Inducing investments and regulating externalities by command versus taxes

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Communication

Inducing investments and regulating externalities by command versus taxes

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A linear tax on an externality-generating activity may not attain the first-best social optimum. The problem arises because a monopolist's gain from improving the characteristics of a product may differ from the social gain, even when consumers are willing to pay for the change.

Keywords Regulation, Externalities, Taxes

Many government regulations aim at forcing or inducing firms to make some investment The Energy Policy and Conservation Act of 1975 required firms to increase the fuel efficiency of the cars they produce, which called for investments in tools to produce front wheel drive vehicles, research and development into lighter weight materials and so on The issue of how fuel prices affect the incentives of firms to produce fuel efficient cars is central to the debate about the effectiveness of Corporate Fuel Economy Averages mandated by the Act (see Crandall, 1986, Greene, 1990, and more generally Hassett and Metcalf, 1993) The 1970 Amendments to the Clean Air Act were explicitly technology forcing, calling for 90% reductions in emission by 1975, an unachievable goal with the technology available in 1970 Similarly, electric utilities were required to reduce emissions of sulphur by installing scrubbers

This paper asks whether linear taxes (levied on the externality generated by a consumer) can achieve the first best optimum by inducing consumers to restrict use of a good generating externalities, and inducing firms to produce goods generating little of the externality for a given level of use I shall show that under some conditions of monopoly the answer is no

Government may then want to regulate directly (by command and control) the product a firm produces The question of how effective different types of regulation can be was addressed in a classic article by Weitzman (1974), who shows that when uncertainty about costs is low and the marginal cost curve is flat, then regulation by quantity instead of by price can be optimal [1] My work also builds on the papers by Millman and Prince (1989) and Jung *et al* (1996) who examine the incentives of firms to invest in new technology under different regulatory methods The main differences between our papers are as follows Whereas earlier works examine only a competitive industry, I focus on monopoly The different assumptions matter to the results Earlier works consider a firm which both generates an externality and invests in a new technology I consider consumers whose use of a good generates the externality, but who can use a new technology only if producers have an incentive to produce new goods This latter problem arises in automobile emissions (where producers can install catalytic converters), or in energy use (where producers can manufacture automobiles with higher fuel efficiency) The problem I consider also arises when firms are consumers For example, airline companies may create noise when they fly planes, but the airlines must rely on producers of aeroplanes (such as Boeing and Airbus) to introduce quieter planes Notice that in the examples just presented, the products sold are differentiated so each producer can have market power My examination of monopoly, as an extreme case, can therefore be relevant to regulatory policy

Assumptions

Consider a good used by consumers that generates an externality The level of the externality can be reduced by inducing consumers to make less use of the good and by inducing firms to produce a good which generates less of the externality for any level of use Any tax must therefore affect two variables - intensity of use and investment decisions by firms

To be more specific, I shall consider policy to reduce energy use by cars Sup-

[1] The Weitzman model, however, cannot justify using command and control regulation of fuel efficiency or of automobile emissions The government wanted firms to adopt unproven technology whose costs were highly uncertain (see House Report No 94- 340, Committee on Interstate and Foreign Commerce, on PL-94-163, Energy Policy and Conservation Act of 1975, p 88) Such uncertainty under the Weitzman model would call for regulation by price Instead, the regulations specified technological standards

pose all consumers are identical The number of consumers is n so that the total number of cars is n.[2]

In the absence of taxes, let the private marginal cost of driving be zero The inverse demand curve per driver is $V(x)$, the area under this curve and above the price is consumer surplus Cars can be of two types inefficient, with high energy use (indexed by H) or efficient, with low energy use (indexed by L) A car of type i driven q miles uses $q\lambda_i$ gallons of gasoline Social damage caused by aggregate gasoline use x is $C(x)$ with $C'(x)>0$ and $C''(x) \geq 0$ For simplicity let the intertemporal discount rate be zero and let a car have a fixed life Thus, q and other variables describe quantities for the life of each car

Perfect competition

Though this paper focuses on a monopolized or cartelized industry, for purposes of comparison I shall first discuss a competitive industry Let the marginal cost of producing a car of type i be K_i Government imposes a tax on gasoline But since the two types of cars have different fuel efficiencies, the ratio of the taxes per mile is λ_H/λ_L

Let a fraction f of cars be efficient and a fraction $(1-f)$ be inefficient Social welfare is

$$nf\int_0^{q_L} V(x)\mathrm{d}x + n(1-f)\int_0^{q_H} V(x)\mathrm{d}x$$
$$-C(n(f\lambda_L q_L + (1-f)\lambda_H q_H))$$
$$-n(fK_L + (1-f)K_H)$$

The first order condition for f is that

$$C'\ (\lambda_H q_H - \lambda_L q_L) = \int_0^{q_H} V(x)\mathrm{d}x - \int_0^{q_L} V(x)\mathrm{d}x + K_H - K_L \quad (1)$$

