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Examining tradeable permits with market power, banking and non-compliance: a finite period model

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Abstract

Our model examines how co-existence of market power and noncompliance affects the efficiency and effectiveness of a cap-and-trade system with banking-borrowing in a finite period model. The dynamic equilibrium analysis here extends the results of the established literature, and we show that the initial allocation of permits to the dominant firm continues to play a significant role in both the cost-efficiency of abatement, as well as effectiveness of the cap-and-trade system. The presence of cheating, however, makes the permit demand of firms more price-elastic compared to a model with no cheating. Moreover, the second-order price sensitivity of the permit demand of the dominant firm plays a critical role in the compliance behavior of the dominant firm. We analyze the relationship between violation of a fringe firm and the dominant firm, illustrating the asymmetrical implications for when the dominant firm is a buyer of permits versus a seller of permits. Since we expect the regulator to reduce initial permit allocations over time, we also examine its impact on non-compliance behavior of the dominant firm.

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1. Introduction

It is well-established that the emission permit market equilibrium fails to achieve an efficient outcome in the presence of market power (Hahn 1984) and non-compliance among firms (Malik 1990). In an imperfect permit market, the outcome diverges from the abatement cost-minimizing efficient equilibrium, except in the rare occasion when the initial permit allocation matches the dominant firm's equilibrium demand for permits. The presence of twin imperfections (in market structure and in regulation) reinforces the critical role of the initial distribution of permits among firms (Egteren and Weber 1996).

In practice, emissions trading systems have typically been implemented in finite time horizons, most prominently in the US (e.g. sulfur dioxide allowance trading program Phase I during 1995-1999 under the US Clean Air Act Amendment 1990) and more recently in the European Union (e.g. two-phase carbon dioxide trading in 2005-07 and 2008-12). Such multi-year trading programs allow for banking and borrowing for greater temporal flexibility in the dynamic cost minimization problem of the polluters.[1]

Augmentation of permit banking and borrowing in an emissions trading model allows for temporal efficiency through reallocation of emissions over time. While Rubin (1996) examined banking and borrowing with no market imperfections, Stranlund, Chavez and Costello (2005) incorporated noncompliance along with banking-borrowing in a perfect competitive setting to examine the regulatory role. In the latter model, the incentive to cheat stems from static gains as well as dynamic gains through saving permits for future use. The Chevallier (2008) model on inter-temporal permit trading in the presence of market power (but no cheating) demonstrated that the resultant price-distortion is a function of price elasticity of demand for permits of the dominant firm.

It remains to be seen how the features of market power, banking/borrowing and noncompliance together impact permit price distortion. What is the role of initial allocation of permits in this extended framework? Our model here examines how co-existence of market power and noncompliance affects the efficiency and effectiveness[2] of the emissions trading system when banking-borrowing is also allowed as can be expected in reality. The model extends the work of Egteren and Weber (1996), Rubin (1996), and Chevallier (2008).

2. Model

[1] While the feature of banking is more prevalent in programs, borrowing is limited. Overlapping cycles of compliance periods (year) allow for implicit borrowing during the windows of overlapping months. There is evidence of borrowing among firms under the EU ETS phase I (2005-08), where operators used their next year's allowances to demonstrate compliance with current year compliance (Trotignon and Ellerman 2008). The operators were allocated their assigned allowances in end-February of each calendar year, but had to surrender units in April of the next year to demonstrate compliance, thus at the time of determining compliance firms had two annual sets of allowances to cover their emissions, except for the final year of the trading period (ibid). In infinite time horizons, unrestricted borrowing is not a desirable feature from the environmental perspective as polluters could have an incentive to postpone abatement infinitely.

[2] Efficiency in this model is achieved with equality of marginal abatement costs across firms and effectiveness is ensured when firms do not cheat.

There are a total of N firms in the permit market, with the dominant firm being represented by the first firm, $i=1$, and the competitive fringe firms by the remaining firms $i=2,\ldots, n$. The cost of emission abatement is denoted as $C_i(e_i)$ for each firm i, where $e_i(t)$ is the emission at time t. C_i is decreasing and convex in emissions, such that $C_i'<0$ and $C_i''>0$, with $C_i(0)=0$. The regulator distributes a predetermined stock of permits among the firms, and the initial endowment for each firm i at time t is denoted by $l_i^0(t)$. Assuming a unique permit price $P(t)$ in each t, a firm i can engage in permit trade with other firms, buying $y_i(t)>0$ (or selling, in case $y_i(t)<0$) amount of permits.

