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Auctions or grandfathering: the political economy of tradable emission permits

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Abstract Despite the prevalence of grandfathered permits, we still observe that a hybrid policy, in which a fraction of initial emission permits is distributed through auctions, is adopted in some cases. We also observe that some polluting industries support auctioned permits, and that most environmental groups support grandfathered permits. This paper attempts to explain these phenomena from the perspective of political economy, and investigates the conditions under which grandfathering, auctions, or a hybrid instrument will be the equilibrium policy. By constructing a two-stage lobbying game, in which the type of policy instrument (auction, grandfathering, or a hybrid instrument) is determined in the first stage, and then the number of permits is decided in the second stage, we highlight the strategic interaction of the lobbying activities between the two stages in explaining the behavior of the lobbying groups.

Keywords Auction · Grandfathering · Interest groups · Lobbying · Environmental policy · Tradable emission permits

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1 Introduction

Tradable emission permits have become an important policy instrument in protecting the environment. One critical issue in designing a tradable emission permit system is how the initial permits are distributed. Although most studies recognize the advantages of auction

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permit systems in terms of efficiency (e.g., Goulder et al. 1997; Fullerton and Metcalf 2001), auction systems have been used far less frequently than grandfathering systems. Many scholars believe that the prevalence of grandfathered permits can be attributed to their political acceptability (Stavins 1998). Since it is well known that the formation of environmental policy is frequently subject to the influence of interest groups (e.g., Ackerman and Hassler 1981; Cropper et al. 1992), in order to explain why the grandfathering system dominates the auction system, incorporating the political influence of interest groups into the model seems necessary. Despite the prevalence of grandfathering, a certain fraction of emission permits is distributed through auctions in some cases.[1] Within a framework that takes the influence of interest groups into consideration, the purpose of this paper is to investigate the conditions under which grandfathering will be the equilibrium policy, and under which permits will be distributed through auctions.

There are a number of papers related to how the demands of interest groups shape the choice of environmental policy instruments, including Buchanan and Tullock (1975), Maloney and McCormick (1982), Dewees (1983), Hahn (1990), Dijkstra (1998), and Damania (1999). Although the present paper also examines the instrument choice problem in a framework of political economy, it departs from previous studies in several ways. First, the existing literature generally treats the types of policy instruments as discrete variables.[2] However, when dealing with tradable emission permits, in addition to the two polar cases, grandfathering and auctions, a hybrid situation, in which some but not all initial permits are distributed through auctions, is also possible. Thus a setting with a discrete type of policy instrument appears inadequate when tradable emission permits are under consideration. Allowing for a continuous type of policy instrument distinguishes this present paper from the others.

Second, many of the previous studies emphasize the output restriction arising from pollution control. They argue that imposing an emission standard will restrict output, which in turn will raise the price of the commodity under consideration, thereby increasing the profits of existing firms. Because the scarcity rents created by regulation accrue to the government under an emission tax, they conclude that firms will prefer an emission standard to an emission tax. We rule out such an output-restriction effect in this paper, and instead focus on the market for emission permits, in which scarcity rents are created. Polluting firms may ask the regulator to reduce the emission cap, so as to increase the value of the grandfathered permits.

Third, perhaps the most significant difference in our paper is that the number of permits and the rule regarding distributing the initial permits are determined sequentially. We highlight the interaction of the lobbying activities between the two stages, which is an issue rarely focused on in previous studies. Several examples (see Stavins 1998) have shown that the selection of policy instruments has a significant impact on the cap of emissions. We believe that the sequential decision making is appropriate for characterizing such a linkage.

This paper is also related to the work of Fredriksson (1997) and Aidt (1998), both of which have origins in Grossman and Helpman (1994). However, our model extends their work to consider a two-stage lobbying game, so that the choice of policy instrument is endogenized. The time line of the game is as follows: the proportion of grandfathered permits

[1] For example, under the sulfur allowance program, the US Environmental Protection Agency withholds 2.24 per cent of the allocated allowances to be used in an auction (see Tietenberg 1999). In addition, the European Union Directive allows member states to auction up to 5 percent of their allocation in the first phase and 10 percent in the second phase.

[2] An exception is Hahn (1990), who specifies a continuous variable to characterize the degree to which a system is market oriented.

to the total number of permits is determined in the first stage, and then the total number of permits is decided in the second stage. Industrial groups and an environmental group are able to influence the formation of the environmental regulation in the two stages by providing political contributions to the government. Under a subgame perfect Nash equilibrium, when choosing the type of instrument (auction, grandfathering, or a hybrid instrument) in the first stage, interest groups will take the impact of changing the rule regarding distributing the pollution rights on their welfare in stage two into consideration.

Within this context, we obtain several results. First, as noted by Coase (1960), the efficiency of resource allocation is independent of the distribution of pollution rights. However, this is not the case when the influence of interest groups is involved. The emission cap will either increase or decrease with the proportion of grandfathered permits to total permits, and will deviate from the socially optimal level. Second, in addition to explaining the prevalence of grandfathered permits, we also provide a possible answer to the question concerning why a hybrid instrument, in which some initial permits are distributed through auctions, is chosen in some situations.

We also find that a polluting industry may promote an auction permit system, in particular when it is endowed with a small number of free permits. Although this finding seems a little puzzling, it is consistent with the empirical evidence provided by Markussen and Svendsen (2005). The survey evidence (Svendsen 1999) also reveals that, at least in the United States, environmental groups prefer a grandfathering permit system to an emission tax, which is equivalent to a system of auctioning permits. Researchers attribute this phenomenon to problems such as uncertainty (Stavins 1998) or ethics (Weck-Hannemann and Frey 1995). This paper provides an alternative explanation. We demonstrate that the effects of a change in the rule regarding distributing permits on the emission cap are crucial in determining the lobbying behavior of interest groups. In order to reduce its financial burden, an industry endowed with a small number of free permits will endorse an auction, because an auction will strengthen its political influence in stage two, which will help the industry to lobby for a greater share of the emission cap, and a lower price of the permits. On the other hand, the environmentalists will want to minimize the number of permits in the second stage, so that they will promote grandfathering in the first stage.

The remainder of this paper proceeds as follows. In Sect. 2, we introduce the model underlying our analysis. In Sect. 3, we discuss the objective functions of the government and the interest groups. The second stage and the first stage of the lobbying game are investigated in Sects. 4 and 5, respectively. In Sect. 6, we present our concluding remarks.

2 The model

We consider a small open economy consisting of I polluting industries. All the firms in the same industry are assumed to be identical, so that the number of firms in each industry can be normalized as one. The markets for each industry's (firm's) product are perfectly competitive, and those can be imported freely from other jurisdictions.[3] For simplicity, the prices of the products are normalized as one. In order to produce outputs, all of the industries employ a variable input, x, and a sector-specific input. The use of x will generate pollutants. By appropriately choosing the unit of pollutant, each unit of x used gives rise to one unit of pollutant.

[3] The reason why we make this assumption is to avoid the situation in which lobbying activities will change the prices of outputs. Doing so helps us to concentrate on the market for emission permits.

