Playing Dirty or Going Clean? Lobbying, Abatement and Firm Heterogeneity

Souvik Datta*

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Abstract

In this paper I use firm-level characteristics to make predictions about the lobbying and abatement decision of firms in a model with two non-cooperating firms. There are three sources of firm heterogeneity, viz. the marginal cost of production, the emission intensity and the marginal cost factor of abatement. The decision to lobby or abate or do both depends on the cost-effectiveness of lobbying against that of abating. I find that a firm will abate and not lobby if its effective marginal abatement cost, which depends on output, is lower than a threshold value. An interesting outcome is that, under my assumption of perfect and complete information, the model predicts that in most cases the firm with the lower effective marginal abatement cost will not lobby but will free-ride on the lobbying effort of the other firm.

Keywords: Lobbying; Abatement; Emission standard; Firm-level heterogeneity.

JEL Classification Codes: D72, H7, Q5.

1 Introduction

Political lobbying is an integral part of the political scene. For example, in the US, campaign contributions for candidates running for elections sees millions of dollars being spent, especially during the Presidential race. Apart from these contributions, firms and other organizations hire lobbying firms in Washington, DC to lobby the government on various issues. Annual lobbying

*PhD Candidate, Department of Economics, University of British Columbia, 997–1873 East Mall, Vancouver, BC, V6T 1Z1, Canada. <souvik@interchange.ubc.ca>

on energy and natural resources issues have been steadily increasing over the years and reached a high of over $400 million in 2009.[1] While the amounts spent on specific issues are, to the best of my knowledge, not currently available we may assume that the lobbying amount was spent on gaining favours from the politicans on environmental policy and lobby against the environmentalists. However, there is also some evidence presented by Maxwell et al. (2000) that shows a sharp reduction in the amount of toxic emissions in seven main industries in the United States over the period 1988-1992 while the dollar value of shipments has increased. These are legal emissions and the reduction cannot be attributed to government regulations. This points to a role of corporate environmentalism that has become more prominent as environmental issues are being thrust more into the limelight. The most often-cited example in the literature on corporate environmentalism is the one taken up by 3M. 3M set up the Pollution Prevention Pays (3P) program in 1975 and the first year of results from 19 projects led to a reduction of 73,000 tonnes of air emissions and 2,800 tonnes of sludge.[2]

These observations form the motivation behind this paper. Are we able to make predictions about the lobbying or abatement decision of a firm by using some basic characteristics of the firm? I use three sources of firm heterogeneity in a set-up that includes two non-cooperative firms in the analysis. The three sources of heterogeneity are the marginal cost of production, the (unabated) emission intensity and their marginal cost of abatement. Using this simple model I can make some testable predictions about the decision of a firm to lobby or abate or do both. There are many possible combinations using the three sources of heterogeneity (see Table 1) but I will focus on the ones that are interesting in the main paper and leave the derivation of the rest to the appendix. The results of all the possible outcomes are also presented in Table 2 and Table 3.

There is a lot of anecdotal evidence of industry lobbying influencing environmental regulations and there have been studies such as Ando (1999) and Cropper et al. (1992) that have found such evidence in government regulatory agencies. While it may seem fairly obvious to see why firms may want to lobby there are various reasons for firms to decide on voluntarily abating their emissions. Firms might reduce emissions as purely a cost-saving measure. For example, in 2008,

[1]Center for Responsive Politics, http://www.opensecrets.org/industries/indus.php?ind=E
[2]http://solutions.3m.com/wps/portal/3M/en_US/global/sustainability/s/milestones/

3P prevented more than 122 million pounds of pollution and saved nearly \$91 million.[3] The growth of green consumerism has also been cited as a reason for the environmental consciousness of firms. Arora and Cason (1996) and Khanna and Damon (1999) find evidence of firm participation in the 33/50 program being influenced by the amount of contact their final goods have with consumers. There may also be pressure from investors, lobby groups, residents in the neighbourhood and employees who may all be affected by the pollution emitted by facilities. Evidence exists of investors having used the Toxics Release Inventory (TRI) data in the US to pressurize firms to reduce emissions (Hamilton, 1995; Konar and Cohen, 1997; Khanna et al., 1998). The effect of regulatory pressure on firms' emissions has also been considered by Khanna and Damon (1999), Videras and Alberini (2000) and Antweiler (2003).

The results of this paper are obtained using a simple model with only two firms. However, there are several sources of heterogeneity and the various combinations of these firm-level characteristics contribute to the richness of the model. The firms behave noncooperatively and there is perfect and complete information. It is as a consequence of these features that one firm ends up free-riding on the lobbying activity of the other firm. One crucial assumption I make throughout this analysis is the constancy of output. Once the firms make an output decision based on their marginal cost structure it cannot be modified. The firms cannot, therefore, make adjustments to their costs by changing the scale of their operations. The main feature of the model is the lobbying and abatement choice of the firms that depend on the firm-level heterogeneity, specifically, which firm will lobby and which firm will not or which firm will abate and which firm will not.

The role of the regulator is to take into account the lobbying revenue and damage from pollution to set an environmental policy. The instrument of choice for the regulator is an emission intensity standard. While a tax is *de rigueur* in a political economy framework it does not reflect reality in environmental policy. There is enough anecdotal evidence to suggest that governments are not very keen on introducing a tax since they tend to be very unpopular with those affected. Therefore, it is much more realistic to use a standard instead of a tax. While tariffs and taxes are quite common in the trade literature because of their prevalence in the real world, environmen-

[3] 3M's 3P, website accessed 20th August, 2009.

tal taxes are not as visible. However, this has changed in recent years and some governments, especially at the provincial level, have started to introduce "green" taxes.

