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## Working Paper

# Does environmental regulation create merger incentives?

Anna Creti<sup>1</sup>, Maria Eugenia Sanin<sup>2</sup>.

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**Contacts:** [anna.creti@dauphine.fr](mailto:anna.creti@dauphine.fr) et [eugenia.sanin@univ-evry.fr](mailto:eugenia.sanin@univ-evry.fr)

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<sup>1</sup> Université Paris Dauphine, PSL Research University, LEDA CGEMP, 75016 Paris, France.

<sup>2</sup> EPEE (EA 2177), Université d'Evry-Val-d'Essonne and Département d'Economie, Ecole Polytechnique, France.

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# Does environmental regulation create merger incentives?

Anna CRETI\* and María-Eugenia SANIN†

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## Abstract

This paper studies merger incentives for polluting Cournot firms under a competitive tradable emission permits market. We find that when firms are symmetric and marginal costs are constant, an horizontal merger is welfare enhancing if efficiency gains are high enough for the merger to take place. The presence of a competitive (or monopolistic) outside market that also trades in the permits market makes profitable a merger that would not happen otherwise. When firms are vertically related in an input-output chain, an horizontal merger in one of the markets increases profits in the other market due to the permits price decrease. Finally we consider an oligopoly-fringe model in which firms differ in their marginal production costs. A merger between the dominant oligopolistic firms decreases the permits price and is always profitable. Such setting is relevant to assess the observed mergers between power generators in several market for permits, like the Regional Greenhouse Gas Initiative (RGGI), allowing us to derive some policy recommendations.

*JEL Classifications:* L13, L41, Q51

*Key words:* mergers, environmental externality, tradable emission permits, social welfare, Cournot competition.

## 1 Introduction

Many papers have analyzed the welfare consequences of horizontal mergers in the presence of imperfect competition (see Motta, 2004 for a complete mapping of the literature). How mergers incentives and welfare properties are modified in the presence of an environmental externality, regulated by tradable emission permits, is a less explored issue to which we contribute. The paper closest to our analysis is Hennessy and Roosen (1999), who show that in a perfectly competitive industry, incentives coming from the permits market may motivate a merger that wouldn't take place otherwise. The last section of Hennessy and Roosen's paper briefly mentions how the previous result could be modified under Cournot competition in the output market, suggesting that it is ambiguous. We study in depth which are the mechanisms behind that ambiguity and its welfare implications. With this purpose, we consider symmetric firms that compete à la Cournot in a polluting industry subject to an environmental regulation based on a perfectly competitive market for permits.

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\*Université Paris Dauphine, PSL Research University, LEDA CGEMP, 75016 Paris, France. E-mail: anna.creti@dauphine.fr

†EPEE (EA 2177), Université d'Evry-Val-d'Essonne and Département d'Economie, Ecole Polytechnique, France. E-mail: eugenia.sanin@univ-evry.fr

Our main findings are that in a symmetric Cournot a horizontal merger: (i) with constant marginal costs, is welfare neutral since the decrease in the regulator’s revenue due to the resulting decrease in permits price is earned by firms; (ii) if it generates efficiency gains for the merged firms, it is welfare enhancing but efficiency gains must be high enough for the merger to take place;<sup>1</sup> (iii) there are some conditions under which a merger becomes profitable in the presence of a perfectly competitive (or monopolistic) outside output market that also trades pollution permits. This last result is particularly relevant to understand how the occurrence of mergers in some sectors may be affected by tradable allowances.

Some papers are worth mentioning to put the previous results in perspective. In line with our first result, Ehrhart *et al.* (2008) show that loopholes of the EU-ETS law fosters tacit collusion in oligopolistic Cournot markets. Canton *et al.* (2012) model mergers that generate cost reductions and consequently an increase in production which is welfare enhancing even if it increases pollution. Similarly Lambertini and Tampieri (2014) model cost reducing mergers and find that the negative effect of a merger on consumer surplus is more than offset by both the raise in industry profits and the fall in pollution. The fact that we consider a market for permits in which the pollution level is fixed by the cap explains the difference between their results and ours. Additionally, Canton *et al.* (2012) find that the stringency of environmental policy increases the minimal size for merger profitability. Such dependence is in fact in line with our second result on efficiency gains.

Regarding the input-output structure where both the input and the output market are subject to the cap-and-trade regulation, we find that a horizontal merger in one of the markets increases profits in that market and in the vertically related one due to the decrease in the permits price resulting from the merger. This input-output structure is particularly relevant to understand merger incentives in the power sector. Finally we consider an oligopoly-fringe model in which firms differ in their marginal costs of production. We find that a merger between the oligopolistic firms decreases permits price and is always profitable as opposed to the symmetric Cournot case in which there is a critical size for profitability as mentioned before.

Our model is a good representation to understand mergers occurred in the power sector who’s CO<sub>2</sub> emissions are regulated in the U.S. Several mergers in the power industry have occurred in the RGGI region since then. In the Dealbook of the New York Times<sup>2</sup> an article of June 16th, 2011 cites Todd A. Shipman, a credit analyst of utilities and infrastructure ratings at Standard & Poor’s, saying that the number of publicly traded energy companies is dramatically shrinking, being the environmental regulation one of the reasons behind that trend. In particular he says: “*Utilities — facing pending regulation on greenhouse gas emissions and renewed enforcement of older rules on air pollution — must reckon with the rising costs of compliance. The added expense come just as growth in electricity demand is being cramped by efficiency gains.*” This phenomenon could also be present in markets for Green and White certificates where few players from related sectors participate and eventually even in the European system for tradable permits (EU-ETS) where several big mergers have occurred in the power sector. These stylized facts and experts’ opinion advocate for the relevance of our analysis.

The paper is organized as follows. In Section 2 we present our benchmark model where

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<sup>1</sup>The impact is similar to the impact that “synergies” have in Farrel and Shapiro (2001).

<sup>2</sup>See New York Time’s Dealbook 16/06/2011.

we account for the impact of a horizontal merger. We develop first the case of symmetric firms with constant marginal costs before and after the merger, and second the case where the merger generates efficiency gains. In Section 3 we analyze the profitability of a horizontal merger in the case where several sectors are subject to the market for permits. In particular, in Subsection 3.1 we consider the case where two different sectors belong to the same permit market and, in Subsection 3.2, the case in which the two sectors subjects to environmental regulation are vertically related (either downstream or upstream). In Section 4 we relax the assumption of symmetric firms before the merger by analyzing a case with an oligopolistic dominant group of firms and a competitive fringe. Finally, in Section 5 we analyze the extent to which our results could be applied to understand merger incentives in the power sector under the RGGI market and eventually in the EU-ETS market. In Section 6 we conclude and derive some policy implications.

## 2 The importance of efficiency gains

Consider a market for a product where the inverse demand function for a quantity  $Q \geq 0$  is given by  $P(Q)$ . Assume that  $P'(Q) < 0$ ,  $P''(\cdot) \leq 0$  or  $P''(\cdot) \geq 0$  not too large for all  $Q$ .  $N$  symmetric firms compete à la Cournot in this market. The production technology exhibits constant returns to scale and  $c$  denotes the marginal cost of production.

Production generates pollution: for each unit of the good  $\alpha > 0$  units of a pollutant are emitted. Pollution is socially costly and firms are required to buy as many pollution permits as their individual emissions. Assume also that the total number of pollution permits  $E > 0$  supplied by the authority, is fixed. Our main assumptions relate to the functioning of tradable pollution permits.

**Assumption 1.** *The market for pollution permits is perfectly competitive.*

Assumption 1 implies that firms have no market power on the permits market. Therefore, the equilibrium price for permits  $\sigma$  is such that the total demand for permits,  $\alpha Q$ , equals the total supply of permits,  $E$ .

$$\alpha Q = E. \tag{1}$$

The previous assumption can be justified by the fact that the environmental regulation covers many states in the case of the RGGI and also many sectors in the case of the EU-ETS. This assumption is quite usual in environmental literature (see for example the seminal paper of Sartzetakis, 1997 and Sartzetakis, 2004).

