The symmetry between controlling pollution by price and controlling it by quantity

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Abstract. Under ideally competitive conditions, both controlling pollution by price (using a combined charge-subsidy scheme) and controlling it by quantity (using a marketable permit scheme) can achieve short- and long-run efficiency and also political acceptability, provided that both schemes embody the same degree of environmental ownership. The resulting full symmetry between control by price and control by quantity, a symmetry overlooked in the literature because of the entry-exit assumptions automatically made for most subsidy schemes, allows a useful practical choice to be made between the two control systems.

La symétrie entre le contrôle de la pollution par les prix et les quantités. Sous des conditions concurrentielles idéales, le contrôle de la pollution soit par les prix (en utilisant un système de taxes et subventions) soit par les quantités (en utilisant un système de mise en marché de permis) peut également réussir à assurer l'efficacité à court et à long terme et être politiquement acceptable, pour autant que ces mécanismes incorporent le même degré de propriété environnementale. La symétrie qui en résulte entre le contrôle par les prix et par les quantités, une symétrie qu'ignore la littérature spécialisée à cause des postulats d'entrée et de sortie que la plupart des mécanismes de subventions entérinent automatiquement, permet de faire des choix pratiques et utiles entre les deux systèmes de contrôle.

I. INTRODUCTION

The essential result of this paper is simple. Under ideal conditions, controlling excessive pollution or congestion of a scarce public or common property resource by using a price-based instrument such as a fee or charge can be made symmetrical,

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in terms of short-run efficiency, long-run efficiency,[1] and political acceptability, to using a quantity-based instrument such as a marketable licence or permit. The symmetry between pure charges and sold or auctioned marketable permits has already been shown by Spulber (1985). Here we show that there is also symmetry between charge-subsidies and corresponding marketable permit schemes where some or all of the permits are freely granted rather than sold. There is thus no *fundamental* reason, as long as the decision has been taken to use some market instrument rather than direct regulation, for choosing control by price instead of control by quantity, or vice versa.

The key condition for attaining this useful freedom of choice is that, in any given application, both types of instrument embody the same degree of 'environmental ownership' in the form of symmetrical, private property rights in the resource. However, the relevant literature implicitly or explicitly, but in either case rather inconsistently, rules out this property rights condition for control by price but does not rule it out for control by quantity. As a result, it often happens that efficient and acceptable instruments are rejected by economists; efficient but unacceptable instruments are proposed instead; while inefficient but acceptable instruments are the ones actually used by policy makers. The aim of this paper is to encourage the use of control instruments that are both efficient and acceptable.

In keeping with the existing literature, the argument below uses the language of pollution control, specifically the control of water pollution. However, it can also apply to a range of natural and man-made resources which are not yet privately owned, such as the atmosphere, land for waste dumping, wilderness and wildlife, road space or airport landing slots, where either one-way or mutual (congestion) externalities may arise.

The 'ideal' conditions that are assumed to hold here constitute perfect competition in its fullest sense. We consider a perfectly competitive industry comprising many small firms, each of which is a rational profit-maximizer producing a single output and discharging a single effluent, emission, or waste stream. The effluent is neither storable on the factory site, nor cumulative in the environment, but is continuously assimilated into a well-mixed but finite environmental reservoir. Firms face perfectly competitive markets for their outputs and for their capital and labour inputs, but they own different sets of fixed factors like enterprise and therefore have different marginal cost schedules for effluent control. Time-dependent phenomena such as uncertainty and technical innovation in pollution control are ignored. Perfect information is freely available to all firms and to the pollution control authority (hereafter just 'the authority'), and transaction costs are zero. Last, but by no means least, a perfect authority, whose sole objective is to maximize public welfare, is assumed.

Contrary to normal practice, in section II and III we first state the case for the equivalence of control by price and control by quantity, and then, in section IV, we

1 As usual in the pollution control literature, 'short run' takes as given the firms that exist in the industry, while 'long run' allows for the entry and exit of firms.

relate the ideas thus raised to the existing literature. Finally, in section v, we draw out some implications for policy.

II. CONTROL BY PRICE: THE CASE FOR THE CHARGE-SUBSIDY

Controlling pollution by price implies the use of charges[2] per unit of effluent added and/or subsidies[3] per unit of effluent reduced. The way in which charges and subsidies can be combined into a 'charge-subsidy' scheme, which achieves short-run efficiency, long-run efficiency, and political acceptability, has been fully spelt out in a neglected paper by Mumy (1980).[4] His scheme is effectively that each polluting firm pays

$$V(E - E_b) \text{ (in, say, dollars per month)} \tag{1}$$

to the authority, where

V = the charge rate (in, say, dollars per ton of effluent) set by the authority, which does not vary from firm to firm or with time.

