

Information Costs of Externality Control Instruments

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Abstract

Externality problems usually cannot find their solution in markets. Hence, Pareto optimality generally requires control of externality-producing behavior. Several legal instruments offer such control, most prominently quantity regulation and Pigouvian taxes. The economic and legal literatures reveal various differences between quantity and price controls that affect the social choice between these regulatory instruments. One of these differences is based on information costs: the design of corrective taxes requires a smaller amount of informational resources than does regulation, and Pigouvian taxes are deemed to be socially superior on this account. The present paper proves this argument wrong (in a *static* model), and explains why an identical information set is required for the design of both regulatory instruments. The paper argues further that if individuals' information costs in compliance are also accounted for, quantity regulation may prove less costly to implement, and hence socially superior to corrective taxes.

Keywords: externality, Pigouvian tax, quantity regulation, information, alleviation

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Introduction

Markets generally cannot overcome the inefficiency generated by externalities. Central intervention may therefore be required to restore first- or second-best Pareto efficiency. The literature suggests various legal instruments such as tort liability, property rights, regulation, Pigouvian taxes, or tradable permits, and debates their relative advantages.¹ These instruments may differ in their effects due to uncertainty, enforcement costs, market structure, innovation, political constraints, distributional effects, individual autonomy, etc. The present paper compares quantity (or command and control) regulation with Pigouvian taxes and reevaluates their comparative advantages with respect to their information costs.

Information costs appear to represent an important difference between quantity and price regulation of externalities. Controlling externalities requires information that is costly to collect and process. The cost of information should therefore weigh in the social choice of externality control instruments. The economic literature argues consistently that information costs work to the advantage of price instruments.² In particular, designing quantity regulation requires more information than designing Pigouvian taxes. Designing quantity regulation demands information about both the marginal costs and benefits of externalities, whereas designing Pigouvian taxes requires information only about marginal costs. Therefore, Pigouvian taxes are superior to quantity regulation on the account of information.

Taking into account alleviation activity by victims, which has been largely neglected by the literature, the present paper proves this argument wrong and shows that a central planner needs the same information in designing quantity regulation and Pigouvian taxes, and therefore has the same costs in both cases. The paper argues further that if the information costs of implementation (i.e., compliance costs) are also accounted for, we can generally expect larger information costs under Pigouvian taxes.

Section I of the paper describes the baseline of a costless implementation world, in which externalities can be equivalently controlled using quantity and price instruments. Section II assumes costly information in the design of regulatory instruments for the control of

¹ A famous example is Coase's (1960) reaction to Pigou (1938).

² Most of the economic discussion on this topic is found in the environmental economics literature. See note 6. See also Shavell (2011).

externalities, and presents the common argument in the economic literature: Pigouvian taxes are superior to quantity regulation because information costs are lower. Section III describes the ubiquitous phenomenon of externality alleviation activity on part of victims, and formalizes this activity to show that the same information set is required by both quantity and price instruments. Section IV presents the concluding remarks.

I. Externality Control in a Perfect World

Externalities induce non-optimality in competitive markets. Pareto optimality can be restored by controlling externalities. It is possible to design various legal instruments to regulate externalities, in particular negative externalities, which are more prevalent than positive ones. Negative externalities can be controlled through command and control (or quantity) regulation, tradable permits, taxes or subsidies, tort liability, and more. These legal instruments differ in their characteristics, but under certain assumptions of a theoretically “perfect world,” they are economically equivalent. Define a perfect world as a world in which implementation of any legal instrument is costless and flawless. Any potential legal instrument can be costlessly implemented with absolute accuracy. In other words, in a perfect world, Pareto optimality is fully accomplished using any externality control mechanism.

From a welfarist perspective, in a perfect world, by construction, there can be no basis for the social superiority of one legal instrument over another. Notwithstanding their legal differences, these instruments are economically identical, i.e., they are all Pareto optimal.³ Externality control instruments may differ in design (e.g., price vs. quantity),⁴ mechanism of control (e.g., internalization vs. control of behavior), enforcement method (e.g., public vs. private, *ex ante* vs. *ex post*), etc., but they achieve Pareto efficiency similarly.

