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Taxes and subsidies in a polluting and politically powerful industry

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In memory of Professor D. Gale Johnson

Abstract

This paper analyzes the effect of political pressure on taxes and subsidies in a polluting industry. Two innovations are offered: (a) The model of the analysis is simple; it is based on profit maximization, the participation constraint, and that politicians are willingly influenced. No additional structure is assumed. (b) It is shown that the conventional conclusion that, as pollution controls, taxes and subsidies are equivalent, does not hold in the presence of political pressure—both in short-run and in the long-run. In addition, production is generally not efficient in a political equilibrium and costs are not minimized.

JEL classification: D78; H23

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A great believer in free markets, D. Gale Johnson devoted his long professional career to the study of the effect of public policies on prices, production and welfare in agriculture. World Agriculture in Disarray (1991) is still a must reading for anyone interested in farm policies and their intended and unintended effects on farmers, consumers, and taxpayers—in industrial as well in developing countries. We hope that the analysis of policy formation in the presence of politically powerful groups, offered in this paper, contributes to the clarification of issues that were in the center of Professor Johnson's interest.

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1. Introduction and summary

In this paper we examine regulations implemented to reduce pollution in a competitive but politically powerful industry. Agriculture can serve as an immediate example. The paper has three messages. The first two deal with contents: (a) the symmetry of the effects of taxes and subsidies breaks down, even in the short-run, in the presence of political pressure; (b) production is inefficient (it is not at minimum AC) both in the short- and long-run. The third message concerns method: an analysis of the political economy can rely solely on general assumptions of individual rationality; in particular, on what game theorists term the participation constraint. It is not necessary to formulate a detailed model with stronger assumptions in order to reach our conclusions.[1]

It is an established finding of analysis, relying on marginal economic principles, that a socially optimal level of pollution can be achieved by either a tax per unit of discharge or a subsidy per unit of reduced emission (for a survey and references, see Cropper & Oats, 1992). The symmetry of the two control instruments was, however, criticized on several grounds, the most common being the marked difference in their long-run effects.

A series of studies focused on endogenous (long-run) entry (e.g., Kamien, Schwartz, & Dolbear, 1966; Kohn, 1985; Polinsky, 1979). The general conclusion that emerged was that a tax regime is more efficient than a subsidy, since it yields fewer active firms, smaller pollution levels and lower production costs. Moreover, several studies have shown that, with subsidies and in the long-run, pollution may be greater than its free market, non-intervention level. Fisher (1981) pointed out incentives of strategic behavior: firms could increase pollution in anticipation of future subsidies.

Although the main criticism of the symmetric effects of taxes and subsidies focused on the long-run, some authors questioned its short-run validity. For example, Just and Zilberman (1979) showed that, with uncertain externalities, subsidies decrease risk of pollution, while under a tax regime, pollution reduction depends on additional restrictions on the structure of risk preference. Differences in income and profits were the principal sources of asymmetry in the effects of the alternative regimes in the last study as well as in those quoted earlier.

More often than not, government intervention, even if well intended, induces lobbying and political pressure. Interest groups organize in order to modify policies: either to fend-off threats or to exploit opportunities. This paper shows that—even with full information, no strategic behavior, and predetermined industry size—the political equilibrium with taxes and subsidies is asymmetric. In the short-run, a tax regime leads to over-production of the polluting good, while with subsidies, too little is produced.

Our analysis of the political economy shows, further, that asymmetry of controls also prevails in the long-run. Taxation reduces output and pollution, while subsidization increases them. Except for one special case, production is not efficient under both regimes: with taxes, firms produce more than the cost minimizing quantity, while with subsidies, they produce less than this amount. The upshot is that, contrary to the professional

[1] Elsewhere (Finkelshtain & Kislev, 1997) we demonstrate asymmetry in a general equilibrium analysis conducted in a more structured model.

conventional wisdom, in the presence of political pressure, a tax regime may be inferior both to a non-intervention, free market equilibrium and to a subsidy regime.

