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Soft regulatory capture: dynamic auditing and other extensions

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Abstract

This master's thesis shows the implications of some extensions to the soft capture model developed by Agrell and Gautier (2017). The base model gives an alternative to classical regulatory capture, in which capture is self-enforcing, getting rid of a flaw that traditional capture theory possesses. This promising theory however lacks the extensions that have been brought to traditional capture models over the years. The extensions presented in this master's thesis are the possibility of a shutdown, capture aversion by the regulator, special interests for the principal, ex-post auditing and a dynamic setting. Through mathematical analysis, it is shown that each change in assumption has a distinct impact on social welfare and on the conditions under which soft capture is tolerated.

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1. Introduction

This master's thesis aims to provide an extension to the soft capture model proposed by Agrell and Gautier (2017). Their paper proposes an alternative to traditional capture models by considering an equilibrium where capture between a regulator and a regulated firm is self-enforcing, removing the need of a side contract that had been present in many of the field's most prominent works (see for example Tirole, 1986; Laffont & Martimort, 2009). When using an explicit side contract, which is typically the case in the literature when information is hard, the assumption must be made that this contract is enforceable even though it has no legal basis. The soft capture model considers the case in which information is soft, meaning that the firm can produce information itself which the regulator then transmits, rather than bribing the regulator after a successful audit (Agrell & Gautier, 2012a).

We will reuse Agrell and Gautier's terminology of a three-layer hierarchy, constituted of a political principal (sometimes also called government, legislator or Congress in the literature, as in Laffont & Tirole, 1991; Hiriart & Martimort, 2012 among others), denoted "she", a regulator/regulatory agency, denoted "he", and an agent. Said agent can be a regulated firm or an industry. Figure 1 illustrates the three-layer hierarchy and the difference between soft capture and traditional regulatory capture. In sections 3.3 and 3.4, we will discuss the possibility to extend the model and

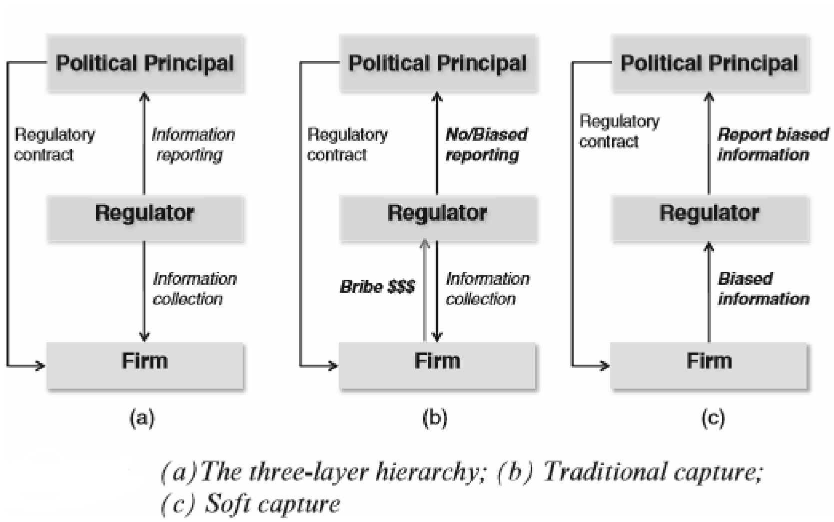

Figure 1. Three-layer hierarchy and difference between soft and traditional capture
Source: Agrell and Gautier, 2012a, p. 286

its results for players with other characteristics than those presented in Agrell and Gautier's (2017) model.

Soft regulatory capture is proposed by Agrell and Gautier (2017) as an alternative to the classical capture approach. Indeed, evidence of bribery is relatively scarce and does not lead to the conclusion that explicit side contracts are widespread. Models such as the one proposed by Berg, Jiang and Lin (2012) detect a correlation between regulatory disfunction and a country's level of corruption, but do not allow to conclude that there is a direct link of causality. The revolving door principle suffers from the same lack of empirical backing (see Makkai & Braithwaite, 1992). Agrell and Gautier (2012a) note that the results obtained through the soft capture model can be thought of as an alternative to the revolving door theory, compatible with the minimal squawk theory as presented in Leaver (2009). Both concepts are further developed in section 2.

Regulation is prominent in today's economy and particularly so when dealing with a firm in a position of power, such as a monopolist. The latter is often used to characterize the regulated firm, for mathematical simplification purposes (see Laffont & Martimort, 2009). Another reason to consider monopolists is that, as argued by Majone (1994), natural monopolies exist in most European countries for services like electricity, gas or water, to protect consumers and therefore inherently call for strong regulatory measures. Similarly, Demski and Sappington (1987) reuse the classical economics result that monopolies allow for minimal cost through increasing technological returns to state that monopolies can therefore be in the best interest of consumers if they are sufficiently regulated. The associated problem is that Guesnerie and Laffont (1984) note an important difference between the theory and practical experience when considering the planning of firms with legal public status. Imperfect information on the part of the planner and unaligned objectives for the firm lead to suboptimal control by the government and thus calls for tighter regulation.

In particular for the European Union, the rise as the regulatory state is a consequence of the European Commission's attempts to extend its influence over policy content and the member states' involvement in policy responses to issues linked with the European Single Market (Lodge, 2008). According to Lodge, the regulatory issues in the European Union highlight the importance of supranational regulation sources. It can be noted that one of the main areas in which the

European Commission is active is in fact the protection of consumers against the abuse of a dominant position. The general process, as described by Garside, Grout and Zalewska (2009), consists of the definition of a market, the detection of a dominant position and the assessment of whether this position was abused or not. This last stage in particular includes the creation of regulatory models, data collection and interpretation by experts and it is therefore particularly important when considering the impact of having a regulator in the middle of the hierarchy.

However, natural monopolies are not the only case in which regulation is necessary. Dal Bó (2006) argues that other economic activities also call for state intervention, such as price fixing or entry control, building on Stigler (1971). Stigler, who pioneered the concept of regulatory capture, depicts politicians as suppliers of regulation when the situation requires it. Stigler's approach focuses on the size and interest of regulatory stakeholders, which is the reason why it is also sometimes called interest group theory. This theory is also advocated by Shapiro (2012), who argues that groups with a more intense interest in regulation will be in a better position to pressure officials for favorable regulation than the public at large. Posner (1974) adds the element of coordination for these groups, which will typically be easier for smaller groups and thus balances Stigler's size argument. Becker (1983) proposes on the other hand that groups that benefit from certain policies tend to be smaller than the groups paying the cost of these policies, even though he acknowledges that a bigger size may create desirable effects. Tirole (1992) draws the conclusion that the power of an interest group depends on its stake on its organization cost, similarly to Posner's coordination component. However, Stigler's view of a political principal who looks to maximize her personal power (through money and votes) differs from the theory that emerged from his pioneering article. Regulatory capture models are indeed often built on the assumption that the principal is benevolent and welfare maximizing. A similar view to Stigler's of the principal's interest is provided by Peltzman (1976). In his model, the principal maximizes her political power by trading between political power among consumers and among producers. Consumers (also called voters in his article), while larger in numbers, have a weaker incentive than producers to spend resources to acquire information about regulation. This leads to an equilibrium in which both parties are imperfectly protected by regulation. While Agrell and Gautier's (2017) model follows the route of a benevolent principal, we adapt it to reflect the idea of personal interests of the political principal in section 3.4.

Regulatory capture played an important role in key economic events, such as the 2008 financial crisis (Shapiro, 2012). With the growing importance of state intervention, the subject remains essential and imperfectly explained. We expect that this will hold only truer in the near future, with the COVID-19 crisis, that drives the state and regulatory agencies to be even more implicated in numerous economic sectors (Gentilini et al., 2020). We argue that the respect of regulations, such as sanitary measures, will play a key role in many activities. And state agencies whose mission is to assure the safety of the workforce have been showed to be potentially captured by Agrell and Gautier (2012a).

Another application of soft capture comes from the shift from heavy bureaucratic rules to incentives schemes, as part of a privatization process of industries formerly owned and directly managed by the state (Majone, 1994). Information therefore becomes crucial to regulate these new players and the term "regulation by information" expresses the idea that information itself can constitute policy by indirectly changing behaviors through adequate incentives (Majone, 1997). Another, more general, shift in regulation is described by Levi-Faur (2013) as a change in the cause of the state's authority. The authority that was once due to the monopoly over the use of coercion is nowadays more based on the monopoly over rule-making and its enforcement by a more decentralized power (see also Deller & Vantaggiato, 2014, for a similar argument). This decentralization makes the regulatory state more reliant on indirect control and self-regulation through incentives schemes, echoing Majone's (1997) proposition. Levi-Faur (2013, p.37) also notes that regulation is "emerging as a distinct professional and administrative function". This means that relationships among the players of the regulatory hierarchy are getting more formal, based on contracts and sets of rules.

This leads us to offer an extension to Agrell and Gautier's (2017) soft capture model, to better explain the regulatory capture phenomenon. In section 2, we revisit the literature associated to regulatory capture. In particular, we consider some of the classical alternative explanations of capture, specifically classical capture with side transfers, minimal squawk and the revolving doors theory. We also look at different extensions provided along the years to the classical regulatory model and discuss their application to soft capture. Additionally, we consider some expected results and effects on regulatory outcome from variables such as the regulator's term length in order to have a base of comparison with the results obtained in section 3. In this third section, we reuse Agrell and Gautier’s model as a benchmark. We then develop different extensions by challenging some of the assumptions made in the base model and derive the effects that these changes have. The results are summarized in section 4, along with their practical implications and two illustrative examples of soft capture, provided by Agrell and Gautier (2012a; 2012b). We conclude in section 5, considering there the limitations of the model presented in section 3 and giving suggestions for future research in the field.

2. Literature review

2.1. Classical regulatory capture

Regulation refers to the control by a public agency over socially valued activities (Selznick, 1985). Regulation typically requires advanced knowledge and involvement with the regulated activity, therefore creating the requirement for specialized agencies (Majone, 1994). Regulatory capture is defined as the mechanism through which the regulated agent manages to control the regulatory agency that is supposed to control him (Dal Bó, 2006). A similar definition is given by Shapiro (2012) and Rex (2018), who insist on the exercise of power over policymaking by the regulated agent. This result had already been predicted by different papers in the 1970s, such as those written by Stigler (1971), Posner (1974) or Peltzman (1976). These early models focus on the obtention of political power for the principal, leading to a favorable outcome for "politically effective groups" (Posner, 1974). Stigler goes even further when addressing the problems of the regulatory system, arguing that the state is used as a tool by special interest groups to consolidate a dominating position and is therefore not instituted to protect the public. This view of the government power as a source of advantage for special interest groups has been further developed by Levine and Forrence (1990). They define capture as regulatory theories based on private motivation and dominated by private interest.

Typical regulatory tools, such as entry control, are the same as the ones used for cartelization (Posner, 1974). Posner also suggests that there is a link between the (lack of) feasibility of private cartelization in a certain economic area and the amount of protective legislation. This is also the conclusion to which Barke and Riker (1982) come, adding that regulation is used within a dominant economic sector to secure its sustainability (by harmonizing costs among the members of an alliance, for example). In a more general setting, other stakeholders may also induce capture (Peltzman, 1976) and the principal may even use this competition to improve the quality of information (Becker, 1983). This is the basis on which the special interest groups theory is built. The application to regulatory capture is considered in section 2.4.

Another important concept is hidden gaming, which is defined by Laffont (1990, p. 302) as "the ability that some players may have to design and play games with other members of the hierarchy that are not observable by the principal". Collusion between the regulator and the agent in the soft capture model is a textbook example of hidden gaming. This means that when creating an incentive structure, the principal must create one such that it will deter hidden games that would otherwise be profitable. Laffont considers this idea of hidden gaming as an extension of the traditional moral hazard theory, which states that agents who do not bear full responsibility have less incentives to avoid risk (see for example Balafoutas, Kerschbamer & Sutter, 2017). Indeed, moral hazard analysis is prominent in the field of contracting with imperfect information (Holmström, 1999). For example, when labor or effort cannot be observed by the principal, the use of a proxy such as output will induce some risk into the contract since the output may also depend on some exogeneous factor.

It should be noted that the very idea of regulatory capture is based on information asymmetry (Laffont & Tirole, 1991), just as interest groups come from imperfect information (Tirole, 1992). When considering a regulator whose objectives are not perfectly aligned with those of the principal (as depicted in Maskin & Riley, 1984, for example), the adverse selection issue is what leads to possible collaboration between the agent and the regulator without the principal being able to easily detect and prevent it. The fact that objectives are not aligned is key for capture to happen. If they were to be identical for the principal and the regulator, any action taken by the regulator to improve his personal condition would consequently benefit the principal. As a matter of fact, the three-layer hierarchy with a regulator perfectly aligned with the principal amounts to the same as a classical principal-agent problem without any room for capture. Perfect information also eliminates any concern over independence, as the principal could simply add a clause with heavy punishment for shirking that would compel the regulator to conduct his task without any possible capture, since the principal would immediately detect collusion (Antle, 1984).

It is easy to imagine why a regulator would not be perfectly aligned with the political principal, as the former typically gives more importance to his own monetary compensation, professional career perspective, or reputation (Demski & Sappington, 1987). In fact, Levine and Forrence (1990) describe regulatory actor’s goals as narrow and self-interested. This is reflected in the soft capture model, as the principal is motivated by social welfare while the regulator maximizes his own net renumeration. A more general view is provided by Alesina and Tabellini (2007). The question in their work is to whom the different players are accountable and how this influences their motivations. The political principal is held accountable by voters and will therefore give more value to social welfare, while the regulator is accountable to other members of the economic area in which he is active, which means that he is driven by career perspectives in the public or private sector (see also Wilson, 2019). Hilton (1972) also notes that the regulatory system on its own does not give regulator strong incentives to maximize social welfare as their mission is often relatively vague. Unaligned objectives can also typically be observed between different levels of authority. For example, the European Union's perspective on how to deal with a specific industry may very well differ from the perspective of a member state where this industry is particularly important, as seen with the recent state aids due to the coronavirus crisis (see Posaner & Larger, 2020, for the example of Lufthansa in Germany).

Legislators generally do not possess the skills and time necessary to obtain the information required for a particular decision and therefore turn to regulators, who can devote their professional attention to the task and whose expertise allows them to extract more information than the principal could (Barke & Riker, 1982). Weitzman (1978) notes that there would be no need for regulators if the desired information can be known exactly before conducting an investigation. Not only that, but it is generally difficult and expensive to characterize a cost parameter for example, which is essential in common regulations, such as price-cap regulation (see for example Grifell-Tatjé & Knox Lovell, 2003; Deller & Vantaggiato, 2014). This kind of regulation mechanisms are the most popular on the global scale due to their simplicity when compared to cost-of-service regulation (Joskow, 2014). The complexity of information gathering and implementation associated to even simple mechanisms therefore requires extensive structures, such as incentive schemes (see Joskow, 2014, for a discussion regarding the case of the electricity distribution market).

Pierre and de Fine Licht (2019) note that providing high-quality information requires a close relationship with the auditee to have a better understanding of his situation. This follows the idea that was already presented by Williamson (1985) that intra firm auditing is more effective than extra firm auditing. This motivates the hypothesis presented in section 3.5 that external auditing cannot provide better information of a firm's cost parameter. This relationship gives the opportunity to the parties to engage in hidden gaming as defined by Laffont (1990). Albino et al. (2013) indeed state that communication between the regulator and the agent is required for capture to happen, as conditions and agreements cannot be conveyed otherwise. The idea is that without interaction, each player will act in his own best interest and that no party has an incentive to obtain the other's favors through favoritism or bribes for example. While this condition is not as important for soft capture, communication is still required if the firm wants to provide the regulator with a homemade signal. Furthermore, regulators are sometimes dependent on the regulated industry for data and expertise regarding complex policies for which autonomous sources may be hard to establish (McCarty, 2013). This dependence on industry information from actors of the industry itself can lead to so-called "information capture" (Shapiro, 2012) in addition to classical regulatory capture.

The need for interaction with the agent to obtain high-quality information is particularly relevant when there is a substantial change in information available to the regulator and/or the firm (Baron & Besanko, 1984b). This can be expected to be the case amid the global COVID-19 pandemic. Fiorina (1989) argues that another reason for which delegation is preferred by legislators is the ability to avoid responsibility for cost of regulation and simultaneously claim credit for its benefits. This argument is also used by Levine and Forrence (1990) and they stipulate that this distancing by the political principal creates slack for the regulator, which shields him from direct accountability to the principal. Epstein and O'Halloran (1999) demonstrate that discretionary power delegation in regulation is linked with the uncertainty of the regulatory environment, which corroborates the intuition that delegation will take place when information is difficult to obtain. Dewatripont, Jewitt, and Tirole (1999a) show that agencies run by professionals may achieve better performance, even when taking adverse selection into consideration. It should be noted that the principal remains the owner of the structure and therefore chooses how to use the information extracted by the regulator, meaning that some findings from theories related to advisors can be applied to regulators (Calvert, 1985).

Even if information could theoretically be directly and easily be obtained by the legislator in a cooperative setting, it is in the agent's best interest to keep his private information for himself so as to obtain an information rent (Sobel, 2013). In a three-layer hierarchy, the regulator may also use his position to block information leakage from interest groups to the principal to strengthen his own position and value. It is therefore also in the regulator's best interest to maintain the information asymmetry between the legislator and the regulated firm if he wants to continue to be used (Lee, 2013). One way for the agent to make information harder to obtain and interpret is to shift costs from one project to another in cases where a particular regulation only matters for a specific part of the projects of the firm (Laffont & Tirole, 1986). This situation can often be observed in practice, as companies in dominant position are more likely to be regulated and, for private firms in particular, those players tend to have a multitude of different projects.

Levine and Forrence (1990) divide policies in two categories: general-interest policies and special-interest policies. The first would be adopted by a benevolent legislator with perfect information while the second would only be adopted by a self-interested group if information were perfect. Therefore, there must be a gap in information for special-interest policies to be adopted by a principal who has no personal interest in them. Consequently, an important research question is to determine how to limit regulatory capture when it is observed that special-interest policies are adopted by benevolent legislators. The principal must indeed create a framework, including incentive structures, to deter collusion between the regulator and the agent. Estache and Wren-Lewis (2011) note two categories: policies that aim at limiting the power of interest groups that try to capture regulators and those that reduce the regulator's ability to exploit the information asymmetry with the principal. Regulatory capture has been argued to be at the source of the conflict between different tiers of government (Laffont & Tirole, 1993) and one proposition to solve this conflict is to make policies less sensitive to the regulator's private information (Hiriart & Martimort, 2012).

Information manipulation that can be achieved by an agreement between the agent and the regulator, be it explicit or not, would for example be to not report part of the information. Tirole (1986) also suggests that the regulator may not acquire the information to begin with if it were difficult to dispose of it. This argument actually works better when considering soft capture than traditional regulatory capture. Indeed, the regulator does not need to dispose of any information in the soft capture model since he never acquires it to begin with. In opposition to traditional capture models, which consider that the regulator first acquires the information and may choose afterwards not to transmit it to the principal if he colludes with the agent.

