# Using the allocation of emission permits for Strategic Trade purposes

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We show that the presence of transaction costs in emission permit markets challenges the common presumption that grandfathering permits corresponds to lump-sum transfers with no strategic effects on output. Fixed transaction-costs influence firms' decision to participate in the permits market, while variable transaction-costs affect firms' output choice by creating a wedge between buyers' and sellers' opportunity cost of using permits. Thus, permit grandfathering *can* be used as a strategic trade instrument *even when firms are price takers in the permit markets.* Grandfathered permits differ from subsidies in that the stimulus they provide is bounded exogenously and rather limited.

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## 1. Introduction

Increasing interest in Emissions Trading Schemes (ETS) is based mainly on the expected efficiency gains derived from allocating abatement effort to the lowest cost facilities. These theoretical expectations led to the introduction of ETSs initially at the national level --mainly in the USA-- and later, following the positive evaluation of the existing schemes, at the international level, the primary example being the EU-ETS for controlling greenhouse gases. Countries participating in an international ETS receive a number of emission allowances (permits) that may, in turn, either auction or allocate free of charge to their domestic firms (grandfathering). Mixed schemes where some governments use auctioning and other grandfathering of permits may exist even within the same trading block. Actually this was the case in Phase I and II of the EU-ETS, during which, despite the existence of general guidelines, "…permit allocation was not coordinated between the member states, leading to differential treatment of otherwise similar companies and sectors across the EU" (OECD (2011) p. 47). The revised allocation rules in Phase III lead progressively towards auctioning, allowing though grandfathering of permits in selective sectors and participating countries.[1] Despite substantial efforts to harmonize allocation rules, this is impossible within a mixed allocation scheme.[2] Furthermore, mixed permit allocation schemes might emerge as more regional or national ETSs for controlling greenhouse gases develop and are connected among them in order to enhance efficiency.[3]

The emergence of international permit markets, to address mainly climate change challenges, in which the initial permit allocation rules differ among countries, implies that competitors in international product markets may be treated differently by their governments. The main concern with respect to the effect of climate policies on international competitiveness relates to the issue of carbon leakage resulting from differences in environmental standards.[4] Another concern that has received less attention relates to the effect that an international ETS with mixed allocation rules might have on competitiveness. More precisely, could grandfathered permits affect market performance and provide the recipients with strategic advantage over permit-purchasing rivals? The layman's presumption is that it does indeed, yet economic

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[1] Commission Regulation (EU) No 1031/2010 of 12 November 2010.

[2] See Böhringer and Lange (2005).

[3] For example, climate change policy in the USA, Australia and New Zealand moves towards implementing ETSs involving output-based rebating, which differs from ordinary grandfathering.

[4] See for example the recent contribution of Böhringer, Fischer, and Rosendahl (2010).

theory treats grandfathered permits as pure transfers. A competitive permit market creates an opportunity cost to the use of a permit equal to its market value; therefore a firm uses the same number of permits whether it receives them for free or purchases them. Seen in this way, granting permits to a firm corresponds to a lump sum transfer that, while it may affect entry or exit decisions, it leaves output decisions of existing firms unaffected. This line of argument led to the suggestion that grandfathering cannot create competitive distortions (Woerdman (2003)), and that countries should be left free to decide independently the permit allocation scheme (Zhang (1999)).

Our analysis shows that the above reasoning is limited to frictionless markets, in which transactions bear no additional costs. We show that in the presence of fixed and/or per-unit transaction costs, permits grandfathering affects output decisions and thus, it can be used for strategic trade purposes distorting international competitiveness. If participation in the permit market entails fixed costs, some firms may choose to stay out of the permit market, complying with the regulatory requirements by abating and using any amount of grandfathered permits they receive. Clearly in this case the amount of granted permits affects production choices. If firms enter the market, variable transaction costs drive a wedge between buyers' and sellers' opportunity cost of using permits in the production process. Therefore, the marginal cost of a permit seller is less than that of a permit buyer, thus inducing the holder of permits to a more aggressive behavior, assuming strategic substitutability of firms' choices in the output market. Granting a number of permits to a firm is equivalent to offering that firm a unit cost reduction.

While it appears that both grandfathered permits and subsidies may be used strategically to increase domestic firms' output, there is an important difference. Unless there are quotas restricting the number of units to be subsidized, the subsidy applies to all units and the government's decision concerns the subsidization rate. In the case of grandfathered emission permits, on the contrary, the amount of subsidy per unit of output is exogenous, determined by the permit price (in case that fixed transaction costs prevent firm's entry into the market) and the per-unit transactions costs. What the government may affect in this case is *the number of subsidized units.* Hence, permit grandfathering corresponds to offering firms pre-established capacity and thus, is closer to *capacity commitments*, in the sense of the Dixit-Spence model (Dixit (1980), Spence (1977)).

Stavins (1995) incorporated transaction costs into the basic permits model to establish that cost efficiency conditions are violated and thus, the full potential of the permit market is not achieved. Furthermore, Stavins shows that, in the presence of transaction costs, the initial distribution of permits affects permit-trading decisions. Cason and Gangadharan (2003) confirm these results in an experimental setting. Montero (1996) incorporates uncertainty in the model with transaction costs and examines their effect on the permit market's performance and control costs. These papers are concerned with the effect that transaction costs may have on the cost effectiveness of the permit market, while the present paper focuses on their effect on the output market, and in particular whether they allow governments to use permits strategically. Our analysis is based on strategic trade theory demonstrating that, in imperfectly competitive international markets, governments can improve their country's welfare, relative to free trade, by intervening in these markets. A significant literature developed around this idea based on the initial contributions by Brander and Spencer (1984 and 1985), Dixit (1984) and Eaton and Grossman (1986). Although the predictions of the theory are sensitive to the mode of oligopolistic competition, Maggi (1996) identifies a single-rate policy, capacity subsidies, and shows that it can be used for strategic trade policy regardless of the mode of competition.

Using the strategic trade policy framework it has been argued that countries could use environmental policy to improve their firms' position, either by affecting the pattern of international trade or the location of firms and industry. Conrad (1993), Barret (1994), and Kennedy (1994), among others, have suggested that environmental policy can be used to indirectly subsidize exports; Markusen et al. (1995) and Rauscher (1995), among others, discuss the incentives to strategically set emission taxes low to attract polluting industries. More recently Pratlong (2005) and Bueb and Schwartz (2011) examine the regulator's incentives to use the pollution cap and the initial distribution of permits strategically in order to boost home firms' position in the international market. Their analysis differs substantially from this paper in that Pratlong (2005) assumes that permits are not traded internationally, while Bueb and Schwartz (2011) assume that only one country implements an ETS. Furthermore, none of these papers deals with transaction costs.

### *Empirical evidence and taxonomy of transaction costs*

The importance of transaction costs in emission permit markets was noticed in a number of theoretical works quite early,[5] and their concerns were later supported by empirical analysis. Rose (1994) suggests the existence of transaction costs in the $SO_2$ permits program, Kerr and Maré (1998) estimate efficiency losses from the presence of transaction costs in the lead permits program and Gangadharan, L. (2000) shows that transaction costs were significant in the RECLAIM program, influencing the choice of participation in the market. Although not focusing on transaction costs, using data from the same program, Fowlie and Perloff (2013) report that their empirical analysis fails to reject the hypothesis that $NO_x$ emissions were independent of how emissions permits were allocated across firms. More recently, a number of papers empirically examine the existence of transaction costs in the EU-ETS. Jaraite et al. (2009), using data from Irish firms participating in the EU-ETS, find that transaction costs are significant, particularly for smaller firms at the early stages of the program. Heindl (2012), using data from two surveys of German firms participating in the EU-ETS, reports significant transaction costs, which result in welfare losses. Furthermore, it is shown that transaction costs are relatively higher amongst smaller firms. Jaraite and Kazukauskas (2012), using data from all countries participating in the EU-ETS, report significant transaction costs that influence firms' behavior in the permit market. They also show that small firms were less likely to participate in the market and a number of them did not sell their surplus allowances. Finally, Hahn and Stavins (2011) review and evaluate empirical evidence of potential violation of cost-effectiveness and neutrality of the permits' allocation due to a number of conditions including transaction costs, in eight cap-and-trade programs. They find that in some programs cost-effectiveness and neutrality hold strong, while in some others these properties are absent due to distortions, among which the most prevalent is the presence of transaction costs.

