INSTRUMENT CHOICE FOR ENVIRONMENTAL TECHNOLOGY LICENSING: STANDARDS VS. TRADEABLE PERMITS

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Abstract- In this paper, we examine the relationship between the choice of regulatory instruments and environmental technology licensing. We analyze and compare firms' licensing behavior under two commonly used regulatory instruments: standards and tradeable permits. Given that the instruments emit the same amount of emissions, we find that in the intra-licensing scheme, the standards instrument is unambiguously superior to the emission-trading in providing more incentives for the licensor to participate in the licensing transaction. This implies that to better promote the spillover of pollution abatement technology, the standards instrument may be more appropriate.

I. INTRODUCTION

Global warming is no doubt the most severe problem in the first twenty first century. In order to internalize environmental externalities such as the greenhouse gas emission, policymakers apply instrumentsto regulate pollution emitters. The most common-used regulatory instruments include environmental taxes, standards, and emission trading. On top of regulation, policymakers often hope to speed up the spillover of pollution abatement technology. One of the effective ways in the acceleration of abatement technology is through licensing. The purpose of this paper is to explore which regulatory instrument can provide more incentives for competitive firms to participate in the abatement technology transaction.

The choice of environmental regulatory instruments has been an important issue in the field of environmental economics. It is well known that the command-and-control instrument has its advantages in flexibility; even though it is less efficient for its violation in the equi-marginal cost principle (Kolstad, 2000). In the review of relevant studies, Reguate (2005) concludes that the ranking of regulatory instruments depends on several factors including whether firms are investing in R&D, the timing of the government's commitment, the convexity of pollution damage function, and the degree of imperfection in the product market.

Interestingly, current studies in the ranking of regulatory instruments have not taken the transfer of abatement technology into account. When firms are considering whether or not to participate in a technology licensing transaction, they are regulated under a regulatory instrument. This means that firms' licensing consideration is dependent on the government's choice of regulatory instrument. Policymakers need to find out the impact of a regulatory instrument on firms' licensing behavior to better promote the spillover of abatement technology transfer through licensing, The purpose of this paper is to examine the relationship between the choice of regulatory instruments and environmental technology licensing. Based on our analytical framework, we find that the emission standards instrument is unambiguously superior to the tradeable permits as it provides more incentives for the licensor to participate in the licensing transaction. This result is due to the reason that the command-and-control mechanism violates the equi-marginal cost principle; the research firm (licensor) can gain more profits from the licensing transaction. In contrast, the tradeable permits instrument is efficient itself before firms participating in licensing. The less-efficient firm (firm 2) does not need to abate emission too much; it can purchase permits from the permit market. Therefore, for firm 2, the profit is higher under the tradeable permits instrument when firms engage in the licensing transaction.

The rest of the paper is organized as follows. Next section provides the model. Section 3 analyzes the profits of firms under each regulatory instrument. Section 4 compares firms' profits and social welfare in these two regulatory instruments. Section 5 concludes.

II. THE MODEL

We consider a duopoly market where its firms produce a homogenous good and engage in a Cournot competition. Denote q_i as the quantity of the good produced by firm $i (i = 1, 2)$. Let $P = a - Q$ be the (inverse) market demand, where P is the market price, a is a positive parameter representing the consumers' highest willingness to pay, and $Q (= q_1 + q_2)$ is the total quantities produced by the firms.

For simplicity, suppose that firms' production incurs no private costs. Firm's production generates pollution in which one output causes one unit of emission. To deal with this negative externality problem, the government sets two regulatory instruments to regulate firms: emission standards and emission-trading, denoting as "C" and "M".Let e_i be the actual amount of emission emitted by firm *i*. In the standards instrument, each firm is regulated by $e_1 = e_2 = \bar{e}$. In the emission-trading system, each firm is allocated by $e_1 = e_2 = \bar{e}$ permits and each emission requires a permit. This means that the total emission under these two regulatory instruments are the same as $e_1 + e_2 \equiv 2\bar{e}$.