From Wilson's (2019) survey of US Government agencies, three main differences can be observed for public agencies when compared with their private counterparts: a more limited role for financial incentives (which in turn increases the importance of career prospects), a larger number of different objectives and less discretionary power. The first point in particular gives an explanation as to why professionals with exterior career concerns are replaced by bureaucrats. Indeed, if their career concerns are internal and prevalent given the lack of financial incentives, this can be used to create a sense of mission for the agency (Dewatripont, Jewitt, and Tirole, 1999b).

Another issue for the legislator could be a bias of one of the parties (an advisor, to reuse the literature's nomenclature). Even if the regulator is not captured by the industry, he could have a different vision of what is socially desirable than the principal. Indeed, Levine and Forrence (1990) describe the public interest that is often used when the principal is considered benevolent as derived from individual preferences about what is socially desirable. This includes an ideology about how the government should behave towards the public at large or some specific group. Calvert (1985) shows that a decision-maker prefers to use a biased advisor over an unbiased one if there is an effort component in the regulatory process. The idea behind this is that the principal will extract more information from the regulator's effort than what he will lose through his bias. Furthermore, the bias can be partially considered when using the information, due to the assumption that biases are known beforehand. In Che and Kartik's (2009) model, a biased advisor withholds information that contradicts his opinion. The principal therefore only follows an advice when it is supported by hard evidence. The results demonstrate that an initially ignorant principal will always obtain more information through a biased advisor than an unbiased one, no matter how large the bias is, because the biased advisor exerts more effort. Dewatripont and Tirole (1999) also argue in favor of advocates, by pointing out that their rewards track their performance more closely than their non-partisan counterparts. The authors also suggest that advocacy by interest groups with different objectives can create incentives for a party to appeal an abusive decision that has been made to favor another interest group. The application of this theory to the soft capture model is however beyond the scope of this thesis but may constitute a basis for further research.

2.2. Minimal squawk

The minimal squawk theory refers to the idea that regulators want to maximize their skills' perception by minimizing the mistakes that are brought to the attention of the public. This is particularly true when the regulatory structure is such that regulators must worry about future employment (Hilton, 1972). To do so, they try to keep interest groups quiet since they are the one squawking about mistakes that harm them (Leaver, 2009). Indeed, interest groups have no interest to squawk when a mistake favors them and this can help explain a pro-industry bias by regulators.

This offers an alternative to the motivation of the regulator offered by Stigler (1971) of wealth maximization through side contracts and by Niskanen (1999) of power maximization for the regulator's current position. The minimal squawk theory is therefore based on the regulator's future career perspectives. A common characteristic with soft capture is that minimal squawk does not require a side contract to produce an equilibrium. It removes the idea of explicit corruption and focuses instead on the regulator's personal concerns when facing uncertainty. This feature makes minimal squawk findings more compatible with those obtained through the soft capture model.

A similar approach is proposed by Dal Bó, Dal Bó and Di Tella (2006). The authors do not restrict the space of possible actions by interest groups to squawking but also allow the use of physical violence, legal harassment or smear campaigns. In opposition to the minimal squawk theory, the regulator does not need to be mistaken when drawing conclusions that disadvantage the firm to face negative consequences. The result at which Dal Bó et al. arrive is that the possibility of threats decreases the cost for the agent to capture the regulator, which in turn reduces his payoff. And lower wages mean that it is more difficult to attract quality experts for regulatory positions, resulting in regulators that have a lower skill level and are easier to capture. A suggested solution to reduce this effect is to provide officials with legal immunity. Dal Bó et al. however note that this option only makes sense when the judiciary system is relatively inefficient. The tradeoff between regulatory wage and ease of capture is also present for soft capture, as shown in section 4.3.

Regarding the minimal squawk theory, Leaver (2009) offers an extension that considers the professional capabilities of the regulator. In short, less skilled regulators fear that the firm will squawk when they commit a mistake that puts the firm at a disadvantage. Since this is not the case when the mistake benefits the firm (as it has no reason to squawk in this scenario), less able regulators will tend to be generous with the firm to preserve their reputation. The idea of different levels of aptitude among the regulators could also be the basis for another extension of the soft capture model. A similar approach to Leaver's is provided by Hakenes and Schnabel (2013), who consider the complexity of the regulation instead of the ability of the regulator. Even though the reason for which it is more difficult to obtain good information changes, the result remains the same. When regulatory approaches are more sophisticated, regulatory decisions tend to be worse (see also Poulain, 2018, for a discussion). Therefore, the authors suggest that it may be preferable to use less sophisticated regulation regimes.

2.3. Revolving doors

Another alternative model to capture with side transfers is the revolving door theory. In a similar fashion to the minimal squawk, regulators act more favorably towards the industry in the hope of future employment. As many regulators come from the regulated industry, they may seek to return to the industry (be it only because they are well informed about it), hence the name revolving doors. Consequently, regulators try to maintain beneficial relationships with the agent (for empirical data regarding the career path of regulators, see Eckert, 1981). This is the rationale behind some legislations that restrict future employment for public servants (following the argument given by Spiller, 1990). It should however be noted that Eckert's research does not allow to draw the conclusion that regulators with previous experience in the professional industry have a higher probability to return to it. A problem of the revolving doors theory is indeed that it is strongly based on intuition and does not have strong empirical backing (Makkai & Braithwaite, 1992).

Guerriero (2011) argues that the revolving door principal can explain regulatory capture, stating that appointed officials are driven by career interests and, through the revolving doors principle, this leads them to maximize their talent's perception by the society, in particular the industry with which they have a stronger connection. Another effect of the regulator's background is proposed by Kwak (2014): even without explicitly considering his own career perspectives, a regulator with experience in the industry may participate in social networks that include the agent or identify as belonging to the same group as him.

2.4. Extensions of regulatory capture models

In this section, we consider different models that have been created to refine the traditional regulatory capture approach. The objective is to determine whether they can be applied to soft capture and to discuss their implementation in this master's thesis or in future research. Regulatory capture has indeed benefitted from decades of contributions and it only makes sense to use these to strengthen the soft capture model.

Some models (as in Laffont & Tirole, 1986) consider the effort of the agent to obtain a certain state of productivity. In other words, the cost or efficiency parameter is no longer exogeneous but influenced by the agent's effort. This can be thought of as the agent engaging in research and development to obtain a better technology (as proposed by Baron and Besanko, 1984b). Effort adds a layer of complexity to the model, as the principal now also needs to consider the optimal achievable effort level of the agent in her incentive scheme. It also provides an explanation regarding the choice of an estimated cost parameter rather than aggregated ex-post realized costs of the firm, since using ex-post costs discourages effort to reduce these costs (Joskow, 2014). Furthermore, it opens the possibility for the regulator to deliberately misrepresent the agent's effort level, as everything that reflects poorly on the agent reflects beneficially on the regulator (Tirole, 1986). Adapting this theory to the soft capture model goes beyond the scope of this thesis but could be considered for further development of the theory. The general idea predicted by Dewatripont et al. (1999b) is that experts with a narrower set of tasks will have more incentives to increase their effort when compared with agents that are pursuing a number of tasks at the same time. Even though in practice, the statistics obtained by Glachant et al. (2013) show that regulators tend to have multiple objectives.

Another opening for research regards the regulator's preferences. Tirole's (1986) work analyzes the impact of the regulator's risk aversion on the regulatory outcome. The intuitive effect of risk aversion is that large incentives component in a regulator's contract may dissuade a risk averse regulator from participating in the regulatory game (see Henderson & Tung, 2012 for a discussion). This inclusion of risk aversion in the soft capture model is therefore also a possibility for future research.

While considering the regulator's preferences, an interesting argument regarding the degree of honesty of the regulator is provided by Becker and Stigler (1974). They argue that the behavior of an individual regarding a bribe can be determined with a thorough and expensive investigation. While there is no empirical evidence to our knowledge showing the possibility to decern between different regulators' honesty levels based on some investment by the principal, the case where the regulator has some aversion to capture can be considered. In the case of explicit side contracts, as used by Becker and Stigler, this aversion can simply be represented by the inefficiency parameter of the side contract (as in Tirole, 1986). In the case of soft capture where there is no explicit side contract, it can be assumed that the regulator loses a certain utility when he is captured. This can be thought of as the unease that may affect a regulator who is not carrying out his task as expected by the principal. This point will be further addressed in section 3.3.

A common proposal in the literature is the creation of consumer advocate groups that compete with the regulated industry over influence (see for example Dal Bó, 2006). Becker (1985) advocates that this kind of competition should correct market failures as efficient policies are more likely to win said competition. The idea is that efficient policies will create more incentives for favorably affected groups to lobby for them than it creates incentives for unfavorably affected groups to lobby against. Becker however notes that this does not hold true when there is unequal access to political influence. Laffont and Tirole (1991) show that an interest group has more influence when its goal is to make regulation inefficient. The unintuitive result obtained through their model is that having a concurrent interest group compete to capture the regulator (the authors speak of environmentalists competing against a polluting firm) actually increases the firm's rent. The reasoning is that both groups want the principal to be uninformed, even though it is for different reasons (the environmentalists want the legislator to be uninformed to reduce pollution through a lower output). Laffont and Tirole note that the interest group being hurt by its own power is similar to a player losing from having more options in game theory. Tirole (1992) reuses this argument to state that an agent has power when his goal is different from the organization's, i.e. when it is in his best interest to have a poorly informed principal. Competing agents at the basis of the three-layer hierarchy is therefore an interesting extension of the soft capture model that could be considered for future research.

The idea to allow different interest groups to compete is also present in other parts of the capture literature, such as the minimal squawk theory. Leaver (2009) suggests giving more political influence to "squawkers" with different interests than those of the regulated firm to combat the pro-industry bias predicted by the minimal squawk theory. On a general note, interests group have more incentives to be active when more economic power is tied to the state (Becker, 1983). We argue that this should induce more pressure by these groups during the COVID-19 crisis as economic relief measures put in place by the government will greatly affect many industries (see Loayza & Pennings, 2020) and thus generate this kind of incentives.

Another recurring idea in the traditional capture literature is the use of more than one regulator to reduce his ability to conceal information (Estache & Wren-Lewis, 2011). When separation between nonbenevolent regulators is feasible, the reduction in discretion may protect the principal against regulatory capture (Laffont & Martimort, 1999). Separation means in this case that the different regulators obtain information about a specific aspect of the firm and do not have access to the information of their peers. It should however be noted that when separation is not feasible (as in the soft capture model of section 3), the possibility of collusion between regulators makes the measure inefficient and makes it ultimately boil down to a duplication of costs for the principal.

Capture in a three-layer hierarchy setting is generally applied to the case of public servants and policy making. However, it could also be applied to different configurations. For example, Tirole (1986) makes the point that the theory should be applicable to the military or education in the same manner as it is applied to the regulatory structure. An interesting managerial application would for example be procurement in which the principal is a private firm. Laffont and Tirole (1986) predict that regulatory capture theory is applicable to this kind of setting, meaning that the assumption of social welfare maximization is relaxed. Indeed, the important common feature is that monetary transfers to the agent due to his information rent decrease the principal's utility function (see also Laffont & Martimort, 1999). An example would be Laffont and Martimort's (1998) model of a firm's top manager (the principal) who deals with internal input suppliers (the agent). It should however be noted that results from a single agent model may not hold true when dealing with multiple agents (Baiman, 1982). A similar model is provided by Laffont (1990), in which the middleman in the three-layer hierarchy is a supervisor in a private firm setting. Henderson and Tung (2012) also state that this kind of incentive issues can be generalized to other cases as long as there is a tradeoff between a design of internal metrics and a need for objective external metrics.

Armstrong and Sappington (2007) propose a model where the principal's utility function depends on both the social welfare and the firm's surplus. It can be thought of as the interest of politicians to keep the industry and the public at large happy for future elections, following Stigler's political approach. This idea of a non-benevolent principal is reused in section 3.4.

A tool at the disposal of the principal may also be a shutdown policy (as proposed by Laffont & Tirole, 1991). If the regulated firm is not essential to society, the legislator may find beneficial to choose the shutdown over contracting with an inefficient firm. A practical example of an industry shutdown by the government can be observed in pollution regulation (see Chen et al., 2018, for the example of shutdowns by local Chinese governments). This will be touched upon in section 3.2.

Ex-post audit is another tool that the government can use to deter collusion. The idea is that the principal can commission a costly audit of the regulator's report and determine if he has misrepresented the firm's private information (Dal Bó, 2006). The assumption is that there is no error made by the external auditor and that his independence and short-term contract shield him from capture pressure. In the case of an audit that shows that the regulator did not exercise his mission as stipulated, the principal can then take actions against him (such as fines or loss of employment). This builds on the literature of corruption control, such as the empirical contribution of Ades and Di Tella (1997). In the case of bribery, legal actions can be taken against both the regulator and the agent, this can be thought as a refund to consumers (see Baron & Besanko, 1984a). The ex-post audit option does not need to contradict the fact that the information is soft. In the application to soft capture, we assume that the external auditor used by the principal can merely detect if the regulator fulfilled his mission, as in Kofman and Lawarrée (1993). As opposed to providing different information that allows for fact checking (as proposed by Sobel, 2013). However, Kofman and Lawarrée's results cannot be transposed directly to the soft capture model as these results only hold when the option to use the regulator (internal auditor in their paper) is free. An adaptation to soft capture is presented in section 3.5.

Regarding the option for the legislator to impose sanctions on both the regulator and the firm (such as a refund to consumers), Baron and Besanko (1984a) show the principal will always inflict the maximum punishment when applicable. The analysis therefore shows that potential penalties, as discussed in section 3.5, can be simplified to a constant as the amount of the fine does not depend on the principal's decision. Even in the case in which liberty restriction can be considered, it is always better to first use a fine to its maximum extent, as imprisonment is socially costly (Polinsky & Shavell, 1984). It should however be noted that sanctions are not simply wealth transfers, as part of the fine is used to pay for litigation and other costly procedures (McCubbins, Noll & Weingast, 1987). As argued by McCubbins et al., sanctions provide some level of protection against collusion when their magnitude is sufficiently great. This requires large investments in monitoring tools by the principal in order to increase the probability of detection, a result that is confirmed empirically by Aberbach (1987). In Townsend's (1979) model, the author shows that random verification schemes strictly dominate deterministic verification, which is verified for external audits (Kofman & Lawarrée, 1993). This result is reused for the application to soft capture done in section 3.5.

Regarding the dynamic aspects of regulatory capture, a point that is often touched upon is the mandate term of the regulator. The issue is non-trivial as there exist intuitive arguments for both longer and shorter terms.

On the one hand, it is a well-known result from the game theory that long relationships create better conditions for collusive behavior (see for example Axelrod, 1987; Kreps et al., 1982). This motivates Tirole (1986) to conclude that short-run relationships may be socially better. This idea is supported by Martimort (1999), who describes the logic of repeated games as the key to understand regulatory efficiency losses linked to bureaucratization. Overall, classical regulatory capture models predict that collusion due to the regulator's discretion is more likely to occur when a longer time horizon is considered (Deller & Vantaggiato, 2014).

On the other hand, long-term regulators need to focus less on future career perspectives and should therefore be more insulated against pressure by the firm, following the revolving door and minimal squawk theory (Hilton, 1972; Dal Bó, 2006). Leaver (2009) suggests that longer contracts and fewer appointments of professionals with experience in the private industry would mitigate the regulator's reputation concerns inherent to the minimal squawk model. His empirical case study on PUC term length does not allow to prove a correlation between softer regulatory decisions and term length, which would be the expected result from the classical capture theory. Furthermore, long-term relationships allow the accumulation of specific assets, such as expertise about the specific area (Williamson, 1985). Similarly, Baron and Besanko (1984b) suggest that a continuing relationship between the regulator and the agent allows the former to incorporate new information into the regulatory policy. Holmström (1999) states that, intuitively, longer time periods should help policing moral hazard as they give more opportunities for behavior observations and thereby better conclusions about unobservable behavior, but he cannot conclude that moral hazard disappears in the long-run.

Majone (1997) demonstrates that the cooperative Nash equilibrium of a repeated one-sided prisoner's dilemma provided by Kreps (1990) also holds true when the second player is facing a series of individuals. This requires the different players taking the first turn of each iteration to have knowledge about the constant player’s previous actions. This can be thought of as the reputation of the player, who uses it as an intangible asset. A player whose reputation is to play cooperatively can engage in collusive behavior with new agents that would otherwise not cooperate with him in a single-period game (Kofman & Lawarrée, 1993). The regulator’s reputation can therefore be thought as a type of commitment that allows the cooperative equilibrium to lie on the other player’s static best response curve, which is a necessary condition when dealing with short-run players (Fudenberg, Kreps & Maskin, 1990).

Given the importance of the regulator’s term length for regulatory capture and the lack of insights from the base soft capture model, an extension addressing this dynamic aspect is needed to open the way for better empirical analysis. In section 3.6, we present an adaptation to soft capture, including the use of a two-period capture model as in Baron and Besanko’s (1984b). We show that here again, the results obtained for soft capture can be thought as an alternative explanation to those obtained through the minimal squawk theory.

3. Model

In this soft capture model, we will reuse Agrell and Gautier's (2017) notations for simplicity purposes. The model is based on the three-layer hierarchy of a political principal, a regulator/regulatory agency and a regulated firm/industry.

An important note is that the information that the regulator passes to the principal is soft, in the sense that the principal cannot discern a report produced by the regulator from a report that he just transmits, and in the sense that a concealment of information cannot be easily detected. Furthermore, the contract between the principal and the firm cannot be determined by the realization of the signal. The incentive structure created by the principal must therefore be based on potential disclosure of information by the regulator. The information being soft allows the firm to produce its own report with information that is already at hand. The idea is relatively simple: the regulator saves on effort to produce his own report and the firm keeps more information rent compared with the situation in which the regulator audits it.

The base model is presented in section 3.1, including a benchmark without capture, the case of a captured regulator and capture-proof contracts. All the results obtained in section 3.1 come directly from Agrell and Gautier's (2017) paper. In section 3.2, we extend the model to consider the possibility of a shutdown. Regulator capture aversion is added in section 3.3. The possibility for the principal to give some importance to the firm's rent is introduced in section 3.4. An ex-post audit mechanism is presented in section 3.5, and the possibility to use this ex-post audit in a dynamic setting in section 3.6. All proofs can be found in the Appendix. The main results are listed in section 4.

3.1. Soft capture by Agrell and Gautier (2017)

In the base model, the principal offers a contract to the regulated firm to regulate its production. As shown in Laffont and Martimort (2009), the revelation principle states that in the case of moral hazard and adverse selection, any optimal incentive scheme is equivalent to an incentive scheme in which the agent reveals his private information. Because of the information asymmetry, the contract is a second-best contract and the firm has some information rent. In order to improve this result, the principal uses an intermediary, the regulator, to provide better information to the principal about the agent's private parameter.

