Optimal Regulation of Private Production Contracts with Environmental Externalities*

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October 2003

*We thank Bob Chambers, Emma Hutchinson, David Martimort and Katleen Segerson as well as the participants of the 2^{nd} World Congress of Environmental and Resource Economists, Monterey, 2002; the 2^{nd} Annual Workshop on the Economics of Contracts in Agriculture, Annapolis, 2002; and the 1^{st} CIRANO-IDEI-LEERNA conference on "Regulation, Liability and the Management of Major Industrial Environmental Risks" in Toulouse, 2003, for their comments on previous versions of the paper. All errors are ours.

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Abstract

We address the problem of optimal regulation of an industry where the production of an environmentally polluting output is contracted with independent agents. The provision of production inputs is divided between the principal and the agent such that the production externality results from their joint actions. The main result shows that in the three-tier hierarchy (regulator-firm-agent) involving a double-sided moral hazard problem, the principle of equivalence across regulatory schemes generally obtains. The only task for the regulatory agency is to determine the optimal total fiscal revenue in each state of nature because any sharing of the regulatory burden between the firm and the agent generates the same solution. The equivalence principle is upset only when the effects of regulation on the endogenous organizational choices of the industry are explicitly taken into account.

Keywords: Regulation, Pollution, Principal-Agent Relationship, Moral Hazard.

1 Introduction

A substantial increase in the number of environmental clean-up cases in the U.S. during the 1980's has been coupled by an increase in the entry rate of small judgment proof firms into hazardous sectors (Ringleb and Wiggins [10]). This phenomenon has been explained by the behavior of firms, which, trying to minimize their liability exposure, segregated their risky activities in small corporations. Such segregation was valuable because claimants were restricted to the assets of the small corporation typically unable to pay the associated liability damages. This result exposed the inefficiency of the tort liability as a primary institutional form for dealing with large-scale, long-term environmental hazards.

As a response to the above empirically identified problem, subsequent literature has largely moved towards the investigation of optimal schemes for lender's liability in the case of judgment-proof firms (e.g., Pitchford [9], Boyer and Laffont [2], and Balkenborg [1]). There has been noticeably less interest in addressing these problems in a standard regulation framework. Similarly to the above literature on vicarious liability, papers examining environmental regulation too, focused only on cases where agents alone influence the level of pollution whereas the principal has little direct means for prevention or abatement. For example, Chambers and Quiggin [3] modelled a non-point source pollution problem as a multi-task principal-agent problem where the agents are independent farmers producing corn and polluting the environment and the principal is the regulatory agency.

In this paper we address the problem of optimal regulation of an industry in which environmentally polluting stages in the production chain are contracted with independent agents. A distinct feature of these contracts is the fact that the provision of production inputs is divided between the principal and the agents such that the resulting environmental pollution is the consequence of their joint actions. The particular sector that we have in mind is agriculture and especially the livestock production, although the results can be applied to other industries where environmentally hazardous activities are contracted or franchised to independent agents.

We model the trilateral relationship between the Environmental Protection Agency (EPA), a contractor (firm) and an agent (producer) with the technology characterized by a joint production of output (live animal weight) and pollution (waste). We assume that output is observable and verifiable and hence contractible, whereas pollution may or may not be verifiable depending on the analyzed scenario. The principal's input and the agent's effort are both unobservable, hence the two-sided moral hazard nature of the problem. From a theoretical point of view, this three-tier hierarchical model can be compared to the recent modelling of supervisory problem in a hierarchy (Faure-Grimaud, Laffont and Martimort [4], [5] and Faure-Grimaud and Martimort [6],) where the principal (here the EPA) uses an intermediary agent (here the principal) to regulate a final agent (here the producer).

