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The Optimal Distribution of Pollution Rights in the Presence of Political Distortions

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Abstract. A critical issue in designing a system of tradable emission permits concerns the distribution of the initial pollution rights. The purpose of this paper is to investigate how the initial rights should be optimally set, when the determination of the number of tradable permits is subject to the influence of interest groups. According to the Coase theorem, in the case where there are low transaction costs, the assignment of the initial rights does not affect the efficiency of the final resource allocation. In the presence of political pressure, we show that the distribution of the initial rights has a significant effect on social welfare. In contrast to the conventional results, we find that grandfathered permits may be more efficient than auctioned permits, even after taking into consideration the revenue-recycling effect.

Key words: auction, grandfathering, interest groups, revenue-recycling effect, tradable emission permits

JEL classification: D72, Q38, H77

1. Introduction

The tradable permits mechanism has recently been receiving a great deal of attention. The clear success of the federal Acid Rain Program in the US has encouraged the adoption of trading in other contexts, such as in reducing greenhouse gas emissions. One critical issue in designing the system of tradable emission permits concerns the distribution of the initial pollution rights (Sorrell and Skea 1999). According to the Coase theorem, in the case of low transaction costs, the efficiency of the final resource allocation is independent of the distribution of property rights. Montgomery (1972) has demonstrated this point in the case of tradable ambient permit.[1] Meanwhile, several studies have pointed out that the property of invariance will be destroyed by the presence of transaction costs or market power in the permit market (e.g., Hahn 1984; Stavins 1995). However, relatively little attention has been paid to the role played by interest groups, which has been shown to be an important factor in the formation of environmental policy (for example, Ackerman and Hassler 1981; Cropper et al. 1992). This paper will demonstrate that when interest groups can influence the number of emission permits, the initial distribution of the pollution rights will have a significant welfare consequence. Thus it is important that these rights should initially be assigned properly. The purpose of this paper is to investigate the optimal distribution of pollution rights when political distortion exists.

We will consider a corruptible government, which is subject to the influence of interest groups, including several industrial groups and an environmental group. By offering political contributions to the government, these interest groups attempt to affect the number of emission permits issued by the government. We will show that the influence of the interest groups will result in a gap between the actual number of permits and the optimal level, which will maximize the social welfare. Our focus is to answer the following question: What distribution of the initial emission permits will give rise to the highest level of social welfare, in the presence of the policy distortion arising from the interest groups. This question would be uninteresting, provided that the efficiency of the final resource allocation is independent of the distribution of the initial pollution rights, as shown by Montgomery (1972). However, because we find that in the presence of political influence, the distribution of the initial permits is crucial in determining the emission cap, the answer to the above question will have important policy implications.

We should note that we are not going to address the question of how the distribution of the initial permits is *actually* decided, which is a positive analysis. Instead, our concern is a normative issue: What is the efficient distribution of the initial permits in the presence of political distortion? The answer to this question can serve as a criterion, which can be used to evaluate the efficiency of the actual distribution rule.

The spirit of this paper is similar to that of Brennan and Buchanan (1980). They discuss how the Constitution should be set to restrain a Leviathan government which will exploit taxpayers. Similarly, this present paper investigates how the way in which permits are distributed initially should be set so as to remedy the policy distortion resulting from the corruptible government.

Two papers have shown that the initial distribution of tradable permits will affect the efficiency of the final resource allocation. Hahn (1984) demonstrates that the efficiency of the final resource allocation may not be independent of the distribution of the initial pollution rights, when one plant has the market power in the permit market. Stavins (1995) obtains a similar result by considering the presence of transaction costs. However, these papers do not consider the influence of interest groups, which is the focus of this present paper.

Within the context mentioned above, this paper finds that the distribution of the initial pollution rights has a significant effect on social welfare. The major contribution of this paper is to point out that, in a plausible situation, the regime under which all permits are freely given to firms will be the most efficient policy. Many studies have argued that grandfathered permits are inferior to auctioned permits in terms of efficiency[2] (e.g., Goulder et al. 1997; Parry 1997; Fullerton and Metcalf 2001). Their arguments focus on the revenue-recycling effect. Because the proceeds from auctioning permits can be used to lower other distortionary taxes, auctioned permits will achieve a higher level of social welfare. This present paper will demonstrate that even after taking the revenue-recycling effect into consideration, grandfathered permits may be more efficient than auctioned permits, especially when the government's corruption is severe. While the adoption of grandfathered permits has been regarded as a compromise between the political feasibility and economic efficiency (e.g., Sorrell and Skea 1999; Burtraw 1999), according to our finding, such a compromise may not exist. The adoption of grandfathered permits can be justified on the grounds of efficiency.

The intuition behind this result is as follows. The political pressure from the interest groups may result in the number of permits actually issued being greater than the socially optimal level. As we will demonstrate, the number of permits actually issued will decrease as the proportion of grandfathered permits to the total number of permits increases. Therefore, granting all permits to firms can reduce pollution emissions, thereby enhancing the social welfare. Although granting permits to firms cannot take advantage of the revenue-recycling effect, if the corruption of the government is sufficiently severe, the efficiency gain from the environmental improvement will outweigh the efficiency loss arising from failing to use the revenue-recycling effect.

The remainder of this paper proceeds as follows. In section 2, we introduce the model underlying our analysis. In section 3, we discuss the objective function of the government and the interest groups. The properties of the equilibrium emission permits are examined in section 4. In section 5, we examine the socially optimal distribution of the initial pollution rights. An extension of the basic model is provided in section 6. In section 7, we present our concluding remarks.