E = the effluent level (in, say, tons per month). This is under the firm's control and so may vary from firm to firm and over time.[5]

E_b = the baseline effluent right (in tons per month) which is initially given *as a property right* to each existing firm by the authority. E_b may vary from firm to firm but does not vary over time.

If a firm has a positive baseline, and its effluent is less than its baseline ($E < E_b$), it receives a subsidy from the authority. If $E_b = 0$ for all firms, the scheme reduces to a pure Pigovian pollution charge. V (which will of course equal the industry's marginal cost of effluent control in equilibrium) is chosen so that the marginal damage cost of the resulting total effluent ΣE is equal to V, thus achieving *short-run efficiency*, given the ideal conditions assumed.[6] ΣE is thus determined on economic grounds and is not necessarily the same as total baseline effluent ΣE_b, which is determined on political grounds (see below). The scheme therefore may not be revenue-neutral for the authority.

Long-run efficiency is achieved because E_b is a full property right. New firms entering the industry are therefore *not* given effluent rights (so for them, $E_b = 0$), while existing firms exiting from the industry *keep* their effluent rights and receive a subsidy of VE_b in perpetuity. Under these entry-exit rules, the opportunity cost to

2 Also known as fees or taxes.

3 Also known as bribes, payments, or compensation.

4 The name 'charge-subsidy' is mine; Mumy himself referred to 'efficient property rights sharing,' to emphasize the property rights involved in the scheme.

5 Mumy actually considered the more restricted case where effluent is strictly proportional to output, and output itself is taxed.

6 Because each firm remains small in relation to the environmental reservoir, the marginal damage cost curve of each firm's effluent is constant. See Burrows (1979) and Collinge and Oates (1982) for the modifications required to the charge scheme if marginal damages increase as the firm's effluent increases.

any firm of producing output Q and effluent E rather than closing down production (or not starting production in the first place, in the case of a new firm) is the sum of $C(Q,E)$, the firm's ordinary cost function excluding effluent charges and subsidies; $V(E-E_b)$, the effluent charge-subsidy; and VE_b, the cost of not receiving the perpetual subsidy for closing down. The net opportunity cost to the firm is then

$$C(Q, E) + V(E - E_b) + VE_b = C(Q, E) + VE, \tag{2}$$

and since $C(Q,E) + VE$ is the social opportunity cost of production, long-run efficiency is achieved. The baseline effluent right E_b disappears from formula (2), so it has no effect on production costs or resource allocation; the invariance proposition of Coase (1960) is thus recovered. Owning E_b effluent rights simply increases the wealth of the firm's owners, and there are no wealth effects, because firms are small. Holderness (1979) observed how Coase invariance exists only 'when rights are assigned to closed classes of individuals or entities,' and the above entry-exit assumptions do indeed close the class of owners of effluent rights.

In a charge-subsidy scheme, baseline effluent rights E_b for each firm should be chosen entirely on political grounds (which is why ΣE_b and ΣE may differ). The choice is unlikely to be easy. In many cases de facto effluent rights clearly exist in the form of existing effluent standards (Buchanan and Tullock 1975, 142; Pezzey 1988, 207). However, both environmental and industrial interests often fear, if for quite opposite and incompatible reasons, that formally recognizing effluent rights will be disadvantageous to them in the long-term struggle that usually precedes the establishment of any property rights over unowned resources. Whichever is the case, the more quickly and firmly that a formula can be found to settle disagreements between environmental and industrial interests, the sooner and greater will be the economic gain which can then be shared between these interest groups and also taxpayers and consumers.

III. CONTROL BY QUANTITY, AND SYMMETRY WITH CONTROL BY PRICE

The authority can achieve effluent control by a quantity instrument, in a way that is formally symmetrical to the above scheme of control by price, as follows. As with charge-subsidies, the control authority starts by knowing the optimal total effluent ΣE. The authority gives ('grandfathers') each existing firm a free baseline amount E_b of marketable effluent permits (MEPS),[7] and takes such steps as are necessary to create an efficient market to bring together potential buyers and sellers of MEPS. If $\Sigma E_b > \Sigma E$, the authority must then rent back $(\Sigma E_b - \Sigma E)$ permits from the lowest offerer; if $\Sigma E_b < \Sigma E$, it must create an extra $(\Sigma E - \Sigma E_b)$ permits and offer these out for rental to the highest bidder. In either case, the equilibrium rental price of an

7 Also known as transferable discharge permits (TDPS), tradeable emission licences, tradeable effluent rights, marketable pollution consents, etc., etc.