2. The economy and the environment

There are N identical polluting firms in a competitive industry. The producers disregard negative externalities associated with their activities. We study the consequences of regulation in this industry in the short-run, when N is given, and in the long-run, when N is endogenous and determined as part of the political-economic equilibrium. Several simplifying assumptions are adopted: (1) the analysis is of partial equilibrium, focusing on the industry and its regulation; (2) firms are identical; (3) pollution is proportional to output, q, with a proportionality coefficient e; (4) the polluting sector, assumed to be small and competitive in the input market, faces constant input prices; (5) the cost function, $c(q)$, increases and the long-run average cost is U-shaped; (6) all functions are second-order differentiable and interior solutions are assumed throughout.

Social welfare is measured as total economic surplus

$$V(Q, N) = \int_0^Q p(z)\mathrm{d}z - Nc\left(\frac{Q}{N}\right) - eQ, \tag{1}$$

where $p(\ )$ is the decreasing inverse demand function for the product, defined over total industry output, $Q = Nq$.

3. The political economy

The government, aiming at pollution control, chooses a regulation instrument, either a tax or a subsidy. Once an instrument was chosen, producers endeavor to affect the ensuing policy but, by assumption, the choice itself is not subject to political debate and influence.

3.1. The polity

Each producer in the regulated industry contributes the sum r (dollars per year) as a political reward. The rewards may take the form of aid in campaigns, demonstrations, letter writing, or even outright bribes. We assume that the producers understand the significance of the political activity; free riding is not practiced. The politicians, accepting the rewards, are ready to modify regulation policies. Accordingly, the politicians are seen as maximizing W in

$$W = W(V, R), \tag{2}$$

where V is defined in (1) and $R = \sum r = Nr$ is the sum of the political contributions in the regulated industry.

By (2), the politicians are interested only in the total sum, R, contributed by the industry; its distribution among the producers makes no difference. However, as indicated, we assume that firms are identical and each producer contributes the same r. One special case deserves attention: sometimes industries, collecting political contributions, impose levies in proportion to output, $r = \rho q$. It will be shown in the following that this proportionality modifies one of the conditions of the long-run political equilibrium.[2]

Long-run equilibrium in a competitive industry is characterized by zero profits. However, at any point in time, firms own tangible and intangible productive assets the returns to which they maximize. As part of their activities, producers are ready to contribute to political causes—whether they realize or do not realize the long-run zero profit destiny of the industry.

The producers in the industry attempt to maximize profits while the politicians (the government) strive to maximize their own welfare W. The parties are seen as striking a deal, trading regulation reforms against political rewards. The details of the deal are not specified, but it is assumed that the social optimum [the set of policies maximizing (1)] is the threat-point of the political game: if the producers do not keep their part of the bargain, the government is powerful enough to force a tax or subsidy maximizing social welfare. The producers may also threaten to accept the welfare-maximizing instrument and deprive the politicians of the desired reward R.

3.2. Rational participation

Two groups of models have been applied to the study of policy formation in the presence of political activity. The first employs explicit game formulation; examples are Zusman (1976) using a Nash (1950) cooperative bargaining game and Grossman and Helpman (1994) who model the political process as a non-cooperative auction game. Fredrikson (1997) applies Grossman and Helpman's model to study pollution taxes in an open economy. Peltzman (1976) and Hillman (1989) belong to the second group. In their work, the government is viewed as setting policy parameters in order to maximize a political support function that trades the welfare of voters with divergent interests.

Individual rationality is an integral part of all game-theoretic models, both cooperative and non-cooperative. Actors will not take part in a game unless their reservation utility is maintained. This axiomatic prerequisite, that the utility of joining a game must be at least as great as the opportunity foregone, is incorporated in formal models as the participation constraint. A similar rationality assumption can also be attributed to models in the second group of studies, although generally individual behavior is not part of their explicit formulation.

In the analysis to follow, individuals or firms may form lobbies and invest financial or other resources to influence political decisions. Apart from profit maximization, the only behavioral assumption is that the producers are politically active only if the participation constraint is satisfied; a more detailed behavioral structure is not assumed. Consequently, the conclusions do not rely on any particular form of the political process. Simplicity and generality are convenient and powerful attributes of a theoretical analysis but, needless to say, they limit the scope of the issues considered. We shall comment on limitations in the conclusion of the paper.

[2] We are indebted to Ayal Kimhi for this insight.

