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QUALITY AND ENVIRONMENTAL REGULATION:  
VERIFYING COMPLIANCE ALONG THE SUPPLY CHAIN

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## **Abstract**

Among the factors providing incentives to monitor the behaviour of input suppliers are the regulatory requirements to which downstream firms are subject. We develop a formal economic model to examine the relationship between the strictness of the regulatory environment and downstream firms' incentives to act as inspectors of their sub-contractors. We consider the interaction between a downstream producer and an upstream input supplier. The downstream chooses the probability with which to monitor the upstream's compliance and the upstream chooses a compliance level which determines compliance of the end product with quality or environmental regulation. We find that the strictness of regulation affects the downstream's monitoring strategy in combination with the level of quality or environmental standards. If the standards are sufficiently low then the strictness of regulation increases incentives to monitor the upstream. Contrary, if the standards are sufficiently high then the pressure on the downstream to monitor the upstream is relaxed and the strictness of regulation decreases incentives to monitor. We argue that the strictness of regulation should not be treated in isolation as a factor determining the choice of downstream firms to monitor their input suppliers.

## **Keywords**

Compliance, monitoring, supply chain, quality and environmental regulation.





## 1. Introduction\*

Increasingly strict and specific quality and environmental regulations are affecting the behavior and choices of firms. Those regulations may concern features of the product and/or production processes to protect consumer rights, the environment or society in general<sup>1</sup>. Compliance with quality or environmental regulation has been under the scrutiny of the public with the different stakeholder groups watching the behavior of the firms and publicizing information about their choices<sup>2</sup>. The level of compliance of firms with those regulations has raised considerable discussion, with a primary focus on the drivers of firms' incentives to comply. Among the factors that drive firms' quality or environmental performance and compliance are firms' economic and financial constraints, market opportunities expected to derive from compliance, regulatory requirements and pressure from customers and other stakeholders (Press, 2007).

In most cases products are complex items consisting of different components supplied by different firms. As a consequence, complying with quality or environmental regulation is not only an internal issue for downstream firms, with input suppliers playing a crucial role in determining compliance or non-compliance of end products. Taking account of input suppliers' choices with respect to quality or environmental compliance is of particular importance when the downstream firms or downstream firms' mother companies and upstream firms are subject to different regulations. This can be for example because the downstream itself or the downstream's mother company and the upstream are located in different places of the world where different regulatory standards are in effect, as it is often the case with downstream firms and their input suppliers (Feenstra, 1998; Bond, 2008). In this case, the differences in effective regulation between the two firms will create different incentives to adopt quality or environmental standards<sup>3</sup>. Alternatively, the upstream may be subject to less scrutiny from the regulator because end product quality or environmental compliance may be more easily verifiable by the regulator than input quality or environmental compliance.

Being subject to less strict regulatory requirements provides lower incentives for quality or environmental compliance. The upstream does not internalize the cost of non-compliance to which the downstream may be subjected. As a result, increasingly frequently downstream firms are called upon to take the role of the inspector of the level of compliance of their input suppliers, with the aim to incentivize upstream suppliers to comply with regulation. Clearly, the drivers of downstream firms' incentives to comply with quality or environmental regulation should also be drivers of their decision to monitor the compliance of their input suppliers. Those drivers should include firms' economic and financial constraints, market opportunities expected to derive from compliance, regulatory requirements and pressure from customers and other stakeholders (Press, 2007).

The extent to which firms are expected to comply with quality or environmental regulation depends on the context and the effectiveness of different regulatory regimes, with "a buyer firm with a home

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\* This work was completed during Dionisia Tzavara's stay as a Jean Monnet Fellow at the Robert Schuman Centre of the European University Institute.

<sup>1</sup> Important instances are the regulation of large combustion plants' SO<sub>2</sub> and NO<sub>x</sub> emissions, the lead in petrol, passengers' cars NO<sub>x</sub> and CO<sub>2</sub> emissions, the efficient use of water in industry, industrial discharges in surface water, or at a procedural level, the provision of eco-management and audit schemes and eco-labelling (Holzinger et al., 2008)

<sup>2</sup> One example is Greenpeace which has been very active in criticizing the use of PVC in a wide range of products, prompting the European industry to engage in strict self-regulation in the recycling of plastic products (Héritier and Eckert, 2009).

<sup>3</sup> Indeed with increased globalization and multinational companies and transnational supply chains dominating economic activity, national regulation is becoming less effective.

base in a strictly regulating country [being] under more pressure to comply with national or international regulatory standards when dealing with its suppliers” (Héritier et al., 2009, p. 6)<sup>4</sup>.

Focusing on the impact of regulatory strictness on downstreams’ monitoring behavior is – for two reasons – of direct relevance for policy makers. First, insights into the conditions under which public regulation strengthens product quality and the environmental friendliness of production is of obvious importance. Second, information about the extent to which governmental regulation influences the monitoring behavior of firms in the supply chain – without taking recourse to the administrative capacity of public authorities – is of importance for political decision-makers when shaping their policy instruments. If governments can rely on firms effectively playing the roles of inspectors vis-à-vis their suppliers, governments need not deploy as much administrative capacity in order to secure compliance with regulations as would be the case if downstream firms would not monitor the behavior of upstream firms.