Using heterogeneity in firm characterstics I can describe the situations under which firms will lobby or abate or engage in both. The main feature of the model is that only one firm will end up lobbying the regulator. So the other firm is free-riding on the lobbying activity of the first firm. Another feature is that while both firms may end up abating, for the firm that lobbies, lobbying and abatement become complementary activities and not substitutes. This arises due to the static nature of the model. For the firm that does not lobby, we can think of them abating more than the other firm and the other firm abating less but being required to compensate the regulator for abating less.

The main contribution of this paper is that it uses firm-level characteristics to make predictions about the lobbying and abatement decision. The results are driven by cost considerations with firms choosing abatement over lobbying if the effective marginal abatement cost is lower than a threshold value. The effective marginal abatement cost is the marginal abatement cost as a function of the output and a marginal abatement cost factor. The rest of the paper is as follows. I set up the model in the next section. Section 3 looks at lobbying and abatement decisions under various combinations of firm heterogeneity and makes predictions about the lobbying and abatement choices faced by each individual firm. Section 4 concludes and discusses scope for further work.

2 The Model

The set-up of the model is quite simple. There are three agents, viz. two firms (indexed by $i = 1, 2$) and a regulator. The firms behave non-cooperatively. There is no informational asymmetry and the firms have perfect and complete information. Heterogeneity in the firms is modelled using three firm-level characteristics. The sources of firm heterogeneity in my model are emission intensity ($\theta_i, i = 1, 2$), marginal cost ($c_i, i = 1, 2$) and a cost factor of abatement ($\alpha_i, i = 1, 2$). There are various ways in which the two firms could be heterogeneous. They can be different with respect to just one out of the three, two out of the three or in all characteristics. Table 1 provides a list of all the possible outcomes except for the case when the firms are similar in all three characteristics.

Table 1: POSSIBLE OUTCOMES OF FIRM HETEROGENEITY

Heterogeneity in one characteristic	Heterogeneity in two characteristics	Heterogeneity in three characteristics
$c_1 = c_2$, $\theta_1 = \theta_2$, $\alpha_1 < \alpha_2$	$c_1 = c_2$, $\theta_1 < \theta_2$, $\alpha_1 < \alpha_2$	$c_1 < c_2$, $\theta_1 < \theta_2$, $\alpha_1 < \alpha_2$
$c_1 = c_2$, $\theta_1 < \theta_2$, $\alpha_1 = \alpha_2$	$c_1 = c_2$, $\theta_1 < \theta_2$, $\alpha_1 > \alpha_2$	$c_1 < c_2$, $\theta_1 < \theta_2$, $\alpha_1 > \alpha_2$
$c_1 < c_2$, $\theta_1 = \theta_2$, $\alpha_1 = \alpha_2$	$c_1 < c_2$, $\theta_1 = \theta_2$, $\alpha_1 < \alpha_2$	$c_1 < c_2$, $\theta_1 > \theta_2$, $\alpha_1 < \alpha_2$
	$c_1 < c_2$, $\theta_1 = \theta_2$, $\alpha_1 > \alpha_2$	$c_1 < c_2$, $\theta_1 > \theta_2$, $\alpha_1 > \alpha_2$
	$c_1 < c_2$, $\theta_1 < \theta_2$, $\alpha_1 = \alpha_2$	
	$c_1 < c_2$, $\theta_1 > \theta_2$, $\alpha_1 = \alpha_2$	

To begin with, I make certain assumptions about the characteristics that determine firm heterogeneity and relax some of these assumptions later. The firms have different marginal costs and I assume that firm 1 has a lower marginal cost than firm 2.

Assumption 1 *Firm 1 has a lower marginal cost than firm 2, i.e.* $c_1 < c_2$.

I also assume that one firm has a higher emission intensity than the other. Emission intensity is denoted by θ and represents the amount of unabated pollution emitted from producing one unit of output. The firm with a higher θ can, therefore, be referred to as the "dirty" firm while the firm with a lower θ can be called "clean". I assume that firm 1 is the clean firm and has an emission intensity θ_1 while firm 2 is the dirty firm and has an emission intensity θ_2. By definition, therefore, $\theta_1 < \theta_2$.

Assumption 2 *Firm 1 has a lower emission intensity than firm 2, i.e.* $\theta_1 < \theta_2$.

The above assumption means that the firm with the higher marginal cost is assumed to have a higher emission intensity. Marginal costs are a reflection of the productivity of a firm and it is reasonable to expect that a less productive firm also has a higher θ. Productivity and emission intensity are, therefore, negatively correlated or, in other words, marginal cost and emission intensity are positively correlated. This assumption will be relaxed later.

There are further costs, namely, lobbying or abatement costs or both. A firm can lobby or abate or do both. If it decides to lobby it incurs the lobbying cost while incurring the abatement cost if it has to abate. I refer to abatement here as the cost incurred to meet a standard as stipulated by a regulator. The profit function of firm i is given by:

$$\pi_i = (p - c_i)q_i - \begin{cases} L_i & \text{if only lobby,} \\ L_i + \alpha_i\left(\theta_i - \Theta\right)q_i & \text{if lobby and abate,} \\ \alpha\left(\theta_i - \Theta\right)q_i & \text{if only abate,} \end{cases} \qquad (1)$$

$$L_i \geq 0,$$

where p is the market price, c_i is the marginal cost, L_i is the lobbying expense, α_i is a cost factor associated with abatement, Θ is the emission intensity standard that has been decided upon by the regulator and q_i is the output of firm i. The lobbying expense is assumed to be a fixed dollar amount and is non-negative, i.e. $L_i \geq 0$. I assume, for now, that the cost factor of abatement α_i is the same for both firms, i.e. $\alpha_1 = \alpha_2$.