A representative firm in industry i solves the following problem:

$$\max_{x_i, a_i} \Pi_i = f_i(x_i) - w x_i - A_i(a_i) + \tau[e_i - \epsilon_i], \quad i = 1, \dots, I. \tag{1}$$

The production function $f(x)$, where we omit the sector-specific input in the expression, has the properties $\partial f_i/\partial x_i > 0$ and $\partial^2 f_i/\partial x_i^2 < 0$. The parameter w denotes the price of purchasing x, which is assumed to be exogenously given. The abatement technology is feasible, and the abatement amount is denoted by a. The net pollutant emitted is denoted by ϵ, which is equal to $x - a$. The abatement cost function, $A(a)$, is a strictly convex function of a, with the properties $\partial A_i/\partial a_i > 0$ and $\partial^2 A_i/\partial a_i^2 > 0$.

To control the pollution damage, the government issues a certain amount of emission permits, each one of which allows the holder to emit one unit of pollutant. Firms are allowed to trade permits in a competitive market, in which the permit price, τ, is determined. These permits may be issued by grandfathering or through auctions. The variable e stands for the initial permits. Under an auction, e_i is equal to zero. Since discharges are illegal without sufficient permits to cover them, if a firm's initial permits are fewer than those it requires, then it has to buy permits from other dischargers. The number of permits that industry i has after trading will be equal to the net emission, ϵ_i.

Given a particular permit price τ, a profit-maximizing firm will choose x and a, the pollution abatement level, to satisfy the following conditions:

$$\partial f_i(x_i)/\partial x_i - w - \tau = 0, \tag{2}$$

$$\partial A_i(a_i)/\partial a_i - \tau = 0. \tag{3}$$

Equation (2) states that the equilibrium level of the dirty input will equate the value of its marginal product with the gross marginal cost. From (3), at the equilibrium level of abatement, the marginal abatement cost should be equal to the price of the permits. Solving these two equations yields the effects of changing τ on x_i and a_i as follows:

$$\frac{\partial x_i}{\partial \tau} = \frac{1}{\partial^2 f_i/\partial x_i^2} < 0, \tag{4}$$

$$\frac{\partial a_i}{\partial \tau} = \frac{1}{\partial^2 A_i/\partial a_i^2} > 0. \tag{5}$$

As we expected, an increase in τ will reduce the industry's demand for x and increase its pollution abatement. Since $\epsilon_i = x_i - a_i$, combining (4) and (5) yields $\partial \epsilon_i/\partial \tau = \partial x_i/\partial \tau - \partial a_i/\partial \tau < 0$; or, in words, net pollution emissions decrease as τ increases.

The government issues a total of E permits. The distribution of E can take place through grandfathering, auctioning, or a hybrid instrument. The amount λE is given to firms freely, and the remaining $(1-\lambda)E$ is sold by auction, where $\lambda \in [0, 1]$. Under an auction, the proceeds from selling the permits are distributed to the general public in a lump-sum form.

The equilibrium condition for the permit market requires:

$$\sum_{i=1}^{I} \epsilon_i = E. \tag{6}$$

The left-hand side is the aggregate demand for permits, which is equal to the summation of all firms' net emissions, and the right-hand side represents the permits issued by the government. The permits market is competitive, and thus the equilibrium permit price is determined by (6) (see Xepapadeas 1997, Sect. 3.3). From (6) we can solve the effect of changing the number of permits on the equilibrium permit price:[4]

$$\frac{d\tau}{dE} = \frac{1}{\sum_{i=1}^{I} \partial\epsilon_i/\partial\tau} < 0. \tag{7}$$

This result is quite intuitive. The more permits that are issued, the lower τ will be. Moreover, since the left-hand side of (6), the aggregate demand for permits, is a strictly decreasing function of τ, this implies that there is a unique corresponding τ that satisfies (6) at a particular E.

In addition to the industrialists, the jurisdiction under consideration also contains another two types of residents: environmentalists and consumers. The same type of residents are identical. The utility function of a representative environmentalist is given by: $u_g = y_g + s - d(E)$, where the subscript g refers to "greens", and y_g stands for the income of the environmentalist, which is assumed to be exogenously given.[5] The variable s stands for the lump-sum transfer from the government, which is financed by auctioning emission permits. The environmentalists regard the lump-sum transfer as exogenously given.[6] This can be justified by arguing that the proceeds from selling permits are a part of the government's general revenues, so that it is hard for the interest groups to affect the transfers. The disutility arising from pollution is denoted by $d(E)$, with the properties $d' > 0$ and $d'' > 0$.

The utility function of a representative consumer is given by: $u_c = y_c + s$. Again, we assume that the consumers' income, y_c, is exogenously given, and that s is regarded as fixed by the consumers.

3 The lobbying game

The previous section reveals that the welfare of the industrialists and the environmentalists is closely related to the environmental regulation, and thus they have incentives to affect the format of the regulatory regime. Industrialists and environmentalists are assumed to organize themselves into separate groups that coordinate offers of political contributions to the government. The industrial groups are denoted by $i = 1, \ldots, I$, and the green lobby is denoted by g. Since the consumers consider that their welfare is independent of the environmental regulation, they will not engage in the lobbying activity.[7] Each lobbying group offers political contributions, m, to the government in return for more favorable policies.

Before discussing the determination of the equilibrium policy, it will prove convenient in what follows to define each lobbying group's gross-of-contributions payoff function. The

[4] Totally differentiating the equilibrium condition in (6) yields $\sum_{i=1}^{I}(\partial\epsilon_i/\partial\tau)d\tau = dE$. Rearranging it leads to (7).

[5] Environmentalists can work in competitive industries which do not emit pollution, or they can receive income from capital or other wealth, so that their income is independent of the environmental regulation.

[6] For simplicity, we assume that the industries do not receive the transfers. The results are independent of the way in which the proceeds are distributed, as long as the transfers are regarded as fixed by the recipients. More discussions regarding this issue can be found in Sect. 6.

[7] Alternatively, we can assume that consumers constitute a large part of the total population and are thus too numerous to overcome the free-rider problem and organize themselves into a lobbying group.

gross-of-contributions payoff function of industry i in stage two, which is denoted by W_i^2, is given by:

$$\begin{aligned} W_i^2 = \Pi_i &= f_i(x_i) - wx_i - A_i(a_i) + \tau[e_i - \epsilon_i] \\ &= f_i(x_i) - wx_i - A_i(a_i) + \tau[\alpha_i\lambda - \beta_i]E, \quad i = 1, \ldots, I \end{aligned} \tag{8}$$

where $\alpha_i\lambda$ is equal to e_i/E, which measures the proportion of the initial permits to the total permits, and β_i is equal to ϵ_i/E, which measures the proportion of the net pollution emissions to E. The fraction α_i is non-negative, and the sum of all the αs is equal to one. As a practical matter, α_i is usually based on historical emissions, so it is assumed to be exogenously given throughout this paper. The aim of each lobbying group is to maximize its net payoff, which is equal to the gross payoff function minus the political contributions.

The gross-of-contributions payoff function of the environmental group in stage two, W_g^2, is given by:

$$W_g^2 = U_g = n_g y_g + n_g s - D(E) \tag{9}$$

where n_g denotes the number of environmentalists, and D stands for the aggregate disutility, which is equal to $n_g d(E)$.