Transaction costs consist of administrative and trading costs which create a margin between the buying and selling price of permits. Taking the EU-ETS as an example, they are incurred first at the stage in which firms prepare their administrative systems to comply with the requirements of the regulation; second, at the stage of trading and they include search, information, bargaining and decision making costs; and finally at

[5] See for example Baumol and Oates (1988) and Hahn and Hester (1989).

the reporting stage, and they include application, registry accounts, monitoring, reporting and verification costs.[6] The first category includes mainly fixed and sunk costs, the third category, periodic costs, incurred in every reporting period, and the second category, costs that depend on the number of transactions and the volume of permits traded. Transaction costs differ according to whether firms trade directly at exchanges (in the case of EU-ETS there is a number of exchanges, such as ECX, NordPool and EEX), or use brokers operating in the emissions market for over the counter exchanges. In both cases transaction costs can be split into direct transaction costs (which include exchange membership, brokers' fees, and financial services) and indirect transaction costs (which include personnel to manage transactions and risk, data/advisory services and financial reporting). In this paper we group transaction costs into fixed and variable (per permit traded) costs and we analyze their effect on firms' output choice separately.

The rest of the paper is structured as follows. Section 2 describes the model. Section 3 examines the effects of emission permits grandfathering on international trade. First, the Cournot equilibrium in the absence of transaction costs is presented and then, variable and fixed transaction costs are introduced separately. The incentives to use grandfathering of permits as a strategic trade instrument are analyzed assuming that only one country grandfathers permits while the other auctions them. The case that both countries grandfather permits is examined at the end of Section 3. The last Section concludes the paper and discusses some topics for future research.

**2. The model**

Assume a domestic and a foreign firm exporting their entire production of a homogeneous good to a third country, where they compete in quantities (Cournot duopoly).[7] Let $q_i$ denote firm *i*'s output, $i = d, f$, and $p = a - \left(q_d + q_f\right)$ the market price. Production costs are zero.

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[6] These are costs incurred by firms in preparing their annual emissions report. The regulatory authority incurs also monitoring verification and enforcement costs, which might also be significant but are not borne by firms and thus, we do not take them into account.

[7] This is a standard simplifying assumption in strategic trade theory, made to emphasize the profit-shifting motive by isolating it from issues of terms of trade and consumer welfare. The main results of the paper carry over even when other motives for trade policies are taken into account. Note the particular case of the EU-ETS, where some countries may grandfather permits to firms exporting to the common market. For these countries profit-shifting effects are concentrated to their firms while

Production generates emissions $e$ of a global pollutant, common to many other industries in many countries, at a constant rate per unit of output. Firms can reduce emissions through abatement $\alpha_i$, at a cost $CA_i(\alpha) = \alpha_i^2/2$. There is a one to one relationship among units of abatement, emission and output. Thus, firm $i$'s net (unabated) emissions are $e_i(q,\alpha) = q_i - \alpha_i$. Both countries participate in an international environmental agreement setting country specific emission targets, implemented through an ETS. Each country is allocated a number of permits corresponding to its emission target, and decides whether to auction or grandfather them, and the amount of grandfathered permits (if any) per firm, $\overline{e}_i \geq 0$. Each permit corresponds to a unit of emission.

After the initial allocation of permits, the pollutant emitting firms from all industries and countries can participate in a common permit market. Since the pollutant is common to many industries, a large number of firms from many countries participate in that pollutant's permit market, where they can buy or sell permits at the exogenously given price $P^T$ (partial equilibrium analysis). Participation requires a fixed cost $T \geq 0$, necessary to enter the market and a cost $t \in \left[0, P^T\right]$ per permit exchanged.[8] For simplicity, we assume that variable transaction costs are borne only by the seller. This creates a gap between the market price $P^T$ and the net price the seller receives, $P_s^T = P^T - t$.[9] Firms must hold a number of permits equal to their net (unabated) emissions. Thus, firm $i$'s net demand for permits is $e_i - \overline{e}_i = q_i - \alpha_i - \overline{e}_i$. Assuming that firm $i$ pays the fixed cost and enters the market, its cost of complying with the regulation and hence its profit, is conditional upon being (a) seller of permits, selling part or its entire permits' endowment, or (b) buyer of permits:[10]

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consumer-welfare effects are dispersed over the entire EU. In this case, the exports-to-a-third-country assumption is unnecessary.

[8] We assume for simplicity that both fixed and per permit transaction costs are exogenous and they do not differ across countries. However, the insights offered by the model carry over to situations where transaction cost differ across countries and regulators could partially reduce transaction costs.

[9] Nothing changes assuming also transactions costs on purchases: $P^T$ is then interpreted as full price, including purchasing transactions costs.

[10] In the case that $\overline{e}_i = q_i - \alpha_i$, the firm uses the entire permits' endowment and does not enter the market.

$$\pi_i = \begin{cases} \left(a-q_i-q_j\right)q_i-\left(\alpha_i^2/2\right)-P_s^T\left(q_i-\alpha_i-\overline{e}_i\right)-T, & if\ \overline{e}_i > q_i-\alpha_i \quad (a) \\ \\ \left(a-q_i-q_j\right)q_i-\left(\alpha_i^2/2\right)-P^T\left(q_i-\alpha_i-\overline{e}_i\right)-T, & if\ \overline{e}_i < q_i-\alpha_i \quad (b) \end{cases} \tag{1}$$

We consider the following general game. From the outset, it is determined whether a government auctions or grandfathers its available permits to its firms (we do not endogenize this decision). At the first stage, governments assumed to practice grandfathering allocate their available permits to their firms. At the second stage firms decide whether to pay $T$ and participate in the permit market. At the third stage firms, entering the market, choose how many permits to sell, or purchase, and compete in quantities.

## 3. Emission permits and international trade

In analyzing the effects of emission permits grandfathering we start by setting up the framework in the absence of transaction costs. Then, in order to simplify the presentation, we examine separately the case of variable and fixed transaction cost. For reasons that will become clear later on, expositional clarity requires that we examine the case of variable transaction cost first.

### 3.1 The case with no transaction costs

Assume $T = t = 0$, the latter implying $P_s^T = P^T$. Firms maximize profits, with respect to output and abatement, subject to the constraints that output, abatement, and net emissions are non-negative. In order to simplify the presentation, we consider only the last constraint, hence, the resulting Lagrangian is:

$$\max_{q_i,\alpha_i} L_i = \left(a-q_i-q_j\right)q_i-\alpha_i^2/2-P^T\left(q_i-\alpha_i-\overline{e}_i\right)+\lambda_i\left(q_i-\alpha_i\right),$$

where, $i = d, f$. Maximization yields the following first order conditions:

$$\begin{aligned} &\frac{\partial L}{\partial q_i} = a-q_j-2q_i-P^T+\lambda_i = 0 && (a) \\ &\frac{\partial L}{\partial \alpha_i} = -\alpha_i+P^T-\lambda_i = 0 && (b) \\ &\frac{\partial L}{\partial \lambda} = q_i-\alpha_i \geq 0, \quad \text{with equality if } \lambda_i > 0 && (c), \end{aligned} \tag{2}$$

where $\lambda_i$ is the Lagrange multiplier. Firm $i$ chooses abatement by equating the marginal cost of the two options of complying with the regulation. First order conditions (2b) and (2c) yield,

$$\alpha_i = \begin{cases} q_i, & \text{for } \lambda_i > 0,\ q_i - \alpha_i = 0 \quad (a) \\ P^T, & \text{for } \lambda_i = 0,\ q_i - \alpha_i > 0 \quad (b). \end{cases} \tag{3}$$

