Rent Seeking over Tradable Emission Permits*

Ashwin Rode[†]

February 16, 2020

Department of Economics
University of Chicago
1126 E. 59th St.
Chicago, IL 60637 USA
Phone: +1 281 795 8930
Fax: +1 773 702 8490
Email: aarode@uchicago.edu

*This paper has benefited greatly from the feedback of others, most notably Bob Deacon, Olivier Deschenes, Kyle Meng, Paulina Oliva, Sanjay Patnaik, Dick Startz, and Douglas Steigerwald. I am also grateful for the valuable comments offered by participants in the Econometrics Research Group and Environmental Lunch Seminar at UC Santa Barbara. While conducting this research, I was a recipient of the Joseph L. Fisher Doctoral Dissertation Fellowship, awarded by Resources for the Future.

†Department of Economics/Energy Policy Institute at Chicago, University of Chicago

Rent Seeking over Tradable Emission Permits

February 16, 2020

Abstract

The allocation of emission permits at no cost during the establishment of a cap-and-trade program creates opportunities for rent-seeking. I examine the consequences of such rent-seeking by exploiting an unusual feature of the UK's permit allocation procedure in Phase 1 of the EU's CO_2 Emissions Trading Scheme, whereby it is possible to observe both a firm's actual permit allocation as well as an earlier, technocratically-based provisional allocation that was never implemented. Firms had the opportunity to appeal their provisional allocation. I find that a firm's financial connections to members of the House of Commons strongly predict its post-appeal allocation. Even after controlling for the provisional allocation, along with industry and financial characteristics, a connection to an additional member is associated with a significant increase in a firm's actual permit allocation. Using results from a contest-theoretic framework, I estimate the welfare loss from rent-seeking to be over 100 million euros- a significant amount relative to the abatement costs firms incurred to reduce emissions.

JEL classification: D72, H23, Q58

Keywords: Rent Seeking, Environmental Economics, Tradable Permits, Political Connections

1 Introduction

Emission permit trading programs, which have become an important part of environmental and climate change regulation worldwide, aim to limit emissions of a pollutant by creating a fixed supply of tradable emission permits (i.e. an emissions "cap"). A common feature of nearly all existing and proposed programs is the free allocation of a subset of permits to regulated firms at the outset of the program. Such "grandfathering" of free permits represents a distributional tool that can offset regulatory costs for the receiving firms and thus reduce political opposition to the policy (Stavins, 1998; Fowlie, 2010), while not altering its overall cost or environmental goals (Coase, 1960; Montgomery, 1972; Brandt and Svendsen, 2004).

Notwithstanding these attractive properties, however, grandfathering can also open the door to rent-seeking behavior. The basic concept of rent seeking posits that when public policy results in a transfer, economic agents will direct resources towards competing for the transfer. Starting with the initial work of Tullock (1967), rent-seeking efforts have been viewed as socially unproductive because the resources could have been instead used productively to add to income. Because permits represent valuable economic assets, it is plausible that a regulated firm will engage in rent seeking to increase its allocation. This idea has been conjectured in the non-academic press[1], articulated more formally by Nordhaus (2006, 2007), and theoretically developed by Hanley and MacKenzie (2010), but with few exceptions, has received little empirical attention (Joskow and Schmalensee, 1998; Hanoteau, 2003; Brandt and Svendsen, 2004; Anger et al., 2008). Moreover, no attempt has been made to quantify the welfare consequences of rent-seeking in an emission permit trading context.

In this paper, I exploit a unique feature in the implementation of Phase 1 of the European Union's (EU's) Emissions Trading Scheme (ETS) in the UK, along with a theoretical model of a rent-seeking contest for permits, to quantify the distributional consequences and overall welfare loss from rent seeking. The EU ETS gave away tradable carbon dioxide (CO_2) emission permits to nearly 12,000 industrial plants (known as "installations") across Europe. Prior to the beginning of the scheme in 2005, each member state was responsible for allocating its national emissions cap to installations within its borders. My empirical approach exploits an unusual feature of the permit allocation procedure in the UK. For the vast majority of installations in the UK (representing over 90% of the national cap), I observe not only the actual number of permits allocated, but also the number of permits the installation

[1] See for example, "Soot, smoke and mirrors: Europe's flagship environmental programme is foundering" in *The Economist*, Nov. 16, 2006. See also, "Britain's worst polluters set for windfall of millions" in *The Guardian*, Sept. 12, 2008.

would have received under a provisional allocation plan published one year prior to the final, realized allocation plan. In the intervening year, firms could appeal their provisional allocations. Because the national cap remained virtually identical in the two allocation plans, efforts by firms to secure higher allocations for themselves took place in the context of a zero-sum game. This setting provides a unique opportunity to study the implications of rent-seeking behavior. While the provisional allocation plan was based on technocratic forecasts of future emissions, the final plan reflected lobbying activity during the appeal period (Mallard, 2009; Duggan, 2009). Due to the structure of the allocation process, the appeal period in particular became the locus of lobbying activity related to allocations. The UK government explicitly invited "consultation" regarding specific allocations only after the release of the provisional allocation plan, and firms responded vigorously to this invitation. For example, on a February day in 2004, thousands of executives filled an exhibition center in Birmingham to question government officials on the recently published provisional plan (Duggan, 2009).

To represent the distributional and efficiency considerations inherent in this setting, I model a rent-seeking contest in which polluting firms can influence their permit allocations through lobbying. Unlike the model of Hanley and MacKenzie (2010), firms in my model face heterogeneous marginal costs of lobbying (Franke et al., 2013). The differences in lobbying costs affect not only the amount of resources a firm devotes to lobbying but also whether or not a firm chooses to pursue lobbying at all. The model generates predictions about the allocation of the permit endowment among firms as well as the welfare loss from resources wasted in rent-seeking. In particular, all else being equal, a firm's equilibrium permit allocation is decreasing in its marginal cost of lobbying, and the total amount spent on rent-seeking by all firms is equal to the value of the contested rents.

As an empirical proxy for a firm's cost of lobbying, I utilize data on the firm's pre-existing financial connections to members of the House of Commons. Although members were not directly involved in the permit allocation process, a firm's connections to members are plausibly indicative of how easily it can exert influence in diverse regulatory spheres. I find that a connection to an additional member is associated with a significant increase in a firm's realized permit allocation, even after controlling for the firm's provisional allocation, industry and other characteristics. Although there exist no direct records of lobbying expenditures, the theoretical results on rent-dissipation provide a basis for a calculation of how much was spent on rent-seeking over permits in the UK. I estimate the welfare loss from rent-seeking in the UK alone to be over 100 million euros. This is a non-trivial amount when juxtaposed against available estimates of total annual emission abatement costs firms incurred under the EU ETS, which are in the range of 450 million to 900 million euros for the entire EU (Ellerman et al., 2010).

The rest of the paper is organized as follows: Section 2 presents a model of a rent-seeking contest for emission permits; Section 3 explains the institutional details of permit allocation in the EU ETS; Section 4 describes the data sources and contains empirical tests of the model's predictions; Section 5 concludes.

2 A Rent-Seeking Contest for Emission Permits

2.1 Structure of the Contest

Consider a competitive emission permit market with an emissions cap of $\bar{A}$, in which n firms are to participate. Although emission permits are allocated at no cost, the realized allocations are influenced by the lobbying efforts of firms. The contest for permits begins with the regulator announcing a provisional allocation for each firm. The emissions cap constrains the regulator's choice of allocations; letting $A_i \geq 0$ denote the provisional allocation for firm i, it is required that $\sum_{i=1}^{n} A_i = \bar{A}$. After the provisional allocations are announced, a portion of the cap is reallocated based on firms' lobbying efforts. Formally, let $x_i \geq 0$ denote the lobbying effort of firm i and let $\widetilde{A}_i$ denote firm i's realized, post-contest allocation of permits. The post-contest allocation of firm i is given by:

$$\widetilde{A}_i = \begin{cases} A_i^{1-\gamma} + \left(\frac{x_i}{\sum_{j=1}^{n} x_j}\right)\phi & if\ \sum_{j=1}^{n} x_j > 0 \\ A_i & otherwise \end{cases} \qquad \forall i = 1, 2, ..., n, \tag{1}$$

where $\phi \equiv \sum_{i=1}^{n}\left[A_i - A_i^{1-\gamma}\right]$.[2]

The formula specified in (1) is purely redistributive in that the sum of the post-contest allocations of all firms is the same as the sum of the provisional, pre-contest allocations of all firms, both equalling the total cap $\bar{A}$.[3] The variable ϕ expresses the number of permits subject to contest, and the number of permits an individual firm captures in the contest is proportional to the ratio of its own lobbying effort to the total lobbying efforts of all firms.[4]

The parameter $\gamma \in [0, \infty)$, which is common knowledge to the firms and regulator, determines the value of ϕ. In particular, γ represents the extent to which the regulator can be swayed by lobbying efforts. For instance, if $\gamma = 0$, lobbying has no influence on the regulator, and provisional allocations stand unchanged.[5] At the other extreme, as γ converges to ∞, the provisional allocations are completely overridden, and the realized allocations depend solely on relative lobbying efforts.

After allocations are realized according to (1), firms make decisions about how much output to produce and how much of the pollutant to emit. Firm i produces output according to a strictly concave, twice differentiable production function $q_i(e_i, z_i)$, where e_i denotes emissions and z_i denotes a vector of other inputs. Let p, τ, and η respectively denote the prices of output, emission permits, and other factors. Let ω_i denote firm i's unit cost of lobbying effort. Firm i's profit maximization problem is

[2] Equivalently, $\phi \equiv \bar{A} - \sum_{i=1}^{n} A_i^{1-\gamma}$.