4. Short-run equilibrium

This section is devoted to a description of short-run industrial equilibrium, where the number of firms is given, $\bar{N}$. Denote the profit of the typical firm by $\pi = pq - c(q)$, and mark by a superscript *pr* free market, non-intervention variables. Accordingly, in the absence of intervention, the profit maximizing output of a single firm is

$$q^{pr} = \arg\max_{q \geq 0}[pq - c(q)], \tag{3}$$

yielding the short-run equilibrium condition:

$$p^{pr}(\bar{N}q^{pr}) - c'(q^{pr}) = 0. \tag{4}$$

With pollution, the equilibrium defined by (3) and (4), though profit maximizing, is socially not optimal. We turn therefore to welfare maximization and continue with the incorporation of political pressure and the demonstration of the asymmetric effects of the control instruments.

4.1. Welfare maximization

In the short-run, socially optimal, welfare maximizing output, Q^{w}, is

$$Q^{w} = \arg\max_{Q \geq 0}[V(Q, \bar{N})], \tag{5}$$

with the first-order condition:

$$p(Q^{w}) = c'\left(\frac{Q^{w}}{\bar{N}}\right) + e. \tag{6}$$

Production by (6) is lower than by (4); namely, for the industry $Q^{w} \leq Q^{pr} = \bar{N}q^{pr}$ and at the firm $q^{w} \leq q^{pr}$. This motivates government intervention.

The government may use either of two alternative instruments of intervention. First, it may levy a per-unit tax, t, on production; namely, a firm producing under a tax regime q^{t} units of output, pays taxes to the amount tq^{t}. Second, the government may subsidize a reduction in the production of each firm below some predetermined level, $\bar{q}$. In this case, the typical firm is paid a subsidy of $s(\bar{q} - q^{s})$.[3]

The implementation of the control regimes modifies the private first-order conditions and it becomes

$$p(\bar{N}q^{t}) - c'(q^{t}) = t \text{ and } p(\bar{N}q^{s}) - c'(q^{s}) = s. \tag{7}$$

In the absence of political pressure, the government takes into consideration condition (7) and sets per unit tax or subsidy to maximize V. The first-order conditions for the choice of t and s are, respectively,

$$\frac{\partial V}{\partial t} = \bar{N}(p(\bar{N}q^{t}) - c'(q^{t}) - e)\frac{\partial q^{t}}{\partial t} = 0, \tag{8}$$

[3] If $\bar{q}$ is too small, firms may give up the subsidy rather than lose income. We shall therefore assume, for simplicity, that $\bar{q}$ is set at minimum AC.

and

$$\frac{\partial V}{\partial s} = \bar{N}(p(\bar{N}q^s) - c'(q^s) - e)\frac{\partial q^s}{\partial s} = 0. \tag{9}$$

Since $\partial q^t/\partial t < 0$ and $\partial q^s/\partial s < 0$, the expressions $(p - c'(q^t) - e)$ and $(p - c'(q^s) - e)$ must vanish and, comparing with (7), it is seen that the control measures are set at $t = s = e$, yielding $q^t = q^s = q^{\mathrm{w}}$. At these levels of production, pollution will be socially optimal in the short-run—with a given number of producers—although production may be inefficient: if, before the imposition of the control, firms were at minimum AC, they produce with government intervention at lower q levels.

4.2. Asymmetry of political effects

Proposition 1 characterizes short-run political equilibrium.

Proposition 1. *Consider the regulation of a polluting and politically powerful industry with a predetermined number of firms. Then*:

(i) *Under a tax regime*, $0 < t < e$ *and*, *therefore*, *equilibrium production and pollution exceed the socially optimal levels but fall short of the free market*, *non-intervention levels*;

(ii) *Under a subsidy regime*, $0 \leq e < s$ *and*, *therefore*, *equilibrium production and pollution fall short of both the free market*, *non-intervention levels and the social optimum*.

