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The Financing of Safety Controls

Stéphan Marette *

Summary

The aim of this paper is to investigate the link between an inspection policy designed to prevent industrial accidents and some financing instruments able to finance it. A simple theoretical model shows that the intensity of controls and the way to finance it depend on the market structure. Under a given number of firms, the per-firm probability of controls is lower than one and a combination of lump-sum tax and fixed fee is used for limiting market distortions. Under free entry/exit, the per-firm probability of controls is equal to one, and only a fixed fee is selected. Following these findings, we empirically study the ability of firms to cover a fixed fee that could finance the budget for additional inspectors, necessary to guarantee safety of high-risk plants in France. We show that the overall burden linked to the fixed fee covering the cost of new inspectors represents less than 1% of annual profits of firms with numerous high-risk plants.

Résumé

L'objectif de cet article est d'étudier le lien entre une politique d'inspection visant à réduire les risques industriels et son mode de financement. Un modèle théorique montre que l'intensité des contrôles et son mode de financement dépendent de la structure de concurrence sur les marchés.

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Quand le nombre de firmes en concurrence est donné, la probabilité de contrôle est inférieure à un et une combinaison alliant taxe et frais fixe payés par les entreprises permet de limiter les distorsions de marché. Dans un contexte de libre entrée, la probabilité de contrôle est égale à un et, seul un frais fixe payé par les entreprises est utilisé pour financer la politique de contrôle. À partir de ces résultats, cet article étudie la capacité des firmes à couvrir un frais fixe qui pourrait financer de nouveaux inspecteurs pour renforcer les contrôles des sites industriels à haut risque en France. Il est montré que la charge liée à l'embauche de nouveaux inspecteurs représente moins de 1 % des profits annuels des firmes disposant de nombreux sites à risques.

Keywords: Inspection policies, market regulation, regulatory funding, market structure.

Mots clés : Politique d'inspection, réglementation, financement des réglementations, structure de concurrence.

J.E.L. : L1, L5

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1. Introduction

In Europe, Canada, and the United States, agencies enforce market regulation by means of a monitoring policy. From counterfeiting to food safety, from nuclear plant safety to stock trading, the lack of money is always the reason put forward to justify some difficulties/inefficiencies in inspection policies.

Funding is particularly important for monitoring firms' compliance with environmental/safety regulations. Public management to control firms' efforts at reducing risks and pollution is very costly because each plant needs to be inspected. The European Environmental Agency (2000) has mentioned the lack of resources of public environmental authorities in different member states. In the US, the issue recently gained momentum with the 2007 James Baker panel recommending that the energy group BP (British Petroleum) should drastically improve the refinery safety in the US following the fatal explosion at the Texas City refinery in 2005 (Shelley, 2007).

In the US, the 15,500 sites that are included in the Risk Management Program (RMP) of the Environmental Protection Agency (EPA) because of hazardous chemicals handling are monitored by only 50 inspectors (Kunreuther and Schmeidler, 2004). Even if evaluating the optimal number of inspectors with a complete cost-benefit analysis is difficult, this figure of 50 inspectors seems insufficient for guaranteeing safety, and Kunreuther and Schmeidler (2004) mention infrequent inspections coming from the RMP. Minott (2001, p. 1) notes that some experts discussing the RMP said that "it would be preferable if implementing agencies would increase their own enforcement efforts, perhaps with the help of funding generated by fees charged to regulated plants." [1] This last point is the topic of this paper. [2]

This issue of funding concerns all public audits that check the regulatory compliance of firms or agents. The limited amount of resources available for thorough monitoring raises the issue of the available amount of money and the intensity of controls influencing the budget constraints of the regulatory agencies. The common method for financing an inspection program is the general government budget. Nevertheless, financing regulatory programs with general-public taxes can end up limiting programs' monitoring activities when budgets are tight. As Becker (1999) mentioned, "unfortunately, generous funding for entitlements, farm or urban subsidies and other programs tend to crowd out desirable forms of government spending" such as the control of environmental or product safety by the government. Because of this, policymakers often turn to alternative ways for funding an agency's activity, such as fees for particular purposes. The earmarking of the fees is a way to counterbalance the lack of money for safety inspections.

The aim of this paper is to examine the way to finance controls designed to prevent industrial accidents in a context of imperfect competition. We want to know whether or not firms concerned by these controls should and could bear one part of costs linked to inspections. Our objective also consists in studying the firms' ability to cover the financial burden linked to these controls for preventing industrial accidents. A clear examination of the funding, the profitability and the market context is necessary to define an efficient policy.

A theoretical model seeks the best way to finance market regulation as long as it is cost effective to do so, in a context in which the regulatory compliance is costly for (symmetric) firms. We consider various combinations of means of

1. The U.S. Environmental Protection Agency imposes fees that are directly used to finance environmental cleanup, especially of so-called Superfund sites (see EPA 2003, p. 16).

2. This debate also concerns products and services safety. For instance, in 2007, the US Federal Drug Administration proposed a 29% increase in the annual user fees paid to the agency by pharmaceutical companies to improve oversight of prescription drug safety and reduce approval times for new medications (see Medicalnewstoday, 2007).

financing commonly used by public agencies around the world, in particular a fixed fee paid by all firms (present on the market) and a public program financed through taxes (as a lump-sum tax incurred by the rest of an economy). The number of controls made by the regulator influences the firms' incentive to comply with the regulation.

We show that the intensity of controls depends on the optimal choice between a public tax and an industry fee used to finance an inspection policy. Under a given number of firms, the per-firm probability of controls is lower than one, since firms' incentive to comply with regulation holds under positive profits. A lump-sum tax is often combined with a fixed fee for limiting distortions. As the lump-sum tax is costly for tax-payer, the fixed fee negatively influences the randomized control policy. Under free entry/exit, the per-firm probability of controls is equal to one, and only a fixed fee that regulates the number of firms is used. Indeed, because of zero profits, the probability of controls is equal to one for impeding a deviation that would avoid the cost of regulatory compliance leading to positive profits.

Following these findings, we focus on the firms' ability to finance the budget for additional inspectors necessary to guarantee safety of high-risk plants in France. An empirical study of profits suggests that firms with numerous plants may cover the estimated fixed fee linked to the recruitment of new inspectors for improving safety. We show that the overall burden linked to the fixed fee covering the cost of new inspectors represents less than 1% of annual profits of firms with numerous large plants (so-called *Seveso* plants).

This paper is linked to two separate strands of literature. The first strand of literature, initiated by Becker (1968), includes numerous papers on optimal monitoring policies linked to incomplete monitoring activity (Polinsky and Shavell, 1979, 1991, and 1992), a dynamic approach (Harford and Harrington, 1991, and Harrington, 1988) or self revelation (Jones and Scotchmer, 1990; Malik, 1993 or Livernois and McKenna, 1999). This strand of research mainly considers penalties as a credible threat for reaching a regulatory aim, without detailing the regulator's optimal budgeting choices and the complete choice of funding instruments. These studies abstract from the market context and the firms' probability depending on the competitive intensity. Our framework differs since we explicitly investigate some regulator's alternative sources of revenue (fee and/or tax) in a context in which the firms' competition is taken into account. The present paper differs from papers on safety/quality standards (see for instance Marette, 2007), since it directly focuses on the financing of such a policy.

