).

## References

Aidt, T. S. (1998). Political internationalisation of economic externalities and environmental policy. *Journal of Public Economics*, **69**, 1–16.

Armstrong, M. and Vickers, J. (1996). Regulatory reform in telecommunications in Central and Eastern Europe. *Economics of Transition*, **4**(2), 295–318.

Armstrong, M., Cowan, S., and Vickers, J. (1994). *Regulatory Reform: Economic Analysis and British Experience*. MIT Press, Cambridge, Massachusetts. London, England.

Baldwin, R. E. and Robert-Micoud, F. (2001). *Entry and Asymmetric Lobbying: Why Governments Pick Losers*. NBER Working Paper, 8756.

Besanko, D. and Spulber, D. F. (1992). Sequential equilibrium investment by regulated firms. *RAND Journal of Economics*, **23**(2), 153–170.

Che, Y.-K. (1995). Revolving doors and the optimal tolerance for agency collusion. *RAND Journal of Economics*, **26**(3), 378–397.

Currie, D. A., Levine, P., and Rickman, N. (1999). Delegation and the ratchet effect: Should regulators be pro-industry? CEPR Discussion Paper 2274.

Dalen, D. (1995). Efficiency improving investment and the ratchet effect. *European Economic Review*, **39**, 1511–1522.

de Figueiredo, Jr., R., Spiller, P. T., and Urbiztondo, S. (1999). An informational perspective on administtative procedures. *Journal of Law, Economics and Organisation*, **15**(1), 283–305.

Dixit, A. (1996). Special-interest lobbying and endogenous commodity taxation. *Eastern Economic Journal*, **22**(4), 375–388.

Dobbs, I. (2004). Intertemporal price cap regulation under uncertainty. *Economic Journal*, **114**, 421–440.

EIA (1997). *Electricity Reform Abroad and US Investment. Privatised Electricity: A Performance Appraisal*. Energy Information Administration, US Department of Energy, Washington DC.

Epstein, D. and O'Halloran, S. (1995). A theory of strategic oversight: Congress, lobbyists and the bureaucracy. *Journal of Law, Economics and Organisation*, **11**(2), 227–255.

Faure-Grimaud, A. and Martimort, D. (2003). Regulatory inertia. *RAND Journal of Economics*, **34**(3), 413–437.

Faure-Grimaud, A. and Martimort, D. (2005). *Political Stabilisation by an Indepoendent Regulator*. IDEI, Toulouse, Mimeo.

Fredriksson, P. G. and Gaston, N. (2000). Environmental governance in federal systems: The effects of capital competition and lobby groups. *Economic Inquiry*, **38**(3), 501–514.

Grossman, G. M. and Helpman, E. (1994). Protection for sale. *American Economic Review*, **84**(4), 833–850.

Grossman, G. M. and Helpman, E. (1996). Electoral competition and special interest politics. *Review of Economic Studies*, **63**, 265–286.

Grossman, G. M. and Helpman, E. (2001). *Special Interest Politics*. MIT Press, Cambridge MA.

Guasch, J. L. (2004). *Granting and Renegotiating Infrastructure Concessioins. Doing It Right*. The World Bank Institute, DC.

Guasch, J. L., Laffont, J.-J., and Straub, S. (2005). Concessions and infrastructure in Latin America. Mimeo.

Kessides, I. (2004). *Reforming Infrastructure: Privatisation, Regulation and Competition*. World Bank Policy Research Report, Washington DC.

Laffont, J.-J. (2000). *Incentives and Political Economy*. OUP, Oxford.

Laffont, J.-J. (2005). *Regulation and Development*. MIT Press, Cambridge MA.

Laffont, J.-J. and Martimort, D. (1998). Collusion and delegation. *RAND Journal of Economics*, **29**(2), 280–305.

Laffont, J.-J. and Martimort, D. (1999). Separation of regulators against collusive behaviour. *RAND Journal of Economics*, **30**(2), 232–262.

Laffont, J.-J. and Tirole, J. (1993). *A Theory of Incentives in Procurement and Regulation*. MIT Press, Cambridge, Massachusetts. London, England.

Levine, P. and Rickman, N. (2001). Price regulation, investment and the commitment problem. CEPR Discussion Paper 3200.