Our principal result shows that in the three-tier hierarchy involving double-sided moral hazard, the equivalence across regulatory schemes generally holds. For a given amount of tax revenue, the regulator can achieve the same outcome regardless of the tax legal incidence. The EPA's only task is to determine the optimal total tax in each state of nature because any sharing of the tax burden between the principal and the agent results in the same optimal solution. In this regard our result provide an important extension of an earlier work by Segerson and Tietenberg [11], who studied the structure of penalties in a three-tier hierarchy under the assumption of risk neutrality for all parties and the moral hazard on the agent's side, and showed that the efficient outcome can be reached by imposing a penalty on either party.

However, when the effects of regulation on the industry's endogenous organizational choices are explicitly taken into account, the equivalence principle breaks down and the design of the optimal regulatory scheme becomes more complicated. When the regulator wants to foster contracting as a dominant mode of organizing livestock production, the optimal taxation scheme prescribes the minimal and the maximal shares that the agent and the principal have to pay. In a situation where the EPA needs to simultaneously regulate independent producers and principal-agent contract organizations without being able to discriminate, the uniquely determined optimal division of the aggregate tax burden between the principal and the agent is necessary.

The rest of the paper is organized as follows. In the next section we present stylized facts about contracting in animal agriculture. The main part of the paper is contained in Section 3 where we present the three-tier hierarchical regulation model and derive the equivalence result. Section 4 investigates the consequences of endogenous industry structures on the equivalence result. Concluding remarks are given in section 5.

2 Contracting in animal agriculture: institutions and technology

Contracting became an integral part of the production and marketing of selected livestock commodities such as broilers, turkeys and hogs. The potential impact of livestock production on environmental quality has become a major concern in areas with high density of concentrated animal feeding operations (CAFOs). It is increasingly common for environmental advocacy groups to argue that contracting is an important cause of adverse environmental quality effects in livestock production, largely because contracting increases the scale of livestock operations, simultaneously reducing opportunities for economics of scope in livestock utilization through reduced specialization.

Most of the livestock contracts are production contracts. A production contract is an agreement between a processing firm (also known as integrator) and a farmer (grower) that binds the farmer to specific production practices. Growers provide land, production facilities, utilities (electricity and water) and labor. Housing and waste handling units have to be constructed and equipped in strict compliance with the integrator's specifications. Growers are also fully responsible for compliance with federal, state and local environmental laws regarding disposal of dead animals and manure. An integrator company provides animals to be grown to processing weight, feed, medications and services of field men who supervise the adherence to the contract stipulations and provide production and management expertise. Typically, the company also owns and operates hatcheries, feed mills and processing plants, and provides transportation of feed and live animals. The integrator also decides on the volume of production both in terms of the rotations of batches on a given farm and the density of animals inside the house.

The most notable characteristic of modern livestock production systems based on contracts has been the shift to large-scale, intensive, specialized, confined animal operations. Opponents of such production systems cite many negative environmental impacts of increased geographic concentration of manure stocks. Among various externalities generated by the production and management of animal waste, nutrient runoff and leaching and air quality problems (ammonia emissions) are the most pervasive ones. For both of those, nutrient management plays a critical role. The nutrients of greatest concern are nitrogen and phosphorus. The amount of nutrients from animal waste that ends up deposited in the environment is directly related to the type of animals raised, the composition of animal feed, and the waste management technology that farmers use. Once feed composition and the waste handling and storing technology are fixed, the amount of pollution (nutrient content in manure) generated by a particular type of animal (e.g., a sow, a feeder pig, or a finished hog) is more or less deterministic.

The problems associated with the design and implementation of environmental regulation of CAFOs are different than those related to regulating traditional family farms. In the later case the standard economic prescription of taxing the externality such that the polluter pays the environmental cost of his action is not feasible due the non-point source nature of the pollution problem (see for example Innes [8]). On the contrary, CAFOs are more similar to point source industrial polluters, hence some of the traditional regulatory instruments may prove to be adequate. However, the fact that a significant portion of CAFOs are in fact contract operations makes the design of the regulatory policy regimes substantially different. Actually, the economic incidence of the regulatory compliance cost is difficult to predict because contracts between growers and integrators are likely to change in response to changes in regulatory environment.