This paper is also linked to the strand of literature that concerns the optimal way to finance monitoring regulation. For instance, in earlier work in which the number of controls and the number of firms are exogenous, Crespi and Marette (2001) and Marette and Crespi (2005) show that different tools for financing emerge at the equilibrium. Conversely, in the present paper, the number of controls and the number of firms are exogenous or endogenous, which requires more studies for capturing the interaction between the funding and the market mechanisms. This paper adds to this literature by showing that the financing and the probability of controls depend on the number of firms, either endogenous or exogenous. It also considers some empirical estimations regarding the firms' ability to cover a potential fee, an issue that is generally overlooked by the literature.

A very simple model is presented in section 2, while the main results are detailed in section 3. Simulations of fees for financing new inspections guaranteeing safety of high-risk plants in France are given in section 4, and section 5 concludes.

2. A Simple Model

Our model is a very simple framework allowing different sources of inspection financing. Trade occurs in a single period, and n producers may choose to produce with a safe or a dangerous plant. This decision is private information for each producer. A safe plant corresponds to a plant leading to the absence of any environmental damage. The sunk cost for a safe/clean plant is C for each producer and the marginal cost is zero. A dangerous plant entails a damage D with probability $(1-\lambda) > 0$. Even if the probability $(1-\lambda)$ is the same for the n firms, the realization of damage for a firm is independent from the realization of the other firms' damages. For simplicity, the marginal and fixed costs of producing only with a dangerous plant are zero. With a probability $(1-\lambda)$, the per-firm damage D is incurred by a third-party, while there is no damage with a probability $\lambda < 1$. The inverse demand by consumers is $p(Q) = a - Q$, where $p(Q)$ and Q respectively denote the price and the quantity with $a > 0$. [3]

Assume that only the regulator is able to ensure a monitoring policy for inducing regulatory compliance that implies only safe plants. The overall cost of monitoring depends on the number of firms inspected, which we assume will be done randomly. This cost is denoted xR, where R is the fixed cost per inspected firm/plant and x is the number of inspected firms with $x \leq n$. The selection of x determines the number of random inspections and it does not depend on any past experience or voluntary-information signaled by the firm. Thus x/n is the

3. The analysis could be extended to the case, where "aware" consumers bear the overall damage D in a context of perfect or imperfect information (see Akerlof, 1970). Consumers would accept to buy dangerous products sold by n sellers, if their overall surplus is positive (where $Q*$ and $p*$ are the equilibrium quantity and price), even if they would prefer having safe products leading to an overall surplus $\int_0^Q (p(Q) - p*)dq - nD$ is positive (where $Q*$ and $p*$ are the equilibrium quantity and price), even if they would prefer having safe products leading to an overall surplus $\int_0^Q *(p(Q) - p*)dq$.

probability that a firm will be inspected. The per-firm cost of monitoring R provides a perfect revelation concerning the plant safety and the absence of regulatory compliance. [4] The instruments for financing this spending are (1) a fixed fee F paid by each firm, (2) a public financing by means of a lump-sum tax T paid by taxpayers and/or (3) a monetary penalty P paid by the cheating firm regarding the regulation. [5]

The single round of trading proceeds in four stages. In stage 1, the regulator announces its policy, namely, whether or not to propose a safety standard, an inspection policy x, and a selection of financing instrument(s) (1), (2) and/or (3). The regulator seeks to maximize welfare (defined by the sum of the sellers' profits, the consumers' surplus and the third party's and tax payers' losses), while inspecting a number of firms x.

In stage 2, n producers simultaneously choose whether or not to comply with the regulation (with every firm knowing the regulation policy). They incur the cost C (sunk in stage 3 and 4), if they decide to invest in a safe plant. We distinguish between a situation (*a*) where the number of firms n is given (due to barriers to entry for instance) and a situation (*b*) where this number is endogenous, namely, in a context of free entry/exit. Under situation (*a*), we assume that the regulator has no interest in limiting the number of firms, implying instruments (1) to (2) are affordable for the n firms, though under situation (*b*), the regulator sways the number of firms. These two assumptions allow us to also consider a particular situation where the optimal number of firms defined under situation (*b*) is higher than the existing number of firms and potential entrants because of a relatively high concentration on a market.

Under situation (*b*), the decision of quality compliance is preceded by a simultaneous entry decision in this context of free entry/exit (see also Marette, 2007). The entry/exit decision is public information for all firms and the regulator, while the environmental safety choice is private information for each firm.

In stage 3, the regulator makes its inspection if a safety standard is selected. The regulator imposes a penalty P if an infraction is found, namely if a firm does not incur the cost C leading to safe plants. In stage 4, producers simultaneously set quantities (Cournot competition) and earn their profits, allowing them to pay the cost C and/or the fee F.

4. One extension could consider imperfect monitoring during the inspection, which might be introduced with an additional probability parameter. Imperfect monitoring would reduce the attractiveness of the monitoring policy. The regulator could allocate money to improve the monitoring process (through inspector training and/or new technologies), which would reduce the number of inspections (defined by x in our framework). However, the bureaucracy may stifle the regulator's improvements of the monitoring process.

5. We abstract from several points. There is no liability for compensating the third party, which is unaware of the damage in the short term. We also abstract from any imperfect detection by the regulator during a firm visit.

We now turn to the characterization of the subgame perfect Nash equilibrium of this four-stage game (solved by backward induction) and then conduct a welfare analysis allowing the selection among the different rules.

2.1. Firms' Strategy

We successively describe the production choice (stage 4) and the standard compliance (stages 3 and 4) of a firm. Each firm knows the regulation (or its absence), namely, the choice of a safety standard, the number of firms inspected x (in stage 3), and the values of the fee F imposed on every firm.

If a firm selects a safe plant, no penalty P is imposed in the case of control (whatever the selected standard), while the fee F and the fixed cost C are incurred. The profit of a firm i with safe plants is $(a-Q)q_i-(C+F)$.

If a firm selects a dangerous plant and the regulator imposes a safety standard, a penalty P is imposed on the inspected firms (in stage 3). The probability of being inspected by the regulator is x/n. With a probability $(1-x/n)$, no inspection occurs, which leads to a profit, $(a-Q)q_i-F$. With a probability x/n, the firm is inspected and must pay a penalty P. The financial situation of a firm influences the penalty received by the regulator. If a firm's available profit, after the payment of a fee F, $(a-Q)q_i-F$ is high enough to cover the penalty P, the profit in case of inspection is $(a-Q)q_i-F-P$. Conversely, if the firm is not able to completely cover the penalty (i.e., insolvency), its profit is completely allocated for paying a part of the penalty and its profit is zero. The expected profit of a firm choosing dangerous plants is

$$Max\Big\{(a-Q)\,q_i-F-x/nP;(1-x/n)\,[(a-Q)\,q_i-F]\Big\}.$$

In the absence of a safety standard, the choice of dangerous plants leads to a profit $(a-Q)q_i-F$ since there is no inspection ($x=0$).

