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The effects of rent seeking over tradable pollution permits

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Abstract

The establishment of a tradable permit market requires the regulator to select a level of aggregate emissions and then distribute the associated permits (rent) to specific groups. In most circumstances, these decisions are often politically contentious and frequently influenced by rent seeking behaviour. In this paper, we use a contest model to analyse the effects of rent seeking effort when permits are freely distributed (grandfathered). Rent seeking behaviour can influence both the share of permits which an individual firm receives and also the total supply of permits. This latter impact depends on the responsiveness of the regulator to aggregate rent seeking effort. Using a three-stage game, we show that rent seeking can influence both the distribution of rents and the ex post value of these rents, whilst welfare usually decreases in the responsiveness of the regulator.

Keywords: tradable permit market, rent seeking, initial allocation

JEL *classification numbers*: D72, D78, Q53

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1 Introduction

Tradable pollution markets have become an increasingly mainstream regulatory tool for controlling pollution. Since Montgomery (1972), economists have known that under certain conditions, such markets can achieve an efficient (that is, cost-minimising) allocation of pollution control efforts across polluters, irrespective of the initial allocation of permits by a regulator. This is because post-allocation trading will allow all potential gains from trades to be realised. However, the initial allocation of permits has become a matter of both political debate and increasing academic interest, since firms' gains and losses can in the real world depend partly on this initial allocation. Moreover, since permits are valuable, allocation creates rents over which firms can be expected to compete ex ante by rent seeking. In many existing tradable permit markets, regulators' decisions over the distribution and absolute level of emissions have often been influenced by interested parties (see, for example, Svendsen (2005)).[1] This lobbying for rents is typically seen as socially unproductive and often as a significant and sustained problem.

An important question for economists is how rent seeking strategies are determined in tradable permit markets, how this influences social welfare, and whether these effects depend on the degree to which a regulator allows rent seeking to determine both the distribution and absolute level of these rents. This paper seeks to answer this question, using a contest model. Our conclusion is that when regulators are responsive to aggregate rent seeking (i.e. are willing to change the total supply of permits) then rent seeking strategies for tradable permits differ significantly from standard (non-tradable) rents. This is a direct result of firms having the ability to trade pollution permits following on from an initial allocation, which produces an equilibrium price effect. When the regulator's responsiveness to aggregate rent seeking increases we find this results in an ambiguous change in welfare, which is dependent on the trade-off between the increase in aggregate emissions and any decrease in rent seeking from a reduction in the permit

[1] Anecdotal evidence exists for the existence of lobbying (from individual senators) in the US SO_2 trading scheme (Ellerman et al. 2000) and under the 'Waxman-Markey' Bill (HR. 2454). In the set up of the European Union Emissions Trading Scheme (EU-ETS), industry was heavily involved in lobbying behaviour (Svendsen, 2005; Ellerman et al. 2007).

value. This suggests that no simple answers are available in an actual policy context to how governments should respond to opportunities for rent seeking over tradable permits: a surprising result.

In this paper we use a contest framework to analyse rent seeking. Starting from the seminal works of Krueger (1974), Posner (1975) and Tullock (1980), a substantial body of work has focused on rent dissipation issues, where the total rents available for capture across all agents are taken as fixed (for surveys of the literature, see Nitzan, 1994; Hillman and Riley, 1989; Congleton et al., 2008; Konrad, 2009). Chung (1996) extends a Tullock-style rent seeking contest model to include a rent that is endogenously determined by aggregate efforts and finds that the extended contest generates excessive effort levels which are socially wasteful. More recently, Shaffer (2006) finds that effort levels tend to adjust in the direction of the change in the rent. For example, when the lobbying is "productive" (where the rent is increasing in aggregate efforts), agents tend to invest more effort in rent seeking. However, this literature typically assumes that rents are non-tradable, which limits the insights one can draw when considering tradable pollution permit markets. In our analysis, we allow the total value of rents to be endogenously determined by aggregate rent seeking effort, extending this to both the quantity (total supply of permits) and price (ex-post value of traded permits) dimensions.

A tradable permit market involves an ex post reallocation of rents. It has long been understood that such an ex post reallocation of emission rights is key to an efficient allocation of emission reductions among polluters (Montgomery, 1972). Few authors, however, have considered rent seeking contests when ex post reallocation is not just possible but essential to the operation of the policy instrument. Dari-Mattiacci et al. (2009) and Sui (2009) find that although contests are allocatively efficient, effort levels tend to increase when ex post reallocation is permitted. However, it is not clear how these rents differ from standard rents in terms of agents' rent seeking strategies and regulatory responses. In the context of tradable pollution permit markets, Lai (2008) has investigated the social welfare consequences of firms and environmental groups lobbying over the determination of an aggregate emissions cap and finds allocating freely may be more efficient than auctioning.

However, the incentives for firms to rent-seek for their own private benefit (to increase their own individual share of permits at the expense of rival firms) are not considered by Lai.

In the contest modelled herein, polluting firms have the option to invest in rent seeking effort that has the potential to increase their own permit allocation within a tradable permit market and, simultaneously, the aggregate supply of permits from the regulator (i.e. political pressure to increase individual and aggregate level emissions). We allow the regulator to select a provisional aggregate emissions target (for example, by announcing draft legislation) which can be subsequently influenced by firms' rent seeking effort. We provide cases where the regulator views rent seeking as 'purely' socially wasteful and, alternatively, where the regulator obtains political contributions from rent seekers. This is a partial way of modelling variations in the 'quality' of regulation, which might be thought important from a political economy stand-point. The responsiveness of the regulator can also be viewed as representing regulator 'quality'. Our focus is on how the market value of the ex post reallocated rent, which is endogenously determined by the marginal costs of participating firms and the aggregate supply of permits (which may be determined by rent seeking itself), alters rent seeking behaviour and social welfare. We find differences in firms' rent seeking choices compared to a conventional contest. We see that a fundamental aspect of firms' incentives to rent-seek depends on the market value of the permits, that is, the value of the ex post reallocated rents.