2. The Model

We consider a small open economy, which contains I polluting industries. All the firms in an industry are assumed to be identical, so that the number of firms in each industry can be normalized as one. The markets of the products are perfectly competitive, and the products can be freely imported from other jurisdictions. Since the economy is small, the industries in this jurisdiction are price takers in their respective product markets.[3] Without loss of generality, the prices of the products are normalized as one.

In order to produce outputs, all of the industries employ a variable input, x, and an immobile sector-specific input.[4] The use of x will generate pollutants. These pollutants do not spill over into other jurisdictions. By appropriately choosing the unit of pollutant, using one unit of x gives rise to one unit of pollutant.

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,[5] where the permit price, τ, is determined. The initial permits can be distributed by an auction, by initiating a grandfathering system which allocates permits on the basis of the past emission records of firms, or in a hybrid way. The initial amount of emission permits for industry i is denoted by e_i. Under the regime in which all permits are obtained through auctioning, 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.

With these notations, industry i solves the following problem:

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

where $f(x)$ is the production function,[6] with the properties $\partial f_i/\partial x_i > 0$ and $\partial^2 f_i/\partial x_i^2 < 0$, and w is the price of purchasing x, which is assumed to be exogenously given. The abatement technology is feasible, and the abatement amount is denoted as a. Thus the net pollutant emitted, ϵ_i, is equal to $x_i - a_i$. The abatement cost function, $A_i(a_i)$, is a strictly convex function of a_i, with the properties $\partial A_i/\partial a_i > 0$ and $\partial^2 A_i/\partial a_i^2 > 0$.

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

$$\partial f_i/\partial x_i - w - \partial A_i/\partial a_i = 0 \tag{2}$$

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

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 Equation (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 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 decrease the industry's demand for x and increase its pollution abatement. Because $\epsilon_i = x_i - a_i$, combining Equations (4) and (5) yields $\partial\epsilon_i/\partial\tau = \partial x_i/\partial\tau - \partial a_i/\partial\tau < 0$; or in words, the net pollution emission decreases as τ increases.

Then we turn to the permit market, where the firms located in other jurisdictions are not allowed to trade permits. The government issues an emission cap, which is denoted by E. The amount λE is given to firms freely, and the remaining $(1-\lambda) E$ is sold by means of an auction, where $\lambda \in [0, 1]$. Under an auction, the revenues from selling the permits are distributed to the general public in a lump-sum form. In section 6, we will investigate the situation where the revenues from selling permits are used to cut pre-existing distortionary taxes.

The equilibrium condition of the permit market is given by:

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

The left-hand side comprises the aggregate demand for permits in the jurisdiction, and the right-hand side the permits issued by the government. From Equation (6) we can solve for the effect of changing the number of permits on the equilibrium permit price:[7]

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

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

In addition to the industrialists, the jurisdiction also contains two other types of residents: environmentalists and consumers. Residents of the same type are identical. The utility function of a representative environmentalist is given by:[8] $u_g = y_g + s - d(E)$, where y_g stands for the income of the environmentalist, which is assumed exogenously given.[9] The variable s stands for a lump-sum transfer from the government, which is financed by selling the permits. The environmentalists regard the lump-sum transfer as exogenously given.[10] This can be justified by arguing that the revenues from selling permits are part of the government's general revenues, so that the interest groups hardly 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 Political Process

The goal of this paper is to investigate what distribution of the initial permits will give rise to the highest level of social welfare, when the determination of the emission cap is subject to the influence of the interest groups. To answer this question, we first need to realize how the emission cap is determined.

The previous section reveals that the profits of the industries and the welfare of the environmentalists are closely related to the emission cap, and thus they have incentives to affect the formation of the cap. Industries 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 $i = 1,..., I$, 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.

Each lobbying group offers political contributions, m, to the government in return for more favorable policies. The model does not explain the process of lobby formation;[11] rather we take it as given that environmentalists and industrialists overcome the free-rider problem. We also do not consider the issue of cooperation between lobbying groups, which is not difficult to deal with. When two or more groups decide to cooperate, they can be treated as a single group that seeks to maximize the joint welfare.

Before discussing the determination of the number of permits, it will prove convenient in what follows to define the welfare of the lobbying groups. The gross-of-contributions welfare of industry i is given by:

$$\begin{aligned}\Pi_i &= f_i(x_i) - wx_i - A_i(a_i) + \tau[e_i - \epsilon_i] \\ &= f_i(x_i) - wx_i - A_i(a_i) + \tau[\alpha_i\lambda - \beta_i]E\end{aligned} \tag{8}$$

where $\alpha_i \lambda$ is equal to e_i/E, which measures the proportion of industry i's grandfathered permits to E, and β_i is equal to ϵ_i/E, which measures the proportion of industry i's net pollution emissions to E. Note that $\sum_{i=1}^{I}\alpha_i = \sum_{i=1}^{I}\beta_i = 1$. The fraction $\alpha_i \geq 0$ is generally determined according to historical emissions, so it is assumed to be exogenously given throughout this paper. We also assume that before entering the stage where the emission cap is determined, λ has been decided, so the interest groups will regard it as given.[12] The aim of each lobbying group is to maximize its net welfare, which is equal to the gross welfare minus the political contributions.