Externality control instruments potentially deviate from Pareto efficiency because of frictions in implementation. Implementation is costly, and therefore optimally imperfect: political forces (e.g., legislative processes, influence of private interests) may differ; uncertainty may produce differential effects; markets may be absent or not competitive. The present paper

³ The distributional outcome of various instruments differs, but most likely not in a manner that is relevant from a welfaristic point of view. See, e.g., Fullerton (2011). But compare, e.g., West and Williams (2004).

⁴ See also Roberts and Spence (1976).

focuses on the differences in the cost of information required for the design of externality control instruments.

II. An Informational Argument

Assuming that information is costly, implementation, and hence social welfare, are affected by informational requirements. All else equal, in particular the level of (in)accuracy, informational costs should obviously be minimized. Information is generally required for the design and enforcement of externality control mechanisms. This paper deals with design issues; in the concluding remarks it refers briefly to implementation.

In the literature, the analysis of information costs in the design of externality control instrument is divided into *static* and *dynamic*. Static analysis assumes that the regulator must produce information from scratch, whereas a dynamic framework allows for information flows between the regulator and the regulated entities over time. For example, a dynamic analysis accounts for potential informational feedback the regulator may receive from a regulated industry over time by using pure- or quasi-price-based instruments, such as tradable permits.⁵

This paper focuses on the static framework of information costs. The common academic understanding among economists is that when designing quantity regulation, informational requirements are more demanding than when designing Pigouvian taxes.⁶ Therefore, holding all else equal, the information costs of externality control instruments make corrective taxes superior to quantity regulation. This argument needs to be examined in some detail.

Consider the following simple model of externality (in production). Assume that I individuals consume x^j products, $j = 1 \dots J$. Product j is produced using private capital (labor or otherwise), c_i^j , and a public resource (e.g., emissions), e^j . Thus, the production function is $X^j = X^j([c_1^j, \dots, c_I^j], e^j)$, which is increasing and concave in its variables. Individual utility is $u_i = u_i([x_i^1, \dots, x_i^J], E_i)$, where $E_i = E_i(e^1, \dots, e^J)$ represents the externality – i.e., the negative

⁵ See, e.g., Karp and Zhang (2005, p.280); Weisbach (2010); Kaplow (2010).

⁶ See, e.g., Cropper and Oates (1992, p. 686); Sandmo (2000, pp. 45-49); Kaplow and Shavell (2002); Stavins (2003, pp.359-360); Revesz and Stavins (2004, p. 34-35); Revesz and Stavins (2007, p.35); Fullerton (2001, p.238); Fullerton et al., (2010, pp. 430-1); Sterner (2003, pp. 136-141); Newell and Stavins (2003).

effect that the use of public resources (e.g., emissions) in production has on utility. Utility is increasing and concave in consumption, and decreasing and convex in externality; externalities are increasing and convex in emissions.⁷

The Pareto-efficient outcome is the result of the following optimization problem:

$$\max_{x_i^j, c_i^j, e^j} u_i([x_1^1, \dots, x_1^J], E_1)$$

Subject to:

$$(1) u_i([x_i^1, \dots, x_i^J], E_i) = \bar{u}_i \quad i = 2, \dots, I$$

$$(2) X^j([c_1^j, \dots, c_I^j], e^j) = \sum_i x_i^j \quad j = 1, \dots, J$$

$$(3) C_i = \sum_j c_i^j \quad i = 1, \dots, I$$

and where $E_i = E_i(e^1, \dots, e^J)$.

The Lagrangian function for the Pareto problem is:

$$(4) L = u_i([x_1^1, \dots, x_1^J], E_1(e^1, \dots, e^J)) + \sum_{i=2}^I \lambda_i [u_i([x_i^1, \dots, x_i^J], E_i(e^1, \dots, e^J)) - \bar{u}_i] + \sum_{j=1}^J \delta_j [X^j([c_1^j, \dots, c_I^j], e^j) - \sum_i x_i^j] + \sum_{i=1}^I \gamma_i [C_i - \sum_j c_i^j]$$

Solving for first order conditions and simplifying, we obtain:

$$(5) - \sum_i \frac{\frac{\partial u_i}{\partial E_i} \frac{\partial E_i}{\partial e^j}}{\frac{\partial u_i}{\partial x_i^j}} = \frac{\partial X^j}{\partial e^j} \quad j = 1, \dots, J$$