[3] Unlike Hanley and MacKenzie (2010), I allow rent-seeking to influence only the allocation of the cap, not the cap itself. In the case I study empirically, there is no evidence that lobbying shifted the overall cap.

[4] This contest function dates back to Tullock (1980) and has been widely used since (Grossman, 2001; Hodler, 2006; Hanley and MacKenzie, 2010). Skaperdas (1996) argues that the class of functions propounded by Tullock (1980), which is based on ratios of efforts, is the only class that satisfies a number of desirable and plausible properties of a contest function.

[5] The provisional allocations also remain unchanged regardless of the value of γ if no firm undertakes any lobbying.

$$\underset{e_i,x_i,z_i}{\boldsymbol{Max}}\, pq_i(e_i, z_i) - \eta z_i - \omega_i x_i - \tau(e_i - \widetilde{A}_i), \tag{2}$$

where $\widetilde{A}_i$ is defined by (1).

The firm's demand for emissions and other inputs to production are implicitly defined by the first order conditions for an interior solution to this profit maximization problem.[6] Although the firm's profits are increasing in its permit allocation, it is straightforward to show that the firm's optimal choice of emissions and other inputs are independent of its permit allocation, and that in equilibrium the marginal product of emissions will be equalized across all firms. These properties, which accord with the textbook case of emission permit trading (Montgomery, 1972), allow production decisions to be separated from lobbying decisions. Unlike in models of imperfect competition (Hahn, 1984) or transaction costs (Stavins, 1995) in the permit market, inefficiencies do not arise in this model due to a breakdown of the equimarginal principle; instead efforts wasted in lobbying are the sole source of social losses.[7]

Hence firm i's choice of lobbying effort can be isolated to the following maximization problem:

$$\underset{x_i \geq 0}{\boldsymbol{Max}}\, \tau\widetilde{A}_i - \omega_i x_i, \tag{3}$$

where firm i takes as given the lobbying efforts of other firms. Next, I solve for the Nash equilibrium of such a contest with n firms.

[6] I assume that firms are price-takers. This assumption would clearly not be reasonable, for example, in the extreme case where a single firm receives all the permits and behaves as a monopolist. However, studies suggest that market power is not a major concern in the EU ETS (Convery and Redmond, 2007; Hahn and Stavins, 2011).

[7] The equimarginal condition will fail to hold if efforts devoted to lobbying somehow hampered production. However, for the purposes of the model, I abstract away from this potential source of inefficiency, focusing only on the efforts wasted in lobbying.

2.2 Nash Equilibrium with n Firms

Differentiating (3) with respect to x_i yields the following first order conditions for an interior solution:

$$\tau\phi\frac{x_{-i}}{(x_i+x_{-i})^2} = \omega_i \ , \tag{4}$$

where x_{-i} refers to the sum of lobbying efforts of firms other than firm i. These conditions state that each firm chooses a level of lobbying effort that equalizes its marginal benefits and marginal cost.[8]

The first order conditions together with the non-negativity constraints on lobbying efforts lead to the following best response functions:

$$x_i = \begin{cases} \sqrt{\frac{\tau\phi x_{-i}}{\omega_i}} - x_{-i} & if\, x_{-i} \in (0, \frac{\tau\phi}{\omega_i}) \\ 0 & if\, x_{-i} \geq \frac{\tau\phi}{\omega_i} \end{cases} \qquad for\, i = 1, 2\ , ...n. \tag{5}$$

A strategy profile in which all firms exert zero lobbying effort cannot constitute a Nash equilibrium. According to the contest function specified in (1), the best response of firm i to $x_{-i} = 0$ is to exert an arbitrarily small amount of lobbying effort, $x_i = \epsilon > 0$, and thereby capture the entire quantity of contested permits. However, this cannot constitute a Nash equilibrium either. Suppose for example that $x_{-i} = 0$ and $x_i = \epsilon > 0$. Although firm i's choice of an arbitrarily small amount of lobbying effort, ϵ, is a best response to $x_{-i} = 0$, the best response function (5) indicates that the other (non-i) firms' choices of zero lobbying effort are not best responses to a sufficiently small ϵ. This reasoning implies that a Nash equilibrium cannot involve only one firm with strictly positive effort while all other firms refrain from lobbying. Thus at least two firms must exert strictly positive lobbying effort in a Nash equilibrium.

[8] The second order sufficient conditions for a maximum are satisfied. The second derivatives of each firm's profit function are negative when evaluated at the interior optimum. Specifically, $-\tau\phi\frac{2x_i}{(x_i+x_{-i})^2} < 0$ for $i = 1, \ldots, n$.

Generally, there exists a unique Nash equilibrium to this contest in which k firms exert strictly positive lobbying effort, with $k \in [2, n]$. To see this, let $j = 1, 2, ..., k$ index the lobbying firms. For these k firms, the first order condition (4) holds with equality. Summing both sides of (4) over $i = 1, 2, ..., k$ and rearranging, the total equilibrium lobbying effort is

$$x = \frac{(k-1)\tau\phi}{\sum_{j=1}^{k} \omega_j}, \tag{6}$$

and combining (6) with the best response function (5), the equilibrium lobbying efforts of individual firms are

$$x_i = \begin{cases} \frac{\tau\phi(k-1)}{(\sum_{j=1}^{k}\omega_j)^2} \cdot \left(\left(\sum_{j=1}^{k}\omega_j\right) - \omega_i(k-1)\right) & for\, i = 1, 2, ..., k \\ 0 & for\, i = k+1, k+2, ..., n. \end{cases} \tag{7}$$

A Nash equilibrium can involve $k \leq n$ lobbying firms if the lobbying costs of these k firms are sufficiently close to each other, and the lobbying costs of the non-lobbying firms are sufficiently higher than those of the lobbying firms. In particular, for (7) to be a Nash equilibrium, it is required that $\omega_i < \frac{1}{k-1}\sum_{j=1}^{k}\omega_j \, for\, i = 1, 2, ..., k$. Furthermore, the best response function (5) requires that $x_{-i} \geq \frac{\tau\phi}{\omega_i} \, for\, i = k+1, k+2, ..., n$. Noting that for the non-lobbying firms $x_{-i} = x$, this requirement can be expressed as $\omega_i \geq \frac{1}{k-1}\sum_{j=1}^{k}\omega_j \, for\, i = k+1, k+2, ..., n$.

These requirements for a Nash equilibrium imply that the k lobbying firms must be the k firms with the lowest ranking lobbying costs. Also, because $\omega_i < \sum_{j=1}^{2}\omega_j \, for\, i = 1, 2$ is trivially true, an equilibrium cannot involve fewer than two lobbying firms. Lastly, it can be shown that the number of lobbying firms in equilibrium is unique. (See Appendix A for proof that k is uniquely determined.)

The above results are summarized as the following proposition, a version of which is established by Franke et al. (2013):

PROPOSITION 1: *Nash equilibrium of the n firm contest*

a. *Only the k firms with the lowest ranking lobbying costs participate in lobbying, where $k \in \{2, \dots, n\}$ and is uniquely determined.*

b. *If firm i participates in lobbying, its lobbying cost must be strictly less than the sum of the lobbying costs of the k lobbying firms, divided by $k-1$.*

c. *If firm i does not participate in lobbying, its lobbying cost must be greater than or equal to the sum of the lobbying costs of the k lobbying firms, divided by $k-1$.*

d. *The lobbying efforts of the participating firms are defined by (7).*

Proposition 1 formalizes the idea that the number of firms that participate in lobbying depends critically on the dispersion of the marginal costs of lobbying across firms. Those firms whose costs are too high relative to those of other firms will choose to refrain from lobbying. In the extreme case where all n firms face equal marginal costs, the equilibrium will have participation by all firms ($k = n$). At the other extreme, a sufficiently high degree of dispersion in costs can produce an equilibrium where only the two firms with the lowest costs will participate ($k = 2$).[9]

2.3 Lobbying Efforts, Expenditures, and Permit Allocations in Equilibrium

The equilibrium lobbying effort of a lobbying firm (i.e. (7)) is decreasing in the firm's own cost of lobbying, however the effect of an increase in another firm's lobbying cost is ambiguous. (See Appendix A for proof.)

Total expenditures on lobbying effort, which are obtained by summing the lobbying expenditures of all firms (i.e. $\sum_{j=1}^{n} \omega_j x_j$), are $\tau\phi(k-1)\left[1 - \frac{(k-1)\sum_{j=1}^{k}\omega_j^2}{\left(\sum_{j=1}^{k}\omega_j\right)^2}\right]$. The following

[9] In the case of $n = 3$ firms, the conditions for an equilibrium with full participation ($k = 3$) are tantamount to the triangle equality; i.e. there will be participation by all 3 firms only if the marginal lobbying cost of any one firm is strictly less than the sum of the marginal lobbying costs of the other two firms.

proposition establishes that when the number of lobbying firms is arbitrarily large, rents are fully dissipated, a canonical result in rent-seeking models.

Proposition 2: *When the number of lobbying firms, k, is arbitrarily large, total expenditures on lobbying effort equal the value of the rents, $\tau\phi$.*

Proof: For a given k, an upper bound on total lobbying expenditure is $\left(\frac{k-1}{k}\right)\tau\phi$. The upper bound is reached when the lobbying costs of the k lobbying firms are equal; higher variance in the lobbying costs of the k firms leads to lower total lobbying expenditure. This is because the quantity $\frac{\sum_{j=1}^{k}\omega_j^2}{\left(\sum_{j=1}^{k}\omega_j\right)^2}$ is monotonically increasing in the variance of the ω_j's and attains a minimum value of $\frac{1}{k}$ when the variance of the ω_j's is zero (i.e. when $\frac{\sum_{j=1}^{k}\omega_j^2}{k} - \frac{\left(\sum_{j=1}^{k}\omega_j\right)^2}{k^2} = 0$).

