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# The "windfall profits 2.0"

## during the third phase of EU-ETS\*

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### Abstract

The first two phases of the EU-ETS were characterized by a profit increase, which was primarily due to free allowances given through grandfathering. To avoid these windfall profits and to decrease leakage, two major modifications have been implemented for the third phase: electric companies no longer receive free allowances, while energy intensive and trade exposed sectors are granted free allowances that are calculated based on firm production capacity. This paper theoretically shows a new type of profit increase in sectors that are not exposed to international competition. This paper also illustrates the profit increase for the third phase of the EU-ETS and shows that profits in the electricity sector may increase by approximately 2% when free allowances are given to the other sectors.

*Keywords:* Tradable permits, Oligopoly markets, Output-based allocation, EU-ETS.

Classification JEL : F18 ; H2 ; Q5.

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# 1 Introduction

The first two phases of the European Union Emission Trading Scheme (EU-ETS) (2005-2012) were primarily characterized by a profit increase in all covered sectors, called "windfall profits." The electricity sector in particular benefited from this regulation (see Demailly & Quirion (2006)[3], (2008)[4]; Grubb & Neuhoff (2006)[9]; Neuhoff et al. (2006)[14]; Sijm et al. (2006) [21]; Smale et al. (2006) [22]). The primary explanation for the profit increase was that most allowances were given freely through grandfathering. To avoid these windfall profits and to decrease leakage, the distribution of free allowances in the EU-ETS changed in 2013. Thus, in the third phase, electric companies no longer receive free allowances, while Energy Intensive and Trade Exposed (EITE) sectors are granted free allowances that are calculated based on firm production capacity. This paper theoretically determines a possible phenomenon in which profits increase in the third phase of the EU-ETS and shows that, surprisingly, the electricity sector may benefit from the distribution of free allowances to the other sectors.

In the third phase of the EU-ETS, three categories of sectors covered by the EU-ETS are now considered. As of 2013, the power sector no longer receives free allowances; sensitive sectors, such as cement and steel, which face a significant risk of carbon leakage, may receive free allowances of up to 100% of their need; and other sectors receive a free allocation of 80% of their share of the pollution cap, which will be reduced by 10 percentage points each year, phasing free allocation out by 2020. Notice that, while all permits were previously grandfathered, a new mechanism for allocation entered into effect in 2013; it combines an ex-ante lump-sum transfer based on historic output (and multiplied by a benchmark) with an ex-post adjustment of this lump-sum according to rules related to actual capacity and activity level. Two thresholds have also been defined; the firm gets more (less) allowances if and only if the increase (decrease) of the production capacity is above (below) the upper (lower) threshold.

The primary difference between the new system and the previous one is that in the latter, grandfathered free allowances were lump-sum transfers from the regulator to firms, whereas in the new one, free allowances are determined according to firms' production capacity. Thus, the new system gives incentives to firms to adjust output to receive more free allocation,

and ultimately affects product prices and productions. In order to take into account this mechanism, we approximate this new system by an output-based allocation, which has the same characteristic. Obviously, the new system entered into effect in 2013 is not a proper output-based allocation but we consider that this latter captures sufficiently well its main feature.

Another motivation for analyzing output-based allocation is that several Emission Trading Schemes, such as the one in California or the one in Australia, use this mechanism of allocation. Moreover, pure output-based allocation is one of the various options proposed for the EU-ETS post 2020. Furthermore, the literature has not analyzed the impact of output-based allocation on profits in a context of several sectors covered by the same Emission Trade System. However, Fisher (2001)[7] analyzes the effect on profits in a single sector. While Monjon & Quirion (2011)[13] focuses on the impact on leakage of output based allocation when several sectors are regulated, Böhringer & Lange (2005)[1] analyzes the impacts in terms of welfare. Quirion (2007)[16] compares grand-fathering and output-based allocation in terms of profits. To the best of our knowledge, this paper is the first one to show how output-based allowances may induce a profit increase.<sup>1</sup>

This paper considers two sectors: an EITE sector and another sector not exposed to international competition. Moreover, firms compete "à la Cournot" in the market for products because the EU-ETS covers several oligopolistic sectors, such as electricity, cement, and steel.<sup>2</sup> The paper also assumes an iso-elastic demand function because this function has an interesting property that pertains to the issue in focus. A constant elasticity demand ensures the potential profit-increasing effect of a cost increase, which appears in the general demand framework. Indeed, Seade (1985)[20] shows that in a Cournot framework, an increase in the marginal cost of all firms can, counterintuitively, increase all profits. In other words, the permit price