We focus on the interesting case in which the environmental regulation effectively constrains firms' decisions, *i.e.*,  $\sigma > 0$ . A sufficient condition for this to be the case is that the total supply of permits is smaller than the total pollution that would be generated by a hypothetical monopolist:

**Assumption 2.** *Define  $Q^m = \arg \max_Q [P(Q) - c] Q$ . The total supply of permits  $E$  is such that  $E \leq \alpha Q^m$ .*

This assumption ensures that the price of permits  $\sigma$  is positive after a merger of any size.

We consider a game in which firms choose their production levels of the final good and the market for permits clears simultaneously.

**A horizontal merger.** Let us derive the conditions under which a merger is profitable, from a private and a social point of view.

In the absence of merger, firm  $i$  solves the following problem:

$$\max_{q_i \geq 0} [P(Q) - c - \alpha\sigma] q_i, \quad (2)$$

where  $Q = \sum_{i=1}^N q_i$ . Indeed, for each unit of the final good produced, firm  $i$  emits  $\alpha q_i$  units of pollution that must be covered with permits. Consider an interior solution of the previous optimization problem in which firm  $i$ 's quantity is characterized by the corresponding first-order condition:

$$P'(Q)q_i + P(Q) - c - \alpha\sigma = 0. \quad (3)$$

Equation (3) is sufficient provided that the demand is concave or not too convex, which holds under our assumptions.

An equilibrium of the game is a production profile  $\{q_i\}_{i=1,\dots,N}$  and a permits price  $\sigma$  such that, for each firm  $i = 1, \dots, N$ , Equation (3) is satisfied and the permits market clears, *i.e.*:

The crucial feature implied by the market clearing condition (1) on the permits market is that the total quantity of good produced only depends on the exogenous supply of permits  $E$  and the pollution factor  $\alpha$ . Using Equations (3) and (1), the profit of each firm at the symmetric equilibrium is given by (see derivation in Appendix):

$$\pi_{\text{pre}}^* = -P' \left( \frac{E}{\alpha} \right) \frac{1}{N^2} \left( \frac{E}{\alpha} \right)^2. \quad (4)$$

Suppose now that  $M$  firms,  $N \geq M \geq 2$ , decide to merge. Such a merger reduces the number of firms from  $N$  to  $N - M + 1$ . The profit of each firm at the symmetric equilibrium is thus given by:

$$\pi_{\text{post}}^* = -P' \left( \frac{E}{\alpha} \right) \frac{1}{(N - M + 1)^2} \left( \frac{E}{\alpha} \right)^2. \quad (5)$$

Denote by  $\Delta\sigma \equiv \sigma^{\text{post}} - \sigma^{\text{pre}}$  the difference between the permits price before and after the merger. Using the first-order conditions in Equation (3), we obtain:

$$\Delta\sigma = P' \left( \frac{E}{\alpha} \right) \frac{E}{\alpha^2} \frac{M - 1}{N(N - M + 1)} < 0. \quad (6)$$

Simple computations show that the variation in the revenue of the regulator associated to the sale of permits exactly corresponds to the change in the industry's profit ( $\Delta\Pi \equiv \Pi^{\text{post}} - \Pi^{\text{pre}}$ ):

$$\Delta\Pi = -\Delta\sigma \times E > 0. \quad (7)$$

Our results from a welfare perspective can be summarized as follows.

**Proposition 1.** *In a symmetric Cournot case with constant marginal costs, any merger is welfare neutral and does not affect consumers surplus. The permits price decreases, which implies that the regulator's revenue from permits sales is redistributed to firms.*

*Proof.* See Appendix. □

Since the quantity produced is constant, a merger is welfare neutral. This would be the case even in the extreme case of full monopolization i.e.  $N = M$ .

For the merger to take place,  $M$  has to satisfy the following condition.

*Condition 1* In a symmetric Cournot case with constant marginal costs, a merger of  $M$  firms is profitable if and only if:

$$\frac{1}{(N - M + 1)^2} \geq \frac{M}{N^2}. \quad (8)$$

This condition holds for any demand function and is similar to the one derived by Salant *et al.* (1983) who looks at the profitability of a merger in a constant marginal cost and symmetric Cournot oligopoly with a linear demand function. A discussion on whether the previous condition is more or less restrictive than in the case where there is no market for permits is provided in the Appendix. In particular, we find that if demand is linear, the permits market relaxes the profitability condition of mergers.

**Efficiency gains.** Assume that the merger creates efficiency gains, that is, after the merger takes place the participants have a lower marginal production cost:  $c_m = c - \delta$ , with  $\delta \geq 0$  and where  $m$  stands for a firm participating in the merger. In the pre-merger game, individual profits are the ones in Equation (4). From profit maximization of the merged firm and of the symmetric non-merged firms we get, respectively, the following equilibrium values:

$$\begin{aligned} q_m^* &= \frac{1}{(N - M + 1)} \left( \frac{(N - M)(c_m - c)}{P'(Q)} + Q \right), \\ q_i^* &= \frac{1}{(N - M + 1)} \left( Q + \frac{(c_m - c)}{P'(Q)} \right). \end{aligned} \quad (9)$$

where  $i$  stands for the outside firms. Substituting the above equilibrium quantities inside the profit function we get profits for the merged firms and the individual  $N - M$  outsiders:

$$\begin{aligned} \pi_{m,\text{post}}^* &= \frac{1}{-P'(\frac{E}{\alpha})} \left( \frac{P'(\frac{E}{\alpha})\frac{E}{\alpha} + (N - M)\delta}{N - M + 1} \right)^2 \\ \pi_{i,\text{post}}^* &= \frac{1}{-P'(\frac{E}{\alpha})} \left( \frac{P'(\frac{E}{\alpha})\frac{E}{\alpha} - \delta}{N - M + 1} \right)^2. \end{aligned} \quad (10)$$

*Condition 2* In a constant marginal cost and symmetric Cournot model, a merger of  $M$  firms creating productive efficiency gains is profitable if and only if (see Proof in Appendix):  $\delta \geq \delta_m$ .

The previous condition implies that efficiency gains must be large enough to give firms incentives to merge.

It is worth noting that the merger is never profitable for the outsiders, *i.e.* it can be easily shown that  $\pi_i^{\text{post}} < \pi_i^{\text{pre}}$ .

From the FOCs we can calculate the change in permits price after the merger that after

simplification can be expressed as compared to the case without efficiency gains as:

$$\Delta\sigma^\delta = \Delta\sigma + \frac{(N-M)}{(N-M+1)} \frac{\delta}{\alpha}. \quad (11)$$

The second term may be stronger than the first one and the price of permits may *increase* after the merger. This is the case for a sufficiently high efficiency gain<sup>3</sup> *i.e.*

$$\delta_\sigma > \frac{-P'(\frac{E}{\alpha}) \frac{E}{\alpha} (M-1)}{N(N-M)} \quad (12)$$

This increase is due to the fact that, after the merger, the merged firms profiting from an efficiency gain have incentives to increase their production. Since total quantity produced is fixed by the supply of permits, this simply results in a higher demand for permits that, with a fixed supply, produces an increase in permits price.

The overall industry's profit increases after a merger for any  $\delta$ :

$$\Delta\Pi = -\Delta\sigma E - \delta \left( \frac{\delta}{P'(\frac{E}{\alpha})} + \frac{N}{\alpha} \right) \frac{(N-M)}{N(N-M+1)} \geq 0. \quad (13)$$

Consequently, since consumer surplus is unaffected due to the fact that total quantity at the industry level remains constant, the merger is welfare enhancing.<sup>4</sup>

The previous results can be summarized in the following proposition.

**Proposition 2.** *In a Cournot symmetric case, a merger is welfare enhancing if it generates production efficiency gains for the merged firms. The efficiency gain must be high enough for the merger to take place. The merger is never profitable to outsiders.*

*Proof.* See Appendix. □

The result is particularly relevant to analyze mergers in the power sector where part of the included firms are using low cost technologies that could also be less polluting.

So far we have assumed that only the firms that are present in the final market participate in the permits market. We relax this assumption in the following Section 3 and show that a merger in one market affects the allocation of production in all the markets that cover their emissions with permits.