The gross-of-contributions welfare of the environmental group is given by:

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

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

The goal of the government is to maximize the weighted average of the social welfare and the collected political contributions by choosing the number of permits. Following Grossman and Helpman (1994), the political support function of the government is given by:

$$G = \sum_{i=1}^{I} m_i + \theta_g m_g + \theta W. \tag{10}$$

The parameter $\theta \geq 0$ denotes the weight the government attaches to the social welfare. The more corruptible the government, the smaller θ will be. The parameter $\theta_g \geq 0$ can be interpreted as the lobbying efficiency of the environmentalists, which is subject to some exogenously determined factors, such as political skills. Note that the weights attached to the industrial groups are equal to one, so θ_g measures the environmental group's relative lobbying efficiency.

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 given by:

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

where n_c is the number of consumers. In Equation (11), we apply the government's 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 the environmental group everywhere reflects its true welfare.[13] Under the global-truthfulness assumption, the government's political support function, Equation (10), can be rewritten as:

$$G = \sum_{i=1}^{I} \Pi_i + \theta_g U_g + \theta W \tag{12}$$

The equilibrium number of permits, denoted by E°, is chosen by the government to maximize Equation (12).

4. The Equilibrium Number of Permits

This section discusses the determination of the equilibrium number of emission permits. We first examine each group's lobbying behavior, and then turn to the effect of changing the distribution of the pollution rights on the equilibrium number of permits.

4.1. LOBBYING BEHAVIOR

Differentiating Equation (12) with respect to E yields the first-order condition of the government's maximizing political support:

$$\frac{\partial G}{\partial E} = \sum_{i=1}^{I} \frac{\partial \Pi_i}{\partial E} + \theta_g \frac{\partial U_g}{\partial E} + \theta \frac{\partial W}{\partial E} = 0 \tag{13}$$

Equation (13) implies the equilibrium number of permits, E°. To deliberate over the meaning of Equation (13), we need to first discuss an important property of the contribution function implied by the global-truthfulness assumption. We recall that when the political contribution function is globally truthful, the contribution function of the lobbying group rewards the government for every change in the action by exactly the amount of the change in the group's welfare. More specifically, a marginal increase in E will induce industry i to contribute the amount $\partial \Pi_i / \partial E$. If $\partial m_i / \partial E$ is defined as industry i's marginal willingness to contribute (MWTC) for a change in E, then under the property of global-truthfulness, industry i's MWTC for a change in E will be equal to $\partial \Pi_i / \partial E$. Similarly, $\partial m_g / \partial E$ is defined as the MWTC of the environmental group, which is equal to $\partial U_g / \partial E$.

Let us examine the MWTC of each group more thoroughly. The MWTC of industry i is equal to:[14]

$$\frac{\partial m_i}{\partial E} = \frac{\partial \Pi_i}{\partial E} = (1 - \eta)\alpha_i \lambda \tau + \beta_i \eta \tau \tag{14}$$

where $\eta = -(d\,\tau/dE)(E/\tau)$ is the elasticity of τ with respect to E. This elasticity plays an important role in the following analysis. We also note that η is reversely related to the demand elasticity for the permits.[15] Since the demand for emissions is generally inelastic (Tietenberg 1999), which means that the permit price is sensitive to the change in E, the case where $\eta > 1$ is likely to occur.

According to Equation (14), the MWTC of industry i 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 changing E on the value of the endowed permits. We can see this by rewriting $(1 - \eta)\alpha_i \lambda \tau$ as $d(\tau e_i)/dE$. Under an auction ($\lambda = 0$), the endowed permit is equal to zero, so that the endowment effect will vanish. When λ is positive, an increase in E will increase industry i's endowed permits, but will lower the permit price. Thus, in the case where $\lambda > 0$, the sign of the endowment effect is ambiguous, and depends on the elasticity of τ with respect to E, i.e., η. If η is less than one, then the endowment effect is positive. Industry i will increase its political contributions as the government expands E. On the other hand, if $\eta > 1$, or equivalently the change in τ is sensitive to the change in E, then the endowment effect will be negative. With a negative endowment effect, industry i will attempt to reduce the number of permits issued in order to increase the value of the endowed permits.

Unlike the endowment effect, the sign of the expenditure effect, which reflects the saving in the financial burden related to an expansion in E, is definitely positive; this can be seen by rewriting this effect as: $-\epsilon_i \cdot d\tau/dE > 0$. The expenditure effect always leads the industries to increase their contributions in response to more permits being issued.

To sum up, in the case where $\lambda > 0$, when $\eta < 1$, both the endowment effect and the expenditure effect are positive. Industry i will increase (decrease) its political contributions as the government issues more (fewer) permits. Conversely, when $\eta > 1$, the expenditure effect remains positive, whereas the endowment effect becomes negative. If the endowment effect is sufficiently strong, then an increase in E will lower industry i's contributions.

Although an individual industry's MWTC could be negative, the summation of all industries' MWTCs is greater than zero. This can be seen by adding all industries' MWTCs, which is equal to $[\lambda + (1-\lambda)\eta]\tau > 0$. As a result, the government will receive more (fewer) contributions from the industries as a whole when increasing (decreasing) the number of permits.

The MWTC of the environmental group can be obtained by differentiating Equation (9) with respect to E, which is equal to:

$$\frac{\partial U_g}{\partial E} = -D'(E) < 0 \tag{15}$$

The MWTC of the environmental group is unambiguously negative, which means that the government will receive more contributions from the environmentalists as E is reduced.