An obvious solution to manure nutrient management problem is the source reduction. Pollution can be reduced by restricting the output or by reducing the amount of unusable nutrients in feed.[1] The former regulatory scheme is easily implementable because the output is readily observable by all interested parties. The later scheme is considerably more complicated because the precise feed composition is known only to the integrator and could be discovered by the growers and the regulator only after bearing the costs of laboratory analyses. The regulatory objective can be however achieved by providing the integrator with the incentives to use environmentally friendly feed instead of the traditional environmentally unfriendly mix, even when this type of feed is less productive (more costly) in terms of feed efficiency. The main question becomes how to regulate an industry where production choices are affected by the signed contracts rather than by the independent producers' optimizations.

3 Regulation of the three-tier relationship

3.1 The basic model

We model the hierarchical structure by a game with three players: the regulator (EPA), the principal (P) and the agent (A). This structure corresponds to an integrator firm contracting the production of live animals with independent producers (growers). The production of output generates a negative externality that needs to be regulated by the

[1] The amount of nitrogen in manure can be reduced by substituting synthetic amino-acids for crude proteins (corn, soybeans) in animal feed. The phosphorus pollution can be reduced by adding phytase to the diets. When the prices of corn and soybeans are high, it may be actually profitable to replace crude proteins with synthetic ones. On the other hand, rations based on phytase are always more expensive than the regular inorganic phosphorus diets (for details see Vukina [12]).

EPA.

The production process is described as follows. An agent exerts effort e (possibly multidimensional) that the principal cannot observe and the principal supplies some production inputs x. In the case of livestock production, the production input of concern is animal feed. This feed may have some impact on the environmental pollution. Actually the principal can choose a good feed which is less efficient in the production of output (live weight) but environmentally friendlier, or bad feed which is highly productive but more polluting. Thus, we assume that effort e and input x generate output q and pollution d according to the following conditional multidimensional distribution function

$$h(q, d \mid e, x)$$

for which the cumulative conditional distribution is denoted $H(q, d \mid e, x)$. Pollution is a production externality jointly determined with the production state of nature.

3.1.1 Observability and verifiability assumptions

The observability and verifiability of inputs, output and pollution is crucial for the regulation problem in this hierarchical model. Effort is assumed to be unobservable and thus generates a moral hazard problem between P and A. Inputs x provided by the principal are assumed unobservable which leads to a double sided moral hazard model. In addition, we assume that production is observable and verifiable which implies that it is contractible in the principal-agent relationship. The assumption of production contractibility is realistic given that payment mechanisms in contracts are always contingent on the production level.

Finally, the degree of observability and verifiability of pollution depends on the context. We first analyze the benchmark case where production and pollution are observable and verifiable by all parties. This corresponds to the point source pollution case. Other interesting situations cover the case where the pollution is non-contractible (non-point source pollution scenario), the case where pollution is verifiable only by the EPA, and the case where pollution is verifiable by the principal and the agent but not by the EPA.

3.1.2 Contracting and regulation

Because of the moral hazard problem, the principal faces an incentive problem in dealing with the agent that necessitates an optimal design of a production contract. According to the sufficient statistics theorem (Holmström [7]), the wage w received by an agent needs to be contingent on all verifiable informative signals about unobserved effort; in this case (potentially) production q and pollution d. The contract is then simply a functional form $\{w(q,d)\}$. Before contracting between P and A occurs, the EPA commits to some regulatory scheme to control pollution. When production and pollution are verifiable, P is required to pay $F(q,d)$ and A is required to pay $T(q,d)$ to the EPA. Total tax revenue is then $R(q,d) \equiv F(q,d)+T(q,d)$. Because both production and pollution are in this case observable and verifiable and there are no restrictions imposed on $F(q,d)$ and $T(q,d)$, this is the most general possible regulatory scheme that the EPA can implement.