Assumption 3 *The cost factor of abatement α_i is the same for both firms.*

Demand for the product is linear and the firms engage in a Cournot duopoly game to decide on the output. However, I assume that the abatement cost, if a firm has to abate, does not enter the output decision. I make a further simplification and assume that a firm does not change its output once it plays the Cournot output game. While the model is not built in a multi-stage game framework it may be convenient to think of the output decision being made at Stage 0. Lobbying and abatement decisions occur in Stage 1. The decisions and solution in Stage 1 have no bearing on the outcome in Stage 0 which precludes the need to solve the game by backward induction.

Assumption 4 *Neither firm is able to change its output decision once it has been made.*

Is the assumption to fix a firm's output far-fetched? No. It is often difficult to change the scale of a plant's production quickly. So it is quite reasonable to assume that a firm is unable to change the quantity it produces in response to a change in its cost structure. Given a linear demand structure, $p = a - b(q_1 + q_2)$, the profit maximizing output of firm i is obtained from the standard Cournot model and is $q_i^* = \frac{a - c_i}{3b}$. Since the marginal costs are not symmetric the firm with a higher marginal cost, firm 2 in this case, will have a lower output than firm 1. It is also very straightforward to show that firm 1 will have a higher profit than firm 2. What about their respective unabated emissions? While firm 1 has a lower emission intensity than firm 2 it also produces more output than firm 2. So it is not obvious which firm has greater unabated emission. It can be shown that if the difference in marginal costs is sufficiently small firm 2 will have a higher unabated emission than firm 1. I assume, for simplicity, that this indeed is the case so that firm 2 has a higher unabated emission than firm 1.

Assumption 5 *Firm 1 has a lower unabated emission than firm 2, i.e.* $\theta_1 q_1 < \theta_2 q_2$.

I will, from now, concentrate on the cost part of the profit function that includes the lobbying and abatement expenditure since $(p - c_i)q_i$ will remain unchanged for both firms. Before analyzing the behaviour of firms in terms of their lobbying and abatement activities I need to introduce the regulator and discuss its role.

The objective of the regulator is to consider the lobbying activities of the firms and balance it against the damages caused by pollution to decide on the appropriate regulation. The stringency of regulation depends on how the lobbying activities influence the regulator. The regulator sets an emission intensity standard Θ that is applicable to both firms. The possibility of a firm garnering a favour for itself by influencing the regulator independently is ignored. So, even if one firm is successful in enforcing a weak regulation it will apply to the other firm too. The regulator's welfare function is determined by the lobbying amount it receives from the polluting firms and the damage the pollution causes in its area. So the regulator has an objective function[4] given by:

$$G = \lambda(L_1 + L_2) - (1 - \lambda)\left[\min\{\theta_1, \Theta\} q_1 + \min\{\theta_2, \Theta\} q_2\right]^2, \tag{2}$$

where λ is the weight assigned to lobbying and $(1 - \lambda)$ is the weight assigned to the damages

[4] The pollution damage can be transformed into monetary form by normalizing the "price" of pollution to one.

from pollution. The range of λ is $[0, 1]$. L_1 and L_2 are the lobbying expenditures of firms 1 and 2 respectively. Θ is the emission intensity standard, applicable to both firms, set by the regulator. The outputs of the two firms are, respectively, q_1 and q_2. The term in square brackets denotes the damage caused by pollution. It is a quadratic expression to signify that the effect of the damage becomes progressively worse with higher emissions. The pollution from firm i is the product of emission intensity and output of firm i. The emission intensity is the lower of the emission intensity chosen by the regulator Θ and the exogenously given original emission intensity of firm i. Θ is the ex-post emission intensity only if the regulator chooses the standard such that it is below the firm's original θ_i. The weights assigned to lobbying and pollution will determine how the regulator sets Θ. If $\lambda = 1$ the regulator only cares about lobbying revenue and when $\lambda = 0$ the concern for the regulator is only the damage from pollution. We may also think of λ as a measure of lobbying effectiveness. If λ is less than 1 the firms will not be able to lobby as effectively as when it is closer to 1. It is clear from (2) that lobbying increases the regulator's welfare while the damage from pollution reduces it.

The objective of the regulator will be to balance the cost from pollution and benefit from lobbying revenue by choosing an emission intensity standard so that the welfare is maximized. However, for the purposes of this paper I will assume that the regulator is weak and has a minimum amount of welfare it accepts on society's behalf. Any further damages from pollution can be compensated by the lobbying amount. This will lead to the situation where the welfare will remain at that minimum level and the polluting firms will lobby the regulator to relax the standard in return for more political contribution. Therefore, this model differs from the standard Grossman and Helpman (1994) political economy model where the policymaker can capture rents from tariff formation. The implicit assumption of a weak government, while presumably strong, is quite realistic especially with regard to environmental policy. Environmental policy is still not a priority for governments that believe other issue require more immediate intervention. Therefore, it is realistic to believe that regulators accept damage from pollution as long as the welfare of society is not seriously compromised.

Let us assume, therefore, that the regulator has a lower limit to the damage that pollution can cause if it were to ignore lobbying. This implies that the regulator has an acceptable limit to the damage that society can accept from pollution. If the regulator were to set Θ in the absence of lobbying such that damages would be minimized then that optimal value of Θ would be zero. I ignore that possibility and assume that there is a minimum welfare loss that the regulator can accept. Denote that limit by $\bar{G}$ which, by definition, is negative.[5]

Assumption 6 *The regulator fixes a minimum welfare amount at $\bar{G}$ which sets the limit to how much damage the society is willing to accept in the absence of any lobbying. The value of $\bar{G}$ is negative.*