Let I_i represent a firm decision regarding the quality selection. A value $I_i=1$ means that a safe plant is selected, while a value $I_i=0$ means that dangerous plant is selected. By combining the previous expressions $(a-Q)q_i-(C+F)$with a safe plant and $Max\{(a-Q)q_i-F-x/nP;(1-x/n)[(a-Q)q_i-F]\}$ with dangerous plant, the expected profit function of firm i is rewritten as

$$\pi(I_i)=Max\Big\{(a-Q)\,q_i-I_iC-F-(1-I_i)\,x/nP;(1-I_i)\,(1-x/n)\,[(a-Q)\,q_i-F]\Big\}.$$

Under Cournot competition in stage 4, the quantity selection leads to the following first-order condition: $d\pi(I_i)/dq_i=(a-2q_i-\sum_{k=1}^{n-1}q_k)=0$. Under a symmetric Cournot-Nash equilibrium, all sellers select the same quantity ($q_i=q_j=q*$) equal to $q*=a/(n+1)$ with an equilibrium price equal to $p*=a-nq*$. The substitution of those values in $\pi(I_i)$ leads to the per-firm profit:

$$\pi(I_i,F)=Max\left\{\frac{a^2}{(n+1)}-I_iC-F-(1-I_i)\,x/nP;(1-I_i)\,(1-x/n)\left[\frac{a^2}{(n+1)^2}-F\right]\right\} \quad (1)$$

As the n firms are equivalent, they adopt the same strategy, leading to $I_i = I$ for $i = 1, \ldots, n$. A firm selects a safe plant (linked to the investment C), if $\pi(1, F) \geq \pi(0, F)$ and dangerous plant otherwise. [6] The consumers' surplus is

$$CS = \int_0^{nq*} (a - q - p*)dq = n^2 a^2 / 2(n+1)^2 \tag{2}$$

The expected third-party loss is $V = n(1 - I)(1 - \lambda)D$ and it depends on the n firms' choice I. [7]

2.2. The Financing of Regulatory Controls

Regarding the financing of the regulatory controls, the overall cost of the policy Rx has to be covered by the different instruments. Penalties are collected if some sellers decide to select a dangerous plant, while the regulator decides a safety standard. For each inspected producer, the probability of collecting a penalty is $(1 - I)$, with $I = 0$ corresponding to a firm's decision to select a dangerous plant. For the regulator, the received penalty from a cheating firm is $\overline{RP} = (1 - I)Min\left\{P, \left[a^2 / (n+1)^2 - F\right]\right\}$, since the receipt is capped by the firm's profit as discussed above. After x inspections, the expected amount of money received via penalties is $x\overline{RP}$. This amount is complemented with the fees paid by the n firms (namely nF) and the lump-sum tax T. As the budget constraint facing the regulatory must be balanced, the cost Rx is lower or equal to the overall receipt. Thus, the budget constraint for the regulator is

$$B(P, F, T) = (1 - I)Min\left\{P, \left[a^2/(n+1)^2 - F\right]\right\} + nF + T - Rx = 0. \tag{3}$$

The welfare given by the sum of the profits, the consumers' surplus and the third party's and tax payers' losses depends on the number of firms selecting a high- or dangerous plant. Let $\delta \geq 1$ denote a multiplier that represents the opportunity cost of public funds for the taxpayer paying a lump sum tax T. [8] As such, the overall welfare is

$$W(I, F, T) = n\pi(I, F) - n(1 - I)(1 - \lambda)D + CS - \delta T. \tag{4}$$

6. We assume that firms select the safe plant if $\pi(1, F) = \pi(0, F)$, in order to avoid any additional cost linked to litigations or a loss of good reputation.

7. The assumption of risk neutrality for the third party suffering from the damage makes our welfare conclusions more conservative: if third party is risk averse, the desire for and the benefits from regulation and inspection increase.

8. When the opportunity cost of public funds is $\delta = 1$, the government is indifferent about pure transfers from domestic treasury to the inspection agency (and different agents concerned by the regulation and taken into account in the welfare measure). When $\delta > 1$, transfers from the rest of the economy are costly, not only in monetary terms but also in polical terms.

Note that if $I = 1$ (respectively $= 0$), no damage (respectively no cost C) is incurred by society (respectively by the firms). The welfare corresponding to the different types of financing instruments is detailed in the appendix (in the proofs of the different propositions).

3. The Policy

The regulator maximizes the welfare given by (4) subject to (3) and the firms' quality choice represented by the comparison between $\pi(1, F)$ and $\pi(1, F)$. In this section, we distinguish between a situation (a) where the number of firms n is given and a situation (b) where this number is endogenous.

3.1. A Given Number of Firms

First, under situation (a), the regulator does not limit the number of firms n, implying instruments (1) to (3) are affordable for the n firms. This means that the profits according to quality choices are $\pi(1, F) \geq 0$ and $\pi(0, F) \geq 0$. We also assume that the welfare with a dangerous plant and without any control is $W(0, 0, 0) \geq 0$, which corresponds to a case where the per-firm damage D is not too high.

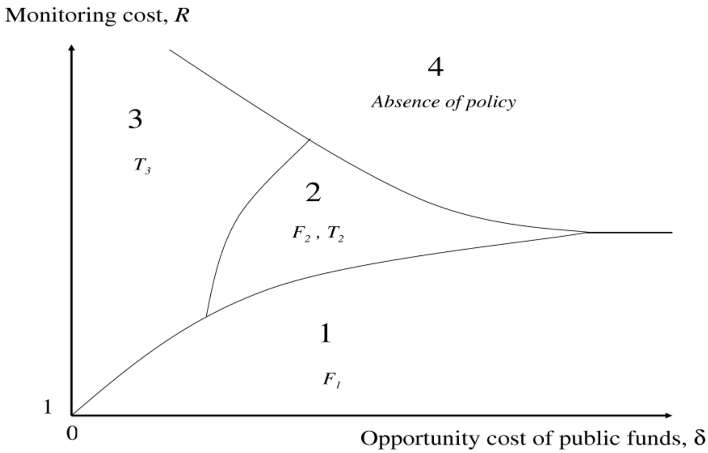
First, the figure 1 and the proposition 1 present the optimal regulatory choice. The relative values of δ and R determine the regulator's strategy (concerned about maximizing social welfare) and define the limits of areas 1 to 4 (the frontiers of these regions are detailed in the appendix). Below, we present the propositions and provide an intuitive interpretation (see mathematical details and the proofs of propositions in the appendix).

Proposition 3.1 – *When the number of firms n is given, the socially optimal policy is*

1. *a standard leading to safe plants with a fixed fee* F_1*, a penalty* $P(F_1)$ *and probability of control* $x(F_1)/n < 1$*, in region 1,*
2. *a standard leading to safe plants with a fixed fee* T_2*, a lump-sum tax* F_2*, a penalty* $P(F_2)$ *and probability of control* $x(F_2)/n < 1$*, in region 2,*
3. *a standard leading to safe plants with a lump-sum tax* T_3*, a penalty* $P(0)$ *and probability of control* $x(0)/n < 1$*, in region 3,*
4. *no policy and no financing instruments, leading to dangerous plants, in region 4.*

In regions 1, 2 and 3, the monitoring cost R is relatively low and the regulation is optimal since there are no dangerous plants entailing damage. If, on the other hand, in region 4, the monitoring cost R is relatively large, the absence of regulation

Figure 1 : *The Optimal Financing Choices*



is optimal and dangerous plants are selected. The costs of regulation in region 4 exceed the benefits. Under the absence of regulatory controls in region 4, firms have no incentive to invest in safe by incurring the fixed cost C.[9]

In regions 1, 2 and 3, no penalty is collected by the regulator, since all firms select safe plants. As, for simplicity, all firms have the same costs function, they comply with the regulation since the penalty provides a credible incentive under this symmetric equilibrium (see the proof of proposition 1).[10] In order to limit the number of controls, the penalty $P(F)$ is equal to the highest level that a firm with a dangerous plant could pay. Such a penalty leads to a probability of being control equal to $x(F)/n = C/[a^2/(n+1)^2 - F]$. This probability is lower than one as soon as firms have positive profits with a safe plant, namely for $a^2/(n+1)^2 - C - F > 0$, which is the case when C and n are relatively low. This possibility of profits limits the incentive to deviate for a firm and the number of necessary controls.