When the number of lobbying firms, k, is arbitrarily large, total lobbying expenditures are equal to $\tau\phi$. The reason for this is two-fold. First, the larger the value of k, the more stringent are the limitations on the variance of the lobbying costs. Specifically, when k is arbitrarily large, the conditions for a Nash equilibrium imply that the variance of the lobbying costs of the k firms must be zero. (Recall that, for any Nash equilibrium in which k firms lobby, it must be that $\omega_i < \frac{1}{k-1}\sum_{j=1}^{k}\omega_j \; for\, i = 1, 2, ..., k$.) Second, as the variance of the lobbying costs of the k firms reaches zero, total lobbying expenditure must itself reach its upper bound, $\left(\frac{k-1}{k}\right)\tau\phi$. It is evident that this upper bound reaches $\tau\phi$ for an arbitrarily large k. *Q.E.D.*

Combining the Nash equilibrium lobbying efforts with (1) implies the following post-contest allocations:

$$\widetilde{A}_i = \begin{cases} A_i^{(1-\gamma)} + \phi\left(1 - \frac{(k-1)\omega_i}{\sum_{j=1}^{k}\omega_j}\right) & for\, i = 1, 2, ..., k \\ A_i^{(1-\gamma)} & for\, i = k+1, k+2, ..., n. \end{cases} \tag{8}$$

Equation (8) forms the basis of the empirical work in Section 4. The relationship between the provisional allocation, A_i, and the realized allocation, $\widetilde{A}_i$, is specified by (8). Furthermore, for the lobbying firms, $\widetilde{A}_i$ is decreasing in own lobbying cost but increasing in the lobbying costs of other firms.[10] Taking the natural log of both sides of (8) yields

$$ln(\widetilde{A}_i) = (1-\gamma)ln(A_i) + \psi_i, \tag{9}$$

where the quantity ψ_i equals zero for non-lobbying firms. For lobbying firms, $\psi_i > 0$ and is decreasing in own lobbying cost but increasing in the lobbying costs of other firms. In other words, a firm that can lobby at relatively low cost (compared to other firms) will have a relatively high value of ψ_i and realize a higher permit allocation. This insight is incorporated into the empirical analysis by using data on political connections to develop a proxy measure for a firm's relative cost of lobbying.

While ψ_i is a function of a firm's relative cost of lobbying, the model implies a very particular functional form for ψ_i. Specifically, $\psi_i = ln\left(A_i^{(1-\gamma)} + \phi\left(1 - \frac{(k-1)\omega_i}{\sum_{j=1}^k \omega_j}\right)\right) - ln(A_i^{(1-\gamma)})$, which can be approximated as $\psi_i \approx \frac{\phi\left(1-\frac{(k-1)\omega_i}{\sum_{j=1}^k \omega_j}\right)}{A_i^{1-\gamma}}$, using the fact that for any small ϵ, $ln(1+\epsilon)$ is closely approximated by ϵ.[11] This particular functional form suggests that even if two firms face identical costs of lobbying, the firm with a higher provisional allocation will have a lower value of ψ_i. While I do not incorporate this additional model prediction into the main empirical specifications, I do address it in a sensitivity check by including an interaction term between a firm's provisional allocation and a measure of its cost of lobbying (Table 6). The inclusion of the interaction term does not materially alter the results.

After describing the institutional details of permit allocation in the EU ETS, I test the predictions of the model, as expressed in (9), using data from the UK's allocation procedure in Phase 1. I am able to construct firm-level provisional and realized allocations. While I

[10] The relevant derivatives with respect to own lobbying costs, for $i = 1, 2, ..., k$, are $\frac{\partial \widetilde{A}_i}{\partial \omega_i} = \frac{-\phi(k-1)\left[\left(\sum_{j=1}^k \omega_j\right) - \omega_i\right]}{\left(\sum_{j=1}^k \omega_j\right)^2} < 0$.

[11] This approximation is valid if the number of permits a firm gains in the contest (i.e. $\phi\left(1 - \frac{(k-1)\omega_i}{\sum_{j=1}^k \omega_j}\right)$) is small relative to the permits the firm retains (i.e. $A_i^{(1-\gamma)}$). The high level of "persistence" of the provisional allocation (observed in the data) suggests that the approximation is reasonable.

cannot observe actual lobbying effort or expenditures, I develop a proxy measure for a firm's relative cost of lobbying using data on political connections. This allows me test whether firms that arguably face lower costs of lobbying realize higher allocations, controlling for their provisional allocations. Such a test will shed light on the distributional consequences of rent-seeking for emission permits. As indicated in Proposition 2, the efficiency implications of rent-seeking depend centrally on the number of contested permits, ϕ. The value of the contested permits is $\tau\phi$, which is also the total welfare loss associated with lobbying expenditures if k is sufficiently large. In Section 4.2.3, I explore ways to characterize ϕ. The welfare loss is then assessed by multiplying ϕ by an expected permit price at the time the allocation procedure took place.

3 Permit Allocation in the EU ETS

The EU ETS is divided into multi-year trading periods known as phases. Phase 1 spanned the years 2005-2007 and was intended to be a trial phase. Phase 2 spanned 2008-2012, and Phase 3 runs from 2013-2020. (Ellerman and Joskow, 2008). For the first two phases, both the cap-setting and allocation processes of the EU ETS were highly decentralized. Prior to each phase, every member state was responsible for setting a national cap and developing a National Allocation Plan that specifies the distribution of the cap to installations located in the state. Each installation was issued a fixed number of permits for every year within a phase, and there was no restriction on banking or borrowing across years within the same phase (Ellerman and Joskow, 2008). A permit confers the right to emit one metric ton of CO_2 in a given year.

3.1 Allocation to Sectors and Installations

The UK Phase 1 National Allocation Plan was the first to be published in provisional form (in January 2004) and influenced the plans of other member states.[12] All Phase 1 permits were allocated at no cost (Ellerman *et al.*, 2007). Although the sector classifications changed drastically from the provisional to the final plan, the two plans were guided by similar mechanical formulae. In both plans, permits were allocated to existing installations through a two-stage procedure that first involved allocations to sectors followed by allocations to installations within sectors. Firms did not receive explicit consideration in this procedure and could have multiple installations in more than one sector.

The allocations to sectors other than the power generation sector were based on the expected future emissions of those sectors. The power generation sector received only a residual allocation equal to the difference between the total cap and the allocations to all other sectors. Concerns of competitiveness motivated this differential treatment. Because the power generation sector is insulated from international competition compared to other sectors, electricity producers were expected to be able to pass on the costs of permits to their customers.

An individual installation was entitled to a fraction of the permits allocated to the sector to which it belongs. This fraction was equal to the installation's share of the sector's total "relevant emissions", which is a measure of historical emissions. In most cases, an individual installation's relevant emissions were computed by averaging annual emissions over a baseline period after dropping the lowest year's emissions. For Phase 1, the baseline period was 1998-2003. A sector's relevant emissions are simply the sum of the relevant emissions of all installations in that sector.

[12]The lead government department in charge of developing the UK plan was the Department of Environment, Food, and Rural Affairs (DEFRA), however the Department of Trade and Industry and the Environment Agency were also involved.

3.2 Changes between the Provisional and Final National Allocation Plan

The government explicitly invited consultation from industry after the publication of the provisional plan. The sectoral redefinition that emerged from this consultation was the major cause of changes in allocations between the provisional and final plans. Sector categories were the subject of much debate during the formulation of the final plan. The UK's Department of Trade and Industry was already involved in projecting sectoral emissions well before the EU ETS, and its projections informed those used in the provisional plan (Ellerman et al., 2007). However, the sector categories of the provisional plan were widely viewed by industry as being too coarsely defined. There was a desire for more disaggregated sector categories whose projections would reflect the particular circumstances of each industry. In response, the government commissioned independent consultants to produce more detailed sectoral projections of output, which the Department of Trade and Industry then used to project emissions (Ellerman et al., 2007; Department of Environment, Food, and Rural Affairs, 2005). The number of sector categories multiplied between the provisional and actual plans. While the provisional plan had 13 sectors for classifying installations (Department of Trade and Industry, 2004), the final plan had 51 sectors (Department of Environment, Food, and Rural Affairs, 2005).

Aside from sectoral redefinition, the application of alternative rules for determining an installation's relevant emissions also contributed to differences between provisional and final allocations. The final plan reflected the application of special rules for determining relevant emissions for installations that underwent commissioning, added capacity, and/or were affected by intersite shifting of production during the baseline period (Ellerman *et al.*, 2007). Installations had to provide evidence in order to be considered for treatment under these special rules (Department of Environment, Food, and Rural Affairs, 2005).

While sectoral redefinition and the application of special rules are proximate explanations for differences between provisional and final allocations, it has been widely emphasized that these were the manifestations of lobbying. According to Buchner *et al.* (2006), the allocation process for Phase 1 of the EU ETS in general "can best be described as an extended dialogue between the government and industry" in which there was "much lobbying" on the part of industry. Mallard (2009) remarks that changes between the provisional and final UK plans represent "perhaps the clearest example of the effects of lobbying". Duggan (2009) points out that in their pursuit of the maximum number of costless permits, many companies in the UK pleaded to be treated as "'special cases or exceptions to the rules". The empirical tests in the following section aim to evaluate the distributional and efficiency consequences of such lobbying.

4 Empirical Tests

4.1 Data Sources

4.1.1 Provisional and Actual National Allocation Plans

Table 1 summarizes the scope of the provisional and final plans.

