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Prices vs. quantities: public finance and the choice of regulatory instruments

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Prices vs quantities: public finance and the choice of regulatory instruments

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Abstract

We consider a full-information setting in which a government regulates a particular economic activity. We demonstrate that public finance concerns lead the government to prefer quotas with the shortest possible duration, or, what is equivalent in our setting, taxes.

Keywords: regulation, public finance, e- uent taxes, tradable quotas, environmental management

JEL Classification codes: H2, L51, Q28, Q38

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1 Introduction

Since the seminal work of Weitzman (1974), it has generally been assumed that, in a full-information setting, quotas and taxes are equivalent regulatory instruments.[1] However, we demonstrate that, unless the government is indifferent about revenues, the equivalence result holds only if the duration of quotas is no longer than one decision period. This finding suggests that quota duration needs to be explicitly considered in policy analyses, an issue that typically has been ignored.

Our analysis starts from the observation that taxes and quotas have different public finance properties. If a system of quotas is in place a relaxation of regulation results in an increase in revenues through the sale of an additional quantity of quotas. If a tax regime is in place, however, a corresponding relaxation of regulation leads to a smaller increase in revenues, as the gain from a larger tax base (quantity effect) is counteracted by the lower tax rate (price effect). Conversely, tightening regulation involves a higher cost in the quota regime than in the tax regime, as the reduction in tax base is compensated for by a higher tax rate.

Figure 1 illustrates this difference. The regulated activity, denoted by y, is measured on the horizontal axis, while the tax rate t and the quota price p are measured on the vertical axis. The downward-sloping curve indicates the marginal benefit to market agents of this activity. In the case of tax regulation, when the tax rate is t_0, government revenues are given by the area of the rectangles A and B. If the tax rate is reduced from t_0 to t_1 revenues change from $A + B$ to $B + C$; that is, they increase by $C - A$. Conversely, increasing the tax rate from t_1 to t_0 reduces revenues by $C - A$.

In the case of quota regulation, the quota price resulting from an allocated quota may be read off the benefit curve; for example, if the quota is y_0, the resulting quota price is p_0. Revenues obtained from selling this quantity of quotas equal the area $A + B$. If the government decides to sell more quotas so that their quantity is increased from y_0 to y_1, revenues increase by C. A corresponding reduction in quotas would require a government outlay of $C + D + E$ since in order to purchase the difference $y_1 - y_0$ the government must raise the quota price from p_1 to p_0.

The above analysis suggests, therefore, that from a revenue point of view taxes and quotas are quite different. A tax instrument is 'flexible' in the sense that the effect on government revenues is symmetric for upward and downward changes in the tax. In the quota case, on the other hand, a reduction

[1] See e.g. Baumol and Oates (1988, p. 57) and Fisher et al (1996, 11.2.3.1, p 405). The contribution of Weitzman was, of course, to demonstrate that this equivalence broke down under uncertainty; see Stavins (1996) and Hoel (1998) for discussions.

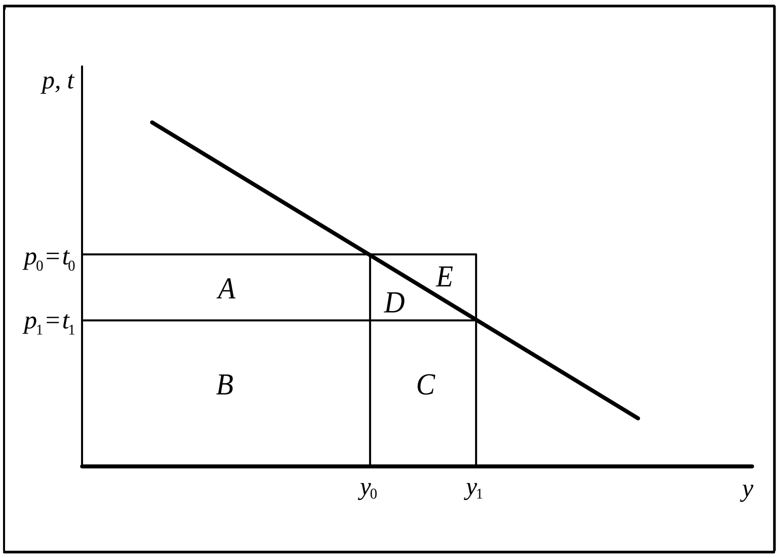

Figure 1: Public Finance Properties of Taxes and Quotas.

in quotas has a larger impact on government revenues than a corresponding increase in quota supply.