Proof. In a political equilibrium, under a tax regime, satisfaction of the participation constraint implies

$$p^t q^t - c(q^t) - tq^t - r > p^t \hat{q} - c(\hat{q}^t) - e\hat{q}^t, \tag{10}$$

where $\hat{q}^t = c'^{-1}(p^t - e)$ and the right hand side of (10) is the threat-point of the political game. Note that $\hat{q}$ maximizes profits when the market price is p^t and the tax is e and, also, at the threat-point the reward $r = 0$. By (10), the perceived net profit at the threat-point should not exceed profits at the political equilibrium.[4] The calculation, at the threat-point, of profits for the price prevailing when the instrument t is implemented, is a reflection of the myopic outlook of the producers who do not comprehend fully the market equilibrium that will prevail if their threat ever materializes.[5]From $\hat{q}^t$ being profit maximizing, it follows that

$$p^t q^t - c(q^t) - eq^t < p^t \hat{q}^t - c(\hat{q}^t) - e\hat{q}^t. \tag{11}$$

[4] Formally, (10) could be written as a weak inequality; however, if equality prevails, the participation constraint is barely satisfied but producers still have to invest in lobbying activity. In most cases, they will prefer the threat point, $t = e$ and $r = 0$. We therefore wrote (10) as a strict inequality.

[5] Note that if the producers do comprehend the equilibrium condition, then they understand that the realization of the treat-point ($t = e$) will raise prices above p^t. However, the inequality in (10) will remain valid.

Combining Eqs. (10) and (11) we find $(e-t)q^t - r > 0$ and, as $r \geq 0$, and $t \geq 0$, $0 \leq t < e$, as proposed. With t between 0 and e, $Q^{\mathrm{w}} < Q^t \leq Q^{pr}$.Similarly for subsidies, the participation condition is

$$p^s q^s - c(q^s) + s(\bar{q} - q^s) - r > p^s \hat{q}^s - c(\hat{q}^s) + e(\bar{q} - q^s), \tag{12}$$

here $\hat{q}^s = c'^{-1}(p^s - e)$. Now, replacing the right hand side of (12) by $p^s q^s - c(q^s) + e(\bar{q} - q^s)$ it is seen that $(s-e)(\bar{q} - q^s) - r > 0$. Since $(\bar{q} - q^s) \geq 0$, it follows that $s > e \geq 0$, as proposed.

By Proposition 1, under a tax control, the political equilibrium is a compromise, with production between free market and the socially desired level. A subsidy regime, on the other hand, induces too little production and "too little" pollution. The intuitive explanation is simple. Under taxes, the political pressure is to reduce the tax; while with subsidies, it is to increase the subsidy, up to and above the social optimum. (Political pressure may eliminate a tax altogether or even turn it into a subsidy. We are not considering these possibilities here.)

A Pigovian tax, being a compromise, even if modified by interest groups, is welfare enhancing. Not always so under a subsidy; with political pressure, a subsidy—being too high—may reduce welfare relative to non-intervention equilibrium. The situation is even more ambiguous, since both taxes and subsidies are not optimal and they operate in opposite directions, welfare loss under a subsidy regime may be smaller than under a tax.

5. The long-run

In the long-run, the number of firms in the industry, N, as well as the tax or the subsidy, are endogenously determined, affecting both pollution and intra-firm production efficiency. As indicated in the Section 1 of the paper, it has already been established that, in the long-run, pollution reducing subsidies cannot improve welfare. For completion, we repeat this finding and then show what equilibrium is reached if the government—despite the theoretical admonitions—opts for subsidies and the regulated industry is politically powerful.

5.1. Welfare maximization in the long-run

Optimal, welfare maximizing, industrial output and number of firms are

$$(Q^{\mathrm{w}}, N^{\mathrm{w}}) = \arg \max_{Q,N \geq 0} [V(Q,N)], \tag{13}$$

maintaining the first-order conditions:

$$p(Nq) = c'(q) + e, \tag{14}$$

$$\frac{c(q)}{q} = c'(q). \tag{15}$$

Eq. (15) is the familiar long-run condition of minimum average cost. The competitive non-intervention equilibrium is characterized by (15) and $p(Q) = c'(q)$, which leads to over-production of the polluting good. The government may then levy a tax or offer a subsidy. The conditions of the ensuing long-run equilibrium at the firm level are now presented in pairs, for taxes and subsidies,

$$p = c'(q^t) + t \qquad p = c'(q^s) + s, \tag{16}$$

$$p = \frac{c(q^t)}{q^t} + t \qquad p = \frac{c(q^s) - s\bar{q}}{q^s} + s, \tag{17}$$

from which we get

$$\frac{c(q^t)}{q^t} = c'(q^t) \qquad \frac{c(q^s) - s\bar{q}}{q^s} = c'(q^s). \tag{18}$$