In this paper we examine the role of the strictness of quality or environmental regulation in determining the choice of a downstream firm to act as an inspector vis-à-vis the suppliers of its inputs or in other words to monitor the quality or environmental compliance of those suppliers. We also look at the upstream’s choice of compliance resulting from the downstream’s effort to incentivize the input supplier. We present a formal economic model and discuss our findings in the light of empirical evidence about downstream firms acting as inspectors of their input suppliers in order to highlight potential mismatches between theory and empirical evidence. Our aim is to place the role of the strictness of the regulatory regime in a wider group of factors driving downstream firms’ decision to act as inspectors vis-à-vis their suppliers, such as market considerations, like price or consumer preferences for example.

We develop a formal economic model with a downstream firm and an input supplier which contract upon the rules of sharing a potential penalty for non-compliance. We are interested in the case where the downstream firm and the input supplier are not subject to the same quality or environmental regulations<sup>5</sup>. As a result, only the downstream can be held responsible for non-compliance of the end product with regulation, in which case a fine for non-compliance will be imposed. The downstream cannot affect directly the level of compliance but chooses the probability with which to monitor the upstream to induce it to comply with quality or environmental regulation.

We find that the strictness of regulation provides higher incentives to downstream firms to monitor their suppliers provided that quality or environmental standards are not very high. The level of quality or environmental standards in our model acts as a substitute instrument to the strictness of regulation. We also find that the intensity of competition in the downstream market plays a role in providing incentives to firms to monitor their suppliers. Finally, we find that the strictness of regulation always increases the incentives of the upstream to supply compliance.

The paper is organized as follows. In section 2 we present the literature relevant to our study and discuss how our model fits in existing literature. Then in section 3 we present our model’s assumptions and solutions. In section 4 we perform comparative statics to examine the effect of variables such as the strictness of regulation and the intensity of competition on the choices of firms. Section 5 discusses the findings of our model and section 6 concludes the paper.

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<sup>4</sup> Take for example the cases of Germany and South Africa with the former being a country where regulation is high and effectively implemented and the latter being a country where while legislation is well developed, detection and implementation are highly problematic to the extent that the regulatory environment is ineffective (Héritier et al., 2009).

<sup>5</sup> This, as discussed above, can be for example because, contrary to the downstream, the input supplier is based in a country where the regulatory requirements are lax so that they provide no incentives to the supplier firm to comply with quality or environmental standards. Alternatively, this can be because it is more difficult to verify the quality of environmental compliance of the input rather than that of the end product.

## **2. The relevant literature and how our study fits in that**

Empirical evidence about the role of regulatory requirements driving quality or environmental compliance is inconclusive. Different studies focusing on different industries argue for a decisive role of regulatory requirements as well as for the opposite, namely that regulation is not a decisive factor of firms' choice to meet quality or environmental standards. For example, Doonan et al (2005) studying the environmental performance of Canadian pulp and paper firms find that strong regulatory intervention is a decisive factor for performance. Scott (2003) and Popp (2006) as cited in Press (2007, p. 329) in different studies of pollution controlling innovation also find that regulatory requirements are considered drivers of the firms' choice to innovate with the aim to control pollution. Contrary however, Kautto and Melanen (2004) in a study of waste management policies find that the role of regulatory requirements is not considered as a primary factor for industrial waste reduction. Prakash and Potoski (2006) in a study of the adoption of ISO 14001 standards show that trade between countries with stricter and weaker regulatory regimes results in increasing adoption of the ISO standards in the weaker regulatory regime countries when those countries are exporting to strict regime countries. In other words, Prakash and Potoski (2006) demonstrate that importers in strict regime countries create incentives for their trading partners in weak regime countries to comply with environmental standards. The same effect does not emerge when the importers operate in weak regulatory regimes. In the same direction, Vogel (1997) discusses how stricter regulatory standards disseminate from stronger regulation countries to laxer regulation ones rather than the other way around.

Héritier et al. (2009) present an empirical study of downstream firms' incentives to monitor their input suppliers, in a set up where the downstream's home country and the upstream's country of operation differ in terms of the effectiveness of the regulatory regime. In their study asset specificity, high-end downstream products and strict political rules are examined as factors providing incentives to monitor input suppliers and effectively as incentives to supply compliance. Focusing on two sectors, the automotive and the textile industry, the study concludes that in both sectors the strictness of regulation does not play a decisive role in determining downstream firms' choice to monitor the behaviour of their input suppliers. According to the authors, what provides incentives to downstream firms to monitor suppliers are asset specificity in inter-firms relations and the targeting of high-end markets.

Downstream firms' incentives to monitor the quality of their input suppliers have drawn considerable attention in the literature. More specifically existing literature looks at the terms of product failure cost-sharing, the incentives of downstream firms' to inspect the quality provided by their suppliers and the suppliers' incentives to supply quality. For example, Reyniers and Tapiero (1995a, b) analyze the choice of a supplier to supply quality controlling effort and the choice of a producer/input-buyer to inspect or not inspect the quality of materials supplied. They do this in a game theoretic setting where the contract between supplier and producer consists of a penalty for every item detected to be defective on inspection and a post-sales cost sharing rule for every item detected to be defective after the sale of the product. In their model the cost sharing rule is a fixed share rule, where each firm bears a fixed share of the penalty. Lim (2001) examines a similar setting where the supplier can be one of  $n$  types with respect to its technology and where there is asymmetry of information on the side of the producer with regard to the type of the supplier. The supplier is a passive player in Lim's model and the only choice it makes is to accept or reject the contract.