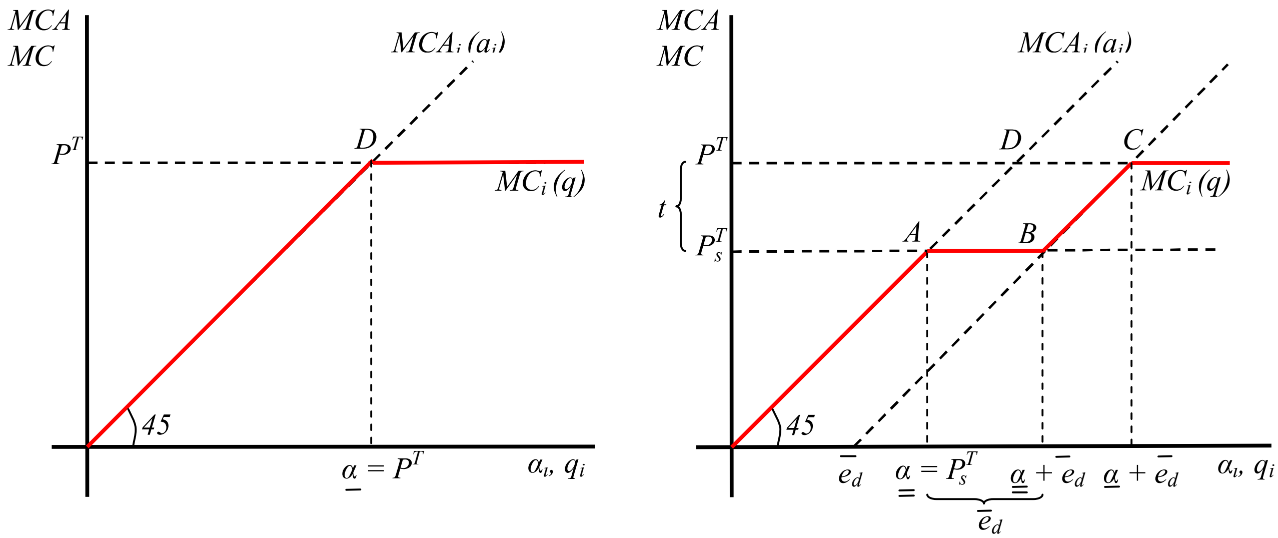
For $\lambda_i>0$, firm $i$ abates all its emissions ($q_i=\alpha_i$) and sells its entire endowment of permits. For $\lambda_i=0$, firm $i$'s net emissions are positive ($q_i>\alpha_i$) and needs to use permits. Depending on the initial endowment of permits ($\bar{e}_i \geq (\leq) q_i - \alpha_i$) the firm might be a seller or a buyer of permits. Intuitively, a firm will abate until its marginal abatement cost becomes equal to $P^T$.

Let $\underline{\alpha}$ be such that $MCA_i(\underline{\alpha}) = P^T$; obviously, $\forall \alpha \leq (\geq) \underline{\alpha}$ firm $i$ complies through abatement (permits). Under our cost assumptions, $\underline{\alpha} = P^T$. Thus, the "envelope" marginal cost of compliance with the regulation function expressed in terms of output $MC_i(q)$, depicted in Figure 1a, is,[11]

$$MC_i = \begin{cases} q_i, & \forall q_i < P^T \quad (a) \\ P^T, & \forall q_i \geq P^T \quad (b). \end{cases} \tag{4}$$

Notice that grandfathering any number of permits reduces $CA_i(\alpha)$ but leaves $MCA_i(\alpha)$, and thus, $MC_i(q)$, unchanged: permits are a pure transfer to the firm leaving its output decision unaffected.

[11] Recall that we have assumed a one to one relationship among $e$, $q$ and α.




**a.** $t = 0$ **b.** $t > 0$

**Figure 1. Marginal cost of compliance**

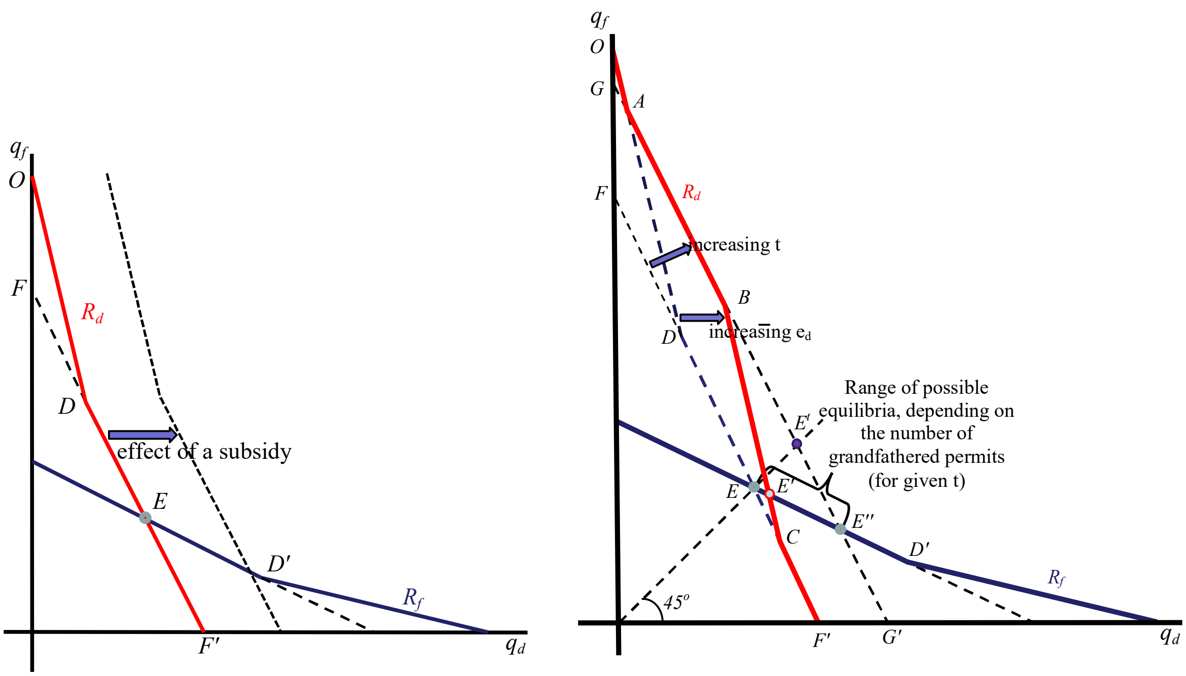
Substituting (2b) in (2a) and using (3a) yields firm *i*'s reaction function, $R_i$, $i = d, f$, for $\lambda_i > 0$, while for $\lambda_i = 0$ the reaction function is derived from (2a) directly,

$$q_i = \begin{cases} \left(a - q_j\right)/3, & \forall q_j \leq \underline{\alpha} = P^T \qquad (a) \\ \left(a - P^T - q_j\right)/2, & \forall q_j > \underline{\alpha} = P^T \qquad (b). \end{cases} \tag{5}$$

Figure 2a illustrates both firms' reaction functions $R_i$. The steepest part of the domestic firm's reaction function $R_d$, line segment *OD*, corresponds to output levels for which the domestic firm complies with the regulation by engaging solely in abatement selling its entire endowment of permits. For higher levels of $q_d$ the domestic firm sells or purchases permits (depending on $\overline{e}_d$) at price $P^T$. At point *D* ($q_d = \underline{\alpha} = P^T$), $R_i$ has a kink corresponding to the kink in the firm's marginal cost of compliance. An increase in the permit price slides point *D* to the right, along the segment *FF'*. The foreign firm's reaction function is drawn in a similar way.

Since in the zero transaction cost case grandfathering does not affect firms' marginal cost, firms are completely symmetric. Thus, two equilibria can emerge, according to whether (5a) or (5b) holds for both firms. To avoid discussing many sub-cases that are qualitatively almost similar, we rule out the symmetric equilibrium corresponding to (5a), by assuming $P^T < a/4$.[12] Applying (5b) we get the equilibrium output,

$$q_i^* = \frac{1}{3}\left(a - P^T\right). \tag{6}$$




**a.** $t = 0$ **b.** $t > 0$

**Figure 2. Reaction functions**

In this equilibrium, no firm can meet the regulatory requirements only through abatement. This implies that $q_i^* > \underline{\alpha} = P^T$, which is guaranteed by the $P^T < a/4$ assumption. Point E on Figure 2a depicts the symmetric Cournot equilibrium in the absence of transaction costs with both firms entering the permit market.[13]

### 3.2 The case of variable transaction cost

Assume now that while entry into the permit market is costless ($T = 0$) there is a cost $t$ per permit exchanged. We further assume that the home country grandfathers a number $\overline{e}_d$ of permits to the domestic producer, while the foreign country auctions all

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[12] The equilibrium output when (5a) holds is $q_i^0 = a/4$ and setting $q_i^0 \le \underline{\alpha} = P^T$ yields the condition in the text. In this equilibrium, firms will make use of no permits, unless they are grandfathered.