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<sup>1</sup>The instrument of output based allocation is closed to the output based rebates, which are associated to a tax on emissions. For more details, see Fisher & Fox (2012)[8]

<sup>2</sup>Requate (2006)[19] surveys the different implications of environmental regulation in the presence of imperfect competition in the market for products.

increase may help firms to coordinate an increase in the prices of their products.<sup>3</sup> This paper considers a weak elasticity of demand in the nonexposed sector, as demand in the electricity sector is normally considered to be quite inelastic. Furthermore, these two previous assumptions (isoelasticity and weak elasticity) are consistent with Fabra & Reguant (2014)[6], which shows that the pass-through in the electricity sector is high. This paper examines, on the one hand, the implementation of a market for permits and, on the other hand, the output-based allocation of free allowances for the EITE sector firms. Output-based allocation reduces the effective marginal cost, which generates both production and pollution increases and, consequently, a permit price increase. If the nonexposed sector is sufficiently inelastic, profits may then increase with the permit price increase.

We call this phenomenon "windfall profits 2.0" because the free allowances induce a profit increase. However, this phenomenon is clearly different from that observed during the first two phases because the output-based free allowances may induce a profit increase in a different sector. This paper also numerically illustrates the profit increase for the third phase of the EU-ETS. We consider the three primary sectors covered by the EU-ETS: electricity, cement, and steel. We show that this increase in profits will be less substantial than that observed during the two first phases and that profits in the electricity sector may, in fact, increase by 2% when free allowances are given to the other sectors.

The remainder of this paper is structured as follows: Section 2 describes our model. In Section 3, we determine the effect of the distribution of proportional free allowances in one sector on firm profits in both sectors. In Section 4, we calculate the effect on profits for power companies in Europe resulting from the distribution of output-based allowances in the sensitive sectors during the third phase of the EU-ETS. Section 5 concludes the paper.

## 2 Set-up

Assume two geographical areas exist,  $H$  and  $F$ . Trade between the two zones is allowed, and there is no trade barrier. Assume two sectors,  $A$  and  $B$ , exist. The first sector is not exposed

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<sup>3</sup>This phenomenon cannot be observed with linear demand.

to international competition, while the second one is exposed to international competition. In each sector, there are  $n^j$  ( $j = A, B$ ) symmetric firms competing in a market and producing a homogenous good. To be more precise,  $n^B = n^{BH} + n^{BF}$ , where  $n^{BH}$  and  $n^{BF}$  are, respectively, the number of domestic and foreign firms competing in the second sector. The domestic market is served by firms from both countries. However, transportation from one area to another is costly and represented by a unit cost, denoted by  $\tau$ . The cost of transport is used to model the intensity of international competition.

The production technology is polluting in both sectors. Let  $c_i^j(\mu_i^j)$  and  $\mu_i^j$  be the marginal cost and the polluting factor, respectively, of firm  $i$  in sector  $j$ . The foreign production technology is also polluting and has the same initial emission rate as domestic technology. Let  $c^{BF}$  denote the foreign marginal production cost. Firms compete "a la Cournot," simultaneously choosing their quantity to maximize profits. Moreover, assume an iso-elastic demand function in each market. Let  $\beta^j$  be the elasticity of demand in sector  $j$ . Firms face a demand given by

$$P^j(Q) = \alpha^j Q^{-\frac{1}{\beta^j}} \quad \text{with} \quad Q = \sum_{i=1}^n q_i^j, \quad (1)$$

where  $\alpha_j$  is the market size in sector  $j$ .

**Assumption 1**  $\beta^j > 1/n^j$ . Assumption 1 states that the elasticity is higher than  $1/n^j$ , which, as shown below, ensures the existence of the equilibrium.

We also assume that

$$\tau < \left( \frac{\beta n^{BH} c^{BH}}{n^{BH} \beta - 1} - c^{BF} \right). \quad (2)$$

In other words, we assume that the transportation cost is sufficiently low that exporting is profitable for foreign firms before the introduction of the market for permits.

**Regulation** To reduce pollution, the regulator implements a market for permits in the domestic area. A firm must own a permit to pollute one unit. Let  $z$  be the reducing factor used by the regulator. Then, firms are price takers in the market for permits. The permit price is denoted by  $\sigma$  and clears when the supply equals the demand. Assume that the permits

for sector  $A$  are auctioned. However, assume that the firms in sector  $B$  may be granted free allowances on the basis of their production, and let  $\omega$  be the output-based rate for a firm in sector  $B$ . Free allowances are then equal to  $\varepsilon_i = \omega\mu_0q_i$ . The allowances depend on current production and the initial polluting factor. If the free allowances depend on the current polluting factor, the allowances are no longer calculated on the basis of output but on the basis of emissions. Notice that free allowances are expressed in units of emissions.

