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A Theory of Soft Capture*

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Abstract

In this paper, we propose an alternative model for capture that is based not on reciprocity but on congruence of interests between the firm and the regulator. A regulator is charged by a political principal to provide an imperfect signal for the type of a regulated firm. Only the firm can observe its type, and the production of a signal is costly. The firm can provide a costless alternative signal of lower accuracy to the regulator. In a self-enforcing equilibrium, the regulator transmits the firm-produced signal and saves information-gathering costs, and the firm enjoys higher information rents.

Keywords: Information; regulatory capture

JEL classification: *D*72; *L*51

I. Introduction

Regulatory capture is an area that has attracted considerable attention from both academia and practitioners in legal and organizational contexts. Generally, the notion that an agency, which monitors a sector in order to prevent abuse of market power or to ensure non-discriminatory service provision, is unduly influenced by the very firms that it is set to supervise is *per se* a justified motivation to scrutinize regulatory design.

Capture is often analyzed using a three-layer hierarchy composed of a political principal (government), a regulatory agency, and an industry or a firm. Regulatory capture is then a side agreement between the regulator and the firm to act against the interests of the political principal.[1] When the

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[1] In the general setting, capture can be induced not only by the regulated firm, but also by clients, staff, or other stakeholders who have interests in rent extraction (see Peltzman, 1976; Becker, 1983).

regulatory environment is designed under asymmetric information, capture originates in the combination of regulatory discretion and information rents left to the firm (Tirole, 1986; Laffont and Tirole, 1993, Chapter 11).

In most capture models, the firm influences the regulatory behavior by a mechanism based on threats[2] (damaged reputation) or rewards (bribes, revolving doors); see Dal Bó (2006) for a survey. Capture here is based on an exchange of favors between the regulator and the regulated firm. The regulator leaves extra rents to the firm, for instance by not disclosing valuable information or by lenient enforcement of regulations. In return, the firm or the industry offers a bribe[3] or the possibility of post-regulatory employment in a regulated firm (revolving doors). Taking the possibility of capture into account, the government optimally limits the regulatory discretion (Hiriart and Martimort, 2012) and/or decentralizes its objective to the regulator, who is then accountable for the regulatory outcome.

According to this classical view, we should observe either capture of regulators by special interest groups or a regulatory design that prevents capture.

Empirical support for monetary corruption is scarce and mostly inconclusive, possibly because of the lack of data and imperfect proxies. Contributions such as those of Dal Bó and Rossi (2007), Kenny (2009), Estache *et al.* (2009), and Berg *et al.* (2012) all show coincidences between various indicators of regulatory dysfunction and the prevalence of corruption in certain countries (often developing countries), but the link of causality to regulatory bribery has not been established. Alternative hypotheses, such as corruption that affects other stages of the production or the administration, could yield similar outcomes without primarily relying on the regulator. Anecdotal evidence in Europe and the US does not suggest that bribery of regulators is a widespread practice or that it would increase with the number of regulatory authorities.

The "revolving door" hypothesis also has a disputed empirical support (Eckert, 1981; Freitag, 1983; Cohen, 1986; Makkai and Braithwaite, 1992)[4] but mechanisms do exist to limit the porosity between firms and regulators

[2] The model of Dal Bó and Di Tella (2003) is one of very few models that include the threat of punishment (violence, harassment, or slander) to capture the regulator.

[3] Estache and Wren-Lewis (2011) address open corruption problems associated with sector regulation in developing countries (e.g., the payment of maritime liner registration fees in cash in Liberia). Although such open money transfers tend to be rare in the Western world, firms might organize side payments more discreetly. Regulated firms can, for example, provide contracts for services to firms associated with the civil servant (regulator) or with members of their family, provide valuable private information on traded assets or foreseen business projects, real estate or other (costly) indirect transfers.

[4] Although more lenient applications of regulatory monitoring and empathy towards regulated entities are prevalent among low- and medium-level staff members of regulatory authorities, only a small fraction of these staff members seek or obtain employment in the regulated

(e.g., ethical commissions that try to avoid conflict of interests for civil servants).[5]

Finally, to the best of our knowledge, few regulators are directly (economically) accountable for regulatory outcomes.[6] Most regulators are civil servants with fixed salaries that are publicly known, and they operate under restrictions concerning complementary economic activities. Thus, we have a "paradox of capture": the existence is widely acknowledged but evidence is scarce (Agrell and Gautier, 2012).

In this paper, we consider another mechanism for influencing regulatory rule-making and implementation: regulated firms can transmit pieces of information relevant to the decision makers. Indeed, many regulated firms finance R&D, produced in-house or by third parties, and they disseminate the results of these studies. This knowledge can be (and actually is) used for regulatory purposes for the benefit of both the regulator and the firm – the regulator because it saves on information-gathering costs, and the firm because it controls the content of the information. Thus, the regulator is captured by accepting biased information from the firm. We refer to this situation as soft capture, and we believe that this form of capture is quite common in regulated industries. In technical infrastructure regulation, such as transport, energy, water, and telecommunication, the regulator might be subject to political pressure to present new technical regulation for specific service dimensions[7] (e.g., technical or service quality norms, cost allocation schemes, grid codes) within a given time and budget frame. Because they face the risk of professional failure if an inadequate regulation is presented

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sector. However, Makkai and Braithwaite (1992) document "situational capture" as a consequence of the extra workload caused by the higher incidence of detected non-compliance. In our setting, this can be interpreted as a problem of moral hazard linked to the cost of effort in enforcement.

[5] Some jurisdictions operate with disclosure rules or "cooling-off" periods for the taking up of employment in regulated firms. However, using a model Heyes (2003) shows that this practice might be ineffective in terms of welfare when regulators act strategically to increase their market value through complexity in regulation.

[6] Henderson and Tung (2012) show that even with the recent introduction of performance-based salary scales for (banking) regulators in the US, the amounts remain modest and the award is largely based on *ex post* discretionary assessment by the political principal.

[7] Note that here we refer to "capture of decisions" as opposed to "capture of (accounting) information" in Estache and Wren-Lewis (2011), or to capture of "regulatory substance" as opposed to "regulatory governance" in Berg *et al.* (2012). Thus, an industry-financed study on service quality, which provides data on willingness to pay, is not likely to be intended for direct use in implementation (although this does occur; see Agrell and Gautier, 2012), but is likely to influence the regulator in the choice of relevant metrics of quality provision. Analogously, in occupational safety regulation, the submission of technical assessments for the costs and effectiveness of particular worker protection measures (Agrell and Gautier, 2012) is not aimed at the ruling for a particular firm but at the very definition of relevant thresholds for the imposition of such measures across firms.

and the risk of career concerns if they refuse the task, the regulators might have private career incentives to accept industry input, sector consultations, or cooperative development of such regulatory projects.[8]

Models based on information provision as an incentive for capture are relatively rare. In a paper addressing lobbying of vote-seeking political principals, Austen-Smith and Wright (1992) present a model where two competing interest groups invest in biased information transmission, subject to the possibility of costly auditing from the principal. The results show that, on average, information provision is welfare-increasing and that the presence of multiple information providers might discipline the tendency to distort information.[9]

Soft capture is not based on threats and rewards: both parties are better off if the regulator recycles the information produced by the firm rather than producing its own. The regulator provides the political principal with information in compliance with the expected outcome by the principal. Also, as it transmits less precise information, the firm increases its information rent. Hence, the capture benefits both parties without requiring any form of side contracting or side payments between parties. Thus, there is no conclusive evidence to be found when the regulator is softly captured by the firm.

