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An Examination of Efficient Policy Instruments Addressing Two Market Distortions

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Abstract

This paper compares the efficiency of two policies (taxation and subsidy) that may be implemented when regulators are uncertain about firms and environmental harm. When firms with pricing power engage in production activities that negatively impact the environment, two market distortions occur (distortions due to external diseconomies and distortions due to pricing power). For distortions caused by external diseconomies, the regulator introduces a tax policy akin to a Pigou tax so that firms reach the socially optimal output. For distortions caused by pricing power, the regulator introduces subsidy policies to reduce production costs to achieve the level of output found in perfect competition. Comparing the expected social welfare when these two policies are implemented reveals the desirable policies and the conditions for their implementation. This paper concludes that, when comparing the slopes of the market demand and marginal harm functions, tax policy is desirable when the slope of the marginal harm function is the greater of the two. On the other hand, even though internalizing externalities is always desirable, subsidy policies are preferable when the slope of the marginal harm is relatively slight.

1. Introduction

Within the framework of basic economic theory, the effects of any economic instrument, such as environmental taxes, emissions trading, subsidies, etc., are equivalent. Environmental policy instruments, such as environmental taxes and emissions trading, have been implemented in countries worldwide as measures to halt global warming. For the effects of environmental policy to be equal, the market must be perfectly competitive, and the regulator must possess complete information about the firms it regulates and about environmental harm. It is difficult, however, for regulators to accurately ascertain the private information possessed by the firms they regulate. Moreover, the ambiguity in the causal relationship between regulated companies and environmental harm makes it extremely difficult to accurately measure the extent of the latter. Thus, regulators' uncertainty about regulated firms and environmental harm indicates that environmental policies such as taxation and quotas are not identical in efficacy. In this regard, Weitzman (1974) presented a theorem that reveals the next best policy instrument under uncertainty. The theorem holds that price regulation (quantity regulation) is an efficient policy if the slope of the marginal abatement cost function is relatively greater (smaller) than the slope of the marginal harm function.

Weitzman (1974) compared the efficiency of price and output regulation; studies that extend that

analysis include Mandell (2008), Heuson (2010), Ambec and Coria (2013), Mansur (2013), and Ma (2020).

Many countries' environmental policies target energy-intensive companies. Firms that can leverage large quantities of energy in their production activities often have a large market share. Such firms have pricing power over the market. When a price-dominant firm in the market engages in production activities that create economic harm, two distortions are created in the market. One of these distortions is due to external diseconomies; the other is pricing power.

This paper compares the efficiency of policies implemented to eliminate the two distortions when uncertainty exists in the market. First, we consider the magnitude of social welfare when regulators introduce taxation policies on firms to eliminate distortions caused by external diseconomies. This taxation policy, which has the characteristics of a Pigou tax, causes firms in its scope to recognize the social cost of optimal output as their own cost. Next, we focus on the magnitude of social welfare when regulators implement subsidy policies for firms to eliminate distortions caused by pricing power. This subsidy policy is implemented to achieve socially sufficient output by firms in its scope, as determined by a perfectly competitive market. European countries and other countries actively involved in environmental conservation have introduced subsidy and tax systems. Note that while these subsidies support efforts to reduce energy consumption and carbon dioxide emissions, the subsidy system examined in this paper differs from a system for promoting a low environmental impact society.

This paper concludes that it is desirable to implement a taxation policy when the slope of the market demand function is steeper than that of the marginal harm function. We further conclude that when the slope of the marginal harm function is relatively slight, implementing a subsidy policy to increase the output of firms that harm the environment is preferable.

2. Model

Assume a market in which only one firm exists. Let us take px=a-bx as the inverse market demand function in this market.

$$p(x) = a - bx$$

Here, x is the output, while a and b are constants ($a, b > 0$). Let

$$C(x, \theta) = \left(\frac{1}{2}x + \theta\right)x$$

be the cost function of the monopolist, where θ represents a continuous random variable. Assuming that this monopoly firm also inflicts harm on the environment through its production activities, the magnitude of the harm can be expressed in the following manner. Note that ε represents a continuous

random variable independent of the continuous random variable θ. Note further that $f(>0)$ is a constant.

$$D(x,\varepsilon)=\left(\frac{f}{2}x+\varepsilon\right)x$$

This market has two distortions: one is due to market monopolization, and the other is due to external diseconomies in the form of environmental damage. In response to these two distortions, a tax policy is implemented in response to the distortion created by pricing power, and a subsidy policy is implemented in response to the distortion caused by external diseconomies, and the social welfare under each of these is compared.