This paper focuses on rent seeking for tradable pollution permits, however, the rationale can directly apply to more general contests where the prize won has the ability of being ex post reallocated. The paper is organised as follows. Section 2 introduces the model. In Section 3, the firm's optimal choice of emissions is determined. In Section 4, the firm's equilibrium rent seeking strategy is discussed and aggregate rent seeking effort is then derived. Section 5 investigates the regulator's optimal choice of aggregate emissions and discusses whether alternative responses to rent seeking can be welfare improving. Section 6 provides a discussion of policy implications and Section 7 concludes.

2 The model

Consider a set of firms $\{1, 2, \ldots, n\}$ that participate in a competitive tradable pollution permit market. In this market, permits are initially allocated freely but each firm has the ability to alter the amount of permits it receives from the regulator by investing in rent seeking effort denoted by s_i for $i = 1, 2, \ldots, n$.[2] A unilateral increase in firm i's rent seeking investment will result in that firm obtaining relatively more permits prior to the beginning of the market. Additionally, we allow for the possibility that aggregate rent seeking effort influences the regulator's final decision when selecting an absolute level for the aggregate emissions cap. That is, market participants can apply political pressure on the regulator to increase the aggregate emissions level.[3] Therefore, an increase in rent seeking by firm i increases their share of the "pie" *and* provides pressure to increase the absolute size of the "pie". After the initial distribution of the rents, firms are free to trade and reallocate these permits.

Our model is split into three stages. In stage one, the regulator selects a provisional level of aggregate emissions for the trading permit market denoted by $\tilde{A}$ (such as draft legislation). In stage two, given this information, each firm invests in rent seeking effort $s_i \; \forall \; i$ to obtain a share of the aggregate emissions which results in a "final" aggregate allocation for the permit market denoted by A.[4] In stage three, the market commences

[2] Our results are qualitatively similar when one considers a hybrid allocation approach where both auctioning and grandfathering can be used (where the rent now available for rent seekers is simply the total allocation minus the permits allocated from the auction). This approach has been advocated by energy companies for the forthcoming US wide cap-and-trade program (Point Carbon, 2009). Furthermore, our results may provide analysis on how firms rent seek for permits where allocation mechanisms use "reserves", energy intensity targets and "safety valves" prior to the beginning of the scheme (Pizer, 2002; Newell et al., 2005). To introduce full auctioning of permits, the distribution of permits can be modelled as a multi-unit auction (see, Krishna, 2002). In this case, rent seeking influences the aggregate level of emissions but not the distribution of permits.

[3] Importantly, this does not require cooperation between market participants. Each participant rent-seeks in order to obtain a permit allocation for themselves. It is only as a result of this accumulated rent-seeking activity that provides pressure on the regulator to increase the aggregate emissions.

[4] As our focus is on the distributional impact of permit allocation and the subsequent affect on the tradable permit market and social welfare, we assume that regulated firms are the only rent seeking agents. This is conceivable when a draft legislation has been determined and the associated permit allocation is contestable, for example, one could interpret the political activity under the 'Waxman-Markey' Bill (H.R. 2454) or the lobbying surrounding the National allocation Plans (NAPs) in the EU-ETS as similar to our three-stage game. Environmental groups may also invest in rent seeking activity in order to influence the aggregate target, however, they would not participate in rent seeking for permit distribution. The determination of environmental policy under political influence from interest groups has been widely analysed. For surveys, see, for example, Keohane et al. (1998), Oates and Portney (2003) and Stavins

and each firm selects a level of pollution to emit in the market.

To model how the provisional aggregate emissions level in stage one differs from the final emissions level in stage two, we introduce an *exogenous* political "responsiveness" parameter $\mu \in [0, \bar{\mu})$ which is common knowledge among all firms and the regulator.[5] The political responsiveness parameter μ represents the political, cultural and governance relationships between the regulator and regulated firms. When $\mu = 0$ the regulator is unresponsive to aggregate rent seeking and the resulting aggregate emissions cap is simply the provisional aggregate emissions chosen by the regulator $\tilde{A}$. An upper bound on μ will exist where the responsiveness is sufficiently large to reduce the equilibrium permit price to zero. Typically, we may expect μ to be small, where an increase in rent seeking is smaller than the resulting increase in aggregate emissions. For $\mu > 0$, the regulator is responsive to firms' rent seeking efforts. Formally, the final aggregate emissions cap A set by the regulator is determined by

$$A = \tilde{A} \cdot \left(1 + \mu \sum_{i=1}^{n} s_i \right) \tag{1}$$

where the final rent available in the contest is endogenously determined by the regulator's initial draft legislation $\tilde{A}$ and aggregate rent seeking effort $\sum_i^n s_i$. We follow a framework similar to Helm (2003). To solve the subgame perfect Nash equilibrium, we solve the model using backward induction and as a result outline and solve stage three first.

3 Stage three: firms' choice of equilibrium emissions

In stage three, the tradable permit market commences and firm i selects a level of emissions. Assuming the equilibrium permit price p^* and the level of allocation a_i^0 obtained in stage two is taken as given (and hence the aggregate allocation A finalised in stage two),

(2004).