Given the presence of externalities in production, equation (5) denotes one of the conditions for Pareto optimality. Pareto optimality (condition (5)) is not achieved in competitive markets, and therefore intervention by a central planner may be warranted. Implementation of the Pareto-efficient outcome through quantity regulation requires the regulator to control e^j such that (5) is

⁷ Convexity/concavity restrictions can be somewhat relaxed and still allow for a unique solution, but this is not the focus of the present paper.

satisfied. The alternative Pigouvian tax instrument requires a tax on e^j that equals the LHS of (5).⁸

Accordingly, Pareto optimality is recovered using either instrument, whether by dictating the extent of externality allowed or by imposing the (marginal) social costs of the externality on its producer. The two Pareto-inducing mechanisms differ in operation and hence in design. The quantity regulation mechanism requires the policy maker to identify the Pareto-optimal behavior and enforce it. Corrective taxes impose an additional price on the externality-producing entity, which induces optimal behavior through internalization.

The difference in design entails different informational prerequisites, which are not explicitly formalized in the typical externality model. To identify the character of optimal behavior, the Pareto-relevant variables must be observed and measured. In the case of quantity regulation, the necessary information lies on both sides of (5). The LHS variables are known as the marginal social harm due to externalities, and the RHS variables are the marginal social benefit of externality. Only by comparing these two schedules is the regulator able to compute the optimal level of externality, which is then dictated by regulation. The design of a price instrument, i.e., Pigouvian taxes, arguably involves a narrower set of information: only the LHS of (5), i.e., marginal social harm, must be observed and measured. The regulator is exempt from the informational burden of observing and measuring the schedule of marginal social benefit. For example, the regulator is not required to assess the profits (or other benefits) associated with various levels of externality, the control/abatement costs required for a certain reduction in levels of externality, or the effect of various production methods or of different raw materials on levels of externality. Corrective taxes harness the information of the externality-producing entity by a method known as internalization. By causing the externalities to be internalized, corrective taxes induce externality-producing entities in competitive markets to make a Pareto-optimal choice of behavior. Therefore, the argument goes, given the costly information in designing regulatory

⁸ The optimal Pigouvian tax is not linear but a non-linear function of e^j as dictated by the LHS of (5).

mechanisms (and assuming first-best Pareto-efficient implementation), Pigouvian taxes are superior to quantity regulation.⁹

Several economists have claimed that the argument should be further refined, yet with no qualitative revision. Rather than examining information costs borne by the regulator only, they note, social welfare analysis requires consideration of all the costs of information production, including those borne by individuals – that is, the cost of the information that individual entities must bear to implement the regulations. Under such analysis, the sets of knowledge required by either a quantity or price instrument are identical, and the difference between the two is in the allocation of social responsibility to produce information. In particular, a corrective tax instrument, as described above, harnesses the (marginal benefit) information of the externality-producing entity. For the externality-producing entity to internalize the social costs of its externality and correctly choose the optimal behavior, it must observe and measure the schedule of its marginal benefit as a result of such behavior (i.e., the RHS of (5)). Thus, in the case of a quantity instrument, the regulator must produce information about the schedule of marginal benefit, whereas in the case of a price instrument this information is produced by the regulated entities. The different allocation of responsibility to produce the marginal benefit information is likely to be of economic significance. Apparently, information about benefits from externalities (e.g., the effect of abatement costs) can be produced more cheaply by externality-producing entities. Typically, this kind of information is specific to the externality-producing entity, internal to its activities, and requires specialization or experience.¹⁰ This refined argument is inaccurate, and it will be addressed in the concluding remarks.

III. The Fallacy of the (*Static*) Informational Argument

The fallacy of static informational argument stems from neglecting potential mitigating behavior on the part of the “victims.” Coase (1960) stressed this point in his treatment of externalities as

⁹ Indeed, the costly design of control mechanisms renders a first-best efficient control of externality socially undesirable, and we must account for the second-best character of information costs. But the analysis follows the common analysis in the economics literature. See the additional discussion in the Concluding Remarks.