It is assumed that the firm produces a good in quantity q, at constant marginal cost θ, without incurring any fixed costs. This is just to facilitate the notation as the model can be extended to firms incurring fixed costs without any changes to the results. A non-constant marginal cost could also be considered (such as classical economies of scale). This would however burden the notation and the main results would remain true. In short, economies of scale would further advantage the efficient firm as it produces more than the inefficient one (see below), which creates an even larger difference in cost parameter and therefore a larger information rent. The agent's reservation utility is normalized to zero. The θ cost parameter is the firm's private information but the principal knows that the firm is either efficient or inefficient, such that $\theta \in \{\underline{\theta}, \overline{\theta}\}$. To lighten the notations below, $\Delta\theta = \overline{\theta} - \underline{\theta}$ and $\nu = P(\theta = \underline{\theta})$. The contract proposed by the principal is a wholesale contract where the firms produces a quantity q for a transfer t. Which gives a firm utility of

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

The regulator produces a signal σ for the principal. This signal is correlated with the firm's private cost parameter θ. It is also a binary variable, with $\sigma \in \{\sigma_1, \sigma_2\}$. A signal σ_1 means that there is a higher probability for the firm to be efficient and a signal σ_2 indicates a higher probability of facing an inefficient firm. The informativeness of the signal is represented by $\mu = P(\sigma = \sigma_1 | \theta = \underline{\theta}) = P(\sigma = \sigma_2 | \theta = \overline{\theta})$. It should be noted that, for simplicity, the informativeness of μ is considered to be symmetric[1]. When μ increases, the correlation between the signal and the true cost parameter increases. With $\mu = 1$, the signal perfectly transmits the firm's private parameter and with $\mu = \frac{1}{2}$, the signal does not transmit any information (which will be referred to as white noise below). The idea of μ typically being between $\frac{1}{2}$ and 1 is that the regulator improves the principal's a priori knowledge about the true cost parameter, thereby reducing the firm's information rent, without being able to reveal the firm's type beyond any doubt.

[1] On a general note, it can be said that if the signal were to be asymmetric, i.e. $\mu_{eff} = P(\sigma = \sigma_1 | \theta = \underline{\theta})$ and $\mu_{ineff} = P(\sigma = \sigma_2 | \theta = \overline{\theta})$, the principal prefers $\mu_{eff} \geq \mu_{ineff}$ if $\nu \geq \frac{1}{2}$ and $\mu_{eff} \leq \mu_{ineff}$ if $\nu \leq \frac{1}{2}$. The idea is that better information about a state is more valuable when this state is more likely to occur, as can be seen in equations (4) and (5) below. A similar way to interpret this is that if $\mu_{eff}, \mu_{ineff} \geq \frac{1}{2}$, σ_1 will be observed more often than σ_2 when $\nu \geq \frac{1}{2}$ and it is therefore more interesting to obtain better information when σ_1 is observed.

The regulator incurs a cost $m > 0$ to produce a signal with informativeness μ. As noted before, the principal can only verify the existence of the regulator's report, not its quality. Indeed, the problem to prevent capture would be trivial if the principal were able to detect noisy signals. Like the agent, the regulator's reservation utility is normalized to zero. And similarly to the agent's situation, the regulator has a contract with the principal that stipulates that he receives a wage w when submitting his signal. The regulator's utility therefore can be written as

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

Regarding the political principal, the assumption made is that she values the goods in quantity q at $S(q)$ with the properties that $S(0) = 0$, $S'(q) > 0$ and $S''(q) < 0$, following the classical literature of consumption (Mankiw, 2020). This gives a principal utility function

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

It can be noted here that this does not restrict the principal to purely benevolent. The value $S(q)$ that she gives to the goods can also be based on some personal interest. As noted in section 2.4, the important feature is that she dislikes transfers to the agent.

The timing of events is as follows:

1. The agent learns its private cost parameter θ. It is assumed that θ is a state of nature and therefore not dependent on the firm's action.
2. The principal offers a contract to the regulator, stipulating a wage w to be paid for a signal σ.
3. The regulators produces a signal σ at cost m.
4. Based on the signal σ he receives, the principal offers a contract to the firm, offering a transfer t for a quantity of goods q.
5. The firm accepts or rejects the contract offered by the principal.

Having received the signal with informativeness μ, the principal revises her beliefs regarding the type of the firm. After observing a signal σ_1, the conditional probability of facing an efficient firm is updated based on the hypothesis that the signal is at least white noise (i.e. $\mu \geq \frac{1}{2}$).

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

The same goes for a signal σ_2.

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

Since $\mu \geq \frac{1}{2}$, it is unsurprising to find that observing σ_1 makes the efficient type $\underline{\theta}$ more likely and that σ_2 makes it less likely. Additionally, the effect of μ on ν_1 and ν_2 can be expressed as

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

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

This means that a higher μ makes a signal more informative by increasing ν_1 and decreasing ν_2.

The principal's problem becomes

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

Which is the maximization of the sum of the product between the principal's utility given the firm's type and the conditional probability of the firm's type, for the two possible efficiency states. It is subject to the firm's incentive compatibility and rationality constraints

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

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

Equation (8) echoes the revelation principle: the efficient firm must prefer to reveal itself as efficient. Equation (9) makes the assumption that even an inefficient firm must participate in the game. This assumption is relaxed in section 3.2.

The second-best contracts are obtained by solving the principal's problem, giving

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

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

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

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

The results obtained in (10) through (13) are similar to the classical menu pricing findings. The efficient firm is given an information rent $\Delta\theta\overline{q}_i$ while the production of the inefficient firm is distorted downwards to reduce the aforementioned information rent. If the principal receives a signal σ_1, she concludes that she is more likely to face an efficient firm and therefore reduces the quantity $\overline{q}_1$to reduce the information rent of the efficient firm. If $\mu > \frac{1}{2}$, then $\nu_1 > \nu > \nu_2$ and therefore $\overline{q}_1 < \overline{q}_2$. It is important to note that the quantity produced by the efficient firm does not depend on the regulator's signal.

The firm's information rent is

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

And the impact of μ on $\underline{U}(\mu)$ is given by

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

Since, $\overline{q}_1 < \overline{q}_2$, the first term is negative. The second term is also negative (a higher quality signal leads to a reduction in quantity for the high cost firm when the regulator reports σ_1) and the third term is positive (following exactly the same reasoning as the second)[2]. As μ increases, the second term gains weight while the third loses importance. Therefore, Agrell and Gautier make the following assumption.

Assumption 1. $\frac{\partial \underline{U}}{\partial \mu} < 0, \forall \mu \in \left[\frac{1}{2}, 1\right]$.

The intuitive interpretation is that a more informative signal decreases the firm's information rent. $S'''(q) > 0$ is a sufficient condition for this assumption[3].

The principal's utility function becomes

[2] The proof can be found in Appendix (A1).
[3] See Appendix (A2) for the proof.

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

Which is characterized by

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

Therefore, a more informative signal increases the principal's utility, which is an intuitive result[4]. Furthermore, an increase in informativeness is all the more beneficial when the informativeness is already high. The idea is that an increase of $\overline{q}_2$ and a decrease of $\overline{q}_1$ is more valuable to the principal when these values are already close to the first-best level[5]. This utility function however does not take the regulator's wage w into account. Without the risk of capture, the principal can simply set $w = m$, which is the lowest wage at which the regulator accepts to participate in the game, and her utility becomes $\widetilde{W}(\mu) - m$ when she decides to use the regulator. The alternative for the principal is to base the contract with the firm on her a priori information and to save on the regulator's wage. In this case, the principal's utility is $\widetilde{W}\left(\frac{1}{2}\right)$ since she has no informative signal. The principal therefore prefers to use the regulator when $\widetilde{W}(\mu) - m \geq \widetilde{W}\left(\frac{1}{2}\right)$. Which translates to

Lemma 2. *If* $\widetilde{W}(1) - \widetilde{W}\left(\frac{1}{2}\right) \geq m$, *then* $\exists\, \tilde{\mu}_1 \in \left[\frac{1}{2}, 1\right]$ *such that if* $\mu \geq \tilde{\mu}_1$, *the principal sets* $w = m$ *and the regulator transmits a signal. Otherwise, she sets* $w = 0$ *and the regulator is not used.*

For the sake of analysis, it is below assumed that $\widetilde{W}(1) - \widetilde{W}\left(\frac{1}{2}\right) \geq m$. Otherwise, the principal's solution would always be to not use the regulator's services.

Soft capture can occur when the firm produces a report instead of the regulator. The firm's interest is to preserve its information rent and the regulator's motivation is to save on the cost of his audit. The assumption below is that the firm can produce a signal of pure white noise ($\mu = \frac{1}{2}$) without incurring any costs (as noted by Agrell and Gautier, considering costly signals adds to the notation and does not affect the conclusions) and offers this signal to the regulator for free with a probability

[4] The proof of Lemma 1 can be found in Appendix (A2).
[5] The partial derivatives of $\overline{q}_1$ and $\overline{q}_2$ with respect to μ can be seen in Appendix (A1) and their impact on the convexity of $\widetilde{W}(\mu)$ in Appendix (A2).

x. The regulator always accepts this report, as he saves the production cost of his report and still receives a wage $w = m$ from the principal. This reasoning is illustrated in Figure 2. Consequently, his utility becomes $V = m$. The principal cannot distinguish between a report produced by the regulator himself and one coming from the agent. Otherwise, she could easily prevent capture by punishing the regulator when he transmits the firm's signal. The firm's information rent when its report is transmitted to the principal is derived from (14),

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

Considering the possibility of the regulator being captured, the principal revises her beliefs from (4) and (5) by replacing μ by $\hat{\mu} = \frac{x}{2} + (1-x)\mu$.

$$\tilde{\nu}_1(x) = P\left(\theta = \underline{\theta} \middle| \sigma_1\right) = \frac{\nu\left[\frac{x}{2} + (1-x)\mu\right]}{\nu\left[\frac{x}{2} + (1-x)\mu\right] + (1-\nu)\left[\frac{x}{2} + (1-x)(1-\mu)\right]}, \tag{18}$$

$$\tilde{\nu}_2(x) = P\left(\theta = \underline{\theta} \middle| \sigma_2\right) = \frac{\nu\left[\frac{x}{2} + (1-x)(1-\mu)\right]}{\nu\left[\frac{x}{2} + (1-x)(1-\mu)\right] + (1-\nu)\left[\frac{x}{2} + (1-x)\mu\right]}. \tag{19}$$

The properties of these beliefs are given by

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

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

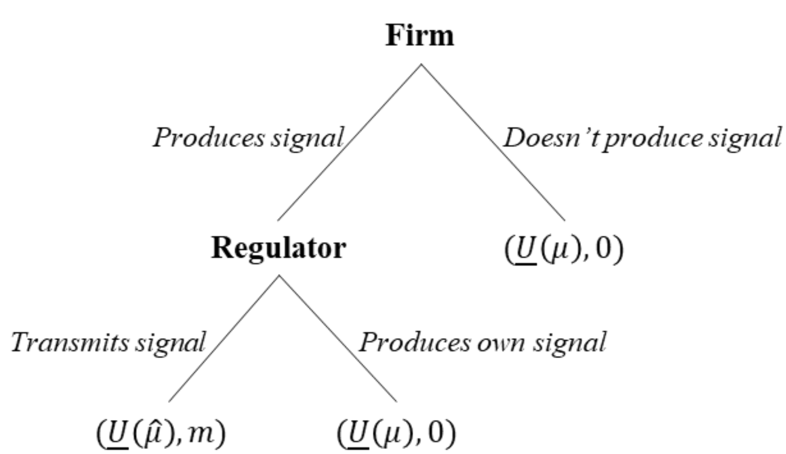

Figure 2. Regulator's choice when receiving a signal from the firm

This reflects the consideration of the principal that the regulator may be captured by giving less importance to his signal when he is more likely to be captured[6]. The principal's utility becomes

Lemma 4. $\widetilde{W}(\hat{\mu})\ with\ \hat{\mu} = \frac{x}{2} + (1-x)\mu < \mu, \forall x > 0.$

The result would be the same if the regulator always transmitted a signal of quality $\hat{\mu} < \mu$ (or another intermediary solution such as an even less informative signal that is produced less often).

The principal still needs to pay the regulator m to obtain any signal that is not pure white noise, as it is the threat of the regulator's audit that motivates the firm to reveal any kind of relevant information. The principal's actual utility is therefore $\widetilde{W}(\hat{\mu}) - m$.

Given that $\widetilde{W}(\mu)$ is increasing in μ (Lemma 1) and that $\hat{\mu} < \mu$ for $x > 0$ (Lemma 4), it follows that $\widetilde{W}(\mu) - \widetilde{W}(\hat{\mu}) > 0$. Since the principal's utility has decreased with the introduction of soft capture, Lemma 2 needs to be updated.

Lemma 5. $If\ \widetilde{W}\left(1-\frac{x}{2}\right) - \widetilde{W}\left(\frac{1}{2}\right) \geq m, then\ \exists\ \tilde{\mu}_2 \in [\tilde{\mu}_1, 1]\ such\ that\ if\ \mu \geq \tilde{\mu}_2, the$ $principal\ sets\ w = m\ and\ the\ regulator\ transmits\ a\ signal. Otherwise, she\ sets\ w = 0$ $and\ the\ regulator\ is\ not\ used.$

Lemma 5 can be visualized in Figure 3. This means that at the equilibrium, leaving the firm unregulated is the principal's best option when the informativeness of the regulator's signal is relatively low. The principal can now offer an incentive scheme to the regulator to shield herself from the effect of soft capture. Therefore, the principal offers a new contract to the regulator based on the regulatory outcome. The idea is that the principal wants the regulator to also have an interest in favoring $(\underline{q}_1, \underline{t}_1)$ and $(\overline{q}_2, \overline{t}_2)$ contracts over $(\underline{q}_2, \underline{t}_2)$ and $(\overline{q}_1, \overline{t}_1)$ contracts. The regulator's wage is therefore tied to the production level such that $\underline{w}_i, \overline{w}_i$ is a function of $\underline{q}_i, \overline{q}_i$ with $i = 1, 2$. The

[6] The proof of Lemma 3 is given in Appendix (A3).

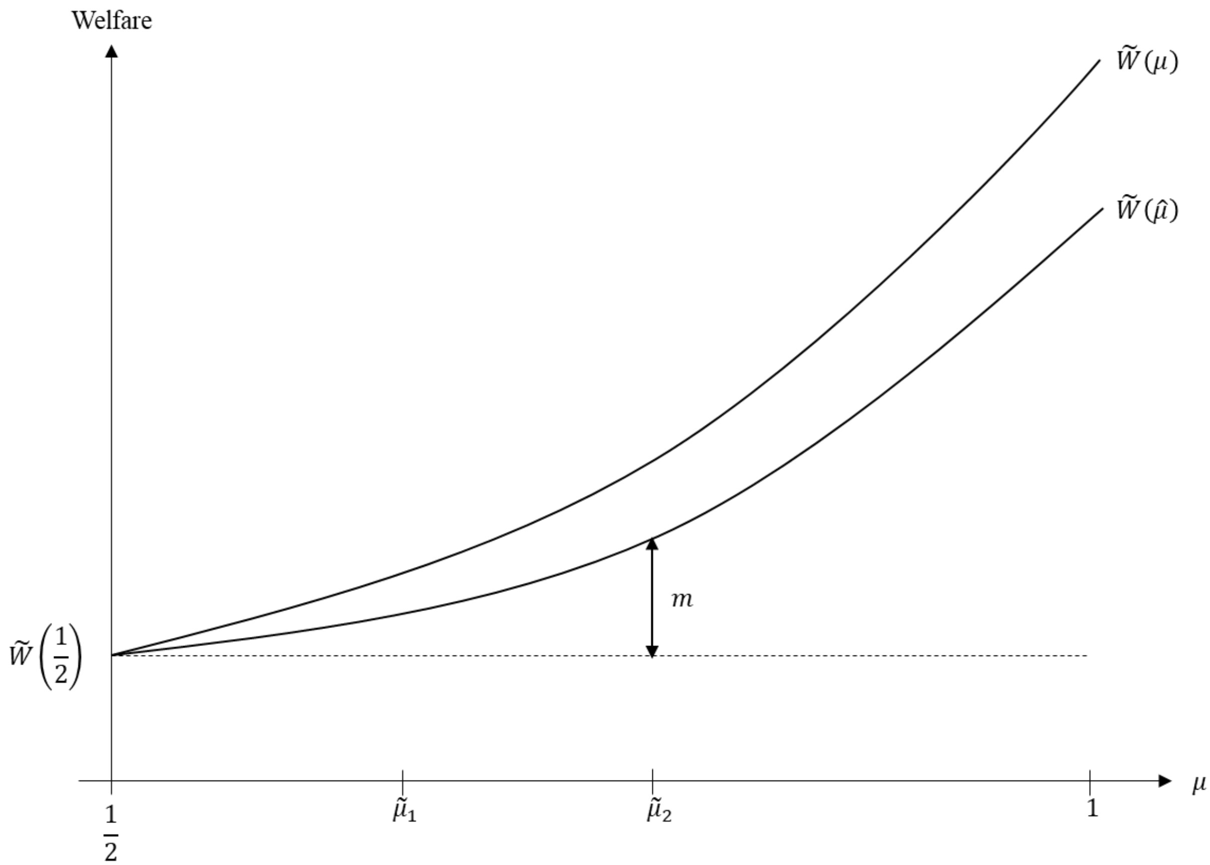

Figure 3. Soft capture's impact on welfare
Source: Agrell and Gautier, 2017, p. 584

regulator however cannot receive a negative wage, meaning that $\underline{w}_i, \overline{w}_i \geq 0$. The constraint that the regulator prefers to produce a signal himself is given by

$$\nu\mu\underline{w}_1 + \nu(1-\mu)\underline{w}_2 + (1-\nu)\mu\overline{w}_2 + (1-\nu)(1-\mu)\overline{w}_1 - m$$

$$\geq \nu\hat{\mu}\underline{w}_1 + \nu(1-\hat{\mu})\underline{w}_2 + (1-\nu)\hat{\mu}\overline{w}_2 + (1-\nu)(1-\hat{\mu})\overline{w}_1 - (1-x)m. \qquad (20)$$

The left-hand side of inequation (20) is the regulator's utility when he is not captured (his wage minus the incurred costs) and the right-hand side is his utility when he is captured by the firm (again, his wage minus the incurred costs). It should be noted that the cost term on the right hand-side of the inequation is smaller since the regulator saves on xm costs when he transmits the firm's white noise with probability x. Unlike Lemma 4, this does change when the firm instead opts to always offer a signal of quality $\hat{\mu}$. This leads us to conclude that it is in the firm's best interest to favor the option of always producing a signal of quality $\hat{\mu}$ over the option of transmitting white noise with a probability x, as it makes it harder for the principal to protect herself against capture. This is the only point from section 3.1 that differs from the insights provided by Agrell and Gautier.