Firms also engage in inter-temporal trade in permits, with both banking and borrowing being allowed except in the end-point T, with $B_i(t)>0$ denoting the amount of permits banked in t for future use (or borrowed, when $B_i(t)<0$). We consider a continuous but finite time-horizon of T, and since a firm i does not inherit any permits in the beginning, we have $B_i(0)=0$. Since a firm cannot borrow from the future, in the endpoint we have $B_i(T)\geq 0$. If $l_i(t)$ is the permit holding of firm i at time t, then the net permit banked in any point t can be represented as, $\dot{B}_i(t) = l_i^o(t) + y_i(t) - l_i(t)$.

With regulatory enforcement being imperfect, there is scope for cheating among firms. A firm's emission level $e_i(t)$ may well exceed its permit holding $l_i(t)$ at time t, and we denote this as violation of firm i at time t as $v_i(t) = Max\{e_i(t) - l_i(t), 0\}$, i.e. by definition $v_i \geq 0$. In case permit holding is greater than actual emissions, then by definition violation is zero. We assume that while firms know about their actual emission $e_i(t)$, the regulator would know only when it audits the firm. The probability of firm i being audited is denoted by $\beta_i(v_i)$, which is considered to be an increasing function of violation with $\beta_i'(v_i)>0$ and $\beta_i''(v_i)\geq 0$. When the regulator detects violation, the associated penalty is $F_i(v)$, which is also an increasing function of violation with $F_i' > 0, F_i'' > 0$ for $v_i \geq 0$, and with $F_i(0) = 0$. Consequently the net change in banked permits at t, can be re-written in terms of initial endowment of permits, current permit trade, emissions and violation as: $\dot{B}_i(t) = l_i^o(t) + y_i(t) - e_i(t) + v_i(t)$.

Considering a Stackelberg leader-follower scheme in the market equilibrium, we first solve for the fringe firms' and dominant firm's optimization exercise in section 3; and then examine the features of the market equilibrium and firms' cheating behavior in section 4.

3. Cost Minimization and Market Equilibrium

3.1 Fringe Firms' optimization

The price-taking fringe firms minimize the total discounted stream of cost associated with emission abatement, permit purchase and expected penalty from violation, subject to the banking budget of permits. Considering r as the discount rate, we have:

$$Min_{e_i, y_i, v_i} \int_0^T e^{-rt}\{C_i(e_i(t)) + P(t)y_i(t) + \beta_i(v_i(t))F_i(v_i(t))\}dt$$

s.t.

$$\dot{B}_i(t) = l_i^o(t) + y_i(t) - e_i(t) + v_i(t)$$

$$B_i(t) = 0, \; and \quad B_i(T) \geq 0 \qquad for\ i = 2, 3, \ldots, n.$$

The corresponding current value Hamiltonian and the first order conditions can be written as: $H = C_i(e_i(t)) + P(t)y_i(t) + \beta_i(v_i(t))F_i(v_i(t)) + \lambda_i(t)\{l_i^o(t) + y_i(t) - e_i(t) + v_i(t)\}$ where $\lambda_i(t)$ is the Lagrange multiplier.

$$\frac{\partial H}{\partial e_i(t)} = C_i'\big(e_i(t)\big) - \lambda_i(t) = 0 \quad (1)$$

$$\frac{\partial H}{\partial y_i(t)} = P(t) + \lambda_i(t) = 0 \quad (2)$$

$$\frac{\partial H}{\partial v_i(t)} = \beta_i{}'(v_i)F_i(v_i) + \beta_i(v_i)F_i{}'(v_i) + \lambda_i(t) = 0 \quad (3)$$

$$\frac{\partial H}{\partial \lambda_i(t)} = l_i^o(t) + y_i(t) - e_i(t) + v_i(t) = 0 \quad (4)$$

$$\frac{\partial H}{\partial B_i(t)} = \dot{\lambda}_i - r\lambda_i(t) = 0 \quad (5)$$

$$\lambda_i(T)B_i(T) = 0 \quad (6)$$

First-order conditions (1), (2) and (3) yield the equilibrium condition for the fringe firms,

$$-\lambda_i(t) = -C_i'\big(e_i^*(t)\big) = P(t) = \beta_i{}'(v_i^*)F_i(v_i^*) + \beta_i(v_i^*)F_i{}'(v_i^*) \quad (7)$$

The above condition gives the equilibrium levels (denoted with *) of emission, permit purchase, and violation at time *t* for the fringe firms.