One feature of this model is that both the proportion of grandfathered permits (λ) and the total number of permits (E) are subject to the influence of interest groups. The time line of the lobbying game is as follows: in the first stage, the fraction of grandfathered permits is determined, and then in the second stage, given λ, the total number of permits is chosen. Although we specify that each industry attempts to influence the overall emission cap, our setting also allows us to consider the case where each industry lobbies for its own permits by setting $I = 1$.[8] We will see that different interpretations will lead to different equilibrium policies.

Tradable permits that are distributed through auctioning are equivalent to emission taxes in our model. When an interest group lobbies for auctioned permits, it will endorse emission taxes as well. Therefore, the decision made in stage one is actually a problem of instrument selection. Several examples have indicated that the selection of policy instruments gives rise to significant impacts on the quantity of emissions (see Stavins 1998). The sequence of decision making in our setting can characterize the close relationship between the selection of policy instruments and the cap of emissions.

In order to obtain a subgame perfect Nash equilibrium, we start from the second stage of the lobbying game. The goal of the incumbent government is to remain in office. To this end, the government chooses the relevant policy variables to maximize the weighted average of the social welfare and the collected political contributions. Following Grossman and Helpman (1994), the political support function of the government in the second stage is given by:[9]

$$G^2 = \theta\left(\sum_{i=1}^{I} m_i^2 + m_g^2\right) + W \tag{10}$$

[8] When $I = 1$, firms still can trade permits within the industry.

[9] The empirical studies testing the Grossman-Helpman model reveal that the governments attach positive weights to both the political contributions and the social welfare (see, e.g., Goldberg and Maggi 1999; Gawande and Bandyopadhyay 2000). These results can justify the setting of the government's objective function.

where m_i^2 and m_g^2 stand for industry i's contributions and the environmental group's contributions in stage two, respectively. The parameter $\theta > 0$ is the weight the government attaches to the contributions received from lobbying groups.[10]

The social welfare function, W, is defined as the sum of the profits of the industries, and the welfare of the environmentalists and the consumers, which is equal to:

$$W = \sum_{i=1}^{I} \Pi_i + \tau(1-\lambda)E + n_c y_c + n_g y_g - D(E) \tag{11}$$

where n_c is the number of consumers. In (11), we apply the government budget constraint: $(n_c + n_g)s = (1-\lambda)\tau E$.

For ease of exposition, we assume that all lobbying groups' contribution schedules are globally truthful; that is, the contribution schedule of a lobbying group everywhere reflects its true welfare.[11] According to Grossman and Helpman (1994), a truthful contribution schedule of industry i in stage two takes the form:

$$m_i^2 = \max[0, \Pi_i - B_i^2], \quad i = 1, \ldots, I. \tag{12}$$

In words, a truthful contribution pays the government the true welfare effect of a change in E in excess of a base level of welfare B_i^2, which is the reservation welfare for industry i. The determination of an interest group's reservation welfare will be discussed in Sect. 5. Similarly, a truthful contribution schedule of the environmental group in stage two is given by:

$$m_g^2 = \max[0, U_g - B_g^2] \tag{13}$$

where B_g^2 stands for the environmental group's reservation welfare in stage two. We will assume that all interest groups provide positive contributions.

As we demonstrate in Appendix B, an interest group's reservation welfare is independent of E. Therefore, under the global-truthfulness assumption, $\partial m_i^2/\partial E$ will be equal to $\partial \Pi_i/\partial E$, and $\partial m_g^2/\partial E$ will be equal to $\partial U_g/\partial E$. As we will see, these relationships are important in determining the equilibrium environmental policies.

4 The equilibrium emission permits

We first discuss the lobbying behavior of interest groups in stage two, and then turn to the effect of λ on the equilibrium number of permits.

[10] Grossman and Helpman (1996) show that the government's objective function emerges from a political game in which interest groups use political contributions to influence the outcome of the election, and two parties compete for seats in parliament. By considering the specification of probabilistic voting, they show that the weight θ is related to the incumbent party's probability of winning.

[11] Bernheim and Whinston (1986) show that a truthful schedule is a best response to any strategy of the opponent, even if it is not the only best response. Therefore, they argue that truthful Nash equilibria may be focal among the set of Nash equilibria. This justifies the assumption of global-truthfulness.

4.1 Marginal willingness to contribute

Differentiating (10) with respect to E yields the first-order condition of the government's maximizing problem:

$$\frac{\partial G^2}{\partial E} = \theta\left(\sum_{i=1}^{I}\frac{\partial m_i^2}{\partial E} + \frac{\partial m_g^2}{\partial E}\right) + \frac{\partial W}{\partial E} = \theta\left(\sum_{i=1}^{I}\frac{\partial \Pi_i}{\partial E} + \frac{\partial U_g}{\partial E}\right) + \frac{\partial W}{\partial E} = 0 \qquad (14)$$

where we apply the property that all interest groups' contribution schedules are globally truthful.

Equation (14) determines the equilibrium number of permits, which is denoted by E°. To deliberate over the meaning of (14), we need to first discuss an important property of the contribution schedule implied by the global-truthfulness assumption. Under the global-truthfulness assumption, a marginal increase in E will induce industry i to contribute the amount $\partial \Pi_i/\partial E$. Therefore, industry i's marginal willingness to contribute (MWTC) for lobbying E, which is defined as $\partial m_i^2/\partial E$, is equal to $\partial \Pi_i/\partial E$. Similarly, the MWTC of the environmental group, which is defined as $\partial m_g^2/\partial E$, is equal to $\partial U_g/\partial E$.

Let us examine the MWTC of each group more thoroughly. In Appendix A we derive industry i's MWTC for lobbying E as follows:

$$\frac{\partial \Pi_i}{\partial E} = (1-\eta)\alpha_i\lambda\tau + \beta_i\eta\tau \qquad (15)$$

where $\eta = -(d\tau/dE)(E/\tau)$ is the elasticity of τ with respect to E. The elasticity of τ with respect to E is closely related to the demand for emissions. If the demand for emissions is quite inelastic, which generally occurs (see Tietenberg 1999), then the change in the price of permits will be greater than the change in the number of emissions demanded, which implies that $\eta > 1$. Hereafter, we will focus on the case where $\eta > 1$.

According to (15), industry i's MWTC for lobbying E consists of two parts: the endowment effect, $(1-\eta)\alpha_i\lambda\tau$, and the expenditure effect, $\beta_i\eta\tau$. The endowment effect measures the impact of E on the value of the initial permits. This can be seen by rewriting $(1-\eta)\alpha_i\lambda\tau$ as $d(\tau e_i)/dE$. Under an auction ($\lambda = 0$), no permits are distributed initially, so that the endowment effect is equal to zero as well. When both λ and α_i are greater than zero, an increase in E will increase the quantity of the initial permits of industry i, whereas it will decrease the price of permits. Thus the sign of the endowment effect is ambiguous, and depends on η, the elasticity of τ with respect to E. When $\eta > 1$, which implies that an increase in E will substantially lower the price of permits, the endowment effect is negative. With a negative endowment effect, industry i will attempt to restrict E, in order to enhance the value of the initial permits.