Using $\hat{\mu} = \frac{x}{2} + (1-x)\mu$, $\mu - \hat{\mu}$ can be written as $x(\mu - \frac{1}{2})$ and inequation (20) simplifies to

$$\left(\mu - \frac{1}{2}\right)\left[\nu\left(\underline{w}_1 - \underline{w}_2\right) + (1-\nu)(\overline{w}_2 - \overline{w}_1)\right] \geq m. \tag{21}$$

The best possible contract that the principal can offer to the regulator is therefore setting $\underline{w}_2$ and $\overline{w}_1$ at zero. $\underline{w}_1$ and $\overline{w}_2$ are selected such that the constraint given by inequation (21) becomes binding. As noted by Agrell and Gautier, the contract should specify a large wage for out-of-equilibrium quantities ($q \notin \underline{q}_1$, $\underline{q}_2$, $\overline{q}_1, \overline{q}_2$) to protect the regulator from any deviation by the principal. The regulator's expected wage becomes

Lemma 6. $\widetilde{w} = \dfrac{\mu m}{\mu - \frac{1}{2}} > m.$

As $\widetilde{w} > m$, it is costly for the principal to deter collusion, a result that is also typical in the classical capture theory[7]. It is interesting to note that the less informative the signal, the more expensive it is for the principal to create a capture-proof contract that satisfies the condition given by inequation (20). In other words, a regulator producing a particularly informative signal needs to be paid less by the principal to prevent soft capture, which is not an intuitive result. The principal's utility becomes $\widetilde{W}(\mu) - \widetilde{w}$.

The principal can now choose to offer a contract to the regulator that deters collusion, to offer a contract that will lead the regulator to be captured or to not use the regulator. The second choice is preferable to the first if

$$\widetilde{W}(\hat{\mu}) - m \geq \widetilde{W}(\mu) - \widetilde{w}. \tag{22}$$

Which is equivalent to

$$\widetilde{w} - m \geq \widetilde{W}(\mu) - \widetilde{W}(\hat{\mu}). \tag{23}$$

[7] The proof of Lemma 6 is provided in Appendix (A4) and a short discussion can be found in Appendix (A5).

The left hand-side of the inequation (23) is the cost of preventing capture, which is decreasing in μ given that $\frac{\partial \tilde{w}}{\partial \mu} < 0$ .While the right hand side is the utility loss associated to soft capture, which is increasing in μ from Lemma 1. This gives

Lemma 7. $If\ \widetilde{W}(1) - m > \widetilde{W}\left(1 - \frac{x}{2}\right), then\ \exists\ \tilde{\mu}_3 \in [0,1] such\ that\ if\ \mu \geq \tilde{\mu}_3, the\ principal$ $sets\ up\ an\ incentive\ scheme\ to\ prevent\ soft\ capture\ and\ tolerates\ soft\ capture\ if\ \mu < \tilde{\mu}_3.$
$If\ \widetilde{W}(1) - m \leq \widetilde{W}\left(1 - \frac{x}{2}\right), the\ principal\ always\ tolerates\ soft\ capture.$

Lemma 7 can be visualized in Figure 4. This leads to Agrell and Gautier's main result[8].

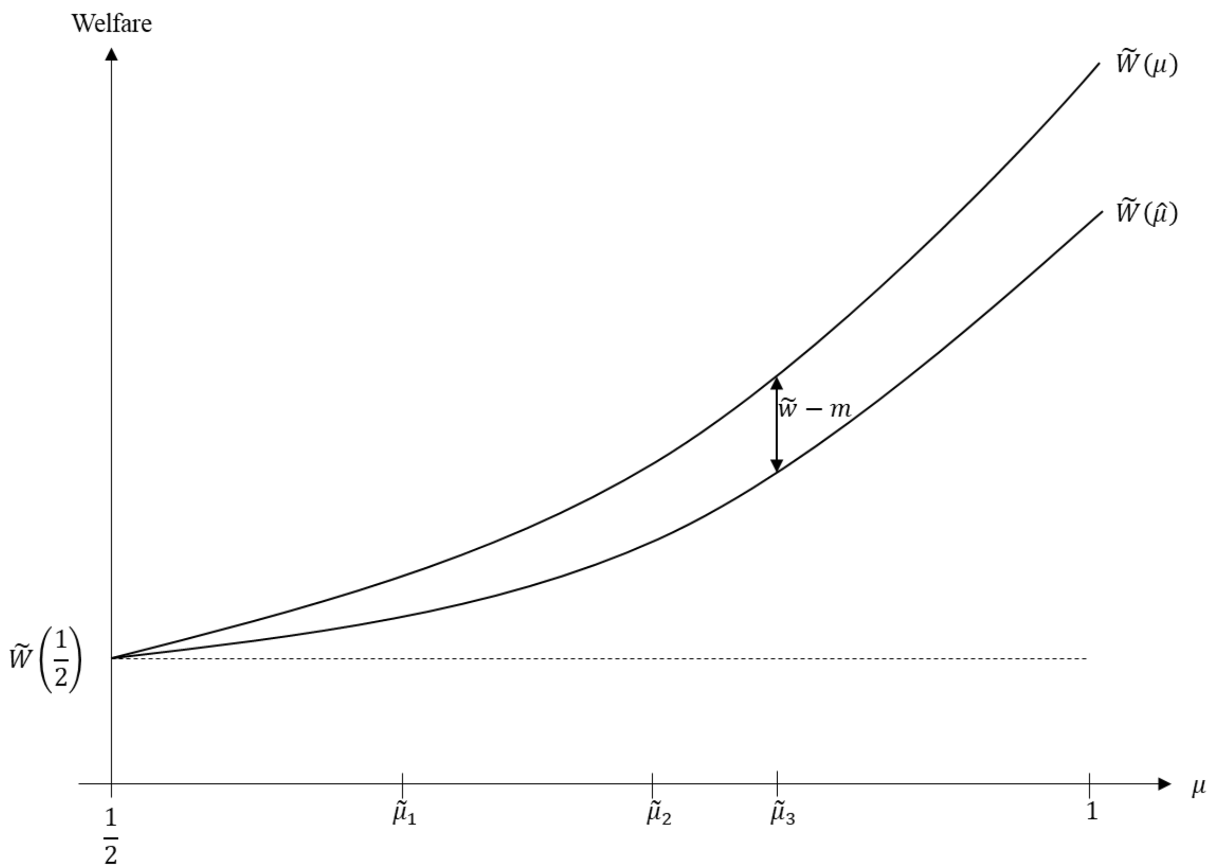

Figure 4. Impact of capture-proof contracts on welfare

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[8] The proof of Lemma 7 is presented in Appendix (A6).

Proposition 1. *There exists a non − empty set of values for* μ *such that the principal tolerates soft capture at the equilibrium if* $\tilde{\mu}_2 < 1$ *and one of the following conditions holds true*:

$$(a)\ \widetilde{W}(1) - m \leq \widetilde{W}\left(1 - \frac{x}{2}\right);$$

$$(b)\ \widetilde{W}(1) - m > \widetilde{W}\left(1 - \frac{x}{2}\right)\ and\ \widetilde{W}\left(\frac{1}{2}\right) > \widetilde{W}(\tilde{\mu}_2) - \frac{\tilde{\mu}_2 m}{\tilde{\mu}_2 - \frac{1}{2}}.$$

If condition (a) holds true, the principal tolerates soft capture for $\mu \geq \tilde{\mu}_2$ and if condition (b) holds true, the principal tolerates soft capture for $\mu \in [\tilde{\mu}_2, \tilde{\mu}_3]$ and uses a capture-proof contract for $\mu \geq \tilde{\mu}_3$.[9] The visualization of the space in which capture is tolerated when condition (b) holds true can be seen in Figure 5. The direct consequence of Proposition 1 is given by

Corollary 1. *If the probability* x *of producing a white noise signal increases, then the parameter space in which the principal tolerates soft capture decreases.*

In other words, the principal will be less inclined to tolerate capture if it happens frequently[10].

Agrell and Gautier also consider the possibility for the firm to use monetary bribes (as is the case in classical regulatory capture models) in addition to the soft capture. When using capture, the firm increases its utility by

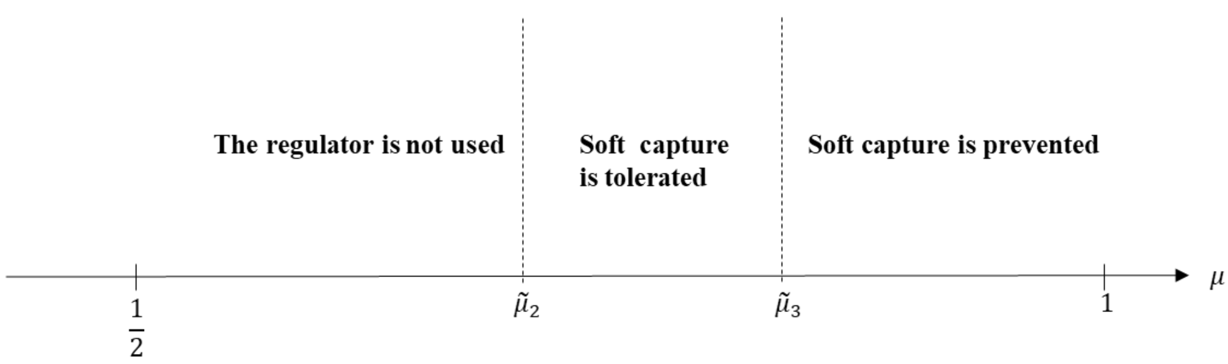

Figure 5. Situation in which soft capture is either tolerated or prevented based on informativeness

[9] The proof of Proposition 1 is given in Appendix (A7).
[10] The proof of Corollary 1 is given in Appendix (A8).

$$\Delta\theta\left(\mu-\frac{1}{2}\right)\left(\overline{q}_2-\overline{q}_1\right)>0. \tag{24}$$

Since only the efficient firm is willing to bribe the regulator, the probability of a bribe is given by νx. Furthermore, as discussed in section 2.4, the side transfer is not perfectly efficient and the regulator only receives a fraction $k \in [0,1]$ of the amount paid by the firm. Therefore, the highest possible bribe that the firm can offer the regulator is given by

$$B=\nu x k\Delta\theta\left(\mu-\frac{1}{2}\right)\left(\overline{q}_2-\overline{q}_1\right)\geq 0. \tag{25}$$

To prevent soft and hard capture, the principal must now offer a wage equal to $\widetilde{w}+B\geq\widetilde{w}$. As it is more costly for the principal to deter capture, the space in which soft capture is tolerated increases.

All the results presented in section 3.1 come directly from Agrell and Gautier (2017), except for those explicitly described as different.

In the sections below, we consider different extensions to the model presented by Agrell and Gautier. These extensions are taken individually, unless explicitly stated otherwise. The combination of different extensions is possible and the results from each extension remain true, but this would only burden the notation. The important changes to the base model are stated, no mention of a result from the aforementioned model means that it is not impacted by the extension.

3.2. Shutdown

The first extension considered in this master's thesis is the possibility for the principal to shut down an inefficient firm, as proposed by Laffont and Tirole (1991). When the firm is not considered essential, the principal may be better off choosing to shut the inefficient type down rather than dealing with a potentially captured regulator. Indeed, the principal does not need the regulator anymore if she chooses to go down the shutdown path, as she will be able to extract the entirety of the efficient firm's rent (see below). The possibility of a shutdown means that the constraint given by inequation (9) no longer needs to be respected.

The new contract that the principal offers to the firm is given by

$$S'\left(\underline{q}_s\right)=S'\left(\underline{q}\right)=\underline{\theta}, \tag{26}$$

$$\underline{t}_s = \underline{\theta}\underline{q}_s. \tag{27}$$

Since the principal shuts down the inefficient type, she does not need to observe the regulator's signal and can set $\overline{q}_s = \overline{t}_s = 0$. This makes the constraint given by inequation (8) trivial and she can set the values for both quantity and transfer of the efficient firm at the first-best level. From equation (26), it is apparent that $\underline{q}_s = \underline{q}$, given that $S''\left(\underline{q}\right) < 0$.

The principal's utility is now given by

$$\widetilde{W}_s = \nu\left[S\left(\underline{q}\right) - \underline{\theta}\underline{q}\right]. \tag{28}$$

Comparing this with equation (16), this gives

Lemma 8. $\exists \nu_a, \nu_b \in [0,1]$ *such that*
(a) *if* $\nu < \nu_a$, *the principal never chooses the shutdown option,*
(b) *if* $\nu > \nu_b$, *the principal always chooses the shutdown option,*
(c) *if* $\nu \in [\nu_a, \nu_b]$, *the shutdown choice is dependent on* μ.

The interpretation of Lemma 8 is that extracting the information rent of the efficient firm comes at the cost of losing the utility gained by using the inefficient firm[11]. When there are particularly few efficient firms, the second effect outweighs the first. When there are particularly few inefficient firms, it is the first effect that prevails. This is even true when the informativeness of the regulator's signal is perfect ($\mu = 1$), which may seem counterintuitive. But even when the regulator's signal is perfectly informative, the principal does not profit sufficiently from it to pay the regulator m when the utility she loses from shutting down the inefficient type tends to zero. When both type of firms are fairly frequent, this tradeoff depends on the quality of the signal provided by the regulator. The more informative the signal, the less interesting it is for the principal to select the shutdown option. For the remainder of the section, it will be assumed that $\nu \in [\nu_a, \nu_b]$.

This means that Lemma 5 needs to be updated.

[11] The proof of Lemma 8 can be found in Appendix (A9).

Lemma 9. $If\ \widetilde{W}\left(1-\frac{x}{2}\right)-\widetilde{W}_s \geq 0, then\ \exists\ \tilde{\mu}_{2_s} \in [\tilde{\mu}_2, 1]\ such\ that\ if\ \mu \geq \tilde{\mu}_{2_s}, the\ principal\ sets\ w = m\ and\ the\ regulator\ transmits\ a\ signal. Otherwise, she\ sets\ w = 0\ and\ chooses\ the\ shutdown\ option.$

By supposing that $\nu \geq \nu_a$, the shutdown is preferred by the principal to offering a second-best contract based on his a priori knowledge. This makes the condition of Lemma 9 more constraining, reducing the space in which capture is tolerated in the absence of capture-proof contracts. The shutdown's effect on $\tilde{\mu}_{2_s}$ can be seen in Figure 6.

This impacts Proposition 1, which needs to be adapted.

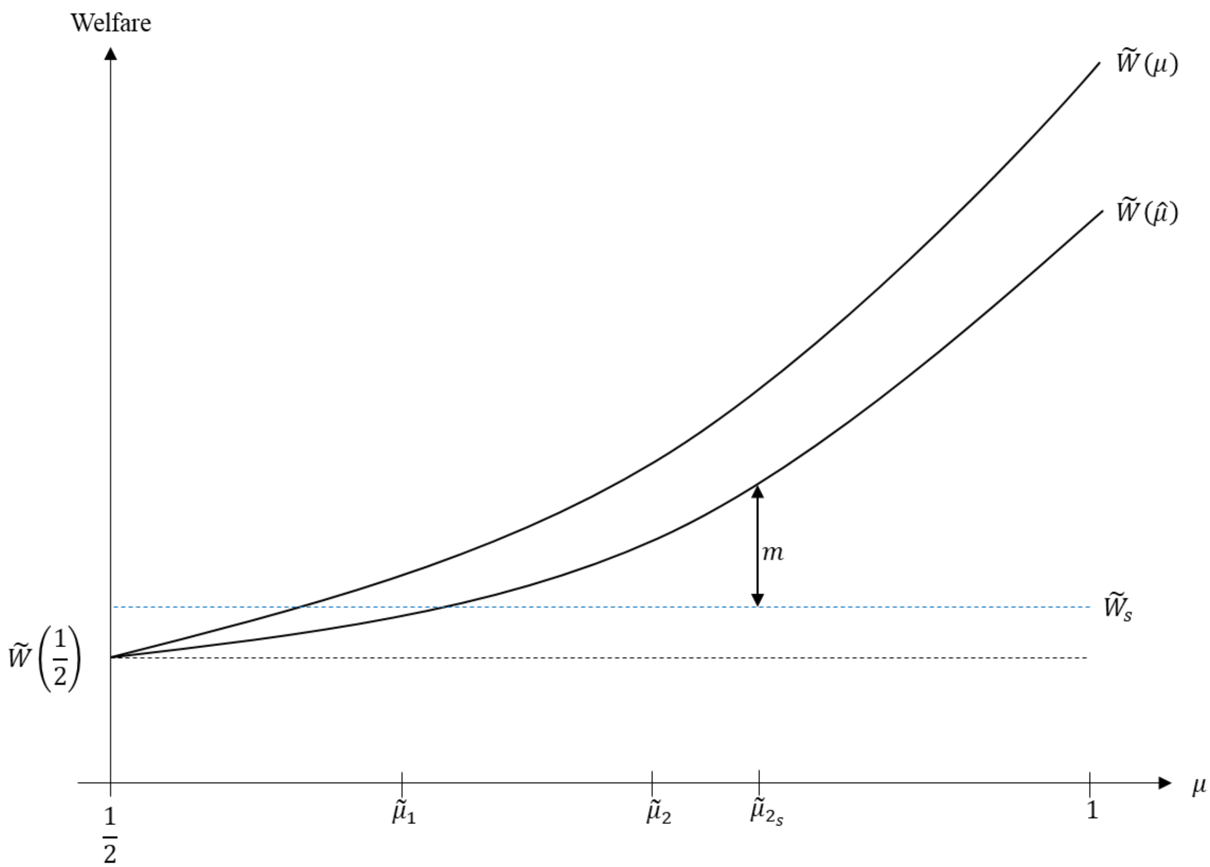

Figure 6. Soft capture with the possibility of a shutdown

Proposition 2. $There\ exists\ a\ non-empty\ set\ of\ values\ for\ \mu\ such\ that\ the\ principal\ tolerates\ soft\ capture\ at\ the\ equilibrium\ if\ \tilde{\mu}_{2_s} < 1\ and\ one\ of\ the following\ conditions\ holds\ true$:

$(a)\ \widetilde{W}(1) - m \leq \widetilde{W}\left(1 - \frac{x}{2}\right);$

$(b)\ \widetilde{W}(1) - m > \widetilde{W}\left(1 - \frac{x}{2}\right)\ and\ \widetilde{W}_s > \widetilde{W}\left(\tilde{\mu}_{2_s}\right) - \frac{\tilde{\mu}_{2_s} m}{\tilde{\mu}_{2_s} - \frac{1}{2}}.$

If condition (a) holds true, the principal tolerates soft capture for $\mu \geq \tilde{\mu}_{2_s}$ and if condition (b) holds true, the principal tolerates soft capture for $\mu \in \left[\tilde{\mu}_{2_s}, \tilde{\mu}_3\right]$ and uses a capture-proof contract for $\mu \geq \tilde{\mu}_3$.

Since $\tilde{\mu}_{2_s} \geq \tilde{\mu}_2$, the first condition of Proposition 2 is stricter than it was in Proposition 1. Additionally, the space in which soft capture is tolerated decreases for the same reason when one of condition (a) or condition (b) is respected. This means that the introduction of an option for the principal to shut down an inefficient firm decreases the room in which soft capture is tolerated. The result of Corollary 1 remains unchanged.