The per-firm probability of control $x(F)/n$ increases with the fixed fee F. Indeed, a large fee results in negative firms' incentives to select a safe plant, which increases

9. The alternative assumption $W(0,0,0) < 0$ could be considered with the product ban scenario if no control is selected.

10. For simplicity, we abstracted from heterogeneity among firms (see Marette and Crespi, 2005). The consideration of size/cost differences would lead to heterogeneous profits, implying possible fee/tax/penalties discrimination. For instance, the firms with the largest profit could pay a larger fixed fee than the other firms. Different levels of damages, risks (probability of accident) or costs of inspection also appeal for different fees or penalties among firms. As profits would be different, the incentive to comply with regulation could differ at the equilibrium with some firms preferring not to respect regulation (see Marette and Crespi, 2005). In this case, penalties that would be incurred by inspecting cheating firms could finance the budget of the agency.

the number of controls and lowers overall welfare. For thwarting this distortion, the regulator may choose to complete or to replace this fixed fee *F* by the public financing *T*. However, this lump-sum tax is costly for the taxpayer when the opportunity cost of public funds is relatively large. Maximizing welfare consists of minimizing the number of inspections, $x(F)$, in order to achieve compatibility with the policy, thus minimizing the financing instruments that influence profits and/or tax-payer losses. The trade off between instruments distortions leads to the following optimal choices.

In area 1, only the fixed fee is selected. [11] A relatively low inspection cost has a minor impact on the increase in the number of controls, while a relatively large opportunity cost of public fund impedes the use of the lump-sum tax. The per-firm cost of inspection *R* is affordable, since all sellers may cover the fixed fee with their profits. In area 2, both fixed fee and lump-sum taxes are selected. For "midrange" values of per-firm cost of inspection *R* and opportunity cost of public funds, it is socially optimal to complete the fixed fee by the lump sum tax to balance the budget. The taxpayer only suffers from the tax that is a relatively small part of the resources earmark for the regulator. In area 3, only the lump-sum tax is selected, since the inspection cost is relatively large and the opportunity cost of public funds is relatively low. The per-firm probability of control $x(F)/n$ increases with the fixed fee *F*. Indeed, a large fee results in negative firms' incentives to select a safe plant, which increases the number of controls and lowers overall welfare. To thwart this distortion, the regulator chooses to completely replace this fixed fee *F* with public financing *T*.

If, on the other hand, the monitoring cost *R* is relatively large, the absence of regulation (and control) is optimal and there are only dangerous plants. The costs of regulation exceed the benefits for large values of *R*. Under the absence of regulatory controls and sanctions, firms have no incentive to invest in high quality plant by incurring the fixed-cost *C*.

11. A possible explanation for the reluctance to earmark fees for inspection policies is the risk of collusion between the auditor and the audited firms. A public agency may choose more or less than the necessary amount of controls, depending on any political influences upon the agency. Obviously, the risk of "collusion" between the agency and the inspected firms would obfuscate the agency's regulatory obligations. However, as the *Economist* (2002, p. 1) noted for financial auditing, "a firm's relationship with its auditors is, after all, a curious one: it pays the fees of the institution with the prime responsibility, in the first instance, for spotting any irregularities. That is not an insuperable problem: that taxpayers pay for the police does not lead them to expect to be allowed to get away with daylight robbery." The sanctions for firms and members of agencies for abusive collusion should deter fraudulent behaviors.

3.2. An Endogenous Number of Firms

The ability of firms to enter and/or leave an industry changes the optimal policy and introduces some interesting features of the financing instruments selection. When the number of firms is endogenous (scenario *b*), the choice of financing instruments may influence the number of firms able to enter/exit the market. Recall that in stage 2, the decision of quality compliance is preceded by a simultaneous entry decision by firms under scenario *b*. The entry decision is a public information, while quality needs to be inspected. We also assume an opportunity cost of public funds $\delta = 1$ and a lump-sum tax T that can be positive or negative. [12]

Proposition 3.2 – *Under free entry, the socially optimal policy is*

1. *a standard with a fixed fee* F_α*, a transfer* $T_\alpha < 0$*, a penalty* $P(F_\alpha, 0)$ *and* $x(F_\alpha, 0)/n = 1$*, leading to the entry of* $n*(1)$ *firms with safe plant, if* $R < a^2/8 - C$ *and* $C + R < (1 - \lambda)D$*,*
2. *the absence of inspection policy with a fixed fee* F_β *and a transfer* $T_\beta = -n*(0)F_\beta$*, leading to then entry of* $n*(0)$ *firms with dangerous plant, if* $(1 - \lambda)D < a^2$ *and,* $(1 - \lambda)D < R + C$*,*
3. *a fixed fee* $F_\omega > 0$ *that leads to the absence of entry and production, if* $R > a^2/8 - C$ *and* $(1 - \lambda)D > a^2/8$.

The selection of a fixed fee allows regulator to control the number of firms when numerous firms are able to enter the market. The comparison between the per-firm expected damage $(1 - \lambda)D$ coming from a low quality plant and the per-firm full cost of safe plants $C + R$ (including the per-firm cost of inspection) determines the policy.

If $C + R > (1 - \lambda)D$, dangerous plants without inspection policy lead to a higher welfare than the welfare with safe plants. The fixed fee $F_\beta > 0$ allows the regulator to limit the number of firms and the overall damage.

If $C + R < (1 - \lambda)D$, having safe plants leads to a higher welfare than the welfare with dangerous plants. As firms have zero profits under free entry with a safe plant, the probability of control has to be equal to one for avoiding any deviation by a firm with a dangerous plant that is less costly. [13] The fixed fee is the only tool financing the public inspection. As the fixed fee is larger than the cost of inspection, the regulator transfers the "profit" to the rest of society via $T_\alpha < 0$, allowing a balanced budget for the regulator.

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12. All results of proposition 2 are robust with $\delta > 1$, since transfers linked to T are costly.
13. Once entered, a deviating firm would make a positive expected profit with a probability of control lower than one, since the cost of safe is avoided and the penalty $P(F_\alpha, 0)$ tends toward zero.

The regulator keeps some firms out of a market in a context of fixed costs C and R. The regulator increases the fixed fee F for reducing the number of firms and reducing the number of inspected firms. [14] The issue associated with entry showed that under free-entry equilibrium, the number of firms is greater than the socially optimal number with positive fixed costs (see Mankiw and Whinston, 1986 and Perry 1984). Thus we see that it is the financing of the quality regulation itself that is implicated in the concentration.

