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Negative Externality and Appropriate Government Intervention with Uncertainty in Monopoly Market

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1. Introduction

When a monopolist entity engages in production activities that damage the environment, two factors hinder the efficiency of resource allocation: external diseconomies and pricing power. Buchanan (1969) and Barnett (1980) are representative studies that analyze cases in the market where these two factors occur.

External diseconomies are when the actions of one economic agent adversely affect the utility or profit of another economic agent without passing through the market. For example, production activities by pollution-emitting firms generate social losses and health hazards. These losses are not incorporated into the profit maximization problem of the firms concerned. Therefore, the market-determined output is excessive compared to the socially optimal level. If environmental damage increases as production increases, then overproduction contributes to environmental degradation.

Interest and concern regarding environmental issues are at an all-time high, and the support for implementing environmental policies is increasing. These include economic instruments that impose taxes or subsidies on pollution emitters. The objective of the economic approach is to incorporate external diseconomies into the market mechanism to correct overproduction. It is well known that when external diseconomies occur, optimal output is achieved through the use of Pigouvian taxes and subsidies.

If a firm has pricing power, it attempts to raise prices and earn higher profits by reducing output. As a result, the market-determined output is lower than it would be in a perfectly competitive market. The higher prices caused by underproduction lead to a decrease in consumer surplus, but if policies can be implemented to increase output to the level of a perfectly competitive market, it is possible to increase consumer surplus and reduce the dead-weight loss.

In this study, we assume a market in which a firm with pricing power generates external diseconomies. The external diseconomies cause overproduction, while pricing power causes underproduction.

Under a perfectly competitive market, the government could adjust the output level a socially optimal one by introducing a Pigouvian tax or Pigouvian subsidy. However, in imperfectly competitive markets, the output level that maximizes firms' profits is smaller than the socially optimal level. Therefore, the introduction of a taxation policy in an imperfectly competitive market will further reduce the output level and cause it to deviate from the socially optimal level. On the other hand, the subsidy policy works by increasing

output from the firm's chosen output level to the socially optimal level. Note that the subsidy policy in this paper is designed to increase output and differs from Pigouvian subsidies in perfectly competitive markets. In other words, the introduction of taxation and subsidy policies in imperfectly competitive markets has the property of working in opposing directions around firm-determined output levels.

In monopoly markets with external diseconomies, the effects of the two distortions on output are diametrically opposed. In such cases, Buchanan (1969) showed that implementing Pigou taxation increases efficiency but decreases social welfare; Barnett (1980) extended Buchanan's work (1969); and Buchanan (1969) showed that the effect of the tax on output is the same in both cases. In a recent related study, Martin-Herràn and Rubio (2018) analyze optimal environmental policy assuming a monopolistic market.

In order for the government to make efficient policies, the government needs to know precisely the production costs of firms and the environmental damage caused by firms. However, it is extremely difficult for governments to accurately capture production costs and environmental damage. Therefore, this study analyzes a model in which the government is uncertain about firms' production costs and environmental damages in a monopoly market with external diseconomies.

The most famous work on uncertainty is by Weitzman (1974), and its applications are numerous. For example, Mandell (2008) successfully adds to Weitzman's theorem the condition under which the policy mix is chosen. Ambec and Coria (2013) also considered the nature of pollutants and showed that the policy chosen depends on whether multiple pollutants are complementary or alternative. Miyamoto (2014) examined the policy mix using a lobbying model, and Shinkuma and Sugata (2016) constructed a long-term model that takes into account the entry of new firms and identified the conditions under which taxation policies and emissions trading become dominant. Extensions of Weitzman (1974) that assume firms have pricing power include Heuson (2010), Kato (2011), Mansur (2013), Basso, Figueroa and Vásquez (2017), and Wang, Hao and Wang (2023)

Theoretical tests of policy efficiency often compare the effects of environmental taxes, environmental subsidies, and direct regulation, as seen in the above studies. Environmental taxes have already been introduced in many countries around the world, including France, Sweden, and Japan. Taxing greenhouse gases generated by production activities would theoretically lower production after the tax. When considering subsidy policies in comparison to the effects of environmental taxes, subsidy policies are also often aimed at environmental protection.

In the next section, I will describe a model that works on three assumptions: first, it is a monopolistic market; second, monopolist causes environmental damage through their

production activities; and third, the government has two types of uncertainty (about the monopolistic firms' production costs and uncertainty about environmental damage).
Using a very simple monopoly market model, this study identifies how best to increase social welfare, whether through taxation policies to internalize externalities, subsidy policies to achieve a socially optimal level of production, or policies in which the government should not intervene.
In conclusion, taxation policies are efficient when marginal damages are large, and subsidy policies are efficient when marginal damages are small. When marginal damages are moderate, the government should not intervene to raise the expected social welfare.