Baiman et al. (2000) analyze the role of information available upon contracting in determining the terms of the contract, the quality of the product and the cost of quality. In their model the supplier of the input acts to prevent the input from being defective while the buyer of the input exercises appraisal activity to verify the quality of the input. The authors examine single and double moral hazard cases where the actions of one or both parties are not observable by the other party. In a model where both input supplier and input buyer determine the quality of the end product, Baiman et al. (2001) study the effects of product architecture design, type of failure information, the supplier firm's incentives to

supply quality and the buyer firm's incentives to correct quality and monitor the quality of the supplier. In their model product architecture design can be such that detected failures can be attributed with certainty to one or the other firm or such that failure can be attributed with certainty to one of the two. Information about defective items can be either the result of a the buyer's inspection or the result of external failure.

Balachandran and Radhakrishnan (2005) analyze the optimal warrantee/penalty contract based on information from incoming inspection and external failure, when supplier quality choice is not observable by the input buyer, the input buyer quality choice is not observable by the supplier and incoming inspection does not detect all defective components while external failure does not allocate responsibility for the fault. The authors compare the two sources of information, internal inspection and external failure, relative to a first-best solution. Hwang et al. (2006) analyze a buyer firm's effort to induce its supplier to exert quality increasing effort under two different regimes. According to the first regime, the buyer firm inspects inputs supplied and either imposes a penalty for defective inputs or pays only for good items. According to the second regime the quality of the input is certified externally, the input supplier acquires a certificate and the buyer pays for all units supplied if the certificate certifies high quality. In Hwang et al.'s setting both inspection and certification are imperfect. The authors derive conditions under which each of the two regimes is preferred by the buyer firms.

Chao et al. (2009) analyze the optimal design of product recall costs contracts when both an input supplier and a manufacturer supply effort to enhance the quality of the product. In their analysis, when there is moral hazard on both sides about the supply of effort and asymmetric information on the side of the manufacturer about the input supplier's process quality. The optimal contract in this framework is used to incentivize both parties to supply quality. Hsieh and Liu (2010) analyze the choice of quality improving investment and inspection strategies of an input supplier and a buyer firm in a set up where both production and inspection are imperfect. The input supplier chooses the level of investment to improve the quality of the input as well as the rate of outbound inspection of input quality. The buyer firm chooses the level of investment to improve quality of the final product as well as the rates of inbound inspection (when the input arrives from the supplier) and outbound inspection (when the final product leaves the manufacturer). The authors derive optimal values for the choice variables under different information setups.

Our motivation is very different from existing literature discussed above as we explicitly consider quality or environmental regulation as being the driver of downstream firms' incentives to monitor their suppliers. In the literature presented above what provides the incentives to the firms to supply quality and monitor quality is the market itself and post-sales costs. Those costs are considered to be either product replacement costs or loss of reputation and associated reputation-restoring costs or loss of customer loyalty. In our case quality or environmental care are not examined from the aspect of satisfying consumer preferences, busting sales or avoiding bad reputation costs but rather from the aspect of satisfying quality and environmental regulation. In our paper we explicitly model the strictness of the regulatory regime and its effects on incentives to comply and to monitor compliance. In fact, the effect of the strictness of regulation is reflected in the sanction function into three separate components, namely the actual fine, the probability of detection of non-compliance and the probability of effective implementation of regulation (the probability of a imposing a fine for non-compliance).

With our motivation being to consider the effects of regulation on incentives to monitor the suppliers, we model the supplier's choice in a very different way compared to the literature presented above. In our case the supplier's technology is fixed, it is not affected by the supplier's choice. In the literature presented above the supplier's choice of quality (whether it is a discrete choice or a continuous one) affects the supplier's technology through changing the probability of product failure. Because we are interested in the effectiveness of regulation in providing incentives to monitor and effectively to comply, what interests us is the probability of detection and the probability of imposing a fine rather than the probability of non-compliance (or product failure as in the literature above).

Instead in our case, it is post-sales costs (the potential fine for non-compliance) which are not fixed but rather a function of non-compliance. In our case, the level of compliance is directly linked to the level of the fine rather than the probability of non-compliance. Also, the implications of examining compliance rather than product quality are different as, so long as the market is prepared to pay for additional quality firms have incentives to supply additional quality. Contrary in the case of compliance when the regulatory standard is met there is no more a requirement for compliance. We abstract from issues of asymmetry of information and we do not consider any market-driven post-sales costs. Also, we consider a case where quality or environmental compliance is determined only by the input supplier, with the downstream firm not taking any part in satisfying quality or environmental regulation. Similarly to existing literature as this is presented above, we do not model the market for the end product.

### **3. The model**

We model the interaction between one downstream firm – the producer of the end product – and one upstream firm – the input supplier. The downstream produces a product, for the production of which it buys an input from the upstream. We assume that one unit of the end product requires one unit of the input, so that our analysis below is based upon ‘all units produced’. The downstream firm is subject to quality or environmental regulation, and can be held responsible for non-compliance of the end product with regulation. Non-compliance is defined as the distance from the regulatory standard for quality or environmental care<sup>6</sup>  $S_m$ . It is the role of the regulator to detect compliance and impose penalties<sup>7</sup>. The quality or environmental compliance of the downstream product – the end product – is exclusively determined by the quality or environmental compliance of the input and the downstream can do nothing to affect the compliance of the end product<sup>8</sup>. This assumption is made to isolate the effect of monitoring effort on the level of compliance of the upstream without having to consider other factors affecting quality or environmental compliance (such as for example the downstream allocating resources to correct for the level of compliance of the input).