If the regulator ignores lobbying by setting λ equal to 0, it will be able to find a value of the emission intensity standard Θ such that $\bar{G}$ is attained. With the presence of lobbying, that value of Θ can be weakened. While this would lead to higher damages from the weaker standard, the loss would be compensated by the increased revenue received by the regulator from lobbying. Assume, for now, that the emission intensity standard is binding on both firms and that the regulator assigns positive weights to both lobbying and pollution damage. We can write the modified objective function as:

$$\bar{G} \leq \lambda(L) - (1-\lambda)\left[\Theta q_1 + \Theta q_2\right]^2, \tag{3}$$

where L is the total lobbying the regulator receives. This weak inequality will hold with equality since there is no incentive for firms to lobby more than necessary. We can then find the value of Θ such that the difference between lobbying revenue and pollution damage is equal to $\bar{G}$ by equating the two sides in (3) to get:

$$\Theta^* = \sqrt{\frac{\lambda L - \bar{G}}{(1-\lambda)Q^2}}, \tag{4}$$

where $Q = q_1 + q_2$. Recall that $\bar{G} < 0$ so the numerator is positive. We can see from this expression that the emission intensity standard Θ increases when lobbying amount L increases. It also increases when the regulator assigns more weight λ to lobbying. In other words, increased

[5]Assume that the regulator ignores lobbying. Then the welfare depends on the pollution damage which is negative. The regulator, therefore, has a minimum welfare amount in mind below which it is unwilling to go.

lobbying and more favour to lobbying by the regulator weakens the emission intensity standard. These observations lead to the following proposition.

Proposition 1 *The emission intensity standard set by a regulator is weakened by an increase in lobbying amount as well as by an increase in the weight assigned to lobbying. The standard is made stronger if the government reduces the minimum welfare loss* $\bar{G}$.

To find out the effect that each firm's lobbying has on Θ^* we differentiate (4) with respect to firm 1's lobbying L_1 and firm 2's lobbying L_2. The expressions are identical:

$$\frac{\partial \Theta}{\partial L_1} = \frac{\partial \Theta}{\partial L_2} = \frac{\beta}{2\Theta^*} > 0, \tag{5}$$

where $\beta = \lambda/(1-\lambda)$. The effect of lobbying on the standard Θ is positive, i.e. it becomes weaker and more favourable to firms. The reason that the effect of lobbying by both firms on the regulator's policy instrument is the same is that it does not really matter to the regulator as to the source of the contribution. It treats a dollar equally regardless of whether it came from firm 1 or firm 2.

3 Lobbying and Abatement

3.1 Binding Emission Standard

Now that we have found out the optimal Θ and the effect that each firm's lobbying has on the regulator's emission intensity standard let us turn to the two firms and look at their lobbying contribution choice. For that we need to return to the profit function (1). The FOC for profit maximization with respect to lobbying expenditure L_i for firm i is:

$$-1 + \alpha_i q_i \frac{\partial \Theta}{\partial L_i} \leq 0 \tag{6}$$

$L_i \geq 0$ with complementary slackness.

We can rearrange (6) and use (5) to get:

$$\alpha_i q_i \leq \frac{2\Theta^*}{\beta} \tag{7}$$

$L_i \geq 0$ with complementary slackness.

The left-hand side of (7) is the marginal abatement cost that is also a function of the firm's output. A firm with a high output will also have a high abatement cost since the output in my model is assumed to be fixed. A high abatement cost factor α_i will also lead to a high abatement cost. The condition (7) is a convenient way to look at the firm's decision problem as to whether it should lobby or abate. If the abatement cost is lower than the $\frac{2\Theta^*}{\beta}$ threshold it will be more cost-effective to abate while it should put in at least some effort in lobbying when the condition (7) holds with equality.

Since, by the set-up of the model, $q_1 > q_2$ and because $\frac{\partial\Theta}{\partial L_1} = \frac{\partial\Theta}{\partial L_2}$, (7) will hold with equality for firm 1 and with a strict inequality for firm 2:

$$\alpha q_1 = \frac{2\Theta^*}{\beta}, \tag{8a}$$

and

$$\alpha q_2 < \frac{2\Theta^*}{\beta}, \tag{8b}$$

These conditions indicate that it is more cost-effective for firm 1 to lobby but not for firm 2 and therefore $L_1 > 0$ for firm 1 while we end up with a corner solution for firm in terms of lobbying effort and so $L_2 = 0$. Therefore, firm 1 will lobby and firm 2 will not lobby. What is firm 1's lobbying effort? That is obtained by substituting Θ from (4) into (8a):

$$L_1 = \frac{\bar{G}}{\lambda} + \beta\left(\frac{\alpha q_1}{2}\right)^2. \tag{9a}$$

The pollution emission standard Θ that the regulator is going to set is obtained from (8a):

$$\Theta = \frac{\alpha q_1 \beta}{2}. \tag{9b}$$

In terms of abatement activity, both firms will have to abate since the emission intensity standard, by assumption, is binding for both of them. So the total abatement cost will be $\alpha(\theta_i - \Theta^*)q_i$ for firm i. The total abatement cost for firm 2 will be more than that of firm 1 provided that $\theta_1 q_1 < \theta_2 q_2$. Otherwise, if the inequality is reversed, firm 1 will have a higher total abatement cost than firm 2. We can write these results in the next proposition.

Proposition 2 *Assuming that the emission standard is binding for both firms, the "clean" (with respect to the emission intensity) firm will lobby the regulator to weaken the emission standard while the "dirty" firm will not lobby. The total abatement cost of the "dirty" firm will be higher than that of the "clean" firm.*

The FOC conditions (8a) and (8b) and the slackness conditions are crucial for analyzing the lobbying decision of firms. Using these two conditions we can predict the conditions under which a firm will lobby. These conditions will depend on the characteristics of the firm in terms of the scale of production (reflected in the amount of output produced) and various cost parameters. The firm whose FOC is not binding will not lobby while the firm whose FOC is binding and equal to zero will lobby. Using this property let us now look at the firm characteristics that will determine which firm lobbies.