**Production and abatement costs** Firms may use an abatement technology to reduce emissions; this modifies both the polluting factor and the marginal cost of production. Thus, the cleaner a technology is, the higher its marginal cost. Meunier & Ponsard (2012)[12] assume that the unit cost of abatement in sector  $j$  for firm  $i$  is equal to

$$c_u(\mu) = c_i^j(\mu^j) + \frac{\gamma^j}{2}(\mu_0^j - \mu_i^j)^2, \quad (3)$$

where  $\mu^j$  is the resulting pollution factor of a firm and  $\mu_0^j$  is the initial pollution factor in sector  $j$ . Moreover, the right-hand side of the above expression represents the marginal cost of production, and the second part is the unit cost related to abatement.<sup>4</sup>

### 3 Output-based allocation and profit increase

We show that granting output-based allocation in a given sector may increase profits in another sector. First, we assess the advantages of granting output-based allocation in an EITE sector. Second, we focus on the effect of implementing pollution permits on profits in the nonexposed sector when the permit price is exogenous. We analyze a surprising effect of increased profits that may occur when demand is inelastic. Third, we endogenize the permit price and study the effect of output-based allocation on the equilibrium permit price. Finally, we show that

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<sup>4</sup>As Requate (2005)[18] notices, two types of abatement technologies are usually considered: end-of-pipe abatement and process integrated technology. However, the cleaner technology is a special case of process-integrated technology.

output-based allocation may increase profits in the nonexposed sector.

### 3.1 Improving competitiveness in the EITE sector

First, we discuss the effects of granting output-based allocation in sector  $B$ . To be more precise, we start by calculating the price and the individual quantities produced in equilibrium by domestic and foreign firms, and we then analyze the advantages in terms of competitiveness.

The profit of domestic firm  $i$  may be written as follows:

$$\pi_i^{BH}(q_i^{BH}, \mu_i^{BH}) = P^B(Q^B)q_i^{BH} - (c_i^{BH} + (\mu_i^{BH} - \omega\mu_0^{BH})\sigma)q_i^{BH} - \gamma^B(\mu_0^{BH} - \mu_i^{BH})^2 \frac{q_i^{BH}}{2}. \quad (4)$$

Firms maximize profits by choosing production and polluting factors. Derivating the profit function of firm  $i$  with respect to  $q_i^{BH}$  and  $\mu_i^{BH}$ , we obtain

$$\frac{\partial \pi_i^{BH}}{\partial q_i^{BH}} = P'^B(Q^B)q_i^{BH} + P^B(Q^B) - c_i^{BH} - (\mu_i^{BH} - \omega\mu_0^{BH})\sigma - \frac{\gamma^B}{2}(\mu_0^{BH} - \mu_i^{BH})^2 = 0, \quad (5)$$

$$\frac{\partial \pi_i^{BH}}{\partial \mu_i^{BH}} = -(c_i^{BH} + \sigma)q_i^{BH} + \gamma^B q_i^{BH}(\mu_0^{BH} - \mu_i^{BH}) = 0. \quad (6)$$

Firms modify their polluting factor in response to the implementation of pollution permits. However, the higher the output-based coefficient is, the lower the polluting factor will be. Indeed, granting output-based allowances softens the effect of implementing pollution permits.

Let us now focus on foreign firms' decisions, provided by

$$\pi_i^{BF}(q_i^{BF}, \mu_i^{BF}) = P^{BF}(Q^{BF})q_i^{BF} - (c_i^{BF} + \tau)q_i^{BF}. \quad (7)$$

Derivating the profit function of firm  $i$  with respect to  $q_i^{BF}$ , we obtain

$$\frac{\partial \pi_i^{BF}}{\partial q_i^{BF}} = P'^B(Q^B)q_i^{BF} + P^B(Q^B) - (c_i^{BF} + \tau) = 0. \quad (8)$$