TABLE 1
Categorization of market instruments for effluent control by method of control, and by effluent rights embodied

Control by price or by quantity?	Effluent rights owned by firm		
	Zero	Intermediate	Free market level of effluent
Price	P1. Pure charge	*P2. Charge-subsidy*[a]	P3. Pure subsidy
Quantity	Q1. Sold or auctioned MEPs	Q2. Freely granted (grandfathered) MEPs	*Q3. Granted and bought back MEPs*[a]

a Instruments in *italics* are frequently ignored in the literature (for example, by Milliman and Prince 1989).

MEP becomes V, the optimal effluent price.[8] If a firm's effluent $E > E_b$, it legally must rent $(E-E_b)$ permits at a rental price V, whereas if $E < E_b$ it will wish to lease out $(E_b - E)$ spare permits. If the firm closes down ($E = 0$), it can lease out all E_b spare permits and receive a permanent income of VE_b. As with the charge-subsidy scheme, firms entering the industry do not receive effluent rights (i.e., $E_b = 0$). In all cases a firm producing output Q and effluent E therefore ends up paying $V(E-E_b)$ to the authority but faces opportunity costs of production equal to $C(Q,E) + VE$. These are the same formulae as (1) and (2) for the charge-subsidy scheme, so the MEPs achieve the same short- and long-run efficiency, and, as before, baseline effluent permits can be distributed according to political criteria without impairing efficiency. The whole scheme is presumably similar to that envisaged in a comment on Mumy by Beavis and Walker (1981), though with the important difference that here the total ΣE_b of the effluent baselines does *not* need to be exactly equal to the 'total amount of acceptable discharge,' that is, the optimal total effluent ΣE; if it does, political and economic considerations become entangled again.

The available schemes for control by price and control by quantity are summarized in table 1, and under our ideal conditions we have shown that the two types of control are fully symmetrical in terms of efficiency and acceptability. Our key conclusion is therefore that the best control scheme is to formalize the de facto effluent rights of each firm into precise baselines, and then incorporate these baselines as property rights into either charge-subsidy or MEP schemes, with the choice between charge-subsidies and MEPs being determined by practical departures from the ideal conditions.

IV. ARGUMENTS AGAINST SUBSIDIES

There is little in sections II and III that is technically new, as already noted. However, the symmetry we have established and depicted in table 1 is widely rejected in the

8 The talk is of renting rather than selling permits in order to make the symmetry between marketable permits and charge-subsidies more obvious. If the interest rate is r and the permit is permanent, the selling price would be V/r. Other details of this market, for example, whether it uses quoted prices or auctions, are not discussed here.

literature. It is therefore important to examine this rejection here, before briefly reviewing in section v why a fundamentally free choice between control by price and control by quantity is desirable and how it should be made, and suggesting how the debate can move forward.

The literature on effluent charges and subsidies stretches from Kamien, Schwartz, and Dolbear (1966) to modern textbooks like Baumol and Oates (1988, chap. 14).[9] Its essential conclusion is that subsidies are undesirable, for three reasons: one economic, one administrative, and one political. The economic reason given is that, in the long run, subsidies encourage excessive entry into a polluting industry, and avoiding this would require the practically and politically impossible task of tracking down potential polluters and subsidizing them to stay out of the industry. However, this conclusion entirely depends on the (usually implicit) assumptions that subsidy payments are available to all firms that enter, and terminated for all firms that exit. The case for these standard 'open-class' entry-exit assumptions, which differ crucially from our 'closed-class' assumptions above, is rarely given. While the standard assumptions may represent the way in which real subsidy schemes generally operate, as noted by Baumol and Oates (1988, 214), there is no theoretical reason why a new firm should not have to buy or rent its effluent rights from existing owners of the environment, just as it must buy or rent its new factory site from existing owners of land.

The administrative reason given, for example, by Baumol and Oates (1988, 216), is that it would be infeasible to pay subsidies *indefinitely* to firms which have exited. If so, the solution would be the suggestion in Dewees and Sims (1976, 330) that the authority buys out exiting firms' effluent rights by offering lump-sum subsidies in compensation (although this could make big demands on the authority's cashflow). The political reason is that given by writers such as Spulber (1985, 106), who object to firms' owning effluent rights, on the grounds that society owns the environment, and recommend pure charging instead. As argued above, this ignores the political reality that many firms have de facto effluent rights and the clout to defend them.