In this paper, we develop a formal model of soft capture in a three-tier hierarchy. Our main result is to show that the principal can tolerate (soft) capture at equilibrium.[10] Regarding this, two conditions should be satisfied. First, the information provided to the principal by the regulator should be soft rather than hard information. If the information is verifiable, any possible bias will be immediately detected and soft capture would not be an issue. This implies that soft capture is more of a concern when the regulator is asked to develop a methodology for conducting regulations (a typical example of soft information) than when it is asked to apply a specific regulation. Second, the information received by the principal should remain sufficiently informative. Without this condition, the principal would no longer maintain a costly intermediate for transmitting pure noise. Messages remain informative either if the firm does not systematically send them or if the regulator does not always accept them. In one of these

[8] The origin of the information might also be obscured through the use of consultants, sponsored interest groups, and think-tanks, blurring the information about which stakeholder is trying to influence the decision.

[9] In our model, the regulator is the sole source of information for the political principal. Dual sourcing of information (e.g., lobbying by the firm and reporting by the regulator) is not considered here. See Laffont and Martimort (1998) on this point.

[10] Likewise, Che (1995) found that, under some circumstances, tolerated capture might be the preferred outcome.

cases, information remains valuable even if it contains some noise or bias introduced by the firm and adding an intermediate remains justified.

The paper is organized as follows. In Section II, we present the baseline model. In Section III, we describe the benchmark contract in the absence of capture. In Section IV, we introduce the possibility of soft capture. In Section V, we consider capture-proof contracts. We discuss some extensions in Section VI and we conclude in Section VII. All proofs are relegated to the Appendix.

II. The Model

We consider a three-tier hierarchy composed of a political principal, a regulatory agency, and an agent. The agent is a regulated industry that we model as a representative firm. The production of the firm is regulated by the political principal who offers the firm a contract, specifying a production level and a transfer. As in classical models of incentive regulation, we assume that the regulated industry has some private information on its cost of production. The political principal then designs an optimal incentive contract, following Baron and Myerson (1982). Because of asymmetric information, the contract is only a second-best contract and the firm enjoys information rents that are costly for the principal. To limit these rents, the principal appoints an intermediate, the regulator,[11] whose main task consists in filling in the information gap between the firm and the political principal. To this end, the regulator is asked to produce a cost assessment report for the political principal. The delegation of the monitoring task might be justified by the lack of competency or time by the political principal. This additional piece of information on the firm's hidden cost parameter improves the contract by limiting the information rents left to the firm.

Firm

The representative firm produces a good in quantity q at a constant marginal cost θ. The cost parameter is the firm's private information but it is common knowledge that $\theta \in \{\underline{\theta}, \overline{\theta}\}$, with $\Delta\theta = \overline{\theta} - \underline{\theta} > 0$ and $\Pr(\theta = \underline{\theta}) = \nu$. The firm signs a contract with the political principal that specifies the production level q and a transfer t. The firm's utility is

$$U = t - \theta q. \tag{1}$$

The firm's reservation utility is normalized to zero.

[11] Following the usual convention, the political principal is denoted "she" and the regulator "he".

Regulator

The regulator is requested to provide the political principal with a signal σ. A signal is a piece of information correlated with the firm's hidden cost parameter. Analogous to the cost parameter θ, the signal is a binary variable $\sigma \in \{\sigma_1, \sigma_2\}$. The signal $\sigma = \sigma_1$ (resp. σ_2) – if correctly interpreted (see below) – increases the probability of facing an efficient (resp. inefficient) agent compared to the prior. We measure the informativeness of the signal produced by the regulator by the conditional probability $\mu = \Pr(\sigma = \sigma_1 | \theta = \underline{\theta}) = \Pr(\sigma = \sigma_2 | \theta = \overline{\theta})$.[12] When μ increases, the correlation between the firm's true type θ and the signal increases. With $\mu = 1$, the signal and the type are perfectly correlated while $\mu = 1/2$ signifies a white noise.

The production of the signal is costly for the regulator. To produce a signal of quality μ, the regulator must incur a cost $m > 0$. The signal is useful to the principal to revise her prior beliefs regarding the firm's cost, thereby reducing the costly rents left to the firm.[13] We assume that the signal is soft information, meaning that the contract between the principal and the firm cannot be made contingent on the realization of the signal. However, the potential disclosure of information by the regulator is observable and the regulator's compensation can be made contingent on that.[14] Thus, the political principal cannot verify the quality of an assessment but merely its existence.

The regulator and the political principal sign a contract specifying that, conditional on submitting a signal, the regulator receives a payment w. In this case, the regulator's utility is

$$V = w - m. \tag{2}$$

The regulator has a reservation utility of zero and he is protected by limited liability.

Political Principal

The political principal remains in charge of the main regulatory tasks and designs a regulatory contract (t, q). When the firm produces a quantity q,

[12] For notational simplicity, we study a symmetric informativeness, leaving the case of asymmetric precision for further work.

[13] Thus, our model is a standard model of regulation under asymmetric information with *ex ante* non-verifiable signals (Laffont and Martimort, 2002, Chapter 2).

[14] Examples could be cost, impact, or efficiency studies performed by or for the regulator and included in reports or preambles to regulatory rulings.

the value for the principal of these q units is $S(q)$ with $S' > 0$, $S'' < 0$, and $S(0) = 0$. The principal's net surplus[15] W is defined as

$$W = S(q) - t - w. \tag{3}$$

Timing of the Events

1. The firm learns its private cost parameter θ.
2. The political principal offers a contract (w) to the regulator for the delivery of a signal σ.
3. The regulator produces a signal σ at cost m.
4. The political principal observes σ and offers a contract (t, q) to the firm.
5. The firm accepts or rejects the contract, and production takes place.

III. Benchmark Results in the Absence of Capture

We solve the game recursively, starting with the contract design by the principal.

After observing the signal transmitted by the regulator, the principal revises her prior beliefs on the firm's private cost parameter. Given the informativeness of the signal μ, the conditional probabilities of facing a type $\underline{\theta}$ after observing the signal σ_i, $i = 1, 2$ are updated to (using the Bayes rule)

$$\nu_1 = \Pr(\theta = \underline{\theta}|\sigma_1) = \frac{\mu\nu}{\mu\nu + (1-\mu)(1-\nu)} \geq \nu, \tag{4}$$

$$\nu_2 = \Pr(\theta = \underline{\theta}|\sigma_2) = \frac{(1-\mu)\nu}{(1-\mu)\nu + \mu(1-\nu)} \leq \nu. \tag{5}$$

Signals are informative in the sense that the probability of facing the efficient type $\underline{\theta}$ after observing the signal σ_1 (resp. σ_2) is higher (resp. lower) than the priors. Furthermore, a higher μ makes the signal more informative by increasing ν_1 and decreasing ν_2:

$$\frac{\partial \nu_1}{\partial \mu} = \frac{\nu(1-\nu)}{[\mu\nu + (1-\mu)(1-\nu)]^2} > 0,$$
$$\frac{\partial \nu_2}{\partial \mu} = \frac{-\nu(1-\nu)}{[(1-\mu)\nu + \mu(1-\nu)]^2} < 0. \tag{6}$$

[15] We assume that the political principal attributes no value to the utility of the regulator, a conventional assumption.