Domestic firms take into account the permit price, whereas foreign firms are not subject to this regulation. The increase in the marginal cost of production of domestic firms is equal to



the permit price times the emission rate. The individual quantities produced by domestic and foreign firms are given in equilibrium by

$$q_i^{BH} = \left(\frac{\alpha^B}{\beta^B}\right)^{\beta^B} \frac{((n^{BF} + n^{BH})\beta^B - 1)^{\beta^B} (\beta^B n^{BF} (c^{BF} + \tau) + (1 - n^{BF} \beta^B)(c^{BH} + (\mu_i^{BH} - \omega \mu_0^{BH})\sigma))}{(n^{BH}(c^{BH} + (\mu_i^{BH} - \omega \mu_0^{BH})\sigma) + n^{BF}(c^{BF} + \tau))^{\beta^B + 1}}, \quad (9)$$

$$q_i^{BF} = \left(\frac{\alpha^B}{\beta^B}\right)^{\beta^B} \frac{((n^{BF} + n^{BH})\beta^B - 1)^{\beta^B} (\beta^B n^{BH} (c^{BH} + (\mu_i^{BH} - \omega \mu_0^{BH})\sigma) + (1 - n^{BH} \beta^B)(c^{BF} + \tau))}{(n^{BH}(c^{BH} + (\mu_i^{BH} - \omega \mu_0^{BH})\sigma) + n^{BF}(c^{BF} + \tau))^{\beta^B + 1}}. \quad (10)$$

The following lemma determines the effect of output-based allocation on domestic production. In other words, the lemma analyzes the effect of output-based allowances on competitiveness.

**Lemma 1.** *Domestic production in the exposed sector increases with the output-based rate.*

*Proof.* [Proof of Lemma 1] To demonstrate the improvements in competitiveness, we must demonstrate that  $\partial Q^{BH} / \partial \omega > 0$ .

From equation (9), we obtain the total quantity in sector  $B$  for domestic firms  $Q^{BH}$ . Derivating this function with respect to  $\omega$  and adding Assumption 1, we easily find that  $\partial Q^{BH} / \partial \omega > 0$ .  $\square$

The above lemma can be interpreted to show the incentive for the regulator to offer output-based allocation to improve competitiveness. A strategic trade effect arises: output-based allocation decreases the perceived marginal cost, increases domestic production, and reduces importations. This lemma is not surprising and justifies the use of mechanisms for output based allocation to alleviate leakage for Energy Intensive and Trade Exposed sectors.

### 3.2 The profit-altering effect of pollution permits in the nonexposed sector

The profit of firm  $i$  in sector A may be written as follows:

$$\pi_i^A(q_i^A, \mu_i^A) = P^A(Q^A)q_i^A - (c_i^A + \mu_i^A \sigma)q_i^A - \gamma(\mu_0^A - \mu_i^A)^2 \frac{q_i^A}{2}. \quad (11)$$

The first-order conditions satisfy

$$\frac{\partial \pi_i^A}{\partial q_i^A} = P'^A(Q^A)q_i^A + P^A(Q^A) - c_i^A - \mu_i^A \sigma - \frac{\gamma}{2}(\mu_0^A - \mu_i^A)^2 = 0, \quad (12)$$

$$\frac{\partial \pi_i^A}{\partial \mu_i^A} = -(c_i'^A + \sigma)q_i^A + \gamma q_i^A(\mu_0^A - \mu_i^A) = 0. \quad (13)$$

We then obtain

$$\mu_i^A = \left( \mu_0^A - \frac{1}{\gamma}(c_i'^A + \sigma) \right). \quad (14)$$

We sum the  $n$  first-order conditions in sector  $A$ , and we derive total production. Because firms are symmetric, we consider the symmetric equilibrium ( $q_1^A = q_2^A = q_i^A = Q^A/n^A$ ) and, using (14), obtain

$$q_i^A = \frac{1}{n^A} \left( \frac{\alpha^A(1 - 1/(n^A \beta^A))}{(c_i^A + \mu_0^A \sigma) + \frac{1}{2\gamma}((c_i'^A)^2 - \sigma^2)} \right)^{\beta^A}. \quad (15)$$

Taking the derivative of equation (12) with respect to  $\sigma$ , we obtain

$$P'^A Q'^A = \frac{n^A \mu_i^A}{(n^A - 1/\beta^A)}. \quad (16)$$

Because we analyze the effect of the permit price on firms' profits, we analyze the derivative of the function  $\pi_i^A$  with respect to  $\sigma$ , and we obtain

$$\frac{\partial \pi_i^A}{\partial \sigma} = q_i^A [P'^A(Q'^A - q_i'^A)] - \mu_i^A q_i^A. \quad (17)$$

By replacing (16) in (17), we obtain

$$\frac{\partial \pi_i^A}{\partial \sigma} = q_i^A \mu_i^A \left[ \frac{1 - \beta^A}{n^A \beta^A - 1} \right]. \quad (18)$$