## 3 When markets are linked by the permits market

### 3.1 The presence of an outside output market

Consider that on top of the product market considered so far, there is a demand for permits coming from another industry denoted by 'o' for 'outside', *i.e.*:  $\alpha_o Q_o(\sigma)$  where  $\alpha_o$  is the pollution factor of the outside industry and  $Q_o(\sigma)$  is its production when the permits price is  $\sigma$ , *i.e.*:  $\alpha Q(\sigma) + \alpha_o Q_o(\sigma) = E$ . The equilibrium on the permits market now is:

<sup>3</sup>Notice that  $\delta_\sigma < \delta_m$  for a low number of outsiders *i.e.*  $N - M + 1 < \frac{M-1}{N-\sqrt{M}}$ .

<sup>4</sup>Notice that if  $\delta = 0$  we are back in the case where  $\Delta\Pi = -\Delta\sigma^\delta E$  and the merger is welfare neutral.

A merger between  $M$  of the  $N$  firms is now profitable if and only if:

$$\frac{-P'(Q(\sigma_{\text{post}}))}{-P'(Q(\sigma_{\text{pre}}))} \frac{Q(\sigma_{\text{post}})^2}{Q(\sigma_{\text{pre}})^2} \frac{1}{(N - M + 1)^2} > M \frac{1}{N^2}. \quad (14)$$

We observe that this condition differs from the the *Condition 1* by a multiplicative positive factor  $\frac{-P'(Q(\sigma_{\text{post}}))}{-P'(Q(\sigma_{\text{pre}}))} \frac{Q(\sigma_{\text{post}})^2}{Q(\sigma_{\text{pre}})^2} > 0$  that can be higher or lower than 1, making the profitability condition more or less binding than in the case without the presence of an outside market.

Indeed, any merger now affects the total quantity produced by the industry in which the merger takes place: the permits price variation due to the merger produces a change in the demand for permits coming from the outside industry, which impacts the profitability of the proposed merger. As an example, suppose that the merger leads the merged firm to contract its output. The merger's competitors respond by expanding their production due to the strategic substitutability of quantities but, overall, the total quantity produced by the industry is likely to decrease, leading to a decrease in permits price. This decrease in permits price reinforces the profitability of the merger, although it also tends to give producers more incentives to expand their output, in particular to the outside industry.

Under our assumptions on  $P(\cdot)$ , we have  $-P'(Q)Q$  increasing in  $Q$ . Therefore, to understand whether a merger is more or less profitable with respect to the case with no outside industry, we must analyze (i) its impact on permits price and (ii) how the equilibrium production  $Q(\cdot)$  varies with the permits price. Regarding the second point, since  $Q(\sigma)$  and  $Q_o(\sigma)$  are linked through the market clearing condition, analyzing  $Q(\cdot)$  boils down to analyzing how the quantity of the outside industry varies with the permits price. Let us distinguish three distinct cases:

- *Perfectly competitive outside industry.* In that case, the price on the outside market is equal to the marginal cost, which includes the permits price. Therefore:  $Q'_o(\sigma) < 0$ .
- *Monopolistic outside industry.* In that case, a standard argument yields:  $Q'_o(\sigma) < 0$ .
- *Imperfectly competitive outside industry.* The analysis of this case is less immediate. Indeed, following Myles (1987), whether the (total or individual in the symmetric case) quantity decreases with an increase of the marginal cost of all the firms depends on the slope of the elasticity of the inverse demand function. Similarly, what happens in a non-competitive outside market could impact the permits price (Sanin and Zanaj, 2011).

For simplicity let us consider the linear case  $Q_o(\sigma) = C - D\sigma$ , i.e.  $Q'_o(\sigma) < 0$ , and linear demand in the output market  $P(Q) = a - bQ$ .

In such configuration the industry production varies with the permits price according to the following expression:

$$Q(\sigma) = \frac{E - \alpha_o C + \alpha_o \sigma D}{\alpha} \quad (15)$$

which implies  $Q'(\sigma) = \frac{\alpha_o D}{\alpha} > 0$ .

We can then derive the following proposition.

**Proposition 3.** *Assume that  $Q'_o(\sigma) \leq 0$  for all  $\sigma \geq 0$  and that, for simplicity,  $Q_o(\sigma) = C - D\sigma$ . A merger leads to a lower permits price if the pollution intensity of the outside*

market is small enough (*i.e.*  $\alpha_o < \frac{E}{C}$ ). Moreover, when the number of merged firms is lower than  $\underline{M} = N + \frac{1}{2} - \frac{1}{2}\sqrt{4N+1}$  and the price decrease is strong enough (*i.e.*  $A \equiv \frac{(a-c-\alpha\sigma_{post})^2}{(a-c-\alpha\sigma_{pre})^2}$  is high enough) a merger that would not take place without the presence of the outside market now becomes profitable.

*Proof.* See following reasoning. □

FOCs before and after the merger are in this case:

$$\begin{aligned} \alpha\sigma_{pre} + b \left(1 + \frac{1}{N}\right) Q(\sigma_{pre}) - a + c &= 0, \\ \alpha\sigma_{post} + b \left(1 + \frac{1}{N-M+1}\right) Q(\sigma_{post}) - a + c &= 0. \end{aligned} \quad (16)$$

After substituting Equation (15) inside Equations (16) we can compute  $\Delta\sigma$  for this case:

$$\Delta\sigma = \frac{b\alpha(M-1)(\alpha(E - \alpha_o C) + \alpha_o(a-c)D)}{(N\alpha^2 + b\alpha_o D(1+N))(-\alpha^2(N-M+1) - b\alpha_o D(N-M+2))}. \quad (17)$$

A *sufficient condition* for Equation (17) to be negative after the merger is:<sup>5</sup>

$$\Delta\sigma < 0 \Leftrightarrow (E - \alpha_o C) > 0. \quad (18)$$

Looking at Equation (18) and comparing it with Equation (15), we see that it is a condition on the relative size of the sector compared to the outside one. In particular, the outside sector needs to be small enough for the total demand for permits to decrease after the merger provoking a decrease in permits price. In particular, this condition can be interpreted as a condition on the polluting intensity of the outside sector:  $\alpha_o < \frac{E}{C}$ .

Regarding the condition of merger profitability in the presence of an outside market, there is an additional aspect to consider. In the case of linear demand  $-P'(Q(\sigma_{post})) = -P'(Q(\sigma_{pre})) = b$  and from the FOCs in Equations (16) we know that  $Q(\sigma_{pre}) = \frac{a-c-\alpha\sigma_{pre}}{b(1+\frac{1}{N})}$  and  $Q(\sigma_{post}) = \frac{a-c-\alpha\sigma_{post}}{b(1+\frac{1}{N-M+1})}$ , respectively. Then, the profitability condition in Equation (14) becomes:

$$\frac{(a-c-\alpha\sigma_{post})^2}{(a-c-\alpha\sigma_{pre})^2} \frac{(1+\frac{1}{N})^2}{(1+\frac{1}{N-M+1})^2} > M \frac{(N-M+1)^2}{N^2}. \quad (19)$$

Notice that, if the permits price increases after the merger, the LHS is lower than 1 and the profitability condition in the presence of an outside market becomes more restrictive than condition in Equation (8). Instead, if the permits price decreases the LHS can be higher or lower than 1 and the condition can be more or less restrictive than in the case without the presence of the outside market. It is particularly interesting to study whether it is possible that a merger that is not profitable (*i.e.* not verifying Equation (8)) becomes profitable solely due to the existence of an outside market (*i.e.* it verifies Equation (19)) that absorbs the demand change in the permits market after the merger. This is the case when the number of merged

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<sup>5</sup>Since  $(a-c) > 0$  by simply looking at the FOCs expressions in Equations (16).

firms  $M$  satisfies the following condition:

$$\frac{(a - c - \alpha\sigma_{\text{post}})^2 (N + 1)^2 (N - M + 1)^2}{(a - c - \alpha\sigma_{\text{pre}})^2 (N - M + 2)^2} > M (N - M + 1)^2 > N^2. \quad (20)$$

To study the first inequality let us call  $A \equiv \frac{(a - c - \alpha\sigma_{\text{post}})^2}{(a - c - \alpha\sigma_{\text{pre}})^2} > 1$ . The LHS of inequality (20) is satisfied for high values of  $A$ .<sup>6</sup>

The inequality on the RHS in (20) is satisfied for the following values:<sup>7</sup>

$$1 < M < N - \frac{1}{2}\sqrt{4N + 1} + \frac{1}{2}. \quad (21)$$

The intersection of these conditions is non-empty. This means that the existence of an outside market makes the merger profitable. The mechanism is simple: the decrease in the permits price due to the merger is strong enough for  $A$  to be big. Moreover, condition (21) ensures that the number of merged firms is small enough.