A lucid analysis of the market context matters for defining a policy. While a complex combination of instruments and a probability of being inspected lower than one is socially optimal with a given number of firms, a fixed fee reflecting the fixed cost of inspection and a probability of being inspected equal to one are selected when the number of firms is endogenous.

Note that the optimal number of firms may be lower or larger than the number of firms n considered in proposition 1. If the optimal number of firms is lower than n, the fixed fee can be selected for reducing the number of firms. Conversely, a number of firms n lower than the optimal number of firms should lead the regulator to select the policy presented in proposition 1. In this case, the regulator may even choose more than the necessary amount of regulation, depending on the incumbent's influences on the policy. Kim (1997) underscores how regulation is sub-optimal when an incumbent behaves strategically against the government (the regulator, as a follower, deters entry by newcomers [with some fees], protecting the incumbents' oligopoly situation), an aspect we do not consider here. Further, the argument for restricting the number of firms needs to be mitigated with respect to the government's ability to collect information regarding parameters such as firms' fixed costs and the optimal number of firms.

For restricting entry or encouraging exit in a context of numerous potential producers, a fixed fee larger than the per-firm cost of inspection is favored. Implementing such a fee may be thwarted by the lobbying of an industry that threatens to lay off workers or to locate abroad. Even if an "optimal number of firms" may be politically charged, the point we are emphasizing is simply that the choice by the regulatory authority to maximize social welfare subject to the constraints of the financing mechanisms necessarily affects the number of firms in an industry. In particular, strengthening regulations without hurting the industry is impossible in such a context.

In defining the analytical framework, very restrictive assumptions were made for simplicity. In particular, a very simple per-firm expected damage $(1-\lambda)D$ was assumed. Several extensions could be introduced. First, the parameter λ

14. From proposition 2, the optimal number of firms in the industry declines with R and C, a interesting result because each firm has the same cost structure (symmetric firms), thus the result does not occur because higher-cost (presumably smaller) firms are driven out of the market.

corresponding to the absence of risk could depend on a costly firm's effort that should be taken into account in the number of controls defined by (A1) in the appendix. Firms may differ in their cost C for having safe/clean production process. As profits would be different, the incentive to comply with regulation could differ at the equilibrium with some firms preferring not to respect regulation. In this case, penalties that would be incurred by inspecting cheating firms could finance the budget of a regulatory agency (Marette and Crespi, 2005). Second, the per-firm damage D could depend on the firm's output q with $D'(q) > 0$ and $D''(q) > 0$. In this case, a per-unit tax (that depends on quantity as a Pigouvian tax) could complete the other tools presented in propositions 1 and 2, if the per-firm damage is not fully eliminated with an effort C.

Moreover, we focus only on public inspection. However, the private auditing made by the third party may partially replace the public auditing when there is a lack of public money. In this case, the public agency needs to monitor the third-party auditors and this task must be financed according to mechanisms similar to the ones previously presented.

Despite limitations, an important result of this section is the emergence of the fixed fee as the tool to partially or fully finance the inspection cost. A crucial point raised in propositions 1 and 2 consists in knowing whether or not firms are able to cover a fixed fee with their current profits (see equation 1). We now turn to an example focusing on the firm's ability to cover a fixed fee. The following section presents simulations for helping public debates about the sensitive issue of financing inspection for high-risk plants.

4. The Financing of High-Risk Plants Controls in France

The chemical factory AZF explosion in Toulouse (France, September 21st 2001) killed 30 people, injured 3,000 and destroyed numerous buildings. This AZF unit of oil giant Total was classified as a *SEVESO* site, namely a plant with a high threshold of risk according to the *Seveso* II European Directive (Council Directive, 1996). This major accident pointed out the need for improved risk management of industrial sites in France and in Europe. Regulatory authorities attempted to reinforce legislations and measures such as risks assessment, liability, sanctions or independent audits.

After the AZF blast, 150 new inspectors in 2002 and 100 new inspectors in 2004 were hired for completing the DRIRE's staff in France (Sénat, 2003). The DRIRE (Directions Régionales de l'Industrie, de la Recherche et de l'Environnement), are regional directions in charge of public inspections of 65,000 high-risk plants (owned by 10,000 firms), including 1,290 *Seveso* plants, with a high threshold of risk (Council Directive, 1996). The DRIRE expenses including the wages of these 250 new inspectors are financed by the general government budget voted by the French parliament without any additional direct payments by firms with high-risk plants.

Despite these 250 new inspectors, many comments and reports underlined the lack of public inspectors for monitoring the safety of the different plants in France. During a public hearing before a parliamentary commission, Philippe Vesseron, the chairman of the national direction in charge of the industrial risks in the Ministry for Ecology and Sustainable Development, mentioned the "desirable" recruitment of 1,000 new inspectors for guaranteeing the safety of plants and their neighbourhood (see Assemblée Nationale, 2002 and Coroller, 2001).[15] The absence of regulatory compliance by some firms can be deterred by inspections and sanctions (Guyotat, 2004). Based on this evaluation of 1,000 new inspectors, 750 inspectors were still missing in 2004 for insuring safety in France, if the 250 DRIRE's recruitments are taken into account.[16]

As it is very hard to evaluate the optimal number of inspections even with a complete cost-benefit analysis, this figure of 1,000 "desirable" new inspectors including the 750 missing inspectors may be discussed or criticized. However this figure may be used as a reasonable evaluation of the regulatory need, since a relatively large number of industrial accidents in France seems to confirm the social benefit of more controls (and inspectors) compared to the present situation (Lomazzi, 2004). In 2001, the Department for Assessing Risks and Industrial Pollution (Bureau d'Analyse des Risques et des Pollutions Industrielles, BARPI) in the Ministry for Ecology and Sustainable Development, recorded 1,589 incidents in France (IFEN, 2002).

This section aims at thinking about the way to finance the additional number of inspectors, evaluated to 750 according to the previous paragraph. One stumbling block of an efficient control policy is the difficulty for raising financial revenues (Coroller and Ecoiffier, 2002). This section will estimate a per-plant fixed fee that could finance the annual cost of these 750 new inspectors. This section is a simple simulation for helping the debate about the way to finance inspection. Clearly, the

15. The European Environmental Agency (2000) also mentioned the lack of resources of the public environmental authorities.

16. Note that 400 new inspectors have been recruited by the Drire between 2004 and 2007 (see **Drire, 2005**). These recruitments should be also financed by the general government budget voted by the French parliament without any additional direct payments by firms with high-risk plants. Based on this evaluation of 1,000 new inspectors, 350 inspectors would be still missing in 2004 for insuring safety in France, if the 250 DRIRE's recruitments and the 400 recruitment would be taken into account. We do not take into account these recruitments in our estimation, but results of tables 1 and 2 in this section would be robust for financing the 350 missing inspectors.

simulated fixed fee is an upper bound of what firms could pay, since one share of the overall cost can be directly finance by taxpayers rather than firms (see proposition 1).