The effect of the permit price on firm profits is presented in the next lemma:

**Lemma 2.** *If demand is sufficiently inelastic in sector  $A$  ( $\beta^A < 1$ ), profits in sector  $A$  increase*

*with the permit price.*

Profits increase when demand elasticity is weak ( $< 1$ ) and decrease otherwise. In other words, the permit price may help firms to coordinate an increase in their product prices. Indeed, when demand is iso-elastic and elasticity is low, the effect on the mark-up prevails over the effect on quantities. Our paper builds on this counterintuitive result. Note that this result is well known in the literature. According to Seade (1985)[20], profits increase with cost increases when the elasticity of the demand slope is sufficiently high. The elasticity of the slope of demand is constant with an iso-elastic demand function and equal to the inverse of the elasticity.

From the seminal work of Seade (1985)[20], a stream of environmental economics literature has developed. Kotchen & Salant (2011)[11] consider common-pool resources and show that implementing a tax or a regulatory constraint may increase profits. In the latter article, the condition under which profits increase is similar to that determined by Seade (1985)[20]. Hepburn et al. (2012)[10] determine the neutral-profit allowances and show that implementing pollution permits may increase profits when the demand curvature is quite large, even without free allowances. They assume asymmetric firms with respect to both marginal costs and pollution intensity. They do not consider the possibility of individual firms either modifying their emissions intensity or abating. Christin et al. (2013)[2] focus on the design of pollution permits and show that the effect of a permit price increase on firm profits depends on the type of available abatement technologies. They consider two abatement technologies: end-of-pipe and process-integrated abatement technologies. Both technologies considered differ from the one that we assume.

### ***3.3 Equilibrium in the market for permits***

In the market for permits, the aggregate demand for permits is equal to the total number of permits that firms need and that they have not been granted for free,  $\mu^A Q^A(\sigma) + \mu^B Q^B(\sigma) - \omega Q^B(\sigma)$ . The total supply is the number of permits that the social planner is ready to sell, that is,  $z(\mu_0^A Q^A(0) + \mu_0^B Q^B(0))$  minus free allowances  $-\omega Q^B(\sigma)$ . Thus, a perfectly competitive

permit market clears when supply equals demand, or

$$\mu^A Q^A(\sigma) + \mu^B Q^B(\sigma) = z (\mu_0^A Q^A(0) + \mu_0^B Q^B(0)) \quad (19)$$

In the case of grandfathering, free allowances do not modify the equilibrium permit price. However, in the case of proportional free allowances, free allowances may alter the equilibrium permit price. Indeed, as we noticed previously, output-based allocation decreases the effective marginal cost; however, production depends on the effective marginal cost. On the basis of the first-order conditions (5), we deduce that

$$\frac{\partial Q^B}{\partial \omega} > 0 \quad (20)$$

In other words, production increases with free allowances in sector  $B$ . Moreover, as a consequence of the increase in production, the demand for permits in sector  $B$  is modified. Indeed, the polluting factor is similarly altered by output-based allocation, i.e.,  $\partial(\mu^B Q_B)/\partial \omega > 0$ . On the basis of these results, we can deduce the following lemma:

**Lemma 3.** *Increasing the output-based rate in a given sector induces an increase in the equilibrium permit price:*

$$\frac{\partial \sigma^*}{\partial \omega} > 0 \quad (21)$$

This lemma shows that the distribution of output-based free allowances affects the equilibrium permit price. Indeed, the distribution of output-based free allowances in a single sector modifies the demand for permits in this sector whereas the demand in the other sector is not altered. Because the pollution cap for both sectors is fixed, the distribution of output-based free allowances in one sector increases the permit price and then affects the second sector. In other words, the total supply for permits is more reduced than the total demand for permits.

### 3.4 Windfall profits 2.0: profits increase in the nonexposed sector

On the basis of Lemma 2 and Lemma 3, we can deduce the following proposition:

**Proposition 1.** *If demand is sufficiently inelastic in sector A, profits in sector A increase with the output-based rate of sector B.*

*Proof of Proposition 1.* Let us focus on equation (21); the equilibrium permit price increases with the output-based rate for a firm in sector B. We add the conclusion of Lemma 2, which is  $\partial\pi_i^A/\partial\sigma > 0$  for a  $\beta^A < 1$ , and we quickly obtain that  $\partial\pi_i^A/\partial\omega > 0$ .  $\square$

This result is surprising because granting free allowances to a given sector may increase profits in another sector. The two channels are the permit price increase due to output-based allocation in the EITE sector and the profit-increasing effect in the electricity sector, which comes from the quite inelastic demand for electricity. In such a case, both sectors benefit from the distribution of output-based allocation in the EITE sector. This mechanism makes the environmental regulation acceptable to firms. However, the product price in the non exposed sector increases. In other words, this mechanism may be harmful for the customers of the electric sector.