The previous results proves to be particularly relevant in the case of the EU-ETS market. The fact that several industries are linked through the permits market regulation changes the profitability of a merger inside each industry. In this sense, the fact that for example the cement industry is also under the EU-ETS regulation could change the profitability of a merger in the power sector.

### 3.2 A horizontal merger in an input-output structure

We continue exploring the analysis of horizontal mergers but in the context of vertically related industries, which is particularly relevant in the power sector. An upstream industry produces an input which is then used (on a one-to-one basis) by a downstream industry to produce a final good. The production of both the input and the output generates pollution, although possibly with different intensities. This is the case in the EU-ETS where polluting input sectors (*e.g.* electricity or gas) sell their goods to polluting downstream sectors (*e.g.* steel, cement, paper), both subject to an environmental regulation. We build on the so-called double Cournot model of Salinger (1988), or more recently Gabszewicz *et al.*, (2013). The downstream industry, denoted with ‘ $d$ ’, has  $N_d$  firms competing à la Cournot on a final market in which the inverse demand function is given by  $P_d(Q_d)$  and where the total quantity of final good produced is  $Q_d$ . Downstream firms are symmetric, the marginal cost being  $c_d$  and the pollution factor  $\alpha_d$ . The upstream industry, denoted by ‘ $u$ ’, has  $N_u$  firms competing à la Cournot on the intermediate good market. Upstream firms are symmetric, the marginal cost being  $c_u$  and the pollution factor  $\alpha_u$ .

Both upstream and downstream firms are assumed to be price-takers on the permits market. The timing of the game is as follows: upstream firms decide their production levels; downstream firms choose their quantities; the permits market clears.

<sup>6</sup>Note that the inequation is a third-degree polynomial in  $M$  that has 3 roots. For high values of  $A$  the polynomial is always positive in the range  $1 < M < N$ .

<sup>7</sup>Notice that this polynomial has 3 positive roots: one is equal to 1, another one higher than  $N$  and only one equal to  $N - \frac{1}{2}\sqrt{4N + 1} + \frac{1}{2}$  in the relevant set of parameters.

**Downstream equilibrium.** Downstream firms  $i = 1, \dots, N_d$  maximize their profits as follows:

$$\max_{q_{i,d}} [P_d(Q_d) - c_d - \alpha_d \sigma - p_u] q_{i,d} \quad (22)$$

$$FOC : p_u = P_d(Q_d) - c_d - \alpha_d \sigma + P'_d(Q_d) \frac{Q_d}{N_d}.$$

where  $p_u$  is the price paid for the upstream good. Since one unit of input is required for each unit of output produced, it must be the case that  $Q_d = Q_u$ . The previous FOC then represents the inverse demand curve in the input market.

**Upstream equilibrium.** Each input producer  $j = 1, \dots, N_u$  maximizes its profit:

$$\max_{q_{i,u}} [P_u(Q_u) - c_u - \alpha_u \sigma] q_{i,u}, \quad (23)$$

$$FOC : P_u(Q_u) - c_u - \alpha_u \sigma + P'_u(Q_u) \frac{Q_u}{N_u} = 0,$$

with  $P'_u(Q_u) = P'_d(Q_u) \left(1 + \frac{1}{N_d}\right) + P''_d(Q_u) \frac{Q_u}{N_d}$ .

**Permits market equilibrium.** Since we assume  $Q_d = Q_u \equiv Q$ , and since agents are price-takers in the permits market we can write:

$$Q = \frac{E}{\alpha_d + \alpha_u}. \quad (24)$$

**Equilibrium profits.** The profit of downstream and upstream producers are given by:

$$\pi_d^* = -P'_d(Q) \left[ \frac{Q}{N_d} \right]^2, \quad (25)$$

$$\pi_u^* = - \left[ P'_d(Q) \left(1 + \frac{1}{N_d}\right) + P''_d(Q) \frac{Q}{N_d} \right] \left[ \frac{Q}{N_u} \right]^2.$$

After substituting Equation (24) in Equations (25) we get:

$$\pi_d^* = -P'_d \left( \frac{E}{\alpha_d + \alpha_u} \right) \left[ \frac{E}{N_d(\alpha_d + \alpha_u)} \right]^2 \quad (26)$$

$$\pi_u^* = - \left[ P'_d \left( \frac{E}{\alpha_d + \alpha_u} \right) \left(1 + \frac{1}{N_d}\right) + P''_d \left( \frac{E}{\alpha_d + \alpha_u} \right) \frac{E}{N_d(\alpha_d + \alpha_u)} \right] \left[ \frac{E}{N_u(\alpha_d + \alpha_u)} \right]^2.$$

### 3.2.1 Downstream horizontal merger

The constraint in Equation (24) ensures that the equilibrium output both in the downstream and the upstream market respects the environmental constraint. Then, the profitability of a downstream merger is simply the condition in Equation (8).

Increasing the concentration of the downstream sector has an indirect effect on the upstream market. By using Equation (26) and defining  $\bar{\alpha} = \alpha_d + \alpha_u$ , the difference between

post-merger and pre-merger profits in the upstream industry is shown to be positive. This is the case because the quantity produced in both market stays the same. Therefore, Equation (24) holds and the price of the upstream good is also unchanged. As in Equation (6), however, the merger in the downstream sector decreases the permits price. This effect benefits both upstream and downstream sectors. The profits of the downstream sector increases since fewer firms produce the quantity  $Q$ , thus leading to a decrease permits demand and price. Therefore, Equation (7) still holds. The difference in the profits post and pre-merger for the vertically related industry can be written as follows:

$$\Delta\Pi_u \equiv \pi_{u,\text{post}}^* - \pi_{u,\text{pred}}^* = -\Delta\sigma E \frac{1}{N_u^2} + P_d'' \left( \frac{E}{\bar{\alpha}} \right) \frac{E}{(\bar{\alpha})} \left[ \frac{1-M}{N_d(N_d-M+1)} \right] \left[ \frac{E}{N_u(\bar{\alpha})} \right]^2 \geq 0. \quad (27)$$

meaning that an industry profits from the decrease in permits prices produced by the merger in another vertically related industry.

### 3.2.2 Upstream horizontal merger

Since the produced quantity remains unchanged, there is a direct effect of the merger on permits price that benefits directly the upstream firms and indirectly the downstream firms. All the previous results remain the same simply by exchanging the subindex  $d$  by  $u$  and *vice versa*.

**Proposition 4.** *When a merger takes place in one industry, the decrease in permits price profits the vertical related industry.*

*Proof.* In Appendix. □

## 4 Pollution reallocation when firms are heterogeneous

Consider now that firms differ in their marginal costs of production. With this purpose we slightly change our setting and consider the following ‘oligopoly - fringe model’ that could describe the power market in countries like France or in some American states.

**Oligopoly-fringe model.** There are two types of firms producing in the final market:

- $D$  dominant firms, denoted by  $i = 1, \dots, D$ , whose production technology exhibits constant returns-to-scale with marginal cost  $c_d$ .
- A fringe composed of  $F$  competitive firms  $i = 1, \dots, F$ , whose production technology exhibits decreasing returns-to-scale with total cost  $C_f(q_f) = \frac{1}{2}c_f^2 q_f$  where  $q_f = \sum_{i=1}^F q_{i,f}$ . The fringe is assumed to be a price-taker on the product market.

Both types of firms simultaneously decide their quantities and the permits market clears.

The fringe efficiency, summarized by  $c_f$ , affects the relative size of the proposed merger: for instance, when  $c_f$  is low (large), the fringe produces a large (small) quantity and the merger between dominant firms involves a small (large) fraction of the total output.

Absent any merger, an (interior) equilibrium is a profile of quantities  $\{\{q_{i,d}\}_{i=1,\dots,D}; \{q_{i,f}\}_{i=1,\dots,F}\}$  and a permits price  $\sigma$  such that each dominant firm  $i = 1, \dots, D$ , maximizes its profit according to the following FOCs:

$$\begin{aligned} P(Q) - c_d - \alpha\sigma + P'(Q)q_{i,d} &= 0; \\ P(Q) &= c_f q_{i,f} + \alpha\sigma; \end{aligned} \quad (28)$$

where the second line shows the competitive fringe's FOC.