Table 1: Scope of Provisional and Final National Allocation Plans

	Provisional Plan	**Final Plan**
Number of Installations	867	1056
Number of Matched Installations	703	703
Total Permits to All Installations	224,575,161	228,204,110
Total Permits to Matched Installations	214,258,348	214,113,670

The two plans do not cover an identical universe of installations. One-hundred sixty four installations are present in the provisional plan but not in the final plan, and a large number of installations were added by the time of the final plan. However, the degree of overlap is considerable. I am able to match 703 installations between the two allocation plans, representing well over 90% of the UK national cap.[13] The total number of permits,

[13]Matching between the two plan is possible through a unique identification number assigned to each

Table 2: Gains and Losses at Sector Level

Sector in Provisional Plan	*Number of Installations*	*Allocation (Provisional)*	*Allocation (Final)*	*Change*
Bricks/Ceramics	98	2,788,687	1,640,357	-1,148,330
Cement	13	9,084,646	7,598,514	-1,486,132
Chemicals	79	6,981,427	6,661,667	-319,760
Food & Drink	97	3,119,708	3,249,503	129,795
Glass	27	1,673,063	1,732,602	59,539
Iron & Steel	12	21,489,003	19,915,330	-1,573,673
Lime	8	2,117,815	2,204,131	86,316
Non-ferrous	2	2,446,757	2,984,474	537,717
Offshore	113	10,826,881	15,918,647	5,091,766
Other Combustion Activities	77	2,289,186	2,284,408	-4,778
Power Stations	86	129,502,676	124,184,409	-5,318,267
Pulp & Paper	77	4,138,668	5,049,444	910,776
Refineries	14	17,799,831	20,690,184	2,890,353
TOTAL	**703**	**214,258,348**	**214,113,670**	**-144,678**

whether to all installations or to the matched installations, remains almost the same in two plans. Thus any changes in allocations are essentially redistributive.

Considerable redistribution took place at the sectoral level. Table 2 displays the total provisional and final allocations of all matched installations in each of the thirteen sector categories of the provisional plan. The oil and gas industry, which encompasses the "Offshore" and "Refineries" sectors, appears to have benefited in the redistribution, while the "Power Stations" sector lost. To account for such sectoral shifts, industry controls are included in the empirical specifications.

Firm-level allocations are constructed by aggregating the allocations of installations op-

installation.

erated by the same firm.[14] The matched installations represent a total of 270 firms.[15] As described previously, firms do not receive explicit consideration in the formula for allocation, the two-stages of which involve allocations to sectors and then installations within sectors. The same firm can have multiple installations, not all of which fall into the same sector. For the subsequent, firm-level, emprical analysis, each firm is assigned to one of 8 industry categories based on Standard Industrial Classification (SIC) codes. The industry groupings used are: Chemicals (Major Group 28), Food and Drink (Major Group 20), Fossil Fuels (Major Groups 12, 13, and 29), Metal Manufacture (Major Groups 33 and 34), Pulp and Paper (Major Group 26), Stone/Clay/Glass/Concrete (Major Group 32), Transportation Equipment (Major Group 37), and Utilities (Major Group 49).[16]

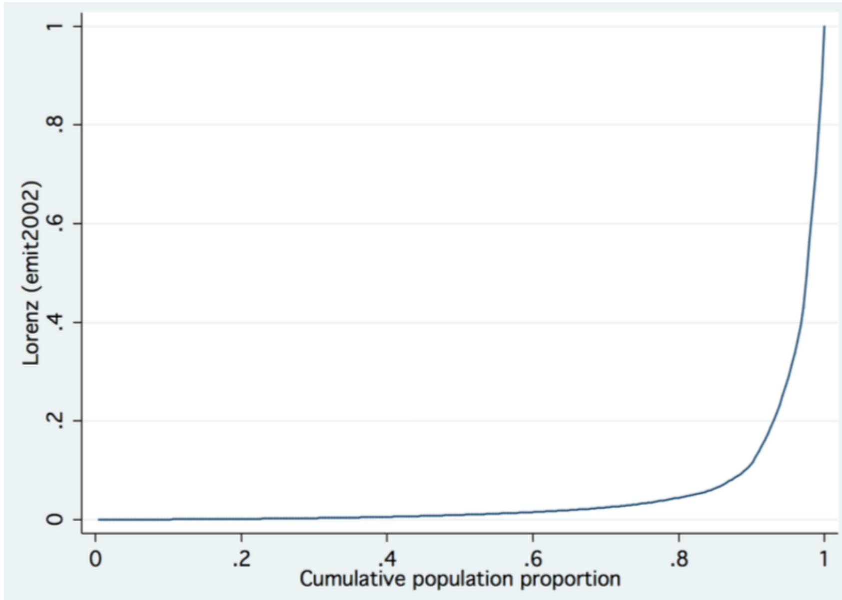
The distribution of emissions across firms is highly skewed, with a relatively small number of large emitters accounting for the bulk of emissions. Figure 1 plots a Lorenz curve of emissions; the top 20% of emitting firms accounted for approximately 95% of emissions in 2002.

[14]The provisional and actual plans report the firm each installation is associated with. In some instances, the reported firm may be a subsidiary of another firm. The firm-level allocations I have constructed include allocations to the firm and its subsidiaries. I have carefully identified subsdiaries by individually ascertaining the ownership status in 2004 of each reported firm. The sources relied upon include company websites, financial reports, press releases, and company descriptions from Hoovers and Bloomberg Businessweek Company Insight Center.

[15]In the regressions the sample sizes are lower because I exclude universities, hospitals, and government entities. These entities account for less than 0.5% of the cap in both plans. Also, lack of financial data accounts for the lower sample size in regressions that include firm financial variables.

[16]A firm was placed into one of these groupings primarily on the basis of the sectors its installations were classified under in the provisional plan. The provisional plan sectors of "Chemicals", "Food & Drink", and "Pulp & Paper" correspond directly to the SIC-based industry groups. The provisional plan sectors of "Bricks/Ceramics", "Cement", "Glass", and "Lime" all map to the "Stone/Clay/Glass/Concrete" industry group, while the "Iron & Steel" and "Non-ferrous sectors" map to Metal Manufacture. "Power Stations" fall under the Utilities group. The Fossil Fuels group includes firms engaged in the extraction of fossil fuels and/or refining; the "Offshore" and "Refineries" sectors in the provisional plan fall in this grouping. Finally, the "Other Combustion Activities" sector includes firms whose business activities may fall into any of the industry groups; companies that manufacture Transportation Equipment are included in this sector. The installations of most firms fall into only one sector of the provisional plan. For firms with installations in more than one sector, there was typically one dominant sector that represented the core business activity. For example, British Petroleum is classified in the Fossil Fuels group even though 2 out of its 20 installations fall in the "Chemicals" sector in the provisional plan. When necessary, the Amadeus database published by Bureau van Dijk was consulted to establish a firm's industry grouping. See `http://www.bvdinfo.com/Products/Company-Information/International/AMADEUS.aspx`.

Figure 1: Lorenz Curve of Distribution of Emissions across Firms in 2002



4.1.2 Political Connections

The data source for political connections is the *Register of Members' Financial Interests*, which is published several times a year by the UK House of Commons.[17] This publication documents the financial connections to firms of every member of the House of Commons (MP). Each MP is required by law to disclose information about any financial interest or any benefit received, "which others might reasonably consider to influence his or her actions or words as a Member of Parliament".[18] Types of connections required to be disclosed include gifts from a firm to the MP, shareholdings, remunerated directorships, and employment, which is typically in the form of invited talks or strategic advisory roles.[19] I use issues of the register spanning the years 2000-2004.[20] Forty-seven firms had connections to at least one MP during this time; twenty-two firms had connections to only one MP, fourteen firms

[17] Issues of the *Register* can be downloaded from `https://www.parliament.uk/mps-lords-and-offices/standards-and-financial-interests/parliamentary-commissioner-for-standards/registers-of-interests/register-of-members-financial-interests/`.

[18] For a detailed description of disclosure rules for UK MPs, see `https://publications.parliament.uk/pa/cm201516/cmcode/1076/107604.htm`.

[19] Similar measures have been used in other papers on political connections. See for example Khwaja and Mian (2005), Faccio et al. (2006), and Ferguson and Voth (2008).

[20] In particular, the following issues were used: November 10, 2000; May 14, 2001; May 14, 2002; November 26, 2002; December 4, 2003; and January 31, 2004.

had connections to 2-5 MPs, and 11 firms had connections to more than 5 MPs. The most common type of connection was the receipt of gifts by MPs from firms. Thirty-four firms gave gifts to at least one MP.[21] Less common forms of connection include employment of MPs (7 firms), having MPs as shareholders (9 firms), or having MPs on the board of directors (3 firms).

Measuring connections to MPs is not without drawbacks. By focusing on data from the *Register*, it is possible to capture only a specific type of political connection.[22] Other channels through which a firm might wield political influence are ignored. For example, a firm may be able to positively affect its allocation through influence at the particular agencies directly involved in the allocation process. There is no way to quantify such influence.[23] However, although it is incomplete, the data in the *Register* is plausibly representative in that a firm connected to MPs is likely to also be influential in other domains and faces a relatively lower cost of engaging in rent-seeking activities.

Another concern is that instead of being simply an indicator of a firm's cost of lobbying, the cultivation of political connections may represent an endogenous response to the allocation process. To mitigate this concern, I do not consider instances of political connections created after the release of the provisional plan. The tight time horizons under which the EU ETS came into being also help to rule out the possibility that the pursuit of higher permit allocations was driving the formation of political connections. According to Ellerman et al. (2007), as of late 2001 and for some time after, an operational EU-wide emissions trading scheme by 2005 was widely viewed as a low probability scenario. A political agreement on the EU ETS among the then 15 member states was reached only in summer of 2003. Furthermore, as suggested by the growing literature on the topic, political connections can

[21] For example, MP Peter Hain (Labour) attended Wimbledon on July 4, 1999, as a guest of British Petroleum.