2. The model

Consider a monopolistic market with only one firm. Let the inverse demand function of the market be $p(x) = a - bx$ Let p denotes the price and x denotes the monopolist's output level. Let a, b is a constant $(a, b > 0)$. The production cost of the monopolist is $C(X, \theta) = (c + \theta)x$ and c is constant and takes a value smaller than a $(a > c > 0)$. The government has uncertainty about the cost of this firm. Let θ denotes this uncertainty. θ is a continuous stochastic variable whose expected value is zero $(E[\theta] = 0)$.

In addition, the monopolist cause damage to the environment in the process of producing goods, causing a decline in social welfare. This damage is denoted as $D = (\lambda + \varepsilon)x$. λ denotes the marginal damage $(\lambda > 0)$. The government is also uncertain about the pollution damage. This uncertainty is indicated by ε is a continuous stochastic variable whose expected value is zero $(E[\varepsilon] = 0)$. The two continuous stochastic variables θ, ε are independent of each other.

Let us assume that social welfare W is obtained by subtracting damage D from the sum of consumer surplus $CS = \int_0^x p(x)dx - p(x)x$ and producer surplus $PS = p(x)x - C(x, \theta)$. The output $x = x^*$ that maximizes social welfare W satisfies the first-order condition $p(x) = \frac{d}{dx}C(x, \theta) + \frac{d}{dx}D(x, \varepsilon)$. The right-hand side of this equation is the sum of marginal cost and marginal damage, which is called the social marginal cost. In other words, the optimal output that maximizes social welfare x^* is the output at which price and social marginal cost are equal. However, the government cannot correctly know the optimal output x^* because social marginal cost involves uncertainty. Therefore, the government takes $E[x^*] = \bar{x}^*$, the expected value of x^*, as the second best output (See Table 1).

The monopolist chooses the output x^0 that will maximize its own profit. The government will choose the quantity of output that maximizes its profit. x^0 The government can observe the expected value of x^0 and that is zero ($E[x^0] = \bar{x}^0$) (see Table 1).

The government either imposes a taxation policy based on the expected value of marginal damages to maximize social welfare W or a subsidy policy to increase output to achieve optimal output. In the case of a taxation policy, let the government fix a tax rate equal to the expected value of marginal damage. That is, $t = \lambda$. The profit maximization problem for the monopolist is then $\max_x p(x)x - C(x,\theta) - tx$. Let x^t be the output obtained by solving this problem (See Table 1). On the other hand, in the case of a subsidy policy, the government gives the monopolist a subsidy of s per unit if it increases its output from $\bar{x}^0$. The maximization problem then becomes $\max_x p(x)x - C(x,\theta) + s(x - x^0)$, so if there exists an optimal solution x^s in the range $\bar{x}^0 < x$, then the first-order condition is $p(x) + p'(x)x = C'(x^s) - s$. Therefore, the government sets the expected value of the subsidy rate to be equal to the difference between the expected marginal cost and marginal revenue under the expected value of optimal output $\bar{x}^*$. Thus, the expected value of the subsidy rate s is $s = a - c - 2\lambda$, and the optimal subsidy rate is $s^* = max\{0, a - c - 2\lambda\}$.

Table 1. Output level and its expected value

	True value	expected value
Optimum production	$x^* = \frac{a - c - \lambda - \theta - \varepsilon}{b}$	$\bar{x}^* = \frac{a - c - \lambda}{b}$
Non-intervention	$x^0 = \frac{a - c - \theta}{2b}$	$\bar{x}^0 = \frac{a - c}{2b}$
taxation policy	$x^t = \frac{a - c - \lambda - \theta - \varepsilon}{2b}$	$\bar{x}^t = \frac{a - c - \lambda}{2b}$
subsidy policy	$x^s = \frac{2(a - c - \lambda) - \theta}{2b}$	$\bar{x}^s = \bar{x}^*$

Comparing the expected values of output, $\bar{x}^t < \bar{x}^*$ and $\bar{x}^t < \bar{x}^0$. The expected value of optimal output (and the output of the subsidy policy) $\bar{x}^*$, and the expected value of output without government intervention $\bar{x}^0$, vary with the expected value of the slope of the marginal damage function λ. Let λ^* be the expected value of the slope of the marginal

damage function such that $\bar{x}^* = \bar{x}^0$, then $\lambda^* = \frac{a-c}{2}$. If the expected value of the slope of the marginal damage function is small, i.e., $\lambda < \lambda^*$, then $\bar{x}^t < \bar{x}^0 < \bar{x}^*$. On the other hand, if the expected value of the slope of the marginal damage function is large, i.e., $\lambda^* < \lambda$, then $\bar{x}^t < \bar{x}^* < \bar{x}^0$.