4.2. COMPARATIVE STATICS

In order to obtain the equilibrium policy, we substitute Equations (14) and (15) into Equation (13), which yields:

$$\frac{\partial G}{\partial E} = \sum_{i=1}^{I}[(1-\eta)\alpha_i\lambda + \beta_i\eta]\tau - \theta_g D' + \theta(\tau - D')$$
$$= [\lambda + (1-\lambda)\eta]\tau - \theta_g D' + \theta(\tau - D') = 0 \tag{16}$$

In deriving Equation (16), we apply the relationship $\sum_i \alpha_i = \sum_i \beta_i = 1$, and the result $\partial W/\partial E = \tau - D'$.

Equation (16) allows us to calculate how the equilibrium number of permits changes as λ changes. The comparative-static exercise reveals that $dE^\circ/d\lambda = -(\partial^2 G/\partial E\partial\lambda)/(\partial^2 G/\partial E^2)$. The second-order condition for maximizing G requires that $\partial^2 G/\partial E^2 < 0$, so the sign of $dE^\circ/d\lambda$ is the same as that of $\partial^2 G/\partial E\partial\lambda$. Partially differentiating Equation (16) with respect to λ yields:

$$\frac{\partial^2 G}{\partial E\partial\lambda} = (1-\eta)\tau \tag{17}$$

According to Equation (17), when η is greater than one, the number of permits will decrease with λ. If $\eta < 1$, the number of permits will increase with λ.

Since there is a unique τ corresponding to a given E, the above results also imply that in the case where $\eta > 1$ the equilibrium permit price will increase with λ; on the other hand, the equilibrium permit price will decrease with λ as $\eta < 1$.

We summarize these results in the following proposition:

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

The intuition behind Proposition 1 is as follows. Inspecting Equations (14) and (15) indicates that a change in λ will affect the industries' MWTCs through the endowment effect; the environmentalists' MWTC is independent of λ. As we already know, when $\eta > 1$, the endowment effect is negative. With a negative endowment effect, an increase in λ will lower the industrial groups' MWTCs to enlarge E, or raise their MWTCs to reduce E, as shown by Equation (14). Thus, the equilibrium number of permits will decrease with λ, provided that η is greater than one. On the other hand, if $\eta < 1$, an increase in λ will intensify the endowment effect, which is positive, so the opposite will occur.

The proportion of grandfathered permits to the total number of permits is related to the distribution of the property right of the environment. Under an auction, the property right of the environment belongs to the general public, whereas under the regime in which all permits are grandfathered to firms, the polluters own the property right. In the absence of political interference, according to the Coase theorem, "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). This argument is demonstrated in the following lemma:

Lemma 1. *In the absence of political pressure from interest groups, the socially optimal E, which is denoted by* E^*, *and the maximum of social welfare,* $W(E^*)$, *are independent of* λ.

Proof. See Appendix B. □

However, the result in Proposition 1 reveals that the presence of the influence of interest groups will destroy the invariance property of the initial assignment of the pollution right. Thus the distribution of the initial permits has significant effects on social welfare, which is the focus of the next section.

5. The Optimal Distribution of Pollution Rights

Now we turn to our major question: What distribution of the initial permits will maximize the social welfare, when the formation of the emission cap is subject to the influence of interest groups. Note that we are not going to discuss how the distribution rule is actually decided. What we are interested in is to obtain a criterion, which can be used to evaluate the efficiency of the policy actually adopted.

The influence of interest groups will lead the equilibrium emission cap to deviate from the optimal level, which will maximize the social welfare. Thus an efficient rule for distributing the initial permits should correct the policy distortion arising from the interest groups. Because of this, we first need to know the gap between the equilibrium emission cap (E°) and the optimal level (E^*).

From Equation (16), we have the following equation:

$$\tau - D'(E) = -\{[\lambda + (1-\lambda)\eta]\tau - \theta_g D'\}/\theta \tag{18}$$

Rearranging Equation (18), we obtain:

$$\tau - D'(E) = \frac{\theta_g - \phi}{\theta + \phi} D' \tag{19}$$

where $\phi = \lambda + (1-\lambda)\eta > 0$.

Equation (19) implies the relationship between τ° and E°. In the following lemma, we link this relationship to that between E^* and E°.

Lemma 2. *If* $\tau^{\circ} < D'(E^{\circ})$, *then* $E^{\circ} > E^{*}$ *and* $\tau^{\circ} < \tau^{*}$; *if* $\tau^{\circ} > D'(E^{\circ})$, *then* $E^{\circ} < E^{*}$ *and* $\tau^{\circ} > \tau^{*}$.

Proof. See Appendix C. □

Equation (19) and Lemma 2 reveal that the relationship between E^{*} and E° is ambiguous, and depends on the magnitude of θ_g and ϕ. If θ_g is greater than ϕ, then τ° is greater than $D'(E^{\circ})$, and thus E° is less than E^{*}. On the other hand, if θ_g is less than ϕ, then τ° is less than $D'(E^{\circ})$, and E° is greater than E^{*}.

The reason for this result can be seen from Equation (16). Suppose that the government initially sets E at the socially optimal level E^{*}, which requires $\tau^{*} = D'(E^{*})$. By substituting the relationship $\tau^{*} = D'(E^{*})$ into $\partial G/\partial E$, we obtain:

$$\frac{\partial G(E^{*})}{\partial E} = \phi\tau^{*} - \theta_g D'(E^{*}) = (\phi - \theta_g)D'(E^{*})$$

When deciding the number of permits, the government faces a trade-off between the political support from the industrial groups and that from the environmental group. If $\phi > \theta_g$, the increase in the industrial groups' political support will be greater than the decline in the environmentalists' political support associated with an increase in E. The government will issue more permits in order to receive more political contributions, thereby resulting in $E^{\circ} > E^{*}$. Conversely, if $\phi < \theta_g$, then the government will reduce E, and thus E° will be less than E^{*}.