[5] The political responsiveness parameter represents the affect of *aggregate* rent-seeking effort on the regulator's choice of emissions. Even for values of $\mu = 0$, rent-seeking effort will continue to determine the distribution *among* firms. Negative values of μ can also be considered, however, this is less realistic for the context of rent-seeking for pollution permits. As Shaffer (2006) explains, allowing for $\mu < 0$ results in a destructive contest where the rent decreases in aggregate rent-seeking efforts.

firm i's payoff from the tradable permit market is:

$$\max_{e_i} \Pi_i = p^*(a_i^0 - e_i) - c_i(e_i) \qquad \text{for all } i = 1, 2, ..., n \tag{2}$$

where e_i is the level of net emissions (inclusive of abatement choices) and $c_i(e_i)$ is the abatement cost function where $c_i'(e_i) \leq 0$, $c_i''(e_i) \geq 0$. The term $(a_i^0 - e_i)$ shows firm i's net supply of permits to the market (which can also be negative). Given the levels of allocation to each firm (and the subsequent equilibrium permit price determined by the aggregate emissions), differentiating (2) with respect to e_i yields the following first order condition:

$$-p^* - c_i'(e_i) = 0 \qquad \text{for all } i = 1, 2, ..., n \tag{3}$$

which is solved for e_i^* and the market clearing condition is given by:

$$\sum_{i=1}^{n} e_i = A \tag{4}$$

The first order condition (3) states the familiar result that each firm will choose a level of emissions to equate their marginal abatement costs with the equilibrium permit price. Condition (4) is the market clearing condition where, in equilibrium, the aggregate emissions must equate to the aggregate supply of permits.

Differentiating (3) with respect to p^* and (4) with respect to A we obtain:

$$-1 - c_i''(e_i)\frac{\partial e_i}{\partial p^*} = 0 \qquad \text{for all } i = 1, 2, ..., n \tag{5}$$

$$\sum_{i=1}^{n} \frac{\partial e_i}{\partial p^*}\frac{\partial p^*}{\partial A} = 1 \qquad \text{for all } i = 1, 2, ..., n \tag{6}$$

where substitution yields:

$$\frac{\partial p^*}{\partial A} = -\left[\frac{1}{\sum_{i=1}^{n} \frac{1}{c_i''(e_i)}}\right] < 0 \tag{7}$$

Expression (7) shows that as the aggregate allocation increases, the equilibrium permit price decreases. Note that the extent of this depreciation is based on the slope of firms' marginal abatement costs, where steeper marginal abatement costs result in a larger change in the equilibrium permit price. As will be discussed later in the paper, the relationship in (7) is the key to understanding how rent seeking for ex post reallocated rents (such as pollution permits) differs from standard rents.

4 Stage two: firms' optimal rent seeking effort

In this stage, firm i selects a level of rent seeking effort to obtain an initial allocation of permits for the beginning of the tradable permit market in stage three. Let us assume that in stage one $\tilde{A}^0$ was chosen by the regulator where each firm knows that the final aggregate emissions cap for the tradable permit market is determined by $\tilde{A}^0 \left(1 + \mu \sum_{i=1}^{n} s_i\right)$. This rent seeking, from the view point of society, is unproductive. Formally, we represent the allocation of permits to firm i by:

$$a_i = \begin{cases} f(s_i, s_{-i})A & \text{if } \sum_{i=1}^{n} s_i > 0 \\ \frac{\tilde{A}}{n} & \text{otherwise} \end{cases} \qquad \text{for all } i = 1, 2, ..., n \tag{8}$$

where A is the aggregate emissions level given in (1) with $\tilde{A} = \tilde{A}^0$ and the contest success function is given by the conventional Tullock (1980) rent seeking model with constant returns to rent seeking and linear costs:[6]

$$f(s_i, s_{-i}) = \frac{s_i}{s_i + s_{-i}} \tag{9}$$

From (1), (8) and (9) observe that a_i is increasing in s_i and decreasing in s_{-i}. As shown above, rent seeking allows each firm to capture a share of the "pie" and simultaneously increase the aggregate emissions cap.

[6] Throughout the paper we use the interpretation of a divisible prize among agents. However, provided risk neutrality of the agents, a non-divisible rent, where there is a non-zero probability of winning, is functionally equivalent. Therefore, the alternative interpretation of this model is where agents participate in a contest for a single prize which can then be ex post reallocated after initial distribution.

4.1 Equilibrium effort

We now consider the incentives to rent seek for a permit allocation that can be ex post reallocated. Firms may invest in rent seeking effort to not only influence their own allowance of permits but, from (1), the aggregate allocation. This means that the permit price is endogenously determined by the level of aggregate allocation and hence the level of aggregate rent seeking effort.

Firm i now selects a level of rent seeking to maximise its payoff:

$$\max_{s_i} p^*(a_i - e_i^*(A(s_i))) - s_i - c_i(e_i^*(A(s_i))) \tag{10}$$

where $e_i^*(A)$ is the equilibrium level of emissions chosen in stage three, a_i is given by (8) and the cost of rent-seeking is given by s_i. Differentiating (10) with respect to s_i and noting from (3) that in the perfectly competitive market $\frac{\partial c_i}{\partial e_i} = p^*$ so that $p^* \frac{\partial e_i^*}{\partial s_i} = c_i'(e_i^*(A(s_i)))$ we obtain the following first order condition:[7]

$$p^* \frac{\partial a_i}{\partial s_i} + \frac{\partial p^*}{\partial A} \frac{\partial A}{\partial s_i}(a_i - e_i^*) - 1 = 0 \qquad \text{for all } i = 1, 2, ..., n \tag{11}$$

where

$$\frac{\partial a_i}{\partial s_i} = f'(s_i, s_{-i})A(s) + f(s_i, s_{-i})A'(s) \tag{12}$$

To begin our discussion on rent seeking strategies under ex post reallocation, note that (11) illustrates two important marginal effects on firm i's rent seeking effort. The first term in (11) shows a positive marginal effect where a unilateral increase in firm i's rent seeking will increase its permit allocation and wealth, given the permit price p^*. From (12) one can see, from the first term, that this positive marginal influence is based on the marginal increase in firm i's share of permits (given a fixed allocation) and, from the second term, a marginal increase in permits from an increase in the aggregate cap (given a constant share of permits). The effect of the second term in (11) is ambiguous and directly related to ex post reallocation. As will be discussed further below, when

[7] The second order conditions are satisfied for sufficiently small (absolute) values of $\frac{\partial^2 p^*}{\partial A^2}$. We assume throughout that the second order conditions are satisfied at the optimal levels.

rent seeking increases this may increase the aggregate emissions cap and decrease the equilibrium permit price. This is a positive marginal effect when the firm is an ex post net buyer of permits (i.e. $a_i - e_i^* < 0$), as permits now become cheaper to purchase. However, if the firm is an ex post net seller of permits (i.e. $a_i - e_i^* > 0$) this marginal effect is negative as the additional permits sold are now sold at a lower price. It follows from (11) that net buyers of permits tend to invest more in rent seeking than net sellers of permits. This result shows that allowing ex post reallocation in the form of a tradable permit market for rents creates a situation where equilibrium rent seeking effort is now dependent on equilibrium rents held.