Given its posterior beliefs, the optimal contracts offered by the principal after observing the signal σ_i are obtained as the solution of

$$\max_{\{(\underline{t}_i, \underline{q}_i);(\overline{t}_i, \overline{q}_i)\}} \nu_i[S(\underline{q}_i) - \underline{t}_i] + (1 - \nu_i)[S(\overline{q}_i) - \overline{t}_i], \tag{7}$$

subject to the firm's incentive compatibility and individual rationality constraints:

$$\underline{t}_i - \underline{\theta}\underline{q}_i \geq \overline{t}_i - \underline{\theta}\overline{q}_i, \tag{8}$$

$$\overline{t}_i - \overline{\theta}\overline{q}_i \geq 0. \tag{9}$$

Solving the problem, we obtain the optimal second-best contracts:

$$S'(\underline{q}_i) = \underline{\theta}, \tag{10}$$

$$S'(\overline{q}_i) = \overline{\theta} + \frac{\nu_i}{1 - \nu_i}\Delta\theta, \tag{11}$$

$$\underline{t}_i = \underline{\theta}\underline{q}_i + \Delta\theta\overline{q}_i, \tag{12}$$

$$\overline{t}_i = \overline{\theta}\overline{q}_i. \tag{13}$$

The optimal quantity transfer pairs result from a well-known trade-off between efficiency and rent extraction. That is, the quantity produced by the high-cost firm is distorted downward to reduce the rents left to the low-cost firm, while the quantity produced by the efficient firm is set at the first-best level: $\underline{q}_1 = \underline{q}_2 = \underline{q} = S'^{-1}(\underline{\theta})$.

The distortions applied to the production of a high-cost firm depend on the observed signal. After observing σ_1, the principal concludes that the probability of facing an efficient agent is higher than her prior and the optimal contract calls for a stronger reduction in $\overline{q}_1$ to lower the information rent. On the contrary, after observing σ_2, the principal considers that she is more likely to face an inefficient agent and the optimal contract calls for a smaller reduction in $\overline{q}_2$. In other words, we have $\overline{q}_1 < \overline{q}_2$.

We are now in the position to derive the information rents ($\underline{U}$) and the expected welfare ($\tilde{W}$) resulting from the optimal contract with the agent. For the purposes of comparative statics, we explicitly express these as functions of the informativeness parameter μ.

The firm's information rent is equal to

$$\underline{U}(\mu) = \mu\Delta\theta\overline{q}_1 + (1 - \mu)\Delta\theta\overline{q}_2. \tag{14}$$

A change in the informativeness of the signal has the following impact on $\underline{U}$:

$$\frac{\partial \underline{U}}{\partial \mu} = \Delta\theta \left[(\overline{q}_1 - \overline{q}_2) + \mu\frac{\partial q_1}{\partial \mu} + (1 - \mu)\frac{\partial q_2}{\partial \mu} \right]. \tag{15}$$

The first term in equation (15) is negative ($\overline{q}_1 < \overline{q}_2$), the second term is negative ($\partial\overline{q}_1/\partial\mu < 0$), and the last term is positive ($\partial\overline{q}_2/\partial\mu > 0$). If μ is sufficiently large, then the information rent unambiguously decreases with μ. In the following, we assume that $\underline{U}$ decreases with the informativeness of the signal for all relevant values of μ.

Assumption 1. $\partial\underline{U}/\partial\mu < 0$ *for all* $\mu \in [1/2, 1]$.

Assumption 1 implies that a more informative signal always reduces the rents left to the regulated firm. In the Appendix, we show that $S''' \geq 0$ is a sufficient condition for Assumption 1.

The expected welfare (evaluated at the optimal contract) is given by

$$\tilde{W}(\mu) = \nu[S(\underline{q}) - \underline{\theta}\underline{q} - \underline{U}(\mu)] + (1-\nu) \times \{\mu[S(\overline{q}_2) - \overline{\theta}\overline{q}_2] + (1-\mu)[S(\overline{q}_1) - \overline{\theta}\overline{q}_1]\}. \quad (16)$$

The following lemma characterizes the impact on the welfare evaluated at the optimal contract of a change in the informativeness of the signal.

Lemma 1. *The function* $\tilde{W}(\mu)$ *is increasing and convex in* μ.

Lemma 1 and Assumption 1 imply that a more informative signal benefits the principal but hurts the firm. This conflict naturally creates the scope for capture.

Moving one step back in the game, the welfare is equal to $\tilde{W}(\mu)$ if the principal received a signal σ from the regulator. As a signal is produced at cost m, the principal must offer a compensation $w \geq m$ to the regulator for getting a signal. Setting $w = m$, the principal obtains a signal and the total surplus is $\tilde{W}(\mu) - m$.

As an alternative, the principal can set $w < m$, in which case the regulator does not produce any signal. The firm is then offered a contract based on the priors. As for $\mu = 1/2$, $\nu_1 = \nu_2 = \nu$, the optimal contract in the absence of signal is given by equations (10)–(13) evaluated at $\mu = 1/2$. Thus, if the principal sets $w = 0$, the regulator is abolished, no signal is produced, and the corresponding welfare is $\tilde{W}(1/2)$.

Adding a tier between the political principal and the firm is socially valuable whenever $\tilde{W}(\mu) - m \geq \tilde{W}(1/2)$. In the following lemma, we derive the conditions under which a regulator is socially valuable. Figure 1 illustrates the lemma.

Lemma 2. *If* $\tilde{W}(1) - \tilde{W}(1/2) \geq m$*, then there exists a* $\tilde{\mu}_1 \in [1/2, 1]$ *such that if* $\mu \geq \tilde{\mu}_1$*, the principal sets* $w = m$ *and the regulator produces a signal; otherwise, she sets* $w = 0$ *and does not observe a signal.*

The principal employs a regulator when the gains from more accurate information on the firm's cost parameter exceed the costs of gathering

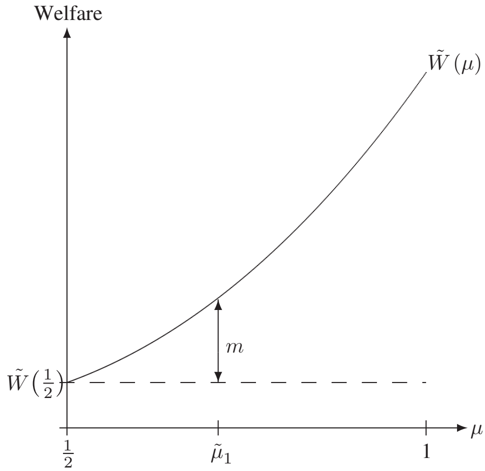

Fig. 1. Welfare in the absence of capture

information. For the remainder of the analysis, we assume that $\tilde{W}(1) - \tilde{W}(1/2) \geq m$ and $\tilde{\mu}_1 < \mu \leq 1$.