3.3. Capture aversion

The second possible extension is to consider a regulator that has some form of aversion to capture, following the idea of Becker and Stigler (1974). In this model, we simply suppose that the regulator's utility is reduced by a constant $c > 0$ when he colludes against the principal. This can be viewed as honesty, professional deontology or the regulator disliking to be involved in activities that constitute a breach of contract. Even though aversion is often considered as proportional to the object of the aversion (as in Laffont & Martimort, 2009), it makes sense for c to be a constant. Indeed, since the regulator does not receive a monetary bribe (which can be thought of as a quantity), but chooses between producing a signal himself or accepting the one offered by the firm, i.e. he faces a binary choice. Collusion therefore does not depend on how much the regulator benefits from it, as long as it brings him a positive utility. When accepting the firm's signal, the regulator thus loses some utility simply because he chose to collude.

3.3.1. Unique regulator type

In this first part, we consider that all regulators have the same capture aversion. Before the introduction of capture-proof contracts, the colluding regulator's utility is given by $V = m - c$. If $c \geq m$, the problem becomes trivial as the regulator never participates in any collusion against the principal. We will therefore assume that $c < m$ from here on. It is interesting to note that no level of capture aversion $c < m$ makes any difference on the results of the base model before the introduction of capture-proof contracts.

When introducing capture-proof contracts, inequation (20) needs to be updated to

$$\nu\mu\underline{w}_1 + \nu(1-\mu)\underline{w}_2 + (1-\nu)\mu\overline{w}_2 + (1-\nu)(1-\mu)\overline{w}_1 - m$$

$$\geq \nu\hat{\mu}\underline{w}_1 + \nu(1-\hat{\mu})\underline{w}_2 + (1-\nu)\hat{\mu}\overline{w}_2 + (1-\nu)(1-\hat{\mu})\overline{w}_1 - (1-x)m - xc. \tag{29}$$

And using the same method as for inequation (21), this simplifies to

$$\left(\mu - \frac{1}{2}\right)\left[\nu\left(\underline{w}_1 - \underline{w}_2\right) + (1-\nu)(\overline{w}_2 - \overline{w}_1)\right] \geq m - c. \tag{30}$$

Setting $\underline{w}_2$ and $\overline{w}_1$ at zero and selecting $\underline{w}_1$ and $\overline{w}_2$ such that the constraint given by inequation (30) becomes binding, the regulator's expected wage is given by

$$\tilde{w}_c = \frac{\mu(m-c)}{\left(\mu - \frac{1}{2}\right)} < \tilde{w}. \tag{31}$$

The proof is exactly the same as for Lemma 6. However, $\tilde{w}_c > m$ is no longer a direct result. In fact, it requires $\mu < \frac{m}{2c}$.[12] This means that when the regulator's capture-aversion is high or when the informativeness of the signal is low, the regulator cannot expect a strictly positive utility. However, the regulator's expected utility cannot be strictly negative if the principal wants him to participate in the game, so a necessary condition is given by $\tilde{w}_c \geq m$. Lemma 6 can now be updated.

Lemma 10. $\tilde{w} > \tilde{w}_c \geq m$.

[12] The proof is provided in Appendix (A10).

Unsurprisingly, the regulator's aversion to capture makes it less costly for the principal to create a capture-proof contract. The case in which the principal prefers tolerating capture over the capture-proof contract is now characterized by

$$\widetilde{w}_c - m \geq \widetilde{W}(\mu) - \widetilde{W}(\hat{\mu}). \tag{32}$$

While this does not change the formulation and results of Proposition 1 and Corollary 1, the impact of having $\widetilde{w}_c < \widetilde{w}$ is straightforward. A lower expected wage for the regulator in the capture-proof contract reduces the space in which capture is tolerated by decreasing $\tilde{\mu}_3$. This can be visualized in Figure 7. The intuitive result is therefore that capture aversion by the regulator reduces the space in which soft capture is tolerated by the principal.

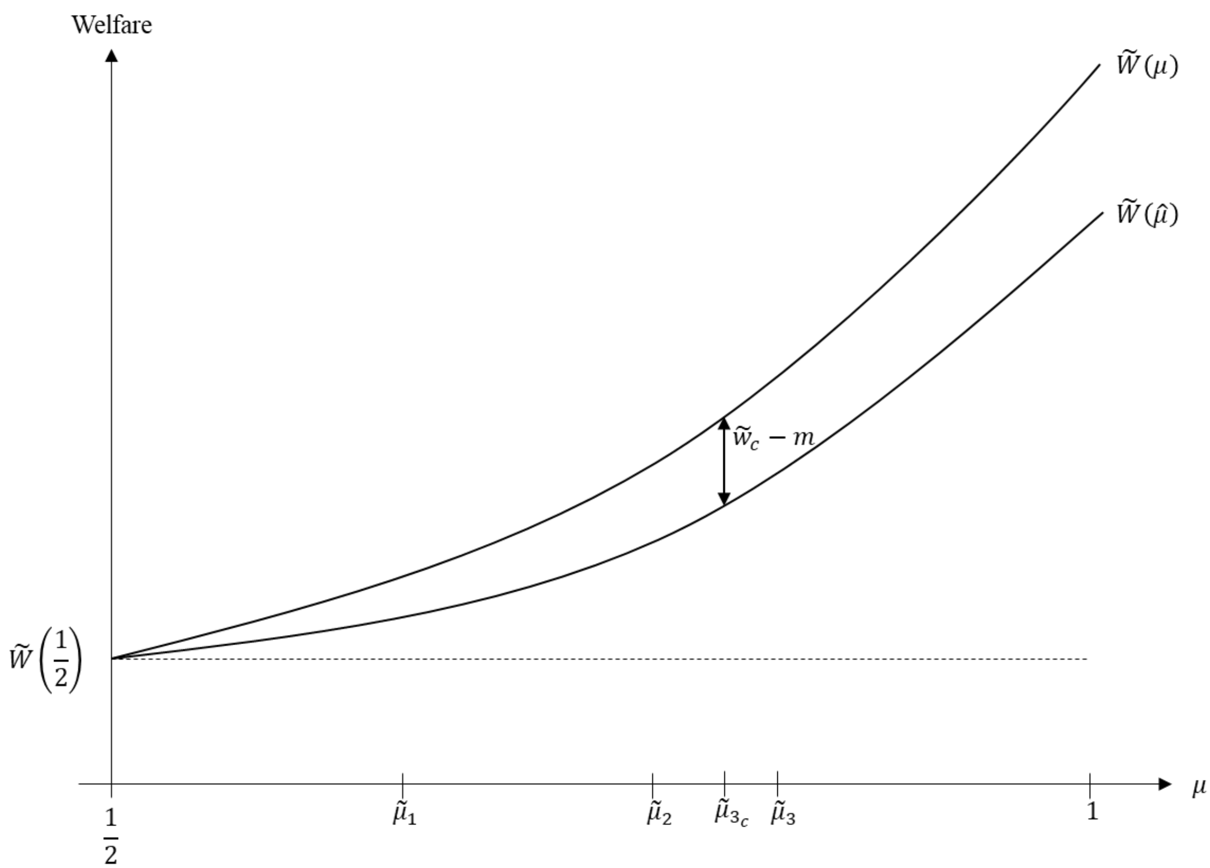

Figure 7. Soft capture prevention when the regulator has an aversion to colluding

3.3.2. Two regulator types

We will now consider the possibility for the regulator to be either honest or dishonest. With probability y the regulator is dishonest and loses no utility when captured. And with probability $(1-y)$ the regulator is honest and utility is reduced by a constant $c \in]0,m[$ when he colludes against the principal.

The principal is now presented with a new problem. When preventing capture, she can choose to create a capture-proof contract for both regulator types or she can choose to only protect herself against capture of honest regulators. The intuition is that if it is particularly easy for the principal to prevent capture of honest regulators and, at the same time, difficult to prevent capture of dishonest regulators, it may be optimal to only protect herself against capture of honest regulators. The first choice is equivalent to the base model, the second to the one developed previously in section 3.3.1.

Always preventing capture is preferred to preventing capture of honest regulators when

$$\widetilde{W}(\mu) - \widetilde{w} \geq y\big[\widetilde{W}(\hat{\mu}) - \widetilde{w}_c\big] + (1-y)\big[\widetilde{W}(\mu) - \widetilde{w}_c\big]. \tag{33}$$

In terms of the specified parameters, this translates to

$$\frac{c}{y} \leq \frac{\mu - \frac{1}{2}}{\mu}\big[\widetilde{W}(\mu) - \widetilde{W}(\hat{\mu})\big]. \tag{34}$$

The principal therefore prefers to always prevent capture when (all other things being equal): a) the informativeness of the signal is high; b) the probability for the regulator to be dishonest is high; c) the utility that the honest regulator loses when colluding against the principal is low[13]. The last result is less straightforward than the others. The interpretation is that when c is low, the principal saves less by offering $\widetilde{w}_c$ instead of $\widetilde{w}$ to the regulator than what she loses by tolerating some capture to happen.

Always tolerating capture is preferred to preventing capture of honest regulators when

$$\widetilde{W}(\hat{\mu}) - m \geq y\big[\widetilde{W}(\hat{\mu}) - \widetilde{w}_c\big] + (1-y)\big[\widetilde{W}(\mu) - \widetilde{w}_c\big]. \tag{35}$$

[13] The proof can be found in Appendix (A11).

In the same way as above, this translates to

$$\frac{\frac{m}{2} - \mu c}{(1-y)\left(\mu - \frac{1}{2}\right)} \geq \widetilde{W}(\mu) - \widetilde{W}(\hat{\mu}). \tag{36}$$

The principal therefore prefers to always tolerate capture when (all other things being equal): a) the informativeness of the signal is low; b) the probability for the regulator to be dishonest is high; c) the utility that the honest regulator loses when colluding against the principal is low[14]. The explanation for the last result is that a low utility loss when colluding for the regulator leads to a higher wage $\widetilde{w}_c$, making the difference between $\widetilde{w}_c$ and m become larger than the utility gain provided by the regulator's signal.

Combining these two results, it can easily be shown that the principal will tolerate soft capture of the dishonest regulator and only the dishonest regulator when the probability of facing a dishonest regulator is low and when the honest regulator's utility loss associated to colluding is high.

3.4. Non-benevolent principal

Up until this point, W has been referred to as the principal's utility function, by opposition to Agrell and Gautier's use of social welfare. This is to reflect the comment made in section 2.4 that the results of the soft capture model also hold when the principal's utility of the products $S(q)$ comes from her own use (or her company's use for example), the important feature being that she dislikes transfers to the agent (Laffont & Tirole, 1986; Laffont & Martimort, 1999). In this section, we consider that $S(q)$ indeed represents the utility that society gains from this production and we suppose that the principal's utility function depends on social welfare but also on the firm's rent. As discussed in section 2.4, the motivation was already provided by Stigler (1971). Considering this type of utility function helps to reflect that the political principal is motivated by political goals and that she therefore requires support from the public at large (through votes) and by the industry (for example by supporting her campaign). In particular, we reuse Armstrong and Sappington's (2007) model, in which the principal's utility function is given by

$$W = S(q) - t - w + \alpha U = S(q) - (1-\alpha)t - w - \alpha\theta q. \tag{37}$$

[14] See Appendix (A12) for the proof.

With the assumption that $\alpha \in [0,1]$. In other words, the principal gives more importance to social welfare than to the firm's rent. Considering $\alpha > 1$ is of no interest because the principal would then choose an infinitely high transfer to the firm.

The results given by equations (11) to (13) change, the solution now being

$$S'\left(\overline{q}_{i_n}\right) = \overline{\theta} + \frac{\nu_i}{1-\nu_i}(1-\alpha)\Delta\theta, \tag{38}$$

$$\underline{t}_{i_n} = \underline{\theta}\underline{q}_i + \Delta\theta\overline{q}_{i_n}, \tag{39}$$

$$\overline{t}_{i_n} = \overline{\theta}\overline{q}_{i_n}. \tag{40}$$

With $\alpha \in [0,1]$, $S'\left(\overline{q}_{i_n}\right) \leq S'\left(\overline{q}_i\right)$ and given that $S''(q) < 0$, the immediate result is $\overline{q}_{i_n} \geq \overline{q}_i$.

The firm's rent is given by

$$\underline{U}_n(\mu) = \mu\Delta\theta\overline{q}_{1_n} + (1-\mu)\Delta\theta\overline{q}_{2_n}. \tag{41}$$

Since $\overline{q}_{i_n} \geq \overline{q}_i$, the firm's rent unsurprisingly increases before the introduction of capture when the principal gives some importance to it. Her utility function is now

$$\widetilde{W}_n(\mu) = \widetilde{W}(\mu) + \alpha\nu\underline{U}_n(\mu). \tag{42}$$

This result no longer allows to prove Lemma 1 with these new conditions. However, for a sufficiently small α, $\widetilde{W}_n(\mu)$ still increases in μ. We therefore make the assumption that

Assumption 2. $\dfrac{\partial \widetilde{W}_n(\mu)}{\partial \mu} > 0, \forall \mu \in \left[\dfrac{1}{2}, 1\right]$.

In other words, it is still in the principal's best interest to obtain a more informative signal. It should be noted that since $\widetilde{W}(\mu)$ was obtained by maximizing social welfare for a given level of informativeness, using $\widetilde{W}_n(\mu)$ instead of $\widetilde{W}(\mu)$ can only decrease social welfare. With Assumption 2, the impact of the principal's new utility function can be observed.

Lemma 11. *If* $\widetilde{W}_n(1) - \widetilde{W}_n\left(\frac{1}{2}\right) \geq m$, *then* $\exists\ \tilde{\mu}_{1_n} \in [\tilde{\mu}_1, 1]$ *such that if* $\mu \geq \tilde{\mu}_{1_n}$, *the principal sets* $w = m$ *and the regulator transmits a signal. Otherwise, she sets* $w = 0$ *and the regulator is not used.*

Since $\frac{\partial[\widetilde{W}_n(\mu)-\widetilde{W}(\mu)]}{\partial\mu} < 0$, it follows that $\widetilde{W}_n(1) - \widetilde{W}_n\left(\frac{1}{2}\right) < \widetilde{W}(1) - \widetilde{W}\left(\frac{1}{2}\right)$, making the condition more restrictive and leading to $\tilde{\mu}_{1_n} > \tilde{\mu}_1$.[15] The space in which the principal prefers not to use the regulator increases. The intuition is that small informativeness gains have a lower impact on the principal's utility than in the base model. Paying the regulator's wage is therefore only profitable when the informativeness of his signal is important.

The change in the principal's utility function also affects the outcome when soft capture is introduced.

Lemma 12. *If* $\widetilde{W}_n\left(1 - \frac{x}{2}\right) - \widetilde{W}_n\left(\frac{1}{2}\right) \geq m$, *then* $\exists\ \tilde{\mu}_{2_n} \in \left[\tilde{\mu}_{1_n}, 1\right]$ *such that if* $\mu \geq \tilde{\mu}_{2_n}$, *the principal sets* $w = m$ *and the regulator transmits a signal. Otherwise, she sets* $w = 0$ *and the regulator is not used.*

Using the result $\frac{\partial[\widetilde{W}_n(\mu)-\widetilde{W}(\mu)]}{\partial\mu} < 0$, then $\widetilde{W}_n\left(1 - \frac{x}{2}\right) - \widetilde{W}_n\left(\frac{1}{2}\right) \leq \widetilde{W}\left(1 - \frac{x}{2}\right) - \widetilde{W}\left(\frac{1}{2}\right)$, making the condition more restrictive and leading to $\tilde{\mu}_{2_n} \geq \tilde{\mu}_2$. This result is analog to the previous one, the space in which the regulator is used decreases.

And with the addition of capture-proof contracts, inequation (23) must be updated.

$$\widetilde{w} - m \geq \widetilde{W}_n(\mu) - \widetilde{W}_n(\hat{\mu}). \tag{43}$$

As $\frac{\partial[\widetilde{W}_n(\mu)-\widetilde{W}(\mu)]}{\partial\mu} < 0$, $\widetilde{W}_n(\mu) - \widetilde{W}_n(\hat{\mu}) \leq \widetilde{W}(\mu) - \widetilde{W}(\hat{\mu})$, making the condition less restrictive. The space in which a capture-proof contract is preferred also decreases. This is reflected in the update of Lemma 7.

[15] The proof can be found in Appendix (A13).

Lemma 13. $If\ \widetilde{W}_n(1) - m > \widetilde{W}_n\left(1 - \frac{x}{2}\right), then\ \exists\ \tilde{\mu}_{3_n} \in [0,1]\ such\ that\ if\ \mu \geq \tilde{\mu}_{3_n}, the$ $principal\ sets\ up\ an\ incentive\ scheme\ to\ prevent\ soft\ capture\ and\ tolerates\ soft\ capture$ $if\ \mu < \tilde{\mu}_3. If\ \widetilde{W}(1) - m \leq \widetilde{W}\left(1 - \frac{x}{2}\right), the\ principal\ always\ tolerates\ soft\ capture.$

Just like above, $\frac{\partial[\widetilde{W}_n(\mu) - \widetilde{W}(\mu)]}{\partial\mu} < 0$ implies that the condition of Lemma 13 is stricter than in Lemma 7. Therefore, $\tilde{\mu}_{3_n} \geq \tilde{\mu}_3$ and, as stated above, the space in which a capture-proof contract is preferred decreases when the principal gives some importance to the firm's rent. Finally, Proposition 1 can be adapted.

Proposition 3. $There\ exists\ a\ non-empty\ set\ of\ values\ for\ \mu\ such\ that\ the\ principal$ $tolerates\ soft\ capture\ at\ the\ equilibrium\ if\ \tilde{\mu}_{2_n} < 1\ and\ one\ of\ the\ following$ $conditions\ holds\ true$:

$(a)\ \widetilde{W}_n(1) - m \leq \widetilde{W}_n\left(1 - \frac{x}{2}\right);$

$(b)\ \widetilde{W}_n(1) - m > \widetilde{W}_n\left(1 - \frac{x}{2}\right)\ and\ \widetilde{W}_n\left(\frac{1}{2}\right) > \widetilde{W}_n(\tilde{\mu}_{2_n}) - \frac{\tilde{\mu}_{2_n} m}{\tilde{\mu}_{2_n} - \frac{1}{2}}.$

If condition (a) holds true, the principal tolerates soft capture for $\mu \geq \tilde{\mu}_{2_n}$ and if condition (b) holds true, the principal tolerates soft capture for $\mu \in [\tilde{\mu}_2, \tilde{\mu}_3]$ and uses a capture-proof contract for $\mu \geq \tilde{\mu}_{3_n}$. The impact of the principal's update utility function on the space in which soft capture is tolerated in indeterminate. Indeed, $\tilde{\mu}_{2_n} < 1$ is a stronger condition with $\tilde{\mu}_{2_n} \geq \tilde{\mu}_2$ but condition (a) is weaker due to $\frac{\partial[\widetilde{W}_n(\mu) - \widetilde{W}(\mu)]}{\partial\mu} < 0$, as discussed for Lemma 13. In particular, $\tilde{\mu}_{2_n} \geq \tilde{\mu}_2$ and $\tilde{\mu}_{3_n} \geq \tilde{\mu}_3$, meaning that when the principal gives some importance to the firm's rent, the space in which the regulator is not used increases, the space in which the capture-proof contract decreases and the impact on the space in which soft capture is tolerated is indeterminate. From Lemma 12 and Lemma 13, the results of Corollary 1 stay true in this case.