The maximization problem when external diseconomies are considered is $\max_x p(x)x-C(x,\theta)-D(x,\varepsilon)$. Its solution, x^*, is obtained from its first-order condition, that is,

$$x^*=\frac{a-\theta-\varepsilon}{1+2b+f} \tag{1}$$

However, since the regulator is unable to accurately ascertain x^* because of uncertainty, it sets the next best output, $\bar{x}$, by taking an expected value. That output is given as follows:

$$\bar{x}^*=\frac{a}{1+2b+f} \tag{2}$$

3. Taxation and Subsidy Policies

The regulator attempts to lessen the external diseconomies and achieve the next best output, $\bar{x}^*$, through taxation policy.

Since the market is a monopoly, the output is less than in a competitive market. Output x^p in a competitive market that satisfies demand is given by the following equation:

$$x^p=\frac{a-\theta}{1+b} \tag{3}$$

Taking the expected value of this output, we obtain the following:

$$\bar{x}^p=\frac{a}{1+b} \tag{4}$$

The regulator now implements a taxation policy on the firm to correct distortions caused by external diseconomies. For tax rate t, the firm's maximization problem becomes $\max_x p(x)x-C(x,\theta)-tx$. Taking the expected value of that tax as determined by its first-order condition as $\bar{t}$, we obtain $\bar{t}=$

$a-(2b+1)\bar{x}^*$. The firm's maximization problem under tax rate t is $\max_x p(x)x - C(x,\theta) - \bar{t}x$. Its solution, x^t, is obtained from its first-order condition. We thus obtain $x^t = \bar{x}^* - (\theta/2b+1)$.

Let W^t be social welfare under taxation, expressed by $W^t = CS^t + PS^t + T - D$. Here, CS^t is consumer surplus, PS^t is producer surplus, T is tax revenue, and D^t is the magnitude of harm at the time of taxation. CS^t is found by integrating the market demand function $p(x)$ on output between 0 and $x^t$and then subtracting payment $p(x^t)x^t$. Producer surplus can be expressed as the size of income minus expenses and taxes paid. Tax revenue is given by $T = \bar{t}x^t$, while the magnitude of harm is given by $D^t = D(x^t, \varepsilon)$. Taking the expected value of social welfare at the time of taxation, we obtain the following:

$$E[W^t] = a\bar{x}^* - \frac{1}{2}(1+b+f)\bar{x}^{*2} + \frac{(1+3b-f)}{2(2b+1)^2}\sigma_\theta \tag{5}$$

Here, σ_θ denotes the variance of continuous random variable θ.

We next consider the case where the government implements a subsidy policy. The subsidy policy addressed in this paper does not have the character of a Pigouvian subsidy to correct external diseconomies but is a policy to achieve sufficient output for society as determined in a competitive market, as in (4). For subsidy rate s, the firm's profit maximization problem is $\max_x p(x)x - C + sx$. Let $\bar{s}$ be the expected value of the tax rate determined from its first-order condition. Its magnitude is therefore $\bar{s} = E[s] = (2b+1)\bar{x}^p - a$. The firm's maximization problem under subsidy rate s is $\max_x p(x)x - C + \bar{s}x$, the solution to which, x^s, is obtained from its first-order condition. We thus obtain $x^s = \bar{x}^p - (\theta/2b+1)$.