IV. Soft Capture

The Scope for Capture

The mechanism above is not immune to capture when the firm can substitute the regulator and produce a signal σ by itself. Suppose that the firm can, with some probability x, produce a signal that is less informative than the signal produced by the regulator. If offered the information for free, the regulator can transmit the signal to the political principal, receiving the payment $w = m$ because the principal cannot distinguish the origin or precision of the signal. Given that the production cost is lower, the regulator's utility is strictly higher: $V = m$. The firm also benefits from providing the signal to the regulator. Consider, for instance, a signal that is pure noise, corresponding to $\mu = 1/2$. If the political principal is made to believe that the signal has been produced by the regulatory agency, then the expected rent of the firm with type $\underline{\theta}$ is equal to

$$\frac{\Delta\theta}{2}(\overline{q}_1 + \overline{q}_2) > \underline{U}(\mu). \tag{17}$$

The implicit collusion between the firm and the regulator above is in contrast to other models of collusion in three-tier hierarchies (Tirole, 1986; Laffont and Tirole, 1993, Chapter 11; Kofman and Lawaree, 1993) where side contracting and side payments (or some form of reciprocity) are necessary conditions for collusion. In these latter models, the firm should bribe the regulator for not disclosing information that is valuable to the principal but detrimental to the firm. In contrast, with soft capture, there is no need for an explicit agreement to support collusion. The mechanism is self-enforcing and undetectable, and its apparent lack of commitment is deceptive.

In practice, there are many channels that the firm can use to disclose (noisy or biased) information to the regulator.[16] Firms can produce their own research, data collection, and analyses or they can finance third parties (consultants, researchers, universities, etc.). These studies or research reports, produced or sponsored by firms, might be disseminated through professional forums and conferences, or published as reports. Firms can also train regulatory staff and make available their special field expertise. All these practices are commonly observed (e.g., in the field of utility regulation), and there is no doubt that the information emanating from the firm percolates throughout the regulators.

One condition for this mechanism to work is that the signal is soft and not hard information. In traditional models of regulatory capture, it is often assumed that the regulator produces either a verifiable signal, perfectly correlated with the firm's type, or nothing. The regulator has the discretion to disclose or not to disclose the signal produced, if any, but he cannot falsify a signal. It is the discretion left to the regulator to report or not to report a signal that creates room for regulatory capture. The soft capture model we develop in this paper raises the possibility for the regulated firm to manipulate the accuracy, content, or informativeness of the information provided to the political principal by the regulator. Clearly, this will not be possible if the signal is hard information on the firm's type. Thus, soft capture can only be envisioned if the accuracy of the signal produced by the regulator is non-verifiable (i.e., if the signal is soft information).

In practice, the information transmitted by the regulator to the principal is often based on a mixture of public and private data. Naturally, a direct reproduction of the firm's information renders the regulator's lack of effort obvious. Thus, the softly captured regulator indeed produces some regulatory substance (e.g., a revenue cap regime with parameters), but biased to suit all or some of the firms. A regulatory task, such as the development of a cost assessment methodology for a regulated industry, is a typical

[16] In fact, agencies sometimes actively solicit data from (likely biased) sources, as shown, for example, from an interview with a lobbyist in Bernhagen and Bräuninger (2005, p. 47): "I am actually surprised how often they [ministerial civil servants] ring me up looking for data. I would have assumed they should be the ones who have it."

example of soft information that can be manipulated by the industry. On the contrary, the use of such a methodology to effectively assess the cost of a regulated firm is more like an accounting exercise, and it can hardly be considered soft information. However, a softly captured regulator might agree to use an industry-financed computer code to estimate grid construction costs in the actual revenue-cap methodology (see Grifell-Tatjé and Lovell, 2003).

A Model with Soft Capture

In this section, we develop the baseline model to integrate the possibility for the regulator to be captured by the regulated. To do so, we suppose that before the regulator produces his signal, the regulated firm can produce its own. We consider a stochastic production technology for the firm: with probability x, the firm produces a noisy signal; with probability $1-x$, the firm produces nothing. The signal is produced by the firm at no cost.[17] Given that any additional information transmitted to the principal hurts the regulated industry (Assumption 1), we consider that if the firm succeeds in producing a signal, the latter is totally non-informative, corresponding to $\mu = 1/2$.[18] The ability for a regulated industry to produce a signal depends on many factors, such as, for example, the existence of professional forums or associations that can be used to produce and disseminate information that are favorable to the industry. In Section VI, we consider an endogenous probability x.

If the firm's noisy signal is produced and transmitted to the regulator, he has the choice of either forwarding it to the principal or producing an original signal. As the regulator receives the same payment $w = m$ in both cases, the first option is obviously preferred by the regulator. In the next sections, we discuss contracts between the principal and the regulator that aim to prevent the regulator accepting industry input.

A crucial assumption here is that the principal is unable to observe the origin of a signal. With probability x, the signal is totally uninformative and produced by the firm; with probability $1-x$, it is produced by the regulator and the signal has informativeness μ. The principal thus updates

[17] The rent of the inefficient firm is, in any case, equal to zero. Thus, if producing a signal is costly for the firm, only an efficient firm would produce it, provided the cost exceeds the benefit. Considering costly signals would not qualitatively change the results.

[18] In this formulation, the signal produced by the firm is white noise but not biased. We treat the case of biased signals as an extension in Section VI.

her beliefs according to

$$\tilde{\nu}_1(x) = \Pr(\theta = \underline{\theta}|\sigma_1) = \frac{\nu[(x/2) + (1-x)\mu]}{\nu[(x/2) + (1-x)\mu] + (1-\nu)[(x/2) + (1-x)(1-\mu)]},$$

$$\tilde{\nu}_2(x) = \Pr(\theta = \underline{\theta}|\sigma_2) = \frac{\nu[(x/2) + (1-x)(1-\mu)]}{\nu[(x/2) + (1-x)(1-\mu)] + (1-\nu)[(x/2) + (1-x)\mu]}.$$

Signals are less informative when there is a possibility of capture ($x > 0$) but they remain informative as long as $x < 1$. Formally, an increase in x has the following impact on the preciseness of the signals.

Lemma 3. *(a)* $\tilde{\nu}_1(x)$ *is decreasing in* x, $\tilde{\nu}_1(0) = \nu_1$ *and* $\tilde{\nu}_1(1) = \nu$; *(b)* $\tilde{\nu}_2(x)$ *is increasing in* x, $\tilde{\nu}_2(0) = \nu_2$ *and* $\tilde{\nu}_2(1) = \nu$.

After updating her beliefs, the principal designs a regulatory contract for the firm. This contract is described in equations (10)–(13), and obviously the welfare is lower. The following lemma characterizes the welfare in the presence of soft capture.

Lemma 4. *When the firm transmits a noisy message with probability* x, *the welfare evaluated at the optimal contract is* $\widetilde{W}(\hat{\mu})$ *with* $\hat{\mu} = (x/2) + (1-x)\mu < \mu$, $\forall x > 0$.

The possibility of soft capture reduces the effectiveness of the regulation, as the informativeness of the signal transmitted by the regulator is lower than μ. Notice that Lemma 4 implies that our model, where the firm produces a message that is white noise with probability x, could equivalently be interpreted as a model where the regulated firm is always producing a message that is informative ($\hat{\mu} \geq 1/2$), yet less so than the regulator-produced signals ($\hat{\mu} \leq \mu$).

Even if the firm produces the information for free and is ready to transmit it to the regulator, the political principal must still pay $w = m$ to the regulator to obtain any information. Indeed, if $w < m$, then the regulator has no incentive to submit a signal unless it is transmitted by the firm.[19] When the threat of an independently produced signal is absent, the firm has no incentive to disclose information at all. Hence, to benefit from a signal, potentially obtained for free from the firm, the principal must still pay $w = m$ to the regulator, conditionally on reporting a signal. This nicely illustrates the rationale behind soft capture. It is the threat of a more informative message that motivates the firm to disclose less

[19] However, if the regulator does not submit the signal, the firm has no incentive to provide it to the regulator in the first place.