3.1.1 Fringe firm's permit demand

We derive the fringe firm's response along the equilibrium path by differentiating (7):

$$-\dot{\lambda}_t = -C_i''\frac{\partial e_i}{\partial t} = \frac{\partial P}{\partial t} = (\beta_i{}''F_i + 2\beta_i{}'F_i' + \beta_i F_i{}'')\frac{\partial v_i}{\partial t} \qquad for\ \ i = 2, 3, \dots, n.$$

$$\Rightarrow \quad \frac{\partial e_i}{\partial P} = -\frac{1}{C_i''} < 0$$

$$and \ \ \frac{\partial v_i}{\partial P} = \frac{1}{\beta_i{}''F_i + 2\beta_i{}'F_i' + \beta_i F_i{}''} > 0$$

Since $y_i{}^*(t) = e_i^*(t) - v_i^*(t) - l_i^o(t)$, the change in permit demand of firm *i* is given by:

$$\frac{\partial y_i(t)}{\partial P(t)} = -\frac{1}{C_i''} - \frac{1}{\beta_i{}''F_i + 2\beta_i{}'F_i{}' + \beta_i F_i{}''} < 0 \quad (8)$$

With an increase in permit price, here the fringe firm can choose to abate more and cheat more (both of which become cheaper options, ceteris paribus) until equilibrium is restored with equi-marginal costs across options (equation 7). Thus price sensitivity of permit demand is higher in this model with non-compliance compared to the price sensitivity in a model with no cheating (in the latter, $\frac{\partial y_i}{\partial P} = -\frac{1}{C_i''}$). I.e., the price elasticity of permit demand, $\epsilon_d = \frac{\partial y_i(t)}{\partial P(t)} . \frac{P}{y_i}$ of the fringe firm is greater here compared to a full-compliance model.

3.2 Optimization for the Dominant Firm

The dominant firm determines the price $P(y_1(t))$ in the permit market while minimizing its total discounted cost of abatement, permit purchase and expected penalty over the finite period T, subject to its banking condition and the permit market clearing at each point in time.

$$Min_{e_1, y_1, v_1} \int_0^T e^{-rt}\{C_1(e_1(t)) + P(y_1)y_1(t) + \beta_1(v_1(t))F_1(v_1(t))\}dt$$

s.t.

$$\dot{B}_1(t) = l_1^o(t) + y_1(t) - e_1(t) + v_1(t)$$
$$B_1(t) = 0, \ and \quad B_1(T) \geq 0$$
$$where\ P(y_1)\ is\ such\ that\ y_1(t) + \sum_{i=2}^n y_i(t) = 0 \quad \forall\, t.$$

The corresponding current value Hamiltonian of the dynamic minimization and the first order conditions can be written as follows:

$$H = C_1(e_1(t)) + P(y_1)y_1(t) + \beta_1(v_1(t))F_1(v_1(t)) + \lambda_1(t)\{l_1^o(t) + y_1(t) - e_1(t) + v_1(t)\}$$

$$\frac{\partial H}{\partial e_1(t)} = C_1'\big(e_1(t)\big) - \lambda_1(t) = 0 \qquad (1')$$

$$\frac{\partial H}{\partial y_1(t)} = P'.y_1(t) + P + \lambda_1(t) = 0 \qquad (2')$$

$$\frac{\partial H}{\partial v_1(t)} = \beta_1{}'(v_1)F_1(v_1) + \beta_1(v_1)F_1{}'(v_1) + \lambda_1(t) = 0 \qquad (3')$$

$$\frac{\partial H}{\partial \lambda_1(t)} = l_1^o(t) + y_1(t) - e_1(t) + v_1(t) = 0 \qquad (4')$$

$$\frac{\partial H}{\partial B_1(t)} = \dot{\lambda_1} - r\lambda_1(t) = 0 \qquad (5')$$

$$\lambda_1(T)B_1(T) = 0 \qquad (6')$$

First-order conditions (1′), (2′) and (3′) yield the equilibrium condition:

$$-\lambda_1(t) = -C_1'\big(e_1^*(t)\big) = P'.y_1^*(t) + P(t) = \beta_1{}'(v_1^*)F_1(v_1^*) + \beta_1(v_1^*)F_1'(v_1^*) \qquad (7')$$

where $P'(y_1) < 0,$ and $P'' > 0$

Market equilibrium: Assuming an interior solution exists, from the optimality conditions (7) and (7′), the market equilibrium is characterized by:

$$P(t) = -C_1'(e_1^*) - P'.y_1^* = -C_i'(e_i^*) = -\lambda_1 - P'.y_1^* = -\lambda_i =$$
$$\beta_1'(v_1^*)F_1(v_1^*) + \beta_1(v_1^*)F_1'(v_1^*) - P'.y_1^* = \beta_i{}'(v_i^*)F_i(v_i^*) + \beta_i(v_i^*)F_i{}'(v_i^*) \qquad (9)$$

and $y_1(t) + \sum_{i=2}^n y_i(t) = 0 \quad \forall\, t$

4. Features of the permit market equilibrium

4.1 Efficiency in Abatement Cost

Following the market equilibrium characterized in (9), the relationship between the marginal abatement costs of dominant and fringe firms can be written as:

$$P(t) = -C_1'\big(e_1^*(t)\big) - P'.y_1^*(t) = -C_i'\big(e_i^*(t)\big) \quad for\ i = 2,3,\dots,n.$$

$$\Rightarrow -C_1'(e_1^*) = -C_i'(e_i^*)\left\{1 + \frac{P'.y_1^*}{P}\right\} \tag{9a}$$

It is evident that the efficiency in abatement (equal marginal abatement across firms) is ensured in this model only when the dominant firm does not engage in trade, i.e. when $y_1^*(t) = 0$ *a la Hahn*. The degree of inefficiency, i.e. the difference in the marginal abatement costs of the dominant firm and a typical fringe firm, represented by $\frac{P'.y_1^*}{P}$ is the inverse of the price elasticity of demand for permits of the dominant firm. (This is similar to Chevalier (2008), except that here due to the presence of cheating we cannot equate the dominant firm's permit trade to the emissions in the system without bringing in violations.)

Although efficiency is ensured when permit purchase of the dominant firm is zero, in this model since there is possibility of cheating, zero permit trade does not necessarily imply that initial allocation of permit to the dominant firm is equal to optimal permit holding at time *t*. Thus while the cap and trade system may succeed in achieving equi-marginal abatement cost, optimal violation of the dominant firm could be positive: $y_1^*(t) = e_1^*(t) - v_1^*(t) - l_1^o(t) = 0$; with $v_1^*(t) = e_1^*(t) - l_1^o(t) > 0$. So market equilibrium is not effective in capping the system's emissions as long as equilibrium violations of the firms are greater than zero.

4.2 Effectiveness of the Cap and Trade Program

The emission cap in the system is the total number of permits allocated across firms over time $\int_{t=1}^{T}\sum_{i=1}^{n} l_i^0(t)$, and for simplicity we interpret effectiveness of the cap-and-trade system as zero violations of firms at each point in time, i.e. when $v_1^*(t)$ and $v_i^*(t)$ are zero for all *t*. In other words, we ignore the case of any firm over-complying ($v_i^*(t) < 0, i = 1, \ldots, n$) and offsetting violation across time. The simplifying definition of non-effectiveness of the cap and trade model in our finite period model as non-zero violation in any point in time, implies that no firm ever has incentive to over-comply, and helps us to obtain insight into the nature of non-compliance behavior of the firms, and in particular that of the dominant firm. The conditions for compliance implies that, in equilibrium the marginal expected penalty is greater or equal to the marginal cost of emission permit, and greater than the marginal abatement cost for the firms. For the compliant fringe firm we get the condition, as follows:

$$-\lambda_i(t) = -C_i'\big(e_i^*(t)\big) = P(t) \leq \beta_i'(0)F_i(0) + \beta_i(0)F_i'(0) \qquad for\ i = 2,3,\ldots,n \quad \forall\, t$$

Since $F_i(0) = 0$, considering the equilibrium at equality we get the condition for compliance:

$$\beta_i(0)F_i'(0) = P = -C_i'(e_i^*) \geq 0 \tag{10}$$

It is evident that as in Egteren Weber (1996), here the compliance decision of the fringe firm *i* is independent of the initial allocation of permit, $l_i^o(t)$, in any point *t*.