Finally, assuming that the EPA is the leader of the game, it chooses the regulatory scheme first, before contracting and production take place. The principal and agent have the opportunity to react after the regulatory scheme is proposed but the EPA cannot renegotiate the regulatory rules after observing their behavior.

3.1.3 Regulatory objective and preferences

The objective of the EPA is to maximize a social welfare function $S(q,d,R)$ that depends on production q and pollution d and possibly on the tax revenue R because collecting public funds may be costly.[2] Further, the agent's utility function is $U(w-T,e)$ where U is increasing concave in its first argument (net income) and decreasing concave in its second argument (effort). The principal's utility function is $V(q-w-F,x)$ where V is

[2]It is worth noting that the $EPA's$ objective implicitly takes into account both the principal's and the agent's utilities. As will be shown later, both the principal's and the agent's participation constraints are binding at the optimum and consequently they both reach their constant reservation utility levels.

also increasing concave in net income ($q - w - F$, where the price of output is normalized to one) and decreasing concave in the second argument (input x). Both P and A are therefore risk averse. The exogenous reservation utilities of the principal and the agent are respectively U_0 and V_0.

3.2 Benchmark case

Throughout this section we assume that production and pollution are observable and verifiable for all parties. Given that the negative externality (pollution) is not internalized either by the agent or by the principal implies that the EPA has to design taxes in order to achieve a second best trade-off between production and pollution. At the same time, the regulation design requires that the individual rationality constraints of both P and A be satisfied. Of course, we implicitly assume that the EPA always finds some production socially desirable.

This hierarchical regulation problem can be solved in two stages. Reasoning backwards, we first examine the principal-agent relationship given some regulatory scheme defined by $F(q, d)$ and $T(q, d)$ and then, we consider the optimal choice of these functions by the EPA taking into account the actions of P and A.

For a given a tax system, the principal faces a moral hazard problem related to the agent's effort and thus proposes a wage contract $w(q, d)$. Knowing the stochastic law of production and pollution conditional on effort and input, the objective of P is to choose input x and wage w that maximize its expected utility, and at the same time, satisfy the incentive and rationality constraints of the agent. For a given choice of input x, the expected utility of the principal $V^*(x)$ is the solution of the following maximization problem

$$\begin{aligned}
&V^*(x) = \max_{w(.,.)} E_{q,d} V(q - F(q,d) - w(q,d), x) \\
&s.t. \\
&E_{q,d} U(w(q,d) - T(q,d), e^*) \geq U_0 \\
&e^* \in \arg\max_e E_{q,d} U(w(q,d) - T(q,d), e).
\end{aligned} \tag{1}$$

Since the nature of this problem is rather general, the solution to (1) can be quite complex. Therefore, we will simply assume that this solution exists.

Next, given the solution to the principal's optimization problem (1), the EPA chooses a taxation scheme that maximizes expected social welfare and satisfies both the participation constraint and the incentive constraint of the principal, the latter corresponding to the optimal choice of input x. The EPA's problem is thus

$$\begin{aligned}
&\max_{F(.,.),T(.,.)} E_{q,d} S(q, d, R(q,d)) = \int\int S(q, d, R) dH(q, d \mid e^*, x^*) \\
&s.t. \\
&V^*(x^*) \geq V_0 \\
&x^* \in \arg\max V^*(x)
\end{aligned} \tag{2}$$

where e^* is the solution to (1).