Following the literature as presented above, we do not model the market for the end product. Our aim is to isolate the choice of price from that of quality or environmental compliance and thus isolate the effect of the strictness of regulation on the downstream’s choice of monitoring strategy. The choice of the downstream to monitor the upstream is not the result of being able to sell the end product at a higher price but rather of the strictness of political rules<sup>9</sup>. Similarly, the choice of quality or environmental compliance of the upstream is not the result of being able to sell the input at a higher price but rather of the strictness of political rules also.

Because the downstream and the upstream are subject to different quality or environmental regulation requirements, only the downstream can be held reliable for non-compliance of the end product with regulation. We reflect the strictness of the political rules in the following assumptions. Depending on the strictness of the political rules which is measured by  $k$ , so that stricter rules are reflected in higher  $k$ ’s, there is a probability that the downstream’s product will be detected not complying. We call this probability  $h(n, k)$  and we assume that besides the strictness of political rules it is a function of the number of downstream firms in the market, so that a higher number of firms will

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<sup>6</sup> One example of environmental standard could be emission standards.

<sup>7</sup> Other than detecting compliance and imposing penalties, the regulator is passive in our model. In other words, we do not model the optimal choice of the standard or the level of the penalty. We believe both of those choices to be outside the scope of our analysis and suggest those for further research.

<sup>8</sup> Alternatively we could assume that there can be perfect distinction between compliance failure due to inputs or due to downstream production, so that our model is exclusively focusing on failure of compliance due to input non-compliance.

<sup>9</sup> We can for example assume that the consumer can verify the quality or environmental compliance of the product only after purchase and higher quality or environmental compliance cannot be reflected in the price of the end product.

make it more difficult to detect non-compliance<sup>10,11</sup>  $\partial h(n, k) / \partial n < 0$ . Also, a regulatory environment which is more strict will make detection more likely  $\partial h(n, k) / \partial k > 0$ . There is a second probability<sup>12</sup> that once non-compliance is detected a fine will be imposed, which we call  $f(k)$ . This second probability is a function of the strictness of the political rules only, so that more strict regulations will make it more likely that a fine will be imposed  $df(k) / dk > 0$  and reflects the effectiveness of implementation of the regulatory regime. These two probabilities determine whether the downstream firm will be held reliable for non-compliance, in which case it will be called upon to pay a fine.

If non-compliance is detected and a fine is imposed, the fine is assumed to be a function of the level of quality or environmental compliance. The level of compliance is defined relevant to the extend of non-compliance so that if non-compliance is  $S_m - s$ , then  $s$  is the level of compliance. The fine is then  $F(s)$ . The probability of detection, the probability of imposing a fine and the level of the fine will determine the potential punishment imposed on the downstream for non-compliance of the end product which will be  $h(n, k)f(k)F(s)$ . This potential fine is imposed on the downstream and it is assumed that the regulator cannot punish the upstream for non-compliance<sup>13</sup>. This assumption again is made with the aim to isolate the effect of the downstream's monitoring effort, so that the upstream's compliance is only an effect of the monitoring effort and not an effect of the potential punishment imposed directly by the regulator. The fine is assumed to be a decreasing function of the level of compliance,  $dF(s) / ds < 0$ . We make the assumption that the fine is given by<sup>14</sup>  $F(s) = S_m - s$  where  $S_m$  is the regulatory standard for quality or environmental care, so that effectively the fine is equal to the distance of the supplier's level of compliance from the standard set by the regulator.

The downstream cannot affect compliance directly but chooses the probability with which to monitor the upstream to induce it to comply with quality or environmental regulation. We capture the effect of the downstream's monitoring strategy by assuming that the downstream is able to pass a fraction of the potential fine to the upstream firm. Monitoring entails a cost for the downstream firm and quality or environmental compliance entails a cost for the upstream. Compliance benefits the upstream through reducing the level of the potential fine while engaging in monitoring benefits the downstream through the reducing the fraction of the potential fine that it is called upon to pay.

The firms' choices are the following. The downstream chooses a monitoring strategy. The downstream's monitoring strategy is modeled as the probability  $p$  with which the firm chooses to monitor its input supplier<sup>15</sup>. If it chooses to monitor the supplier with a positive probability then it incurs a cost of monitoring equal to  $M$ . The effect of monitoring is that the downstream can pass a

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<sup>10</sup> Note that the detection probability can also be a function of the presence of NGO's, activist groups or consumer organizations which 'keep an eye' on firms' compliance, so that the regulator is alerted to non-compliance in case the regulator is not very competent or eager to detect non-compliance. Incorporating a variable to capture the effect of additional players such as NGO's, activist groups or consumer organizations is very easy, but for reasons of simplicity of exposition we leave this variable out of our model.

<sup>11</sup> As an example of the number of firms affecting negatively the probability of detection, one may think of a case of pollution where it may be more difficult for the regulator to attribute pollution to any particular firm when the number of firms operating in the market/area is higher rather than lower.