[13] In fact, in order to further limit the number of sub-cases we will need a stronger assumption, namely that $P^T < a/5$ (see further down in the text).

available permits. Since the selling price is lower than the purchasing price, the domestic firm will start purchasing permits after exhausting its endowment. Therefore, the domestic firm is a seller of permits receiving a price $P_s^T = P^T - t$ if its net emissions are less than its permits' endowment $q_d - \alpha_d < \overline{e}_d$; it does not participate in the permits market if $q_d - \alpha_d = \overline{e}_d$; and it is a buyer of permits paying a price $P^T$, if $q_d - \alpha_d > \overline{e}_d$. Thus, it is as if the domestic firm solves three different constrained maximization problems which for simplicity we can present by the following Lagrange function,

$$\max_{q_d, \alpha_d} L_d = \left(a - q_d - q_d\right) q_d - \alpha_d^2 / 2 - \left(P^T - t\right)\left(q_d - \alpha_d - \overline{e}_d\right) + \lambda_d \left(q_d - \alpha_d\right).$$

The resulting first order conditions with respect to abatement and the Lagrange multiplier yield the first two parts of the solution for domestic firm's abatement, for $q_d - \alpha_d < \overline{e}_d$, implying $t>0$. Part (a) corresponds to the case that $\lambda_d>0$, i.e. the domestic firm abates all its emissions and sells its entire endowment of permits and part (b) to the case that $\lambda_d=0$, i.e. the domestic firm uses part of its permits' endowment and sells the remaining. Part (c) corresponds to the case that the domestic firm does not enter the permit market, covering its net emissions, which are positive ($\lambda_d=0$) , with its permits endowment, that is, $q_d - \alpha_d = \overline{e}_d$. Part (d) corresponds to the case that the domestic firm is a buyer of permits, $q_d - \alpha_d > \overline{e}_d$, implying $t=0$. In this case $\lambda_d=0$, since $q_d - \alpha_d > \overline{e}_d > 0$.

$$\alpha_d = \begin{cases} q_d, & \text{for } q_d - \alpha_d < \overline{e}_d \text{ and } \lambda_d > 0 \quad (a) \\ P_s^T, & \text{for } q_d - \alpha_d < \overline{e}_d \text{ and } \lambda_d = 0 \quad (b) \\ \\ q_d - \overline{e}_d, & \text{for } q_d - \alpha_d = \overline{e}_d \text{ and } \lambda_d = 0 \quad (c) \\ P^T, & \text{for } q_d - \alpha_d > \overline{e}_d \text{ and } \lambda_d = 0 \quad (d). \end{cases}$$

Let $\underline{\underline{\alpha}}$ be such that $MCA_d\left(\underline{\underline{\alpha}}\right) = P_s^T$ which under our cost assumptions implies $\underline{\underline{\alpha}} = P_s^T$. Then, the domestic firm's "envelope" marginal cost of compliance function, expressed in terms of output, illustrated in Figure 1b, becomes:

$$
MC_d = \begin{cases} q_d, & \forall q_d < \underline{\underline{\alpha}} \equiv P_s^T \quad (a) \\ P_s^T, & \forall q_d \in \left[\underline{\underline{\alpha}}, \underline{\underline{\alpha}} + \bar{e}_d\right] \quad (b) \\ & \\ q_d - \bar{e}_d, & \forall q_d \in \left[\underline{\underline{\alpha}} + \bar{e}_d, \underline{\alpha} + \bar{e}_d\right] \quad (c) \\ P^T, & \forall q_d \geq \underline{\alpha} + \bar{e}_d \quad (d) \end{cases} . \tag{7}
$$

For output levels up to $q = \underline{\underline{\alpha}}$ the domestic firm meets the regulatory requirement using abatement, selling its entire endowment of permits at $P_s^T$. For $q_d \in \left(\underline{\underline{\alpha}}, \underline{\underline{\alpha}} + \bar{e}_d\right]$ the domestic firm uses part of its permits' endowment selling the remaining permits at $P_s^T$. For higher levels of output the firm returns to abatement, up to the level $q_d = \underline{\alpha} + \bar{e}_d$, at which $MCA_d\left(\underline{\alpha} + \bar{e}_d\right) = P^T$. To support even higher levels of output the firm purchases permits at $P^T$.

Receiving $\bar{e}_d$ permits free of charge reduces the domestic firm's opportunity cost of permits from $P^T$ to $P_s^T$, for output levels $\left[\underline{\underline{\alpha}}, \underline{\underline{\alpha}} + \bar{e}_d\right]$. Thus, grandfathered permits are no longer a pure transfer since they may affect output decisions.

Using the solution for abatement and the first order conditions with respect to output, yields domestic firm's reaction function $R_d$,

$$
q_d = \begin{cases} \left(a - q_f\right)/3, & q_f \geq a - 3P_s^T \quad (a) \\ \left(a - P_s^T - q_f\right)/2, & a - 3P_s^T - 2\bar{e}_d \leq q_f \leq a - 3P_s^T \quad (b) \\ & \\ \left(a + \bar{e}_d - q_f\right)/3, & a - 3P^T - 2\bar{e}_d \leq q_f \leq a - 3P_s^T - 2\bar{e}_d \quad (c) \\ \left(a - P^T - q_f\right)/2, & q_f \leq a - 3P^T - 2\bar{e}_d \quad (d). \end{cases} \tag{8}
$$

In Figure 2b, $R_d$ has been drawn in four parts, each solid segment from upper left to lower right corresponding to the sub-cases presented in equation (8). Line segments *OA* and *BC*, illustrate domestic firm's reaction function when abating its entire emissions and thus, selling (8a) or using (8c) its entire endowment of permits respectively; *AB* when it sells part of permits' endowment (8b), and *CF′* when purchasing permits at $P^T$ (8d). Lines $FF'$ and $GG'$, correspond to the reaction function of a firm with marginal cost $P^T$ and $P_s^T = P^T - t$ respectively; their distance depends on the value of transaction cost $t$ and cannot be affected by the number of grandfathered permits $\overline{e}_d$. By increasing the latter, the home government succeeds in moving the line segment *BC* parallel towards the southeast, by sliding points *B* and *C* along segments *GG′* and *FF′*, respectively.

There is a unique equilibrium that can be represented by any combination of the domestic and foreign firm's reaction function segments, given in equations (5) and (8) respectively. All the potential equilibrium situations are fully described in the Appendix. Here, however, we limit the analysis to the most interesting one, by placing quite reasonable conditions on $t$ and $\overline{e}_d$. We first assume that in equilibrium no firm's output is ever so limited that the firm would use no permits. Thus, the equilibrium will never involve neither the segment (5a) —with $i = f$, $j = d$— of the foreign firm's reaction function, nor the (8a) segment of the domestic firm's reaction function. As it can be seen in the Appendix, this requires $t < S \equiv a - 4P^T$, for which it is sufficient that $a > 5P^T$, assumed hereafter.

We also restrict our attention to the range of values of $\overline{e}_d$ for which grandfathering is strategically effective, but not unnecessarily excessive. We first rule out the case of grandfathered permits being so few, as to leave output decisions unaffected: the equilibrium cannot be at the intersection of $R_f$ with segment (8d) of $R_d$ (segment *CF′* on Fig. 2b). A necessary and sufficient condition for this is that $\overline{e}_d > \overline{e}_{d\min} \equiv \frac{1}{3}\left(a - 4P^T\right)$ (see the Appendix). Finally, we do not allow the equilibrium to occur on the *AB* segment of Fig. 2b, *i.e.*, to be the simultaneous solution of (5b) and (8b), since such equilibrium would imply that the domestic firm does not exhaust its entire stock of free permits. In order to see why, assume for a moment that $\forall q_d$, $\overline{e}_d \equiv q_d$, *i.e.*, the domestic government commits to cover any output its firm decides to produce, by grandfathering that firm all the necessary permits.[14] In that case, $R_d = GG'$ (given by (8b)) and the equilibrium is at point $E'' \equiv \left(q_d^{E''}, q_f^{E''}\right) = GG' \cap \mathrm{R}_f$, where $MC_d = P_s^T$ and $MC_f = P^T$; the corresponding domestic output equilibrium is $q_d = \left(a - P^T + 2t\right)/3 \equiv q_{d\max}(t)$; and $q_{d\max}(t) \equiv \overline{e}_{d\max}(t)$. Given that the maximum

[14] The argument does not change if we assume that $\forall q_d$, $\overline{e}_d \equiv q_d - P^T$, *i.e.*, the government grants only the necessary permits beyond the equilibrium level of abatement, in which case $R_d = OAG'$.

possible value of $t$ is $P^T$ then $\overline{e}_{d\max}(t) \in \left[\left(a-P^T\right)/3, \left(a+P^T\right)/3\right]$. Since the position of the $GG'$ curve depends on $t$ but *not* on $\overline{e}_d$, $q_{d\max}(t)$ represents the maximal value of $q_d$ that can be obtained through the use of grandfathered permits. If $\overline{e}_d > \overline{e}_{d\max}(t)$, point $B$ slides along the $GG'$ curve below $E''$, yet $E''$ still remains the equilibrium point: all permits in excess of $\overline{e}_{d\max}(t)$ will remain unused.[15,16] When the intersection of $R_f$ with $R_d$ occurs on the $AB$ segment of the latter, point $B$ is always to the southeast of $E''$: if the equilibrium lies on $AB$, it necessarily implies excessive grandfathering, a possibility that can be reasonably ruled out.