We summarize these results in the following proposition:

Proposition 2. *If* $\lambda + (1-\lambda)\eta > \theta_g$, *then* E° *will be greater than* E^{*}. *If* $\lambda + (1-\lambda)\eta < \theta_g$, *then* E° *will be less than* E^{*}.

By knowing the relationship between E° and E^{*}, we can determine the most efficient rule regarding distributing the initial permits. The most efficient rule can be obtained from the effect of changes in λ on the social welfare. Totally differentiating the social welfare function with respect to λ yields:

$$\frac{dW}{d\lambda} = \frac{\partial W}{\partial \lambda} + \frac{\partial W}{\partial E}\frac{dE^{\circ}}{d\lambda} \tag{20}$$

The effect of changing λ on the social welfare consists of two components: the direct effect and the indirect effect. Rearranging the social welfare function, Equation (11), yields $\sum_i f_i - w\sum_i x_i - \sum_i A_i + n_c y_c + n_g y_g - D(E)$, so the direct effect, $\partial W/\partial\lambda$, is equal to zero. The reason for this is that, by holding the number of permits constant, the way in which the permits are distributed does not affect the social welfare. Since $\partial W/\partial E = \tau - D'(E)$, the indirect effect is equal to:

$$\frac{\partial W}{\partial E}\frac{dE^\circ}{d\lambda} = [\tau^\circ - D'(E^\circ)]\frac{dE^\circ}{d\lambda} \tag{21}$$

By substituting Equation (19) into Equation (21), and then inserting the result into Equation (20), we have:

$$\frac{dW}{d\lambda} = \left[\frac{\theta_g - \phi}{\theta + \phi}\right] D' \frac{dE^\circ}{d\lambda}. \tag{22}$$

Because the demand for emission permits is generally inelastic, which implies that η is likely to be greater than one, we will focus on the case where $\eta > 1$. The results in the case where $\eta < 1$ can be obtained by means of a similar analysis as can be seen in what follows.

When η is greater than one, $dE^\circ/d\lambda$ is less than zero, and the sign of $dW/d\lambda$ depends on that of $\theta_g - \phi$. If $\theta_g < 1$, then $\theta_g - \phi$ will be less than zero, and $dW/d\lambda$ will be greater than zero, for all $\lambda \in [0, 1]$.[16] Thus, the most efficient λ that considers the distortion arising from political influence (we will simply call it the second best λ and denote it by λ^* thereafter) is equal to one. In other words, granting all permits to firms will give rise to the highest level of social welfare in this case.

The reasoning behind this result is not hard to understand. Recall that the weight measuring the industrial groups' lobbying efficiency is equal to one, so that θ_g measures the environmental group's relative lobbying efficiency. The inequality $\theta_g < 1$ indicates that the industrial groups are more efficient at lobbying than the environmental group, thereby resulting in $E^\circ > E^*$. A reduction in the gap between E° and E^* will enhance the social welfare. Since $dE^\circ/d\lambda < 0$ in this case, an increase in λ will lower E°. Meanwhile, Lemma 1 reveals that E^* is independent of λ. Therefore, an increase in λ will narrow the gap between E° and E^*, and will enhance the social welfare.

In the case where $\theta_g = 1$, $dW/d\lambda$ is less than zero, for all $\lambda \in [0, 1)$, and $dW/d\lambda$ will be equal to zero as $\lambda = 1$. Again, grandfathered permits will maximize the social welfare in this case.

When $1 < \theta_g$, the sign of $\theta_g - \phi$ is ambiguous, and so is that of $dW/d\lambda$. However, one thing is certain: grandfathering all permits to firms is no longer the second best instrument. By substituting $\lambda = 1$ into Equation (22), we find that $dW/d\lambda = [(\theta_g - 1)/(\theta + \phi)]D' \cdot dE^\circ/d\lambda < 0$, indicating that a decrease in λ will enhance social welfare. Conversely, substituting $\lambda = 0$ into Equation (22) yields:

$$\left.\frac{dW}{d\lambda}\right|_{\lambda=0} = \left[\frac{\theta_g - \eta}{\theta + \phi}\right] D' \frac{dE^\circ}{d\lambda} \tag{23}$$

According to Equation (23), if $\theta_g \geq \eta$, the second best λ will be equal to zero; i.e., an auction will maximize the social welfare. In this case, the environmental group is more efficient in lobbying than the industrial groups, so that the equilibrium number of permits will be less than the socially optimal level. The gap between E° and E^{*} will be minimized at $\lambda = 0$.

If $1 < \theta_g < \eta$, there then arises an interior solution that maximizes the social welfare. According to Equation (22), the interior second best λ can be obtained by solving $\theta_g - \phi = \theta_g - \lambda - (1-\lambda)\eta = 0$, which yields:

$$\lambda^{*} = \frac{\eta - \theta_g}{\eta - 1} \tag{24}$$

With an interior λ^{*}, Equation (19) reveals that τ° will be equal to $D'(E^{\circ})$, which implies that $E^{\circ} = E^{*}$; in other words, the policy distortion arising from the interest groups has been completely corrected in this situation.