<sup>12</sup> Note that alternatively the effect of the regulatory environment could be modelled as a single probability. However, as discussed above, our purpose is to distinguish between the effects of different inefficiencies of regulation such as inefficiencies in detection and inefficiencies in implementation. This allows us to perform some interesting comparative statics.

<sup>13</sup> Remember that we are assuming that the downstream and the upstream are subject to different regulatory requirements.

<sup>14</sup> Our fine function directly links the level of compliance with the regulatory standard so that the fine is a function of the extent of non-compliance.

<sup>15</sup> We do not model the type of monitoring (the kind of activity, or the kind of investment). Rather we are interested in the effect of monitoring on payoff functions.

fraction<sup>16</sup>  $b$  of the potential fine to the upstream. In this case the upstream bears the fraction  $bh(n,k)f(k)F(s)$  of the potential fine and the downstream bears the rest  $(1-b)h(n,k)f(k)F(s)$  of the fine. If the downstream chooses not to monitor the supplier then it does not incur any cost and it pays the entire fine, in case a fine is imposed. The upstream chooses the level of compliance. For the upstream, quality or environmental compliance  $s$  entails a cost  $c(s)$  (compliance requires an investment/allocation of resources), such that a higher level of compliance increases cost  $c'(s) > 0$  at an increasing rate  $c''(s) > 0$ . We make the assumption<sup>17</sup> that  $c(s) = cs^2/2$  where  $c > 0$ .

The choices of the two firms are made as following<sup>18</sup>. The downstream chooses the probability with which to monitor the upstream to minimize its fraction of the potential fine (this is the benefit of monitoring the upstream), plus the cost of monitoring. The upstream chooses the level of compliance  $s$  to minimize the cost of compliance  $c(s)$  plus the fraction of the potential fine that the downstream passes on to the upstream (this is the benefit of compliance). This means that payoff functions are<sup>19</sup>

$$P_d = p[M + (1-b)h(n,k)f(k)F(s)] + (1-p)h(n,k)f(k)F(s) \quad (1)$$

for the downstream and

$$P_u = c(s) + pbh(n,k)f(k)F(s) \quad (2)$$

for the upstream, where  $c(s) = cs^2/2$  and  $F(s) = S_m - s$ . Note that the downstream's payoff can be simplified to

$$P_d = pM + (1-pb)h(n,k)f(k)F(s) \quad (3)$$

so that effectively the fraction of the fine that the downstream will be called upon to pay is equal to  $(1-pb)h(n,k)f(k)F(s)$  where the actual fraction is determined by the fraction  $b$  of the fine allocated to the upstream scaled down by the probability of monitoring.

We assume that the two firms make their choices in the following sequence. First, the downstream chooses its monitoring strategy and commits to it – we can assume for example that resources are allocated to this and thus commitment is binding. Then the upstream chooses the level of quality or environmental compliance, taking as given the downstream's monitoring strategy. Once choices are made, compliance is observed by the regulator, the penalty is imposed accordingly and firms get their payoffs. To solve for the firms' choices, we start from stage 2 with the choice of the upstream.

The first order condition  $\partial P_u / \partial s = 0$  for the minimization of the upstream's potential costs is

$$cs - pbh(n,k)f(k) = 0 \quad (4)$$

The first term is the marginal cost of compliance and the second term is the marginal benefit which derives from decreasing the potential fine for non-compliance. From this we get compliance as a function of the monitoring strategy chosen by the downstream given by

$$s(p) = \frac{pbh(n,k)f(k)}{c} \quad (5)$$

<sup>16</sup> Following existing literature (see Hsieh and Liu (2010), Chao et al. (2009), Hwang et al. (2006), Balachandran and Radhakrishnana (2005), Lim (2001), Reyniers and Tapiero (1995a, b)), we assume a fixed post-sales cost allocation rule.

<sup>17</sup> Following existing literature we assume that the cost of compliance is increasing at an increasing rate with the level of compliance. Without compromising qualitative results, the choice of the specific functional form for the cost function is made to simplify the analysis.

<sup>18</sup> Remember that we do not model any asymmetries of information in our analysis.

<sup>19</sup> Note that in our case payoff functions are in fact cost functions, which is why our firms make their choices to minimize their respective payoffs.

Note that, for a given probability of monitoring, the level of compliance is also a function of the number of downstream firms, of the strictness of regulation as well as of the fraction  $b$  of the potential fine allocated to the upstream firm.

Substituting  $s(p)$  into the downstream's payoff function and differentiating with respect to  $p$  we get the first order condition<sup>20</sup>  $\partial P_d / \partial p = 0$  for the minimization of the downstream's potential costs which is

$$M - bh(n, k)f(k) \left( S_m - \frac{pbh(n, k)f(k)}{c} \right) - (1 - pb) \frac{b[h(n, k)f(k)]^2}{c} = 0 \quad (6)$$

Here the marginal cost of monitoring is  $M$  while the other terms give the marginal benefit of monitoring which derives from decreasing the fraction of the potential fine to be paid by the downstream and from inducing higher compliance and thus again decreasing the level of the fine (indirectly). Solving for the downstream's choice of monitoring strategy we get

$$p^* = \frac{cS_m}{2bh(n, k)f(k)} + \frac{1}{2b} - \frac{cM}{2[bh(n, k)f(k)]^2} \quad (7)$$