4.2 Aggregate rent seeking effort

Our main focus in this paper is aggregate rent seeking effort and how this is affected by the regulation of pollution under a tradable permit market. To find aggregate rent seeking, (11) is summed over all n firms which is simplified a result of the market clearing condition (4) where, in equilibrium, the aggregate supply of permit will equal the aggregate emissions. Thus the first order conditions becomes:

$$p^* \sum_{i=1}^{n} \frac{\partial a_i}{\partial s_i} - n = 0 \tag{13}$$

From (13), the interior equilibrium solution exists when the aggregate marginal cost is equal to the marginal aggregate benefit of rent seeking. We assume for tractability a symmetric equilibrium $s = s_i = s_{-i}$. This assumption is less restrictive than may first appear as the incentive effects on rent seeking from the net demand (supply) or permits are eliminated under aggregation. Therefore (13) is driven solely by the aggregation of the marginal benefits and costs where a symmetric solution provides the fundamental elements for the regulated market.[8] Solving (13), yields the aggregate equilibrium rent

[8] This approach is common when considering aggregate effects in tradable permit markets. For example, Newell and Pizer (2003) and Fell et al. (2008) use a representative agent approach to estimate expected costs of climate change from alternative mechanisms.

seeking effort for regulated firms:

$$S^* = p^* \frac{(n-1)}{n} \frac{\tilde{A}^0}{1 - p^* \mu \tilde{A}^0} \tag{14}$$

for $p^* \mu \tilde{A}^0 < 1$ ($\bar{\mu} = \frac{1}{p^* \tilde{A}^0}$) where the marginal increase in value of the ex post reallocated rent $p^* \mu \tilde{A}^0$ is lower than the marginal cost of rent seeking, otherwise agents would choose the maximum possible level of resource-seeking. The major distinction between standard rent-seeking approaches and our ex post reallocation rent seeking strategy is that the equilibrium permit price now determines the market value for the ex post reallocation rent.

Differentiating the aggregate rent seeking strategy (14) with respect to the regulator's optimal allocation choice, reveals, after some manipulation:

$$\frac{\partial S^*}{\partial \tilde{A}^0} = \frac{(n-1)}{n} p^* \frac{[1 + \varepsilon_p]}{\left(1 - p^* \mu \tilde{A}^0\right)^2} \tag{15}$$

where $\varepsilon_p = \frac{\partial p^*}{\partial \tilde{A}^0} \frac{\tilde{A}^0}{p^*}$ is the elasticity of the equilibrium price level based on a change in the regulator's aggregate allocation choice.[9] In standard rents, $\frac{\partial S^*}{\partial \tilde{A}^0}$ is unambiguously positive as the increase in rent increases wealth. However, from (15), we see that the size of ε_p will determine whether $\frac{\partial S^*}{\partial \tilde{A}^0}$ is positive or negative. Importantly, we find increasing the total supply of permits has an ambiguous effect on rent seeking. This is in direct contrast to frameworks that investigate standard rents (Shaffer, 2006).

5 Stage one: regulator's optimal choice of aggregate emissions

In stage one, the regulator will select a level of aggregate emissions $\tilde{A}^*$. As a consequence the resulting aggregate emissions level will be determined by expression (1) so that $A^* = \tilde{A}^* \left(1 + \mu \sum_{i=1}^n s_i^*\right)$ where $\sum_{i=1}^n s_i^*$ are the aggregate rent seeking efforts from stage two.

[9] Note this is the inverse of a standard price elasticity of demand.

Let us initially assume that the regulator, such as the US EPA, is solely concerned about maximising social welfare in that region. We return to the case where the regulator is concerned about the attainment of political contributions at the end of this section.

5.1 The regulator's optimal choice of aggregate emissions

The regulator's aim is to maximise the net welfare W which consists of firms' net profits from the tradable permit market $\sum_{i=1}^{n} \Pi_i(A)$ minus the damage from the emissions and the cost of the (socially unproductive) rent seeking effort. More formally, the regulator's objective function is:

$$\max_{\tilde{A}} W = \sum_{i=1}^{n} \Pi_i(A) - D(A) - S^* \tag{16}$$

where $D(A)$ is the damage caused by emissions where $D'(A), D''(A) \geq 0$ and S^* is the aggregate rent seeking cost from all firms participating in the tradable permit market.

Using backward induction, the regulator knows equilibrium rent seeking effort by observing (14) that occurs in stage two according to a given level of μ and A. In order to show the regulator's optimal choice of allocation, it is important to compare this result to the socially optimal case when there exists no rent seeking effort. That is, what aggregate allocation level would the regulator choose under the presence of zero rent seeking? As shown in Appendix A, when zero rent seeking occurs the regulator selects an aggregate emissions cap so that:

$$p^* = \frac{\partial D(A)}{\partial A} \tag{17}$$

which is optimally solved for $\tilde{A}^B$ (here we have $\frac{\partial A}{\partial \tilde{A}} = 1$ hence $\frac{\partial D(A)}{\partial A} = \frac{\partial D(A)}{\partial \tilde{A}}$). This states that the regulator should set a level of aggregate emissions so that the marginal benefit (the equilibrium permit price) is equated to the marginal damage of emissions.