The following proposition summarizes what we have found:

Proposition 3. *In the case where* $\eta > 1$ *and there exists political pressure from the interest groups*, (i) *if* $\theta_g \leq 1 < \eta$, *then the regime in which all the permits are grandfathered to firms will be the second best policy* ($\lambda^{*} = 1$); (ii) *if* $1 < \theta_g < \eta$, *then the second best* λ *will be equal to* $(\eta - \theta_g)/(\eta - 1) \in (0, 1)$; *(iii) if* $1 < \eta < \theta_g$, *then the regime in which all the permits are auctioned will be the second best policy* ($\lambda^{*} = 0$).

We also note that an interior λ^{*} decreases with θ_g, and increases with η. Consider that an interior λ^{*} is set, so $E^{\circ} = E^{*}$. Supposing that θ_g increases, the government can now receive more political support by issuing fewer permits, thereby resulting in $E^{\circ} < E^{*}$. In order to correct this distortion, the second best λ should be lowered so as to increase E°. This explains the adverse relationship between λ^{*} and θ_g. On the other hand, an increase in η will increase the industries' aggregate MWTC for expanding E, so that E° will be greater than E^{*}. To eliminate the gap between E° and E^{*}, the second best λ should be raised to reduce E°. Moreover, since the demand elasticity for the permits is reversely related to η, we can say that the second best λ will decrease with the demand elasticity for the permits.

Proposition 4. *In the case where* $\eta > 1$, *the interior second best* λ *decreases with* θ_g. *It also increases with* η; *or, the less elastic the demand for the permits, the higher the second best* λ *will be.*

6. Extension

Although many studies have pointed out that grandfathered permits are less efficient than auctioned permits, due to its political acceptability, grandfathering is prevalent in the countries that adopt tradable emission permits. Thus the use of grandfathered permits appears to be a trade-off between political feasibility and economic efficiency (see, e.g., Sorrell and Skea 1999; Burtraw 1999). However, the results in Proposition 3 imply that such a trade-off may not exist, because grandfathered permits may give rise to a higher level of social welfare than auctioned permits.

The studies that argue that auctioned permits are more efficient than grandfathered permits focus on the revenue-recycling effect.[17] Auctioned permits generate revenues that can be used to finance cuts in the marginal rates of pre-existing distortionary taxes, thereby reducing some of the deadweight cost associated with these taxes. By contrast, grandfathered permits do not bring in revenues and cannot finance cuts in distortionary taxes. Therefore, they conclude that grandfathered permits are less efficient than auctioned permits.

So far we have assumed that the revenues from auctioning permits are distributed to the general public through a lump-sum transfer. The revenue-recycling effect plays no role in this setting (Goulder et al. 1997). In order to take the revenue-recycling effect into consideration, we now assume that the revenues from auctioning permits are used to lower other pre-existing distortionary taxes, which are not explicitly specified in the model.[18] The social welfare function of the jurisdiction becomes:

$$\widetilde{W} = \sum_{i=1}^{I} \Pi_i + \gamma(1-\lambda)\tau E + n_c y_c + n_g y_g - D(E) \tag{25}$$

where γ denotes the marginal cost of public funds related to distortionary taxes, which would exceed one.[19] Thus the term $\gamma\,(1-\lambda)\tau\,E$ in Equation (25) stands for the efficiency gain arising from the revenue-recycling effect. Although this specification is simple, we believe that it captures the essence of the revenue-recycling effect.

We first demonstrate that in the situation where the government seeks to maximize the social welfare, auctioned permits will be the most efficient policy, provided that the revenue-recycling effect is considered. Suppose that the government will set E to maximize the social welfare function, $\widetilde{W}$. Differentiating $\widetilde{W}$ with respect to E yields:

$$\frac{\partial \widetilde{W}}{\partial E} = \tau - D'(E) + (\gamma-1)(1-\lambda)(1-\eta)\tau \tag{26}$$

Maximizing the social welfare requires that $\partial\widetilde{W}/\partial E$ equal zero. Then totally differentiating $\widetilde{W}$ with respect to λ yields:

$$\frac{d\widetilde{W}}{d\lambda} = \frac{\partial \widetilde{W}}{\partial \lambda} + \frac{\partial \widetilde{W}}{\partial E}\frac{d\widetilde{E}^{*}}{d\lambda} = -(\gamma - 1)\widetilde{\tau}^{*}\widetilde{E}^{*} < 0 \tag{27}$$

The first-order condition of the government's optimization, $\partial\widetilde{W}/\partial E = 0$, will ensure that the indirect effect vanishes. Equation (27) indicates that the most efficient λ is equal to zero; in other words, if there is no political pressure from the interest groups, then all the permits should be distributed through an auction. This result corresponds to the argument in the previous literature.

We then consider the second best situation in which the government is corruptible. In this situation, the political support function of the government is given by: $\widetilde{G} = \sum_i \Pi_i + \theta_g \widetilde{U}_g + \theta \widetilde{W}$, where $\widetilde{U}_g = n_g y_g - n_g d$.[20] The equilibrium number of permits, $\widetilde{E}^{\circ}$, will satisfy the following first-order condition:

$$\frac{\partial \widetilde{G}}{\partial E} = [\lambda + (1-\lambda)\eta]\tau - \theta_g D' + \theta[\tau - D'(E) + (\gamma - 1)(1-\lambda)(1-\eta)\tau] = 0 \tag{28}$$

In deriving this first-order condition, we apply Equation (26). Equation (28) gives rise to the effect of changing λ on $\widetilde{E}^{\circ}$ as follows:

$$\frac{d\widetilde{E}^{\circ}}{d\lambda} = \left(\frac{-1}{\partial^2 \widetilde{G}/\partial E^2}\right)[1 - (\gamma - 1)\theta](1-\eta)\widetilde{\tau}^{\circ} \tag{29}$$

Again we focus on the case where $\eta > 1$. Inspecting Equation (29) reveals that the revenue-recycling effect, which implies $\gamma > 1$, makes $d\widetilde{E}^{\circ}/d\lambda$ not necessarily less than zero. The condition for $d\widetilde{E}^{\circ}/d\lambda < 0$ requires that $\theta < 1/(\gamma-1)$.