Having excluded (8b)—along with (8a) and (8d)—from representing $R_d$ in equilibrium, we are left only with one interesting sub-game perfect equilibrium, obtained using (5b) and (8c), the reaction functions of the foreign and the domestic firm respectively:

$$q_d^{**} = \frac{1}{5}\left(a + P^T + 2\overline{e}_d\right), \quad q_f^{**} = \frac{1}{5}\left(2a - 3P^T - \overline{e}_d\right), \tag{9}$$

$\forall P^T < a/5$, and $\forall \overline{e}_d \in \left(\overline{e}_{d\min}, \overline{e}_{d\max}\right]$, as illustrated by point $E'$ on Figure 2b.[17]

Contrary to the zero transaction cost case, increasing the number of granted permits shifts the equilibrium to the right, along the foreign firm's reaction function. Thus, the presence of variable transaction cost transforms grandfathered permits, from pure transfers, to subsidy-like stimulants. At the first stage, the government decides the number of permits to grandfather considering the marginal benefits and costs from an extra permit grandfathered. Since we have adopted a partial equilibrium approach, the marginal cost from granting an extra permit to the domestic firm is zero; therefore, the government will grant $\overline{e}_d = \overline{e}_{d\max}(t)$. Note that apart from the technical upper bound placed on $\overline{e}_{d\max}(t)$ (for $t = P^T$) there is also a regulatory bound that we should place;

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[15] Granting excessive amounts of permits is analogous to the fallacy of using excess capacity in order to deter entry.

[16] If the government $\forall q_d$ grants only $\overline{e}_d \equiv q_d - P^T$, some free permits may be substituted to cheap abatement.

[17] For $\left(q_d^{**}, q_f^{**}\right)$ to represent the equilibrium pair of $\left(q_d, q_f\right)$, it must also be that $q_d^{**} < q_d^{Stack}$ (where $q_d^{Stack}$ is the equilibrium output of the Stackelberg game with $MC_d$ represented by (7c) and $MC_f$ by (4b)), otherwise the domestic firm may use less than its full endowment in permits. It can be easily shown that $\forall \overline{e}_d$, $q_d^{Stack} = \left(a + P^T + 2\overline{e}_d\right)/4 > q_d^{**}$, hence $\left(q_d^{**}, q_f^{**}\right)$ is indeed the equilibrium output pair.

namely $\overline{e}_d \leq \overline{e}_{dreg} \equiv a/3$, corresponding to the amount of permits required to produce the unregulated output without engaging in abatement**:** no government would grandfather more permits than those required to produce the unregulated output of a firm. The value of $t$ determines which of the two bounds is stricter: $\forall t < P^T/2 \Rightarrow \overline{e}_{d\max} < \overline{e}_{dreg}$.

Since the number of permits to be grandfathered in all sectors is limited, in a general equilibrium setting, the cost of granting an extra permit to the firm operating in a given sector corresponds to the forgone benefit from granting that permit to a firm in another sector. Without analyzing the issue, let us only sketch the factors that determine the marginal strategic benefits from offering an additional permit to a given sector. First, the number of permits already offered: even if (9) shows market shares to be linearly affected by $\overline{e}_d$, revenues are not linear on $\overline{e}_d$; second, the size of the international market; third, the intensity of competition;[18] and fourth, the percentage of domestic firms in the total number of firms in the international market.

Finally it should be pointed out that, while similar in their effects, grandfathered permits and subsidies have some important differences. Subsidies allow discretion over the magnitude of the marginal cost's reduction, this reduction applying universally on all exported units. The doted curve in Fig. 2a illustrates the effect of a subsidy. Grandfathering permits allows discretion over the number of units the marginal cost reduction applies to, but the magnitude of the reduction is exogenously determined by $t$: as discussed above, grandfathered permits are effective only in the region $(\overline{e}_{d\min}, \overline{e}_{d\max}]$. Hence, while any output combination on the foreign firm's reaction function can be reached through the appropriate subsidy, grandfathered permits can at most move the equilibrium to point $E''$, where $q_d = \left(a - P^T + 2t\right)/3 \equiv q_{d\max}(t)$. Compared to subsidies, grandfathered permits are a much less powerful, but in the same time more discrete, policy instrument. Analytically, grandfathering permits is closer to what is known in the Industrial

[18] With symmetric firms, this can be expressed by the total number of firms operating in that market. This is a distinct factor from the previous one since, as is well known, multiplying both the market size and the number of firms by the same number, is not neutral: while market shares remain the same, the intensity of competition increases.

Organization literature as “capacity constraints” (see Tirole 1988) than to direct subsidies.

The inability of grandfathering to push the equilibrium beyond point $E''$ may be an advantage, if one considers that government policy is often conducted under imperfect information about crucial variables. Whether direct subsidization or grandfathering, the crucial information requirements for the government are a) the domestic (and foreign) firm’s marginal cost function, and b) the output demand. Insufficient knowledge of either one impairs the government’s capacity to correctly locate the reaction functions on Fig 2. This might result in either a too timid (grandfathering too few permits or giving a too small subsidy), or a too aggressive policy, relative to what it is required for maximizing the domestic firm’s profit. Too few permits or too small a subsidy may prevent the domestic industry from reaping the entire amount of potential benefits. While in some cases too few permits may be totally ineffective, the subsidy, however small, will have an effect. Since typically firms overstate their costs in order to get a more favorable treatment, the case of a policy that is too timid is not so important. On the other hand, a too aggressive policy may lead to excessive aggressiveness in the output market. By deleting part of the firm’s marginal cost, a subsidy may induce decisions similar to those induced under revenue maximization: too much output sold at a too low price.[19] Erring on the side of grandfathering too many permits can hardly have an effect. If the domestic firm’s profit is maximized at point E″ (see Fig 2b), any amount of grandfathered permits in excess of what it is required to reach that point will be sold in the permits market. Only if the Stackelberg equilibrium lies between $E'$ and $E''$, granting an excessive amount of permits could lead the firm to produce larger than the profit maximization output, and even then, the output associated to $E''$ represents an upper bound. What makes grandfathering a safer instrument against a “policy overdose” is that permits are tradable while subsidies not.

### 3.3 The case of fixed transactions costs

[19] It has been often argued that when management is separated from ownership, the manager’s objective is to maximize sales-revenue. Unless the owners impose some constraints on the manager’s behaviour, the latter behaves very aggressively, choosing a larger than the profit-maximizing level of output. While in Cournot competition this distortion produces some beneficial strategic effects that may enhance profits at the expense of the rival, a too aggressive behaviour reduces profits.

Let us now assume that entry into the permit market requires a fixed cost $T > 0$ but zero variable cost $t = 0$. Firms must decide whether to pay $T$ and participate in the market, or avoid this payment and rely upon their abatement technology and the grandfathered permits they receive in order to comply with the regulation. As in the previous Section, we assume that the foreign firm does not receive free permits. The situation is still depicted by the three-stage game presented in Section 2.

Four situations can potentially represent the equilibrium in the above game according to whether none, one, or both firms enter the permit market. Assuming, as in the previous Section, $a > 5P^T$, guarantees that $\nexists \overline{e}_d$ such that in the third-stage equilibrium the foreign firm produces so little output as to comply only through abatement. In order to further simplify the discussion, we assume that the foreign firm always enters the permits market and purchases the permits it needs.[20] Hence, the simplified game is as follows: the foreign firm pays $T$ from the outset; at the first stage the domestic government decides the number of permits it grandfathers; at the second stage the domestic firm decides whether to pay $T$ or stay out of the permit market; at the third stage both firms compete in quantities. At each stage, all previous actions are perfectly observable.