¹⁰ This is a specific application of the social advantage of information decentralization. In other words, markets generally possess great capacity to deal more cheaply and efficiently with information problems or costs, although there may be exceptions, such as information failures.

reciprocal by arguing that both sides to the externality problem are causes of externality and both can mitigate its effect by changing their behavior. If the behavior of both sides to the externality problem is accounted for, the (static) informational argument proves wrong: designing both quantity and price instruments requires an identical set of knowledge from the regulator. This part provides examples of potential mitigation activities on the part of the “victims”, and then formalizes such behavior in order to reveal its consequences for the cost of information.

A. Harm Alleviation

It is probably impossible to suggest externality examples in which only one side to the externality can affect harm. In particular, externality-absorbing entities can always mitigate external harm that was not actively generated by them.¹¹ In Coase’s (1960) famous examples, both sides to the externality problem can affect the resulting harm. The harm from air pollution can be mitigated by reducing outdoor activities; water pollution can be addressed by filters or desalination processes; land pollution can be remedied. Generally, any “local” effect of externalities can be alleviated by relocation. In air, water, and land pollution scenarios, many effects are indeed localized. Congestion situations are another set of local externalities.

Even “global” effects described in the climate change literature can be alleviated by non-emitting entities, privately or publicly. These activities are termed “adaptation” in the climate change literature.¹² For example, various actions can be taken against the risks of sea level rise, disruption of water supply, heat-related diseases, drought, or extreme weather events such as hurricanes by means of urban planning (e.g., dikes, seawalls, sewerage systems), immigration, investment in better weather forecasting technology, improving research, prevention of climate-related diseases and responses to them, shifting patterns in agriculture (e.g., improved irrigation, biotechnologically-produced climate-resilient seeds), or the promotion of “carbon sinks” (e.g., reforestation).

¹¹ Ignoring Coase’s insight of the reciprocal effect of both sides to an externality problem, and without loss of generality, I adopt the generic terms of “externality-producing entity” or injurer and “externality-absorbing entity” or victim. The environmental economics literature, for example, consistently distinguishes between pollution-emitting entities and the victims of pollution.

¹² See, e.g., Adger et al. (2007); Klein et al. (2007); European Environment Agency, National Adaptation Strategies, at <http://www.eea.europa.eu/themes/climate/national-adaptation-strategies> (last visited, 13.01.2013).

B. Externality Control with Harm Alleviation

Harm alleviation has not been completely ignored by the economics literature, and since the 1970s a few scholars, starting with Baumol (1972), have formally addressed this realistic possibility,¹³ although none have considered the consequences in terms of information costs. I revise here the above model in line with the economics literature in order to include the victims' mitigating behavior.

Assume that individuals can use private capital, a_i , to alleviate their own harm due to externalities. Hence, $E_i = E_i(e^1, \dots, e^J, a_i)$, where E_i is decreasing and convex in a_i . The resource constraint is accordingly revised as follows:

$$(3') \quad C_i = \sum_j c_i^j + a_i \quad i = 1, \dots, I$$

The revised Lagrangian function for the Pareto optimization problem is:

$$(4') \quad \hat{L} = u_i \left([x_1^1, \dots, x_1^J], E_1(e^1, \dots, e^J, a_1) \right) + \sum_{i=2}^I \lambda_i \left[u_i \left([x_i^1, \dots, x_i^J], E_i(e^1, \dots, e^J, a_i) \right) - \bar{u}_i \right] + \sum_{j=1}^J \delta_j [X^j([c_1^j, \dots, c_I^j], e^j) - \sum_i x_i^j] + \sum_{i=1}^I \gamma_i [C_i - \sum_j c_i^j - a_i]$$

Solving for first order conditions and simplifying, we obtain the same result as in (5):

$$(5') \quad - \sum_i \frac{\frac{\partial u_i}{\partial E_i} \frac{\partial E_i}{\partial e^j}}{\frac{\partial u_i}{\partial x_i^j}} = \frac{\partial X^j}{\partial e^j} \quad j = 1, \dots, J$$

Only this time, E_i is also a function of private alleviation activity, a_i . In other words, (5') describes optimal conditions for externality production given an optimal choice of a_i . Thus, prescribing regulation of externalities according to (5'), whether through a quantity or price instrument, is contingent upon the knowledge of the optimal level of alleviation activity. Specifically, the LHS of (5') – i.e., the marginal harm of externality – is contingent upon the optimal alleviation activity. In information terms, the optimal alleviation must be known to produce information about the schedule of marginal harm.