Moreover, the attractiveness of changing regulation depends on both the choice of regulatory instrument and the direction of change. In particular, easing regulation is more attractive in the quota case than in the tax case; in the quota case revenues increase by C, while they increase by $C - A$ in the tax case. The reason for this difference is that there is no price effect in the quota case (or, rather, the price effect is born by the initial quota holders, not by the government). The opposite is true when regulation is made stricter; then revenues are reduced by $C - A$ in the tax case, whereas the reduction is $C + D + E$ in the quota case.[2]

Research on the choice of regulatory instruments has mostly relied on a modelling framework in which these different public finance aspects of taxes and quotas are irrelevant. The focus in the literature following Weitzman (1974) has been on how the choice of instrument affects allocative efficiency in the market in question. The partial equilibrium approach employed in these analyses has consequently disregarded implications of regulatory policies in

[2] Due to this asymmetry, we would expect a government with preferences for stricter regulation to prefer tax regulation (since this would commit future governments to a stricter level of regulation), whereas governments favoring a laxer policy would prefer quota regulation (since this would commit future governments to a laxer level of regulation). We explore this idea in Baldursson and von der Fehr (2004).

other sectors of the economy; in particular, public finance considerations, such as using proceeds from regulation to reduce distortionary taxation, have not been explicitly taken into account.[3]

In the literature on optimal incentive regulation, however, public finance concerns are important. There the source of the regulatory problem is private information and incentives that are not in line with social objectives. If public finance is not an issue, the problem of regulation in some sense becomes trivial since the regulator may then elicit desired behavior through use of arbitrarily large economic incentives. Public finance therefore has been an integral part of this theory.[4]

We consider the implications of the different public finance characteristics of taxes and quotas outlined above in a multi-period version of the static set up of Weitzman and others (see e.g. Baumol and Oates, 1988). Regulatory policy may be adjusted in each period by setting the tax rate or by selling/buying quotas. If quotas are long-lived firms typically hold a positive amount of quotas at the time of policy revision. The government then has incentives to relax policy – sell more quotas – in excess of what it would have done had there been no preexisting quotas. Agents will, however, rationally expect this behavior and compensate for it by a lower valuation when quotas are sold. The consequence is a slacker policy without any net revenue gains.

Long-lived quotas therefore create a problem of time inconsistency: public finance concerns lead the government to issue more quotas over time even if there are no changes in fundamental market conditions.[5] If the government were able to commit to a quota policy then public finance incentives as such would not lead to intertemporal adjustments in quota allocation. In the absence of such commitment possibilities, the time inconsistency problem induces the government to reduce the lifetime of quotas or choose taxes.

[3]Related problems have been studied in a general equilibrium setting where considerations of efficiency in a particular regulated market are balanced against effects in other sectors. In that case public finance aspects enter naturally, for example through the possibility of reaping a 'double dividend' from the collection of environmental fees through simultaneous reduction of distortionary taxes; see e.g. Bovenberg and De Mooij (1994) and Goulder et al. (1999). These models are not, however, concerned with the comparison of taxes and quotas and are typically static with full equivalence in the implementation of price and quantity controls. Implicitly, in such models, quotas have a lifetime equal to the length of the decision period and taxes are set for one period at a time.

[4]Public finance considerations may arise from distributional concerns as well as social cost of public funds due to distortionary taxation; see e.g. Armstrong et al. (1994) and Laffont and Tirole (1993).

[5]The seminal contribution on time inconsistency of optimal economic policy is Kydland and Prescott (1977).

2 The modelling framework

Consider a partial equilibrium model in which a group of agents, assumed to be infinitesimally small, identical and price-takers, is involved in the same type of economic activity. This economic activity gives rise to some negative externality and is subject to government regulation.

Time is divided into periods. The length of a period is determined by the frequency with which the government can adjust its regulatory policy. In any given period, the order of play is as follows: first, the government sets (adjusts) its policy; next agents choose their levels of economic activity y; and, lastly, payoffs are realised. Payoffs are discounted by a time-invariant per period discount factor $\delta \leq 1$. For simplicity, we shall consider a model with two periods only. Results would seem to carry over straightforwardly to an arbitrary number of periods.

We take decisions of agents in other markets, as well as their costs and profits prior to any activities to reduce the negative externality ('abatement'), to be exogenous and given. All agents produce the same amount prior to abatement, which we take to be equal to 1 without loss of generality. However, agents have access to an abatement technology: if an agent produces an amount $y < 1$ the cost to the agent is $c(y) > 0$, where c is a smooth function, decreasing in y (the smaller the externality the larger the cost to the firm) and convex (unit costs of abatement are increasing in the amount of abatement $a = 1 - y$). Without loss of generality, we can take the mass of agents to be equal to 1 and, since agents are perfectly symmetric and subject to the same policy, aggregate output, denoted by Y, and aggregate cost of abatement, denoted by C, are equal to y and c, respectively. Since aggregate and individual level activity and costs can be identified we do so and use the lower case letters for both variables in what follows.