Now we can move on to find the second best rule of distributing the initial permits. The total effect of changing λ on the social welfare is given by:

$$\begin{aligned}\frac{d\widetilde{W}}{d\lambda} &= \frac{\partial \widetilde{W}}{\partial \lambda} + \frac{\partial \widetilde{W}}{\partial E}\frac{d\widetilde{E}^{\circ}}{d\lambda} \\ &= \underbrace{-(\gamma - 1)\widetilde{\tau}^{\circ}\widetilde{E}^{\circ}}_{\text{direct effect}} + \underbrace{\frac{1}{\theta}\{\theta_g D' - [\lambda + (1-\lambda)\eta]\widetilde{\tau}^{\circ}\}\frac{d\widetilde{E}^{\circ}}{d\lambda}}_{\text{improvement in environmental quality}}\end{aligned} \tag{30}$$

where we apply the relationship $\partial\widetilde{W}(\widetilde{E}^{\circ})/\partial E = \{\theta_g D' - [\lambda + (1-\lambda)\eta]\widetilde{\tau}^{\circ}\}/\theta$, which is obtained from Equation (28). Without the revenue-recycling effect, which implies that $\gamma = 1$, the direct effect of changing λ on the social welfare will vanish. Once the revenue-recycling effect exists or $\gamma > 1$, the direct effect of changing λ on $\widetilde{W}$ is less than zero, meaning that a decrease in λ will enhance social welfare.

When $\eta > 1$, if θ_g is small and $\theta < 1/(\gamma-1)$, the second term on the right-hand side of Equation (30) will be positive, indicating that an increase in λ will improve social welfare. A small θ_g will result in $E^{\circ} > E^{*}$. An increase in λ will narrow the gap between E° and E^{*}, and will thus enhance social welfare.

The direct effect and the effect associated with the improvement in the environmental quality work in opposite directions. If both θ and θ_g are sufficiently small, the second term will outweigh the direct effect, and thus $d\widetilde{W}/d\lambda$ will be greater than zero, for all $\lambda \in [0, 1]$. In other words, if the corruption of the government is severe and the lobbying efficiency of the environmental group is weak, grandfathered permits will give rise to a higher level of social welfare than auctioned permits. Although grandfathering all permits to firms cannot take advantage of the revenue-recycling effect, it will reduce the equilibrium emission cap, thereby reducing the environmental damage. When θ is sufficiently small, the equilibrium emission cap will be far beyond the optimal level. The efficiency gain from reducing the environmental damage due to grandfathering will outweigh the cost of adopting grandfathered permits, which arises from failing to take advantage of the revenue-recycling effect. This result demonstrates that the adoption of grandfathered permits is no longer a compromise between the political feasibility and economic efficiency; instead it is the second best policy, especially where the government is characterized by severe corruption.

7. Concluding Remarks

In the absence of political influence, according to the Coase theorem, the efficiency of the final allocation is independent of the distribution of the initial pollution rights. This paper demonstrates that in the case where the determination of the emission cap is subject to the influence of interest groups, the rule regarding distributing the initial pollution rights has a significant impact on welfare. We find that in the presence of policy distortion, grandfathered permits may give rise to a higher level of social welfare than auctioned permits. Therefore, when adopting grandfathered permits, the government does not necessarily face a trade-off between the political acceptability and the economic efficiency; grandfathered permits can be the second best policy.

All the weights of the industries are assumed to be the same in the model. When industries have different lobbying efficiency, and the industries that are net suppliers of the permits are more efficient in lobbying, these industries will ask the government to reduce the number of permits. Because the equilibrium number of permits is less than the socially optimal level, auctioning all the permits, which will enlarge the number of permits, may become the second best policy.

We assume that the jurisdiction under consideration is a small open economy, so that the prices of outputs are independent of interest groups' lobbying activities. This assumption not only simplifies our analysis, but also helps us focus on the market for permits. If we relax this assumption to consider a closed economy in which the lobbying of the interest groups will affect the prices of the products, then the industries will have stronger incentives to reduce the emission cap. The reason for this is that a decline in the emission cap will reduce the volume of the products, and raise the prices. This gives rise to the industries receiving an additional benefit, and thus the emission cap will be less than that in the case of a small open economy. However, considering a closed economy will not qualitatively change the results in sections 5 and 6.

In this paper, the revenues from auctioning the permits are distributed to the environmentalists and the consumers. However, in practice the proceeds may be refunded to industries (Tietenberg 1999). If the proceeds are refunded according to relative output levels, there may then arise strategic effects in which an industry will attempt to shift rents away from other industries through refunds. This issue, we believe, merits further research.