Firms can invest in end-of-pipe pollution abatement technologies to reduce emission; each firm's amount of emission abatement is $q_i - e_i$. We assume that the abatement technology of firm 1 is superior to firm 2's, and the marginal abatement cost of firm 1 is k times cheaper than firm 2. Before firms engaging in licensing, firm 2's total abatement cost is $(q_2 - e_2)^2/2$ and firm 1's total abatement cost is $k(q_1 - e_1)^2/2$, where $0 < k < 1$.After firms participate in licensing and firm 2 pays a lump-sum licensing fee F to obtain firm 1's superior abatement technology, its total abatement cost reduces to $k(q_2 - e_2)^2/2$. Given the above setting, we compare the profits under each regulatory instrument. To ensure a meaningful answerfor the model, we assume $a > 6\bar{e}$ holds.

III. LICENSING DECISIONS

In this section, we provide in the subsections 3.1 and 3.2 for firms' licensing behaviour analysis in the standards and tradeable permits, respectively. In each subsection, the model consists of a two-stage game. In the first stage, firm 1 decides whether or not to license its abatement technology to firm 2. In the second stage, firms decide their outputs and abatement decisions. We apply backward induction to find out the subgame-perfect Nash equilibrium.

3.1 Emission Standards

We first discuss firms' licensing decisions under the command and control regulatory instrument. Each firm is required to satisfy the emission constraint $e_1 = e_2 = \bar{e}$. Denote the superscripts "*NC*" and "*LC*" as the non-licensing and licensing schemes in the emission standard instrument, respectively.

Note that each firm is subject to the same amount of emission $\bar{e}$, this implies that each firm*i*'s needs to abate $q_i - \bar{e}$ amount of emission. The profits of firms in the non-licensing scheme can be represented as:

$$\pi_1^{NC} = (a - q_1 - q_2)q_1 - \tfrac{k}{2}(q_1 - \bar{e})^2, \pi_2^{NC} = (a - q_1 - q_2)q_2 - \tfrac{1}{2}(q_2 - \bar{e})^2.$$

The outputs and profits of firms are

$$q_1 = \frac{2a - (1-3k)\bar{e}}{3k+5}, \quad q_2 = \frac{(1+k)a + 2\bar{e}}{3k+5},$$

$$\pi_1^{NC} = \frac{1}{(3k+5)^2}[4a^2 - 4\bar{e}a + \bar{e}^2 + k(2a^2 + 10\bar{e}a - 18\bar{e}^2) + k^2(6\bar{e}a - 9\bar{e}^2)],$$

$$\pi_2^{NC} = \frac{1}{2(3k+5)^2}[3a^2 + 12\bar{e}a - 13\bar{e}^2 + k(6a^2 + 12\bar{e}a - 30\bar{e}^2) + k^2(3a^2 - 9\bar{e}^2)].$$

In the licensing scheme, the profit functions of firms become:

$$\pi_1^{LC} = (a - q_1 - q_2)q_1 - \tfrac{k}{2}(q_1 - \bar{e})^2 + F \quad \text{and} \quad \pi_2^{LC} = (a - q_1 - q_2)q_2 - \tfrac{k}{2}(q_2 - \bar{e})^2 - F. \qquad (1)$$

The outputs of firms in the licensing scheme are $q_1 = q_2 = (a + \bar{e}k)/(k+3)$. The highest willingness to pay for firm 2 to purchase the abatement technology is

$$F^C = \pi_2^{LC} - \pi_2^{NC}$$

$$= \frac{1-k}{2(3k^2 + 14k + 15)^2}[23a^2 - 108a\bar{e} + 117\bar{e}^2 + k(36a^2 - 188a\bar{e} + 240\bar{e}^2) + (2)$$

$$k^2(18a^2 \quad 102a\bar{e} \quad 144\bar{e}^2) \quad k^3(3a^2 \quad 18a\bar{e} \quad 27\bar{e}^2)]$$