Suppose the gasoline tax per gallon is set at C', where C' is evaluated at its socially optimal level The tax will induce a consumer to choose the value of q_H or of q_L where marginal private benefit ($V'(q_i)$) equals marginal social cost ($C'\lambda_i$)

A consumer will be indifferent between buying an efficient rather than an inefficient car if his consumer surplus is the same Since his tax payment is $C'\lambda_i q_i$, and the cost of a car is K_i, indifferent requires that

$$C'\lambda_H q_H + \int_0^{q_H} V(x)\mathrm{d}x + K_H$$
$$= C'\lambda_L q_L + \int_0^{q_L} V(x)\mathrm{d}x + K_L \quad (2)$$

But then Equations (1) and (2) are identical In other words, a tax can sustain the socially optimal equilibrium in which a fraction, f, of consumers buy efficient cars and in which each driver fully bears the externality of driving

Monopoly

Consider next an industry with only one producer, suppose the investment necessary to produce cars of a particular type is a fixed rather than a variable cost, and that the number of cars sold is set at n Call the fixed cost nK_i Clearly, then, either all or none of the cars produced will be fuel efficient The problem I address thus concerns the quality of a product a monopolist produces[3] It is well known that a monopolist restricts output and thus can generate less of an externality than does a competitive industry The point made here differs I suppose that the monopolist's quantity of output is fixed and so questions of underproduction do not appear

If all consumers are identical and if each consumer purchases one unit of the good, then the monopolist will set a price that extracts all consumer surplus The following analysis makes that assumption Note, however, that the qualitative results derived are not knife-edge results and will apply to more general models, which could allow for heterogeneous consumers, variable purchases and so on

I shall consider the monopolist's problem first graphically and then analytically In Figure 1 a representative consumer's demand curve for travel over the lifetime of a car is Dd All other variables depicted are also per capita The marginal social cost of driving with a fuel efficient car is OL, the corresponding curve for an inefficient car is OH Suppose the socially optimal solution calls for efficient cars The socially optimal level of driving per capita is then q_L, where the marginal social cost curve intersects the demand curve Though government usually imposes a tax on gasoline rather than on mileage, for a given λ_i one tax can be transformed into the other For our purposes it is convenient to analyse a tax per mile A tax of t_L per mile driven on an efficient car will lead drivers to choose q_L

But we must also consider the profitability of producing efficient cars Suppose the monopolist prices cars to extract all consumer surplus Then with efficient

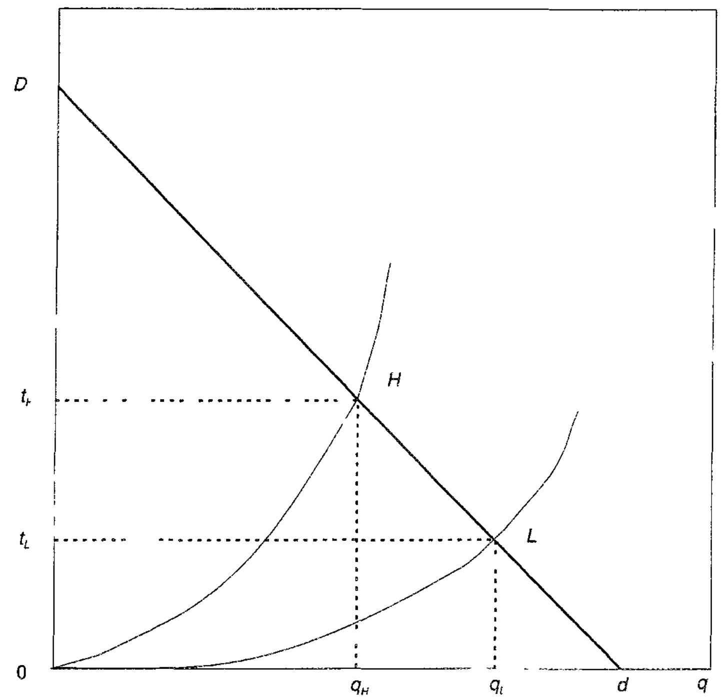

Figure 1 Representative consumer demand curve

[2]For sufficiently high benefit from using a car a socially optimal solution must have this characteristic

[3]For a seminal analysis of such a problem see Spence (1975) who, however, does not consider externalities or taxation Moreover, his results concerning the differences between the social gains and the increased profits arising from a quality improvement require that consumers differ That assumption is unnecessary for my results

cars it can charge a price equal to the area of triangle Dt_LL

What if the firm produced inefficient cars? A tax per mile on an efficient car of t_L is a tax per mile on an inefficient car of $t_H = t_L\lambda_H/\lambda_L$. The maximum price the monopolist could charge for an inefficient car is the area of triangle Dt_HH. Thus, the firm will produce efficient cars if the capital cost per car is less than the area t_HHLt_L. But social optimality imposes a different condition – the firm should produce efficient cars if the cost is less than the area OL_H

The firm may therefore have either too much or too little incentive to produce efficient cars. Indeed, there may exist no linear tax that makes the production of efficient cars profitable. A low tax imposes a low penalty on driving an efficient car, reducing demand for an efficient car. A high tax causes consumers to drive little even with an efficient car, and so again consumers benefit little from buying an efficient rather than inefficient car. Analytic proof is given below