In order to solve for the regulator's optimal aggregate allocation in (16), we first sum over all firms' profit functions which gives $-\sum_{i=1}^{n} c_i(e_i)$ and differentiating with respect to $\tilde{A}$ yields:

$$-\sum_{i=1}^{n} \frac{\partial c_i}{\partial e} \frac{\partial e^*}{\partial A} \frac{\partial A}{\partial \tilde{A}} \tag{18}$$

Using (3), this simplifies to:

$$p^* \frac{\partial A}{\partial \tilde{A}} \sum_{i=1}^{n} \frac{\partial e_i^*}{\partial A} \tag{19}$$

and noting that $\frac{\partial e^*}{\partial A} = 1$, this reduces to:

$$\frac{\partial}{\partial \tilde{A}} \left(\sum_{i=1}^{n} \Pi_i(A) \right) = p^* \frac{\partial A}{\partial \tilde{A}} \tag{20}$$

Differentiating (16) with respect to $\tilde{A}$ and substituting in (20) yields the regulator's first order condition:[10]

$$p^* \frac{\partial A}{\partial \tilde{A}} - \frac{\partial S^*}{\partial A} \frac{\partial A}{\partial \tilde{A}} - D'(A) \frac{\partial A}{\partial \tilde{A}} = 0 \tag{21}$$

Therefore $\tilde{A}^*$ is chosen so that (21) holds. Note there are three influences on the regulator's optimal choice of allocation. First there is an *upward* influence in the form of marginal increase in firms' profit due to the increased aggregate allocation $p^* \frac{\partial A}{\partial \tilde{A}}$. Note that $\frac{\partial S^*}{\partial A} \frac{\partial A}{\partial \tilde{A}}$ which is shown in (15) has an ambiguous influence in terms of the marginal change in optimal aggregate rent seeking effort and finally a downward influence due to the additional damage produced. Furthermore, we obtain an expression that allows analysis of the aggregate emissions level:

Lemma 1 *In the presence of rent seeking effort, the regulator's optimal choice of aggregate allocation* $\tilde{A}^*$ *is chosen so that:*

$$p^* \Delta = \frac{\partial D(A)}{\partial A} \tag{22}$$

where $\Delta = \left[1 - \frac{(n-1)}{n} \frac{[1+\varepsilon_p]}{\left(1+\mu S^* \left(1+\frac{[1+\varepsilon_p]}{(1-p^*\mu\tilde{A})}\right)\right)\left(1-p^*\mu\tilde{A}\right)^2} \right]$.

Proof. See Appendix B. ■

Direct comparison of (17) and (22) show that aggregate emissions are only socially optimal when $\Delta = 1$, that is $|\varepsilon_p| = 1$, where the change in the equilibrium permit price is equal to the change in the regulator's choice of allocation.

[10]The second order conditions are satisfied for the optimal value given a sufficiently small (absolute) $\frac{\partial^2 S^*}{\partial A^2}$.

To observe the influence of ε_p on the regulator's choice of aggregate emissions, let us begin by analysing the case were the regulator is unresponsive to rent seeking $\mu = 0$. Given $\mu = 0$, the regulator's choice of allocation becomes:

$$p^* \left[1 - \frac{(n-1)}{n}\left[1 + \varepsilon_p^0\right]\right] = \frac{\partial D(A)}{\partial A}$$

which shows that for $\left|\varepsilon_p^0\right| > 1$, aggregate emissions are larger than socially optimal. Emissions increase as the reduction in rent seeking is relatively larger than the increase in damages from additional emissions. Similarly, when $\frac{1}{n+1} < \left|\varepsilon_p^0\right| < 1$, the change in equilibrium price is relatively unresponsive so that any increase in emissions will increase damages more than the benefit from reduced rent seeking effort.

For the case of a responsive regulator, the analysis is similar. Let us first consider the case when $\Delta > 1$. Notice from Lemma 1 that $\Delta > 1$ does not occur for $|\varepsilon_p| < 1$. That is, if an inelastic ε_p occurs, the change (reduction) in rent seeking is small, therefore the reduction in rent seeking does not outweigh the damages of additional emissions. Instead let us concentrate on $|\varepsilon_p| > 1$. To ensure that Δ remains positive let us focus on elasticity levels of the range $1 < |\varepsilon_p| < |\bar{\varepsilon}_p|$ where $|\bar{\varepsilon}_p|$ is defined by:[11]

$$[1 + \bar{\varepsilon}_p] = -\frac{\left(1 - p^*\mu\tilde{A}^0\right)}{(n-1)p^*\mu\tilde{A}^0}\left[n - p^*\mu\tilde{A}^0\right] < 0$$

Aggregate emissions are above the socially optimal ($A^* > \tilde{A}^B$) level as a relative responsiveness equilibrium permit price $1 < |\varepsilon_p| < |\bar{\varepsilon}_p|$, results in relatively larger rent seeking reductions. Counter-intuitively, it is not the actual rent seeking that increases the aggregate emissions but the reduction in social costs associated with a reduction in rent seeking that allows the regulator to issue additional permits.