Levine, P., Stern, J., and Trillas, F. (2005). Utility regulation and time inconsistency: Comparisons with monetary policy. *Oxford Economic Papers*, **57**(3), 447–478.

Levy, B. and Spiller, P. T. (1994). The institutional foundations of regulatory commitment: A comparative analysis of telecommunications regulation. *Journal of Law, Economics and Organisation*, **10**(2), 201–246.

Lyon, T. P. (1995). Regulatory hindsight review and innovation by electric utilities. *Journal of Regulatory Economics*, **7**, 233–254.

Martimort, D. (1999). The life cycle of regulatory agencies: Dynamic capture and transaction costs. *Review of Economic Studies*, **66**, 929–947.

Newbery, D. M. (1999). *Privatisation, Restructuring and Regulation of Network Utilities*. MIT Press, Cambridge, Mass.

Olsen, T. and Torsvick, G. (1993). The ratchet effect in common agency: Implication for privatisation and regulation. *Journal of Law, Economics and Organisation*, **9**, 136–158.

Salant, D. J. (1995). Behind the revolving door: A new view of public utility regulation. *RAND Journal of Economics*, **26**(3), 362–377.

Salant, D. J. and Woroch, G. (1992). Trigger price regulation. *RAND Journal of Economics*, **23**, 29–51.

Sloof, R. (2000). Interest group lobbying and the delegation of policy authority. *Economics and Politics*, **12**(3), 247–274.

Spulber, D. F. and Besanko, D. (1992). Delegation, commitment and the regulatory mandate. *Journal of Law, Economics and Organisation*, **8**(1).

Stigler, G. J. (1971). The theory of economic regulation. *Bell Journal of Economics and Management Science*, **2**, 3–21.

Straub, S. (2005). Opportunism, corruption and the multinational firm's mode of entry. Mimeo.

Trillas, F. (2000). *Privatised Utilities: Regulatory Reform and Corporate Control*. Ph.D. thesis, European University Institute, Florence.

Urbiztondo, S. (1994). Investment without regulatory commitment: The case of elastic demand. *Journal of Regulatory Economics*, **6**, 87–96.

# A Details of Second-Period Equilibrium Categories

**Second-Period Equilibrium b**: $\alpha \in [1, \underline{\alpha}_2]$. Only $\underline{IC}_2$ and $\overline{IR}_2$ constraints bind. Putting $\zeta_2 = 0$ and eliminating $\mu_2$ and $\xi_2$ the first order conditions (foc) for this equilibrium gives the following four equations in $\underline{q}_2, \overline{q}_2, \underline{e}_2$ and $\overline{e}_2$:

$$\underline{U}_2 = U(\underline{q}_2, \underline{e}_2, \underline{\beta}_2) = \Phi(\overline{e}_2) \tag{A.1}$$

$$\overline{U}_2 = U(\overline{q}_2, \overline{e}_2, \overline{\beta}_2) = 0$$

$$\psi'(\underline{e}_2) = 1; \quad i.e., \underline{e}_2 = e^{RO}$$

$$\frac{(1-\nu_2)}{(1-\eta(\overline{q}_2)\overline{L}(\overline{q}_2))}(1-\psi'(\overline{e}_2)) = \nu_2 \left[\frac{1}{(1-\eta(\underline{q}_2)\underline{L}(\underline{q}_2))} - \alpha\right] \Phi'(\overline{e}_2) \tag{A.2}$$

**Second-Period Equilibrium c**: $\alpha \in (\underline{\alpha}_2, \overline{\alpha}_2]$. Only $\overline{IR}_2$ binds. The foc are:

$$\underline{L}_2 = \frac{\underline{p}_2 - c}{\underline{p}_2} = \frac{\alpha - 1}{\alpha\eta(\underline{q}_2)} \tag{A.3}$$

$$\overline{U}_2 = U(\overline{q}_2, \overline{e}_2, \overline{\beta}_2) = 0 \tag{A.4}$$

$$\psi'(\overline{e}_2) = \psi'(\underline{e}_2) = 1; \text{ i.e.,} \overline{e}_2 = \underline{e}_2 = e^{RO} \tag{A.5}$$