[22] The relatively few connections to MPs observed in the UK data may reflect the relatively diminished role of campaign finance in the UK political system vis-à-vis the political system in countries such as the US (Mahoney, 2009).

[23] The UK does not systematically collect and release data on the financial connections of employees from any of the involved agencies.

Table 3: Connected vs. Non-connected Firms

	Not Connected	*Connected*	*Total*
Number of Firms	200	47	247
2002 Emissions (tons)	101,455,365	138,441,587	239,896,951
Provisional Allocation	92,616,052	120,595,201	213,211,263
Final Allocation	90,119,235	123,225,555	213,344,790
Change (Permits)	-2,496,817	2,630,344	133,527
Change (Percent, unweighted mean)	34.22%	26.08%	32.67%
Change (Percent, mean weighted by provisional allocation)	**-2.7%**	**2.2%**	**0.06%**

Excludes universities, hospitals, and other government entities.

secure a range of benefits for firms in various regulatory contexts. The decision of a firm to cultivate connections takes into account the full range of these benefits, which extend far beyond free permits. In the short run, political connections can be reasonably interpreted as indicative of the ease with which a firm can undertake rent-seeking.

Table 3 compares the 47 (privately owned) firms connected to at least one MP, with the 200 privately owned firms that are not connected to any MP.[24]

The data on 2002 emissions reveal that the politically connected firms are on average larger emitters, with the 47 connected firms accounting for well over half of the total 2002 emissions. However, there are small and large emitters among both the connected and non-connected firms.[25] Because permit allocations are based on historical emissions, the 47 connected firms unsurprisingly received the bulk of the permits in both the provisional and final plans. What is notable however, is the redistribution of permits toward the connected firms. In the transition from the provisional to the final plan, connected firms gained 2,630,344 permits, while non-connected firms lost 2,496,817 permits. In percentage terms, firm permit allocations increased by an (unweighted) average of 32.67%, with non-connected and connected firms experiencing average increases of 34.22% and 26.08% respectively. However,

[24] Although the matched installations represent a total of 270 firms, the comparison in Table 3 excludes universities, hospitals, and government entities and hence covers only 247 firms. Universities, hospitals, and government entities account for less than 0.5% of the cap in both plans.

[25] Among connected firms, emissions in 2002 ranged between 1,110 tons and 28,439,827 tons. Among non-connected firms, emissions in 2002 ranged between 57 tons and 19,348,748 tons.

these unweighted averages disproportionately reflect the influence of small emitters whose gains in permits were small in absolute terms, but large relative to their provisional allocations. As demonstrated in Figure 1, small emitters, though numerous, account for only a small fraction of total emissions. The average percent change, weighted by the firms' provisional allocatons, better reflects the reallocation that occured between the provisional and final plans. By this metric, firms on average experienced negligible change in allocation (0.06%). However, connected firms gained an average 2.2% while non-connected firms lost an average of 2.7%.

4.2 Results

4.2.1 Distributional Effects of Political Connections

The empirical specifications are motivated by equation (9). In the most basic specification, the natural log of a firm's realized allocation is regressed on the natural log of its provisional allocation and a measure of its political connections. Formally, for firm i,

$$ln(Final\,Allocation_i) = \beta_1 ln(Provisional\,Allocation_i) + \beta_2 Political_i + \epsilon_i, \qquad (10)$$

where ϵ_i denotes the stochastic error term.[26] The purpose of the *Political* variable is to shed light on ψ_i from equation (9), which indicates the additional permits gained by a firm with a lower cost of rent-seeking than the non-lobbying firms. Further specifications also include industry dummy variables and control for other firm characteristics. In the preferred specifications, the observation for each firm is weighted by the firm's provisional allocation. This approach addresses the issue of scale that is evident in Figure 1 and Table 3.[27]

[26]The existence of a mean zero error term, ϵ_i, would not alter the central prediction of the theory (i.e. *ceteris paribus* a firm with a lower relative lobbying cost will lobby more and realize a higher permit allocation) if firms are risk-neutral. Suppose (risk-neutral) firms understand that their final allocation will not just be that specified as the first part of equation (1) but will also be adjusted by a mean zero idiosyncratic term. Under expected profit maximization, (3) would still capture the firm's lobbying decision and the firm's decisions would remain the same.

[27]Such weighting makes my results comparable to those of Khwaja and Mian (2005), who analyze the effect of political connectedness on firm default rates on loans from state-owned banks in Pakistan. Their

Table 4: Regressions with Binary Political Variable

Dependent Variable: *Ln(Final Allocation)*	*(1)*	*(2)*	*(3)*
Ln(Provisional Allocation)	0.995*** (0.030)	0.958*** (0.059)	0.980*** (0.026)
Political	**0.131*** **(0.068)**	**0.142** **(0.124)**	**0.055** **(0.045)**
ln(Total Fixed Assets)			0.033*** (0.009)
ln(Employees)			-0.024 (0.018)
Profit Margin			0.00345** (0.0014)
Industry Controls?	No	Yes	Yes
Weighted Regression?	Yes	Yes	Yes
N	247	247	185
R^2	0.90	0.92	0.99

Excludes universities, hospitals, and other government entities. Observations weighted by provisional allocation. Standard errors (in parentheses) are clustered by industry. The superscripts ***, **, and * denote significance at 1, 5, and 10 percent levels respectively.

Table 4 displays the regression results using a binary measure of political connections. The variable $Political_i$ takes on a value of 1 if firm i is connected to at least one MP. Column 1 includes only the provisional allocation and the *Political* variable as regressors, while columns 2 and 3 respectively add industry controls and other firm characteristics. The firm characteristics included are 2003 values of the natural log of fixed assets, natural log of the number of employees, and profit margin.[28] Across all columns, the provisional allocation strongly predicts the realized allocation; the coefficient on $ln(Provisional\, Allocation_i)$ is only slightly less than 1 and is in fact not statistically different from 1. The predictive power of the provisional allocation is also reflected in the extremely high R^2 values.

unit of observation is a firm-bank pair, and they weight each observation by the number of dollars loaned by the bank to the firm.

[28]These are obtained from the Amadeus database published by Bureau van Dijk. See `http://www.bvdinfo.com/Products/Company-Information/International/AMADEUS.aspx`.

Table 5: Regressions with Number of Connected MPs

Dependent Variable: *Ln(Final Allocation)*	*(1)*	*(2)*	*(3)*
Ln(Provisional Allocation)	0.995*** (0.025)	0.966*** (0.036)	0.960*** (0.031)
Number of MPs	**0.054**** **(0.021)**	**0.036*** **(0.018)**	**0.033***** **(0.009)**
(Number of MPs)^2	**-0.0021**** **(0.0008)**	**-0.0014*** **(0.0007)**	**-0.0012***** **(0.0003)**
ln(Total Fixed Assets)			0.029*** (0.008)
ln(Employees)			-0.018 (0.009)
Profit Margin			0.0042** (0.0018)
Industry Controls?	No	Yes	Yes
Weighted Regression?	Yes	Yes	Yes
N	247	247	185
R^2	0.90	0.91	0.99

Excludes universities, hospitals, and other government entities. Observations weighted by provisional allocation. Standard errors (in parentheses) are clustered by industry. The superscripts ***, **, and * denote significance at 1, 5, and 10 percent levels respectively.

Using the binary measure of political connections, I find at best weak evidence that politically connected firms benefited in the redistribution of permits. While the coefficient on *Political* is positive, it becomes statistically insignificant with the inclusion of industry controls and firm characteristics.

In the regressions of Table 5, the *Political* variable is measured by the number of MPs a firm is connected to and its square. As in Table 4, column 1 includes only the provisional allocation and the political variables as regressors, and columns 2 and 3 respectively add industry controls and other firm characteristics.

The results from Table 5 suggest that the degree of connectedness matters. Moving from no connections to a connection with one MP is associated with at least a 3.3% increase in the final allocation, and this amount is even higher (5.4%) when not accounting for firm characteristics and industry.[29] The negative coefficient on the quadratic term suggests diminishing returns from connections to additional MPs. Unlike the results in Table 4, the results using the number of MPs are statistically significant and relatively stable in magnitude across columns. The binary measure of political connectedness fails to account for what appear to be important differences across firms in the strength of connectedness.[30]

4.2.2 Sensitivity Checks

Table 6 reproduces the specifications of Table 5, but adds a multiplicative interaction term suggested by the theory. Specifically the interaction term is the product of the number of MPs firm i is connected to and $\frac{1}{Provisional\ Allocation_i}$. The coefficient on the interaction term has the opposite sign as suggested by the theory. However it is never statistically significant, and its inclusion does not materially alter the results.

I also estimate the regressions in Table 5 using an unweighted regression, however the results fail to attain statistical significance and are unstable. (See Table B.1 in Appendix B.) The differences between the unweighted and weighted regressions suggest that large firms, which account for the bulk of emissions, are the ones who are able to use political influence to increase their allocations. To directly model such heterogeneity without using regression weights, as advocated by Solon et al. (2015), I split the firms in the sample into two groups− those in the top quintile (Table B.2 in Appendix B) and those in the bottom four quintiles (Table B.3 in Appendix B) of provisional allocations. For firms in the top quintile, the coefficients on number of MPs and its square closely resemble those of Table 5

[29] To place these estimates in economic perspective, a 5.4% increase in final allocation would represent 46,642 additional permits for a firm with a final allocation equal to the average across all firms (863,744 permits); taking an expected permit price in 2004 of 10 euros (Ellerman and Joskow, 2008), this increase represents a value of 466,420 euros. I also find evidence that connections to MPs are associated with a higher probability of an upward revision (i.e. a realized allocation higher than the provisional one).