There are three sources of firm heterogeneity in this model. The two firms can be different in terms of their emission intensity θ_i, the output produced q_i (caused by a difference in marginal cost c_i) and the cost factor of abatement α_i. I have initially assumed that the marginal cost of firm 1 is lower than that of firm 2. If I reverse the inequality and assume that $c_1 > c_2$ the output of firm 1 will be lower than that of firm 2. Therefore, the equality in (8a) will be relaxed while equality will be gained in (8b). The new conditions will be:

$$\alpha q_1 < \frac{2\Theta^*}{\beta}, \tag{10a}$$

$$\alpha q_2 = \frac{2\Theta^*}{\beta}. \tag{10b}$$

since $q_1 < q_2$. So firm 2 will now lobby but not firm 1. The result we get here is that bigger and dirtier firms will lobby. The lobbying amount is determined in the same way as before and is:

$$L_2 = \frac{\bar{G}}{\lambda} + \beta \left(\frac{\alpha q_2}{2}\right)^2. \tag{11}$$

In terms of the abatement activity, both firms will have to abate since the emission intensity standard is binding for both of them. So the total abatement cost will be $\alpha(\theta_i - \Theta^*)q_i$ for firm i. The total abatement cost for firm 2 will be more than that of firm 1 since $\theta_1 q_1 < \theta_2 q_2$. Therefore, the bigger and dirtier firm will have to lobby and abate. Reversing the assumption on marginal costs gives us the following proposition.

Proposition 3 *Assuming that the emission standard is binding for both firms, the bigger (in terms of output) and dirtier (with respect to the emission intensity) firm will lobby the regulator to weaken the emission standard while the smaller and cleaner firm will not engage in lobbying. The total abatement cost of the dirtier firm will be higher than that of the cleaner firm.*

Let us now relax the assumption that the marginal cost of abatement is the same for both firms and assume that it is lower for the dirty firm, i.e. $\alpha_1 > \alpha_2$. This can be explained by the observation that abatement is a "low-hanging fruit" for the dirtier firm. The firms are, in this case, heterogeneous in all three characteristics. If we return to the FOC conditions for the two firms we get the following conditions:

$$\alpha_1 q_1 = \frac{2\Theta^*}{\beta}, \tag{12a}$$

$$\alpha_2 q_2 < \frac{2\Theta^*}{\beta}. \tag{12b}$$

Since $q_1 > q_2$ (because $c_1 < c_2$) and $\alpha_1 > \alpha_2$ the effective marginal abatement cost will hold with equality for firm 1 but with strict inequality for firm 2. We are then in a corner solution for firm 2 with respect to its lobbying effort and, as a result, $L_2 = 0$. In terms of abatement effort, firm 2 will have to abate more since $\theta_2 > \theta_1 > \Theta$ but the cost of abatement is ambiguous. Firm 1 will have a higher abatement cost compared to firm 2 if $\frac{\alpha_1 q_1}{\alpha_2 q_2} > \frac{\theta_2 - \Theta}{\theta_1 - \Theta}$ while firm 2 will have a higher total abatement cost if the inequality is reversed and both firms will have the same abatement cost when it holds with equality. This ambiguity is quite straightforward to explain. Since the marginal abatement cost of the larger firm (firm 1) is larger than that of the smaller firm (firm 2) it works against it even though the smaller firm with the lower marginal abatement cost has a larger emission intensity. Firm 1 will have a lower total abatement cost only if firm 2 has a sufficiently high emission intensity θ_2. We can write this result in the following proposition:

Proposition 4 *Assume that the emission standard is binding for both firms and the marginal abatement cost factor is negatively correlated with the emission intensity. The larger and cleaner firm will lobby while the smaller and dirtier firm will not. The total abatement cost of the dirtier firm will be higher than that of the cleaner firm only if its emission intensity is sufficiently high. Otherwise, its total abatement cost will be less (or equal).*

What about the situation when the marginal abatement cost factor and emission intensity are positively correlated so that that the larger firm (firm 1) has a lower emission intensity as well as a lower marginal abatement cost? We then have:

$$\alpha_1 q_1 \leq \frac{2\Theta^*}{\beta}, \tag{13a}$$

$$\alpha_2 q_2 \leq \frac{2\Theta^*}{\beta}. \tag{13b}$$

Since $q_1 > q_2$ and $\alpha_1 < \alpha_2$ we cannot say with certainty which FOC will hold with equality. It will depend on the $\alpha_i q_i$ term. If $\alpha_1 q_1 > \alpha_2 q_2$ then firm 1 will lobby and firm 2 will not. What can we say about their abatement expenses? Unfortunately, not much. Even if $\alpha_1 q_1 > \alpha_2 q_2$ the result is ambiguous because $\theta_1 < \theta_2$. Firm 1 will have a higher abatement cost if $\frac{\alpha_1 q_1}{\alpha_2 q_2} > \frac{\theta_2 - \Theta}{\theta_1 - \Theta}$. However, if we know that $\alpha_1 q_1 < \alpha_2 q_2$ firm 2 will have a higher abatement cost compared to firm 1 since $\frac{\alpha_1 q_1}{\alpha_2 q_2} < \frac{\theta_2 - \Theta}{\theta_1 - \Theta}$. In this case firm 1 will not lobby but firm 2 will.

Proposition 5 *Assume that the emission standard is binding for both firms and the marginal abatement cost is positively correlated with the emission intensity. The larger and cleaner firm will lobby while the* *smaller and dirtier firm will not if the marginal cost of abatement is sufficiently high for the former. Otherwise, only the smaller and dirtier firm will lobby.*

The assumption up to now has been that the larger firm has a lower emission intensity. However, it may be the case that larger firms are the ones that are comparatively dirtier. So let us now consider the situation where $c_1 < c_2$ which implies that firm 1 produces more than firm 2 and $\theta_1 > \theta_2$ so that firm 1 is dirtier too. Given these assumptions there are two possible outcomes with regard to the marginal cost of abatement. Firstly, the emission intensity and the marginal cost of abatement can be positively correlated so that the firm with the higher emission intensity also has a higher marginal cost of abatement. Secondly, if we assume that abatement is a "low-hanging fruit" for the dirtier firm we have the situation where emission intensity and marginal cost of abatement are inversely related.