In equilibrium, the profits of firms are

$$\pi_1^{LC} = \frac{1}{2(k+3)^2(3k+5)^2}[(73a^2 - 108ae + 117e^2) + k(98a^2 + 20ae - 102e^2) \qquad (3)$$

$$+k^2(30a^2 + 256a\bar{e} - 466\bar{e}^2) - k^3(6a^2 - 180a\bar{e} + 318\bar{e}^2) - k^4(3a^2 - 36a\bar{e} + 63\bar{e}^2)]$$

$$\pi_2^{LC} = \frac{1}{2(3k-5)^2}[(3a^2 + 12a\bar{e} - 13\bar{e}^2) + k(6a^2 + 12a\bar{e} - 30\bar{e}^2) + k^2(3a^2 - 9\bar{e}^2)]. \qquad (4)$$

3.2 Emission-trading System

Next, we discuss firms' licensing behavior under the tradeable permits instrument. Denote *"NM"* and *"LM"* as the non-licensing and licensing schemes in the tradeable permits system, respectively. Based on the previous setting, the profit functions of firms are

$$\pi_1^{NM} - (a - q_1 - q_2)q_1 - \tfrac{k}{2}(q_1 - e_1)^2 - u(e_1 - l_1) \text{ and}$$

$$\pi_2^{LM} = (a - q_1 - q_2)q_2 - \tfrac{1}{2}(q_2 - e_2)^2 - u(e_2 - l_2).$$

Note that $\mu$is the price of each emission permit, e_i is firm i's actual emission, and l_i is firm i's permit received by the government with $l_1 + l_2 = e_1 + e_2 = 2\bar{e}$. As firm 1's abatement technology is more efficient, one can expect that firm 1 is the supplier and firm 2 is the demander in the permit market given $l_1 = l_2 = \bar{e}$.

The firms' outputs, actual emissions and equilibrium permit pricein the non-licensing scheme are

$$q_1 = \frac{a + 2k\bar{e} + ak}{5k+3}, \quad q_2 = \frac{a + 2k\bar{e} + ak}{5k+3}, \quad e_1 = \frac{6\bar{e} - a + 2k\bar{e} + ak}{5k+3}, \quad e_2 = \frac{a + 8k\bar{e} - ak}{5k+3}, \text{ and}$$

$$u^{NP} = \frac{2k(a - 3\bar{e})}{5k+3}.$$ [1]

Suppose the government issues the same amount of permits to each firm, i.e., $l_1 = l_2 = \bar{e}$. This implies that the transaction of permit between firms is $l_1 - e_1 = e_2 - l_2 =$ $[(a - 3\bar{e})(1-k)]/(5k+3) > 0$ as $0 < k < 1$. In equilibrium, the profits of firms are

$$\pi_1^{NM} = \frac{1}{(5k+3)^2}[a^2 + k(4a^2 - 2a\bar{e}) + k^2(a^2 + 14a\bar{e} - 26\bar{e}^2)],$$

$$\pi_2^{NM} = \frac{1}{(5k+3)^2}[a^2 + k(2a^2 + 10a\bar{e} - 18\bar{e}^2) + k^2(3a^2 + 2a\bar{e} - 8\bar{e}^2)].$$

In the licensing scheme, firm 2 uses the same pollution abatement technology as firm 1. One can expect that the permit market will disappear as firms' output and abatement decisions are identical. Each firm will achieve the same amount of actual emission $e_1 = e_2 = \bar{e}$ .Nevertheless, firm 2 still needs to pay a licensing fee F. The profit functions of firms are the same in (1).

$\pi_1^{LM} = (a - q_1 - q_2)q_1 - \frac{k}{2}(q_1 - e)^2 + F$ and $\pi_2^{LM} = (a - q_1 - q_2)q_2 - \frac{k}{2}(q_2 - e)^2 - F$.