[30] Number of connections seems to be the only measure of "strength" that matters. Distinguishing between types of connections (e.g. gifts vs. shareholdings vs. positions on boards of directors) does not yield significant results, nor do the results differ if connections are broken down by political party (e.g. Labour vs. Conservative). Fifty-three percent of the connections observed in the data are to MPs in the Labour party, which was in power at the time.

Table 6: Regressions with Interaction Term

Dependent Variable: *Ln(Final Allocation)*	*(1)*	*(2)*	*(3)*
Ln(Provisional Allocation)	0.993***	0.965***	0.952***
	(0.027)	(0.037)	(0.032)
Number of MPs	**0.055****	**0.037***	**0.037*****
	(0.021)	**(0.019)**	**(0.009)**
(Number of MPs)^2	**-0.0021****	**-0.0014***	**-0.0013*****
	(0.0008)	**(0.0007)**	**(0.0003)**
Interaction Term	-1048.126	-1316.413	-3403.007
	(1560.926)	(875.517)	(1801.976)
ln(Total Fixed Assets)			0.027**
			(0.009)
ln(Employees)			-0.013
			(0.010)
Profit Margin			0.0046**
			(0.0018)
Industry Controls?	No	Yes	Yes
Weighted Regression?	Yes	Yes	Yes
N	247	247	185
R^2	0.90	0.91	0.99

Interaction term is the product of $Number\,of\,MPs$ and $\frac{1}{Provisional\ Allocation}$. Excludes universities, hospitals, and other government entities. Observations weighted by provisional allocation. Standard errors (in parentheses) are clustered by industry. The superscripts ***, **, and * denote significance at 1, 5, and 10 percent levels respectively.

albeit fail to attain statistical significance due to the smaller sample size. In contrast, there is no compelling evidence that political connections are associated with an increase in the final allocation for firms in the bottom four quintiles as the coefficients on number of MPs are highly unstable and never economically significant in a positive direction.

Furthermore, I repeat the weighted and unweighted regressions measuring final and provisional allocations in levels rather than logs. Results from the full-sample weighted and unweighted regressions using levels are reported in Appendix B, tables B.4 and B.5, respectively. The weighted results are statistically significant and are qualitatively consistent with those of Table 5. Moving from no connections to a connection with one MP is associated with over 200,000 extra permits on average, representing a 0.07 standard deviation increase in the final allocation. The negative coefficient on the quadratic term suggests diminishing returns to additional MPs. The results from the full-sample unweighted regression are statistically insignificant but are qualitatively similar. Splitting the sample firms into those in the top quintile (Table B.6 in Appendix B) and bottom four quintiles (Table B.7 in Appendix B) of provisional allocation, I find a strong, statistically significant association of final allocation with number of MPs for firms in the top quintile but a negligible association for firms in the bottom four quintiles.

4.2.3 Calculation of Welfare Loss

The reallocation that occurred between the provisional and final allocation plans appeared to have particularly benefited large firms with strong political connections. Under full dissipation of rents, the amount firms spent on rent-seeking activity is equal to the value of the contested permits. The value of contested permits is obtained by multiplying the number of contested permits (ϕ) by the expected price of a permit at the time of allocation. Thus any attempt to calculate welfare losses must begin by characterizing the number of contested permits.

It is possible to characterize a lower bound on the number of contested permits solely by examining the data on provisional and final allocations, without invoking theory or assuming anything about the relative costs of lobbying firms face. While the net change in the total number of permits between the two plans was negligible (133,527 permits, see Table 3), some firms lost permits (losers) while others gained permits (gainers). In particular, the gainers gained 13,862,086 permits, while the losers lost 13,728,559 permits. The losses of the losers constitute a lower bound on the number of contested permits. In terms of the theoretical framework, the observation of losers losing 13,728,559 permits (and gainers gaining virtually the same amount) is incompatible with there being fewer than 13,728,559 contested permits. Such an observation does not preclude higher numbers of contested permits; indeed it is still possible that entire cap was contested. However, it cannot be the case that fewer than 13,728,559 permits were contested.[31] Multiplying this number by an expected permit price in 2004 of 10 euros (Ellerman and Joskow, 2008) yields a lower bound on the welfare losses from rent-seeking (137,285,590 euros), assuming full dissipation of rents.

Another way to infer the number of contested permits is to hew to the theory and use the estimated coefficient on $ln(Provisional\,Allocation)$. This coefficient ($\beta_1$ in equation (10)) corresponds to the quantity $(1-\gamma)$ from the theoretical model. An estimate of ϕ, denoted $\hat{\phi}$ can be calculated as follows:

$$\hat{\phi} = \sum_{i=1}^{n} \left[A_i - A_i^{\hat{\beta}_1} \right], \tag{11}$$

where $\hat{\beta}_1$ is an estimate of $1-\gamma$ and A_i is firm i's provisional allocation. Using $\hat{\beta}_1 = 0.993$ (Table 6, Column 1) and computing the expression (11) yields 22,189,151 as an estimate of the number of contested permits and 221,891,510 euros as the estimated welfare loss. This loss substantially exceeds the lower bound. Even higher estimates of the number of contested permits and corresponding welfare losses emerge if the value of $\hat{\beta}_1$ is taken from the specifications that control for firm characteristics and industry (e.g. Table 6, Columns

[31] For example, if the number of contested permits was zero, there would be no gainers or losers and allocations would remain unchanged.

2 and 3). However, the theory does not suggest the inclusion of these controls and the estimated welfare losses may be implausibly high. Moreover, in every specification, $\hat{\beta}_1$ is not statistically different from 1 and hence the estimate of γ is not statistically different from zero. Thus, it cannot be rejected that institutions were successful at keeping rent-seeking in check. More fundamentally, there are reasons to suspect the theoretical framework may be abstracting away from potentially important features of the lobbying process (e.g. the advantages faced by larger firms, as suggested in the data). Hence welfare calculations that rely on a literal interpretation of model parameters like β_1 should be complemented by more data-driven bounding exercises for determining the number of contested permits, of the type described in the previous paragraph.

The estimated welfare losses from rent-seeking (137,285,590 euros or 221,891,510 euros) are relatively small compared to the value of the the cap, which is over 2.1 billion euros. However, the losses are staggering when juxtaposed against the amount firms spent annually on abatement of emissions. While no estimates exist of abatement or abatement costs for the UK as a whole, it is possible to compare the welfare losses with EU-wide abatement expenditures. Ellerman et al. (2010) estimate that Phase 1 of the EU ETS led to between 40 million and 100 million tons of abatement annually across all member states at a total cost of 450 million to 900 million euros. Thus the welfare losses from rent dissipation in the UK *alone* are substantial relative to annual abatement expenditures in the *entire EU*.

The discussion of welfare losses has assumed full-dissipation of rents. The theoretical framework predicts full dissipation rents only when there are a sufficiently large number of lobbying firms. The data do suggest that the number of lobbying firms is plausibly large enough to lead to full dissipation. For example the number of firms whose final allocation exceeds the provisional allocation is 160 ($k = 160$). The number of firms connected to at least one MP is 47 ($k = 47$). In either of the cases, $\frac{k-1}{k}$ is very close to one, which generates nearly complete rent-dissipation. It should be emphasized however, that the calculations of welfare loss presented here are valid only in the case of full dissipation.

5 Conclusion

This paper empirically characterizes the distributional and efficiency consequences of rent-seeking behavior using uncommon data on redistributions of emission permit allocations from Phase 1 of the EU ETS in the UK. The unique zero-sum context in which firms attempted to improve their own allocations makes it possible to test and apply theories of rent-seeking behavior that have previously been relatively inaccessible to empirical study. Evidence suggests that large firms connected to MPs were able to improve their allocations and that the degree of connection, as measured by the number of MPs a firm was connected with, mattered. Furthermore, the welfare losses from rent-seeking behavior in this case could have represented a significant cost over and above the abatement costs firms incurred to reduce their emissions.

The welfare loss I estimate can be reasonably construed as a one-time loss rather than an ongoing loss. Considering that Phase 1 was a trial phase of the EU ETS, it is plausible that rent-seeking behavior was more of a factor than in the subsequent phases. As the rules and regulatory procedures became more established over time, opportunities and incentives for rent-seeking diminished. Duggan (2009) notes that the formulation of the UK's National Allocation Plan in Phase 2 involved far less agitation on the part of industry. However, my findings do offer a cautionary tale for countries with institutions less effective at curbing rent-seeking activity. If rent-seeking can occur even in a developed country with strong insitutions like the UK, it is likely to play a much bigger role as emissions trading is implemented in developing countries.

My findings also point to institutional design features that can potentially mitigate the welfare losses from rent seeking. In particular, auctioning of permits to firms at the outset circumvents some of the obvious political economy pitfalls of grandfathering. Apart from precluding rent-seeking over costlessly allocated permits, there is also an efficiency advantage in that the auction revenues can be used to offset distortionary taxes (Goulder et al., 1999; Cramton and Kerr, 2002). However, auctions are not entirely free of political economy concerns. Cramton and Kerr (2002) point out that vested interests will fight bitterly to oppose auctions in favor of grandfathering, while MacKenzie and Ohndorf (2012) point out that the revenues raised from auction may themselves become a rent-seeking prize- one that may be contested not only by the regulated firms but also by myriad actors in the broader economy (MacKenzie, 2017).