3.5. Ex-post audit

Another possible extension is considering the possibility of an ex-post audit by an independent third party. Agrell and Gautier (2017) suggest the use of an external auditor, such as in Renouf and Balgi (2013), to offset the regulator's interest to always collude if possible (as discussed in section

3.1) and this section aims to test this intuition. The principal has here another option to deter capture, by having the regulator audited and punished if he colluded against her. This uses the same assumption as in Kofman and Lawarrée (1993) that the external auditor can only detect if the regulator fulfilled his mission and not the true cost parameter. The model is limited to stochastic verification, which has been shown to be the dominant strategy by Townsend (1979).

The principal therefore chooses a probability z with which the regulator is audited. This audit has a fixed cost $\tau > 0$, a probability of detecting collusion $d > 0$ when the regulator is captured and the maximum sanction that the principal can inflict a regulator who has been caught colluding is given by $s > 0$. Following the findings from Baron and Besanko (1984a), the principal always sets the sanction at s. This sanction is directly transferred to the principal and the parameter s already considers the possible inefficiencies discussed in section 2.4.

This section necessitates another assumption:

Assumption 3. $\textit{The principal chooses auditing because it prevents soft capture, not because the act of auditing itself gives a positive utility. In other words}: \tau - xsd > 0.$

If Assumption 3 were not respected, the principal would always fix $z = 1$, as auditing more frequently would always increase her utility. Which consequently makes this case of little interest and unrepresentative of the practical reality.

The risk of being audited discourages the regulator from colluding when

$$zsd \geq m. \tag{44}$$

The principal therefore fixes $z = \frac{m}{sd}$. When using the ex-post audit, the principal's utility becomes

$$\widetilde{W}(\mu) - m - \frac{m}{sd}\tau + x\frac{m}{sd}sd = \widetilde{W}(\mu) - m - \frac{m}{sd}\tau + xm. \tag{45}$$

Without considering at first capture-proof contracts, the principal prefers to use ex-post auditing rather than to tolerate capture when

$$\widetilde{W}(\mu) - m - \frac{m}{sd}\tau + xm \geq \widetilde{W}(\hat{\mu}) - m. \tag{46}$$

This simplifies to

$$\widetilde{W}(\mu) - \widetilde{W}(\hat{\mu}) \geq \frac{m}{sd}\tau - xm. \tag{47}$$

Given the convexity of $\widetilde{W}(\mu)$ from Lemma 1, $\widetilde{W}(\mu) - \widetilde{W}(\hat{\mu})$ is increasing in μ. This allows to give an alternative to Lemma 7.

Lemma 14. $If\ \widetilde{W}(1) - \frac{m}{sd}\tau - xm > \widetilde{W}\left(1 - \frac{x}{2}\right), then\ \exists\ \tilde{\mu}_3{}' \in [0,1]\ such\ that\ if\ \mu \geq \tilde{\mu}_3{}',$ *the principal uses an external audit to prevent soft capture and tolerates soft capture if* $\mu < \tilde{\mu}_3. If\ \widetilde{W}(1) - m \leq \widetilde{W}\left(1 - \frac{x}{2}\right), the\ principal\ always\ tolerates\ soft\ capture.$

The parametric effects on the space in which the ex-post audit is preferred are intuitive. A higher probability to detect and a higher possible sanction increase the space in which the ex-post audit is preferred to tolerating soft capture, while a higher auditing cost decreases it. Adding the possibility of a capture-proof contract, Lemma 7 is updated.

Lemma 15. $If\ \widetilde{W}(1) - m > \widetilde{W}\left(1 - \frac{x}{2}\right)\ or\ if\ \widetilde{W}(1) - \frac{m}{sd}\tau - xm > \widetilde{W}\left(1 - \frac{x}{2}\right), then$ $\exists\ \tilde{\mu}_{3_a} \in [0, \tilde{\mu}_3]\ such\ that\ if\ \mu \geq \tilde{\mu}_{3_a}, the\ principal$ *prevents soft capture and tolerates soft capture if* $\mu < \tilde{\mu}_{3_a}. If\ \widetilde{W}(1) - m \leq \widetilde{W}\left(1 - \frac{x}{2}\right) and\ if\ \widetilde{W}(1) - \frac{m}{sd}\tau - xm > \widetilde{W}\left(1 - \frac{x}{2}\right), the$ $principal\ always\ tolerates\ soft\ capture.$

Having both options increases the space in which the principal establishes a capture preventing mechanism and therefore reduces the space in which capture is tolerated. This can be seen in Figure 8. In particular, $\tilde{\mu}_{3_a} = min\{\tilde{\mu}_3, \tilde{\mu}_3{}'\}$. The principal prefers the ex-post audit to the capture-proof contract if

$$\widetilde{W}(\mu) - m - \frac{m}{sd}\tau + xm \geq \widetilde{W}(\mu) - \widetilde{w}. \tag{48}$$

Which simplifies to

$$\widetilde{w} \geq (1 - x)m + \frac{m}{sd}\tau. \tag{49}$$

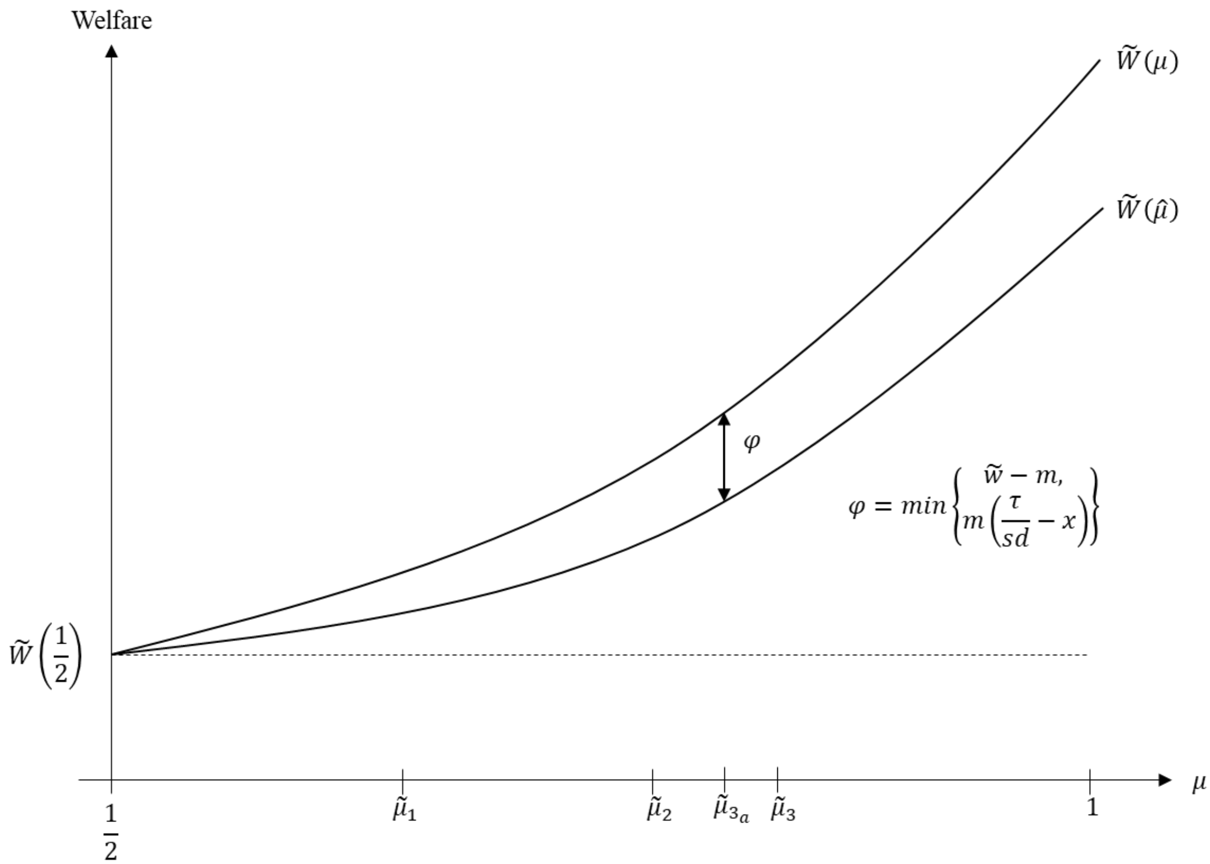

Figure 8. Soft capture prevention using ex-post auditing and capture-proof contracts

Using Lemma 6, this gives

$$\frac{\mu}{\mu - \frac{1}{2}} \geq 1 - x + \frac{\tau}{sd}. \tag{50}$$

Aside from the obvious result that the principal prefers the ex-post audit when its cost is low, its detection rate is high and its associated sanction is high, three other observations can be made[16]. The ex-post audit is preferred when (a) the informativeness of the regulator's signal is low; (b) the probability for the regulator to transmit a noisy signal is high. Additionally, the principal never chooses both the ex-post audit and the capture-proof contract. Given the structure of inequation (50), there is always one option that dominates the other for a given level of informativeness μ. Result (a) comes from the incentive-scheme that the principal creates for the capture-proof

[16] See Appendix (A14) for the proof.

contract. The regulator's wage $\widetilde{w}$ decreases with the informativeness of his signal and therefore, all other things being equal, an increase in the signal's informativeness decreases the benefit of the ex-post audit option relatively to the capture-proof contract. Observation (b) is the confirmation of the intuition that an ex-post audit is a good option when the probability of the regulator transmitting a noisy information is high. In particular, this confirms Agrell and Gautier's (2017) result that an ex-post audit is an adequate tool to combat soft capture when the probability x of the firm creating a noisy signal is endogenous. Furthermore, this creates a counterweight to the observation made in section 3.1 that emitting a noisy signal with a high probability, rather than emitting complete white noise with a lower probability, makes capture prevention through contracts more costly. The condition for which x has an impact on the choice to use the ex-post audit or not is given by

Lemma 16. *If* $\frac{\mu}{\mu-\frac{1}{2}} \in \left]\frac{\tau}{sd}, 1+\frac{\tau}{sd}\right[$, *there exists* $x_a \in]0,1[$ *such that if* $x \geq x_a$, *the principal prefers to use a random audit of the regulator to prevent capture. If* $x < x_a$, *the principal prefers to use a capture proof contract.*

Lemma 16 reflects the two main results from above. When the informativeness of the signal is particularly low, the principal always prefers the ex-post audit. If the informativeness of the signal is particularly high, she always prefers the capture-proof contract. For an intermediary signal quality, the decision depends on the probability of capture x.

Proposition 1 can now be updated.

Proposition 4. *There exists a non-empty set of values for* μ *such that the principal tolerates soft capture at the equilibrium if* $\tilde{\mu}_2 < 1$ *and one of the following conditions holds true*:

$(a)\ \widetilde{W}(1) - m \leq \widetilde{W}\left(1-\frac{x}{2}\right)$ *and* $\widetilde{W}(1) - \left(1-x+\frac{\tau}{sd}\right)m \leq \widetilde{W}\left(1-\frac{x}{2}\right)$;

$(b)\ \widetilde{W}(1) - m > \widetilde{W}\left(1-\frac{x}{2}\right), \widetilde{W}\left(\frac{1}{2}\right) > \widetilde{W}(\tilde{\mu}_2) - \frac{\tilde{\mu}_2 m}{\tilde{\mu}_2 - \frac{1}{2}}$

and $\widetilde{W}\left(\frac{1}{2}\right) > \widetilde{W}(\tilde{\mu}_2) - \frac{\tilde{\mu}_2\left(1-x+\frac{\tau}{sd}\right)m}{\tilde{\mu}_2 - \frac{1}{2}}$.

Conditions (a) and (b) are both made more restrictive through the additional condition, which means that the space in which capture in tolerated is unambiguously reduced by the introduction of the ex-post audit option. In particular, if condition (b) holds true, the principal tolerates soft capture for $\mu \in [\tilde{\mu}_2, \tilde{\mu}_{3_a}]$ and uses a capture-proof mechanism for $\mu \geq \tilde{\mu}_{3_a}$. Since $\tilde{\mu}_{3_a} \leq \tilde{\mu}_3$ from Lemma 15, $[\tilde{\mu}_2, \tilde{\mu}_{3_a}]$ is smaller than $[\tilde{\mu}_2, \tilde{\mu}_3]$. Reusing Corollary 1, a last observation can be made:

Corollary 2. $If\ the\ probability\ x\ of\ producing\ a\ white\ noise\ signal\ increases, then\ the\ parameter\ space\ in\ which\ the\ principal\ tolerates\ soft\ capture\ decreases.$ $Furthermore, the\ introduction\ of\ the\ external\ audit\ accentuates\ this\ phenomenon.$

This again confirms the previous results that the ex-post audit is particularly well-suited to prevent soft capture when x is exogenously high or endogenous[17].

3.6. Dynamic model

The final extension to the soft capture model presented in this master's thesis is the consideration of a dynamic game. All the previous results are considering a static setting, but in practice, the principal may use the regulator more than once. In this case, it is irrelevant whether the agent remains the same or not, the important aspect is the relation between the principal and the regulator. This extension uses the findings and notations from the ex-post audit extension from section 3.5.

When limiting the principal to capture-proof contracts, each time period in the static game is played the same way as in the static model. Indeed, the regulator does not need to worry about the principal's reaction to any collusion since the principal cannot observe it. This changes when the ex-post audit is considered. In this case, the regulator not only faces a sanction s when the auditor discovers that he has colluded against the principal, he is also fired and loses any future income from his regulatory position. This was not explicitly stated in section 3.5 since getting fired had no influence on the regulator's utility. The problem of using the ex-post audit as presented in section 3.5 is that the principal sets $w = m$ and the utility of future regulatory employment is therefore equal to zero for a regulator that cannot collude. The solution is to set $w \in]m, \tilde{w}[$ while using an ex-post audit. The value that the regulator gives to his future employment in period i is given by $\delta^i(w - m)$ where $\delta \in]0,1[$ is an actualization factor. The principal then selects an audit

[17] The proof of Corollary 2 can be found in Appendix (A15).

probability z_i for each time period i. From here on out, we will refer to this option to prevent capture as dynamic auditing. In this section, we consider the two extreme cases of an infinite time horizon and a two-period game. As in Baron and Besanko (1984b), the results can be generalized to any number of time periods, which will be discussed in the end of the section.

3.6.1. Infinite time horizon

Starting with the infinite horizon model, the regulator prefers not to collude against the principal when

$$z_i d\left\{s + \sum_{i=0}^{\infty}\left[\delta^i (w - m)\right]\right\} \geq m. \tag{51}$$

In other words, when the risk of getting detected exceeds the benefit of colluding against the principal. Using $\delta < 1$, the principal sets

Lemma 17. $z_i = \dfrac{m}{d\left(s + \frac{w-m}{1-\delta}\right)} < z \ \forall i.$

For $\delta \in \,]0,1[$ and $w > m$, z_i is smaller than z from section 3.5.[18] This means there is a tradeoff for the principal between paying a higher wage and needing to finance an audit less often. The principal prefers the dynamic audit to tolerating soft capture when

$$\widetilde{W}(\mu) - w - \frac{m(\tau - xsd)}{d\left(s + \frac{w-m}{1-\delta}\right)} \geq \widetilde{W}(\hat{\mu}) - m. \tag{52}$$

Furthermore, the principal will prefer the dynamic audit option to the repeated static audit if

$$\widetilde{W}(\mu) - w - \frac{\tau m}{d\left(s + \frac{w-m}{1-\delta}\right)} + \frac{xmsd}{d\left(s + \frac{w-m}{1-\delta}\right)} \geq \widetilde{W}(\mu) - m - \frac{m}{sd}\tau + xm. \tag{53}$$

Which is equivalent to

$$\frac{(1-x)sd + \tau}{s} - w\frac{d}{m} \geq \frac{(\tau - xsd)}{s + \frac{w-m}{1-\delta}}. \tag{54}$$

[18] The proof is shown in appendix (A16).

Using Assumption 3, the term on the right hand-side is always positive[19]. Furthermore, there exists $\varepsilon > 0$ such that the term on the left hand-side is negative for $x = \frac{\tau}{sd} - \varepsilon$.[20] Finally, the term on the left hand-side increases quicker with x than the term on the right hand-side[21]. By combining these three observations, this gives

Lemma 18. $\exists x_1 < \dfrac{\tau}{sd}$ *such that if* $x \leq x_1$, *the principal prefers to pay the regulator* $w > m$ *and audit him with frequency* $\dfrac{m}{d\left(s + \frac{w-m}{1-\delta}\right)}$. *Otherwise, the principal prefers to pay the regulator* $w = m$ *and audit him with frequency* $\dfrac{m}{sd}$.

This means that when probability of capture is low enough, the savings associated with a less frequent audit outweigh the losses due to a higher regulator wage.

And similarly, the principal will prefer the dynamic audit to the static capture-proof contract if

$$\widetilde{W}(\mu) - w - \frac{\tau m}{d\left(s + \frac{w-m}{1-\delta}\right)} + \frac{xmsd}{d\left(s + \frac{w-m}{1-\delta}\right)} \geq \widetilde{W}(\mu) - \widetilde{w}. \tag{55}$$

Which can be rewritten as

$$\frac{m(\tau - xsd)}{d\left(s + \frac{w-m}{1-\delta}\right)} \leq \widetilde{w} - w. \tag{56}$$

It is straightforward to see that the term on the left hand-side is equal to zero when $x = \frac{\tau}{sd}$ and that it is decreasing in x.[22] Therefore

Lemma 19. $\exists x_2 \geq 0$ *such that if* $x \geq x_2$, *the principal prefers to pay the regulator* $w > m$ *and audit him with frequency* $\dfrac{m}{d\left(s + \frac{w-m}{1-\delta}\right)}$. *Otherwise, the principal prefers to pay the regulator* $\widetilde{w}$ *and to not audit him.*

[19] See Appendix (A17) for the proof.
[20] The proof is presented in Appendix (A18).
[21] As shown in Appendix (A19).
[22] Appendix (A20) shows that inequations (55) and (56) are equivalent.

It is possible that the principal never selects the capture-proof contract, i.e. $x_2 = 0$. At $x = 0$, the principal prefers the capture-proof contract if $\tau > \frac{d(\tilde{w}-w)\left(s+\frac{w-m}{1-\delta}\right)}{m}$.[23] If τ is small enough, this condition is never fulfilled and the principal always prefers the dynamic audit to the capture-proof contract. Lemma 19 means that when the probability of capture is high enough, the savings associated with a lower wage exceed the costs of auditing.

Reusing the finding from Lemma 16 and combining the results from Lemma 18 and 19, dynamic auditing in an infinite horizon game is characterized by

$\mathbf{Lemma\ 20}.\ If\ \frac{\mu}{\mu-\frac{1}{2}} \in \left]\frac{\tau}{sd}, 1+\frac{\tau}{sd}\right[, there\ exists\ a\ non-empty\ set\ of\ values\ [x_2, x_1]$ $such\ that\ the\ principal\ prefers\ capture-proof\ contracts\ if\ x < x_2, she\ selects$ $repeated\ static\ auditing\ if\ x > x_1\ and\ the\ dynamic\ audit\ option\ is\ preferred\ if$ $x \in [x_2, x_1]$.