Finally, consider $\Delta \in (0, 1)$. In order to do this, we have to define the limits of ε_p. Firstly, we can define a lower bound of $|\varepsilon_p|$ for which $\Delta > 0$. This occurs when $|\varepsilon_p| > \left|\varepsilon_p^T\right|$

[11] For $|\varepsilon_p| > |\bar{\varepsilon}_p|$, Δ still may be positive but result in a lower aggregate allocation than socially optimal. In this case, the price is extremely sensitive, so much so that, the regulator's optimal choice of aggregate emissions is chosen below the socially optimal level.

where ε_p^T is determined by:

$$\left[1+\varepsilon_p^T\right] = \frac{\frac{n}{n-1}\left(1-p^*\mu\tilde{A}\right)^2(1+\mu S^*)}{1-\frac{n}{n-1}\left(1-p^*\mu\tilde{A}\right)\mu S^*}$$

Similarly, we can define the lower bound by $\hat{\varepsilon}_p$ is determined by:

$$[1+\hat{\varepsilon}_p] = \frac{1+\mu S^*}{1-\frac{\mu S^*}{1-p^*\mu\tilde{A}^0}}$$

When $|\hat{\varepsilon}_p| > |\varepsilon_p| > \left|\varepsilon_p^T\right|$, the inelastic price changes are not enough to outweigh the increase in damages. As a result, actual aggregate emissions tend to be smaller than socially optimal as the regulator takes this into account and reduces the amount of permits available ($A^* < \tilde{A}^B$).

5.2 Regulatory responsiveness and welfare

From above, we were able to show that the regulator's optimal choice of allocation depends on how responsive the equilibrium permit price is to changing allocations. Another type of responsiveness is that of the regulator towards the setting of the initial allocation. Can a change in regulatory responsiveness (i.e. a change in rent seeking culture) change welfare? That is, given the optimal regulator's decision determined in (22), how does changing the responsiveness parameter μ alter welfare for society?

Solving for $\frac{dW}{d\mu}$, shows how the regulator's responsiveness alters welfare.

Proposition 1 *The welfare change given by an increase in the regulator's responsiveness is:*

$$\frac{dW}{d\mu} = [p^* - D'(A^*)]\frac{\partial A^*}{\partial \mu} - \frac{\partial S^*}{\partial \mu}$$

Proof. See Appendix B. ■

From Proposition 1, two main factors determine whether increasing responsiveness changes welfare. The first term $[p^* - D'(A^*)]\frac{\partial A^*}{\partial \mu}$ shows the distance away from the socially optimally level of allocation which is derived in Lemma 1. Under a socially optimal emissions cap, expression (17) shows that $p^* - D'(A^*) = 0$. However, Lemma 1 shows that, in most cases this tends to be non-zero. In fact, when $p^* - D'(A^*) < 0$ emissions are larger than socially optimal and tend to reduce welfare given a change in responsiveness (an additional increase in emissions away from the socially optimal level will reduce welfare whereas when $p^* - D'(A^*) > 0$ and an increase in responsiveness moves emissions closer to the socially optimal level and improves welfare). Second, the marginal change in rent seeking alters welfare.

Everything else constant, Proposition 1 shows that a reduction in rent seeking unambiguously improves welfare. This is not surprising as rent seeking is a socially unproductive activity. However, from Lemma 1 it is unclear as to the net effect on welfare given a change in responsiveness. Implicit differentiation of (14) with respect to μ reveals:

$$\frac{\partial S^*}{\partial \mu} = \frac{S^*}{p^*\left(1 - p^*\mu\tilde{A}^*\right)}\left[\frac{\partial p^*}{\partial \mu} + \tilde{A}^0(p^*)^2\right] \tag{23}$$

In terms of changing rent seeking effort, (23) shows that as regulatory responsiveness increases, the change to social welfare is affected by two opposing factors. Using the chain rule we know $\frac{\partial p^*}{\partial \mu} = \frac{\partial p^*}{\partial A^*}\frac{\partial A^*}{\partial \mu}$. Differentiation of (1) with respect to μ yields:

$$\frac{\partial A^*}{\partial \mu} = \tilde{A}^* \cdot \left(S^* + \mu\frac{\partial S^*}{\partial \mu}\right) \tag{24}$$

Substituting (24) into (23) and collecting $\frac{\partial S^*}{\partial \mu}$ terms yields:

$$\frac{\partial S^*}{\partial \mu} = \frac{\left[\frac{\partial p^*}{\partial A^*}S^* + (p^*)^2\right]}{\frac{p^*\left(1-p^*\mu\tilde{A}^*\right)}{S^*\tilde{A}^*} - \mu\frac{\partial p^*}{\partial A^*}} \tag{25}$$

where $\frac{\partial p^*}{\partial A^*}$ is given by (7). The denominator of (25) is always positive therefore the sign of $\frac{\partial S^*}{\partial \mu}$ is determined by $\left[\frac{\partial p^*}{\partial A^*}S^* + (p^*)^2\right]$. The first effect $\frac{\partial p^*}{\partial A^*}S^*$ we denote as the *price effect.* When responsiveness increases, the equilibrium price per unit of emissions decreases which reduces socially wasteful rent seeking and improves welfare (net of damages associated with increased emissions). This effect is absent in standard rent seeking frameworks and is due to the changing equilibrium permit price altering the value of the ex post reallocated rent. Second, the *wealth effect* $(p^*)^2 > 0$ has a dampening affect on social welfare. Increased responsiveness results in a larger supply of permits distributed to firms which increases rent seeking effort and reduces social welfare. When the wealth effect dominates the price effect, marginal rent seeking effort is positive $\left(\frac{\partial S^*}{\partial \mu} > 0\right)$ and this reduces social welfare whereas when $\frac{\partial p^*}{\partial \mu} + \tilde{A}^0(p^*)^2 < 0$ the price effect dominates the wealth effect which results in negative marginal rent seeking activity $\left(\frac{\partial S^*}{\partial \mu} < 0\right)$ and an improve in social welfare.

5.3 The regulator and political contributions

Up to this point, we have considered a regulator that acts benevolently by selecting a level of aggregate emissions to maximise social welfare where it views rent seeking as socially wasteful. However, it is clear that regulators (politicians) may obtain a benefit in the form of political contributions which may alter the incentives to select the level of aggregate emissions (Hillman, 1982; Grossman and Helpman, 1994). In this subsection, we extend our model by allowing the regulator to optimise the standard social welfare function with the additional (weighted) political contribution benefits.