$$\underline{U}_2 > \overline{U}_2 + \Phi(\overline{e}_2) \tag{A.6}$$

**Second-Period Equilibrium Type d**: $\alpha > \overline{\alpha}_2$. For this unconstrained case the foc are:

$$\underline{L}_2 = \frac{\underline{p}_2 - c}{\underline{p}_2} = \frac{\alpha - 1}{\alpha\eta(\underline{q}_2)} \tag{A.7}$$

$$\overline{L}_2 = \frac{\overline{p}_2 - c}{\overline{p}_2} = \frac{\alpha - 1}{\alpha\eta(\overline{q}_2)} \tag{A.8}$$

$$\overline{U}_2 > 0 \tag{A.9}$$

$$\psi'(\overline{e}_2) = \psi'(\underline{e}_2) = 1; \text{ i.e.,} \overline{e}_2 = \underline{e}_2 = e^{RO} \tag{A.10}$$

$$\underline{U}_2 > \overline{U}_2 + \Phi(\overline{e}_2) \tag{A.11}$$

# B Details of The Investment Decision

Differentiating the foc in Appendix A we can evaluate the derivatives $\mid \frac{\partial U_2}{\partial \beta_2} \mid$:

**Second-Period Equilibrium Type b**: $\frac{\partial \underline{U}_2(\mathbf{H})}{\partial \underline{\beta}_2} > -1$; $\frac{\partial \underline{U}_2(\mathbf{L})}{\partial \underline{\beta}_2} > -1$; $\frac{\partial \overline{U}_2(\mathbf{H})}{\partial \overline{\beta}_2} = \frac{\partial \overline{U}_2(\mathbf{L})}{\partial \overline{\beta}_2} = 0$. To prove this result, first note that the second-period information rent $\Phi = \psi(\overline{e}_2) - \psi(\underline{\tilde{e}}_2)$ is a function of $\overline{e}_2$ and $\Delta\beta_2$, the latter depending on investment in the first period. Write $\Phi = \Phi(\overline{e}_2, \Delta\beta_2)$. Then differentiating (A.1)-(A.2) we have that

$$\frac{\partial \underline{U}_2}{\partial \underline{\beta}_2} = \frac{\partial \Phi}{\partial \overline{e}_2} \frac{\partial \overline{e}_2}{\partial \underline{\beta}_2} - \psi'(\underline{\tilde{e}}_2) = -\frac{\partial \Phi}{\partial \overline{e}_2} \frac{a_2}{a_0 + a_1} - \psi'(\underline{\tilde{e}}_2) \tag{B.1}$$

Therefore the result holds iff $\frac{a_2}{(a_0+a_1)} \frac{\partial \Phi}{\partial \overline{e}_2} < (1 - \psi'(\underline{\tilde{e}}_2))$ where we have defined

$$\begin{aligned}
a_0 &= \frac{(1-\nu_2)}{(1-\eta\overline{L}_2)} \left[ \frac{\eta \overline{L}_2{}'(1-\psi'(\overline{e}_2))^2}{(1-\eta\overline{L}_2)(\overline{p}_2(1-\frac{1}{\eta})-c)} + \psi''(\overline{e}_2) \right] \\
a_1 &= \nu_2 \left[ \mu_2(\psi''(\overline{e}_2) - \psi''(\tilde{\overline{e}}_2) + \frac{\eta \underline{L}_2{}' \left(\frac{\partial \Phi}{\partial \overline{e}_2}\right)^2}{(1-\eta\underline{L}_2)^2(\underline{p}_2(1-\frac{1}{\eta})-c)} \right] \\
a_2 &= \nu_2 \left[ -\mu_2 \psi''(\tilde{\overline{e}}_2 + \frac{\eta \underline{L}_2{}' \frac{\partial \Phi}{\partial \overline{e}_2}(1-\psi'(\underline{\tilde{e}}_2))}{(1-\eta\underline{L}_2)^2(\underline{p}_2(1-\frac{1}{\eta})-c)} \right]
\end{aligned}$$

From the definitions of $a_2$ and $a_1$ and the fact that $a_0 > 0$ we have that $\frac{a_2}{(a_0+a_1)} \frac{\partial \Phi}{\partial \overline{e}_2} < \frac{a_1}{a_0+a_1}(1-\psi'(\underline{\tilde{e}}_2)) < (1-\psi'(\underline{\tilde{e}}_2))$, which proves the result.