This refines the outcome from Lemma 16, in the sense that when the informativeness of the signal is such that the choice between capture-proof contracts and repeated static auditing depends on the probability of capture, dynamic ex-post auditing is an intermediary solution and is preferable to the other two for some level of capture probability[24].

This allows us to update Proposition 4:

$\mathbf{Proposition\ 5}.\ There\ exists\ a\ non-empty\ set\ of\ values\ for\ \mu\ such\ that\ the\ principal$ $tolerates\ soft\ capture\ at\ the\ equilibrium\ if\ \tilde{\mu}_2 < 1\ and\ one\ of\ the\ following$ $conditions\ holds\ true$:

$(a)\ \widetilde{W}(1) - m \leq \widetilde{W}\left(1-\frac{x}{2}\right), \widetilde{W}(1) - \left(1 - x + \frac{\tau}{sd}\right)m \leq \widetilde{W}\left(1-\frac{x}{2}\right)\ and$

$$\widetilde{W}(1) - \left[\frac{\tau - xsd}{d\left(s+\frac{w-m}{1-\delta}\right)} - 1\right]m - w \leq \widetilde{W}\left(1-\frac{x}{2}\right);$$

[23] Even though it makes no difference in practice since there is no capture to worry about at $x = 0$.
[24] Lemma 20 is proven in Appendix (A21).

$$(b)\ \widetilde{W}(1) - m > \widetilde{W}\left(1 - \frac{x}{2}\right), \widetilde{W}\left(\frac{1}{2}\right) > \widetilde{W}(\tilde{\mu}_2) - \frac{\tilde{\mu}_2 m}{\tilde{\mu}_2 - \frac{1}{2}},$$

$$\widetilde{W}\left(\frac{1}{2}\right) > \widetilde{W}(\tilde{\mu}_2) - \frac{\tilde{\mu}_2\left(1 - x + \frac{\tau}{sd}\right)m}{\tilde{\mu}_2 - \frac{1}{2}}\ and$$

$$\widetilde{W}\left(\frac{1}{2}\right) > \widetilde{W}(\tilde{\mu}_2) - \frac{\tilde{\mu}_2\left\{\left[\frac{\tau - xsd}{d\left(s + \frac{w-m}{1-\delta}\right)} - 1\right]m + w\right\}}{\tilde{\mu}_2 - \frac{1}{2}}.$$

This new version looks very notation-heavy but the takeaway is the same as for Proposition 4. Conditions (a) and (b) both being more restrictive means that the space in which capture is tolerated further decreases. This means that the possibility to use dynamic auditing makes the scope for soft regulatory capture narrower.

3.6.2. Two time periods

We now consider the case in which there are only two time periods. In the two-period game, z_i is no longer the same for all i. Indeed, for dynamic auditing to prevent soft capture, the principal needs to set z_i such that

$$z_1[sd + \delta(w - m)] \geq m, \tag{57}$$

$$z_2 sd \geq m. \tag{58}$$

The principal chooses z_i such that those conditions are binding, giving $z_1 = \frac{m}{sd+\delta(w-m)} > z$ and $z_2 = \frac{m}{sd} = z$. The principal's utility when preventing capture with dynamic auditing in the two-period setting can now be compared to her utility in any two periods of the infinite horizon game. This gives respectively for the two-period setting and the infinite horizon setting

$$2\widetilde{W}(\mu) - 2w - \tau(z_1 + z_2) + xsd(z_1 + z_2), \tag{59}$$

$$2\widetilde{W}(\mu) - 2w - 2\tau z_i + 2z_i xsd. \tag{60}$$

And the comparison of the two gives

$$2\widetilde{W}(\mu) - 2w - \tau(z_1 + z_2) + xsd(z_1 + z_2) < \widetilde{W}(\mu) - 2w - 2\tau z_i + 2z_i xsd. \tag{61}$$

This result means that preventing soft capture with dynamic auditing is always more costly in the two-period setting than in the infinite horizon setting[25]. In other words, dynamic auditing is always used less when the regulatory game is played in two periods than when it is played in an infinite number of periods. It can easily be demonstrated, as in Baron and Besanko (1984b), that increasing the time horizon makes the result tend to those obtained in the infinite time horizon. Increasing the time horizon therefore makes dynamic auditing more appealing and since dynamic auditing decreases the space in which soft capture is tolerated, this allows us to conclude:

Lemma 21. *Increasing the time horizon during which the principal and the regulator interact decreases the space in which soft capture is tolerated.*

In other words, Lemma 21 states that a longer interaction between the principal and the regulator is a favorable outcome for the principal. She should therefore, when given the choice, favor working with the same regulator continuously over dealing with different regulators.

[25] The proof is shown in Appendix (A22).

4. Results

In this section, we will relist and explicit the main findings from the base model developed by Agrell and Gautier (2017) and each extension presented in this master's thesis, in particular how they affect decisions by the players.

4.1. Soft capture

In the base model, Agrell and Gautier consider a three-layer hierarchy in which the principal faces a firm that can be efficient or inefficient and whose efficiency type is its private information. The principal uses a regulator as an intermediary to obtain better information about the efficiency state of the firm by producing a signal with a certain level of informativeness. The firm is then tempted to offer a noisy signal to the regulator to protect its information rent. When the regulator transmits this noisy signal to the principal instead of producing his own, he is said to be softly captured by the agent.

Agrell and Gautier show that there exists an equilibrium in which the principal prefers to tolerate soft capture rather than dismiss the regulator or to create a capture-proof contract. This decision is made on the basis of the informativeness of the regulator's signal, a very informative signal will lead to a capture-proof contract and a very poorly informative signal will lead to not using the regulator. The informativeness of the signal is decisive because it increases the principal's utility and, at the same time, decreases the cost of creating a capture-proof contract. Preventing capture is indeed costly and all the more so as the informativeness of the signal is poor. Additionally, a higher probability for the regulator to be captured decreases the space in which soft capture is tolerated. Finally, Agrell and Gautier prove that adding the possibility of monetary bribes (as done in classical capture models) increases the cost of preventing capture. Therefore, the space in which capture is tolerated increases.

4.2. Shutdown

In the first extension, we consider the possibility for the principal to shut down an inefficient firm, as in Laffont and Tirole (1991). This can be done in practice for any interaction in which not contracting with a firm of the inefficient type is possible. While this is typically not the case for a political principal dealing with a natural monopoly, this condition can hold true in other settings. In this case, the regulator is no longer needed by the principal when she opts to shut down an inefficient firm, as the efficient firm no longer has any information rent left to extract. The ability to fully extract the information rent of the efficient firm comes at the cost of losing the ability to profit of the inefficient firm. Therefore, the principal's decision to shut down is dependent on the probability to encounter an efficient (respectively inefficient) firm. When this probability increases (respectively decreases), it is more interesting for the principal to use the shutdown. The decision to use the shutdown or not also depends on the informativeness of the regulator's signal, as long as the distribution of efficient and inefficient firms is relatively balanced. When the distribution of efficient and inefficient firms is extremely unbalanced, the choice to shut down or not is independent from the regulator's signal informativeness. But when this distribution is fairly balanced, a more informative signal increases the interest of capture-proof contracts relatively to the shutdown option.

Considering the possibility of a shutdown decreases the space in which soft capture is tolerated. This means that it may be a tool at the disposal of the principal to prevent soft capture. It should however be noted that the rationale to prefer a shutdown rather than to tolerate capture does not consider all the consequences of a shutdown, especially if the principal is considered as a benevolent legislator. Indeed, it does not consider that employees of a firm that has been shut down will be worse off without an employment and that their situation also contributes to social welfare. It is nevertheless an option that can be considered by the principal to improve her position.

4.3. Capture aversion

The second extension introduces the idea of capture aversion on the regulator's part, as proposed by Becker and Stigler (1974). We introduce the assumption that the regulator has a constant loss of utility when he colludes against the principal. As long as this constant is smaller than the cost of producing a signal, this has no effect on the outcome before introducing capture-proof contracts. In other words, the regulator continues to collude at the same rate even if he benefits less from it than before. But when introducing capture-proof contracts, this capture aversion has the effect of decreasing the wage that the principal needs to pay the regulator to prevent soft capture. Preventing capture being less costly, this decreases the space in which capture is tolerated by the principal.

We also consider the possibility of the regulator being "honest" (as in the last paragraph) or "dishonest" (as in the Agrell and Gautier's model) with a certain probability. The principal can now prevent capture for both types, tolerate capture for both types or only tolerate a dishonest regulator being captured. The first option is preferred when the informativeness of the regulator's signal is high, when the probability for the regulator to be dishonest is high and when the utility cost of collusion for the honest regulator is low. The second option is preferred when the informativeness of the regulator's signal is low, when the probability for the regulator to be dishonest is high and when the utility cost of collusion for the honest regulator is low. This means that the principal will only tolerate a dishonest regulator to be captured when the probability for the regulator to be dishonest is low and when the utility cost of collusion for the honest regulator is high. Indeed, a higher proportion of honest regulators makes the wage reduction more interesting for the principal, because it is more frequent, and a higher degree of honesty increases this wage difference. We suggest that this consideration of the regulator's personal preferences brings the result closer to the practical reality. Without it, a regulator being captured is only a question of opportunity and is independent of the characteristics of the regulator, except for his professional ability (represented by the informativeness of his signal). However, one's choice to collude is strongly dependent on one's personal preferences. This could be further extended by considering a continuous distribution of capture aversion instead of a binary model.

4.4. Non-benevolent principal

In the third extension, the focus is on the principal's preferences. In particular, we suppose that principal's utility depends on social welfare and, to a lesser degree, on the firm's rent, as opposed to Agrell and Gautier's (2017) model where it only depends on social welfare. As suggested by Stigler (1971), this can be viewed as a political principal seeking support from both the public at large and the industry to achieve her political goals. The principal can therefore no longer be considered as benevolent since her objective is no longer solely to improve social welfare. Before introducing the capture-proof contract, the first result is that the space in which the regulator is not used increases. Indeed, informativeness is less valuable than in the base model and the regulator's signal must therefore provide more information to justify his wage. When introducing capture-proof contracts, the result is that the space in which the principal prefers to use a capture-proof contract decreases. The interpretation is the same as before, information becomes less valuable and the principal is therefore not willing to pay as much for it as she did in the base model. The effect of the principal's new preferences on the space in which soft capture is tolerated is indeterminate, while social welfare decreases. It is however apparent that the aforementioned space continues to be non-empty, just as in the base model. Soft capture is therefore also a concern for non-benevolent principals as long as they value social welfare more than industry profit.

4.5. Ex-post audit

The fourth extension is based on the idea of an ex-post audit, another tool for the principal to deter capture. The ex-post audit can only detect if the regulator has been colluding, it cannot provide a better signal than the one produced or transmitted by the regulator. This is because the target of the audit is the regulator, not the firm. The audit itself must be costly: the principal's reason for commissioning an audit is to prevent capture, and not because she expects to receive more money through the sanctions she imposes than what she pays to have the audit conducted. Otherwise, the principal's best move would be to always audit the regulator and the prevention of soft capture would be a happy side effect.

With the principal having both the capture-proof contract and the ex-post audit at her disposal, the space in which capture is tolerated decreases. The reason is that the cost of tolerating capture must now be lower than each the additional regulator wage from the capture-proof contract and the cost of the audit. The principal prefers the ex-post audit to the capture-proof contract when the probability of receiving a noisy signal is high and the informativeness of the signal is low. In fact, the principal has no reason in the static setting to use both tools at the same time, as there is always one that is better than the other for a given level of signal informativeness and collusion probability. Ex-post auditing being more advantageous when facing a high probability of collusion makes it a particularly well-adapted tool to prevent capture when the probability for the firm to offer the regulator a noisy signal is endogenous or exogenously high. We also show that the probability of capture only affects the choice between ex-post audits and capture-proof contracts for intermediary levels of signal informativeness. When the signal is particularly (un)informative, the principal's choice between the two options depends solely on the informativeness of the signal. The possibility of an ex-post audit reduces the space in which soft capture is tolerated, the principal is therefore better off by having more options. A more noteworthy result is that the probability for the regulator to be captured decreases the space in which soft capture is tolerated faster than in the base model. This comes back to the point that ex-post auditing is particularly suitable for preventing capture when the probability for the firm to offer the regulator a noisy signal is endogenous or exogenously high.

4.6. Dynamic auditing

The last extension is the consideration of a dynamic setting with ex-post auditing, i.e. repeated interactions between the principal and the regulator. The fact that they deal with the same agent or not is irrelevant. This assumption may not always be verified in practice, as regulators may be easier influenced by agents with whom they have a longer relationship, as discussed in section 2.4. The advantage for the principal in a multi-period game is that the regulator not only faces a financial sanction when caught colluding, but he also loses all utility from future employment. A result from the static ex-post audit model was that the regulator's wage is set at the cost incurred to produce a signal. In order to make the regulator's job loss more painful for him, the principal can opt for a dynamic auditing strategy that consists of both a higher wage than the regulator's costs to produce a signal and an ex-post audit. We consider the two cases of an infinite time horizon and a two-period game.

In the infinite time horizon, the probability of auditing the regulator that is required to prevent capture is lower than in the static auditing model. Consequently, there is a tradeoff for the principal between paying a higher wage to the regulator and needing to audit him less frequently. When the probability of capture is low enough, the latter outweighs the former and dynamic auditing is preferable to static auditing. Inversely, for a high probability of capture, dynamic auditing is preferable to capture-proof contracts. It can therefore be seen as an intermediary solution between capture-proof contracts and ex-post audits that leave no utility to the regulator. Just as for the static ex-post audit model, the probability of capture only affects the principal's choice for intermediary signal informativeness. When the signal is particularly (un)informative, the principal's choice depends solely on the informativeness of the signal. Introducing dynamic auditing as a third option to prevent capture further decreases the space in which soft capture is tolerated by the principal.

In the two-period game, preventing soft capture through dynamic auditing is always more costly than in the infinite horizon setting, making dynamic auditing used less frequently. Increasing the time horizon makes the result tend to those of the infinite time horizon. This means that increasing the time horizon makes dynamic auditing more appealing and is therefore always better for the principal. Indeed, increasing the time horizon decreases the space in which soft capture is tolerated. This means that if the time horizon of the interactions between the principal and the regulator can be influenced by the principal, it is always in her best interest to extend it and to continue to use the same regulator over time. Longer terms being a tool to prevent capture is another result that is shared with the minimal squawk theory, just like the findings from Agrell and Gautier's (2017) base model.

4.7. Implications

Given the results from sections 4.1 to 4.6, some implications can be drawn for the regulatory setting.

Preventing capture is costly for the principal. This is the main reason for which capture can be tolerated at the equilibrium. One solution to limit this phenomenon is to improve the principal's situation when she decides not to use the regulator, such as done in the shutdown extension. This also holds true when the principal has better a priori information. The other solution is to reduce the cost of preventing capture. This can simply be done by having multiple tools at the disposal of the principal: capture-proof contracts, ex-post audits or what is referred to in section 3.6 as dynamic auditing. By having different tools at her disposal, the principal can more easily prevent capture by adapting her actions to the particular setting she is facing.

Additionally, preventing capture becomes less costly and the benefice of preventing it increases at the same time when the informativeness of the regulator's signal increases. This means that a skilled regulator is particularly important when facing the threat of soft capture. Based on this, it should be in the public interest to have skilled professionals in public offices. This does however not consider the fact that better professionals have better opportunities in the private sector, which is discussed in section 5. As better performance (without considering noisy signals) does not lead directly to a better wage, the incentives for skilled regulators to remain in the public sector are poor. This is also reflected in Melly's (2005) empirical analysis of the German public sector, as the public sector wage premium decreases when moving up the wage distribution.

When considering different levels of honesty among regulators, dishonest regulators are always at least as well off as honest regulators. This would suggest that when an alternative possibility of employment in considered (as discussed in section 5), honest regulators may be driven out of the public sector until the proportion of dishonest regulators forces the principal to not differentiate between different levels of honesty in his capture-proof contract[26]. So, a new regulatory agency would retain dishonest regulators better than honest regulators until reaching a critical level of dishonest regulators. To stop this phenomenon, it would be in the principal's best interest to try to obtain information about the regulators' true type, as suggested by Becker and Stigler (1974).

For non-benevolent principals, a key takeaway is that they always use the regulator less often than their benevolent counterparts. It might therefore be socially desirable to take this decision out of the principal's hands, at least partially. This idea is for example reflected in laws that prevent elected officials from contracting directly with private firms, in order to prevent the prevalence of special interests. While it is typically not the case for public firms that might still need to be regulated, the results from section 3.4 suggest that the rate at which a legislator uses professional expertise is a proxy for the importance that she gives to social welfare.

The result that ex-post auditing is particularly well-suited to prevent capture when the probability of the agent to offer a noisy signal is high (cf. section 4.5) also has practical implications. As discussed by Agrell and Gautier (2017), this probability depends on the characteristics of the firm or the industry, such as the existence of industry lobbying for example. Ex-post auditing should therefore be observed more often for regulated industries that have better means to produce noisy signals. This would for example be the case for the financial sector, whose dedicated European think-tank *Eurofi* holds two yearly events to influence financial regulation (Brundsen & Barker, 2019).

Finally, the result that longer regulatory terms allow to prevent soft capture at a lower cost is consistent with the findings of other theories dealing with regulatory capture, such as the revolving doors and minimal squawk. Therefore, the findings of a positive correlation between regulatory terms of office and harder regulatory decision making from Leaver's (2009) empirical study seem to be a logical consequence if soft capture is at play.

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[26] Even though honest regulators profit from the presence of dishonest regulators, as a high probability for the regulator to be dishonest makes it less interesting for the principal to only deter the capture of honest regulators. In other words, having more dishonest colleagues increases the honest regulator's pay.

5. Conclusion

Soft regulatory capture is a promising theory to give an alternative explanation of regulatory capture to the classical theory without needing strong assumptions such as enforceable side contracts. Soft capture is self-enforcing and can explain the lack of evidence of bribes or revolving door favors.

Two illustrative examples of soft capture are presented by Agrell and Gautier (2012a; 2012b): the Occupational Safety and Health Administration in the USA and European energy regulation. In particular in the second case, it is highly apparent that soft capture can initiate from the complexity of a regulatory setting, which is coherent with findings such as those from Hakenes and Schnabel (2013).

In this master's thesis, we presented different extensions to the soft capture model, based on those already applied to classical regulatory capture. In particular, we showed that capture can be more easily prevented when considering the possibility of a shutdown, different levels of regulator honesty, ex-post audits and dynamic settings. These options all lead to better social welfare, while having a principal with personal interests leads to worse social welfare.