Three main reasons explain the simplifying choice of a fixed fee as the single source of financing. First, the propositions 1 and 2 underlined the crucial role of the fixed fee paid by firms for raising revenue of an inspection agency. Second, proposition 1 suggests that the lump-sum tax is a complement of the fixed fee. The study of the existing budget provides precious information about the equilibrium among different taxes. Indeed, the DRIRE including the wages of new inspectors in 2002 and 2004 (see details in the introduction) are financed by the general government budget voted by the French parliament (Sénat, 2003). The main sources of receipts for the general government budget in France are the value added taxes (45% of the receipts), the income taxes paid by households (22% of the receipts), and taxes on profits paid by firms (14% of the receipts). Even if the previous percentages are a rough indicator of the agents' contributions, the increase of firms' contribution via a fixed fee is not "outrageous", since it would slightly put up taxes on profits (see results of table 2 below). The financing of the 750 new inspectors (deemed as necessary for the safety) by a fixed fee paid by the industry seems reasonable regarding the previous-theoretical analysis that concludes to the optimal combination of industry fees and taxes. Note that we restrict our study to the resources raised for covering the costs of the new inspectors only, while the debate could be extended to the DRIRE resources or the general government budget, which would require a complete cost-benefit analysis.

Third, some existing taxes on polluting activities, called TGAP (Taxes Générale sur les Activités Polluantes), are at present paid by the firms in France. Since 1999, the TGAP revenues are earmarked for a decrease of labor taxes and social contributions of firms, which should decrease the labor cost. [17] One of these tax concerns the high-risk plants, namely the TGAP *sur les installations classées*, and this taxes raised €19.82 million in 2000 (CCEE, 2003, p. 168). The fee is computed on a basis of €335.59 per plant, completed with a coefficient that ranges from one to ten according to the activity (CCEE, 2003, p. 167). An interesting point is that this tax on the high-risk plants is equivalent to a "fixed fee", which is tailored to our previous-theoretical results that emphasize the role of a fixed fee. Before the regulation of 1999, this tax on high-risk plants was only used for covering the costs of inspection, according to the principle that the financing should come from the agents generating the externality, including the prevention costs. [18] The French Senate criticized the end of the earmarking decided in 1999, by underlining

17. Loi n° 99-1140 du 29 décembre 1999 de financement de la sécurité sociale.

18. Ordonnance du 23 septembre 1958 and article 17 de la loi n° 76-663 du 19 juillet 1976 relative aux installations classées pour la protection de l'environnement.

some ambiguities of the double dividend theory (Sénat, 2001). One possibility is to re-earmark the revenue of the tax on high-risk plants for financing inspections and the wages of 750 inspectors (see scenarios below). [19]

We now turn to an evaluation of the cost of 750 new inspectors, who are skilled workers (*cadre A* in the French administration). For each inspector, the monthly gross average wage paid for a *cadre A* in the French administration is estimated to €3,600, including their net wage equal to €2,300 and the social contributions equal to €1,300. An amount of 20% including traveling expenses or training is added to the €3,600, which leads to a monthly cost of €4,320 per inspector. The annual cost linked to the wages of 750 new inspectors is €38.88 million (namely 4,320*12*750) that should be covered by the receipts coming from the fixed fee.

Several scenarios and cases are considered for computing the fixed fee. First, we distinguish between the scenario 1, where a new fixed fee covers the overall annual cost equal to V_1 = €38.88 million, and a scenario 2, where the tax on high-risk plants (TGAP *sur les installations classées* detailed above raising €19.82 million per-year is re-earmarked to the financing of 750 new inspectors. Under the scenario 2, the new fixed fee only covers the difference between the cost and the receipts coming from the existing tax, namely (€38.88 - €19.82) million, equal to V_2 = €19.06 million.

We now consider the calculation of the fixed fee, where different cases are considered. In other words, different levels of risk imply different levels of inspection for curbing the risk. Thus, we will distinguish between a general case where all plants/firms incur the same fee and a *Seveso* case, where only *Seveso* plants incur the fee. Under the general case with all firms paying the fee, 65,000 high-risk plants owned by 10,000 firms are taken into account. With the *Seveso* case, only 1,290 *Seveso* plants are taken into account. This corresponds to a case where the new inspectors will mainly focus on the *Seveso* plants. For the *Seveso* plants, different levels of risks are taken into account since the *Seveso* II Directive (Council Directive, 1996) in the European Union set up mandatory requirements for different levels of risk. Lower-threshold plants will be covered by the *lower tier* requirements. Companies who hold even larger quantities of dangerous substances (upper-threshold plants), above the upper threshold contained in the Directive, will be covered by all the requirements contained within the Directive. We will distinguish between a situation where the 1,290 *Seveso* plants incurs the fixed fee and a situation where only the 680 upper-threshold plants incurs a fixed fee (Drire, 2004).

19. The earmarking presents drawbacks since "there is no general reason (...) that the revenue raised by the efficient corrective tax on some polluting activity will exactly equal the efficient level of expenditure on mitigating the harm suffered" (Brett and Keen, 2000, p. 316). Earmarking may be one way to bypass politically weakness (Brett and Keen, 2000) or to get large political support by consumers/voters (Buchanan, 1969).

Table 1 : *Estimation of the Fixed Fee under Different Configurations*

	All plants		Seveso plants	
	65,000 plants	10,000 firms	1,290 plants	680 upper-threshold plants
Scenario 1 with V_1	€598.1	€3,888	**€30,139**	€57,176
Scenario 2 with V_2	€293.2	€1,906	€14,775	€28,029

According to the different configurations, the fixed fee is computed by dividing the overall cost defined by V_1 or V_2 (linked to the scenarios 1 or 2) by the number of firms defined by the different cases considered above. This leads to estimations in table 1.

This table 1 exhibits the different possibilities of fees that correspond to the different configurations. The columns 1, 3 and 4 give a per-plant fee, while the column 2 gives a per-firm fee, since firms own different plants. Each fee is equal to V_i (for $i = 1,2$) divided by 65,000 in column 1, V_i (for $i = 1,2$) divided by 1,290 in column 3 and V_i (for $i = 1,2$) divided by 680 in column 4. The column 2 represents an estimator of the *average* burden that the 10,000 firms could pay (V_i divided by 10,000). This column does not take into account the heterogeneity of firms regarding their size and the number of plants that they own.

With the 750 new inspectors mainly dedicated to the *Seveso* plants, the right columns of the table 1 are credible indicators of the upper limit that *Seveso* plants could pay. Conversely, if the 750 new inspectors do not particularly focus on the *Seveso* plants, the left columns provide an approximation of the lower limit that firms could pay. According to the methodology presented in the previous section and depending on the regulator objectives, the selected fee will balance between the upper and lower limits.

We now turn to the profits of firms with *Seveso* plants for identifying their ability to pay and the scale of the distortions coming from this fixed fee. From section 2, recall that the ability to pay the fixed fee directly depends on the firm's profitability, since such a fee is not passed on to consumers via the price. We focus on the 1,290 *Seveso* plants by abstracting from upper or lower threshold for the risk. We take into account the per-plant fee linked to the scenario 1 for *Seveso* plants (in bold table 1), namely a fee equal to $F^* =$ €30,139.[20] The information regarding the owners of the *Seveso* plants for the 21 regions in the metropolitan France is available on the DRIRE website for the 21 regions (Drire, 2004). In table 2, we isolate the 12 firms with the largest number of plants in France.