Once again, this optimization problem is a very difficult to solve. However, without solving it explicitly, an interesting proposition can be derived. To do this, let's write the agent's wage net of taxes as

$$\widetilde{w}(q,d) \equiv w(q,d) - T(q,d)$$

from which it follows that

$$w(q,d) + F(q,d) = \widetilde{w}(q,d) + R(q,d).$$

This implies that the principal's program rewritten as

$$
\begin{aligned}
&V^*(x) = \max_{\widetilde{w}(.,.)} E_{q,d} V(q - \widetilde{w}(q,d) - R(q,d), x) \\
&s.t. \\
&E_{q,d} U(\widetilde{w}(q,d), e^*) \geq U_0 \\
&e^* \in \arg\max_e E_{q,d} U(\widetilde{w}(q,d), e^*)
\end{aligned}
$$

is invariant to the partition of taxes between P and A because $V^*(x)$ depends only on total taxes $R(.,.)$. This invariance also implies that from the perspective of the EPA only total taxes matter. Therefore, the $EPA's$ optimization program (2) simply becomes

$$
\begin{aligned}
&\max_{R(.,.)} E_{q,d} S(q, d, R(q,d)) \\
&s.t. \\
&V^*(x^*) \geq V_0 \\
&x^* \in \arg\max V^*(x).
\end{aligned}
$$

and the proposition can be stated as follows:

Proposition 1 (Equivalence Principle) *All partitions of total contingent taxes between P and A are welfare equivalent. The optimal regulation of the principal-agent relationship requires only that the total tax revenue be at the optimal level regardless of the allocation of these taxes between P and A.*

The derived equivalence principle is very general and says that, whatever the total tax R (optimal or not), all schemes implementing R are welfare equivalent. This happens because the wage contract w can offset the effect of taxes on the principal's and agent's shares of income. Intuitively, the affected parties care only about the net income and the distribution of total net income is not impacted by the partition of R proposed by the EPA. A direct consequence of this result is that when designing an optimal regulatory scheme the EPA has to worry only about total taxes R and not about partitioning of the regulatory burden between P and A.

3.3 Verifiability, regulation constraints and equivalence

A more realistic case is one where pollution is non verifiable in the sense that pollution may often be difficult to attribute to a particular agent. As is customary in the non-point source pollution cases, we now assume that pollution is observable but not verifiable implying that neither the EPA nor the principal can write contracts contingent on pollution.

Since d is not verifiable by the EPA, taxes cannot be contingent on pollution and need to be redefined as $T(q)$ and $F(q)$. Also, the wage contract $w(q)$ can only be contingent on q. The $EPA's$ optimal regulation problem is now different (and the optimal total taxes R and consequently the total welfare are different) but the equivalence between all schemes imposing the same total tax still remains.

The principal's program now becomes

$$\begin{aligned}
&V^*(x) = \max_{w(.)} E_{q,d}V(q - F(q) - w(q), x) \\
&s.t. \\
&E_{q,d}U(w(q) - T(q), e^*) \geq U_0 \\
&e^* \in \arg\max\nolimits_e E_{q,d}U(w(q) - T(q), e)
\end{aligned}$$

and can still be written as

$$\begin{aligned}
&V^*(x) = \max_{\widetilde{w}(.)} E_{q,d}V(q - \widetilde{w}(q) - R(q), x) \\
&s.t. \\
&E_{q,d}U(\widetilde{w}(q), e^*) \geq U_0 \\
&e^* \in \arg\max\nolimits_e E_{q,d}U(\widetilde{w}(q), e^*)
\end{aligned}$$

with

$$\widetilde{w}(q) = w(q) - T(q) = w(q) - R(q) + F(q).$$

Same as before, the EPA's program amounts to choosing $R(q)$ to maximize the social welfare function under the corresponding participation and incentive constraints of the principal:

$$
\begin{aligned}
&\max_{R(.,.)} E_{q,d} S(q, d, R(q, d)) \\
&s.t. \\
&V^*(x^*) \geq V_0 \\
&x^* \in \arg\max V^*(x).
\end{aligned}
$$

It is now easy to see that, like in the benchmark (point source pollution) case, the *Equivalence Principle* also holds in the non-point source pollution case.

The first of the remaining two interesting cases is when the pollution is non verifiable by the EPA but verifiable by the principal and the agent. In this situation the equivalence result holds. One simply needs to see that the net wage contract can be written as $\widetilde{w}(q, d) = w(q, d) - T(q)$.