In the next section, we illustrate this theoretical result for the three primary sectors covered by the EU-ETS: cement, electricity, and steel.

## 4 Illustration for the cement, electricity, and steel sectors under the EU-ETS

Assume that emissions are reduced by 5%. Three sectors are considered, namely, electricity, steel, and cement, which are the primary sectors covered by the EU-ETS. The electricity sector is auctioned, and the other sectors are regulated by granted free allowances. All of the values for the parameters are provided in Table 1 and are based on Reinaud (2004)[17], Meunier & Ponssard (2012)[12], and Nicolai (2014)[15].

Let us provide some details regarding the data used in the calibration:

1. The market size is based on the EU and represents the average projections of the market size in 2005 for a *BAU* scenario (2005 is the base year for the EU-ETS).

Table 1: Data for the parameters and calibration of the model

Sectors	Electricity	Steel	Cement
Market Size ( $\alpha$ )	3600	200	250
	Meunier & Ponssard (2012)[12]		
Elasticity ( $\beta$ )	0,4	0,6	0,5
	Meunier & Ponssard (2012)[12]		
Price (p)	47	313	64
	Demailly (2008)[4]	Reinaud (2004)[17]	
Unit cost ( $c^H$ )	37	247	46,8
	Nicolai (2014)[15]	Reinaud (2004)[17]	
Initial polluting factor ( $\mu_0$ )	0.37	1.3	0.7
	Meunier & Ponssard (2012)[12]		
Impact over unit cost ( $c'$ )	0,5	4,5	1,5
	Meunier & Ponssard (2012)[12]		
Cost's parameter of abatement ( $\gamma$ )	1017	115	315
	Calculation		
$\tau$		31	25
		Meunier & Ponssard (2012)[12]	
$c^F$		247	35
		Meunier & Ponssard (2012)[12]	
Market Structure	$n = \frac{1}{\beta(1-c/p)}$	$n^{BF} = 1 \ \& \ n^{BH} = \frac{P^B(1-\beta)+\beta(c^F+\tau)}{\beta^B(P^B-c^H)}$	
	12	7	7

2. Elasticities (absolute value) correspond to values over the short-term for observed prices, with the understanding that these elasticities are difficult to estimate in practice. Assume that electricity has a demand elasticity equal to 0,4. The demand elasticities of the steel

and cement sectors are assumed to be equal to 0,6 and 0,5, respectively.

3. Market structures are determined indirectly from market prices ( $BAU$ ) and unit costs by reversing the Cournot solution in a context without regulation and abatement costs (i.e., the number of firms is adjusted to fix on the observed prices and does not correspond to the number of firms observed). In other words, we determine the number of firms that fit the data from the previous parameters. We calculate the number of firms so that  $n^A = 1/\beta^A(1 - c^A/p^A)$ , and we round off to the higher unit.<sup>5</sup> In the simulation, we consider the set of foreign firms to be one exporter, i.e., the number of foreign firms is equal to one ( $n^{BF} = 1$ ). We are more interested in the total production and the emissions than in the particular structure of the foreign market.
4. In order to determine the abatement cost parameter in each sector, we calculate the optimal polluting factor; We use the two values of polluting factor calculated by Meunier & Ponssard (2012)[12] for  $\sigma = 0$  and  $\sigma = 30$ . We determine the value of abatement cost parameter by making a linear interpolation.<sup>6</sup>

**Without regulation** First, we focus on the effect of output-based allocation on the permit price. The base case is no free allowances, i.e.,  $\omega = 0$  for  $\sigma = 3, 9$ , which is not so far from the permit price observed in 2012 under the EU-ETS.

**Permit price** As we mentioned previously, output-based allocation decreases the perceived marginal cost, and production depends on the perceived marginal cost. In other words, granting free allowances increases production in the steel and cement sectors and thus modifies the demand for permits in these sectors. Because total demand increases, the equilibrium permit price also increases. As shown in Table 2, an increase in the output-based rate increases the permit price; e.g., for  $\omega = 0.1$ , the variation of  $\sigma$  is approximately 5,13%, and when  $\omega = 0, 5$ ,

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<sup>5</sup>For sector  $B$ , we calculate  $n^{BH} = [(p^B(1 - \beta^B) + \beta^B(c^{BF}))]/\beta^B(p - c^{BH})$  when  $n^{BF} = 1$ .