For these firms, the overall charge linked to the fee (given in column 4) is equal to the number of *Seveso* plants they own (given in column 3) times the

20. Results are robust with the highest amount in table 1 equal to €57,176.

Table 2 : *The Estimated Cost for Firms with the Largest Number of Seveso Plants in France*

Firms	Activity	Number of Seveso plants	Overall charge linked to the fee F*	% of the operating income
Total (Chem.)	Chemicals	29	€874,031	0.3%
SNPE	Chemicals	25	€753,475	-3%
Air Liquide	Medical Gas	20	€602,780	0.1%
Total (Downstr.)	Oil Distribution	19	€572,641	0.06%
Butagaz	Gas	18	€542,502	4%
Rhodia	Chemicals	16	€482,224	-0.7%
GDF	Gas	15	€452,085	0.03%
Primagaz	Gas	12	€361,668	0.6%
Rubis	Gas	8	€241,112	1%
BP	Oil	8	€241,112	0.2%
Shell	Oil	7	€210,973	0.2%
Esso	Oil	7	€210,973	0.1%

fee amounting to F* = €30,139. We compare this overall charge with the firms' profit. The total operating income (including the cost linked amortization of the capital but excluding the taxes paid by the firm) is considered as an indicator of the profitability. The annual reports (available for the year 2003 on the website of the firms) provide information coming from different subsidiaries in France and abroad. From available information, we estimate the share of the operating income coming from the business in France. Note that for Total, the French Oil Giant, the annual report allows us to distinguish between profits coming from the downstream sector (refining, marketing and oil distribution) and profits coming from the chemistry segment (see the column 1). Finally, the last column in the table 2 provides the ratio between the overall charge linked to the fee and the operating income coming from the business in France. In other words, the last column provides the percentage of the operating income that will be seized for paying the overall charge linked to the per-plant fixed fee F*.

The last column of table 2 shows that the fee is affordable for firms with several *Seveso* plants. Indeed, the overall charge is very low compared to the profits. For 9 firms, this overall charge represents less than 1% of annual profits evaluated with the operating income. Such an amount would slightly modify the capital yield if a fee was imposed. This relatively small distortion suggests that the financing of 750 new inspectors by a fixed fee is credible. Note that the magnitude of the overall cost compared to the profits is slightly changed if other fees of table 1 are taken into account. In particular, the share of the overall charge in the profits decreases when the estimated fee takes into account all firms (as in the left column of table 1). For the 2 firms (SNPE and Rhodia) with some annual losses in table 2, represented by a negative value in the last column, the overall charge linked to the fix fee would have a minor impact (lower than 5%) on the losses increase.

While the evaluations presented in table 2 suggest a minor impact on profits, these results must be carefully interpreted, since they are only extremely simple simulations. First, we only focus on large firms, while some *Seveso* plants also belong to relatively small firms. Imposing such a fixed fee could lead to mergers of small firms or exit as suggested at the end of the previous section. Second, the results of table 2 have to be completed by other studies including a general cost-benefit analysis balancing safety programs and the way to finance it. Third, we focused on a new fixed fee entailing distortions, while a better allocation of the public funds in France could seek to reduce some inefficient spending for earmarking funds for the recruitment of new inspectors.

5. Conclusion

Using a simple single-period model based on asymmetric information that also takes into account the link between the competitive structure and financing of the regulatory program, we showed how fees and public financing may be optimally used. The previous sections demonstrated the benefits of a policy that links the probability of controls, the market structure, and the choice of financing instrument.

Key factors in the choice of the optimal regulation are the market context, the number of firms that are likely to comply with the regulation, and, especially, firms' incentives. The simple model presented here underscores the importance in choosing appropriate financing structures. Although the type of budgetary financing may seem mundane, what this simple model shows is that the choice of financing may have important implications for industry structure and firm compliance and the intensity of controls. Thus, this paper suggests that it is especially imperative for governments not only to examine the types of regulations imposed upon an industry but also to scrutinize the type of financing used by the agencies charged with enforcing those regulations.

Thus, this paper suggests that it is imperative for governments to not only examine the types of regulations imposed upon an industry, but also the type of financing used by the agencies charged with enforcing those regulations. We show that the overall charge linked to the fixed fee covering the cost of new inspectors for improving safety in France represents less than 1% of annual profits of firms with numerous *Seveso* plants.

This analysis needs to be extended with complete cost-benefit analysis and more empirical details about agents and specific markets concerned with regulation. However, all of the questions and results of this paper are crucial for developing a debate regarding the improvement of public inspection. At this juncture in the debate over public inspection and efficiency, it is important for economists to bring their knowledge to the fore. Our hope is that this paper will serve as a reference base for policymakers and governments.

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Appendix

Proof A.1. Proof of proposition 3.1. (and figure 1)

When a safe standard is selected, the regulator minimizes the number of inspections and the financing instruments that influence profits and/or tax-payer losses. By using equation (1), the selected penalty satisfies the condition $\pi(1,F) = \pi(0,F)$, leading to the choice of safe plants. As all sellers respect the standard, the selected penalty does not help to finance the controls, so that only F, and/or T finance the monitoring policy.

For limiting the number of inspected firms x, the penalty is equal to the maximum that a firm may pay with dangerous plants, namely the maximum of profit $\pi(0,F)$ equal to

$$P(F) = \frac{a^2}{(n+1)^2 - F}. \tag{A.1}$$

With such a maximum level of penalty, the equality $\pi(1,F) = \pi(0,F)$ leads to a number of inspected firms

$$x(F) = \frac{nC}{\frac{[a^2}{(n+1)^2 - F]}}. \tag{A.2}$$

As firms are the same, the condition $\pi(1,F) = \pi(0,F)$ (guaranteeing the regulatory compliance) is the same for all firms, which leads to a symmetric equilibrium. There is no deviation leading to a higher profit for a firm selecting a safe plant at stage 2.

This value of $x(F)$ is substituted in the condition (3), that can be rewritten with $I=1$ as

$$nF + T = Rx(F). \tag{A.3}$$

As the budget must be balanced, the methodology for determining the choice of instrument(s) is the following. One financing instrument is determined according to (A3). This instrument is substituted in the welfare (defined by (4)) that is maximized according to the other instrument that must be positive.

We now turn to the detailed proof of proposition 1. In areas 1, 2, 3, all sellers respect the standard, due to the credible threat coming from the penalty *P(F)* and the number of inspection $x(F)$ defined in (A1) and (A2).

First, in area 2 of figure 1, the selection of a lump-sum tax and fixed fee are socially optimal. The budget (A3) is balanced for a fixed fee $\hat{F}(T)$, that is substituted in the welfare equal to $W(1,\hat{F}(T),T)$. The maximization of $W(1,\hat{F}(T),T)$ leads to the choice of T_2 where $dW(1,\hat{F}(T_2),T_2)/dt = 0$ (where $d^2W(1,\hat{F}(T_2),T_2)/dT^2 < 0$).