A comparative static analysis of the effect of a tax and a subsidy on output and the number of firms is detailed in the Appendix A. It yields the following signed derivatives

$$\frac{\mathrm{d}q}{\mathrm{d}t} = 0, \qquad \frac{\mathrm{d}q}{\mathrm{d}s} < 0, \tag{19}$$

$$\frac{\mathrm{d}N}{\mathrm{d}t} < 0, \qquad \frac{\mathrm{d}N}{\mathrm{d}s} > 0, \tag{20}$$

and

$$\frac{\mathrm{d}Q}{\mathrm{d}t} < 0, \qquad \frac{\mathrm{d}Q}{\mathrm{d}s} > 0. \tag{21}$$

As Eqs. (19)–(21) exhibit, with subsidies and in the long-run, firm production is less than non-intervention output, the number of firms is greater and total production of the industry also increases. Thus, efficiency is impaired and pollution increases. A rational government will not choose subsidy as a pollution-regulating instrument (an optimum subsidy cannot be found mathematically). Under a tax regime, as the signs indicate, intervention does not impair intra-firm efficiency and it reduces total output and pollution.

Fig. 1 depicts average and marginal cost. AC and MC are for a free market situation. AC^e and MC^e in the tax panel are the graphs of the cost functions when a tax $t = e$ is imposed. Production stays at q^0 (min AC). Parallel graphs are not shown in the subsidy panel since, as indicated, equating $s = e$ does not set an optimum subsidy for the long-run. The graphs MC^t and MC^s and the corresponding average cost curves represent political equilibrium and are introduced in the following.

We show now that under a tax regime, the optimal policy is, as in the short-run, to set $t = e$. Maximizing (13), the first-order condition can be written as

$$V_Q \frac{\partial Q}{\partial t} + V_N \frac{\partial N}{\partial t} = 0. \tag{22}$$

Inserting the comparative static derivatives from the Appendix A and recalling (15), one gets

$$V_Q \frac{1}{p'} + V_N \frac{1}{qp'} = \frac{1}{p'}\left\{p(Q) - c'\left(\frac{Q}{N}\right) - e - \frac{1}{q}\left[c\left(\frac{Q}{N}\right) + qc'\left(\frac{Q}{N}\right)\right]\right\} = 0 \Rightarrow p = c' + e. \tag{23}$$

That is, $t = e$ maximizes welfare. We turn now to the political equilibria.

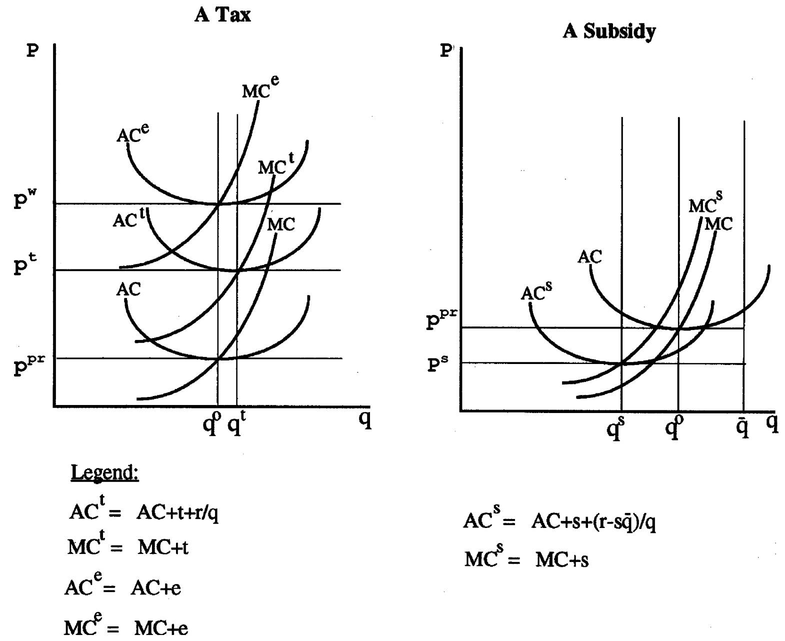

Fig. 1. Long-run equilibrium.