The cap on emissions determines that:

$$\sum_{i=1}^N \alpha q_{i,d} + \alpha q_f = E, \quad (29)$$

where  $q_f = \sum_{i=1}^F q_{i,f} = F q_{i,f}$  and  $Q = \sum_{i=1}^D q_{i,d} + q_f$

A merger between  $M$  of the  $D$  dominant firms simply produces a reduction of the number of dominant firms. Let us assume for the rest of the section that

$$\frac{c_d}{c_f} < \frac{E}{\alpha F} \quad (30)$$

This condition ensures that the market share of dominant firms is positive both before and after the merger. It can also be interpreted as a restriction on the fringe's size: the part of output  $\frac{E}{\alpha}$  produced  $F$  has to be sufficiently low in order to verify the constraint on output due to the existence of a pollution cap.

Let us also assume for simplicity that inverse output demand is linear  $P = a - bQ$ .

After summing the FOCs of the fringe over  $F$ , solving the system of FOCs and the permits equilibrium condition we get the profits of the dominant firms before merging, i.e.:

$$\pi_{Dpre}^* = q_{i,d}^2 \frac{bc_f}{c_f + Fb}. \quad (31)$$

A similar reasoning must be done to calculate profits after the merger:

$$\pi_{Dpost}^* = Q_{Dpost}^2 \frac{bc_f}{(c_f + Fb)} \frac{1}{(D - M + 1)^2}. \quad (32)$$

Since in equilibrium all  $q_{i,d}$  are the same, and considering the permits price equilibrium, the profitability condition  $\pi_{Dpos}^* > M\pi_{Dpre}^*$  can be rewritten as:

$$\frac{(E - \alpha q_{fpre})^2}{D^2} > M \frac{(E - \alpha q_{fpost})^2}{(D - M + 1)^2} \quad (33)$$

where  $q_{f,t} = F \frac{(a - b\frac{E}{\alpha}) - \alpha\sigma_t}{c_f}$  and the subindex  $t$  can take the value *pre* or *post* merger. As usual, the profitability condition is related to the change in permits prices due to the merger,

which in this case is always negative when Equation (30) is satisfied:<sup>8</sup>

$$\Delta\sigma = \frac{b(M-1)(c_f + Fb)(F\alpha c_d - Ec_f)}{\alpha^2(c_f D + Fb(1+D))(c_f(D-M+1) + Fb(D-M+2))} < 0. \quad (34)$$

which in turns determines a positive profit differential for dominant firms:

$$\Delta\Pi = \left(\sqrt{D}-1\right)(c_f + Fb)\left(Fb - \sqrt{D}c_f - Fb\sqrt{D}\right)\frac{F\alpha c_d - Ec_f +}{c_f(c_f + 2Fb)(Dc_f + Fb + FbD)} > 0 \quad (35)$$

From the previous reasoning we derive the following proposition.

**Proposition 5.** *In the oligopoly-fringe model, a merger between the oligopolistic firms is always profitable and accompanied by a permits price decrease.*

*Proof.* See Complementary Material available upon request.  $\square$

With respect to the benchmark case of Cournot competitors (Section 2), here the merger is always profitable, no matter the size of the merged entity. Dominants restrict output knowing that the fringe absorbs the production differential. As a consequence, given that the total output is constant in the pre and post cases, the demand for permits always decreases and so does the corresponding price.

The non-strategic behavior of the fringe also has some straightforward implications on the equilibrium permits price and quantities produced. In terms of comparative statics, we have:

$$\begin{aligned} \frac{\partial(Q_{D_{post}})}{\partial M} &= \frac{Fb(c_f + Fb)(F\alpha c_d - Ec_f)}{\alpha c_f^2(c_f(D-M+1) + Fb(D-M+2))^2} < 0, \\ \frac{\partial(q_{f_{post}})}{\partial M} &= \frac{Fb(c_f + Fb)(-F\alpha c_d + Ec_f)}{\alpha c_f^2(c_f(D-M+1) + Fb(D-M+2))^2} > 0, \\ \frac{\partial(\sigma_{post})}{\partial M} &= \frac{b(c_f + Fb)(F\alpha c_d - Ec_f)}{\alpha^2(c_f(D-M+1) + Fb(D-M+2))^2} < 0. \end{aligned} \quad (36)$$

An increase of the number of dominants who merge leads to a decrease in permits price, an output contraction by the dominants perfectly compensated by an increase of production by the fringe. As a consequence, dominants always have an incentive to become a unique entity after the merger. We can then establish the following corollary:

**Corollary 1.** *The profit of  $M$  dominant oligopolists is always lower than the profit of a unique dominant firm.*

*Proof.* See Appendix.  $\square$

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<sup>8</sup>Notice that permits prices are calculated by solving the system of FOCs, substituting the market for permits clearing condition and rearranging in the case with and without a merger, respectively.

## 5 Case Studies

Big mergers have taken place after the creation of tradable emission permits both in the US and in Europe. In this section we argue that the use of tradable emission permits may be one of the mergers driving reasons. To this end, we give several examples that illustrate the validity of our results.

### 5.1 An application to the RGGI

The Regional Greenhouse Gas Initiative (RGGI) was put in place in 2009 (with a first auction on the 25th of September 2008) as the first mandatory cap-and-trade program to limit CO<sub>2</sub> emissions in the United States.<sup>9</sup> Nine states currently participate in the RGGI: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont. Several states and Canadian provinces act as observers: Pennsylvania, Québec, New Brunswick, and Ontario. New Jersey formerly participated, but it withdrew in 2011.

The market works as follows. One hundred sixty three electric power generators are required to obtain a number of permits (or allowances) equal to the number of tons of CO<sub>2</sub> emitted.<sup>10</sup> CO<sub>2</sub> emission allowances are distributed primarily through auctions (94% of all permits in December 2015). At the end of 2015, RGGI has conducted 30 successful auctions, selling a total of 801 million CO<sub>2</sub> allowances for \$2.4 billion.

Following the 2012 Program Review, the participating states announced changes to the Model Rule, including a new emissions cap set at 91 million tons for 2014, reduced by 2.5 percent per year, reaching approximately 78 million tons in 2020. The Model Rule also included further interim adjustments to the cap in order to account for the surplus of CO<sub>2</sub> allowances accumulated from 2009 to 2013.<sup>11</sup>

The prices in the RGGI market have continuously increased since the end of 2012. Such increase is mostly due to a tighter cap that came into effect in 2013. Due to this update on the market cap we are unlikely to observe a decrease in permits price after each merger takes place but only a deceleration in the price increase to which all these mergers may have contributed.

Given the results underlined in this paper we think it is not a coincidence that the most important mergers in the RGGI area have happened after this great tightening of the market cap in 2014, which are all summarized in Table 1.

INSERT FIGURE 2

Among the mergers that have taken place between firms with predominant presence in the states covered by the RGGI<sup>12</sup>, the biggest one has been the merger of Exelon Corporation and Pepco Holdings Incorporated. Such merger was announced on April 2014 for more than \$12 billion. At the merger time, Exelon served 6.7 million costumers through its subsidiaries in Illinois, Pennsylvania and Maryland and intervned in all stages from generation to delivery of electricity. On the other side, Pepco Holdings served 1.9 million customers in the District

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<sup>9</sup>For more information see IETA RGGI ETS Case Study, May 2015.

<sup>10</sup>For more statistics of this type see ICAP carbon action.

<sup>11</sup>The 2016 Program Review is now being conducted.

<sup>12</sup>For a detail on recent mergers in the U.S. power sector see the quarterly reports of PwC.

of Columbia and Maryland. Pepco Holdings also owns Delmarva Power in Delaware and Maryland. This merger was presented as a horizontal one, even if Exelon holds all activities at a time, being an example of the type of mergers mentioned in Section 3.2. The U.S. Energy Information Agency explains that, according to Exelon, cost reductions available through increased scale and geographic proximity were the primary reasons for the merger (see Today in Energy<sup>13</sup> report in October 2014).