In the second case, where pollution is not contractible between P and A but is verifiable by the EPA, the equivalence result may fail. In this case, the wage cannot depend on d while taxes may vary with pollution d. The agent's net wage $w(q) - T(q, d)$ cannot be written as a function $\widetilde{w}$ because the only verifiable outcome for the principal is q. Obviously in this case, the equivalence result does not survive. Notice that this result implicitly hinges on the assumption that taxes paid by the agent are not contractible. However, even if d is not contractible between P and A, it is sufficient for the principal to be able to propose a contract contingent on taxes to be paid by the agent. If taxes T are contractible, then any wage contract $w(q, T)$ can be replaced by a net wage contract $\widetilde{w}(q, T)$ such that

$$\widetilde{w}(q, T) = w(q, T) - T$$

and the equivalence result is maintained again.

The above discussion shows that the equivalence principle is rather robust and holds as long as the set of constraints restraining the feasible wage contracts is such that the corresponding net wage function belongs to the same feasibility set. This implies that if, for example, the wage contract is constrained to be linear, but taxes are non linear, the equivalence result will no longer hold. Similarly, like in the previous example, if taxes are contingent on some variable that is not contractible between P and A, then the equivalence result may no longer hold, unless the wage contract could be written contingent on taxes.

In all previously analyzed cases, the equivalence principle generally holds because it was implicitly assumed that the regulatory scheme does not alter the bargaining powers of the principal and the agent. However, if we allow the organizational structure of the industry to change in response to imposed regulation, then the equivalence result may no longer apply. For example, after observing the new regulatory scheme, the agents may decide to produce by themselves, which makes their reservation utility endogenous. This implicitly modifies their bargaining power in relationship to the principal compared to the case where they have no organizational alternative. The next section examines in details the question of endogenous industry structure.

4 Regulation under endogenous industry organization

In standard regulation problems, the regulator is the leader of the game in the sense of first proposing a regulatory scheme to which the principal and the agent optimally respond by signing a contract. The implicit assumption so far was that P and A would always sign a contract to jointly produce the output regardless of the regulation that the EPA imposed, provided they get at least their exogenous reservation utilities. The EPA takes this optimal response into account but cannot ex-post adjust the regulatory scheme it has committed to implement. Because of the endogenous nature of the contract signed between P and A, the equivalence principle turns out to be a robust property of the optimal taxation scheme.

However, so far in this paper we ignored the possibility that after observing the regulatory regime, the organization of production via contracts may not survive. Instead, the contracting parties may decide to go their separate ways and prefer to produce individually rather than jointly under contract.

If the regulatory agency could distinguish contract producers from independent producers, the optimal regulatory scheme would tax the parties contingently on whether they contract or independently produce. In this case, the previously obtained equivalence principle still holds. However, if the contract producers cannot be distinguished from the independents (or if the output produced under contract cannot be disentangled from the output produced outside the contract), or if the law does not allow taxing contract producers differently than independent producers, then it becomes important to take into account that agents, after observing the regulatory scheme, may prefer to exit the contract and start producing independently. In the rest of the section, we are looking at two interesting cases.

4.1 A regulation compatible with contract participation

One interesting possibility is the situation where the regulator may prefer contracts over independent production in the targeted industry. For example, it is conceivable that due to economies of scale in feed mixing, the marginal cost of supplying environmentally friendly feed for the integrator may be lower than for small independent producers. In this case the EPA would like to design a regulatory scheme such that it becomes incentive compatible with the endogenous choice to contract in the presence of the alternative opportunity to produce independently and pay only taxes T. The participation constraint of the agent becomes endogenous and depends on taxes T.

In the following, we assume that both q and d are contractible for the EPA. We say that the regulatory scheme is "contracting compatible" if, facing the regulation, agents always prefer to produce under a contract with an integrator rather than independently. If the agent produces independently, his expected utility $U_a(T(.,.))$ is equal to

$$U_a(T(.,.)) = \max_e E\left\{U(q - T(q,d), e)\right\}$$

which is clearly decreasing in $T(.,.)$.