Unlike the endowment effect, the sign of the expenditure effect is definitely positive. This effect can be expressed as $-\epsilon_i \cdot d\tau/dE > 0$, which reflects the saving in the financial burden on purchasing permits due to an expansion in E. Thus the expenditure effect always leads the industries to lobby for a larger emission cap.

To sum up, in the case where $\lambda > 0$ and $\alpha_i > 0$, when $\eta > 1$, the endowment effect is negative, whereas the expenditure effect is positive. If the endowment effect is sufficiently strong, then industry i will intend to reduce the emission cap.

The environmental group's MWTC for lobbying E can be obtained by differentiating (9) with respect to E, which is equal to:

$$\frac{\partial U_g}{\partial E} = -D'(E) < 0. \qquad (16)$$

The MWTC of the environmental group is unambiguously negative, which means that the environmentalists will lobby for a smaller emission cap.

4.2 Comparative statics

In order to obtain the equilibrium policy, we substitute (15) and (16) into (14), and obtain:

$$\frac{\partial G^2}{\partial E} = \theta\left(\sum_{i=1}^{I}[(1-\eta)\alpha_i\lambda + \beta_i\eta]\tau - D'\right) + \tau - D' = 0 \tag{17}$$

where we apply the result that $\partial W/\partial E = \tau - D'$. The equilibrium emission cap, E°, is implied by (17). We also find that if the government does not attach any weight to the political contributions, i.e. $\theta = 0$, then the equilibrium emission cap coincides with the socially optimal level, which maximizes the social welfare. In what follows, we will rule out the situation in which θ is equal to zero.

One major concern of this paper is to investigate how the distribution rule regarding the initial permits (λ) affects the emission cap. This effect is crucial in explaining the lobbying behavior of interest groups in the *first* stage. The comparative-static exercise reveals $\partial E^\circ/\partial\lambda = -(\partial^2 G^2/\partial E\partial\lambda)/(\partial^2 G^2/\partial E^2)$. Because the second-order condition of maximizing G^2 requires that $\partial^2 G^2/\partial E^2 < 0$, the sign of $\partial E^\circ/\partial\lambda$ is the same as that of $\partial^2 G^2/\partial E\partial\lambda$. Partially differentiating (17) with respect to λ yields:

$$\frac{\partial^2 G^2}{\partial E\partial\lambda} = \theta(1-\eta)\tau. \tag{18}$$

According to (18), the number of permits decreases with λ, provided that η is greater than one.

As indicated previously, there is a unique value of τ that corresponds to a given E. Thus we can also obtain that the equilibrium price of permits, τ°, increases with λ, when η is greater than one.

The effects of the proportion of the free permits, λ, on the equilibrium price and the number of permits are summarized in the following proposition:

Proposition 1 *In the case where $\eta > 1$, an increase in λ will reduce E° and raise τ°.*

The intuition behind Proposition 1 is as follows. From Sect. 4.1 we know that, when $\eta > 1$, the endowment effect is negative. With a negative endowment effect, an increase in λ will lower the industrial groups' MWTCs to increase E, or raise their MWTCs to restrict E, as shown by (15). Thus, the equilibrium emission cap will decrease with λ, provided that η is greater than one.

These results are related to the Coase theorem, which can be stated as: "If transaction costs are zero, the initial assignment of a property right—for example, whether to the polluter or to the victim of pollution—will not affect the efficiency with which resources are allocated" (Posner 1993, p. 195). In grandfathering permits it is implicitly assumed that the initial rights to use the environment are granted to polluters, whereas the rights belong to the general public under an auction. According to (17), the socially optimal number of permits, which should equalize τ and D', is independent of λ.[12] However, the result in Proposition 1

[12]This can be seen by setting $\theta = 0$. By so doing, the number of permits will be set at the socially optimal level, and (17) will also become zero. Also see Montgomery (1972).

reveals that the presence of the influence of interest groups will destroy the allocational neutrality of the initial assignment of the pollution rights.[13]

5 Auctions or grandfathering

Now we move on to the first stage of the game, in which the proportion of grandfathered permits is determined. We will first consider the following question: Which policy instrument will each lobbying group support? And then we will turn to investigate the equilibrium λ in Sect. 5.3.

5.1 Lobbying attitude of the industrial groups

We first consider the industrial groups' lobbying attitudes. We define the discounted payoff function of industry i in stage one as:

$$W_i^1(\lambda) = \Pi_i(\lambda) + \delta B_i^2(\lambda), \quad i = 1, \dots, I \tag{19}$$

where $\delta \in (0, 1)$ is the discount factor. In addition to the current profit in stage one, the payoff function also contains B_i^2, industry i's reservation welfare in stage two. When trying to affect λ in stage one, industry i will consider both the direct effect of λ on the current profit and the effect of λ on its reservation welfare in stage two.

To develop the analysis further, we first need to obtain B_i^2. Given the equilibrium contribution of the other interest groups, industry i wishes to make B_i^2 as large as possible (and the contributions as small as possible) to induce the equilibrium policy, E°. Therefore, the government must be indifferent between implementing E° and receiving the equilibrium contributions from all interest groups on the one hand, or receiving contributions from all groups except for industry i on the other (Grossman and Helpman 1994; Rama and Tabellini 1998). Specifically,

$$\theta\left(\sum_{j=1}^{I} m_j^2(E^\circ) + m_g^2(E^\circ)\right) + W(E^\circ) = \theta\left(\sum_{\substack{j=1\\ j\neq i}}^{I} m_j^2(E^{-i}) + m_g^2(E^{-i})\right) + W(E^{-i}) \tag{20}$$

where θ, the weight that the government attaches to the social welfare, is defined in Sect. 3, and E^{-i} is defined as the emission cap that would emerge from political maximization by the government, if the contribution offered by industry i were zero; that is,

$$E^{-i} = \arg\max \quad \theta\left(\sum_{\substack{j=1\\ j\neq i}}^{I} \Pi_j(E) + U_g(E)\right) + W(E). \tag{21}$$

[13] A number of papers have shown that the efficiency of the final allocation of emission permits may not be independent of the distribution of the initial pollution rights, when firms perceive that they have market power in the permit market (see, e.g., Hahn 1984; Van Egteren and Weber 1996; Malik 2002; Maeda 2003). Stavins (1995) and Crals and Vereeck (2005) investigate the impacts of transaction costs on the invariance property of the Coase theorem. However, these papers do not explicitly consider the influence of interest groups, which differs from this present paper.

Then, by following Rama and Tabellini (1998), we insert the expression for truthful contributions, (12) and (13), into (20), and obtain the reservation welfare for industry i in stage two as:

$$B_i^2 = \sum_{j=1}^{I} \Pi_j(E^\circ) + U_g(E^\circ) + \frac{W(E^\circ)}{\theta} - \sum_{\substack{j=1 \\ j\neq i}}^{I} \Pi_j(E^{-i}) - U_g(E^{-i}) - \frac{W(E^{-i})}{\theta}$$
$$= \mathcal{W}(E^\circ) - \mathcal{W}^{-i}(E^{-i}). \tag{22}$$

We see that industry i's reservation welfare in stage two equals the difference between two weighted social welfare functions, $\mathcal{W}(E^\circ)$ and $\mathcal{W}^{-i}(E^{-i})$. In the first weighted social welfare function $\mathcal{W}(E^\circ)$, which is reflected by the first three terms on the right-hand side of (22), individuals represented by a lobby group receive a weight of $1 + 1/\theta$, and those not so represented receive the smaller weight of $1/\theta$. The second weighted social welfare function $\mathcal{W}^{-i}(E^{-i})$, which is reflected by the last three terms on the right-hand side of (22), does not include industry i's welfare.