A linear example

For my purposes all the results of interest appear with linear demand and marginal cost curves. Let the marginal social cost per driver when each car is of type i and is driven q_i miles be $\lambda_i q_i$. Let each consumer's demand curve be $q = 1 - mp$, where m is a parameter. Inverting gives the marginal value of travel, $p = (1 - q)/m$

The socially optimal solution for a car of type i has the private marginal cost per mile on a car of type i equal the social marginal cost per mile. Given our demand curve, social optimality requires that $q_i = 1/(m\lambda_i + 1)$. The tax per mile which supports this solution is $t_i \equiv (1 - q_i)/m = \lambda_i/(m\lambda_i + 1)$

Social cost per capita, SC_i, is the capital cost K_i, plus the integral of marginal cost. Define $\hat{SC}_i \equiv SC_i - K_i$. Then

$$\hat{SC}_i = \int_0^{q_i} \lambda_i q\, dq = \frac{\lambda_i}{2(m\lambda_i + 1)^2} \qquad (3)$$

The firm's revenue per car is a consumer's willingness to pay or

$$CS_i \equiv \int_0^{q_i} \frac{1 - q_i}{m} dq - t_i q_i \qquad (4)$$

which simplifies to

$$\frac{1}{2m(m\lambda_i + 1)^2} \qquad (5)$$

Define $\hat{SW}_i \equiv SW_i - K_i$ where SW_i is social welfare per person when each uses a car of type i. Then $\hat{SW}_i \equiv CS_i + q_i t_i - \hat{SC}_i$ or

$$\hat{SW}_i \equiv \frac{1}{2m(m\lambda_i + 1)} \qquad (6)$$

The firm's gain from producing efficient rather than inefficient cars is the difference in consumer's willingness to pay (after taxes) for the two types of cars. We find that

$$CS_L - CS_H = \frac{1}{2m(m\lambda_L + 1)^2} - \frac{1}{2m(m\lambda_H + 1)^2} \qquad (7)$$

Compare this to the social gains from producing efficient rather than inefficient cars. This gain (ignoring investment costs) is

$$\hat{SW}_L - \hat{SW}_H = \frac{1}{2m(m\lambda_L + 1)} - \frac{1}{2m(m\lambda_H + 1)} \qquad (8)$$

The ratio of such social gain to increased revenue is

$$\frac{\hat{SW}_L - \hat{SW}_H}{CS_L - CS_H} = \frac{(m\lambda_H + 1)(m\lambda_L + 1)}{m\lambda_H + m\lambda_L + 2} \qquad (9)$$

As is easily verified, the derivative of this ratio is positive and for sufficiently high values of m the ratio is arbitrarily large [4]. Thus, the reduction in social damage from the use of efficient cars can exceed the increase in the firm's revenue from selling them. If the difference in costs, $n(K_L - K_H)$, is large, then the firm will have insufficient incentive to produce efficient cars

To illustrate the result further, consider a numerical example. Let the demand curve be $q = 1 - 10p$. Let the marginal social cost per driver when each car is fuel efficient and is driven q_L miles be $0.1q_L$. The corresponding marginal social cost for inefficient cars is $0.2q_H$. Applying the previous equations we find that $\hat{SW}_L = 0.025$, $\hat{SW}_H = 0.0167$, $CS_L = 0.0125$ and $CS_H = 0.0056$. Thus (ignoring capital costs) the social gain per car from fuel efficient cars exceeds the firm's added revenue from selling them by 0.0014, which is about 20% of the possible increase in a firm's revenue. That is, the difference between the firm's incentive to invest in fuel efficient cars and the social benefits from the investment can be significant

The previous analysis applies when government charges the socially optimal tax for a given type of car used – that tax may not induce the firm to produce the proper types of car. Government may therefore do better by setting a (second best) tax which differs from marginal social cost. In particular, it can set t_H so high that the firm earns no profits by producing inefficient cars and set t_L sufficiently low so that the firm can charge a price which exceeds K_L

This tax may have to be set lower than the marginal social cost of driving with an efficient car; marginal cost pricing can be suboptimal. Moreover, when the tax differs from marginal social cost, a problem of time inconsistency arises. After the firm makes the investment and produces efficient cars, a benevolent government has an incentive to maximize social welfare by setting a first best tax, equal to marginal social cost and not below it. A firm which recognizes these governmental incentives therefore has insufficient incentive to make the investment government desires

Rather than rely on incentives provided by taxes, government may therefore have to rely on command and control regulations which specify the emissions controls cars must have or which set fuel efficiency standards. Such regulation faces a credibility problem in the initial period – will government follow through on its threat to shut down firms which violate the regulatory standards. But command and control regulation does not face a time inconsistency problem – a benevolent government will want to impose a tax on fuel equal to the marginal social damage it generates and need not worry that such a tax may give insufficient incentive for firm to invest

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