Hence, providing (22) holds, $\underline{i} \geq 0$, and mimicking investment $\tilde{\underline{i}} \geq 0$ (where $\underline{i} = \tilde{\underline{i}} = 0$ if $\frac{\partial \underline{U}_2}{\partial \underline{\beta}_2} \leq 0$) for the efficient firm, but $\overline{i} = \tilde{\overline{i}} = 0$ for the inefficient firm. For second-period equilibrium categories c and d it is straightforward to obtain the following results:

**Second-Period Equilibrium Type c**: $\frac{\partial \underline{U}_2}{\partial \underline{\beta}_2} = -1$; $\frac{\partial \overline{U}_2}{\partial \overline{\beta}_2} = 0$. Hence, as before if (22) holds, $\underline{i} \geq 0$, and mimicking investment $\tilde{\underline{i}} \geq 0$ for the efficient firm, but $\overline{i} = \tilde{\overline{i}} = 0$ for the inefficient firm.

**Second-Period Equilibrium Type d**: $\frac{\partial \underline{U}_2}{\partial \underline{\beta}_2} = \frac{\partial \overline{U}_2}{\partial \overline{\beta}_2} = -1$. Now, as a result of the extra rent offered by a captured regulator with $\alpha > \overline{\alpha}_2$, $\underline{i}$, $\overline{i}$, $\tilde{\underline{i}}$ and $\tilde{\overline{i}}$ can all be positive.

# C Details of First Period Equilibrium Categories

Let us now consider each row of this table in turn:

**Equilibria** $(a,*)$: $\overline{IC}_1, \underline{IC}_1, \overline{IR}_1$ bind $(\zeta_1, \mu_1, \xi_1 > 0)$.

Then given $x$ and $y$, $\underline{q}_1, \overline{q}_1$, $\underline{e}_1$, and $\overline{e}_1$, are given by (27), (28), (29), (30), (31) and (32), given the functions $i = i(e_1)$ and $i'(e_1)$ obtained in section 4.3. This system of equations allows the possibility of all efforts being greater or less than the Ramsey optimum. The optimal mechanism for a regulator given $\alpha$ is then found by maximizing the intertemporal utility (25) with respect to $x$ and $y$.

**Equilibria** $(b,*)$: $\underline{IC}_1, \overline{IR}_1$ bind $(\zeta_1 = 0;\ \mu_1, \xi_1 > 0)$.

The inefficient firm now does not mimic, so the solution is found by putting $y = 1$, solving (27), (28), (29), (30), (31) and (33), for $\mu_1, \xi_1 > 0$, $\underline{q}_1, \overline{q}_1$, $\underline{e}_1$, and $\overline{e}_1$, for a given $x$, and then maximizing (25) with respect to $x$. Now we have that $\underline{e}_1 = e^{RO}$.

**Equilibria** $(c,*)$: $\overline{IR}_1$ binds $(\zeta_1 = \mu_1 = 0;\ \xi_1 > 0)$.

There is now no mimicking by either type of firm and it is now easy to characterize the equilibrium. Putting $x = y = 1$, information sets L and H become singletons and we have that $\nu_2(L) = 1$, $\nu_2(H) = 0$, $Pr(L) = \nu_1$ and $Pr(H) = 1 - \nu_1$. Then:

$$\underline{L}_1 = \frac{\underline{p}_1 - c}{\underline{p}_1} = \frac{\alpha - 1}{\alpha \eta(\underline{q}_1)} \tag{C.1}$$

$$\overline{U}(\overline{q}_1, \overline{e}_1, \overline{\beta}_1) + \delta \overline{U}_2 = 0 \tag{C.2}$$

$$\overline{e}_1 = \underline{e}_1 = e^{RO} \tag{C.3}$$

**Equilibria** $(d,*)$: Unconstrained. $(\zeta_1 = \mu_1 = \xi_1 = 0)$

This is the simplest case to characterise. Equations (C.1) and (C.3) apply as before and (C.2) now becomes

$$\overline{L}_1 = \frac{\overline{p}_1 - c}{\overline{p}_1} = \frac{\alpha - 1}{\alpha \eta(\overline{q}_1)} \tag{C.4}$$