Optimal alleviation can be derived from another simplified result of the first order conditions:

¹³ See Collinge and Oates (1982); Shibata and Winrich (1983).

$$(6') \quad \frac{\partial u_i}{\partial E_i} \cdot \frac{\partial E_i}{\partial a_i} = \frac{\partial u_i}{\partial x_i^j} \cdot \frac{\partial x_i^j}{\partial c_i^j} \quad i = 1, \dots, I ; \quad j = 1, \dots, J$$

Private resources – a_i and c_i^j – are allocated to equalize marginal utility from consumption and from alleviation of externalities. The optimal level of alleviation is therefore dictated by its comparative effectiveness in increasing utility through reduction of externality vs. increasing utility through consumption of products that produce externalities. The result is reminiscent of the “least costs avoider” effect (in marginal terms). Optimal alleviation activity depends on the costs (in utility terms) of producing goods that are more or less polluting. In policy terms, this means that the optimal level of alleviation, a_i , can be determined only with regard to the marginal effect of externalities on production and harm, and hence on utility. In information terms, it means that in order to compute the optimal level of alleviation activity, a central planner must observe and measure the marginal (social) benefit of production. The result, then, is that in order to evaluate the marginal harm of externality, optimal alleviation activity must be known, which in turn requires assessment of the marginal benefit of production. Therefore, although Pigouvian taxes require only information of the LHS of (5’), this information entails knowledge of (6’), which involves information identical to the RHS of (5’). Thus, a perfectly accurate design of both quantity and price instruments by a central planner requires the same set of information, and hence entails identical information costs. In other words, Pigouvian taxes are not socially superior to quantity regulation on account of the cost of information in their design.

IV. Concluding Remarks

We have seen that the economics literature has failed in comparing the relative information costs in the design of externality control instruments because of the implicit assumption that one side to the externality problem – i.e., externality-absorbing entities – cannot affect the externality. I have argued descriptively that in general reality does not confirm to this assumption, and have showed formally that assuming otherwise makes both price and quantity instruments equivalent on the account of information costs.¹⁴ Nevertheless, given exceptional conditions in reality where

¹⁴ Note that this paper does not necessarily argue that if both parties to the externality problem can affect its level, both should engage in mitigation. It may be optimal that only one side, say, the externality-producing entity, engages

only one side to the externality can affect its level, Pigouvian taxes are indeed less costly than quantity regulation in information terms, and hence socially superior on this grounds.

The present paper assumed complete accuracy in the implementation of control instruments, so that first-best Pareto efficiency is restored through central control. Clearly, given information costs, the first-best efficient outcome is likely to be impossible and undesirable. Generally, it is socially preferable to produce partial information based on which to implement an inaccurate control of externalities; the costly, inaccurate control of externalities is the second-best optimum.

Yet, the assumption of perfect implementation follows the common discussion and analysis in the economics literature that looks at information costs. Modeling of the second-best optimal design of any control instrument, given information costs, is not complicated but it is uninteresting in and of itself, because the theoretical outcome is quite intuitive. Only empirical analysis can be informative regarding the comparatively superior second-best control instrument.

Other obvious, non-second-best theoretical options either compare the information costs of identically inaccurate externality control instruments or compare the extent of inaccuracy in the implementation of various instruments given identical information costs. A simple example of the latter is assuming a central planner produces only marginal harm information. A Pigouvian tax that equals computed marginal harm is inaccurate because it does not take into account optimal alleviation activity; most likely, it takes victims as they are rather than as they should optimally behave. We should therefore expect an imperfect outcome. Quantity regulation, by contrast, is impossible to design on the basis of this information alone because marginal benefit is also required. Quantity regulation can be designed arbitrarily, based on a guess or on an arbitrary schedule of marginal benefits. The outcome will indeed be imperfect, but there is no theoretical basis for a comparison of these outcomes in social welfare terms. In particular, Pigouvian taxes cannot be proved theoretically superior.