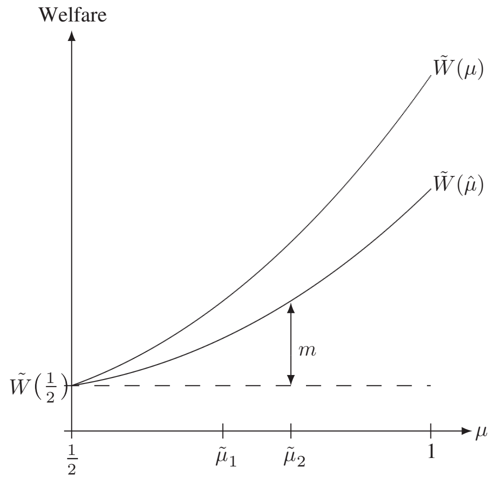

Fig. 2. The cost of soft capture

precise information. Should this threat disappear, the firm would no longer produce information.[20] Hence, the corresponding welfare under soft capture is $\tilde{W}(\hat{\mu}) - m$.

The Cost of Soft Capture

The social cost of soft capture can be measured by the welfare loss associated with less informative signals (i.e., $\tilde{W}(\mu) - \tilde{W}(\hat{\mu}) > 0$). By Lemma 1, the cost of soft capture is increasing in μ as illustrated in Figure 2. Considering the cost of capture, adding a tier between the political principal and the firm is no longer socially desirable for all values of $\mu \in [\tilde{\mu}_1, 1]$. In Lemma 5, we update the conditions under which a regulator is socially valuable in the presence of soft capture.

Lemma 5. *If $\tilde{W}(1 - x/2) - \tilde{W}(1/2) \geq m$, there exists $\tilde{\mu}_2 \in [\tilde{\mu}_1, 1]$ such that if $\mu \geq \tilde{\mu}_2$, the principal sets $w = m$ and the regulator transmits a signal; otherwise it sets $w = 0$, and the principal does not observe a signal.*

There might be an additional inefficiency associated with capture if one considers that the regulator's information-gathering expertise is endogenous and that it depends on the regulatory endowment (staff, budget) decided

[20] This effect is analogous to the results obtained in lobbying models (Austen-Smith and Wright, 1992): a lobbyist would only invest in costly information transmission provided the [decision-maker] enjoys a sufficiently low cost of independent information acquisition, or else the message would be discarded by default as non-informative.

by the principal in the first place. If we consider that having the ability to produce a signal of quality μ costs the principal $c(\mu)$, with $c' > 0$ and $c'' \geq 0$, then, given the convexity of the welfare function (Lemma 1), the principal would choose a lower endowment and hence a lower signal quality when capture is taken into account, and this creates additional inefficiencies.

V. A Capture-Proof Mechanism

In order to benefit from the information-gathering expertise of the regulator and to guarantee absence of capture, the principal must adapt both the level and the structure of the compensation left to the regulator. In particular, the regulator could be made partially responsible for the regulatory outcome; that is, when better information leads to a more efficient regulatory contract, the welfare gain should be shared with the regulator.[21]

To decentralize its objective, the principal should condition the wage paid to the regulator, not on the delivery of a signal but on the regulatory outcome (i.e., the production or the transfer level). A more informative signal makes the contracts $(\underline{q}_1, \underline{t}_1)$ and $(\overline{q}_2, \overline{t}_2)$ more likely and $(\underline{q}_2, \underline{t}_2)$ and $(\overline{q}_1, \overline{t}_1)$ less likely. Hence, the regulator should reward the regulator for the former and punish it for the latter. Denote by $\underline{w}_i$, $\overline{w}_i$, the wage paid to the regulator conditional on a production level of $\underline{q}_i$, $\overline{q}_i$, $i = 1, 2$ and assume further that the regulator is protected by limited liability imposing $\underline{w}_i$, $\overline{w}_i \geq 0$. The capture-proof constraint for the regulator is given by

$$\begin{aligned} &\nu\mu\underline{w}_1 + \nu(1-\mu)\underline{w}_2 + (1-\nu)\mu\overline{w}_2 + (1-\nu)(1-\mu)\overline{w}_1 - m \\ &\quad \geq \nu\hat{\mu}\underline{w}_1 + \nu(1-\hat{\mu})\underline{w}_2 + (1-\nu)\hat{\mu}\overline{w}_2 + (1-\nu)(1-\hat{\mu})\overline{w}_1 \\ &\quad\ -(1-x)m. \end{aligned} \tag{18}$$

The left-hand side of equation (18) is the payoff to the regulator when it produces the signal itself. The right-hand side is the payoff when the regulator is captured. In this case, the firm produces a noisy signal with probability x and the regulator a signal of quality μ with the complementary probability $(1-x)$. The overall signal quality is $\hat{\mu}$ as the principal

[21] Incentive contracts for regulators are rarely used in practice to prevent capture (see Henderson and Tung, 2012). A more common solution is the multiplication and the diversification of the information sources for the principal. Guerriero (2011) documents that rate reviews for regulated US electricity distributors are organized as quasi-judicial hearings where all stakeholders (firms, customers, etc.) have the opportunity to bring information to the Public Utility Commission (PUC). This yields rate reviews that are less dependent on the regulator's ability to gather information from the industry. The parties act as open advocates of their interest and multiple sources of biased information can then mitigate the problem created by capture (Dewatripont and Tirole, 1999).

cannot distinguish who produced the message: the firm or the regulator. With soft capture, the regulator saves on message production cost as it has to pay m only if the firm fails to transmit a message, with probability $(1-x)$.

Using the fact that $\mu - \hat{\mu} = x(\mu - 1/2)$, we can simplify equation (18) to

$$(\mu - 1/2)[\nu(\underline{w}_1 - \underline{w}_2) + (1-\nu)(\overline{w}_2 - \overline{w}_1)] \geq m. \tag{19}$$

From this equation, it is clear that the principal should set $\underline{w}_2 = \overline{w}_1 = 0$ and the wages $\underline{w}_1$ and $\overline{w}_2$ are given by the binding capture-proof constraint (19).[22]

In the following lemma, we compute the cost of preventing capture.

Lemma 6. *For a capture-proof contract, the expected payment to the regulator is equal to* $\tilde{w} = (\mu m)/(\mu - 1/2)$.

Lemma 6 shows that preventing capture is costly as the regulatory payment must be inflated above m. Notice that except for this extra cost, preventing collusion does not lead to any production inefficiencies. The welfare when the principal prevents capture is equal to $\tilde{W}(\mu) - \tilde{w}$.

Comparisons

The principal is put in front of three possible choices: tolerating capture giving a payoff of $\tilde{W}(\hat{\mu}) - m$; preventing capture giving a payoff of $\tilde{W}(\mu) - \tilde{w}$; abolishing the regulator giving a payoff of $W(1/2)$.

A comparison between preventing and tolerating capture can be expressed as follows. Tolerated capture dominates prevented capture if

$$\tilde{W}(\hat{\mu}) - m \geq \tilde{W}(\mu) - \tilde{w}, \tag{20}$$

or equivalently if

$$\tilde{w} - m \geq \tilde{W}(\mu) - \tilde{W}(\hat{\mu}). \tag{21}$$

The left-hand side of equation (21) can be understood as the cost of preventing capture (i.e., the extra regulatory wage that must be paid to prevent capture). This cost is decreasing in μ as $\partial\tilde{w}/\partial\mu < 0$. The right-hand side is the cost of soft capture (i.e., the welfare loss due to less informative signals). By Lemma 1, this cost is increasing and convex in μ.