<sup>6</sup>By Meunier & Ponssard (2012)[12]:  $\mu_0^e(\sigma = 0) = 0,37$ ,  $\mu_i^e(\sigma = 30) = 0,34$ ,  $\mu_0^s(\sigma = 0) = 1,3$ ,  $\mu_i^s(\sigma = 30) = 1$ ,  $\mu_0^c(\sigma = 0) = 0,7$  and  $\mu_i^c(\sigma = 30) = 0,6$ .

the variation is approximately 28%. More importantly, however, the variation is approximately 82% for emissions when the rate is 1, which is the rate retained in the third phase of the EU-ETS.

Table 2: Illustration of the evolution of permit prices for various output-based rates

$\omega$	0	0,1	0,2	0,5	0,8	0,9	1
$\sigma$	3,9	4,1	4,3	5	6,1	6,6	7,1
$\frac{\sigma(\omega)-\sigma(0)}{\sigma(0)}$		5,13%	10,26%	28,21%	56,41%	69,23%	82,05%

**Emissions and leakage** We analyze how emissions and leakage are altered by output-based allocation. Emissions in the steel and cement sectors increase with the output-based rate, whereas emissions in the electricity sector decrease; e.g., as shown in Table 3, for  $\omega = 0,2$ , the variation of emissions is approximately -0,03% in the steel sector, 0,38% in the cement sector and approximately -0,26% in the electricity sector. For  $\omega = 1$ , the percentage of variation in the steel and cement sectors is approximately -0,07% and 3,49%, respectively. The level of emissions for the steel and cement sectors increases with  $\omega$ . Indeed, increasing  $\omega$  improves the sectors' competitiveness and increases the amount of domestic emissions, as we demonstrated in Lemma 1.

Let us now define carbon leakage. The existence of international trade, in addition to penalizing countries through the implementation of permit markets, led to a shift in pollution from one area to another. This carbon leakage, or "leakage," is defined by the UNFCCC<sup>7</sup> as the increase in emissions in countries that did not ratify Annex B of the Kyoto Protocol after the developing countries that ratified Annex B implemented carbon reduction regulations. Carbon leakage can be interpreted in the short term as a substitution between local and

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<sup>7</sup>The United Nations Framework Convention on Climate Change (UNFCCC or FCCC).



foreign production.

$$L_s = \mu_s(Q_s^F(\sigma) - Q_s^F(\sigma = 0)), \quad (22)$$

$$L_c = \mu_c(Q_c^F(\sigma) - Q_c^F(\sigma = 0)), \quad (23)$$

$$L_T = E_T^F(\sigma) - E_T^F(\sigma = 0). \quad (24)$$

Table 3 shows that when the output-based rate increases, the amount of carbon leakage decreases in the sectors. Then, if we define carbon leakage according to equation (24), we can more clearly observe the effect of the allocation of free allowances in the sectors. According to the results shown in Table 3, the leakage for the steel industry decreases; e.g., the variation is approximately -6% for  $\omega = 0,1$  and approximately -95% for  $\omega = 0,9$ . However, we observe the same result for the cement sector, e.g., the variation is -5,4% for  $\omega = 0,1$  and -88% for  $\omega = 0,9$ . Obviously, carbon leakage almost disappears when the output-based rate is 90%.

**Product prices** To analyze the effect of output-based allocation on consumers, we focus on the evolution of product prices in Table 4. The most surprising result is that for a 90% allocation of permits for the steel and cement sectors, electricity prices increase by 2,6%. Thus, the cost of output-based allocation is primarily borne by consumers of electricity. However, the prices of steel and cement decrease. For instance, for  $\omega = 0,9$ , the prices of steel and cement vary by -1,6% and -4%, respectively.