Let us assume that the larger firm has a higher emission intensity and the emission intensity and marginal cost of abatement are positively correlated. We have $c_1 < c_2$, $\theta_1 > \theta_2$ and $\alpha_1 > \alpha_2$. The FOCs for lobbying can be rewritten as:

$$\alpha_1 q_1 = \frac{2\Theta^*}{\beta}, \tag{14a}$$

$$\alpha_2 q_2 < \frac{2\Theta^*}{\beta}, \tag{14b}$$

where the effective marginal abatement cost for firm 1 holds with equality but with inequality for firm 2 because $\alpha_1 q_1 > \alpha_2 q_2$. Firm 1 will therefore lobby a strictly positive amount but firm 2 will not engage in any lobbying activity. Using our assumptions, it is easy to prove that $\alpha_1(\theta_1 - \Theta)q_1 > \alpha_2(\theta_2 - \Theta)q_2$ so firm 1 will spend more on abatement activity than firm 2.

Proposition 6 *Assume that the emission standard is binding for both firms, the larger firm is the dirtier firm and the marginal abatement cost is positively correlated with the emission intensity. The larger and dirtier firm will lobby while the smaller and cleaner firm will not. The total abatement cost of the larger and dirtier firm will also be higher than that of the smaller but cleaner firm.*

If we reverse the correlation between emission intensity and marginal cost of abatement the situation becomes less unambiguous. We now have $c_1 < c_2$, $\theta_1 > \theta_2$ and $\alpha_1 < \alpha_2$. The FOCs can be rewritten as:

$$\alpha_1 q_1 \leq \frac{2\Theta^*}{\beta}, \tag{15a}$$

$$\alpha_2 q_2 \leq \frac{2\Theta^*}{\beta}. \tag{15b}$$

This case is similar to (13a) and (13b). Since $q_1 > q_2$ and $\alpha_1 < \alpha_2$ we cannot say with certainty which firm's effective marginal abatement cost will be lower than the threshold value. It will depend on the $\alpha_i q_i$ term. If $\alpha_1 q_1 > \alpha_2 q_2$ then firm 1 will lobby and firm 2 will not. We cannot say anything with certainty about their abatement expenses. If we know that $\alpha_1 q_1 > \alpha_2 q_2$ firm 1 will have a higher abatement cost compared to firm 2 since $\alpha_1(\theta_1 - \Theta)q_1 > \alpha_2(\theta_2 - \Theta)q_2$. However, this is not certain when $\alpha_1 q_1 < \alpha_2 q_2$ because $\alpha_1(\theta_1 - \Theta)q_1$ could be greater than, equal to or less than $\alpha_2(\theta_2 - \Theta)q_2$. In this case, firm 1 will lobby but not firm 2.

Proposition 7 *Assume that the emission standard is binding for both firms, the larger firm is the dirtier firm and the marginal abatement cost is negatively correlated with the emission intensity. The larger and dirtier firm will lobby while the smaller and cleaner firm will not if the marginal cost of abatement is sufficiently high for the former. Otherwise, only the smaller and cleaner firm will lobby.*

I have assumed till now that the marginal costs for the two firms are unequal. They are, therefore, heterogeneous in terms of size. Suppose that assumption is modified and both firms have the same marginal cost, i.e. $c_1 = c_2 = c$. The output produced will then be equal for both firms, $q_1 = q_2 = q$. This assumption is very useful if we want to look at the lobbying and abatement behaviour of two firms that are of the same size. Firm 2 is the dirtier firm but has a lower marginal abatement cost so emission intensity and the marginal cost of abatement are negatively correlated. This implies that $\theta_1 < \theta_2$ and $\alpha_1 > \alpha_2$. We get the following conditions:

$$\alpha_1 q = \frac{2\Theta^*}{\beta}, \tag{16a}$$

$$\alpha_2 q < \frac{2\Theta^*}{\beta}. \tag{16b}$$

Therefore, using the same argument as in the preceding cases, firm 1 will lobby but firm 2 will not. When it comes to abatement activity firm 1 will abate $\alpha_1(\theta_1 - \Theta)q$ and firm 2 will abate $\alpha_2(\theta_2 - \Theta)q$. The difference in abatement expenditure will depend on $\alpha_1(\theta_1 - \Theta)$ and $\alpha_2(\theta_2 - \Theta)$. If $\alpha_1(\theta_1 - \Theta) > \alpha_2(\theta_2 - \Theta)$ then firm 1 will have a higher abatement expenditure than firm 2. The abatement expenditures will be reversed if $\alpha_1(\theta_1 - \Theta) < \alpha_2(\theta_2 - \Theta)$. These relations may be simplified to ratios so that firm 1 will have a higher abatement expenditure than firm 2 if $\frac{\alpha_1}{\alpha_2} > \frac{\theta_2 - \Theta}{\theta_1 - \Theta}$. Firm 1 will have a higher abatement expenditure if its marginal cost abatement is sufficiently higher than that of firm 2 compared to the ratio that they both have to reduce their emission intensities by. If, on the other hand, firm 2 has to reduce its emission intensity by a sufficiently large amount the total abatement cost it faces will exceed that of firm 1. There may also exist a situtation where the two ratios are equal in which case the abatement expenditures will also be the same.