Taking W^s as social welfare at the time the subsidy policy is implemented, we obtain $Ws^{=C}Ss^{+P}Ss^{-S-}Ds^{\cdot}$. CS^s is obtained by subtracting payment $p(x^s)x^s$ from the market demand function $p(x)$ integrated on output from 0 to x^x. Producer surplus can be expressed in terms of the magnitude of income $p(x^s)x^s$ plus costs $C(x^s,\theta)$ and subsidies $\bar{s}x^s$. Subsidy payment is given by $S = \bar{s}x^s$, while the magnitude of harm is given by $D^s = D(x^s, \varepsilon)$. Taking the expected value of social welfare under the subsidy policy, we obtain the following:

$$E[W^s] = a\bar{x}^p - \frac{1}{2}(1+b+f)\bar{x}^{p2} + \frac{(1+3b-f)}{2(2b+1)^2}\sigma_\theta \tag{6}$$

4. Results of Analysis

From Equations (5) and (6), we compare whether the taxation subsidy policy is more appropriate.

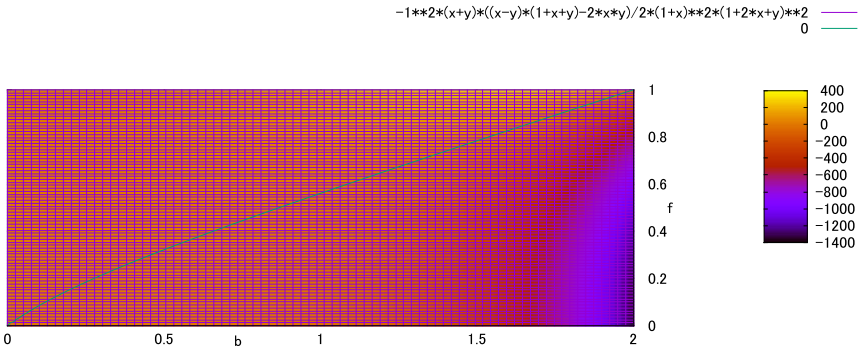
$$E[W^t] - E[W^s] = \frac{-a^2(b+f)\big((b-f)(1+b+f) - 2bf\big)}{2(1+b)^2(1+2b+f)^2} \tag{7}$$

Subsidy policy is preferable when Equation (7) is negative, while taxation policy is preferable when Equation (7) is positive. Considering this condition, we arrive at $E[W^t] > E[W^s]$ when $b \leq f$. From this, we obtain the following theorem:

Theorem: If the slope of the marginal harm function is equal to or steeper than the slope of the market demand function, it is preferable to use a taxation policy.

Suppose the absolute value of the slope of the marginal harm function is comparatively greater than the absolute value of the slope of the market demand function. In that case, taxation policy is the socially optimal policy. Since the implementation of the tax policy means that firms must pay tax corresponding to the magnitude of the harm they cause, firms that continue to cause significant environmental harm will eventually be forced to exit the market. Because firms will have to pay taxes on the damage they cause once the taxation policy is implemented, firms that continue to impose a significant burden on the environment will eventually be forced to exit the market.
The figure below shows a 3D graph of Equation (7) where $a = 1$, viewed from directly above. The line in the figure represents the coordinates of b and f where $E[W^t] - E[W^s] = 0$.

Figure 1: Comparison of expected social welfare



Depending on the possible values of b and f, subsidy policy is efficient where $E[W^t] - E[W^s] < 0$, i.e., $E[W^t] < E[W^s]$. As seen from Figure 1, Equation (7) is negative for large values of b and small values of f. In other words, a subsidy policy is socially preferable when the slope of the market demand function is steep and the slope of the marginal damage function is moderate. This leads to the conclusion that policies that correct externalities, such as environmental policies, should not necessarily be prioritized in policy implementation.

5. Conclusion

This paper examines policy efficiency when regulators are uncertain about firms' cost functions and environmental harm. The firms assumed in this paper possess pricing power and cause environmental harm through their production activities. In this situation, the market experiences two distortions simultaneously: one caused by external diseconomies, the other by pricing power. In response to the first distortion, a Pigou tax was implemented to internalize the externality. For the latter distortion, a subsidy policy was implemented to achieve a perfectly competitive level of output that satisfies demand.

In conclusion, if the slope of the marginal harm function is equal to or steeper than the slope of the market demand function, a taxation policy should be chosen. However, if the slope of the marginal damage function is moderate, a subsidy policy should be selected. Detailed conditions for implementing an efficient subsidy policy are a topic for future examination.

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