The results from this master's thesis are however subject to some limitations. First, many parameters that are considered exogeneous may in fact be endogenous. For example, the probability with which the regulator and the agent collude. Or the probability to detect collusion may very well depend on the degree of noise in the regulator's signal: the regulator could hide his collusion more efficiently if the signal he transmits is still relatively informative. Secondly, it is considered in the model that the players have no alternative outside this three-layer hierarchy. Or more precisely, that their alternatives are independent of their type (such as the honesty of the regulator for example). This seems unlikely in practice and certain results, such as regulators offering a better signal needing to be paid less to prevent capture (as it is easier for the principal to prevent capture through capture-proof contracts), must therefore be challenged. Third, different parameters, as the firm's cost, are considered binary for simplicity of notation. It is however quite apparent that a firm cannot simply be categorized as efficient or inefficient, there exists a great deal of intermediary possibilities. While the core results presented in this master's thesis still hold true in continuous settings, considering this possibility can add some finesse to the analysis. Similarly, the informativeness of the regulator's signal is considered symmetric but it may be asymmetric in practice. Fourth, a great deal of information is supposed to be common knowledge, such as the probability of capture. However in practice, the principal has, at best, a vague estimate of this probability but does not know it with exactitude. This means that econometric models that predict behavior changes cannot consider exact values as done in theory but must focus on global trends derived from the results of this theoretical model.

There still exist many extensions that have been proposed to the classical regulatory capture model and that could offer interesting opportunities to further refine the soft capture theory. One possibility is to use models where the agent's effort impacts his level of efficiency such that the principal must in addition worry about enticing effort from the agent. Another is to consider multiple players on the same layer, such as multiple agents that compete to capture the regulator for different reasons, which is the premise of interest groups theory, or different regulators (e.g. sectoral regulators in addition to a main regulatory agency). A second possible change to the three-layer hierarchy is to add another layer, which can be thought of as the relationship between the principal and a supranational authority, whose objectives may not be perfectly aligned. The middleman having a stake in the regulatory outcome may also be used, as it is done in the advocacy theory. In other words, seeing how an advisor (with a certain level of bias) can exert effort to obtain information when soft capture is at play and seeing how it affects the space in which capture is tolerated. Different levels of skill among regulators could also be considered, with the distribution of the informativeness of the regulator's signal being dependent on his skill level.

Nevertheless, the main necessity for the soft capture is empirical confirmation. To our knowledge, very few studies have been realized to test the results obtained from the soft capture model. This calls for research to verify and challenge these results, in order to better understand the practical impact of soft capture. The characteristics of the soft capture theory and the relevance that regulatory compliance has in modern society make it an important field to further expand.

Appendix

Appendices (A1) through (A8) come directly from Agrell and Gautier (2017).

(A1) Proof that $S'''(q) > 0$ is a sufficient condition Assumption 1

From (11),

$$\frac{\partial \overline{q}_1}{\partial \mu} = \frac{\nu \Delta\theta}{S''(q_1)(1-\nu)(1-\mu)^2} < 0,$$

$$\frac{\partial \overline{q}_2}{\partial \mu} = -\frac{\nu \Delta\theta}{S''(q_2)(1-\nu)\mu^2} > 0.$$

With $\mu \geq \frac{1}{2}$, a sufficient condition for Assumption 1 is

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

Which can be simplified to

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

With $\mu \in \left[\frac{1}{2}, 1\right]$, the left term is always ≥ 1. $S'''(q) \geq 0$ therefore satisfies the condition as $\overline{q}_1 \leq \overline{q}_2$ from (10) and (11).

(A2) Proof of Lemma 1

Given that $\frac{\partial \widetilde{W}}{\partial \underline{q}_i} = 0$,

$$\frac{\partial \widetilde{W}(\mu)}{\partial \mu} = \left[S(\overline{q}_2) - \overline{\theta}\overline{q}_2\right] - \left[S(\overline{q}_1) - \overline{\theta}\overline{q}_1\right].$$

Since $S(\overline{q}) - \overline{\theta}\overline{q}$ increases in q and $\overline{q}_1 < \overline{q}_2$, this is positive, proving that $\widetilde{W}(\mu)$ increases in μ. Furthermore,

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

From equation (11), this gives

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

Which is positive, proving that $\widetilde{W}(\mu)$ is convex.

(A3) Proof of Lemma 3

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

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

Given that $\mu > \frac{1}{2}$, the partial derivative of $\tilde{\nu}_1$ is negative and the partial derivative of $\tilde{\nu}_2$ is positive.

(A4) Proof of Lemma 6

Setting $\underline{w}_2 = \overline{w}_1 = 0$, the binding constraint from inequation (21) gives that

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

And the expected wage of the regulator is given by

$$\widetilde{w} = \mu\left[\nu\underline{w}_1 + (1-\nu)\overline{w}_2\right].$$

Together, this gives the result of Lemma 6.

(A5) Discussion regarding Lemma 6

$\frac{\mu}{\mu-\frac{1}{2}} > 1$ holds for any $\mu > \frac{1}{2}$. Since Lemma 6 regards the prevention of soft capture by the principal, it makes sense to limit the informativeness to $\mu > \frac{1}{2}$. Indeed, the principal would have no reason to prevent soft capture when $\mu = \frac{1}{2}$ since she would elect not to use the regulator anyway.

(A6) Proof of Lemma 7

With $\tilde{w} - m$ decreasing in μ and $\widetilde{W}(\mu) - \widetilde{W}(\hat{\mu})$ increasing in μ, the equation given by the binding constraint (23) has at most one solution. With $\lim_{\mu \to \frac{1}{2}} \widetilde{W}(\mu) = \widetilde{W}(\hat{\mu})$ and $\lim_{\mu \to \frac{1}{2}} \tilde{w} - m = \infty$, it is obvious that the solution is above $\frac{1}{2}$. The condition given in Lemma 7 is the condition to have $\widetilde{W}(\mu) - \widetilde{W}(\hat{\mu}) \geq \tilde{w} - m$ for $\mu = 1$.

(A7) Proof of Proposition 1

The first condition of Proposition 1 comes directly from Lemma 5. Condition (a) comes from Lemma 7. The first part of condition (b) also comes directly from Lemma 7. The second part, $\widetilde{W}\left(\frac{1}{2}\right) > \widetilde{W}(\tilde{\mu}_2) - \frac{\tilde{\mu}_2 m}{\tilde{\mu}_2 - \frac{1}{2}}$, is a necessary condition to have $\tilde{\mu}_2 < \tilde{\mu}_3$.

(A8) Proof of Corollary 1

As $\tilde{\mu}_2$ increases in x from Lemma 5 and $\tilde{\mu}_3$ decreases in x from Lemma 7, the direct result is that the $[\tilde{\mu}_2, \tilde{\mu}_3]$ space decreases in x.

(A9) Proof of Lemma 8

$\widetilde{W}_s \geq \widetilde{W}(\mu)$ boils down to

$$\nu\left[S\left(\underline{q}\right) - \underline{\theta}\underline{q}\right] \geq \nu\left[S\left(\underline{q}\right) - \underline{\theta}\underline{q} - \underline{U}(\mu)\right] + (1-\nu)\{\mu[S(\overline{q}_2) - \overline{\theta}\overline{q}_2] + (1-\mu)[S(\overline{q}_1) - \overline{\theta}\overline{q}_1]\}.$$

Which is satisfied when

$$\underline{U}(\mu) \geq \frac{1-\nu}{\nu}\{\mu[S(\overline{q}_2) - \overline{\theta}\overline{q}_2] + (1-\mu)[S(\overline{q}_1) - \overline{\theta}\overline{q}_1]\}.$$

For $\mu = 1$, using equation (14) gives

$$\Delta\theta\overline{q}_1 \geq \frac{1-\nu}{\nu}[S(\overline{q}_2) - \overline{\theta}\overline{q}_2],$$

$$\frac{\Delta\theta\overline{q}_1}{[S(\overline{q}_2) - \overline{\theta}\overline{q}_2]} \geq \frac{1-\nu}{\nu}.$$

Combing the hypothesis on $S(q)$ and equation (11), it results that $S(\overline{q}_2) \geq \overline{\theta}\overline{q}_2$, which means that the left term is always positive.

And for $\mu = \frac{1}{2}$

$$\Delta\theta \frac{\overline{q}_1 + \overline{q}_2}{2} \geq \frac{1-\nu}{\nu} \frac{S(\overline{q}_1) + S(\overline{q}_2) - \overline{\theta}(\overline{q}_1 + \overline{q}_2)}{2},$$

$$\frac{\Delta\theta(\overline{q}_1 + \overline{q}_2)}{S(\overline{q}_1) + S(\overline{q}_2) - \overline{\theta}(\overline{q}_1 + \overline{q}_2)} \geq \frac{1-\nu}{\nu}.$$

Combing the hypothesis on $S(q)$ and equation (11), it results that $S(\overline{q}_1) \geq \overline{\theta}\overline{q}_1$, which means that the left term is always positive.

With $\lim_{\nu \to 0} \frac{1-\nu}{\nu} = \infty$ and $\lim_{\nu \to 1} \frac{1-\nu}{\nu} = 0$, there exists ν_a, ν_b to make each inequation binding.

(A10) Proof that $\widetilde{w}_c > m$ is equivalent to $\mu < \frac{m}{2c}$

$$\widetilde{w}_c = \frac{\mu(m-c)}{\left(\mu - \frac{1}{2}\right)} > m$$

is satisfied when

$$\frac{\mu m - \left(\mu - \frac{1}{2}\right) m}{\left(\mu - \frac{1}{2}\right)} = \frac{\frac{m}{2}}{\left(\mu - \frac{1}{2}\right)} > \frac{\mu c}{\left(\mu - \frac{1}{2}\right)}.$$

Which gives $\frac{m}{2c} > \mu$.

(A11) Proof that inequations (33) and (34) are equivalent

$$\widetilde{W}(\mu) - \widetilde{w} \geq y\left[\widetilde{W}(\hat{\mu}) - \widetilde{w}_c\right] + (1-y)\left[\widetilde{W}(\mu) - \widetilde{w}_c\right]$$

is equivalent to

$$y\left[\widetilde{W}(\mu) - \widetilde{W}(\hat{\mu})\right] \geq \widetilde{w} - \widetilde{w}_c = \frac{c\mu}{\mu - \frac{1}{2}}.$$

Therefore, always preventing capture is preferred when

$$\frac{c}{y} \leq \frac{\mu - \frac{1}{2}}{\mu}\left[\widetilde{W}(\mu) - \widetilde{W}(\hat{\mu})\right].$$

(A12) Proof that inequations (35) and (36) are equivalent

$$\widetilde{W}(\hat{\mu}) - m \geq y\left[\widetilde{W}(\hat{\mu}) - \widetilde{w}_c\right] + (1-y)\left[\widetilde{W}(\mu) - \widetilde{w}_c\right]$$

is equivalent to

$$(1-y)\left[\widetilde{W}(\mu) - \widetilde{W}(\hat{\mu})\right] \leq \widetilde{w}_c - m = \frac{\frac{m}{2} - \mu c}{\left(\mu - \frac{1}{2}\right)}.$$

Therefore, always tolerating capture is preferred when

$$\frac{\frac{m}{2} - \mu c}{(1-y)\left(\mu - \frac{1}{2}\right)} \geq \widetilde{W}(\mu) - \widetilde{W}(\hat{\mu}).$$

(A13) Proof that $\frac{\partial[\widetilde{W}_n(\mu) - \widetilde{W}(\mu)]}{\partial \mu} < 0$

$$\widetilde{W}_n(\mu) - \widetilde{W}(\mu) = \alpha\nu U_n(\mu),$$

$$\frac{\partial \alpha\nu U_n(\mu)}{\partial \mu} = \alpha\nu \frac{\partial U_n(\mu)}{\partial \mu}.$$

And $\frac{\partial U(\mu)}{\partial \mu} < 0$ from Assumption 1.

(A14) Proof that inequations (49) and (50) are equivalent

From Lemma 6, $\widetilde{w} = \frac{\mu}{\mu - \frac{1}{2}} m$ and injecting this in inequation (49) gives

$$\frac{\mu}{\mu - \frac{1}{2}} m \ \geq (1-x)m + \frac{m}{sd}\tau.$$

Which can be simplified to $\frac{\mu}{\mu - \frac{1}{2}} \geq 1 - x + \frac{\tau}{sd}$.

(A15) Proof of Corollary 2

The mathematical formulation of Corollary 2 is $\frac{\partial\left[\widetilde{W}(1)-\frac{m}{sd}\tau-xm-\widetilde{W}\left(1-\frac{x}{2}\right)\right]}{\partial x} \leq \frac{\partial\left[\widetilde{W}(1)-m-\widetilde{W}\left(1-\frac{x}{2}\right)\right]}{\partial x}$

Which can be simplified to

$$\frac{\partial\left(-\frac{m}{sd}\tau - xm + m\right)}{\partial x} = \frac{\partial m}{\partial x} - \frac{\partial \frac{m}{sd}\tau}{\partial x} - \frac{\partial xm}{\partial x} \leq 0.$$

Since $\frac{\partial m}{\partial x} = \frac{\partial \frac{m}{sd}\tau}{\partial x} = 0$ and $\frac{\partial xm}{\partial x} = m > 0$, the inequality is verified.

(A16) Proof of Lemma 17

Starting from the constraint given by inequation (51) at the binding point and using $\sum_{i=0}^{\infty} \delta^i = \frac{1}{1-\delta}$ since $\delta < 1$, this gives

$$z_i d\left(s + \frac{w-m}{1-\delta}\right) = m.$$

And it is a direct result that $z_i = \frac{m}{d\left(s+\frac{w-m}{1-\delta}\right)}\ \forall i$.

$z = \frac{m}{sd} > z_i = \frac{m}{sd+\frac{w-m}{1-\delta}}$ is always verified since $w - m > 0$ and $\delta \in]0,1[$.

(A17) Proof that inequations (53) and (54) are equivalent

Rewriting both terms gives

$$\widetilde{W}(\mu) - w - \frac{\tau m}{d\left(s+\frac{w-m}{1-\delta}\right)} + \frac{xmsd}{d\left(s+\frac{w-m}{1-\delta}\right)} = \widetilde{W}(\mu) - w - \frac{m(\tau - xsd)}{d\left(s+\frac{w-m}{1-\delta}\right)},$$

$$\widetilde{W}(\mu) - m - \frac{m}{sd}\tau + xm = \widetilde{W}(\mu) - (1-x)m - \frac{m}{sd}\tau.$$

The inequation becomes

$$(1-x)m + \frac{m}{sd}\tau - w \geq \frac{m(\tau - xsd)}{d\left(s+\frac{w-m}{1-\delta}\right)},$$

which can be rewritten as

$$\frac{m[(1-x)sd+\tau]}{sd} - w \geq \frac{m(\tau - xsd)}{d\left(s + \frac{w-m}{1-\delta}\right)},$$

and further simplified to

$$\frac{(1-x)sd+\tau}{s} - w\frac{d}{m} \geq \frac{(\tau - xsd)}{\left(s + \frac{w-m}{1-\delta}\right)}.$$

(A18) Proof that $\exists \varepsilon > 0$ *such that* $\frac{(1-x)sd+\tau}{s} - w\frac{d}{m}$ *is negative for* $x = \frac{\tau}{sd} - \varepsilon$

$$\frac{(1-x)sd+\tau}{s} \geq w\frac{d}{m}$$

can be rewritten as

$$\frac{(1-x)sd+\tau}{sd} = \frac{sd+\tau-xsd}{sd} \geq \frac{w}{m}.$$

For $w > m$, the term on the right hand-side is strictly greater than one and evaluated at $x = \frac{\tau}{sd} - \varepsilon$, the term on the left hand-side is equal to

$$\frac{sd+\tau-\tau+\varepsilon}{sd} = 1 + \frac{\varepsilon}{sd}.$$

And therefore tends to one when $\varepsilon \to 0$.

(A19) Proof that $\frac{\partial\left[\frac{(1-x)sd+\tau}{s} - w\frac{d}{m}\right]}{\partial x} < \frac{\partial\left[\frac{(\tau - xsd)}{s+\frac{w-m}{1-\delta}}\right]}{\partial x}$

$$\frac{\partial\left[\frac{(1-x)sd+\tau}{s} - w\frac{d}{m}\right]}{\partial x} < \frac{\partial\left[\frac{(\tau - xsd)}{s+\frac{w-m}{1-\delta}}\right]}{\partial x}$$

is equivalent to

$$\frac{\partial\left(\frac{-xsd}{s}\right)}{\partial x} < \frac{\partial\left(\frac{-xsd}{s+\frac{w-m}{1-\delta}}\right)}{\partial \tau}$$

or

$$\frac{sd}{s} > \frac{sd}{s + \frac{w - m}{1 - \delta}}$$

Which is true for $w > m$.

(A20) Proof that inequations (55) and (56) are equivalent

Reusing the results from (A17), inequation (55) is equivalent to

$$\widetilde{W}(\mu) - w - \frac{\tau m}{d\left(s + \frac{w - m}{1 - \delta}\right)} + \frac{xmsd}{d\left(s + \frac{w - m}{1 - \delta}\right)} = \widetilde{W}(\mu) - w - \frac{m(\tau - xsd)}{d\left(s + \frac{w - m}{1 - \delta}\right)} \geq \widetilde{W}(\mu) - \widetilde{w}$$

or

$$\frac{m(\tau - xsd)}{d\left(s + \frac{w - m}{1 - \delta}\right)} \leq \widetilde{w} - w.$$

(A21) Proof of Lemma 20

Given the results of Lemma 18 and 19, a sufficient condition is to have $x_2 < x_1$, which is the case when there exists x^* such that

$$\frac{\mu}{1 - \mu} < 1 - x^* + \frac{\tau}{sd}$$

and

$$\frac{\partial\left[\frac{\mu}{1 - \mu}\right]}{\partial x} > \frac{\partial\left[1 - x + \frac{\tau}{sd}\right]}{\partial x}.$$

The second condition is straightforward, as $\frac{\partial\left[\frac{\mu}{1-\mu}\right]}{\partial x} = 0$ and $\frac{\partial\left[1 - x + \frac{\tau}{sd}\right]}{\partial x} < 0$.

The first one is satisfied at $x^* = x_a - \varepsilon$ with $\varepsilon > 0$. This requires $x_a > 0$, which is the case from Lemma 16.

(A22) Proof that $2\widetilde{W}(\mu) - 2w - \tau(z_1 + z_2) + xsd(z_1 + z_2) < 2\widetilde{W}(\mu) - 2w - 2\tau z_i + 2z_i xsd$

By simplifying the terms on both sides, this gives

$$-\tau(z_1 + z_2) + xsd(z_1 + z_2) < -2\tau z_i + 2z_i xsd$$

or

$$(z_1 + z_2)(\tau - xsd) > 2z_i(\tau - xsd).$$

From Assumption 3, $\tau - xsd$ is strictly positive, this therefore simplifies to

$$(z_1 + z_2) > 2z_i.$$

A sufficient condition is to have $z_1, z_2 > z_i$.

$$z_1 = \frac{m}{sd + \delta(w - m)} > z_i = \frac{m}{sd + \frac{w - m}{1 - \delta}}$$

Which is always verified since $\frac{w-m}{1-\delta} > \delta(w - m)$ for any $\delta \in]0,1[$. Since $z_2 = z$, $z_2 > z_i$ comes directly from Lemma 17. Therefore, $(z_1 + z_2) > 2z_i$.

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