To show this, let us assume that the regulator obtains political contributions from rent seekers given by βS^* where $\beta > 0$ is an exogenous parameter representing the extent to which the regulator can attain political contributions from rent seekers. From the regulator's payoff function in (16) we know that the net gain from rent seeking is given by $(\beta - 1)S^*$. When $0 < \beta < 1$ the net benefit from the political contributions is negative and similar (but augmented) results are found to the case when the regulator attains no political contributions. However when $\beta > 1$ the net benefits of attaining political contributions are positive and additional results exist. In particular, the regulator's choice of emissions is now determined by

$$p^* \left[1 + (\beta - 1)\frac{(n-1)}{n} \frac{[1+\varepsilon_p]}{\left(1 + \mu S^* \left(1 + \frac{[1+\varepsilon_p]}{(1 - p^* \mu \tilde{A})}\right)\right)\left(1 - p^* \mu \tilde{A}\right)^2} \right] = D'(A) \qquad (26)$$

In contrast to the previous case, the regulator has an incentive to increase emissions when the elasticity ε_p (given a change in the allocation) is inelastic $|\varepsilon_p| < 1$. Intuitively, as the price is unresponsive, an increase in emissions results in only a small decrease in price and consequently rent seeking effort continues to be relatively large which produces a large amount of political contributions for the regulator. A similar analysis can also be considered for $|\varepsilon_p| > 1$.

We can also analyse the effect on the regulator's payoff when there is a change in the exogenous parameter μ. Unlike the case where there are no political contributions, we find a larger wealth effect will improve the payoff of the regulator whereas a stronger price effect will result in a lower payoff for the regulator.

6 Discussion

In the majority of current tradable pollution permit markets, rent seeking behaviour is a common occurrence. Both under the EU-ETS and U.S. legislation on climate change, such as the 'Waxman-Markey' Bill (HR. 2454), significant lobbying has been invested in order to capture rents. Although rent seeking behaviour is socially wasteful, to what extent does this behaviour affect the consequences of implementing these schemes? This paper has attempted to model incentives for firm and regulator behaviour in a tradable permit market when lobbying can influence the total supply of permits, their initial allocation to individual firms, and where the value of each permit (and thus of rents) depends on ex-post permit trading.

An important contribution of this paper is to show that the incentive to rent seek for tradable pollution permit differs from traditional rents. This is a result of the market creating an equilibrium permit price which influences the rent seeking incentives of firms and the selection of aggregate emissions by the regulator. Therefore to draw meaningful conclusions about the social welfare consequences of this type of rent seeking, one must consider the effects on aggregate emissions and the level of rent seeking. Two opposing effects determine impacts on social welfare. Increased responsiveness (or simply increases in aggregate emissions) will create additional damages, however, the additional supply will decrease the market clearing price and thus reduce the rent seeking activity. Counter-intuitively, it is possible that a regulator's increased responsiveness may actually improve welfare. That is, the reduction in rent seeking creates larger benefits that the additional damages from increased emissions.

From (7) we can see that the change in the equilibrium permit price is based on the slopes of firms' marginal abatement cost functions. That is, relatively steeper marginal abatement costs functions (i.e. each additional unit of abatement is relatively more expensive), result in a more responsive equilibrium permit price. Therefore, it follows that in markets where firms' marginal abatement cost functions are steep and rent seeking is a significant and costly problem, a regulator could increase welfare when regulatory responsiveness exists. This suggests that a "pay no attention to lobbying" rule would not necessarily be the best choice for a regulator in an actual permit market.[12]

7 Conclusion

A contentious and demanding aspect of a regulator's role in a tradable permit market is the initial allocation of permits. In particular, the determination of the aggregate emissions cap and the distribution of permits among participants remain controversial issues. As with most valuable rents, a significant amount of rent seeking effort tends to be employed in actual permit markets to influence both the size and the distribution of the rents. Yet in contrast to traditional contestable rents, tradable rents, such as tradable pollution permits, allow for ex post reallocation. It is important to understand how this alters agents' incentives to rent seek.

To do this, we introduce a contest where polluting firms in a tradable permit market have the option to invest in rent seeking effort that has the potential to increase (i) their own permit allocation within the tradable permit market and (ii) the aggregate supply of permits from the regulator (i.e. political pressure to increase the aggregate level of

[12]Steep marginal abatement cost may actually cause significant amounts of rent-seeking as these firms tend to find investment in abatement relatively expensive and are more likely to consider investing in rent-seeking as an alternative. Steeper marginal abatement costs may well characterise greenhouse gas control policy in the near future as increasingly ambitious targets are set for emission reductions, and simple, cheap abatement options get used up.

emissions). The regulator selects a provisional aggregate emissions target but this can be influenced by firms' rent seeking effort. We analyse two cases where the regulator views rent seeking as 'purely' socially wasteful and where the regulator obtains political contributions from rent seekers. We show the incentives behind firms' rent seeking effort in a tradable permit market and compare this to a standard rent seeking framework. We find individual rent seeking strategies depend on whether, in equilibrium, the firm is a net buyer or seller of the ex post reallocated rent (initial allocation of permits). Regulator's optimal allocation choices are shown to depend on the responsiveness of price to changes in allocations, whilst variations in the responsiveness of regulators to lobbying (shown by the parameter μ) are shown to have potentially positive or negative consequences for social welfare.

The analysis presented here suggests that a regulator should try to understand the likely effects of rent seeking on the equilibrium permit price (and thus the value of the ex post reallocated rent) and the social loss created by rent seeking. We show that the equilibrium permit price effect has the potential to decrease socially wasteful rent seeking effort and in some cases can improve welfare when the regulator's responsiveness to aggregate rent seeking actually increases – a surprising result, in some senses. Allowing ex post reallocation creates a price effect that influences the equilibrium levels of rent seeking not seen in the traditional contestable rents story.