The probability of monitoring is a function of the strictness of regulation, the costs of monitoring and compliance, the regulatory standard and of the number of firms in the downstream market. The downstream's strategy must be such that  $0 \leq p^* \leq 1$ , with  $p^* = 0$  and  $p^* = 1$  being the cases where the downstream never chooses to monitor the upstream and always chooses to monitor the upstream respectively. If the downstream never chooses to monitor the upstream ( $p^* = 0$ ) then  $s^* = s(p^*) = 0$ . This says that if the downstream does not monitor the supplier then the supplier will not comply with quality or environmental regulation. If on the other hand the downstream always chooses to monitor the supplier ( $p^* = 1$ ) then<sup>21</sup>

$$s^* = s(1) = \frac{bh(n, k)f(k)}{c} \quad (8)$$

When  $0 < p^* < 1$ , the downstream's is an intermediate choice where the downstream monitors the upstream with probability  $p^*$  (and thus does not monitor the upstream with probability  $1 - p^*$ ). In this case the level of compliance is

$$s^* = s(p^*) = \frac{S_m}{2} + \frac{h(n, k)f(k)}{2c} - \frac{M}{2bh(n, k)f(k)} \quad (9)$$

and is a function of the strictness of regulation, the costs of monitoring and compliance, the regulatory standard and of the number of firms in the downstream market.

#### 4. Comparative statics

In this section we perform some comparative statics for the non-trivial case where the downstream chooses  $0 < p^* < 1$ . The aim of this section is to examine the effects of the different variables, and most importantly the strictness of regulation, on the choice of the monitoring strategy of the downstream firm and effectively the choice of compliance of the upstream firm.

<sup>20</sup> The second order condition for a minimum is  $\frac{\partial^2 P_d}{\partial p^2} \geq 0$ .

<sup>21</sup> Note that the supplier exactly meets the regulatory requirement whenever  $s^* = s(p^*) = \frac{p^* bh(n, k)f(k)}{c} = S_m$ . Otherwise the upstream firm either over-complies or under-complies.



Starting from the choice of compliance of the upstream firm, we see that the upstream's choice of compliance increases with the strictness of regulation and with the level of the regulatory standard and decreases with the intensity of competition. To see this, remember that

$$s^* = \frac{S_m}{2} + \frac{h(n,k)f(k)}{2c} - \frac{M}{2bh(n,k)f(k)} \quad (10)$$

and thus

$$\frac{\partial s^*}{\partial k} = \frac{h'(n,k)f(k) + h(n,k)f'(k)}{2c} + \frac{M[h'(n,k)f(k) + h(n,k)f'(k)]}{2b[h(n,k)f(k)]^2} > 0 \quad (11)$$

where  $h'(n,k) = \partial h(n,k) / \partial k$  and  $f'(k) = df(k) / dk$ . The strictness of regulation increases both the probability of detection  $h(n,k)$  and the probability that a fine will be imposed  $f(k)$  and this increases the incentives of the upstream to comply with regulation, with the aim to reduce the potential fine. Note that equation (11) links the increase in the probability of detection and the increase in the probability of imposing a fine with the cost of monitoring for the upstream firm, through the increase in the choice of compliance of the upstream.

As the level of the regulatory standard increases, so does the choice of compliance of the upstream firm

$$\frac{\partial s^*}{\partial S_m} = \frac{1}{2} > 0 \quad (12)$$

What happens is that as the level of the standard increases, so does the fine to be imposed by the regulator  $F(s) = S_m - s$ . As a result the upstream chooses a higher level of compliance in order to reduce the potential fine.

As competition becomes more intense in the downstream market the choice of compliance of the upstream firm decreases

$$\frac{\partial s^*}{\partial n} = \frac{\frac{\partial h(n,k)}{\partial n} f(k)}{2c} + \frac{M \frac{\partial h(n,k)}{\partial n} f(k)}{2b[h(n,k)f(k)]^2} < 0 \quad (13)$$

What happens is that more intense downstream competition makes detection of non-compliance less likely ( $h(n,k)$  decreases with  $n$ ). This as a result decreases the upstream's incentives to supply compliance, since when detection is less likely, the potential of a fine to be split between the two firms is lower. Note again that this last result links the upstream's choice of compliance with the downstream's cost of monitoring compliance. Finally, it is useful to note that when the upstream is called to pay a higher fraction of the potential fine it has higher incentives to supply compliance

$$\frac{\partial s^*}{\partial b} = \frac{2Mh(n,k)f(k)}{[2bh(n,k)f(k)]^2} > 0 \quad (14)$$

Turning to the downstream and starting from the effect of the strictness of regulation on its monitoring strategy, differentiating  $p^*$  with respect to  $k$  we get

$$\frac{\partial p^*}{\partial k} = \frac{h'(n,k)f(k) + h(n,k)f'(k)}{b[h(n,k)f(k)]^2} c \left[ \frac{M}{bh(n,k)f(k)} - \frac{S_m}{2} \right] \quad (15)$$

Because both the probability of detection  $h(n, k)$  and the probability of a fine being imposed  $f(k)$  are increasing with the strictness of the regulatory regime, the probability of monitoring is increasing with the strictness of the regulatory regime whenever  $2M > S_m bh(n, k) f(k)$  or whenever the quality or environmental standard is such that

$$\frac{2M}{bh(n, k) f(k)} > S_m \quad (16)$$

A high quality or environmental standard increases the probability of monitoring as

$$\frac{\partial p^*}{\partial S_m} = \frac{c}{2bh(n, k) f(k)} > 0 \quad (17)$$

As a result, when  $S_m$  is high enough, a less strict regulatory regime is required to achieve a high probability of monitoring. At the same time a higher  $k$  (a more strict regulatory regime) increases the compliance level of the upstream firm. This effect is even higher when the upstream is called upon to pay a higher fraction of the fine (this is when  $b$  is high). As a result the potential fine is decreased (or in other words the cost of non-compliance is lowered) which lowers the downstream's incentives to monitor the upstream, especially so when the cost of monitoring is high.