Another merger among firms in the RGGI, announced around the same dates, is the NRG Yield Inc. acquisition of Alta Wind Energy Center of Terra-Gen Power LLC and of ArcLight Capital Partners LLC, for an estimated \$2.5 billion. NRG Yield Inc. is a Delaware unit of NRG Energy Inc., Terre-Gen Alta Wind is a New York-based provider of renewable energy and ArcLight is a Boston-based equity firm. This merger<sup>14</sup> could be an example of the case modeled in Section 2.2 since the inclusion of a renewable source will most probably generate efficiency gains in the context of environmental regulation.

The prospect of a decrease in permits price after the merger could indeed, as shown by our model, be a cost reduction argument that increases merger incentives. Indeed, the average price of CO2 allowances during the first quarter of 2014 (i.e. the quarter before the two mentioned mergers took place) went from around \$3.50 at the beginning of the quarter to almost \$4.50 at the end of the quarter averaging \$3.87. As compared to the previous quarter it increased of 26 percent and 37 percent as compared to the first quarter of 2013.<sup>15</sup>

Many other mergers have taken place among firms belonging to the RGGI and many U.S. investor-owned utilities have indeed consolidated in recent years.<sup>16</sup> In the table below we show all the mergers that took place during 2014, the year when prices started to steadily increase due to the tightening of the cap.

## 5.2 Could our argument also apply to the EU-ETS?

The European Union Emissions Trading Scheme (EU-ETS) started in 2005 as the world's first and biggest international trading system for CO2 emissions. As in the case of the RGGI, firms under regulation are required to obtain a number of permits equal to the number of tons of CO2 emitted. During the first years permits were allocated to firms for free using a method called grandfathering (a percentage reduction of your installation's emissions in 1990) but nowadays most of permits are auctioned.<sup>17</sup> The EU-ETS now covers emissions from more than 11,000 heavy energy-using installations (including power stations and industrial plants) and airlines operating between participating countries (all 28 EU countries plus Iceland, Liechtenstein and Norway). In total it covers around 45% of the EU's greenhouse gas emissions and accounts for over 3/4 of international carbon trading.<sup>18</sup> Power and CHP plants represented around half of the allowances allocated in Phase 2 (2008-2012) of the EU ETS. Differently from the RGGI where the electricity market and the permits market are in almost perfect correspondence, the link between the two markets is most probably weaker. In Section 3.1 we show the case in which other sectors also participate in the permits market.

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<sup>13</sup>See EIA website.

<sup>14</sup>For a comparison of the two mergers mentioned see the PwC Quarterly Reports.

<sup>15</sup>See RGGI Market Report Q1, 2014.

<sup>16</sup>For more information on this see The Public Power Report.

<sup>17</sup>For a description of the auctioning mechanism and results see the Common Auction Platform report.

<sup>18</sup>For a full description of the EU-ETS regulatory framework and coverage see ETS Handbook.

We think that a merger in the EU-ETS case could be described by the conditions detailed in that section.

Several firms concentrations have taken place since the EU-ETS has been established. For instance, The Economist of the 26th of February 2009 explained how the frenetic merger trend present since 2006 has made the European market evolve into an oligopoly<sup>19</sup> dominated by a few-cross border giants, such as EDF from France, E.ON and RWE from Germany and Enel from Italy.<sup>20</sup> Just to cite the most important mergers we are referring to, let us mention Enel's acquisition of Endesa that started at the beginning of 2006 (when Enel bought 67% of Endesa bringing in a Spanish partner called Acciona to appease local feeling) and ended at the 20th of February 2009 when Enel bought Acciona's stake for 11.1 billion euros.<sup>21</sup> Few days before the Spanish government had accepted the merger of Gas Natural with Union Fenosa.<sup>22</sup> That same week Vattenfall, the largest Nordic utility, bought the Dutch energy firm called Nuon for 8.5 billion euros.<sup>23</sup> Back in January of that same year the German RWE also bought the Dutch Essent for 9.3 billion euros.<sup>24</sup>

The reasons behind the previous mergers are, most certainly, multidimensional. In any case such mergers have coincided with a systematic decrease in CO<sub>2</sub> prices in accordance with our results. Indeed, the first merger cited coincides with the most changing year of the EU-ETS (in that period, the price of emissions permits tripled in the first six months of Phase I and then collapsed by half in a one-week period in 2006). Since then, a systematic price decrease has characterized the CO<sub>2</sub> market. Our model shows that the number of important mergers in the power sector may have contributed to the price slowdown, due to other economic factors.

## 6 Conclusion

This paper extends Hennessy and Roosen (1999)'s result on the merger incentives created by the existence of a tradable emission permits market to the case in which the polluting firms are non-competitive, as it is the case in most energy markets and in particular in the power sector. We find that, if firms in the sector are symmetric and competing *à la* Cournot, an horizontal merger is welfare improving but there is a critical size for it to occur and, in the presence of a perfectly competitive (or monopolistic) outside market that also participates in the same tradable emission permits market, under some conditions a merger that would not be profitable without it now takes place. The first result suggests that, as prices go up in the RGGI, merger incentives coming from the CO<sub>2</sub> market will continue to increase. Similarly, the second result says that in the case of the EU-ETS, where more than one industry is under the same CO<sub>2</sub> market, incentives for mergers due to the sole existence of this market are even greater. We also study the case of vertically related sectors, which is particularly relevant in power markets, finding that an horizontal merger in one of two markets that are vertically linked increases profits in both markets due to the provoked decrease in permits price. Finally

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<sup>19</sup>See the article called Power Games in The Economist.

<sup>20</sup>For a detailed list of mergers in the Power Sector see the DG Comp website.

<sup>21</sup>See the Financial Times article of the 21st of February 2009.

<sup>22</sup>See the announcement of the 7th of September 2009 in their website.

<sup>23</sup>See Reuter's article on the day of the announcement, the 23th of February 2009.

<sup>24</sup>See Financial Times article of the 12th of January 2009.

we find that a merger between oligopolistic firms in a market where there is a competitive fringe is always profitable as opposed to the symmetric Cournot case where a critical size is needed.

Our results regarding the modification of the merger profitability condition in the presence of a tradable emission permits market provide new insights for understanding many mergers that have taken place both under the RGGI and the EU-ETS. The policy implications from these results are quite straightforward: there is a trade-off between promoting a high CO<sub>2</sub> price to reduce the environmental externality and promoting competition in energy markets, in particular in the power sector where firms are also vertically related with other firms covered by the same tradable emission permits market. The regulator should then counterbalance *pro et contra* before fixing (or tightening) the cap on emissions and should work closely with competition authorities to avoid putting too much pressure on consumers. These considerations add to the considerations in De Feo et al. (2013) regarding the decrease in competition that could arise in the power sector when a permits market is in place.

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## 8 Appendix

### Proof of equation (4)

In a symmetric equilibrium each firm maximizes

$$\begin{aligned} \max_{q_i \geq 0} & [P(Q) - c - \alpha\sigma] q_i \\ \text{s.t. } & Q = \sum_{i=1}^N q_i \end{aligned}$$

FOC is then:

$$P'(Q)q_i + P(Q) - c - \alpha\sigma = 0$$

Since  $Q = \frac{E}{\alpha}$  by hypothesis we can rewrite

$$P'\left(\frac{E}{\alpha}\right)q_i + P\left(\frac{E}{\alpha}\right) - c - \alpha\sigma = 0$$

and since we are in a symmetric equilibrium

$$P'\left(\frac{E}{\alpha}\right)\frac{E}{\alpha N} + P\left(\frac{E}{\alpha}\right) = c + \alpha\sigma$$

Substituting this FOC inside the profit function we get

$$\pi_{\text{pre}}^* = \left[ P\left(\frac{E}{\alpha}\right) - \left( P'\left(\frac{E}{\alpha}\right)\frac{E}{\alpha N} + P\left(\frac{E}{\alpha}\right) \right) \right] \frac{E}{\alpha N}$$

that simplifies to equation (4).

### Proof of Proposition 1

The quantity produced does not change after the merger due to the equilibrium condition on the permits market:  $Q = \frac{E}{\alpha}$ .