Appendix A

Proposition A1: The number of lobbying firms in equilibrium, k, is uniquely determined.

Proof: Suppose there exists a Nash equilibrium with k lobbying firms and another Nash equilibrium with k' lobbying firms. Without loss of generality, suppose $k' > k$. The equilibrium conditions stipulate

$$\begin{aligned} &\omega_i < \tfrac{1}{k-1}\textstyle\sum_{j=1}^{k}\omega_j \qquad for\, i = 1, 2, ..., k \\ &\omega_i \geq \tfrac{1}{k-1}\textstyle\sum_{j=1}^{k}\omega_j \quad for\, i = k+1, k+2, ..., n \end{aligned} \tag{A.1}$$

and

$$\begin{aligned} &\omega_i < \tfrac{1}{k'-1}\textstyle\sum_{j=1}^{k}\omega_j \qquad for\, i = 1, 2, ..., k' \\ &\omega_i \geq \tfrac{1}{k'-1}\textstyle\sum_{j=1}^{k}\omega_j \quad for\, i = k'+1, k'+2, ..., n \end{aligned} \tag{A.2}$$

where i indexes firms in order of lobbying cost (i.e. firm 1 is the firm with lowest lobbying cost; firm n is the firm with the highest lobbying cost).

Condition (A.2) implies $(k'-1)\omega_{k'} < \sum_{j=1}^{k'}\omega_j$, which can be equivalently expressed as $(k-1)\omega_{k'} + (k'-k)\omega_{k'} < \sum_{j=1}^{k}\omega_j + \sum_{j=k+1}^{k'}\omega_j$. Condition (A.1) implies $(k-1)\omega_{k'} > \sum_{j=1}^{k}\omega_j$, therefore it must be that $(k'-k)\omega_{k'} < \sum_{j=k+1}^{k'}\omega_j$. However, because $\forall\, j < k'$, $\omega_j < \omega_{k'}$, $\omega_{k'} > \frac{1}{k'-k}\sum_{j=k+1}^{k'}\omega_j$, which implies $(k'-k)\omega_{k'} > \sum_{j=k+1}^{k'}\omega_j$ leading to a contradiction. Therefore there cannot exist two Nash equilibria with different numbers of lobbying firms. *Q.E.D.*

Proposition A2: The equilibrium lobbying effort of a lobbying firm is decreasing in the firm's own cost of lobbying. The effect of an increase in another firm's lobbying costs is ambiguous.

Proof: For a lobbying firm i, $x_i = \frac{\tau\phi(k-1)}{(\sum_{j=1}^{k}\omega_j)^2} \cdot \left(\left(\sum_{j=1}^{k}\omega_j\right) - \omega_i(k-1)\right)$.

Differentiating x_i with respect to ω_i yields

$$\frac{\partial x_i}{\partial \omega_i} = \tau\phi(k-1)\left[\frac{2(k-1)\omega_i \sum_{j=1}^{k}\omega_j - k\left(\sum_{j=1}^{k}\omega_j\right)^2}{\left(\sum_{j=1}^{k}\omega_j\right)^4}\right], \tag{A.3}$$

which is strictly negative if and only if $\frac{2\omega_i}{k} < \frac{1}{k-1}\sum_{j=1}^{k}\omega_j$. Because $k \geq 2$, $\frac{2\omega_i}{k} \leq \omega_i$. The condition for a lobbying firm i is that $\omega_i < \frac{1}{k-1}\sum_{j=1}^{k}\omega_j$. Together these imply $\frac{2\omega_i}{k} < \frac{1}{k-1}\sum_{j=1}^{k}\omega_j$.

Differentiating x_i with respect to $\omega_{i'}$ (with $i' \neq i$) yields

$$\frac{\partial x_i}{\partial \omega_{i'}} = \tau\phi(k-1)\left[\frac{2(k-1)\omega_i - \sum_{j=1}^{k}\omega_j}{\left(\sum_{j=1}^{k}\omega_j\right)^3}\right]. \tag{A.4}$$

The denominator is obviously positive. Because ω_i may be greater or less than $\frac{1}{2(k-1)}\sum_{j=1}^{k}\omega_j$, the sign of $\frac{\partial x_i}{\partial \omega_{i'}}$ is ambiguous. *Q.E.D.*

Appendix B

Table B.1: Regressions with Number of Connected MPs (Unweighted)

Dependent Variable: *Ln(Final Allocation)*	***(1)***	***(2)***	***(3)***
Ln(Provisional Allocation)	0.937*** (0.042)	0.922*** (0.057)	0.965*** (0.042)
Number of MPs	**0.016 (0.032)**	**0.008 (0.049)**	**-0.059 (0.056)**
(Number of MPs)^2	**-0.00005 (0.0014)**	**-0.00001 (0.0021)**	**0.0025 (0.0024)**
ln(Total Fixed Assets)			0.015 (0.042)
ln(Employees)			0.030 (0.083)
Profit Margin			0.0054 (0.0043)
Industry Controls?	No	Yes	Yes
Weighted Regression?	No	No	No
N	247	247	185
R^2	0.84	0.86	0.90

Excludes universities, hospitals, and other government entities. Standard errors (in parentheses) are clustered by industry. The superscripts ***, **, and * denote significance at 1, 5, and 10 percent levels respectively.

Table B.2: Regressions with Number of Connected MPs (Unweighted, Firms in Top Quintile of Provisional Allocations)

Dependent Variable: *Ln(Final Allocation)*	***(1)***	***(2)***	***(3)***
Ln(Provisional Allocation)	0.921*** (0.022)	0.903*** (0.042)	0.859*** (0.069)
Number of MPs	**0.055 (0.043)**	**0.042 (0.063)**	**0.032 (0.037)**
(Number of MPs)^2	**-0.0018 (0.0016)**	**-0.0016 (0.0024)**	**-0.0010 (0.0014)**
ln(Total Fixed Assets)			0.032 (0.020)
ln(Employees)			0.014 (0.016)
Profit Margin			0.0019 (0.0037)
Industry Controls?	No	Yes	Yes
Weighted Regression?	No	No	No
N	49	49	35
R^2	0.73	0.78	0.97

Sample is limited to firms in the top quintile of provisional allocations. Excludes universities, hospitals, and other government entities. Standard errors (in parentheses) are clustered by industry. The superscripts ***, **, and * denote significance at 1, 5, and 10 percent levels respectively.

Table B.3: Regressions with Number of Connected MPs (Unweighted, Firms in Bottom 4 Quintiles of Provisional Allocations)

Dependent Variable: *Ln(Final Allocation)*	***(1)***	***(2)***	***(3)***
Ln(Provisional Allocation)	0.857*** (0.046)	0.859*** (0.049)	0.877*** (0.063)
Number of MPs	**-0.0065 (0.0688)**	**-0.020 (0.111)**	**-0.101 (0.105)**
(Number of MPs)^2	**0.0006 (0.0040)**	**0.0016 (0.0066)**	**0.0049 (0.0062)**
ln(Total Fixed Assets)			0.015 (0.081)
ln(Employees)			0.024 (0.128)
Profit Margin			.011 (0.0066)
Industry Controls?	No	Yes	Yes
Weighted Regression?	No	No	No
N	198	198	150
R^2	0.65	0.67	0.72

Sample is limited to firms in the bottom four quintiles of provisional allocations. Excludes universities, hospitals, and other government entities. Standard errors (in parentheses) are clustered by industry. The superscripts ***, **, and * denote significance at 1, 5, and 10 percent levels respectively.

Table B.4: Regressions with Number of Connected MPs (Weighted, Levels)

Dependent Variable: *Final Allocation*	***(1)***	***(2)***	***(3)***
Provisional Allocation	0.956*** (0.021)	0.979*** (0.029)	0.989*** (0.009)
Number of MPs	**298,565***** **(30,128)**	**247,243***** **(19,489)**	**267,234***** **(38,322)**
(Number of MPs)^2	**-10,004***** **(2,099)**	**-8,519***** **(1,151)**	**-8,957***** **(1,877)**
ln(Total Fixed Assets)			128,232* (58,952)
ln(Employees)			-163,150 (107,381)
Profit Margin			3,638 (8,000)
Industry Controls?	No	Yes	Yes
Weighted Regression?	Yes	Yes	Yes
N	247	247	185
R^2	0.99	0.99	0.99

Excludes universities, hospitals, and other government entities. Observations weighted by provisional allocation. Standard errors (in parentheses) are clustered by industry. The superscripts ***, **, and * denote significance at 1, 5, and 10 percent levels respectively.

Table B.5: Regressions with Number of Connected MPs (Unweighted, Levels)

Dependent Variable: *Final Allocation*	*(1)*	*(2)*	*(3)*
Provisional Allocation	0.966***	0.967***	0.987***
	(0.012)	(0.016)	(0.016)
Number of MPs	**58,883**	**60,930**	**68,527**
	(60,227)	**(55,544)**	**(69,390)**
(Number of MPs)^2	**-1,199**	**-1,632**	**-1,693**
	(2,883)	**(2,767)**	**(2,998)**
ln(Total Fixed Assets)			27,156
			(26,945)
ln(Employees)			-28,774
			(39,720)
Profit Margin			-948
			(2,161)
Industry Controls?	No	Yes	Yes
Weighted Regression?	No	No	No
N	247	247	185
R^2	0.99	0.99	0.99

Excludes universities, hospitals, and other government entities. Standard errors (in parentheses) are clustered by industry. The superscripts ***, **, and * denote significance at 1, 5, and 10 percent levels respectively.