3. Expected Social Welfare

I now identify the behaviour of government under which it behaves in such a way that the expected social welfare is greatest. First, social welfare in the taxation policy W^T is obtained by substituting $W = CS + PS - D$ into the equation $x = x^t$. Taking expectation,

$$E[W^T] = \frac{3(a-c)^2}{8b} - \frac{3\lambda(2(a-c)-\lambda)}{8b} + \frac{3}{8b}\sigma_\theta + \frac{3}{8b}\sigma_\varepsilon \quad (1)$$

σ_θ is the variance of θ and σ_ε is the variance of ε. Similarly, the expected social welfare under the subsidy policy is by using $x = x^s$ as follows:

$$E[W^S] = \frac{(a-c-\lambda)^2}{2b} + \frac{3}{8b}\sigma_\theta \quad (2)$$

The expected social welfare in the case of government non-intervention $E[W^0]$ is obtained using $x = x^0$ as follows:

$$E[W^0] = \frac{3(a-c)^2}{8b} - \frac{4\lambda(a-c)}{8b} + \frac{3}{8b}\sigma_\theta \quad (3)$$

First, we compare the efficiency of subsidy and taxation policies. From equations (1) and (2), $E[W^0] - E[W^T] = \frac{\lambda(2(a-c)-3\lambda)-3\sigma_\varepsilon}{8b}$, which can be solved for λ to obtain $\lambda = (a-c) \pm \sqrt{3}\varepsilon$. By taking expectation of the slope of the marginal damage function, we obtain $E[W^S] > E[W^T]$ (but only if $\lambda < \frac{a-c}{2}$).

Next, I compare the expected social welfare under the taxation policy and the government non-intervention. Using equations (1) and (3), I obtain $E[W^0] - E[W^T] = \frac{\lambda(2(a-c)-3\lambda)-3\sigma_\varepsilon}{8b}$. Solving for λ and taking expectation, I obtain $E[W^T] < E[W^0]$ when $0 < \lambda < \frac{2(a-c)}{3}$ and $E[W^0] < E[W^T]$ when $\frac{2(a-c)}{3} < \lambda$.

Finally, using equations (2) and (3), I compare the expected social welfare under the

subsidy policy and the government non-intervention. I obtain $E[W^0] < E[W^S]$ since $E[W^S] - E[W^0] = \frac{(a-c-\lambda)^2}{8b}$ (but only if $\lambda < \frac{a-c}{2}$). From the previous analysis, we obtain the following proposition.

Proposition

If the expected the slope of the marginal damage function is $\lambda < \frac{a-c}{2}$*, then a subsidy policy is efficient, and if* $\frac{2(a-c)}{3} < \lambda$*, then a taxation policy is efficient. In the range* $\frac{a-c}{2} \leq \lambda \leq \frac{2}{3}(a-c)$*, the expected social welfare is greatest when the government does not intervene in the market.*

If the environmental damage caused by monopolies is minor, the government is better off increasing consumer and producer surplus by satisfying market demand rather than by protecting the environment. On the other hand, if a monopolist is causing significant damage to the environment, the government should reduce the negative factor of environmental damage by reducing production, even if it reduces the positive factors in social welfare, such as consumer surplus and producer surplus. However, when the environmental damage caused by a monopolist is neither small nor large, the government's non-intervention in the market can enhance social welfare. In other words, we show that controlling output through policy and idly changing the positive and negative factors in social welfare will result in smaller social welfare.

4. Conclusion

In a market where the government is uncertain about the monopolist's costs and environmental damages, and where there are two distortions, externality and price dominance, the expected value of the slope of the marginal damage function determines the efficient means of intervention. First, if the expected value of the slope of the marginal damage function is small, the subsidy policy is efficient. This means that if the environmental damage caused by the monopolist is small, it is desirable to raise the output to the socially optimal level and increase consumer and producer surpluses. On the other hand, if the expected value of the slope of the marginal damage function is large, a taxation policy is efficient. In this case, increasing production through subsidies would cause severe environmental damage, so it is preferable to reduce production through

taxation to reduce the burden on the environment. It should be noted that when the expected value of the slope of the marginal damage function is moderate, it is more efficient for the government not to intervene in the market. It is well known that in the presence of externalities or price dominance, appropriate government intervention can increase the efficiency of the market. However, when both distortions exist at the same time, it is clear that there are alternatives in which the government's non-intervention can actually increase efficiency.

6. References

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