From the FOC of symmetric firms we find that:

$$\begin{aligned}\sigma^{\text{pre}} &= \frac{P'(\frac{E}{\alpha})\frac{Q}{N} + P(\frac{E}{\alpha}) - c}{\alpha} \\ \sigma^{\text{post}} &= \frac{P'(\frac{E}{\alpha})\frac{Q}{(N-M+1)} + P(\frac{E}{\alpha}) - c}{\alpha}\end{aligned}$$

and consequently the difference is

$$\Delta\sigma = P'(\frac{E}{\alpha})\frac{E}{\alpha^2} \left( \frac{N - (N - M + 1)}{N(N - M + 1)} \right)$$

which can be simplified as the expression in the main text.

On the other hand the sum of profits before and after the merger are

$$\begin{aligned}\Pi^{\text{pre}} &= \left( -P' \left( \frac{E}{\alpha} \right) \frac{1}{N} \left( \frac{E}{\alpha} \right)^2 \right) \\ \Pi^{\text{post}} &= -P' \left( \frac{E}{\alpha} \right) \frac{1}{(N - M + 1)} \left( \frac{E}{\alpha} \right)^2\end{aligned}$$

and consequently the difference is

$$\Delta\Pi = -P' \left( \frac{E}{\alpha} \right) \left( \frac{E}{\alpha} \right)^2 \left( \frac{1}{(N - M + 1)} - \frac{1}{N} \right)$$

which is simply

$$\Delta\Pi \equiv -\Delta\sigma \times E.$$

The previous equations shows that what is earned by the industry after the merger perfectly compensates the government loss due to the decrease in the permits price.

### Discussion on Condition 1

Under the assumption of linear demand  $a - bQ$  and without a permits market, the Salant (1983)'s condition for merger profitability, *i.e.*  $\pi_{\text{post}} > M\pi_{\text{pre}}$ , simply depends on the number of firms in the industry after the merger takes place, that is:

$$(N + 1)^2 > M(N - M + 2)^2$$

The profitability condition in our model is given by Condition 1 that is:

$$\frac{1}{(N - M + 1)^2} \geq \frac{M}{N^2}$$

Notice that Condition 1 holds for any demand function. In our model total production is

fixed by the availability of permits  $E$  and therefore mergers profitability only depends on the number of firms after the merger.

Condition 1 can be more or less restrictive than the case without permits market. In fact, solving the system of the previous two equations we find the following quadratic function of  $N$  :

$$\frac{N^2}{(N - M + 1)^2} - \frac{(N + 1)^2}{(N - M + 2)^2} = 0,$$

that has two real roots, one of them that is always positive *i.e.*:

$$r_1 = \frac{1}{2} \left( M + \sqrt{(M + 1)^2 + 1} \right) - 1.$$

For a number of merging firms  $M > r_1$ , the sole existence of a permits market relaxes the profitability condition.

### Proof of Condition 2

When there are efficiency gains the cost after the merger takes place decrease as follows:  $c_m = c - \delta$ , with  $\delta \geq 0$ .

Firms that do not merge maximize

$$\max_{q_i \geq 0} [P(Q) - c - \alpha\sigma] q_i,$$

while merged firm get together and maximize

$$\max_{q_m \geq 0} [P(Q) - c_m - \alpha\sigma] q_m$$

Cournot system of FOCs is then<sup>25</sup>:

$$\begin{aligned} P'(Q)q_m - c_m &= \alpha\sigma - P(Q) \\ P'(Q) \sum_1^{N-M} q_i - (N - M)c &= (N - M)(\alpha\sigma - P(Q)) \end{aligned}$$

Since non merged firms are symmetric the system can be written as:

$$\begin{aligned} P'(Q)q_m - c_m &= \alpha\sigma - P(Q) \\ P'(Q) \frac{(Q - q_m)}{N - M} - c &= \alpha\sigma - P(Q) \end{aligned}$$

Differently from what happened when the merger does not create a cost asymmetry when there are efficiency gains the full monopolization case cannot be treated simply as a particular case of the general resolution formula since full monopolization makes one type of firm (the ones less efficient) to disappear (note that  $N - M$  in the equation appears in the denominator).

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<sup>25</sup>In the case of full monopolization the second equation becomes  $P'(Q) \sum_1^{N-M} q_i = 0$  simply because there is only the now merged firm that stays in the market.

In the case of non full monopolization we then solve the system by equalizing to find

$$q_m^* = \frac{1}{(N - M + 1)} \left( \frac{(N - M)(c_m - c)}{P'(Q)} + Q \right)$$

and

$$q_i^* = \left( Q - \frac{\delta}{P'(Q)} \right) \frac{1}{(N - M + 1)}.$$

Profits for non-merged firms are then

$$\pi_{i,\text{post}}^* = \frac{1}{-P'(\frac{E}{\alpha})} \left( \frac{(P'(\frac{E}{\alpha})\frac{E}{\alpha} - \delta)}{(N - M + 1)} \right)^2$$

Profit for the merged firm is now

$$\pi_{m,\text{post}}^* = \frac{1}{-P'(\frac{E}{\alpha})} \left( \frac{P'(\frac{E}{\alpha})\frac{E}{\alpha} + (N - M)\delta}{N - M + 1} \right)^2$$

The merger is profitable if:  $\pi_{m,\text{post}}^* \geq M\pi^{\text{pre}}$

$$\frac{1}{-P'(\frac{E}{\alpha})} \left( \frac{P'(\frac{E}{\alpha})\frac{E}{\alpha} + (N - M)\delta}{N - M + 1} \right)^2 \geq -P' \left( \frac{E}{\alpha} \right) \frac{M}{N^2} \left( \frac{E}{\alpha} \right)^2$$

Note that in the case of full monopolization the previous condition boils down to the condition in equation 8:

$$\frac{1}{-P'(\frac{E}{\alpha})} \left( P'(\frac{E}{\alpha})\frac{E}{\alpha} \right)^2 \geq -P' \left( \frac{E}{\alpha} \right) \frac{1}{N} \left( \frac{E}{\alpha} \right)^2$$

giving  $1 \geq \frac{1}{N}$  which is always true.

Let us go back to the case where there is no full monopolization, i.e. from now on  $N > M \geq 2$ :

Since  $-P'(\frac{E}{\alpha}) > 0$  we can simply write the profitability condition as:

$$\left( \frac{P'(\frac{E}{\alpha})\frac{E}{\alpha} + (N - M)\delta}{N - M + 1} \right)^2 - \left( P' \left( \frac{E}{\alpha} \right) \right)^2 \frac{M}{N^2} \left( \frac{E}{\alpha} \right)^2 > 0$$

that is a perfect square of the form  $a^2 - b^2 = (a + b)(a - b)$ .

The condition for positivity is then

$$\left( \frac{P'(\frac{E}{\alpha})\frac{E}{\alpha} + (N - M)\delta}{N - M + 1} - P' \left( \frac{E}{\alpha} \right) \frac{E}{\alpha} \frac{\sqrt{M}}{N} \right) \left( \frac{P'(\frac{E}{\alpha})\frac{E}{\alpha} + (N - M)\delta}{N - M + 1} + P' \left( \frac{E}{\alpha} \right) \frac{E}{\alpha} \frac{\sqrt{M}}{N} \right) > 0$$

giving

$$\begin{cases} \delta > -P'(\frac{E}{\alpha})\frac{E}{\alpha}\frac{N-M+1}{N-M}\left(\frac{1}{N-M+1} - \frac{\sqrt{M}}{N}\right) \\ \delta > -P'(\frac{E}{\alpha})\frac{E}{\alpha}\frac{N-M+1}{N-M}\left(\frac{1}{N-M+1} + \frac{\sqrt{M}}{N}\right) \end{cases}$$

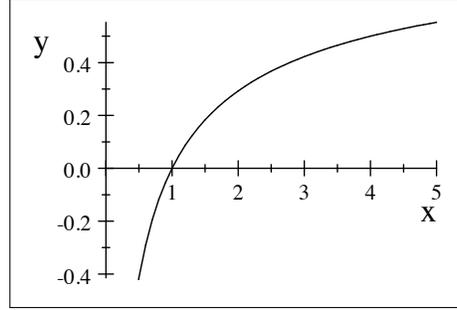
Which condition is more binding depends on the sign of  $\left(\frac{1}{N-M+1} - \frac{\sqrt{M}}{N}\right)$ :