Table B.6: Regressions with Number of Connected MPs (Unweighted, Levels, Firms in Top Quintile of Provisional Allocations)

Dependent Variable: *Final Allocation*	*(1)*	*(2)*	*(3)*
Provisional Allocation	0.954*** (0.013)	0.953*** (0.023)	0.946*** (0.010)
Number of MPs	**177,343**** **(69,490)**	**201,964***** **(51,783)**	**330,714***** **(32,403)**
(Number of MPs)^2	**-5,828** **(3,127)**	**-7,206***** **(918)**	**-11,535***** **(484)**
ln(Total Fixed Assets)			51,071 (57,897)
ln(Employees)			-46,427 (98,917)
Profit Margin			3,480 (10,104)
Industry Controls?	No	Yes	Yes
Weighted Regression?	No	No	No
N	49	49	35
R^2	0.98	0.99	0.99

Sample is limited to firms in the top quintile of provisional allocations. Excludes universities, hospitals, and other government entities. Standard errors (in parentheses) are clustered by industry. The superscripts ***, **, and * denote significance at 1, 5, and 10 percent levels respectively.

Table B.7: Regressions with Number of Connected MPs (Unweighted, Levels, Firms in Bottom 4 Quintiles of Provisional Allocations)

Dependent Variable: *Final Allocation*	*(1)*	*(2)*	*(3)*
Provisional Allocation	1.077***	1.070***	1.017***
	(0.069)	(0.070)	(0.076)
Number of MPs	**-1,049**	**-346**	**-1,624**
	(2,301)	**(3,085)**	**(3,219)**
(Number of MPs)^2	**-119**	**-138**	**-59**
	(187)	**(227)**	**(227)**
ln(Total Fixed Assets)			481
			(1,025)
ln(Employees)			37
			(1,817)
Profit Margin			218
			(148)
Industry Controls?	No	Yes	Yes
Weighted Regression?	No	No	No
N	198	198	150
R^2	0.90	0.91	0.94

Sample is limited to firms in the bottom four quintiles of provisional allocations. Excludes universities, hospitals, and other government entities. Standard errors (in parentheses) are clustered by industry. The superscripts ***, **, and * denote significance at 1, 5, and 10 percent levels respectively.

References

[1] Anger, N., C. Böhringer, and U. Oberndorfer. 2008 "Public interest vs. interest groups: allowance allocation in the EU Emissions Trading Scheme." *ZEW-Centre for European Economic Research Discussion Paper 08-023*.

[2] Brandt, U. S., and G.T. Svendsen 2004 "Rent-seeking and grandfathering: The case of GHG trade in the EU" *Energy & Environment* 15(1): 69-80.

[3] Buchner, B. and C. Carraro, and A. Ellerman 2006 "The Allocation of European Union Allowances: Lessons, Unifying Themes and General Principles" *MIT Joint Program on the Science and Policy of Global Change* Report No. 140.

[4] Coase, R. 1960 "The Problem of Social Cost" *Journal of Law and Economics* 3: 1-44.

[5] Congleton, R.D., A.L. Hillman, and K.A. Konrad 2008 "Forty years of research on rent seeking: an overview." in *The Theory of Rent Seeking: Forty Years of Research* 1: 1-42.

[6] Convery, F.J. and L. Redmond 2007 "Market and Price Developments in the European Union Emissions Trading Scheme" *Review of Environmental Economics and Policy* 1(1): 88-111.

[7] Cramton, P. and S. Kerr 2002 "Tradeable Carbon Permit Auctions: How and Why to Auction not to Grandfather" *Energy Policy* 30: 333-45.

[8] Department of Environment, Food, and Rural Affairs 2005 "EU Emissions Trading Scheme: Approved National Allocation Plan 2005-2007" Accessed from `http://www.decc.gov.uk/en/content/cms/emissions/eu_ets/phase_1/phasei_nap/phasei_nap.aspx` on January 17, 2012.

[9] Department of Trade and Industry 2004 "UK Draft National Allocation Plan for 2005-2007", Accessed from on `http://fool.uk-wire.com/Article.aspx?`

id=200401191044023667U and http://fool.uk-wire.com/Article.aspx?id=200401191044073672U on September 20, 2012.

[10] Duggan, J. (2009) Cap and Trade Comes of Age in Europe" World Resources Institute. Accessed from http://www.wri.org/blog/2009/12/cap-and-trade-comes-age-europe.

[11] *The Economist*, November 16, 2006, "Soot, smoke and mirrors: Europe's flagship environmental programme is foundering" Accessed from http://www.economist.com/node/8167968?story_id=8167968 on January 17, 2012.

[12] Ellerman, A., F. Convery, and C. de Perthuis 2010 *Pricing Carbon: The European Union Emissions Trading Scheme* Cambridge University Press.

[13] Ellerman, A. and P. Joskow 2008 "The European Union's Emissions Trading System in perspective" prepared for the Pew Center for Global Climate Change.

[14] Ellerman, A., B. Buchner, and C. Carraro (eds) 2007 *Allocation in the EU Emissions Trading Scheme: Rights, Rents, and Fairness* Cambridge University Press.

[15] Faccio, M., R.W. Masulis, and J.J. McConnell 2006 "Political Connections and Corporate Bailouts" *Journal of Finance* 61: 2597-2635.

[16] Ferguson, T., and H. Voth 2008 "Betting on Hitler–The Value of Political Connections in Nazi Germany" *Quarterly Journal of Economics* 123(1): 101–37.

[17] Fowlie, M. 2010 "Allocating Emissions Permits in Cap-and-Trade Programs: Theory and Evidence" *UC Berkeley Working Paper*.

[18] Franke, J., C. Kanzow, W. Leininger, and A. Schwartz 2013 "Effort maximization in asymmetric contest games with heterogeneous contestants" *Economic Theory* 52(2): 589-630.

[19] Goulder, L. H., I. W. H. Parry, R. C. Williams III, and D. Burtraw 1999 "The Cost-effectiveness of Alternative Instruments for Environmental Protection in a Second-best Setting" *Journal of Public Economics* 72(3): 329–60.

[20] Grossman, H.I. "The Creation of Effective Property Rights" *American Economic Review* 91(2): 347-352.

[21] *The Guardian*, September 12, 2008, "Britain's worst polluters set for windfall of millions" Accessed from `http://www.guardian.co.uk/environment/2008/sep/12/emissionstrading` on January 17, 2012.

[22] Hahn, R. W. 1984 "Market Power and Transferable Property Rights" *Quarterly Journal of Economics* 99(4): 753-65.

[23] Hahn, R.W. and R.N. Stavins 2011 "The Effect of Allowance Allocations on Cap-and-Trade System Performance" *Journal of Law and Economics* 54(4): S267-S294.

[24] Hanley, N. and I.A. MacKenzie 2010 "The Effects of Rent Seeking over Tradable Pollution Permits" *The B.E. Journal of Economic Analysis & Policy* 10(1): 56.

[25] Hanoteau, J. 2003 "Lobbying for emissions allowances: a new perspective on the political economy of the US Acid Rain program" *Rivista di politica economica* 43: 289-313.

[26] Hodler, R. 2006 "The curse of natural resources in fractionalized countries" *European Economic Review* 50: 1367-1386.

[27] Joskow, P. and R. Schmalensee 1998 "The Political Economy of Market-Based Environmental Policy: The US Acid Rain Program" *Journal of Law and Economics* 41: 37-83.

[28] Khwaja, A.I. and A. Mian 2005 "Do Lenders Favor Politically Connected Firms? Rent-Seeking in an Emerging Financial Market" *Quarterly Journal of Economics* 120: 1371-1411.

[29] MacKenzie, I.A. and M. Ohndorf 2012 "Cap-and-trade, taxes, and distributional conflict" *Journal of Environmental Economics and Management* 63: 51-65.

[30] MacKenzie, I.A. 2017 "Rent creation and rent seeking in environmental policy" *Public Choice* 171: 145-166.

[31] Mahoney, C. 2009 "Why lobbying in America is different" *Politico*, June 4, 2009, Accessed from `https://www.politico.eu/article/why-lobbying-in-america-is-different/` on December 21, 2019.

[32] Mallard, G. 2009 "The European Union's Emission Trading Scheme: Political Economy and Bureaucratic Rent-Seeking" Bath Economics Research Papers No. 22/09. Accessed from `http://opus.bath.ac.uk/15957/1/2209.pdf` on August 23, 2013.

[33] Montgomery, W.D. 1972 "Markets in Licenses and Efficient Pollution Control Programs" *Journal of Economic Theory* 5: 395-418.

[34] Nordhaus, W.D. 2006 "After Kyoto: Alternative Mechanisms to Control Global Warming" *American Economic Review* 96(2): 31-34.

[35] Nordhaus, W.D. 2007 "To Tax or Not to Tax: Alternative Approaches to Slowing Global Warming" *Review of Environmental Economics and Policy* 1(1): 26-44.

[36] Skaperdas, S. 1996 "Contest success functions" *Economic Theory* 7: 283–90.

[37] Stavins, R.N. 1995 "Transaction Costs and Tradable Permits" *Journal of Environmental Economics and Management* 29: 133-148.

[38] Stavins, R.N. 1998 "What Have We Learned from the Grand Policy Experiment: Lessons from SO2 Allowance Trading" *Journal of Economic Perspectives* 12(3): 69-88.

[39] Tullock, G. 1967 "The Welfare Costs of Tariffs, Monopolies, and Theft" *Western Economic Journal* (now *Economic Inquiry*) 5: 224-32.

[40] Tullock, G. 1980 "Efficient Rent-Seeking" in *Toward a Theory of the Rent-Seeking Society* (Buchanan, J.M., R.D. Tollison and G. Tullock eds.) College Station: Texas A&M University Press, 97-112.