The output of firms is $q_1 = q_2 = (a + \bar{e}k)/(k+3)$ .Based on $F = \pi_2^{LM} - \pi_2^{NM}$, the highest willingness to pay for firm 2 is

$$F^L = \frac{k(1-k)}{2(k+3)^2(5k+3)^2}[(21a^2 - 144a\bar{e} + 243\bar{e}^2) + k(21a^2 - 162a\bar{e} + 297\bar{e}^2) + k^2(6a^2 - 46a\bar{e} + 84\bar{e}^2)] \quad (5)$$

Each firm's profit is

$$\pi_1^{LM} = \frac{1}{(k+3)^2(5k+3)^2}[9a^2 + k(45a^2 - 54a\bar{e} + 81\bar{e}^2) + k^2(40a^2 + 60a\bar{e} - 126\bar{e}^2) + k^3(5a^2 + 138a\bar{e} - 279\bar{e}^2) - k^4(3a^2 - 48a\bar{e} + 92\bar{e}^2)] \quad (6)$$

$$\pi_2^{LM} = \frac{1}{(5k+3)^2}[a^2 + k(2a^2 + 10a\bar{e} - 18\bar{e}^2) + k^2(3a^2 + 2a\bar{e} - 8\bar{e}^2)]. \quad (7)$$

IV. COMPARISON

To compare firms' incentives to participate in licensing, we compare firms' profits under these two regulatory instruments. One can tell from (3) and (6) that the value of π_1^{LC} and π_1^{LM} depends on the degree of technology difference between firms, which is represented by k. Recall that $0 < k < 1$. We can first evaluate the profit of firm 1 (the licensor) in an extreme value of k.

$$\pi_1^{LC}\big|_{k\to 0} = \frac{73a^2 - 108a\bar{e} + 117\bar{e}^2}{450}, \quad \pi_1^{LM}\big|_{k\to 0} = \frac{a^2}{9}$$

$$\pi_1^{LC}\big|_{k\to 1} = \frac{24a^2 + 23a\bar{e} - 104\bar{e}^2}{256}, \quad \pi_1^{LM}\big|_{k\to 1} = \frac{24a^2 + 23a\bar{e} - 104\bar{e}^2}{256}$$

Given the assumption $a > 6\bar{e}$, one can find that when the technology difference between the firms is extremely large, i.e., $k \to 0$, we have $\pi_1^{LC} - \pi_1^{LM} > 0$. If the abatement technology difference between the firms is negligence, i.e., $k \to 1$, we have $\pi_1^{LC} = \pi_1^{LM}$. These results imply that in comparison to the tradeable permits system, the licensor obtains higher profit in the emission standard mechanism.

Now, we examine the licensee's profit under these two regulatory instruments.

$$\pi_2^{LC}\big|_{k\to 0}=\frac{27a^2+108a\overline{e}-117\overline{e}^2}{450},\quad \pi_2^{LM}\big|_{k\to 0}=\frac{a^2}{9},\quad \pi_2^{LC}\big|_{k\to 1}=\frac{3a^2+6a\overline{e}-13\overline{e}^2}{32},$$

$$\pi_2^{LM}\big|_{k\to 1}=\frac{3a^2+6a\overline{e}-13\overline{e}^2}{32}.$$

From the licensee's point of view, the results are the opposite. When $k\to 0$, one can obtain that $\pi_2^{LC}-\pi_2^{LM}<0$. When $k\to 1$, $\pi_2^{LC}=\pi_2^{LM}$. We summarize our analysis in the following proposition.

Proposition 1 *In the lump-sum licensing scheme, the command-and-control is superior to the emission-trading regulatory instrument in providing more incentives for the licensor to participate in the licensing transaction.*

CONCLUDING REMARKS

In this paper, we use a simple model to examine which environmental regulatory instrument provides more incentives for firms to participate in an abatement technology licensing. We find that in comparison to the tradeable permits instrument, the licensor is better off if the policymakers apply the emission standards instrument. This result is derived based on the lump-sum licensing fee structure. An interesting extension is to expand our analytical model to the loyalty licensing fee structure.

REFERENCES

[1] Kolstad, C., (2000), Environmental Economics, Oxford University Press.

[2] Requate, T. (2005), "Dynamic Incentives by Environmental Policy Instruments—a Survey," Ecological Economics, 54, 175-195.

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