The government evaluates the damage of the externality according to a social damage function $D(y)$, which is assumed to be convex, smooth and increasing in the level of the externality with $D(0) = 0$. Government revenues - from taxation or quota sales - are valued at $1 + \mu$, where $\mu \geq 0$ is the (constant) marginal cost of public funds.

3 Tax regime

We first consider the case in which the government regulates by a tax. Since tax revenues in a given period are independent of tax rates set at other times there is no intertemporal relationship between periods and hence we can consider each one in isolation.

Given a tax rate t, agents minimise their total private cost associated with the externality $c(y) + ty$, so that the first-order condition for optimal abatement is

$$-c'(y) = t. \tag{1}$$

By the convexity of c the second-order condition for cost minimisation is satisfied.

The government chooses a tax rate to minimise the net aggregate cost of the externality. This is given by the sum of damages and abatement costs less the tax revenue multiplied by the marginal cost of funds to the government, μ:

$$W^T(y,t) = D(y) + c(y) - \mu t y. \tag{2}$$

The government will minimise W^T subject to (1) above. The first-order condition for this problem may be written:

$$D'\left(y^T\right) + c'\left(y^T\right) = \mu t\left[1 - \frac{1}{\varepsilon^T}\right]. \tag{3}$$

Here y^T is the optimal level of activity and

$$\varepsilon^T = -\left.\frac{dy}{dt}\frac{t}{y}\right|_{y=y^T} = \frac{-c'\left(y^T\right)}{y^T c''\left(y^T\right)} > 0 \tag{4}$$

is the elasticity of the level of activity with respect to the tax rate. Hence, strictness of the tax policy depends on the elasticity ε^T:

$$D'\left(y^T\right) + c'\left(y^T\right) \gtreqless 0 \Longleftrightarrow \varepsilon^T \gtreqless 1. \tag{5}$$

In the tax case there is therefore a tradeoff between efficiency in the market in question and public finance concerns. Whether the optimal level of activity exceeds or falls below the level that would be efficient were the market considered in isolation depends on the relationship between the tax rate and revenues. Dynamic considerations play no role here, however, in contrast to the quota case.

4 Quota regime

In the quota case we let $\overline{y}_t$ be the total amounts of quotas available in period t and assume these can be freely traded among agents.

In period t, given a rental price of quotas r_t, agents minimise their total private cost associated with the externality $c(y_t) + r_t y_t$, so that the first-order condition for optimal abatement is $-c'(y_t) = r_t$. Again, by the convexity of

c, the second-order condition for cost minimisation is satisfied. Furthermore, given the assumptions on c, for $\overline{y}_t < 1$ the equilibrium level of abatement must satisfy $y_t = \overline{y}_t$, and so the equilibrium value of the quota rental price is given by

$$r_t = -c'(\overline{y}_t). \tag{6}$$

The duration of quotas may be longer than a single period; in particular, we assume that a fraction $\beta \in [0,1]$ of a quota issued in Period 1 can be carried over to Period 2 (as the game ends after Period 2, there is no corresponding issue of quota duration for quotas issued in this last period). Note that $\beta = 0$ corresponds to the case in which quotas are good for Period 1 (or a single period) only, while $\beta = 1$ corresponds to the case in which quotas last for both periods (or 'forever').

The value, or price, of a quota issued in Period 1, equals the discounted sum of the rental price over the two periods, taking into consideration that only a fraction of the quotas is carried over from Period 1 to Period 2:

$$p_1 = r_1 + \delta\beta r_2. \tag{7}$$

For quotas issued in Period 2, the price simply equals the rental price:

$$p_2 = r_2. \tag{8}$$

Following the logic of backwards induction, we start by considering the government's regulatory problem in Period 2 - the last period - which is to minimise

$$W_2^Q(\overline{y}_2; \overline{y}_1, \beta) = D(\overline{y}_2) + c(\overline{y}_2) - \mu r_2 [\overline{y}_2 - \beta\overline{y}_1] \tag{9}$$

subject to (8) and (6) above. The term $r_2 [\overline{y}_2 - \beta\overline{y}_1]$ represents revenues from selling additional quotas in Period 2. The first-order condition for this problem may be written:

$$D'\left(\overline{y}_2^Q\right) + c'\left(\overline{y}_2^Q\right) = \mu r_2 \left\{1 - \left[1 - \beta\frac{\overline{y}_1}{\overline{y}_2^Q}\right]\frac{1}{\varepsilon_2^Q}\right\} \tag{10}$$

where

$$\varepsilon_2^Q = -\left.\frac{dy_2}{dr_2}\frac{r_2}{y_2}\right|_{y_2=\overline{y}_2^Q} = \frac{-c'\left(\overline{y}_2^Q\right)}{\overline{y}_2^Q c''\left(\overline{y}_2^Q\right)} > 0 \tag{11}$$

is the elasticity of the demand for quotas with respect to the rental price of quotas evaluated at the optimal quota.