By knowing B_i^2, we can turn to the determination of industry i's attitude toward lobbying λ, which depends on the MWTC of industry i. Industry i's MWTC toward lobbying λ, which is equal to $dm_i^1/d\lambda$, is given by:

$$\frac{dm_i^1}{d\lambda} = \frac{dW_i^1}{d\lambda} = \frac{\partial \Pi_i}{\partial \lambda} + \delta \frac{dB_i^2}{d\lambda} \tag{23}$$

where m_i^1 denotes the political contributions provided by industry i in stage one.[14] In deriving the above equation, we apply (19). We note that industry i's MWTC toward lobbying λ consists of two components: the direct effect of λ on the current profits and the effect of λ on B_i^2.

The direct effect of λ on the current profits can be obtained by partially differentiating Π_i with respect to λ:

$$\frac{\partial \Pi_i}{\partial \lambda} = \alpha_i \tau E \geq 0 \quad \text{(windfall wealth effect)}. \tag{24}$$

The direct effect is non-negative. With $\alpha_i > 0$, an increase in λ will increase the industry's initial permits, which in turn will enhance its profits. Since an increase in the fraction of free permits is equivalent to a windfall wealth received by the industry, we will refer to the direct effect of λ on an industry's current profits as the *windfall wealth effect*. With $\alpha_i > 0$, the windfall wealth effect will unambiguously lead industry i to endorse grandfathering.

In Appendix B, we derive the second effect, which equals

$$\frac{dB_i^2}{d\lambda} = \tau^\circ E^\circ - (1-\alpha_i)\tau^{-i} E^{-i} \quad \text{(reservation welfare effect)} \tag{25}$$

where τ^{-i} is the equilibrium permit price when the emission cap is E^{-i}. We will refer to this effect as the *reservation welfare effect* hereafter. Recalling that $B_i^2 = \mathcal{W}(E^\circ) - \mathcal{W}^{-i}(E^{-i})$,

[14] In the truthful Nash equilibrium, m_i^1 takes the form: $m_i^1 = \max[0, W_i^1 - B_i^1]$, where B_i^1 is industry i's reservation welfare in stage one. When deriving (23), we apply the property that B_i^1 is independent of λ. The proof of this property is similar to that where B_i^2 is independent of E.

the reservation welfare effect depends on how λ directly affects $\mathcal{W}(E^{\circ})$ and $\mathcal{W}^{-i}(E^{-i})$. According to (9) and (11), U_g and W are independent of λ, and thus the direct effect of λ on $\mathcal{W}(E^{\circ})$ equals the direct impact of λ on the aggregate profits of all industries; that is, $\partial\mathcal{W}(E^{\circ})/\partial\lambda = \partial(\sum_{j=1}^{I}\Pi_j)/\partial\lambda = \tau^{\circ}E^{\circ}$. Similarly, we have $\partial\mathcal{W}^{-i}(E^{-i})/\partial\lambda = \partial(\sum_{j\neq i}\Pi_j)/\partial\lambda = (1-\alpha_i)\tau^{-i}E^{-i}$.

The sign of the reservation welfare effect is ambiguous. If $E^{\circ} < E^{-i}$, which is implied by $\partial\Pi_i/\partial E < 0$,[15] then $\tau^{\circ}E^{\circ}$ will be greater than $\tau^{-i}E^{-i}$,[16] and so $dB_i^2/d\lambda > 0$. On the other hand, if $E^{\circ} > E^{-i}$, which is implied by $\partial\Pi_i/\partial E > 0$, then $\tau^{\circ}E^{\circ}$ will be smaller than $\tau^{-i}E^{-i}$. The effect of λ on B_i^2 is ambiguous in this case. If α_i is sufficiently small, then $\partial\mathcal{W}^{-i}/\partial\lambda$ will outweigh $\partial\mathcal{W}/\partial\lambda$, and an increase in λ will lower B_i^2. However, when α_i is large, the reverse will occur, thereby resulting in $dB_i^2/d\lambda > 0$.

The above results can be attributed to the following two factors. First, an increase in λ will increase industry i's endowed permits, thereby enhancing its reservation welfare in stage two. We note that this factor is positively related to α_i.

Secondly, industry i's reservation welfare effect is also related to other industries' MWTCs toward lobbying E. An increase in λ strengthens the endowment effects of industry i and other industries. Stronger endowment effects will strengthen other industries' aggregate MWTC toward reducing the emission cap. Suppose the initial equilibrium emission cap is $\bar{E}^{\circ}$. When $\partial\Pi_i/\partial E < 0$, which implies that industry i intends to reduce the emission cap, since other industries as a whole have a greater aggregate MWTC toward reducing the emission cap, industry i can lobby for the equilibrium emission cap $\bar{E}^{\circ}$ by offering fewer contributions. This indicates that industry i can choose a higher level of reservation welfare in stage two. Therefore, in the case where $\partial\Pi_i/\partial E < 0$, when λ increases, the two factors are beneficial to B_i^2, so industry i's reservation welfare effect is positive.

By contrast, when $\partial\Pi_i/\partial E > 0$, which implies that industry i intends to enlarge the emission cap, because other industries as a whole have a greater aggregate MWTC toward reducing the emission cap, industry i needs to offer more contributions so as to lobby for the equilibrium emission cap $\bar{E}^{\circ}$. This indicates that industry i's reservation welfare in stage two is reduced. As a result, in the case where $\partial\Pi_i/\partial E > 0$, when λ increases, the two factors have opposite effects on B_i^2, so the sign of $dB_i^2/d\lambda$ is ambiguous. If α_i is sufficiently large, then the first factor will outweigh the second factor, thereby resulting in $dB_i^2/d\lambda > 0$. If α_i is small, then the results will be reversed.

Considering the case in which all industries are identical may help us understand this point better. In this situation, $\alpha_i = \beta_i = 1/I$, for all i, so that (25) becomes $dB_i^2/d\lambda = \tau^{\circ}E^{\circ} - (1-1/I)\tau^{-i}E^{-i}$. Moreover, all industries will intend to enlarge the emission cap in this case,[17] and thus $\tau^{\circ}E^{\circ}$ will be less than $\tau^{-i}E^{-i}$. If there is only one industry, such that $I = 1$, then $dB_i^2/d\lambda$ will equal $\tau^{\circ}E^{\circ}$, which is positive. On the other hand, if I is sufficiently large, then $dB_i^2/d\lambda$ will be negative, which also implies that the government can benefit from raising λ. This follows from that an increase in the number of the industries will intensify the antagonism among them, and thus the reservation welfare effect of the industries will more likely be negative.

[15] When $\partial\Pi_i/\partial E < 0$, industry i will lobby for a smaller emission cap. Therefore, E° will be less than the equilibrium emission cap in the absence of industry i's contributions.