Another example is Weitzman's (1974) analysis and the ensuing literature. Costly information is modeled by (a specific kind of) asymmetric information. These models compare the outcomes of price and quantity instruments given identically partial information held by a

in mitigation. Nevertheless, the theoretical possibility or potential of both parties to mitigate negative externalities leads to the results presented in this paper.

central planner. The models show that given identical information costs, Pigouvian taxes are not necessarily superior – i.e., less inaccurate. For example, in Weitzman (1974), a central planner produces partial information only about marginal benefits of externalities (e.g., marginal abatement costs); in Stavins (1996) a central planner produces partial information about both marginal costs and marginal benefits of externalities, which are assumed to be correlated.

The main result of this paper can be extended straightforwardly to tradable permits. First, under the framework of analysis of this paper, allowing trading in allocated quantities is inconsequential. Assuming complete information, permits are allocated accurately to externality-producing entities, and therefore trade is unneeded and redundant. Second, to the extent that permits are sold by a central planner, they become equivalent to Pigouvian taxes if their price equals the marginal harm schedule of externalities.¹⁵ In both cases – Pigouvian taxes and the sale of permits – the same amount of information is required for designing a regulatory scheme.

Note further that the present paper focuses on the information required by a *central planner* in the design of regulatory instruments. But the social costs of information include both those of implementation by *private entities* (in compliance with regulation) and of the central planner (in enforcing a regulatory scheme). Focusing on compliance, both the externality-producing and externality-absorbing entities must generate certain information to choose their utility-maximizing actions. Contrary to common intuition, in the case of perfect compliance by externality-producing entities, information costs are identical under Pigouvian taxes and quantity regulation. Under Pigouvian taxes, externality-producing entities internalize the tax and optimize their behavior accordingly (e.g., input/output quantity and quality, abatement measures, production process). Under quantity regulation, externality-producing entities optimize their behavior identically and engage in identical behavior in order to follow prescribed regulation of quantity. Their maximization problem is similar except for the constraint – quantity vs. price; given identical choice under both constraints, so that the price and quantity constraints are perfectly correlated, the maximization problem is identical in both cases. Thus, the information

¹⁵ See, e.g., the Appendix in Roberts and Spence (1976).

required for internal optimization by controlled entities is identical under both tax and quantity instruments.¹⁶

The effects of tax and quantity instruments on externality-absorbing entities are not identical, however. Both control instruments, in their typical form, regulate only the behavior of the externality-producing entity (e.g., the polluting plant), whether by quantitatively controlling certain behavior or by taxing it. The behavior of the externality-absorbing entities (e.g., individuals harmed by pollution) is typically uncontrolled, and they choose their optimal behavior through internalization of harm.¹⁷ In information terms, this means that the absorbing entities must produce the relevant information for their decisions – i.e., optimal level of a_i – which was already identified by the regulator (given perfect implementation). They should do so under both quantity regulation and Pigouvian taxes. But under quantity regulation, the behavior of the externality-producing entity is determined by the regulator and hence this information is known, whereas under Pigouvian taxes the information must be generated by each and every externality-absorbing entity as part of its internalization process. If harm is a function of a quantity choice and measured by it – e.g., by the amount of pollution – quantity regulation provides externality-absorbing entities with more information than a tax instrument does; the former saves on the private information costs in compliance.¹⁸ Therefore, although the information costs of designing both control instruments are identical, compliance costs may render Pigouvian taxes inferior to quantity regulation.

¹⁶ Under both instruments, a fully informed central planner can provide controlled entities with all the necessary information, in addition to the prescribed price or quantity, and relieve them of this informational task.

¹⁷ A Pigouvian tax can be levied on activities of externality-absorbing entities, as indicated by Coase (1960) and Buchanan and Stubblebine (1962). Ignoring private information costs, it makes no difference whether any entity internalizes harm or a tax (or both).

¹⁸ Again, a fully informed central planner knows the quantity chosen by the externality-producing entities under a tax instrument, and can therefore inform externality-absorbing individuals. Indeed, a fully informed central planner is in a better position than the externality-absorbing entities to determine their optimal behavior. But in a second-best world, the informational effect discussed in the text gains social weight.

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