This outside opportunity changes the agent's reservation utility in the optimal wage contract between P and A which becomes $\hat{U}_0(T(.,.)) = \max(U_0, U_a(T(.,.)))$ but does not change the properties of the optimal contract. According to the equivalence principle, the optimal regulation under exogenous reservation utility is always implementable whatever the taxes $T(.,.)$ because only total taxes matter and increasing the tax on the agent can be compensated by reducing the tax on the principal. Since $U_a(T(.,.))$ is decreasing in $T(.,.)$, it is always possible to choose taxes $T(.,.)$ such that the agent's endogenous contract participation constraint is satisfied ($U_0 \geq U_a(T(.,.))$). This means that necessarily $T(.,.) \geq T^*_{\min}(.,.)$ such that $U_0 = U_a(T^*_{\min}(.,.))$. Then, the EPA simply needs to choose taxes $F(.,.)$ such that the sum of taxes in each state is equal to the optimal taxes required by optimal regulation.

Proposition 2 (Non Equivalence Result - A) *The optimal taxation implies that for the optimal total tax revenue ($R^*(.,.)$), there exists a minimum state contingent tax $T^*_{\min}(.,.)$, such that any taxation scheme ($F(.,.), T(.,.)$) satisfying $T(.,.) \geq T^*_{\min}(.,.)$ and $F(.,.) = R^*(.,.) - T(.,.)$ is optimal.*

Contrary to the equivalence principle obtained previously, all shares of the total taxation scheme (R^*) between the principal and the agent are no longer optimal. Instead, the optimal scheme is described by the minimal share that the agent has to pay and consequently the maximal share that the principal has to pay.

4.2 Simultaneous regulation of contracts and independent producers

Another situation worth analyzing is the case where the EPA needs to simultaneously regulate independent producers and principal-agent contract organizations without being able to discriminate. Assume that after setting a regulatory scheme, the agent has the choice to contract with an integrator or to produce independently. If contracting is chosen, then both parties will have to pay the scheduled taxes. If the agent decides to produce independently, the principal leaves the game and gets his reservation utility and the agent pays taxes on pollution.

Consider the regulation of independent producers only. Given the optimal contract between the principal and the agent, the EPA's problem is now to maximize the expected social welfare under the participation and incentive constraints of the agent:

$$\begin{aligned}
&\max_{F(.,.),T(.,.)} E_{q,d}S(q,d,R) = \int\int S(q,d,R)dH(q,d \mid e,x) \\
&E\left\{U(q - T(q,d), e^*)\right\} \geq U_0 \\
&e^* \in \arg\max_e E\left\{U(q - T(q,d), e)\right\}
\end{aligned} \tag{3}$$

The incentive and participation constraints are binding and therefore the optimal tax T^* schedule is uniquely determined by:

$$U(w^*(.,.) - T^*(.,.)) = U_a(T^*(.,.)) = U_0 \tag{4}$$

where

$$U(w^*(.,.) - T^*(.,.)) = \max_e E\left\{U(w^*(q,d) - T^*(q,d), e)\right\}$$

and

$$U_a(T^*(.,.)) = \max_e E\left\{U(q - T^*(q,d), e)\right\}$$

and where $w^*(.,.)$ is the optimal wage offered by P, given the taxes T^* and F^*.