We can thus state the following.

[22] Notice that the contract with the regulator is designed prior to the regulatory contract (q, t). As a result, commitment to the regulatory contract $(\underline{t}_i, \underline{q}_i; \overline{t}_i, \overline{q}_i)$ after observing σ_i might be a concern. By deviating slightly from the optimal second-best contract, the principal saves on the regulator's wage. Commitment to the optimal regulatory contract requires that the regulator specifies a sufficiently large wage for out-of-equilibrium values of $q \notin \{\underline{q}_1, \underline{q}_2, \overline{q}_1, \overline{q}_2\}$.

Lemma 7. *If $\tilde{W}(1) - m > \tilde{W}(1 - x/2)$, then there exists a $\tilde{\mu}_3 \in (0, 1)$, such that the principal prefers to tolerate capture for $\mu < \tilde{\mu}_3$ and to deter capture for $\mu \geq \tilde{\mu}_3$. If $\tilde{W}(1) - m \leq \tilde{W}(1 - x/2)$, then the principal will always tolerate capture.*

Combining all of our results, we can now characterize the tolerance for capture by the principal at equilibrium.

Proposition 1. *There exists a non-empty set of values for μ such that soft capture will be tolerated at equilibrium if $\tilde{\mu}_2 < 1$ and one of the following condition holds true: (a) $\tilde{W}(1) - m \leq \tilde{W}(1 - x/2)$, where soft capture is tolerated for $\mu \geq \tilde{\mu}_2$; (b) $\tilde{W}(1) - m > \tilde{W}(1 - x/2)$ and $\tilde{W}(1/2) > \tilde{W}(\tilde{\mu}_2) - \{\tilde{\mu}_2 m/[\tilde{\mu}_2 - (1/2)]\}$, where soft capture is tolerated for $\mu \in [\tilde{\mu}_2, \tilde{\mu}_3]$.*

As in Che (1995), the principal accepts that the regulator is softly captured by the firm in equilibrium when the cost of preventing capture exceeds the benefits of improved regulation. This happens when the informativeness of the signal under soft capture is high enough in absolute terms and relative to the accuracy of the regulator's own-produced signal. We summarize this point in the following corollary.

Corollary 1. *If the probability x of producing a noisy signal for the firm increases, then the parameter space in which soft capture is tolerated decreases.*

Unsurprisingly, if the firm more often produces a noisy signal and the regulator accepts it, the informativeness of the signal transmitted by the regulator decreases. Consequently, the payoff to the principal decreases if she tolerates soft capture. At the limit, if the firm produces the signal too often, $\tilde{\mu}_2$ will be higher than one and the principal will either prevent capture or dismiss the regulator. This prompts for an analysis of the determinants of x.

VI. Discussion

Endogenous Signal Quality

The mechanism of soft capture is based on the threat of having information produced (at some cost) by the regulator. Potentially hurt by this information, the firm is ready to preempt the regulator's information-gathering mission by offering noisy information as a gift.

So far in our model, we have considered the information production technologies of the regulator and the firm as exogenous. In this section, we discuss the possibilities of having an endogenous signal quality. From the firm's point of view, any information reduces the collected rent (Assumption 1). Consequently, the firm has no incentive to provide informative signals at all. Given the choice of x, which is the probability of sending a signal to the principal, the firm would then set $x = 1$. Here, the regulator would always receive a noisy message from the firm. If this message is invariably forwarded by the regulator, then we have $\hat{\mu} = 1/2$ and the resulting welfare is $\tilde{W}(1/2) - m$. This possibly leads to the collapse of the system as there is no need for the principal to appoint a regulator at cost m for receiving uninformative messages.[23]

Even when the regulator is no longer used as an information-gathering intermediate, he might be of use in other roles, such as a neutral enforcer of industry standards or as a barrier to entry in protectionist settings. We leave these options for further work as they would require a more elaborate market model.

As an alternative, the industry or the regulator might voluntarily limit the acceptance of industry input for regulation, and then keep the message sufficiently informative to justify an information-gathering intermediate. We discuss the two alternatives in turn.

First, increasing x might be costly for the firm or the industry. As we said, the parameter x depends on the industry characteristics: the number of firms, the existence of industry lobbying, the congruence of interests between industry participants, etc., and producing information for the regulator might be costly for the industry. Increasing x then brings both costs and benefits. The importance of soft capture might then be limited by the cost of producing information for the industry.

Second, the regulator might refrain from accepting the industry output, fearing dismissal if the messages are not sufficiently informative. Indeed, if the regulator transmits white noise, he is useless. Then, to maintain his reputation and his job, the regulator might limit the transmission of the

[23] However, the principal might have statutory interests in keeping a regulatory authority. An example here is the European Food Safety Agency (EFSA), which relies on unpaid experts to guide the regulatory information production, in spite of a budget of 78 million euros (2013). On May 8, 2012, the Chair of the Management Board of EFSA was asked to resign because of conflicts of interest; she had decided to take up a position in the International Life Sciences Institute, an organization founded by Coca-Cola, Heinz, Kraft, General Foods, and Procter & Gamble. The EFSA has established and maintains a heavy and expensive system for controlling conflicts of interest at the individual level (limiting corruption risks). Yet, the regulatory rule-making is largely inspired by industry input to the extent of demonstrated plagiarism in regulatory documents (Then and Bauer-Panskus, 2010, p. 9). It has been claimed that the regulatory policy largely coincides with the objectives of the industry that it is set to supervise (Horel, 2013). Reacting to the overt revolving door and mismanagement, the European Parliament postponed the discharge of the 2012 budget for six months, installed a two-year cooling-off period, and instructed the agency to review its internal organization (European Parliament, 2014).

firm's produced signals. This would be particularly true if the principal had the possibility of auditing the regulator periodically to investigate the source of information, and to penalize the regulator in the case of failure. External audit by the political principal or public accountability policies[24] can thus act as a disciplining device and can limit the internalization of the firm's information by the regulator.

These mechanisms can offset the incentives of the firm to flood the regulator with noisy information.

Monetary Bribes

We have shown that the possibility of soft capture inflates the compensation that the principal must pay to the regulator in order to benefit from his information-gathering expertise. Without the threat of capture, the expected payment to the regulator is $w = m$. Taking capture into account, the expected payment is $\tilde{w} > m$. This compensation represents a lower bound on the regulatory wage. Indeed, the firm might not only transmit information to the regulator; it might, in addition, offer a monetary bribe for reporting the signal it has produced. In this section, we calculate the cost of preventing collusion when both soft and traditional capture are considered together.

Whether the regulator discloses a signal or not is a verifiable outcome on which the payment to the regulator is made contingent. This mechanism assures the principal that the firm cannot pay the regulator for withholding information (Tirole, 1986). The principal observes the signal and her main concern is thus to prevent the transmission of noisy firm-produced information.