Similarly, for the compliant dominant firm (i.e. $v_1^*(t) = 0$), we get the condition:

$$-\lambda_1(t) = -C_1'\big(e_1^*(t)\big) = P'.y_1^*(t) + P(t) \leq \beta_1(0)F_1'(0) \qquad \forall\, t$$

Considering the condition at equality:

$$P'\{e_1^*(t) - l_1^o(t)\} + P(t) = \beta_1(0)F_1'(0) \tag{10'}$$

$\Longrightarrow$ compliance at time t of the dominant firm is dependent on its *initial allocation of permits*, $l_1^o(t)$, in contrast to condition for the fringe firm.

4.3 Cheating: Fringe firms vs dominant firm

4.3.1 Sufficient conditions for cheating

The equilibrium conditions for compliance in section 4.2 provide the sufficient conditions cheating for the firms in the market. The sufficient condition for a fringe firm to cheat is:

$\beta_i(0)F_i{}'(0) < P$ for *i= 2, 3, …., n*; (11)

and for the dominant firm to cheat is:

$P'y_1^*(t) + P(t) > \beta_1(0)F_1'(0)$ (11′)

The presence of market power in (11′) means that the implications are different for the dominant firm when it is a *net buyer* versus a *net seller* of permits. In case the dominant firm is a *net buyer* of permits, $y_1^*(t) = e_1^*(t) - l_1^o(t) > 0$, the first product term ($P'y_1^*$) on the left hand-side of the equation (11′) is negative, thus the sufficient condition for non-compliance or cheating implies that $P(t) \gg \beta_1(0)F_1{}'(0)$. However, when the dominant firm is a *net seller*, $P'y_1^*$ is positive, so it is possible to have either $P(t) < \beta_1(0)F_1'(0)$ or, $P(t) > \beta_1(0)F_1'(0)$ as long as the total sum of the two terms ensure the inequality in (11′) to hold, i.e. satisfy the sufficient condition for violation.

In the special case where the penalty functions of the dominant and fringe firms are the same, the above asymmetry can give rise to a case where the following inequality holds:

$P'y_1^*(t) + P(t) > \beta_1(0)F_1'(0) = \beta_i(0)F_i{}'(0) > P$ (12)

such that the fringe firms have zero violation, but the *net seller* dominant firm is cheating as long as the market-power effect $P'y_1^*(t)$ is large enough (or price distortion compared to the competitive equilibrium) to ensure the above. It is more likely for the regulator to choose a higher probability of detection and associated penalty for the dominant firm compared to fringe firms, in order to offset this market-power effect.

4.3.2 Relationship between firms' violations

It is interesting to track the relationship between the non-compliance behaviors of the two types of firms. From the market equilibrium in (9), we have

$$\beta_1'(v_1^*)F_1(v_1^*) + \beta_1(v_1^*)F_1'(v_1^*) - P'.y_1^* = \beta_i{}'(v_i^*)F_i(v_i^*) + \beta_i(v_i^*)F_i{}'(v_i^*)$$

Differentiating the above w.r.t time along the equilibrium path, we get:

$$(\beta_1''F_1 + 2\beta_1'F_1' + \beta_1F_1'')\frac{\partial v_1^*}{\partial t} - (P''.y_1^* + P')\frac{\partial y_1^*}{\partial t} = (\beta_i''F_i + 2\beta_i'F_i' + \beta_iF_i'')\frac{\partial v_i^*}{\partial t}$$

Substituting for $\frac{\partial y_1^*}{\partial t} = \frac{S_1}{P''.y_1^*+2P'}\frac{\partial v_1^*}{\partial t}$ based on the dominant firm's optimal condition, we get

$$\frac{\partial v_i^*}{\partial v_1^*} = \frac{S_1}{S_i}\left(\frac{P'}{P''.y_1^*+2P'}\right) = \frac{S_1}{S_i}\left(\frac{1}{\eta+2}\right) \quad (13)$$

where S denotes the change in marginal penalty for the firms: $S_1 = \beta_1''F_1 + 2\beta_1'F_1' + \beta_1 F_1''$>0 and $S_i = \beta_i''F_i + 2\beta_i'F_i' + \beta_i F_i'' > 0$; and $\eta = \frac{P''.y_1^*}{P'}$ characterizes the curvature of the dominant firm's permit demand (elasticity of slope of its permit demand) and change in price distortion element. Recall, $P'(y_1) < 0$, and $P'' > 0$, such that the elasticity term in equation (13) will be negative when dominant firm is a net buyer of permits, and it will be positive when the dominant firm is a net seller.