Proposition 8 *Assume that two firms are of the same size and that the emission standard is binding for both. If the emission intensity and marginal cost of abatement are negatively correlated so that the firm with a higher emission intensity has a lower marginal cost of abatement, the clean firm will lobby while the dirty firm will not. There is ambiguity in terms of their total abatement expenditures.*

The other interesting case where two firms are of the same size occurs when the emission intensity and the marginal cost of abatement are positively correlated. This is opposite to the previous discussion and therefore, in this case the firm with a higher emission intensity has a higher marginal cost of abatement. Assuming that firm 1 is still the cleaner firm we have $\theta_1 < \theta_2$ and $\alpha_1 < \alpha_2$. We can then derive the following conditions from the FOCs:

$$\alpha_1 q < \frac{2\Theta^*}{\beta}, \tag{17a}$$

$$\alpha_2 q = \frac{2\Theta^*}{\beta}. \tag{17b}$$

Therefore, the effective marginal abatement cost is lower for firm 1 than for firm 2. This implies

Table 2: LOBBYING AND ABATEMENT WHEN TWO FIRMS ARE OF EQUAL SIZE

Heterogeneity combinations	Complementary Slackness	Lobbying	Abatement Expenditure
$\theta_1 = \theta_2$, $\alpha_1 < \alpha_2$	$\alpha_1 q < \frac{2\Theta^*}{\beta}$ $\alpha_2 q = \frac{2\Theta^*}{\beta}$	$L_1 = 0$ $L_2 > 0$	Firm 1 < Firm 2
$\theta_1 < \theta_2$, $\alpha_1 = \alpha_2$	$\alpha_1 q = \frac{2\Theta^*}{\beta}$ $\alpha_2 q = \frac{2\Theta^*}{\beta}$	$L_1 > 0$ $L_2 > 0$	Firm 1 < Firm 2
§ $\theta_1 < \theta_2$, $\alpha_1 < \alpha_2$	$\alpha_1 q < \frac{2\Theta^*}{\beta}$ $\alpha_2 q = \frac{2\Theta^*}{\beta}$	$L_1 = 0$ $L_2 > 0$	Firm 1 < Firm 2
§ $\theta_1 < \theta_2$, $\alpha_1 > \alpha_2$	$\alpha_1 q = \frac{2\Theta^*}{\beta}$ $\alpha_2 q < \frac{2\Theta^*}{\beta}$	$L_1 > 0$ $L_2 = 0$	Firm 1 $\lesseqgtr$ Firm 2

Note: § refers to cases that are discussed in the main paper.

that there is an interior solution for firm 2 in terms of lobbying and a corner solution for firm 1. Therefore, $L_2 > 0$ and $L_1 = 0$ for firm 2 and firm 1 respectively. Compared to the previous case where emission intensity and marginal cost of abatement were inversely related there is no ambiguity in terms of the total abatement expenditure. The abatement expenditure is $\alpha_1(\theta_1 - \Theta)q$ for firm 1 and $\alpha_2(\theta_2 - \Theta)q$ for firm 2. Since $\theta_1 < \theta_2$ and $\alpha_1 < \alpha_2$ we have $\alpha_1(\theta_1 - \Theta)q < \alpha_2(\theta_2 - \Theta)q$. Firm 2 has a higher abatement cost compared to firm 1. This is because firm 2 has to abate more to reach the new emission standard and also the cost of abating to that standard is higher.

Proposition 9 *Assume that two firms are of the same size and that the emission standard is binding for both. If the emission intensity and marginal cost of abatement are positively correlated so that the firm with a higher emission intensity has a higher marginal cost of abatement, the clean firm will lobby while the dirty firm will not. The dirtier firm will, unambiguously, have a higher total abatement cost.*

Table 3: Lobbying and Abatement when Firm 1 is Larger Than Firm 2

Heterogeneity combinations	Complementary Slackness	Lobbying	Abatement Expenditure
$\theta_1 = \theta_2$, $\alpha_1 = \alpha_2$	$\alpha_1 q_1 = \frac{2\Theta^*}{\beta}$ $\alpha_2 q_2 < \frac{2\Theta^*}{\beta}$	$L_1 > 0$ $L_2 = 0$	Firm 1 $>$ Firm 2
$\theta_1 = \theta_2$, $\alpha_1 < \alpha_2$	$\alpha_1 q_1 \leq \frac{2\Theta^*}{\beta}$ $\alpha_2 q_2 \leq \frac{2\Theta^*}{\beta}$	$L_1 \geq 0$ $L_2 \geq 0$	Firm 1 $\lesseqqgtr$ Firm 2
$\theta_1 = \theta_2$, $\alpha_1 > \alpha_2$	$\alpha_1 q_1 = \frac{2\Theta^*}{\beta}$ $\alpha_2 q_2 < \frac{2\Theta^*}{\beta}$	$L_1 > 0$ $L_2 = 0$	Firm 1 $>$ Firm 2
§ $\theta_1 < \theta_2$, $\alpha_1 = \alpha_2$	$\alpha_1 q_1 = \frac{2\Theta^*}{\beta}$ $\alpha_2 q_2 < \frac{2\Theta^*}{\beta}$	$L_1 > 0$ $L_2 = 0$	Firm 1 $\lesseqqgtr$ Firm 2
$\theta_1 > \theta_2$, $\alpha_1 = \alpha_2$	$\alpha_1 q_1 = \frac{2\Theta^*}{\beta}$ $\alpha_2 q_2 < \frac{2\Theta^*}{\beta}$	$L_1 > 0$ $L_2 = 0$	Firm 1 $>$ Firm 2
$\theta_1 < \theta_2$, $\alpha_1 < \alpha_2$	$\alpha_1 q_1 \leq \frac{2\Theta^*}{\beta}$ $\alpha_2 q_2 \leq \frac{2\Theta^*}{\beta}$	$L_1 \geq 0$ $L_2 \geq 0$	Firm 1 $\lesseqqgtr$ Firm 2
§ $\theta_1 < \theta_2$, $\alpha_1 > \alpha_2$	$\alpha_1 q_1 = \frac{2\Theta^*}{\beta}$ $\alpha_2 q_2 < \frac{2\Theta^*}{\beta}$	$L_1 > 0$ $L_2 = 0$	Firm 1 $\lesseqqgtr$ Firm 2
§ $\theta_1 > \theta_2$, $\alpha_1 < \alpha_2$	$\alpha_1 q_1 \leq \frac{2\Theta^*}{\beta}$	$L_1 \geq 0$	Firm 1 $\lesseqqgtr$ Firm 2