Regarding the relationship between the strictness of regulation and the level of quality or environmental standards, what we show above says that the two are substitute instruments in providing incentives to monitor upstream suppliers. In fact, one can see the substitutability of the strictness of regulation and the level of quality or environmental standards by looking at

$$\frac{\partial^2 p^*}{\partial S_m \partial k} = -\frac{2cb[h'(n, k)f(k) + h(n, k)f'(k)]}{[2bh(n, k)f(k)]^2} < 0 \quad (18)$$

Differentiating  $p^*$  with respect to  $n$  to see the effect of the intensity of competition in the downstream market on the downstream's monitoring strategy we get

$$\frac{\partial p^*}{\partial n} = \frac{[\partial h(n, k) / \partial n] f(k)}{b[h(n, k) f(k)]^2} c \left[ \frac{M}{bh(n, k) f(k)} - \frac{S_m}{2} \right] \quad (19)$$

Because the probability of detection  $h(n, k)$  is decreasing with the intensity of competition, whenever the probability of monitoring  $p^*$  is increasing with the strictness of regulation  $k$  (or in other words, whenever  $\partial p^* / \partial k > 0$ ), the above derivative is negative and so the incentives to monitor the upstream are lowered with the number of firms in the downstream market. The opposite is true whenever the probability of monitoring is decreasing with the strictness of regulation ( $\partial p^* / \partial k < 0$ ). In this case more intense competition in the downstream market increases the incentives to monitor the upstream.

Finally, the downstream firm's monitoring costs decrease its incentives to monitor the upstream and through this they decrease the upstream's level of compliance

$$\frac{\partial p^*}{\partial M} = -\frac{c}{2[bh(n, k) f(k)]^2} < 0 \quad (20)$$

and

$$\frac{\partial s^*}{\partial M} = \frac{\partial p^*}{\partial M} \frac{bh(n, k) f(k)}{c} < 0 \quad (21)$$

where the later is a direct effect of the former.

## **5. Discussion**

We develop a model of an interaction between a downstream firm and its input supplier to examine the effects of the strictness of regulation on incentives to monitor the upstream and on the upstream's choice of compliance with regulation. We find that the effect of the strictness of regulation on the choice of upstream compliance is unambiguous; the level of upstream compliance is always increasing with the strictness of regulation. This is a direct effect of the strictness of regulation increasing both the probability of detection of non-compliance and the probability of a fine being imposed. Increasing the potential of a fine increases the upstream's incentives to increase the supply of compliance and to effectively lower the gap between the regulatory standard and actual compliance which determines the level of the fine. The upstream's incentive to supply compliance is increased more when the firm is called upon to pay a higher fraction of the potential fine.

Turning to the downstream, the effect of the strictness of regulation on downstream incentives to monitor the upstream is ambiguous. We show that, for certain levels of quality or environmental regulatory standards the strictness of regulation (as this is reflected in a higher probability of detection of non-compliance and in stricter implementation in the form of the likelihood of imposing a fine) increases downstream firms' incentives to monitor their suppliers. This in our model means that the probability of monitoring the upstream increases in the strictness of the regulatory environment. At the same time increasing the strictness of regulation increases the potential of a fine both through increasing the probability of detection as well as through increasing the probability of a fine being imposed. This increases the downstream's incentives to monitor the supplier. However, stricter regulation increases the upstream's incentives to supply compliance. As a result the potential fine is reduced which lowers the downstream's incentives to monitor, especially so when the cost of monitoring is high. These three effects determine the way that the strictness of regulation affects the choice of monitoring strategy by the downstream.

The level of the regulatory standard plays a substitute role to that of the strictness of regulation in providing incentives to the downstream to monitor the upstream. Whenever the standard is sufficiently high the strictness of regulation lowers incentives to monitor, while the opposite is true when the standard is low. What happens is that higher quality or environmental standards increase the probability of monitoring the upstream. At the same time higher quality or environmental standards increase the upstream's supply of compliance. If those standards are sufficiently high then they are enough to generate incentives to monitor the upstream.

In our model the intensity of competition is also a factor which affects the downstream's monitoring strategy and the upstream's choice of compliance. More intense competition in our model makes detection of non-compliance less likely. As a result the choice of compliance of the upstream firm is lowered. Turning now to the downstream's choice to monitor the upstream, for sufficiently low quality or environmental standards, more intense competition increases the downstream's incentives to monitor its input supplier. When quality or environmental standards are sufficiently high, incentives to monitor the supplier fall with the intensity of competition. Again what determines the effect of the intensity of competition on the downstream's choice is that more intense competition induces the upstream to comply more and thus for certain levels of the regulatory standard the downstream can monitor less especially when the cost of monitoring is high.