This implies that the violation of the fringe firm would move together with violation of the dominant firm, i.e. $\frac{\partial v_i^*}{\partial v_1^*} > 0$ increasing the total violation in the system, when $(\eta + 2)$> 0. This will be true when the dominant firm is a net seller, and also true when the dominant firm is a net buyer as long as η> -2. On the other hand, the violations of the fringe and dominant firm will offset each other in the model, i.e. $\frac{\partial v_i^*}{\partial v_1^*} < 0$ when η< -2. The latter can hold only in the case of the dominant firm being a net buyer of permits in the market, with a high elasticity of the slope of the permit demand. In the special case, where the dominant firm has a linear permit demand curve, we get η=0 and $\frac{\partial v_i^*}{\partial v_1^*} = \frac{S_1}{2S_i}$> 0, with the result that violation of the fringe and dominant firm reinforce each other.

4.3.3 Initial permit endowment of dominant firm and cheating

Over time we expect the regulator to reduce the allocation of permits (as the cap is reduced over time), i.e. $\frac{\partial[\sum_{i=1}^{n} l_i^o(t)]}{\partial t} < 0$. It is thus interesting to examine the effect of the change in initial permit endowment on the violation of the dominant firm. We differentiate (7′) w.r.t. time to obtain:

$$(P''y_1^* + 2P')\left\{\frac{\partial e_1^*}{\partial t} - \frac{\partial l_1^o}{\partial t} - \frac{\partial v_1^*}{\partial t}\right\} = S_1 \frac{\partial v_1^*}{\partial t}$$

Substituting for $\frac{\partial e_1^*}{\partial t} = \frac{S_1}{-C_1''}\frac{\partial v_1^*}{\partial t}$ based on (7′), and rearranging the terms we get,

$$\frac{\partial v_1^*}{\partial l_1^o} = -S_1^{-1}\left(\frac{1}{P''y_1^*+2P'} + \frac{1}{C_1''} + \frac{1}{S_1}\right)^{-1} \quad (14)$$

where $S_1 = \beta_1''F_1 + 2\beta_1'F_1' + \beta_1 F_1''$> 0, and C_1''>0. The terms within the brackets in the right hand side of equation (14) are the inverse of change in marginal cost of permits, inverse of change in marginal abatement cost and the inverse of the change in marginal penalty cost for the dominant firm. The violation of the dominant firm will decline as its initial permit allocation declines, as long as combined effects from the three is negative, such that $\frac{\partial v_1^*}{\partial l_1^o}$ > 0. The necessary and sufficient conditions are:

$$\frac{1}{P''y_1^* + 2P'} < 0, and \left|\frac{1}{P''y_1^* + 2P'}\right| > \frac{1}{C_1''} + \frac{1}{S_1}$$

$$\Rightarrow \eta > -2, and \left|\frac{1}{(\eta+2)P'}\right| > \frac{1}{C_1''} + \frac{1}{S_1} \quad (15)$$

Thus when the change in marginal abatement cost and marginal expected penalty of the dominant firm are relatively high compared to the change in price distortion element, (15) will hold and the dominant firm's violation will reduce with its permit endowment over time.

5. Conclusion

The dynamic equilibrium analysis in our model with twin imperfections of market structure and regulation (i.e. market power and non-compliance) extends the results of the established literature (Hahn 1984, Egteren and Weber 1996, Chevalier 2008). In the presence of cheating, the permit demand curve becomes more price-elastic, compared to a model with no cheating. We find the initial allocation of permits to the dominant firm continues to play a significant role in both the cost-efficiency of abatement (Hahn 1984) as well as effectiveness of the cap-and-trade system (Egteren and Weber 1996). Moreover, the second-order price sensitivity of the permit demand of the dominant firm (characterizing the price distortion in the model) plays a critical role in the relationship between compliance behavior of the fringe firms and the compliance behavior of the dominant firm; as well as in the compliance behavior of the dominant firm as permit endowment changes over time.

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