***Third stage: choice of output and abatement***

Two cases may potentially represent the third-stage equilibrium of the simplified game. In the first, the domestic firm participates in the permit market, therefore any granted permits bear their full opportunity cost, and all the strategic effects described in the previous section are non-existent (since $t = 0$). Since in this case, both firms participate in the permit market, their marginal cost is given by equation (4b) and is illustrated in Figure 1a. Each firm's reaction function is given by equation (5b) and the resulting symmetric Cournot equilibrium output is given by equation (6). The domestic firm's third-stage equilibrium profits in the market-participation case are,

$$\pi_d^P = \frac{1}{9}\left(a - P^T\right)^2 + \frac{1}{2}\left(P^T\right)^2 + P^T\overline{e}_d - T. \tag{10}$$

In the second case the domestic firm stays out of the permit market; thus, the opportunity cost of its grandfathered permits becomes zero. A firm will first use its

[20] We ignore potential strategic effects from grandfathering on the foreign firm's decision to enter the permits market. Implicitly, we assume that the price of permits represents a relatively small fraction of the total output price; in reality this is a rather reasonable assumption.

entire permits endowment $\overline{e}_d$, and then will abate. Its marginal cost function, illustrated in Figure 3, is kinked at $\overline{q}_d$, the output level corresponding to $\overline{e}_d$.

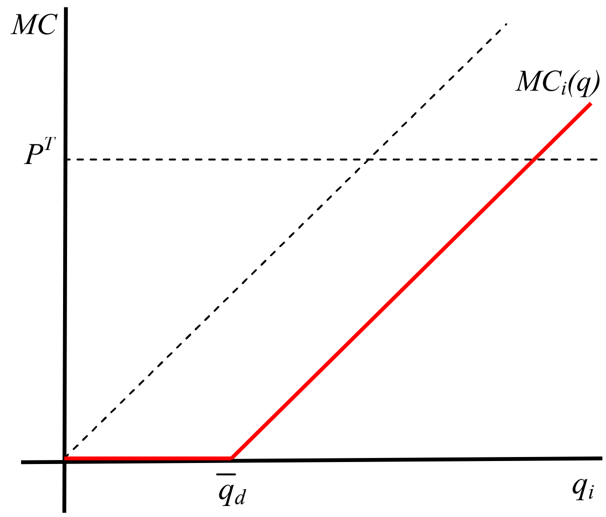


**Figure 3. Marginal cost of compliance when firms do not enter the market**

Figure 3 is similar to Figure 1b, except that now, due to the exclusion of the domestic firm from the permit market, the opportunity cost of the domestic firm's permits is zero. The reaction function of the domestic firm is given by equation (8c) while that of the foreign firm by equation (5b). The asymmetric Cournot equilibrium output in this case is given in equation (9). The domestic firm's third-stage equilibrium profits in the non-participation case are,

$$\pi_d^{NP} = \frac{1}{50}\left[3a^2 + 3\left(P^T\right)^2 - 13\overline{e}_d^2 + 6aP^T + 12a\overline{e}_d + 12P^T\overline{e}_d\right]. \qquad (11)$$

***Second stage: choice of regime (To be or not to be in the permit market?)***

At the second stage of the game the domestic firm must decide whether to pay the fixed cost and enter the permit market by comparing its profits in the two cases. Using equations (10) and (11) we solve $\pi_d^{NP} - \pi_d^P \equiv 0$ to define a critical value of $T$, described by the following *equal-profit* curve:

$$\overline{T} = \frac{1}{450}\left(23\,a^2 + 117\,\overline{e}_d^2 + 248\,\left(P^T\right)^2 - 108\,a\,\overline{e}_d - 154\,a\,P^T + 342\,\overline{e}_d\,P^T\right), \quad (12)$$

such that $\forall T > (<)\overline{T}$, $\pi_d^{NP} > (<)\pi_d^P$ and the domestic firm does not (does) enter the permits market. The value of $\overline{T}$ is quadratic convex in $\overline{e}_d$, with roots $e_{d1} = \frac{1}{3}\left(a - 4P^T\right) < e_{d2} = \frac{1}{39}(23\,a\ -\ 62\,P^T)$. For $T \to 0$, if $\overline{e}_d < e_{d1}$ the domestic firm enters the market as buyer, while if $\overline{e}_d > e_{d2}$ as a seller of permits. For allocations $\overline{e}_d \in \left(e_{d1}, e_{d2}\right)$ the domestic firm stays out of the permit market.

Note that $d\overline{T}/da = \frac{1}{450}\left(46a - 108\overline{e}_d - 154P^T\right)$ is decreasing in $\overline{e}_d$; hence, $\forall \overline{e}_d < e_{d1}$, $d\overline{T}/da > d\overline{T}/da\big|_{e_{d1}} > 0$.[21] Let $\overline{T}_0 \equiv \overline{T}\big|_{\overline{e}_d=0}\left(a, P^T\right) = \frac{1}{450}\left(a - 4P^T\right)\left(23a - 62P^T\right) > 0.$ Since $d\overline{T}_0/da > 0$, and $\overline{T}_0 = 0$ for some positive values of *a*, then $\forall T > 0$, $\exists \tilde{a} > 0$ such that $\overline{T}_0\left(\tilde{a}\right) = T$, and $\forall a \leq (\geq)\tilde{a}$, $\overline{T}_0(a) \leq (\geq) T$. Firms operating in markets with $a \leq \tilde{a}$ will never decide to enter the permit market as net buyers, no matter how many free permits they receive; we define such firms as "small" firms.[22] Firms for which $\overline{T}_0(a) > T$ will enter the permit market if they receive no grandfathered permits and are defined as "large" firms.

Figure 4 depicts two $\overline{T}\left(\overline{e}_d; a\right)$ curves in the $\left(\overline{e}_d, T\right)$ space, each corresponding to a different value of $a$, with $a_1 > a_2$. Assuming that the actual fixed transaction cost in the permit market is $\hat{T}$, such that $\overline{T}_0\left(a_1\right) > \hat{T} > \overline{T}_0\left(a_2\right)$, the solid (dashed) curve corresponds to a large (small) firm. It is clear that a small firm will stay out of the market regardless of the endowment of permits it receives, since $\hat{T}$ always exceeds the dashed equal-profit curve.[23] The equal-profit curve of the large firm intersects the actual fixed cost line $\hat{T}$ at $e_{d3}$ and $e_{d4}$. For initial allocations of permits within the region $\overline{e}_d \in \left[0, e_{d3}\right]$ in which $\hat{T} < \overline{T}$, the large firm enters the market as a permit buyer ($\pi_d^P > \pi_d^{NP}$). If it receives permits $\overline{e}_d \in (e_{d3}, e_{d4}]$ it stays out of the market, while if the

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[21] In fact, it can be shown that an increase in $a$ shifts the entire $\overline{T}\left(\overline{e}_d; a\right)$ curve to the right.

[22] A firm can be "small" because it operates either in a small market, or in a market where many more firms are present. Since we have limited, for simplicity, the number of firms to two, the terms "small firm" and "small market" coincide. If more firms operate in the market, the entire $\overline{T}$ curve shifts down—together with each firm's residual demand—thus, for any given value of *a*, $\tilde{a}$ is increased.

[23] A small firm will enter the market as a seller if it receives a large amount of permits (after the intersection of the dashed curve with the $\hat{T}$ line), a case we have already ruled out as not realistic.

initial endowment of permits exceeds $e_{d4}$ it will enter the market as a seller of permits.