- if  $\left(\frac{1}{N-M+1} - \frac{\sqrt{M}}{N}\right) < 0$  the first condition is always satisfied and the binding condition is  $\delta > \delta_m > -P'(\frac{E}{\alpha})\frac{E}{\alpha}\frac{N-M+1}{N-M}\left(\frac{1}{N-M+1} + \frac{\sqrt{M}}{N}\right)$
- if  $\left(\frac{1}{N-M+1} - \frac{\sqrt{M}}{N}\right) > 0$  then the binding condition is  $\delta > \delta_m > -P'(\frac{E}{\alpha})\frac{E}{\alpha}\frac{N-M+1}{N-M}\left(\frac{1}{N-M+1} - \frac{\sqrt{M}}{N}\right)$

The previous equations are summarized in the main text by the inequality in Condition 2:

$$\delta > \delta_m$$

Corner of full monopolization: if  $M = N$  the expression  $\left(\frac{1}{N-M+1} - \frac{\sqrt{M}}{N}\right)$  is of the form  $1 - \frac{1}{\sqrt{x}}$



Since  $N$  is always higher than 1, the expression is always positive and the binding condition is

$$\delta > -P'(\frac{E}{\alpha})\frac{E}{\alpha}\frac{N-M+1}{N-M}\left(\frac{1}{N-M+1} - \frac{\sqrt{M}}{N}\right)$$

Proof of Proposition 2

**Part 1: Impact of merger in permits price**

From the FOCs

$$\begin{aligned} P'(Q)q_m + P(Q) - (c - \delta) - \alpha\sigma^{post\delta} &= 0 \\ P'(Q)\left(\frac{Q - q_m}{N - M}\right) + P(Q) - c - \alpha\sigma^{post\delta} &= 0 \end{aligned}$$

we can calculate the change in permits price after the merger with efficiency gains that we note  $\Delta\sigma^\delta$ :

$$\Delta\sigma^\delta = \frac{P'(\frac{E}{\alpha})\left(\frac{\frac{E}{\alpha} + (N-M-1)q_m}{(N-M)}\right) + 2P(\frac{E}{\alpha}) - 2c + \delta}{2\alpha} - \frac{P'(\frac{E}{\alpha})\frac{E}{N\alpha} + P(\frac{E}{\alpha}) - c}{\alpha}$$

that after substituting  $q_m^*$  becomes simply

$$\Delta\sigma^\delta = \Delta\sigma + \frac{(N-M)}{(N-M+1)} \frac{\delta}{\alpha}$$

Note that without efficiency gains ( $\delta = 0$ ) the price of permits behaves as before. Permits price decreases ( $\Delta\sigma^\delta < 0$ ) if

$$\delta < \delta_\sigma = \frac{-P'(\frac{E}{\alpha})\frac{E}{\alpha}(M-1)}{(N-M)N}$$

Since

$$\left(\frac{1}{N-M+1} - \frac{\sqrt{M}}{N}\right) < \left(\frac{1}{N-M+1} + \frac{\sqrt{M}}{N}\right)$$

we now observe that:

$$-P'(\frac{E}{\alpha})\frac{E}{\alpha} \frac{N-M+1}{N-M} \left(\frac{1}{N-M+1} - \frac{\sqrt{M}}{N}\right) = \delta_m < \delta < \delta_\sigma = \frac{-P'(\frac{E}{\alpha})\frac{E}{\alpha}(M-1)}{(N-M)N}.$$

Therefore a merger can take place when permits price decrease i.e.  $\delta_m < \delta < \delta_\sigma$ .

If efficiency gains are so high that

$$\delta > \delta_\sigma = \frac{-P'(\frac{E}{\alpha})\frac{E}{\alpha}(M-1)}{(N-M)N},$$

the price after the merger increases.

## Part 2: Relation between the change in permits prices and change in profitability of the industry

We search for

$$\Delta\Pi \equiv \Pi^{\text{post}} - \Pi^{\text{pre}}$$

where

$$\Pi^{\text{post}} = (N-M)\pi_{i,\text{post}}^* + \pi_{m,\text{post}}^*$$

that is

$$\begin{aligned} \Pi^{\text{post}} &= (N-M) \frac{1}{-P'(\frac{E}{\alpha})} \left(\frac{(P'(\frac{E}{\alpha})\frac{E}{\alpha} - \delta)}{(N-M+1)}\right)^2 + \frac{1}{-P'(\frac{E}{\alpha})} \left(\frac{P'(\frac{E}{\alpha})\frac{E}{\alpha} + (N-M)\delta}{N-M+1}\right)^2 \\ \Pi^{\text{pre}} &= -P'(\frac{E}{\alpha}) \frac{1}{N} \left(\frac{E}{\alpha}\right)^2 \end{aligned}$$

Then, we can write:

$$\Delta\Pi \equiv -\frac{P'(\frac{E}{\alpha})^2 E^2 - MP'(\frac{E}{\alpha})^2 E^2 - N^2\alpha^2\delta^2 + MN\alpha^2\delta^2}{NP'(\frac{E}{\alpha})\alpha^2(M-N-1)} > 0$$

In this case with efficiency gains the overall industry's profit increases after a merger for

any  $\delta$  is:

$$\Delta\Pi = -\Delta\sigma E - \delta \left( \frac{\delta}{P' \left( \frac{E}{\alpha} \right)} + \frac{N}{\alpha} \right) \frac{(N - M)}{N(N - M + 1)}.$$

Consumer surplus is unaffected due to the fact that total quantity at the industry level remains constant. The industry gain more than compensates the loss of the government (that is equal to  $-\Delta\sigma \times E$ ). The merger is then welfare enhancing:<sup>26</sup>

$$\Delta W = \frac{1}{-P' \left( \frac{E}{\alpha} \right)} \frac{1}{N(N - M + 1)} \left( N\delta \left( N - M - P' \left( \frac{E}{\alpha} \right) \frac{E}{\alpha} \right) \right) > 0.$$

#### Proof of Proposition 4

The same condition applies here without efficiency gains by simply changing  $N$  by  $N_d$  or  $N_u$  for a downstream or an upstream merger, respectively:

$$\frac{1}{(N_d - M + 1)^2} \geq \frac{M}{N_d^2}.$$

for example.

Therefore the results regarding the no-efficiency-gains case also apply here, in particular, the result regarding a decrease in permits price after the merger and the increase in the profits of the merging sector. We must therefore prove that this decrease in permits price profits the vertically related industry. Without loss of generality let us show that in the case of a downstream horizontal merger.

As shown in the first case of no-efficiency gains:

$$\Delta\sigma = P' \left( \frac{E}{\bar{\alpha}} \right) \frac{E}{\bar{\alpha}^2} \frac{M - 1}{N_d(N_d - M + 1)}$$

We see that the decrease of permits price creates a gain in the vertically related sector

$$\Delta\Pi_u \equiv \pi_{u,\text{postD}}^* - \pi_{u,\text{preD}}^* = -\Delta\sigma E \frac{1}{N_u^2} + P_d'' \left( \frac{E}{\bar{\alpha}} \right) \frac{E}{(\bar{\alpha})} \left[ \frac{1 - M}{N_d(N_d - M + 1)} \right] \left[ \frac{E}{N_u(\bar{\alpha})} \right]^2$$

since  $\Delta\sigma < 0$ ,  $M \geq 2$  et  $P_d'' < 0$ .

#### Proof of Corollary 1

*Proof.* The equilibrium quantity produced by a unique dominant firm and the profit are, respectively:

$$\begin{aligned} Q_{post,M=D}^D &= \frac{(c_f + Fb)}{\alpha c_f (c_f + 2Fb)} (Ec_f - F\alpha c_d), \\ \pi_{post,M=D}^* &= \frac{bc_f}{c_f + Fb} (Q_{postM}^D)^2. \end{aligned}$$

<sup>26</sup>Notice that if  $\delta = 0$  we are back in the case where  $\Delta\Pi = -\Delta\sigma^\delta E$  and the merger is welfare neutral.

Straightforward calculations show that:

$$\pi_{post}^* - \pi_{post, M=D}^* = \frac{(c_f + Fb)(c_f(D - M + 2) + Fb(D - M + 4))(-Ec_f + F\alpha c_d)}{\alpha c_f(c_f + 2Fb)(c_f(D - M + 1) + Fb(D - M + 2))} < 0.$$

□