[16] When E° is less than E^{-i}, τ° is greater than τ^{-i}. The inelastic demand for the emission permits will ensure that $\tau^{\circ}E^{\circ} > \tau^{-i}E^{-i}$.

[17] When $\alpha_i = \beta_i = 1/I$, an industry's MWTC toward lobbying E, $\partial\Pi_i/\partial E$, equals $[\lambda + (1-\lambda)]\tau/I > 0$.

Substituting (24) and (25) into (23) yields:

$$\frac{dW_i^1}{d\lambda} = \underbrace{\alpha_i \tau^\circ E^\circ}_{(+)} + \underbrace{\delta[\tau^\circ E^\circ - (1-\alpha_i)\tau^{-i} E^{-i}]}_{(?)}. \tag{26}$$

Equation (26) determines industry i's attitude toward lobbying λ. The sign of $dW_i^1/d\lambda$ is generally ambiguous. We first consider the case in which $\partial\Pi_i/\partial E < 0$, which implies that industry i will attempt to reduce the emission cap in stage two. As indicated above, the reservation welfare effect is positive in this case. The positive reservation welfare effect along with the windfall wealth effect will result in $dW_i^1/d\lambda > 0$, for all $\lambda \in [0, 1]$; that is, the maximum value of W_i^1 will be reached at $\lambda = 1$. Accordingly, industry i will endorse grandfathered permits ($\lambda = 1$), when $\partial\Pi_i/\partial E < 0$.

When $\partial\Pi_i/\partial E > 0$, which implies that the reservation welfare effect may be negative, industry i's attitude toward lobbying λ is ambiguous, and depends on α_i. If α_i is large, then the previous analysis reveals that the reservation welfare effect is positive. As a result, if α_i is sufficiently large, then industry i will promote grandfathered permits, because $\lambda = 1$ will maximize W_i^1.

However, if α_i is small, then the reservation welfare effect is negative. The reservation welfare effect is likely to outweigh the windfall wealth effect, which is small because of a small α_i, and thus $dW_i^1/d\lambda < 0$, for all $\lambda \in [0, 1]$. This indicates that industry i will support an auction in this situation.

We have shown that a polluting industry may support auctioned permits. This result appears to be contrary to our expectation that industrial groups will endorse grandfathering. However, in the process of forming the final directive for establishing a scheme for greenhouse gas emission allowance trading within the European Union, only a few industries, such as the Combined Heat and Power (CHP) sector, suggested auctions (see Cogen Europe 2002; Markussen and Svendsen 2005). The CHP industry argued that under the distribution rule of initial permits, which was based on historical emission levels, it would receive a small share of emissions.[18] The costs of acquiring additional allowances would penalize the operator investing in cogeneration. Thus the CHP industry suggested auctioning all permits (see Cogen Europe 2002 for more details). This suggestion of the CHP industry is consistent with our result. In the case of the CHP industry, the expenditure effect is its major concern, and thus $\partial\Pi_i/\partial E$ is likely to be positive. In order to reduce the expense incurred in purchasing permits, the CHP industry intends to maximize the number of permits so as to minimize the permit price in stage two. As indicated above, in the case where $\partial\Pi_i/\partial E > 0$ and α_i is small, when λ decreases, industry i is able to lobby for the same amount of the emission cap by offering fewer contributions; namely, industry i is able to lobby for a greater amount of the emission cap by offering the same amount of contributions as λ decreases. As a result, by proposing a smaller λ will strengthen industry i's political influence in the second stage, which in turn will help industry i to lobby for a greater amount of the emission cap.

We summarize what we have obtained so far in the following proposition:

Proposition 2 *When* $\partial\Pi_i/\partial E < 0$, *industry i will endorse grandfathered permits. When* $\partial\Pi_i/\partial E > 0$, (i) *if* α_i *is sufficiently small, then industry i will promote auctions*; (ii) *if* α_i *is large, then industry i will support grandfathering.*

[18] This can be attributed to two reasons. First, the fraction of the CHP electricity generation in the total electricity is small. For example, this fraction was less than 10% in 1994 (Eurostat 2001). Secondly, CHP typically saves between 20% and 50% of CO_2 emissions compared to the separate production of heat and power from fossil fuels (Cogen Europe 2002).

5.2 Lobbying attitude of the environmental group

We now turn to the environmental group's attitude toward lobbying λ. The discounted payoff function of the environmental group in stage one takes the form:

$$W_g^1(\lambda) = U_g(\lambda) + \delta B_g^2(\lambda). \tag{27}$$

As in the case of industry groups, the discounted payoff function of the environmental group consists of the current utility and B_g^2, the environmental group's reservation welfare in stage two. By applying the approach that we use in Sect. 5.1, we obtain B_g^2 as follows:

$$\begin{aligned} B_g^2 &= \sum_{j=1}^{I} \Pi_j(E^\circ) + U_g(E^\circ) + \frac{W(E^\circ)}{\theta} - \sum_{j=1}^{I} \Pi_j(E^{-g}) - \frac{W(E^{-g})}{\theta} \\ &= \mathcal{W}(E^\circ) - \mathcal{W}^{-g}(E^{-g}) \end{aligned} \tag{28}$$

where $E^{-g} = \arg\max \theta[\sum_{j=1}^{I} \Pi_j(E)] + W(E)$. Like in the case of the industrial groups, B_g^2 equals the difference between two weighted social welfare functions, $\mathcal{W}(E^\circ)$ and $\mathcal{W}^{-g}(E^{-g})$.

By knowing B_g^2, we can derive the environmental group's MWTC toward lobbying λ, which is defined as $dm_g^1/d\lambda$, by totally differentiating W_g^1 with respect to λ, and obtain:

$$\frac{dm_g^1}{d\lambda} = \frac{dW_g^1}{d\lambda} = \frac{\partial U_g}{\partial \lambda} + \delta \frac{dB_g^2}{d\lambda}. \tag{29}$$

The first term on the right-hand side of (29) stands for the direct effect of λ. We note that $\partial U_g/\partial \lambda = 0$, and thus the direct effect vanishes. This is because when the total number of permits remains the same, the way in which the permits are allocated does not affect the environmentalists' welfare.

The second term on the right-hand side of (29) reflects the reservation welfare effect of a change in λ. By differentiating (28) with respect to λ, we obtain the reservation welfare effect as follows:

$$\frac{dB_g^2}{d\lambda} = \tau^\circ E^\circ - \tau^{-g} E^{-g} \quad \text{(reservation welfare effect)} \tag{30}$$

where τ^{-g} denotes the equilibrium permit price when the emission cap is E^{-g}.

Since the environmental group always intends to reduce the cap of emissions, the absence of the contributions from the environmentalists will raise the equilibrium emission cap, and thus E^{-g} will be greater than E°. With $E^\circ < E^{-g}$, the inelastic demand for the emission permits implies that $\tau^\circ E^\circ > \tau^{-g} E^{-g}$. Accordingly, the reservation welfare effect is unambiguously positive, thereby inducing the environmentalists to support grandfathering. The reason for this is that an increase in λ will strengthen the industries' endowment effect, which in turn will increase the industries' aggregate MWTC toward reducing the emission cap. Since the industries as a whole have a greater aggregate MWTC toward reducing the emission cap, the environmental group can lobby for the same emission cap by offering fewer contributions. As a result, the environmental group is able to choose a higher level of reservation welfare in stage two.