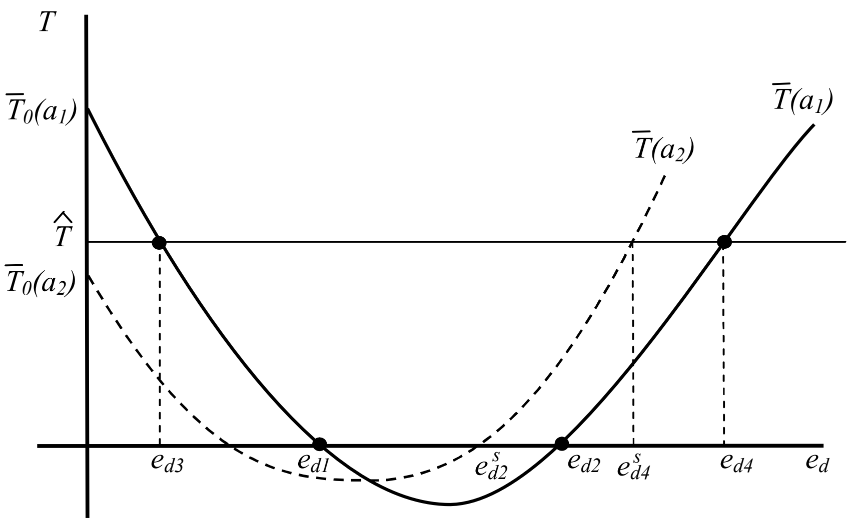


**Figure 4. Equal-profit curves defining market participation**

***First stage: strategic allocation of permits***

The above discussion shows that when grandfathering permits to a small firm, the analysis in Section 3.2 applies with a vengeance: not only a part, but the *entire value* of a grandfathered permit has a subsidy-like effect.[24] The government can shift the domestic firm's reaction function outwards in a manner similar to that described in Figure 2b. Although $q_d^{**}$, given in (9), is linearly increasing in $\overline{e}_d$, the domestic government cannot increase its firm's output beyond $q_{d\max}(t)$ as defined in Section 3.2. When a firm does not pay $T$ and stays out of the market, $t=P^T$ and it can be easily show $q_{d\max}(t=P^T)=\frac{1}{3}\left(a+P^T\right)=\overline{e}_{d\max}(t=P^T)$. However, since grandfathered permits cannot exceed the amount required to produce the unregulated output, that is, $\overline{e}_d \le \overline{e}_{dreg}$, the maximum output that can be reached through strategic grandfathering is $q_{dreg}=q_d^{**}\left(\overline{e}_{dreg}\right)=\frac{1}{3}a+\frac{1}{5}P^T$. The domestic firm has a strategic advantage over its rival that purchases permits.

[24] The result of $T$ on small firm's behaviour is exactly the same as $t=P^T$, i.e. the variable selling transaction cost is equal to the entire permit price.

Figure 5 illustrates the above discussion. When the domestic firm receives zero free permits, it produces $q_d^{**}(\overline{e}_d = 0) = \frac{1}{5}(a + P^T)$, complying with the regulation using only abatement. As its allotment of grandfathered permits increases, its output increases linearly along the $q_d^{**}(\overline{e}_d)$ line. For $\overline{e}_{dreg}$ it still uses partly abatement to cover its regulatory requirements, while at $\overline{e}_{d\max}$ it covers all its regulatory requirements with permits. Even if the domestic government granted more than $\overline{e}_{d\max}$ permits, these permits would remain unused, since selling them requires the payment of *T*, which cannot be recovered from the permits' revenue for volumes lower than $\overline{e}_{d4}^s$, the intersection of line $\hat{T}$ with the $\overline{T}(a_2)$ curve in Figure 4.[25] Similarly to the case of positive variable transaction costs, permits differ from direct subsidies in that they cannot push the equilibrium to any point along the rival's reaction function. There is a maximum amount of grandfathered permits $\overline{e}_{d\max}$ that can shift the equilibrium to a point similar to point $E''$ in Figure 2b, and any permits in excess of $\overline{e}_{d\max}$ will remain unused.

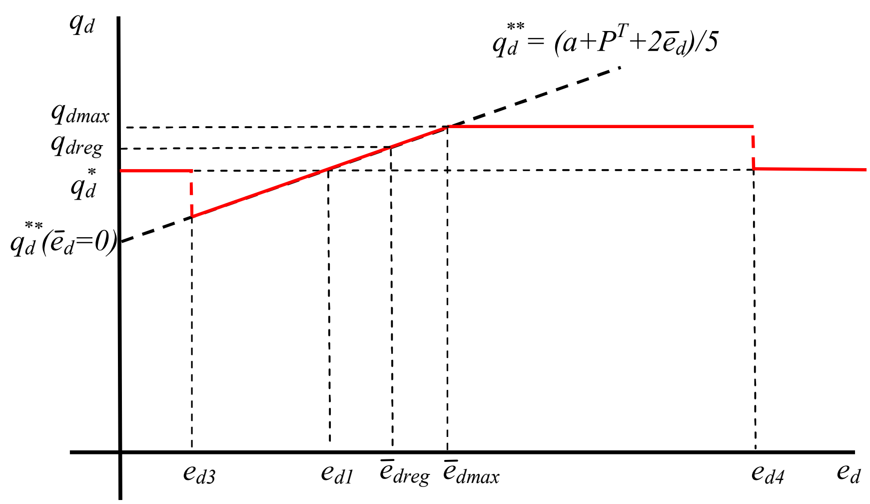


**Figure 5. Strategic effects of permits grandfathering**

In the case of a large firm (corresponding to $\overline{T}(a_1)$ on Figure 4), if the government grandfathers permits in the region $\overline{e}_d \in [0, e_{d3}]$, the domestic firm participates in the

[25] Note that $a > 7{,}5P^T \Rightarrow \overline{e}_{d\max} < \overline{e}_{d2}^s < \overline{e}_{d4}^s$ which implies that the permit allotment required for entering the market as a permit seller is unrealistic.

market and produces $q_d^*$ given by equation (6). If the domestic firm receives $\overline{e}_d \in (e_{d3}, e_{d1})$, then it decides not to enter the market and reduces its output. That is, $\forall \varepsilon > 0$, an initial permit allocation $e_{d3} + \varepsilon$ results in domestic firm's entry into the market, reducing its production from $q_d^*$ to $q_d^{**}(e_{d3})$. For higher amounts of grandfathered permits, domestic firm's output increases linearly, similarly to the case of small firm described above. The solid line segments in Figure 5 depict the relationship between output and grandfathered permits for a large firm.

From the above discussion it is clear that permit grandfathering can be used strategically in the presence of fixed transaction costs in the permit market. In the case of a small firm which does not find it profitable to enter the permit market, the government can improve its position by grandfathering permits up to the $\min\{\overline{e}_{d\max}, \overline{e}_{dreg}\}$. In the case of a large firm the effect of permits grandfathering is not linear. For small amounts of grandfathered permits, the firm does not exit the market as a permit buyer and grandfathered permits do not have any strategic effect (assuming zero variable transaction costs). Larger amounts of permits could have initially a detrimental effect on domestic firm's output; however, increased allocations eventually lead to higher output. Therefore, the regulator must be very careful, since grandfathering the wrong number of permits may adversely affect large firm's output by inducing a change in its decision to participate in the permit market (*regime-switching effect*)

### 3.3 Both countries adopt grandfathering

The above analysis was carried out assuming that the foreign country auctions permits in the sector under consideration. However, if both countries adopt grandfathering, each government aims to maximize its firm's share in the international market. In such case, the only change in the three-stage game described above is that at the first stage both governments decide simultaneously how many permits to distribute to their respective firm $(\overline{e}_d, \overline{e}_f)$, where $\overline{e}_f$ denotes the amount of permits the foreign country grandfathers to its producer.

Assume for simplicity that there is no abatement, and let each government commit to grandfathering its firm all the necessary amount of permits for the output it decides to produce, *i.e.*, $\forall q_i$, $\bar{e}_i \equiv q_i$, $i = d, f$. In that case, $R_d = GG'$ (given by (8b)), and $R_f$ (not drawn) is symmetric to $GG'$ around the $45^0$ line. Symmetric costs imply symmetric equilibrium depicted by point $E^t \equiv \left(q_d^t, q_f^t\right)$, at the intersection of $GG'$ with the $45^0$ line, where $MC_d = MC_f = P^T - t$, and $q_d^t = q_f^t = \frac{1}{3}\left(a - P^T - t\right)$. In order to show that this is indeed the first-stage equilibrium we must show that no government has incentive to deviate from the grandfather-permits-equal-to-output policy. Assume the domestic government considers deviating. If it offers $\bar{e}_d > q_d^t$ it will waste permits, as explained in Section 3.2. If it offers $\bar{e}_d < q_d^t$, point *B* will be to the left of $E^t$, and the equilibrium will occur at some point $\widetilde{E}$ on the *BC* segment of the domestic firm's reaction function. Since $\widetilde{E}$ will necessarily be above the $45^0$ line, the domestic government has no incentive to grant $\bar{e}_d < q_d^t$ permits to its firm. Hence, in the Nash equilibrium, each government grants exactly $\bar{e}_i = q_i^t$, and each firm's equilibrium output corresponds to that of point $E^t$. Total output at $E^t$ is obviously larger than total output at $E$, where no government grandfathers permits, and since total output at $E$ is already larger than the monopoly output, mutual grandfathering lowers profits. Permits grandfathering, like the use of other trade stimulants, traps governments in a prisoner's dilemma situation. If transaction costs are fixed, point $E^t$ is situated as far as possible on the $45^0$ line, therefore the damage to profits from mutual grandfathering is the largest possible, for any given price of permits.