5.2. *Asymmetry of political equilibria in the long-run*

Proposition 2 characterizes the long-run political equilibrium for both a tax and a subsidy regime. Before presenting the proposition, we introduce the notations:

$$Q^{w} = N \arg\min_{q} \left[\frac{c(q) + eq}{q}\right], \tag{24}$$

$$q^{0} = \arg\min_{q} \left[\frac{c(q)}{q}\right]. \tag{25}$$

to mark the socially optimal and efficient, long-run output of the regulated industry and the firms in the industry.

Proposition 2. *Consider the regulation of a polluting and politically powerful industry. The political long-run equilibrium is characterized by*:

(i) *Under a tax regime, production and pollution form a compromise between the corresponding socially optimal and the free market, non-intervention level; that is,* $Q^{w} < Q^{t} < Q^{pr}$.

(ii) *Under a subsidy regime, production and pollution exceed the free market, non-intervention level; namely,* $Q^{s} > Q^{pr} > Q^{w}$.

(iii) *Except for the special case of proportional contributions* ($r = \rho q$), *under both regimes, cost of production is not minimized. With taxes,* $q^{t} > q^{0}$, *under a subsidy regime,* $q^{s} < q^{0}$.

(iv) *When* $r = \rho q$, *then under a tax regime*, q *is optimal*, $q^t = q^0$.
(v) *Under a tax (subsidy) regime, the per-unit tax (subsidy) is smaller (larger) than the per-unit pollution coefficient*, $t < e\ (s > e)$.

Proof. To prove that $Q^t < Q^{pr}$, we show that $p^t > p^{pr}$. From the long-run and zero profit condition, we have

$$p^t = \min_q \frac{c(q) + r + tq}{q} \tag{26}$$

and

$$p^{pr} = \min_q \frac{c(q)}{q} \tag{27}$$

Recall now that at the threat-point $t = e$ and $r = 0$, in a political equilibrium, $t < e$, $r > 0$ (the last inequality may be termed the participation constraint of the politicians). In both cases $r + tq > 0$, yielding $p^t > p^{pr}$; as required.

To prove that $Q^t > Q^{\mathrm{w}}$, we show that $p^t < p^{\mathrm{w}} = p(Q^{\mathrm{w}})$. Write

$$p^{\mathrm{w}} = \min_q \frac{c(q) + eq}{q} = \frac{c(q^{\mathrm{w}}) + eq^{\mathrm{w}}}{q^{\mathrm{w}}}, \tag{28}$$

where q^{w} minimizes $(c(q) + e)/q$. Turn now to the participation constraint. By (26), the left-hand-side of (10) is zero and, therefore, the right-hand-side is negative. So also, if $\hat{q}$ is replaced by $q^{\mathrm{w}}, p^t q^{\mathrm{w}} - c(q^{\mathrm{w}}) - eq^{\mathrm{w}} < 0$. Rewriting,

$$p^t < \frac{c(q^{\mathrm{w}}) + eq^{\mathrm{w}}}{q^{\mathrm{w}}} = p^{\mathrm{w}}. \tag{29}$$

This completes the proof of (i).

To prove (ii), we show that $p^s < p^{pr}$. Write

$$\begin{aligned} p^s &= \min_q \left[\frac{c(q) - s(\bar{q} - q) + r}{q}\right] \le \min_q \left[\frac{c(q)}{q}\right] + \min_q \left[\frac{r - s(\bar{q} - q)}{q}\right] \\ &= p^{pr} + \min_q \left[\frac{r - s(\bar{q} - q)}{q}\right]. \end{aligned} \tag{30}$$

It was shown following (12) that$s(\bar{q} - q^s) - r > e(\bar{q} - q^s) > 0$. Hence

$$\min_q \left[\frac{r - s(\bar{q} - q)}{q}\right] < 0. \tag{31}$$

Substituting into (30), the proof of (ii) is completed.

To prove (iii) for a tax regime where r is not proportional to output, note in Fig. 1, the marginal cost that the firm faces, MC^t, is higher than MC; that is for every q, $\mathrm{MC}^t = \mathrm{MC} + t$. The difference in average cost is larger, $\mathrm{AC}^t = \mathrm{AC} + t + r/q$. Consequently, production is to the right of min AC.

Under a subsidy, $\mathrm{MC}^s = \mathrm{MC} - s$; MC^s is lower than MC. For average cost, $\mathrm{AC}^s = \mathrm{AC} + [r - s(\bar{q} - q)]/q = \mathrm{AC} - s + (r - s\bar{q})/q$. We have already seen that $r - s(\bar{q} - q)] < 0$.