Due to the current political debate that surrounds the initial distribution of pollution permits to regulated firms, this framework has focused solely on the rent seeking of polluting firms. However, environmental groups also invest in rent seeking and often try and influence draft legislation. It is possible to extend this analysis to include rent seeking of environmental groups to alter the initial choice of aggregate emissions that regulated firms contest. Introducing this as well as the effects of coordinated interest groups on social welfare are left for future research. Moreover, it would be interested to consider a dynamic version of the model where permit markets go through a phase of initial allocations over time, as has happened for example with Phase 1 and Phase 2 of the EU ETS. Allowing permit allocations in period t+1 to partly depend on holdings at the end of period t introduces complications to efficiency properties of tradable permit markets, as we have shown elsewhere (MacKenzie et al, 2008), which would be relevant to incentives for lobbying on the part of individual firms.

Appendix A

Proof of derivation for regulator's benchmark case:

Proof. For zero rent seeking activity, firm i objective function is:

$$\Pi_i = p^*(a_i^* - e_i^*) - c_i(e_i^*)$$

for optimal choices (e_i^*, a_i^*). The social welfare function is:

$$\max_{\tilde{A}} W = \sum_{i=1}^{n} \Pi_i - D(A)$$

Given that $a_i^* = A/N = \tilde{A}/N$ and $\frac{\partial A}{\partial \tilde{A}} = 1$. The first order condition is:

$$\frac{\partial \Pi_i}{\partial \tilde{A}} = \frac{\partial p^*}{\partial \tilde{A}}(a_i^* - e_i^*) + p^*(1/N - \frac{\partial e^*}{\partial p^*}\frac{\partial p^*}{\partial \tilde{A}}) - \frac{\partial c_i}{\partial e}\frac{\partial e^*}{\partial p^*}\frac{\partial p^*}{\partial \tilde{A}}$$

which can be simplified by using (3) so that:

$$\frac{\partial \Pi_i}{\partial \tilde{A}} = \frac{\partial p^*}{\partial \tilde{A}}(a_i^* - e_i^*) + p^*/N$$

Summing over all firms yields:

$$\sum_{i=1}^{n} \frac{\partial \Pi_i}{\partial \tilde{A}} = p^*$$

Substituting into the regulator's welfare function yields:

$$p^* = D'(A)$$

■

Appendix B

Proof of Lemma 1:

Proof. Using (1) and (14), it is known that $\frac{\partial A}{\partial \tilde{A}} = 1+\mu S^* \left(1 + \frac{[1+\varepsilon_p]}{(1-p^*\mu\tilde{A})}\right)$ and substituting (15) into (21) yields:

$$p^*\left(1+\mu S^*\left(1+\frac{[1+\varepsilon_p]}{\left(1-p^*\mu\tilde{A}\right)}\right)\right)-\frac{(n-1)}{n}p^*\frac{[1+\varepsilon_p]}{\left(1-p^*\mu\tilde{A}\right)^2}=D'(A)\left(1+\mu S\left(1+\frac{[1+\varepsilon_p]}{\left(1-p^*\mu\tilde{A}\right)}\right)\right)$$

rearranging yields:

$$p^*\left[1-\frac{(n-1)}{n}\frac{[1+\varepsilon_p]}{\left(1+\mu S^*\left(1+\frac{[1+\varepsilon_p]}{(1-p^*\mu\tilde{A})}\right)\right)\left(1-p^*\mu\tilde{A}\right)^2}\right]=D'(A)$$

■

Proof of Proposition 1:

Proof. Totally differentiating (16) with respect to μ yields:

$$\frac{dW}{d\mu}=\frac{\partial W}{\partial \mu}+\frac{\partial W}{\partial \tilde{A}^*}\frac{d\tilde{A}^*}{d\mu}$$

where $\tilde{A}^*$ is the optimally chosen allocation level given by Lemma 1. Given the Envelope Theorem, this is simplified to

$$\frac{dW}{d\mu}=\left.\frac{\partial W}{\partial \mu}\right|_{\tilde{A}=\tilde{A}^*}$$

where $\tilde{A}$ is held fixed at the regulator's optimal level $\tilde{A}^*$. For the aggregate payoff for firms:

$$\frac{\partial \Pi_i}{\partial \mu}=\frac{\partial p^*}{\partial A^*}\frac{\partial A^*}{\partial \mu}(a_i^*-e_i^*)+p^*(\frac{\partial a_i^*}{\partial A^*}\frac{\partial A^*}{\partial \mu}-\frac{\partial e^*}{\partial p^*}\frac{\partial p^*}{\partial A^*}\frac{\partial A^*}{\partial \mu})-\frac{\partial c_i}{\partial e^*}\frac{\partial e^*}{\partial p^*}\frac{\partial p^*}{\partial A^*}\frac{\partial A^*}{\partial \mu}$$

which is simplified to:

$$\frac{\partial \Pi_i}{\partial \mu}=\frac{\partial p^*}{\partial A^*}\frac{\partial A^*}{\partial \mu}(a_i^*-e_i^*)+p^*\frac{\partial a_i}{\partial A^*}\frac{\partial A^*}{\partial \mu}$$

and summing over all firms:

$$\sum_{i=1}^{n} \frac{\partial \Pi_i}{\partial \mu} = p^* \sum_{i=1}^{n} \frac{\partial a_i^*}{\partial A^*} \frac{\partial A^*}{\partial \mu} = p^* \frac{\partial A^*}{\partial \mu}$$

which is substituted to yield:

$$\frac{dW}{d\mu} = p^* \frac{\partial A^*}{\partial \mu} - \frac{\partial S^*}{\partial \mu} - D'(A^*) \frac{\partial A^*}{\partial \mu}$$

and rearranging gives:

$$\frac{dW}{d\mu} = [p^* - D'(A^*)] \frac{\partial A^*}{\partial \mu} - \frac{\partial S^*}{\partial \mu}$$

■

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