## 4. Summary and Conclusions

This paper shows that the presence of transaction cost, fixed and/or variable, in the permit market, affects firms' output decisions and allows governments to use permit grandfathering as a tool for strategic trade policy. We show first, that fixed transaction costs influence firms' decision to participate in the permits market. In accordance with empirical evidence, we find that smaller firms are more likely to stay out of the permit market. In such cases, grandfathered permits, by reducing firms' required abatement, decrease their marginal cost and induce them to become more aggressive in the output market. Second, we show that variable transactions costs reduce the opportunity cost of using an already acquired permit. This reduces marginal cost, inducing the holder of any excessive permits to a more aggressive behavior. Based on the above results, we provide theoretical support to the layman's presumption that grandfathering of emission permits *can* be used as a strategic trade instrument, *even when firms are characterized by price taking behavior in the market of permits.* Although it appears that both permits and subsidies may be used strategically to increase the domestic firm's output, there still exist a difference between the two. Unless there are quotas restricting the number of units to be subsidized, the subsidy applies to all units and the government's decision concerns the subsidization rate. In the case of grandfathered permits, on the contrary, the amount of subsidy per unit of output is exogenous, determined by the permit price and transactions costs. What the government may affect in this case is *the number of subsidized units.*

While a single country adopting free distribution of its permits helps its firms to gain market share in the international market over rival firms from countries where permits are auctioned, multilateral adoption of grandfathering leads all firms to lower profits. This offers support to the coordination in the design of the initial distribution of permits among countries participating in an international agreement and furthermore to the auctioning of permits.

The choice of a simple modeling framework allowed us to examine all possible sub-cases and support our results with analytical solutions. Since the description of the permit market is very simple, our results carry over in a general Cournot setting. However, it is clear that the aforementioned effects depend on market characteristics such as size and concentration, as well as on the total market share of the domestic firms in the international markets. Further research, using a more realistic framework, could provide a better understanding on the effectiveness of using permit grandfathering as an instrument for strategic trade policy and the sectors more likely to be influence by such policy.

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## Appendix

In Figure 2b, the two segments *OA* and *BC* correspond to the situation in which the domestic firm engages in abatement and their slope equals 3. The segments *AB* and *CF* correspond to the case that firm uses its permits' endowment and to the case it purchases permits from the market respectively, and their slope equals 2. Notice that the foreign firm's marginal cost and reaction functions remain the same as in the case of zero transaction costs. The slope of the foreign firm's reaction function is either $1/3$ or $1/2$. This implies that any segment of the domestic firm's reaction function is steeper than any segment of the foreign firm's reaction function which, in turn, implies that there are no multiple intersections, and therefore there exist no multiple equilibria.

The Cournot equilibrium quantities of this game crucially depend of two parameters: the transactions cost per unit of permits, $t$, and the number of permits granted to the domestic firm, $\overline{e}_d$. We assume $t > 0$, $S \equiv a - 4P^T > 0$, and distinguish between two cases, **a** and **b**, according to whether transaction costs are high or low, *i.e.,* $t > (<) S$.

In case **a**, transaction costs are so important, that in almost all regions the foreign firm produces so little output that it stays out of the permits market ($R_f$ corresponds to (5a)). In case **b**, transaction costs are milder, therefore even when output is asymmetric, the foreign firm purchases permits.

Within each case we distinguish three regions, denoted with upper-case roman numbers. In region **I**, common to both cases **a** and **b**, $\overline{e}_d < \overline{e}_{d\min}$: permits are so few that they do not have any impact on the equilibrium outcome; $R_d$ and $R_f$, are given by (8b) and (5b) respectively. In region **III** we have $\overline{e}_d > \overline{e}_{d\max}$ and for this reason the equilibrium depends on *t* but not on $\overline{e}_d$: the domestic firm already possesses more free permits that it wishes to use, therefore any additional permit will not affect output, which has already reached its maximum value for given $(P^T, t)$. Within each case, Region **II** is the interesting one in terms of producing strategic effects: the domestic firm's output increases monotonically with the number of permits it receives, while that of its rival decreases: granting permits increases the domestic firm's market share of and profit from the international market. In the text we describe case **b** and equation (9) corresponds to the equilibrium in Region **IIb**. In details, the Cournot equilibrium $\left(q_d^C, q_f^C\right)$ is:

$\forall t > 0$,

**Region I:** when $\overline{e_d} < \frac{1}{3}S$,

$$q_d^C = q_f^C = \frac{1}{3}\left(a - P^T\right) \tag{A.1}$$

$\forall t \geq S$:

**Region IIa-i:** when $\frac{1}{3}S < \overline{e}_d < \frac{1}{3}\left(S + 4t\right)$,

$$\begin{cases} q_d^C = \frac{1}{5}\left(a + P^T + 2\overline{e}_d\right) \\ q_f^C = \frac{1}{5}\left(2a - 3P^T - \overline{e}_d\right) \end{cases} \tag{A.2}$$

**Region IIa-ii:** when $\frac{1}{3}\left(S + 4t\right) < \overline{e}_d < \frac{2}{5}\left(S + 5t\right)$

$$\begin{cases} q_d^C = \frac{1}{8}\left(2a + 3\overline{e}_d\right) \\ q_f^C = \frac{1}{8}\left(2a - \overline{e}_d\right) \end{cases} \tag{A.3}$$

**Region IIIa:** when $\frac{2}{5}\left(S + 4t\right) < \overline{e}_d$

$$\begin{cases} q_d^C = \frac{1}{5}\left(2a - 3P^T + 3t\right) \\ q_f^C = \frac{1}{5}\left(a + P^T - t\right) \end{cases} \tag{A.4}$$

$\forall t \leq S$:

**Region IIb:** when $\frac{1}{3}S < \overline{e}_d < \frac{1}{3}\left(S + 5t\right)$

$$\begin{cases} q_d^C = \frac{1}{5}\left(a + P^T + 2\overline{e}_d\right) \\ q_f^C = \frac{1}{5}\left(2a - 3P^T - \overline{e}_d\right) \end{cases} \tag{A.5}$$

**Region IIIb:** when $\overline{e}_d > \frac{1}{3}\left(S + 5t\right)$

$$\begin{cases} q_d^C = \frac{1}{3}\left(a - P^T + 2t\right) \\ q_f^C = \frac{1}{3}\left(a - P^T - t\right) \end{cases} \tag{A.6}$$

The above constitutes the full solution of the Cournot game provided that $a > 4P^T$. Let us consider first the $t \leq S$ case. Condition $\frac{1}{3}S < \overline{e}_d < \frac{1}{3}\left(S + 5t\right)$ defines a minimum amount of permits, equal to $S/3$, below which permits granted to the domestic firm have no strategic value. The equilibrium solution in Region IIb (equations (A.5)) shows that within the specified limits, increases in grandfathered permits increase monotonically the output of the domestic firm and reduce monotonically the output of the rival firm. In Region IIIb equilibrium output (equations (A.6)) of neither firm is affected by increasing the number of grandfathered permits. The equilibrium represented by (A.6), however, is asymmetric, with the domestic firm producing more output than its rival. The difference in output ($3t$) is proportional to the level of transactions cost. In the case that $t \geq S$, the analysis remains essentially the same, except that Region II is now breaking in two parts, IIa-i and IIa-ii. While the functional form of equilibrium outcomes changes from one sub-region to the other, the qualitative result, namely that an increase in permits increases linearly domestic firm's output while reducing that of the foreign firm, remains. The marginal impact of this effect is reduced in Region IIa-ii relative to Region IIa-i. In terms of Figure 2b this implies that when $t \geq S$ the equilibrium may fall on the *BC* segment of $R_d$.