Because the reservation welfare effect is positive, (29) reveals that the environmental group's MWTC toward lobbying λ is positive, for all $\lambda \in [0, 1]$. This indicates that the environmental group will endorse grandfathered permits ($\lambda = 1$). This finding is consistent with the empirical evidence provided by Svendsen (1999), which reveals that environmental groups in the US prefer grandfathering. Svendsen explains this phenomenon by arguing that environmental groups promote grandfathering as a way of negotiating higher target reduction levels with industries to attract contributions from their members. We present a different explanation here. By recognizing that grandfathered permits will strengthen the industrial groups' endowment effect, which in turn will increase the environmental group's political influence and minimize the emission cap in the second stage, the environmentalists will support grandfathered permits.

Therefore, we have the following proposition:

Proposition 3 *The environmentalists will endorse grandfathered permits.*

5.3 The equilibrium λ

Now we turn to the policy making of the government in stage one. In a two-stage common agency game, when making the decision in the first stage, the government needs to consider how the choice of λ will affect its political support in the second stage (Bergemann and Välimäki 2003). Following Bergemann and Välimäki (2003), the equilibrium λ, which is denoted by λ°, satisfies:

$$\lambda^\circ = \arg\max G^1 \tag{31}$$

where[19]

$$G^1 = \theta\left[\sum_{i=1}^{I} W_i^1(\lambda) + W_g^1(\lambda)\right] + W(\lambda) + \delta G^2(E^\circ(\lambda)). \tag{32}$$

Recall that G^2 is defined in (10).

The first two terms on the right-hand side of (32) are the political support received by the government in stage one, and the last term is the discounted value of the political support received in stage two. Note that a change in λ indirectly affects the government's political support in the second stage through changing the equilibrium emission cap.

The condition that determines the equilibrium λ is obtained by differentiating G^1 with respect to λ:

$$\frac{dG^1}{d\lambda} = \theta\left(\sum_{i=1}^{I} \frac{\partial W_i^1}{\partial \lambda} + \frac{\partial W_g^1}{\partial \lambda}\right) + \frac{\partial W}{\partial \lambda} + \delta \frac{\partial G^2(E^\circ)}{\partial E}\frac{\partial E^\circ}{\partial \lambda}. \tag{33}$$

According to (14), the maximization of the government's political support in the second stage ensures that $\partial G^2(E^\circ)/\partial E$ equals zero. Moreover, by partially differentiating the social welfare function with respect to λ, we have $\partial W/\partial \lambda = 0$; this is because when the number of

[19] The objective function of the government in stage one should be $\theta[\sum_{i=1}^{I} m_i^1(\lambda) + m_g^1(\lambda)] + W(\lambda) + \delta G^2(E^\circ(\lambda))$. Following footnote 14, we have $m_i^1 = \max[0, W_i^1 - B_i^1]$, and $m_g^1 = \max[0, W_g^1 - B_g^1]$. Then by substituting the expressions of m_i^1 and m_g^1 into the above objective function of the government, we obtain (32), where we omit B_i^1 and B_g^1 because these terms are independent of λ.

permits is fixed, a change in λ only results in a different income distribution, and does not affect the level of social welfare.

Then by substituting (23), (29), and the relationship $\partial W/\partial\lambda = 0$ into (33), we obtain:

$$\frac{dG^1}{d\lambda} = \theta\tau^\circ E^\circ + \theta\delta\left[(I+1)\tau^\circ E^\circ - \sum_{i=1}^{I}(1-\alpha_i)\tau^{-i}E^{-i} - \tau^{-g}E^{-g}\right]. \tag{34}$$

The sign of (34) is ambiguous, and depends on the magnitude of the (aggregate) windfall wealth effect, which is represented by the first term on the right-hand side of (34), and the (aggregate) reservation welfare effect, which is reflected by the second term on the right-hand side of (34).

The windfall wealth effect is positive, and it leads the government to adopt grandfathering ($\lambda = 1$). The sign of the reservation welfare effect is ambiguous. According to (34), if the reservation welfare effect is non-negative, then grandfathering all permits to industries will be the equilibrium policy. Since the windfall wealth effect is positive, a non-negative reservation welfare effect ensures that $dG^1/d\lambda$ is greater than zero, for all $\lambda \in [0, 1]$. A non-negative reservation welfare effect will occur when, for example, (i) there is only one polluting industry in the economy, (ii) each industry lobbies for its own emission cap instead of the overall emission cap,[20] or (iii) all industries coordinate their lobbying as a unified industrial lobbying group,[21] such that $\alpha_i = 1$. As indicated in Sect. 5.1, the antagonism among the industries has been significantly mitigated in these cases, thereby resulting in a positive reservation welfare effect. Thus, the maximum value of G^1 will be reached at $\lambda = 1$,[22] and the equilibrium policy will be grandfathering. Since many existing trading programs focus on a single sector, e.g., the lead trading program and the chlorofluorocarbon/halon trading program, the above analysis may explain why grandfathering is prevalent in these programs.

In practice, we observe some cases in which a certain fraction of the permits is distributed through auctions. This situation requires an interior equilibrium λ. Equation (34) allows for such a possibility. We note that an interior equilibrium λ exists only if the reservation welfare effect is negative. A negative reservation welfare effect induces the government to set a lower λ, whereas the windfall wealth effect always gives rise to a higher λ. When the reservation welfare effect is sufficiently strong, there emerges an interior equilibrium λ, which indicates that a fraction $1-\lambda$ of emission permits will be distributed to the industries through auctions. The stronger the reservation welfare effect, the larger the fraction of emission permits that will be distributed through auctions.

Equation (34) also allows for the possibility that in equilibrium all emission permits are distributed through auctions. This will occur when the reservation welfare effect is negative, and its absolute value is large. For example, suppose that all industries are identical, so (34) becomes

$$\frac{dG^1}{d\lambda} = \theta\tau^\circ E^\circ + \theta\delta[(I+1)\tau^\circ E^\circ - (I-1)\tau^{-i}E^{-i} - \tau^{-g}E^{-g}]. \tag{35}$$

[20] This situation where each industry lobbies for its own emission cap can be characterized by setting $I = 1$ in this present model. The common agency problem in this case is the same as for a set of separate principal-agent arrangements between each industry and the government.

[21] The survey conducted by Hadjikhani and Ghauri (2001) confirms the possibility that industries will cooperatively lobby for their common interests.

[22] In these cases, the right-hand side of (34) reduces to $\theta\tau^\circ E^\circ + \delta[2\tau^\circ E^\circ - \tau^{-g}E^{-g}]$. Since $\tau^\circ E^\circ > \tau^{-g}E^{-g}$, we obtain $dG^1/d\lambda > 0$, for all $\lambda \in [0, 1]$.

As indicated in Sect. 5.1, all industries will intend to enlarge the emission cap in this situation, and thus E° is greater than E^{-i}, and $\tau^\circ E^\circ < \tau^{-i} E^{-i}$. From (35), we can verify that the reservation welfare effect, which is negative, will outweigh the windfall wealth effect, provided that both I and η are sufficiently large. As a result, $dG^1/d\lambda$ will be negative, for all $\lambda \in [0, 1]$, which implies that the equilibrium λ will be zero, and auctioning all permits will be the equilibrium policy instrument.