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Notes

1. Montgomery's proof of independence only applied to what he then called "pollution licenses" (now referred to as ambient-permit systems). This independence does not extend to "emissions licenses" (now referred to as emissions-permit systems). See more discussions in Krupnick et al. (1983).
2. By studying the distributional effects of carbon allowance trading, Dinan and Rogers (2002) show that grandfathered permits are inferior to auctioned permits in terms of equity. Here we will focus on the efficiency issue.
3. This assumption will rule out the situation in which lobbying activities will change the prices of outputs. By so doing helps us to concentrate on the market for emission permits. The situation of a closed economy is discussed in the Concluding remarks.
4. Fredriksson (1999) argues that many pollution-intensive industries are immobile due to their main factor of production being a natural resource. These industries include, for example, pulp and waste paper, petroleum products, organic chemicals, and nonferrous metals.
5. See, e.g., Hahn (1984), Misiolek and Elder (1989), and Chavez and Stranlund (2003) for the cases where the permit markets are imperfectly competitive.
6. We omit the sector-specific input in the expression of the production function.

7. Totally differentiating the equilibrium condition in Equation (6) yields $\sum_{i=1}^{I} (\partial \epsilon_i/\partial \tau)\, d\tau = dE$. Therefore, $d\,\tau/dE = 1/\sum_{i=1}^{I} \partial \epsilon_i/\partial \tau$.
8. The subscript g refers to “greens”.
9. Environmentalists can work in competitive industries which do not emit pollution, or receive income from capital, so that their income is independent of the environmental regulation.
10. For simplicity, we assume that the industries do not receive the transfers. The different ways of distributing the revenues do not change the results, as long as the transfers are regarded as fixed by the recipients.
11. See Mitra (1999, 2002) and Magee (2002) for endogenous lobby formations.
12. Because tradable permits that are distributed through auctioning are equivalent to emission taxes in our model, the determination of λ is actually a problem of instrument selection. In practice the selection of policy instruments is usually followed by the determination of the number of permits (see, e.g., Kosobud 2000).
13. 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.
14. The derivation of Equation (14) can be found in Appendix A.
15. This demand elasticity is defined as: $-(d\sum_i \epsilon_i/d\tau)(\tau/\sum_i \epsilon_i)$.
16. This can be seen by rewriting $\theta_g - \phi$ as $(1-\lambda)(1-\eta) + \delta$, where $\delta = \theta_g - 1$. In the case where $\eta > 1$, when $\theta_g < 1$, which is equivalent to $\delta < 0$, $\theta_g - \phi$ will be less than zero. Since $dE^{\circ}/d\lambda < 0$ in this case, $dW/d\lambda$ is greater than zero, for all $\lambda \in [0, 1]$.
17. In addition to the revenue-recycling effect, those studies also discuss the tax-interaction effect, which states that existing distortionary taxes may interact with the environmental regulation and thereby enlarge the welfare costs. Because the existing distortionary taxes are not explicitly incorporated in the model, we will not discuss this issue in more detail here. Interest readers can refer to Goulder (2002).
18. Similar specifications can be found in Gruenspecht (1988) and Neary (1994).
19. The discussion in Ballard et al. (1985) suggests an opportunity cost in the range of 1.17–1.56 per dollar raised.
20. Since the revenues from auctioning permits do not return to the environmentalists in this case, the subsidy term vanishes. Strictly speaking, the utility function of the environmentalists may contain a term that reflects the efficiency gain from lowering the distortionary taxes. Here we assume that the environmentalists treat the efficiency gain as given, so we omit the efficiency gain term in their utility function.

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Appendix

(A) The derivation of Equation (14)

Differentiating Π_i with respect to E yields

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

According to Equations (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

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

(B) The Proof of Lemma 1

Proof. Differentiating Equation (11) with respect to E yields: $\partial W/\partial E = \tau - D'(E)$. The optimal E that maximizes the social welfare function requires that $\partial W(E^*)/\partial E = \tau^* - D'(E^*) = 0$. The comparative-static result shows that $d E^*/d\lambda = -(\partial W^2/\partial E\,\partial\lambda)/(\partial^2 W/\partial E^2)$. The denominator is equal to $d\tau/dE = D'' < 0$, whereas the numerator is equal to zero. Therefore, E^* is independent of λ. Furthermore, the effect of changing λ on the social welfare is given by:

$$\frac{dW(E*)}{d\lambda} = \frac{\partial W(E*)}{\partial\lambda} + \frac{\partial W(E*)}{\partial E}\frac{dE*}{d\lambda}$$

Clearly, the second term on the right-hand side of the above equation is equal to zero. Rearranging Equation (11) yields $\sum_i f_i - w\sum_i x_i - \sum_i A_i + n_c y_c + n_g y_g - D(E)$, so $\partial W/\partial\lambda$ is equal to zero. Thus we prove that the maximum of social welfare is also independent of λ. □

(C) The Proof of Lemma 2

Proof. We will prove this by contradiction. Suppose not, i.e. when $\tau^\circ < D'(E^\circ)$, $E^\circ \leq E^*$ and $\tau^\circ \geq \tau^*$. Since $D'' > 0$, according to $E^\circ \leq E^*$, we know that $D'(E^\circ) \leq D'(E^*)$. When $E = E^*$, the marginal damage from pollution will be equal to the socially optimal permit price, that is $D'(E^*) = \tau^*$. By combining this equation with the inequality $D'(E^\circ) \leq D'(E^*)$ and $\tau^\circ \geq \tau^*$, we obtain $D'(E^\circ) \leq \tau^* \leq \tau^\circ$. Clearly, this contradicts the premise $\tau^\circ < D'(E^\circ)$, and thus we can prove that $\tau^\circ < D'(E^\circ)$ implies that $E^\circ > E^*$ and $\tau^\circ < \tau^*$. The other case can be proved in a similar way. □