Hence AC^s is also lower that AC, but the difference is larger than for marginal cost. Production, in Fig. 1, is to the left of min AC.For (iv), note that if $r = \rho q$, in Fig. 1, $\mathrm{AC}^t = \mathrm{AC} + t + \rho$ and also $\mathrm{MC}^t = \mathrm{MC} + t + \rho$. Hence average and marginal cost rise equally and $q^t = q^0$.

Finally, (v) was proved to hold for the short-run and similarly, it can be shown to hold for the long-run.

Several aspects of the proposition deserve attention. First, in the presence of political pressure, government intervention, in an economy with external effects, may reduce welfare. This is true both for a tax and a subsidy regime. Second, unlike intervention in a non-political world, production under a tax regime is inefficient, taxes may reduce welfare, and may even be dominated by a subsidy control. Third, as in a non-political world, in the long-run, a subsidy regime always increases pollution and production costs and reduces welfare in comparison with free market equilibrium.

6. Concluding remarks

It was shown in the paper that political pressure affects the efficiency of regulation and production, both in the short-run and the long-run. Considering the reality of political influence, the only surviving conclusions of the normative, politically free analysis is that taxes improve welfare in the short-run and subsidies reduce it in the long-run. Neither control assures socially optimal production and pollution when producers are politically active and politicians are willingly influenced. Moreover, the alternative controls, taxes or subsidies, can only be ranked if specific behavioral functions and magnitudes are known. Relying on the elementary assumption, that the participation constraint is satisfied in the political equilibrium, we could complete the qualitative analysis and show the directions by which political pressure modifies welfare enhancing policies. Nevertheless, weak assumptions limit the scope of the analysis. As an example, the analysis in the paper could not determine the magnitude of the political contributions in equilibrium, not even the relative magnitude of the contributions associated with taxes compared with the rewards agreed upon under subsidies. More detailed and explicit formulation is required to answer such questions. Similarly, a complete analysis of the effect of the sometime suggested policy that taxes be imposed only on incremental production, on output above a certain preset threshold, could not be conducted with the structural assumptions in this paper. These shortcomings are the costs of simplicity, generality and robustness.

Appendix A. Comparative statics

Rewrite (16) and (17)

$$p(Nq^t) - c'(q^t) = t \qquad p(Nq^s) - c'(q^s) = s \tag{A.1}$$

$$p(Nq^t) - \frac{c(q^t)}{q^t} = t \qquad p(Nq^s) - \frac{c(q^s)}{q^s} = s\left(1 - \frac{\bar{q}}{q^s}\right). \tag{A.2}$$

In the analysis, the variables q, N and Q are taken as endogenous while t and s are considered exogenous parameter. For the tax and subsidy cases, and $t = s = 0$, where Eq. (15) holds:

$$\begin{bmatrix} Np' - c'' & qp' \\ Np' & qp' \end{bmatrix} \begin{bmatrix} \dfrac{dq}{dt} \\ \dfrac{dN}{dt} \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \end{bmatrix} \tag{A.3}$$

$$\begin{bmatrix} Np' - c'' & qp' \\ Np' & qp' \end{bmatrix} \begin{bmatrix} \dfrac{dq}{ds} \\ \dfrac{dN}{ds} \end{bmatrix} = \begin{bmatrix} 1 \\ 1 - \dfrac{\bar{q}}{q^s} \end{bmatrix} \tag{A.4}$$

Employing Cramer's rule, condition (A.3) and (A.4) yield:

$$\frac{dq}{dt} = 0, \qquad \frac{dq}{ds} = -\frac{\bar{q}}{qc''} < 0, \tag{A.5}$$

$$\frac{dN}{dt} = \frac{1}{qp'} < 0, \qquad \frac{dN}{ds} = \frac{1}{q^2}\left(\frac{N\bar{q}}{c''} - \frac{\bar{q} - q}{p'}\right) > 0, \tag{A.6}$$

and

$$\frac{dQ}{dt} = \frac{1}{p'} < 0, \qquad \frac{dQ}{ds} = \frac{q - \bar{q}}{qp'} > 0. \tag{A.7}$$

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