The previous results can be straightforwardly extended to analyze a somewhat general problem regarding the choice of instrument between emission taxes and grandfathered permits. It is well known that, without uncertainty, a system of auctioning permits is equivalent to an emission tax. The previous analysis reveals that a non-negative aggregate reservation welfare effect, which may be due to the cooperation among the industries, will ensure that a grandfathered permit system gives rise to more political support for the government than an emission tax. Thus, grandfathering will be the winner in the lobbying game. Conversely, if the reservation welfare effect is negative and sufficiently strong, then an auction approach (or equivalently, an emission tax) will be the equilibrium policy. This result can serve as a plausible answer to explain why several countries adopt emission taxes rather than grandfathered emission permits to manage the environment.

6 Concluding remarks

This paper investigates the problem of instrument selection from the perspective of political economy. We construct a two-stage lobbying game, in which the type of policy instrument is determined in stage one, and then the emission cap is decided in stage two. We highlight the strategic interaction between the lobbying activities in the two stages, which can explain some of the observed lobbying behavior of interest groups. The conditions under which grandfathered permits are likely to be the equilibrium policy instrument are derived, including that each industry lobbies for its own permits, and that all industries cooperate in their lobbying activities. We also find that auctioning all permits will be the equilibrium policy in some circumstances. This result can be applied to a more general question regarding the choice between an emission tax and a system of free permits.

In this paper, the proceeds from auctioning the permits are distributed to the environmentalists and the consumers. However, in practice the proceeds may be refunded to industries on a proportional basis (Tietenberg 1999). If the proceeds are distributed only to industries, and industries recognize the effect of their lobbying behavior on the refunds, then the results depend on how the proceeds are returned. When the proceeds are returned according to each industry's α, regardless of the value of λ, all instruments will be identical, which is equivalent to grandfathering.[23] If the proceeds are refunded according to other criteria, such as relative output levels, then there may arise strategic effects in which an industry attempts to shift rents away from others through refunds.

We assume a government that decides on instruments and the quantity of permits. However, in real-world policy formation the determination of policy instruments and the implementation involve interactions between the legislature and the environmental agency. Hamilton (1997, 2005) shows that legislative votes in the US Congress on instrument selection depend in part on the degree of scrutiny expected from voters. On amendments involving

[23] This can be seen by substituting the refund received by industry i, which is equal to $\alpha_i(1-\lambda)\tau E$, into its objective function, (8). Then (8) becomes $\Pi_i = f_i - wx_i - A_i + \tau(\alpha_i - \beta_i)E$, which is the same as under grandfathering.

technical details, polluting industries have more influence than environmentalists because of lower voter scrutiny. A more complete model should incorporate the interactions between the legislature, the environmental agency, and the interest groups. This issue, we believe, merits further research.

Appendix A: The derivation of (15)

Differentiating Π_i with respect to E yields

$$\begin{aligned}\frac{\partial \Pi_i}{\partial E} &= \frac{\partial f_i}{\partial x_i}\frac{\partial x_i}{\partial \tau}\frac{d\tau}{dE} - w\frac{\partial x_i}{\partial \tau}\frac{d\tau}{dE} - \left(\frac{\partial x_i}{\partial \tau}\frac{d\tau}{dE} - \frac{\partial \epsilon_i}{\partial \tau}\frac{d\tau}{dE}\right)\frac{\partial A_i}{\partial a_i} \\ &\quad + (e_i - \epsilon_i)\frac{d\tau}{dE} + \tau\left(\frac{\partial e_i}{\partial E} - \frac{\partial \epsilon_i}{\partial \tau}\frac{d\tau}{dE}\right) \\ &= \left(\frac{\partial f_i}{\partial x_i} - w - \frac{\partial A_i}{\partial a_i}\right)\frac{\partial x_i}{\partial \tau}\frac{d\tau}{dE} + \frac{\partial \epsilon_i}{\partial \tau}\frac{d\tau}{dE}\frac{\partial A_i}{\partial a_i} \\ &\quad + (e_i - \epsilon_i)\frac{d\tau}{dE} + \tau\frac{\partial e_i}{\partial E} - \tau\frac{\partial \epsilon_i}{\partial \tau}\frac{d\tau}{dE}.\end{aligned}$$

According to (2) and (3), the first term of the above equation will equal zero, and the second term and the fifth term will cancel out. Thus the MWTC of industry i can be reduced to

$$\begin{aligned}\frac{\partial \Pi_i}{\partial E} &= \tau\frac{\partial e_i}{\partial E} + e_i\frac{d\tau}{dE} - \epsilon_i\frac{d\tau}{dE} \\ &= (1-\eta)\alpha_i\lambda\tau + \beta_i\eta\tau.\end{aligned}$$

Appendix B: The derivation of (25)

We first derive $\partial B_i^2/\partial\lambda$, which can be obtained by partially differentiating (22) with respect to λ:

$$\begin{aligned}\frac{\partial B_i^2}{\partial \lambda} &= \sum_{j=1}^{I}\frac{\partial \Pi_j(E^\circ)}{\partial \lambda} + \frac{\partial U_g(E^\circ)}{\partial \lambda} + \frac{1}{\theta}\frac{\partial W(E^\circ)}{\partial \lambda} \\ &\quad - \sum_{\substack{j=1\\ j\neq i}}^{I}\frac{\partial \Pi_j(E^{-i})}{\partial \lambda} - \frac{\partial U_g(E^{-i})}{\partial \lambda} - \frac{1}{\theta}\frac{\partial W(E^{-i})}{\partial \lambda}.\end{aligned} \tag{36}$$

Then by substituting (24) and the relationships $\partial U_g/\partial\lambda = 0$ and $\partial W/\partial\lambda = 0$ into (36), we obtain:

$$\frac{\partial B_i^2}{\partial \lambda} = \tau^\circ E^\circ - (1-\alpha_i)\tau^{-i}E^{-i}. \tag{37}$$

As regards to $\partial B_i^2/\partial E \cdot \partial E^\circ/\partial\lambda$, we partially differentiate B_i^2 with respect to E, and obtain:

$$\frac{\partial B_i^2}{\partial E} = \left(\sum_{j=1}^{I}\frac{\partial \Pi_j(E^\circ)}{\partial E} + \frac{\partial U_g(E^\circ)}{\partial E} + \frac{1}{\theta}\frac{\partial W(E^\circ)}{\partial E}\right) - \left(\sum_{\substack{j=1\\ j\neq i}}^{I}\frac{\partial \Pi_j(E^{-i})}{\partial E} + \frac{\partial U_g(E^{-i})}{\partial E} + \frac{1}{\theta}\frac{\partial W(E^{-i})}{\partial E}\right). \tag{38}$$

According to (14), the terms in the first big brackets will equal zero. Similarly, (21) will ensure that the terms in the second brackets equal zero. Thus, $\partial B_i^2/\partial E$ equals zero, and $dB_i^2/d\lambda$ is the same as $\partial B_i^2/\partial\lambda$. By using a similar approach, we can obtain $dB_g^2/d\lambda$, which equals $\partial B_g^2/\partial\ \lambda$.

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