The previously obtained equivalence principle implies that optimal regulation can now be implemented without discrimination but in the *unique* fashion as follows:

Proposition 3 (Non Equivalence Result - B) *The optimal regulation is uniquely determined such that taxes imposed on contracting agents are also the optimal taxes to be imposed on independent producers: $T^*(.,.)$. The optimal tax imposed on the principal is the difference between the optimal total tax revenue $R^*(.,.)$ in each state and the optimal tax imposed on the agents, that is $F^*(.,.) = R^*(.,.) - T^*(.,.)$.*

Like in the previous case, all shares of the total taxation scheme between the principal and the agent are no longer optimal, causing the equivalence principle to break down. Instead, an optimal division of the aggregate tax burden $R^*(.,.)$ between the principal and the agent is necessary. Notice also that the optimal regulation scheme preserves the industry structure intact. As seen from (4), taxes imposed by the EPA are such that producers obtain the same expected utilities regardless of whether they are contract operators or independent producers, so there is no incentive for them to switch to a different mode of organization.

5 Conclusion

In this paper we studied the optimal regulation of a polluting industry characterized by the prevalence of private production contracts between firms and independent agents (producers). These kinds of contractual arrangements are typically found in animal agriculture, notably in poultry and swine industries. The main result shows that in a three-tier hierarchy (regulator-firm-agent) involving a double-sided moral hazard problem, a principle of equivalence across regulatory schemes generally obtains. The equivalence principle is upset only when the effects of regulation on the endogenous organizational choices of the industry are explicitly taken into account.

We analyze several cases of information asymmetries regarding the verifiability of pollution ranging from point source to non-point source pollution scenarios. In almost all these cases, for a given amount of tax revenue, the regulator can obtain the same provision of inputs and effort regardless of the tax legal incidence. Once the EPA commits to a regulatory scheme, the emerging private production contract between the firm (principal) and the producer (agent) is such that the ex-post utility levels of both parties are insensitive to the particular structure of the taxation scheme. Indeed, taxing only the principal or only the agent generates the same outcome from viewpoint of all parties. In this framework, the only task that EPA has is to determine the optimal total tax revenue in each state of nature, because any sharing of the tax burden between the principal and the agent would result in the same optimal solution. The way the optimal wage changes with respect to taxes is intimately related to the relative risk aversion of the principal and the agent. Neither double-sided moral hazard nor risk aversion impede this equivalence principle. This equivalence principle relies on the fact that the contract between the firm and the agent is optimal and endogenously determined after any change in the tax structure.

The policy implications of this equivalence principle are important. It means that the EPA can implement the optimal regulation in different ways. Indeed, the optimal regulation is attainable with subsidies for one party and taxes for the other. What really matters is the total tax revenue and not the particular levels of taxes or subsidies levied on each party. However, the optimal total tax revenue that must be imposed on the contractual organization depends itself on the preferences of both parties, on their reservation utilities, and the parameters of the cost and production functions.

We also consider that the industry organizational choices may be endogenous to the EPA's regulation. In such cases, the equivalence principle breaks down. For example, when producers can decide to produce independently given the taxes they face, the agent's participation constraint becomes endogenous and the regulatory scheme of the EPA has to be compatible with the incentives to contract. Contrary to the equivalence principle, the optimal regulation requires some minimal and maximal shares that the agent and the principal have to pay. Also, in market structures characterized by the coexistence of independent producers and contract operators, if the EPA is unable or unwilling to discriminate between them, an optimal division of the aggregate tax burden between the principal and the agent is necessary to implement the optimal regulation. In this case the optimal regulation consists of taxing contracting agents by the same optimal tax necessary in the regulation of independent producers. The optimal tax for the principal is then the difference between the optimal total tax revenue and the tax imposed on agents. Exposed to such a taxation scheme, producers will be indifferent between the two organizational structures, and the regulation will not affect the endogenous vertical organization of the industry.

Finally, there could be other conceivable cases where the equivalence principle would no longer hold. One of such cases is the situation where the EPA values the tax revenue collected from the principal and the agent differently (because of different administrative and enforcement costs). Here, the optimal regulatory scheme would require to place the full tax burden on the party for which tax collection is the least expensive. Another such situation could follow from the rigidity in the implementation of the optimal contract between the firm and the agent. This could result, for instance, from the limited liability constraints of the agent or any other institutional rigidities.

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