For the firm, we can compute the benefit of capture using equation (17):

$$\Delta\theta(\mu - 1/2)(\overline{q}_2 - \overline{q}_1) > 0. \tag{22}$$

The firm might be willing to share part of this benefit with the regulator in return for accepting the firm-produced signal. In this case, the firm and the regulator would be engaged in a side contract to act against the interests

[24] Implementations of public performance reviews that are not linked to monetary compensation schemes do exist in certain jurisdictions such as Australia (see, e.g., ITSR, 2014). In these reports, the regulator discloses details regarding the outcomes, procedures, staffing, projects, and priorities that permit an assessment of the functioning of the authority. Similar reviews can also be performed by independent organizations; see, for example, Renouf and Balgi (2013) on the enforcement performance of consumer protection regulators in Australia. Note, however, that the disclosure of quantitative indicators of enforcement or claims processing can provide a distorted image of regulatory performance because the substance of regulation, the rule-making, is less represented. Thus, although information disclosure can mitigate certain effects of capture, it does not eradicate the risk of soft capture.

of the principal. Let us assume that side contracting between the regulator and the firm is costly; we denote by $1-k \leq 1$ the transaction cost of side contracting. When the firm transmits \$1 to the regulator, the latter actually has \$$k$.[25] This transaction cost captures the fact that the legal reward paid by the principal to the regulator is not equivalent to the monetary bribe offered by the firm.

As only the firm of type $\underline{\theta}$ is ready to bribe the regulator, the probability of having a side contract is νx. When the principal designs the contract for the regulatory agency, she must take into account that, with probability νx, the regulator faces an efficient firm ready to bribe the regulator for not producing a signal and for accepting the one it has produced. Thus, for a collusion-proof contract, the principal must take into account that the highest bribe potentially received by the regulator is

$$B = \nu x k \Delta\theta \left(\mu - \frac{1}{2}\right)(\overline{q}_2 - \overline{q}_1). \tag{23}$$

In a capture-proof mechanism, the principal should take into account the opportunity cost of the bribe. For this reason, the cost of preventing both soft and hard capture is equal to $\tilde{w} + B$. The possibility of combining soft and hard capture further increases the cost of an information-gathering intermediate. Consequently, the parameter space where soft capture is tolerated is extended.

Biased versus Noisy Signals

The soft capture mechanism is based on the option for the firm to produce a piece of information that is less informative than the signal potentially produced by the regulator. In our model, we consider that the firm possibly sends a noisy but unbiased signal to the regulator: there is no systematic cost padding in the signal produced by the firm but rather additional noise compared to the regulator's signal production technology.[26]

Suppose that the firm produces a signal according to the following technology. The firm produces a signal with probability $x \leq 1$. Conditional on type $\theta = \overline{\theta}$, the probability of signal σ_2 is $\overline{\mu}$; conditional on type $\underline{\theta}$, the probability of signal σ_1 is $\underline{\mu}$. So far, we have considered that $\underline{\mu} = \overline{\mu} = (1/2)$ (i.e., signals are white noise). Signals would be biased if $\underline{\mu} < 1/2 < \overline{\mu}$.

[25] On the foundations of the transaction cost of side contracting, see Martimort (1999).

[26] Unbiased but noisy signals correspond, for instance, to complex cost assessment methods that are hard to interpret and use, or to technical regulation that is difficult to enforce. In case the regulator has access to all relevant data for a regulatory ruling, the transmission of additional contradictory but irrelevant data makes the regulator believe that the decision is based on uncertain data, thereby inducing a more cautious application.

With biased signals, the scope for capture is even higher as the rents collected by the efficient firm decrease in $\underline{\mu}$ (see equation (17)) and the inefficient firm always has a utility normalized to the reservation level. Soft capture is thus even more of a concern when signals are biased as the benefit of soft capture increases with the bias (i.e., the likelihood of sending the high-cost signal σ_2 conditional on a low-cost $\underline{\theta}$). Having said that, we can replicate our analysis and show that soft capture is tolerated at equilibrium if the bias is limited relative to the cost of monitoring. As a matter of fact, the condition for tolerating soft capture does not depend on a possible bias in the signal but on the information content of the signal relative to the cost of monitoring. Even biased signals must remain informative for soft capture to be considered as a possible outcome.

VII. Conclusions

Accepting the conjecture that capture indeed exists and influences public authority decision-making and economic regulation enforcement, the critical question is to find its intrinsic motivational functions in order to address it adequately. The existing body of literature is primarily based on the hypothesis that regulators are driven by private monetary opportunism in the sense of rent appropriation leading to remedies where collusive outcomes or bribes are thwarted by delegation of the social welfare objective to the regulator. Still, although economic regulation is omnipresent, both the precondition and the remedy are relatively rare in empirical work from the Western world. Although incidents of outright corruption of staff at regulatory agencies are reported, most agencies employ civil servants with origins and futures in public service, who are exercising only limited discretionary power and are subject to restrictions of due process and transparency. Still, many regulatory rulings, albeit motivated, are clearly biased in favor of the regulated entities. Our model offers one explanation to this apparent paradox by soft capture, where the firm acts as a co-producer of information for the regulator, without imposing any agreement on the sharing of benefits from the side of the firm nor commitment to use the information from the side of the regulator. The resulting outcome is soft in the sense that it is voluntary, quality-adjusted, and flexible to the type of information and the abilities of the regulator to produce equivalent information. Indeed, the political principal accepts this capture in equilibrium for the case where the information submitted by the firm is of sufficiently high quality not to justify further investments in independent information acquisition. In a context of stricter budget balancing for governmental agencies, of fiscal competition among firms and countries, and of pressures for technically detailed regulation in, for example, utility regulation, one can plausibly expect soft capture to be at work.

The findings in this work are not limited to the pure moral hazard setting for an effort-averse regulator. They can also be interpreted as an alternative explanation for the revolving door phenomenon in capture, based on the idea of “minimum squawk” (Leaver, 2009). Leaver (2009) finds evidence for correlation between the falling propensity of regulators to open rate-reviews in the case of observed cost decreases (i.e., rent extraction) and reductions in the term limits of the regulator (i.e., reappointment stress). The model in Leaver (2009) is based on a signaling behavior, where the regulator takes a risk to reveal its true type only through a tough decision as the firm would then threaten to announce (squawk) the quality of the decision. The empirical findings from US State Public Utility Commissions suggest that less able regulators set more generous price caps when terms are shorter and that firms earn higher rents when regulators serve short-term mandates. Comparing the squawk with the pre-decision signal in our model and the cost of information as a decreasing function of the time allocated, the outcome is consistent and confirms the intuition. The regulator, presented with convincing yet biased information on a given decision prior to undertaking an investment in information acquisition, might hypothesize that the firm will carefully scrutinize, oppose, and appeal any decision that is not consistent with the information provided. The cost of providing an information signal of the same or higher quality than that of the firm might be prohibitive in the short run, and the risk of subsequent failure might be high for the regulator if faced by a renewal or career decision. Thus, one interpretation might be that the information provision protects the regulator from two concerns: the political principal’s potential audit of the basis for the regulatory enforcement, and the firm’s legitimate review of the technical quality of the rulings to which it is subject.

Soft capture also provides an intuitive instrument for regulatory capture by public or inefficient firms characterized by low internal labor productivity, but potentially limited rent extraction for shareholders available for conventional bribery. An overstaffed public firm is a plausible producer of noisy information; it might also be able to use different channels (branches of government, other regulators, political parties, unions, etc.) in order to pass it to the regulator. The social cost of soft capture in terms of undetected inefficiency in public firms might, of course, be as detrimental as that resulting from excessive dividends paid to private shareholders in efficient firms.