Note that, for given optimal quota $\overline{y}_2^Q$, the right-hand side of (10) is increasing in the amount of quotas carried over from Period 1, $\beta\overline{y}_1$. This suggests that the optimal quota in Period 2 exceeds the optimal activity under tax regulation, $\overline{y}_2^Q > y^T$, if $\beta\overline{y}_1 > 0$. Indeed, differentiating the first-order condition for the government's problem, we find that the optimal quota is strictly increasing in the duration of quotas:

$$\frac{d\overline{y}_2^Q}{d\beta} = \frac{-\frac{\partial^2 W_2^Q}{\partial\beta\partial\overline{y}_2}}{\frac{\partial^2 W_2^Q}{\partial\overline{y}_2^2}} > 0. \tag{12}$$

The positive sign follows from the assumption that the second-order condition for the government's problem is satisfied (i.e. $\frac{\partial^2 W_2^Q}{\partial\overline{y}_2^2} > 0$), and the fact that $\frac{\partial^2 W_2^Q}{\partial\beta\partial\overline{y}_2} = \mu\frac{dr_2}{dy_2}\overline{y}_1 = -\mu c''\left(\overline{y}_2^Q\right)\overline{y}_1 < 0$. Similarly, we have that the optimal quota in Period 2 is strictly increasing in the amount of quotas issued in Period 1 $\frac{d\overline{y}_2^Q}{d\overline{y}_1} > 0$ if quotas last longer than one period, $\beta > 0$. If quotas only last for one period then there is no such connection, i.e. $\frac{d\overline{y}_2^Q}{d\overline{y}_1} = 0$ if $\beta = 0$.

In Period 1 - the first period - the government's problem is to minimise the discounted sum of costs over the two periods, or

$$V(\overline{y}_1, \beta) = W_1^Q(\overline{y}_1, \beta) + \delta W_2^Q(\overline{y}_2; \overline{y}_1, \beta) \tag{13}$$

subject to (10), (7) and (6), where

$$W_1^Q(\overline{y}_1, \beta) = D(\overline{y}_1) + c(\overline{y}_1) - \mu p_1\overline{y}_1 \tag{14}$$

is the net social cost of the externality in Period 1.

Differentiating (13) with respect to β, we find

$$\begin{aligned} \frac{dV}{d\beta} &= -\mu\frac{dp_1}{d\beta}\overline{y}_1 + \delta\frac{dW_2^Q}{d\beta} \\ &= -\mu\delta\left[r_2 + \beta\frac{dr_2}{d\overline{y}_2}\frac{d\overline{y}_2^Q}{d\beta}\right]\overline{y}_1 + \delta\mu r_2\overline{y}_1 \\ &= \mu\delta\beta c''\left(\overline{y}_2^Q\right)\frac{d\overline{y}_2^Q}{d\beta}\overline{y}_1 \\ &\geq 0 \end{aligned} \tag{15}$$

with strict inequality if and only if $\mu\beta > 0$. In the second line of the above derivation we have made use of the Envelope Theorem applied to the second-period minimisation problem of the government. The last inequality follows from (12). In other words, if public funds are costly, the overall cost of the externality is everywhere increasing in the duration of quotas, and so the optimal duration is as short as possible; that is,

$$\beta^Q = 0.$$

Given that quotas last for one period only, the dynamic problem collapses into a series of independent static problems and so each period may be considered in isolation. In any period, the optimal solution in the quota case can then be described by the condition

$$D'\left(\overline{y}^Q\right) + c'\left(\overline{y}^Q\right) = \mu r \left[1 - \frac{1}{\varepsilon^Q}\right],$$

which, of course, corresponds directly to that obtained in the tax case.

5 Conclusion

We have demonstrated that a government will choose quotas with the shortest duration possible. Longer-term quotas create an intertemporal 'inconsistency' problem, in the sense that the government would over time increase the number of quotas beyond the globally efficient level. When regulation is by taxes, no similar problem arises.

Essentially, this is similar to the insight that a monopolistic producer of a durable good prefers leasing to avoid the problems of intertemporal credibility associated with selling, see Coase (1972), Bulow (1982) and von der Fehr and Kühn (1994). Here, tax regulation corresponds to leasing while regulation by long-lived quotas corresponds to selling a durable good. Taxes and quotas are equivalent policy instruments only if quotas have short duration, which amounts to leasing.

In the literature on environmental regulation taxes and grandfathered quotas are often compared as alternatives and in that case taxes are obviously preferred from a public finance perspective. The thrust of this paper is that even if quotas are auctioned under perfect information there remains a disadvantage which makes (long-run) quotas less attractive to policymakers.

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