Despite the formal symmetry that we have shown to exist between freely granted MEPS and charge-subsidies under ideal conditions, the former are both much better known and much less likely to be criticized in the literature than the latter; see, for example, the approval given to granted MEPS in Baumol and Oates (1988, 179). Such writers are much more prepared to accept the notion of environmental property rights with control by quantity than they are with control by price. As a result, they explicitly or implicitly accept the closed-class entry-exit assumptions for control by quantity, and thus ensure that the long-run economic objections of excessive entry to the industry do not arise with freely granted MEPS. Also, MEPS do not get tainted with criticism of related instruments, because of the asymmetric choices of instruments that are made when comparing control by price and control by quantity. For example, Milliman and Prince (1989), in an otherwise comprehensive study of how instrument choice affects technical innovation, choose pure charges

9 An earlier version of this paper (Pezzey 1990) contains a more detailed review of this and related literature.

and pure subsidies (P1 and P3 in table 1) as instruments which control by price, but sold MEPS and freely granted MEPS (Q1 and Q2) as instruments that control by quantity. Choosing to study pure subsidies instead of the charge-subsidy option (P2) tends to associate control by price in general with the specific moral hazard of pure subsidies, which arises when the level of effluent that firms initially (or hypothetically) discharge in the absence of all regulation is used as the starting point for subsidies. The equivalent objection to MEPS does not arise because no one thinks it sensible even to consider option Q3, whereby firms are given permits equal to what their free-market, unregulated discharges would be.

V. IMPLICATIONS FOR POLICY

Conventional economic wisdom thus unnecessarily excludes a rights-based charge-subsidy scheme (option P2 in table 1) from serious consideration as a policy instrument. This may have expensive consequences in real cases where pure charging (option P1) is politically unacceptable because of well-established de facto effluent rights, but control by price is more cost-effective than control by quantity. In any given case, practical choices between control by price and control by quantity, and about how much regulation should be retained as a backstop to market instruments, should be based on how well each instrument copes with the way the real world departs from the ideal conditions set out in section I. These departures include uncertainty; monitoring and enforcement costs, and how they are distributed among firms and the control authority; storage or accumulation of pollutants; changes over time due to economic growth and technical progress; and vulnerability to monopoly power (see Rose-Ackerman 1977 and Pezzey 1988 for surveys of many of these points). Because of the variety of practical circumstances that can occur, there can be *no general presumption that control by quantity is superior to control by price.*

Uncertainty is worth a special mention. It is well established, following a seminal contribution of Weitzman (1974) and a recent summary by Baumol and Oates et al. (1988, chap. 5), that if the authority has good information on the marginal benefits of effluent control, is uncertain about the absolute level of control costs, but is reasonably sure that marginal benefits decrease less steeply than marginal costs increase as effluent is reduced, then control by prices will give greater expected social welfare than control by quantities. Harrison (1983) and Oates et al. (1989, fn4) record cases (concerning aircraft landing noise and urban air pollution, respectively) where these conditions are met, and control by price is economically preferable. In the context of global warming, the choice between carbon taxes and tradeable carbon emission permits may be one where, if effective progress is to be made, using control by price to avoid excessive costs to industry is more important than using control by quantity to achieve precise control over carbon dioxide emissions.

How then can the charge-subsidy idea be added to the menu of instruments considered by policy makers? One way to overcome resistance to the idea may be to change the language used. Kelman's (1981) survey showed that attitudes to effluent

charging are greatly influenced by the choice of particular words, such as 'fees,' 'charges,' or 'taxes.' Clearly, there is also a vast difference in political perception between 'a bribe,' 'a subsidy,' and 'compensation,' even if all three are financially identical; which word many writers have chosen to use can hardly be accidental. However, it is also clear from other policy studies, such as the analysis of the U.S. emissions trading scheme in Hahn (1989, 101), that a fundamental message of economic analysis – that once a resource has become scarce, it needs to be owned, and priced, if it is to avoid becoming even scarcer – is one that many people do not want to hear, particularly when it is applied to the natural environment. The implications of an economic need for the deep oceans and the stratosphere to be 'owned' can indeed be disturbing, both practically and psychologically, and may provoke second thoughts about how far the physical demands of continued economic growth can be allowed to proceed. However, while they do proceed, there is an urgent need to find ways of controlling resource use that are both efficient and acceptable. The delicate task of promoting schemes that contain the necessary elements of subsidy and effluent rights, while trying to avoid direct use of such emotive words, is therefore one that economists should not duck.

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