Capture of regulatory agencies, or information-gathering intermediaries in general, is a composite phenomenon that empirically might be the result of a number of the explanatory factors proposed in the literature (monetary bribes, revolving doors, political reputation and prestige, etc.) in addition to, or in combination with, the relatively intuitive effort–resource motivation that we advance in this work. Consequently, further empirical work based on specific sectors, countries, and legislations might be necessary in order to derive reliable policy results that surpass the general guidelines found in contemporary work on good governance. However, anecdotal evidence suggests that the simple benchmarks related to regulatory endowments as a proxy of regulatory empowerment should be enriched with supplementary analyses of the actual decision-making basis used by the regulators.

Appendix

Complement to Section III

Using the definition of $\overline{q}_i$ in equation (11), we have

$$\frac{\partial \overline{q}_1}{\partial \mu} = \frac{\nu \Delta\theta}{S''(\overline{q}_1)(1-\nu)(1-\mu)^2} < 0, \tag{A1}$$

$$\frac{\partial \overline{q}_2}{\partial \mu} = -\frac{\nu \Delta\theta}{S''(\overline{q}_2)(1-\nu)\mu^2} > 0. \tag{A2}$$

Given that $\mu \geq 1/2$, a sufficient condition for Assumption 1 is

$$-\frac{\partial \overline{q}_1}{\partial \mu} \geq \frac{\partial \overline{q}_2}{\partial \mu}. \tag{A3}$$

This condition can be simplified to

$$\frac{\mu^2}{(1-\mu)^2} \geq \frac{S''(\overline{q}_1)}{S''(\overline{q}_2)}. \tag{A4}$$

Given that the left-hand side of equation (A4) is greater than 1 for all $\mu \in [(1/2), 1]$, this condition is always satisfied if $S''(\overline{q}_1) \leq S''(\overline{q}_2)$ or equivalently if $S''' \geq 0$ given that $\overline{q}_2 \geq \overline{q}_1$.

Proof of Lemma 1: Using the envelope theorem, implying that at the optimal contract $\partial \tilde{W}/\partial \underline{q}_i = 0$, a change in μ has the following impact on $\tilde{W}$:

$$\frac{\partial \tilde{W}(\mu)}{\partial \mu} = [S(\overline{q}_2) - \overline{\theta}\overline{q}_2] - [S(\overline{q}_1) - \overline{\theta}\overline{q}_1]. \tag{A5}$$

Given that the surplus $S(q) - \overline{\theta}q$ increases in q for all $q < S'^{-1}(\overline{\theta})$, this expression is positive as $\overline{q}_1 < \overline{q}_2 < S'^{-1}(\overline{\theta})$.

The second derivative of $\tilde{W}(\mu)$ is given by

$$\frac{\partial\partial \tilde{W}(\mu)}{\partial \mu^2} = [S'(\overline{q}_2) - \overline{\theta}]\frac{\partial \overline{q}_2}{\partial \mu} - [S'(\overline{q}_1) - \overline{\theta}]\frac{\partial \overline{q}_1}{\partial \mu}. \tag{A6}$$

Using equation (11), we can rewrite the above expression as

$$\frac{\partial\partial\tilde{W}(\mu)}{\partial\mu^2} = \left(\frac{\nu_2}{1-\nu_2}\overline{\theta}\right)\frac{\partial\overline{q}_2}{\partial\mu} - \left(\frac{\nu_1}{1-\nu_1}\overline{\theta}\right)\frac{\partial\overline{q}_1}{\partial\mu}, \tag{A7}$$

which is positive, demonstrating the convexity of $\tilde{W}(\mu)$. □

Proof of Lemma 3: For $x = 0$, the expressions for $\tilde{\nu}_i$ and ν_i, $i = 1, 2$ are equivalent by definition. For $x = 1$, the messages are totally noisy and the beliefs are equal to the priors, $\tilde{\nu}_i = \nu_i$, $i = 1, 2$.

The derivatives of $\tilde{\nu}_1$ and $\tilde{\nu}_2$ with respect to x are respectively negative and positive if $\mu > 1/2$:

$$\frac{\partial\tilde{\nu}_1(x)}{\partial x} = \frac{2\nu(1-\nu)(1-2\mu)}{\{\nu[(x/2)+(1-x)\mu]+(1-\nu)[(x/2)+(1-x)(1-\mu)]\}^2},$$

$$\frac{\partial\tilde{\nu}_2(x)}{\partial x} = \frac{-2\nu(1-\nu)(1-2\mu)}{\{\nu[(x/2)+(1-x)(1-\mu)]+(1-\nu)[(x/2)+(1-x)\mu]\}^2}.$$

□

Proof of Lemma 4: In the soft capture case, we have $Prob(\sigma_1|\theta = \underline{\theta}) = Prob(\sigma_2|\theta = \overline{\theta}) = \hat{\mu} = x/2 + (1-x)\mu$. The posterior beliefs of the principal are given by $\tilde{\nu}_1$ and $\tilde{\nu}_2$, or equivalently by the beliefs ν_1 and ν_2, defined in equations (4) and (5), where we replace μ by $\hat{\mu}$.

Given this, the optimal contract when there is soft capture is given by equations (10)–(13), replacing μ by $\hat{\mu}$, and the welfare is given by $\tilde{W}(\hat{\mu})$. □

Proof of Lemma 6: From equation (19), we have

$$\nu\underline{w}_1 + (1-\nu)\overline{w}_2 = \frac{m}{\mu-(1/2)}. \tag{A8}$$

The expected payment to the regulator is equal to

$$\mu[\nu\underline{w}_1 + (1-\nu)\overline{w}_2]. \tag{A9}$$

Combining the two equations, we prove the lemma. □

Proof of Lemma 7: Given that $\tilde{w} - m$ is decreasing and μ and $\tilde{W}(\mu) - \tilde{W}(\hat{\mu})$ is increasing in μ, the equation $\tilde{w} - m = \tilde{W}(\mu) - \tilde{W}(\hat{\mu})$ has at most one solution. Given this, for $\mu \to 1/2$, $\tilde{W}(\mu) \to \tilde{W}(\hat{\mu})$ and $\tilde{w} \to \infty$, the solution is necessarily above 1/2. The condition in the lemma is the condition for having $\tilde{\mu}_2 < 1$; that is, $\tilde{W}(\mu) - \tilde{W}(\hat{\mu}) \geq \tilde{w} - m$ evaluated at $\mu = 1$. □

Proof of Proposition 1: By Lemma 5, $\tilde{\mu}_2 < 1$ is a necessary condition to have tolerated soft capture at equilibrium. (a) If $\tilde{W}(1) - m \leq \tilde{W}(1 - x/2)$, then capture will never be prevented (Lemma 7) and tolerated capture is optimal for $\mu \geq \tilde{\mu}_2$. (b) If $\tilde{W}(1) - m > \tilde{W}(1 - x/2)$, there exists $\tilde{\mu}_3 < 1$ such that capture will be prevented for $\mu > \tilde{\mu}_3$. The condition $\tilde{W}(1/2) > \tilde{W}(\tilde{\mu}_2) - (\tilde{\mu}_2 m)/(\tilde{\mu}_2 - 1/2)$ is the condition to have $\tilde{\mu}_2 < \tilde{\mu}_3$, in which case tolerated capture is optimal for $\mu \in [\tilde{\mu}_2, \tilde{\mu}_3]$. □

Proof of Corollary 1: It is immediate to show that $\tilde{\mu}_2$ increases with x while $\tilde{\mu}_3$ decreases with x. Then, the parameter space for which capture is tolerated necessarily decreases with x. □

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