The selected instruments are

$$F_2 = \hat{F}(T_2) = \frac{\left(a^2(\delta-1)\sqrt{\delta} - \sqrt{RC(\delta-1)}\delta(n+1)^2\right)}{(\delta-1)\sqrt{\delta}(n+1^2)}, \tag{A.4}$$

$$T_2 = \frac{n\left(\sqrt{RC(\delta-1)}(2\delta-1)(n+1)^2 - a^2(\delta-1)\sqrt{\delta}\right)}{(\delta-1)\sqrt{\delta}(n+1)^2}, \tag{A.5}$$

with a number of controls $x(F_2)$ and a penalty $P(F_2)$. This leads to a welfare

$$W(1,F_2,T_2) = \frac{\left(\sqrt{\delta}(\delta-1)n\left[a^2 n(2\delta+n) - 2C(1+n)^2\right] + 4\delta(2\delta-1)\sqrt{RC(\delta-1)}n(n+1)^2\right)}{2(\delta-1)\sqrt{\delta}(n+1)^2} \tag{A.6}$$

The values T_2 and F_2 must be positive, which is respectively the case for $R \geq R_1$ and $R \leq R_2$ with

$$R_1 = \frac{(a^4(\delta-1)\delta)}{(2\delta-1)^2(n+1)^4 C}, \tag{A.7}$$

$$R_2 = \frac{(a^4(\delta-1))}{\delta(n+1)^4 C}. \tag{A.8}$$

For $R < R_1$, a lump-sum tax T cannot be selected with a fixed fee. In this case, a fixed fee satisfying (A3) with $T = 0$ may be selected (and substituted in the welfare defined by (4)). The condition (A3) with $x(F_1)$ and $T = 0$ holds for

$$F_1 = \frac{(a^2 - \sqrt{a^4 - 4C(1+n)^4 R})}{2(n+1)^2}. \tag{A.9}$$

with a number of controls $x(F_1, 0)$ and a penalty $P(F_1)$ (according to (A1) and (A2)). The argument under the root in (A7) is positive for $R < R_1$. The welfare is

$$W(1,F_1,0) = \frac{n\left(a^2(1+n) - 2c(1+n)^2 + \sqrt{a^4 - 4C(1+n)^4 R}\right)}{2(n+1)^2}. \tag{A.10}$$

For $R > R_2$, a fixed fee cannot be imposed with a lump-sum tax. In this case, a lump-sum tax satisfying (A3) with $F = 0$ may be selected (and substituted in the welfare defined by (4)). The condition (A2) with $x(0)$ and $F = 0$ holds for

$$T_3 = \frac{RnC}{[a^2/(n+1)^2]}, \tag{A.11}$$

with a number of controls $x(0)$ and a penalty $P(0,0)$. The welfare is

$$W(1,0,T_3) = \frac{a^2 n(1+n/2)}{(n+1)^2} - \frac{\delta RnC}{[a^2/(n+1)^2]}. \tag{A.12}$$

Under the absence of regulation ($I = 0$), no seller incurs the cost C and no cost of inspection is incurred since inspections are useless. The welfare is

$$W(0,0,0) = \frac{a^2 n(1+n/2)}{(n+1)^2} - n(1-\lambda)D. \tag{A.13}$$

Figure 1 and the proposition 1 are constructed as follows. The frontier between regions 1 and 2 is given by R_1. The frontier between regions 2 and 3 is given by R_2. The frontier between regions 1 and 4 is given by $W(1,F_1,0) = W(0,0,0)$. The frontier between regions 2 and 4 is given by $W(1,F_2,T_2) = W(0,0,0)$. The frontier between regions 3 and 4 is given by $W(1,0,T_2) = W(0,0,0)$. The points (1) to (4) in proposition 1 corresponds to the policy with the highest welfare.

Proof A.2. Proof of proposition 3.2. We mainly detail point (1) as the method for point (2) is similar. Recall that $\delta = 1$ and we allow T positive or negative. Recall that the firms' entry/exit is simultaneous and public information.

Point (1). Under free entry, profits are equal to zero. When the high quality standard is imposed, the inequality $\pi(1,F) \geq \pi(0,F)$, with $\pi(1,F) = 0$ is only satisfied for $x = n$ (or a probability of being inspected $x/n = 1$, which leads to $\pi(1,F) = \pi(0,F) = 0$. In this case firms choose safe plants, so that any penalty $P_\alpha \geq 0$ may be selected, without bringing in money to the regulator.

In this context, the budget of the regulator given by (3) may be rewritten as $\overline{F}(T) = -T/n + R$. The substitution of $\overline{F}(T)$ in the welfare defined by (4) allows to compute the optimal number of firms. Note that T is transfer that does not influence the welfare $W(1,\overline{F}(T),T)$ when $\delta = 1$. It is straightforward to show that overall welfare is at a maximum $(dW(1,\overline{F}(T),T)/dn = 0)$ when

$$n*(1) = INT\left[\frac{(a)^{2/3}}{(R+C)^{1/3}} - 1\right], \tag{A.14}$$

by letting $INT[.]$ be a function that returns the maximum integer satisfying a constraint. The profit equal to zero, namely $\pi(1,F) = 0$, determines the number of firms entering the market, which is the case for

$$n**(1) = INT\left[\frac{a}{(F+C)^{1/2}} - 1\right]. \tag{A.15}$$

The equality $n*(1) = n**(1)$ leads to

$$F_\alpha = [a(R+C)]^{2/3} - C. \tag{A.16}$$

As $F_\alpha > R$, then the budget constraint (3) leads to

$$T_\alpha = n(R+C) - n[a(R+C)]^{2/3}. \tag{A.17}$$

This value T_α is negative, which corresponds to a transfer to the rest of the economy. The budget is balanced with F_α, T_α. It is easy to check that $n*(1) \geq 1$ for $R \leq a^2/8 - C$.

Point (2). The method is equivalent to the method of point (1) with $n*(0) = INT[\frac{a^{2/3}}{((1-\lambda)D)^{1/3}} - 1]$ computed from $dW(0,\overline{F}(T),T)/dn = 0$ and $n**(0) = INT[\frac{a}{F^{1/2}} - 1]$

computed from $\pi(0, F) = 0$, for a budget constraint for the regulator equal to $nF = -T$ (since $x = 0$, when dangerous plants are selected. The equality $n*(0) = n**(0)$ leads to the selection of a fixed fee equal to

$$F_\beta = [a(1-\lambda)D]^{2/3} \tag{A.18}$$

with $T_\beta = -n*(0)F_\beta$. It is easy to check that $n*(0) \geq 1$ for $(1-\lambda)D \leq a^2/8$.

The choice between the policies (1) and (2) depends on the welfare comparison. The welfare $W(0, F_\alpha, T_\alpha)$ with $n*(1)$ safe producers is larger (respectively lower) than the welfare with $n*(0)$ dangerous producers $W(0, F_\beta, -n*(0)F_\beta)$ if $C + R < (1-\lambda)D$ (respectively $C + R > (1-\lambda)D$).

Point (3). A fixed fee $F_\omega \geq Max[F_\alpha, F_\beta] + \varepsilon$ with ε positive leads to the absence of entry/production since the firm's profit would be negative. A welfare equal to zero (linked to the absence of production) is a maximum if $R > a^2/8 - C$ and $(1-\lambda)D > a^2/8$ since a production with low or safe plants entail a negative welfare.