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Table 3 – Continued

Heterogeneity combinations	Complementary Slackness	Lobbying	Abatement Expenditure
	$\alpha_2 q_2 \leq \dfrac{2\Theta^*}{\beta}$	$L_2 \geq 0$	
§ $\theta_1 > \theta_2$, $\alpha_1 > \alpha_2$	$\alpha_1 q_1 = \dfrac{2\Theta^*}{\beta}$ $\alpha_2 q_2 < \dfrac{2\Theta^*}{\beta}$	$L_1 > 0$ $L_2 = 0$	Firm 1 $\lesseqqgtr$ Firm 2

Note: § refers to cases that are discussed in the main paper.

3.2 Binding Emission Standard for only One Firm

I now discuss the situation where the emission standard is binding for one firm but not for the other. It is quite clear that, if it *is* binding, it will be binding for the firm with the higher emission intensity.[6] In this situation Θ will lie above θ_1 but below θ_2. The results, in terms of lobbying, will not change because they do not depend on the new emission standard. The only difference from the situation with the emission standard binding on both firms is that there will be no abatement expenditure for firm 1 but it will be positive for firm 2. The lobbying decision as to which firm will lobby and which firm will not is given by Table 2 and Table 3.

When the two firms are of equal size. two cases strike out as being interesting. The first arises when firm 1 has a lower marginal cost of abatement. In this case firm 1 does not lobby but the dirtier firm does. The dirtier firm also has to abate because there is a point beyond which it finds abating to be more cost-effective than lobbying. We therefore have a situation in which the cleaner firm is being passive while the dirtier firm is doing both lobbying and abatement.

The second interesting case occurs when the the cleaner firm has a higher marginal abatement

[6] I am ruling out the case where both firms have the same emission intensity. Also, my assumption about firm 1 being the cleaner firm still holds.

cost. The cleaner firm will lobby the regulator to weaken the emission standard while the dirtier firm will abate instead of lobbying. The dirtier firm is free-riding on the lobbying efforts of the cleaner firm. Abating turns out to be more expensive for the cleaner firm and so it ends up lobbying the regulator. The dirtier firm finds abating to be more cost-effective.

3.3 No Binding Emission Standard

There might also be a situation where the emission standard set by the regulator is sufficiently weak and none of the firms are bound by it. This could happen if the weight assigned by the regulator to lobbying effort by the firms is sufficiently high. In that case, we will have a situation where firms will only lobby and not find it necessary to abate and the difference in emission intensity will play no role. The lobbying effort will follow the same pattern as in Table 2 and Table 3 but we need only focus on the differences in the marginal cost of abatement α_i and the sizes of the firms because those two factors alone will determine whether a firm lobbies or not.

For two firms of equal size the lobbying decision will depend on the marginal cost of abatement. The firm with the higher value of α_i will find it more cost-effective to lobby than the other firm and, since the firms behave non-cooperatively, the other firm will free-ride and not need to lobby.

The factor that determines the lobbying choice depends crucially on the $\alpha_i q_i$ term. Since it reflects the effective cost of abatement, by taking into account how much the firm has to abate over all its production units as well as the marginal cost of abatement, the firm with the higher value will find it more cost-effective to lobby than to engage in any abatement activity.

4 Conclusion

In this paper I have used firm heterogeneity to look at situations under which firms will lobby or abate or do both. Starting with a simple model with two firms and using three sources of firm heterogeneity, *viz.* emission intensity, marginal cost and cost factor of abatement, I have shown that, under certain assumptions, the cleaner firm will lobby while the dirty firm will abate. A dirtier and bigger firm will also lobby the regulator for weakening the emission intensity standard but the cleaner and smaller firm will not. Instead the latter will just abate if the standard is binding. If it is not, then it will not be required to either lobby or abate. However, if the standard is binding on the bigger and dirtier firm because the lobbying was not as effective, then it will be required abate as well. All these results depend crucially on the effective marginal cost of abatement. If it is sufficiently low, then the firm has no incentive to lobby the regulator. Because the firms are not symmetrical one of the two will have the incentive to lobby. Using a simple model with two firms, I have been able to make a number of predictions. This has been possible due to the sources of firm heterogeneity. The model also includes a few policy variables that enrich the model. The crucial policy variable is the emission intensity standard which is a much more realistic policy instrument than a green tax. An improvement over the current model would be to introduce an emission cap on the total pollution emitted rather than a standard on the emission intensity.

Apart from abatement activities all other sources of firm heterogeneity are observable so it would be very interesting to apply the model for testing the predictions. However, as mentioned in Antweiler (2003), it is very plausible that there exists a high degree of negative correlation between abatement cost factor and the emission intensity if pollution abatement is dependent on plant vintage. While there may be other issues in the transition from theory to the empirical implementation, the model in this paper is an attractive starting point in analyzing the abatement and lobbying decisions of different kinds of firms. There are some other avenues as well that I would like to explore in the future. There is the issue of side payments that firms may make to one another as "bribes" to reduce their pollution if a total emissions cap is in place. This could happen if the marginal cost of the dirty firm is sufficiently high so that it finds it more profitable to encourage the other firm to lower its emissions. Another avenue I would like to explore is the situation where the regulator cares about a localized damage function whereby the damage from emissions of the two firms are additive. In the present model the damage is a function of additive emissions while the modification would be two additive damage functions that are each a function of an individual firm's emissions. This is particulary relevant because regulators care about pollution affecting their local jurisdiction and not the overall emissions (Antweiler, 2003).

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