As argued in the introduction, empirical evidence about the role of regulatory requirements driving downstream firms' incentives to monitor their suppliers is inconclusive. In accordance with empirical evidence our model shows that the effects of regulatory requirements on downstream firms' monitoring incentives depend on the effect and size of other variables as well. In our model, the level of quality or environmental standards is acting as a substitute in providing incentives to monitor the input supplier. As a result the pressure from the strictness of regulation on the downstream's monitoring strategy is relaxed whenever the level of regulatory standards is high enough.

What our study shows, which reinforces existing literature on the topic, is that regulation may or may not be the driver of downstream firms' choice to monitor their input suppliers. However, it is not the only factor and it should not be considered to act in isolation, but rather in combination with other factors. Structural differences among industries should also be considered as explanatory factors of downstream firms' choice to monitor input suppliers. Those structural differences can act in combination with the regulatory environment to provide incentives to monitor input suppliers. Between the different industries there may exist substantial differences in for example requirements for capital investment, entry barriers, production technology requirements, productivity, labor intensity and labor skills, end product complexity. Besides structural differences which should be considered, our study identifies one variable, namely the level of quality or environmental standards, which acts in combination (and in fact as a substitute instrument) with the strictness of regulation to provide incentives to monitor the upstream and to comply with regulation.

## **6. Conclusions**

Downstream firms' incentives to act as inspectors of their input suppliers' behavior have drawn considerable attention. Among the factors providing incentives to monitor the suppliers are the regulatory requirements to which the downstream firms are subject. In our paper we have developed a formal economic model to examine the relationship between the strictness of the regulatory environment and downstream firms' incentives to act as inspectors of their sub-contractors. We have considered the interaction between a downstream, end market producer, and an upstream, input supplier firm. The downstream chooses the probability with which to monitor the upstream's choice of compliance and the upstream chooses a compliance level which determines the compliance of the end product with quality or environmental regulation.

Regulatory strictness influencing downstreams' monitoring behavior vis-à-vis upstreams is of practical relevance for policy makers. For one, policy makers need to know what difference regulatory strictness makes as regards firm behavior. Moreover, if governments can rely on firms effectively playing the roles of inspectors vis-à-vis their suppliers, governments may provide for less administrative capacity in order to secure compliance with regulations.

We find that the strictness of regulation affects the downstream's monitoring strategy in combination with the level of quality or environmental standards. Quality or environmental standards strengthen the downstream firm's monitoring strategy. If the standards are sufficiently low then the strictness of regulation increases incentives to monitor the upstream. If on the other hand, the standards are sufficiently high then the pressure on the downstream to monitor the upstream is relaxed and the strictness of regulation decreases the incentives to monitor the upstream. We also find that the downstream can relax its monitoring strategy especially when the cost of monitoring is high and this is so because the strictness of regulation increases the upstream's incentives to comply. We argue that the strictness of regulation should not be treated in isolation as a factor which determines the choice of downstream firms to monitor their input suppliers but rather in combination with other variables, such as the level of regulatory standards.

Looking at the upstream, we find that the strictness of the regulatory environment always increases the upstream's incentives to comply with regulation. This is because the strictness of the regulatory environment increases the likelihood that a potential fine is imposed on the downstream a fraction of which is passed to the upstream. The upstream has more incentives to comply as the fraction of the potential fine that is passed on it increases and as the level of the regulatory standard increases.

Our research can be extended in several ways. One obvious way is to incorporate competition in our model. In our analysis we have assumed an interaction between one downstream and one upstream firm. Competition in the downstream market is included in the analysis in an abstract way through a variable which affects the probability of detection of non-compliance. It would be interesting to add

competition in the model so much in the upstream as well as in the downstream market. Competition in the upstream market would allow the study of the effects of being able to turn to a different supplier in the event of non-compliance of a supplier and thus study the incentives to comply deriving directly from competition. Competition in the downstream market would allow us to study the effects of being able to turn to a different downstream firm when for example the alternative downstream firm is applying a laxer monitoring strategy and thus examine downstream firms' incentives to loosen their monitoring strategies.

One alternative way to extend this model would be to incorporate quality or environmental regulatory requirements effective on the upstream firm. In our analysis above we have assumed that the upstream is subject to no regulations. Incorporating quality or environmental regulation on the upstream firm would allow us to study possible complementarities among different regulatory requirements effective on the different firms.

Alternatively, it would be interesting to relax assumptions like the fixed post-sales cost sharing rule. In our model we assume that the potential fine is shared between the upstream and the downstream so that each firm pays a fixed share of the fine. It would be interesting to make the sharing rule a fraction of the upstream's choice of compliance. Starting from a high share passed on to the upstream and given that higher compliance would have to lower the upstream's share of the potential fine, it would be interesting to see whether the upstream's incentives to comply with regulation would be compromised with an endogenous post-sales cost sharing rule.

Finally, adding different types of sources of incentives into the model (like for example incentives deriving from competition, or from price considerations or consumer preferences) would make the analysis more complex but also richer. As we argue above, in the cases where the findings of our formal model do not agree with empirical findings (in other words when empirical findings for example conclude that regulation does not drive firms' incentives to monitor their suppliers while our model predicts that it does), it is likely that other factors besides regulation drive firms' choices. Incorporating those into the model would allow us to identify complementarities or conflicts among those factors.

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