Table 3: Illustration of the evolution of emissions for various output-based rates

$\omega$	0	0,1	0,2	0,5	0,8	0,9	1
$E_e$	2,047	2,044	2,042	2,033	2,018	2,012	2,005
$\frac{E_e(\omega)-E_e(0)}{E_e(0)}$		-0,13%	-0,26%	-0,71%	-1,41%	-1,73%	-2,04%
$E_s$	0,846	0,846	0,846	0,846	0,845	0,845	0,845
$\frac{E_s(\omega)-E_s(0)}{E_s(0)}$		-0,02%	-0,03%	0,00%	-0,06%	-0,09%	-0,07%
$E_c$	1,237	1,239	1,242	1,252	1,266	1,273	1,281
$\frac{E_c(\omega)-E_c(0)}{E_c(0)}$		0,16%	0,38%	1,21%	2,34%	2,84%	3,49%
$L_s$	0,008	0,007	0,007	0,005	0,002	0,000	-0,001
$\frac{L_s(\omega)-L_s(0)}{L_s(0)}$		-6,00%	-13,10%	-40,04%	-78,14%	-95,26%	-115,45%
$L_c$	0,028	0,026	0,024	0,017	0,008	0,003	-0,002
$\frac{L_c(\omega)-L_c(0)}{L_c(0)}$		-5,36%	-11,78%	-36,47%	-72,03%	-88,30%	-107,86%
$L_T$	0,035	0,033	0,031	0,022	0,009	0,004	-0,003
$\frac{L_T(\omega)-L_T(0)}{L_T(0)}$		-5,50%	-12,07%	-37,25%	-73,37%	-89,83%	-109,53%

**Profits** Now, we focus on the effect of output-based allocation on profits in Table 5. We find that increasing the percentage of proportional free allowances increases the profit of the sector with lower elasticity, i.e., the electricity sector. This result is counterintuitive because the electricity sector does not receive free allowances. We observe that the profit increase for the electricity sector is approximately 1,8% in the third phase of the EU-ETS ( $\omega = 1$ ).

To conclude, we empirically verify the main result of the article, i.e., granting output-based allocation to the steel and cement sectors induces a profit increase in the electricity sector.

## 5 Conclusion

This paper shows that the distribution of permits in the next phase of the EU-ETS, which aimed to eliminate windfall profits and protect firm competitiveness, may, in fact, increase electric companies' profits. The distribution of capacity-based free allowances in the sensitive

Table 4: Illustration of the evolution of products prices for various output-based rates

$\omega$	<b>0</b>	<b>0,1</b>	<b>0,2</b>	<b>0,5</b>	<b>0,8</b>	<b>0,9</b>	<b>1</b>
$P_e$	48,550	48,643	48,735	49,058	49,565	49,795	50,024
$\frac{P_e(\omega)-P_e(0)}{P_e(0)}$		0,19%	0,38%	1,05%	2,09%	2,56%	3,04%
$P_s$	322,184	321,858	321,474	320,030	318,026	317,139	316,103
$\frac{P_s(\omega)-P_s(0)}{P_s(0)}$		-0,10%	-0,22%	-0,67%	-1,29%	-1,57%	-1,89%
$P_c$	67,707	67,528	67,317	66,521	65,425	64,941	64,374
$\frac{P_c(\omega)-P_c(0)}{P_c(0)}$		-0,26%	-0,58%	-1,75%	-3,37%	-4,09%	-4,92%

Table 5: Illustration of the evolution of profits for various output-based rates

$\omega$	<b>0</b>	<b>0,1</b>	<b>0,2</b>	<b>0,5</b>	<b>0,8</b>	<b>0,9</b>	<b>1</b>
$\pi_e$	4,719	4,724	4,729	4,748	4,778	4,791	4,804
$\frac{\pi_e(\omega)-\pi_e(0)}{\pi_e(0)}$		0,11%	0,23%	0,63%	1,25%	1,53%	1,81%
$\pi_s$	6,903	6,907	6,911	6,928	6,950	6,960	6,972
$\frac{\pi_s(\omega)-\pi_s(0)}{\pi_s(0)}$		0,05%	0,12%	0,37%	0,69%	0,83%	1,00%
$\pi_c$	4,711	4,716	4,721	4,743	4,772	4,784	4,800
$\frac{\pi_c(\omega)-\pi_c(0)}{\pi_c(0)}$		0,10%	0,22%	0,67%	1,29%	1,56%	1,89%

sectors may thus increase profits in the power sector. We call this new phenomenon "windfall profits 2.0." The primary difference between "windfall profits 2.0" and traditional windfall profits is that the product price in the electricity sector increases with the rate of free allowances in the other sectors. Thus, "windfall profits 2.0" are borne by consumers alone rather than by both consumers and the state, as with windfall profits in the previous phases. In other words, consumers of electricity will be more affected during the next phase of the EU-ETS than in previous phases.

## Appendix

### A *Table of Quantities, Emissions and Prices in each Sector*

In Tables 6 and 7, we present the individual and total quantities, the emissions rates and the market prices for each sector.

Table 6: Quantities, emission rate and prices in sector  $A$

	<b>Sector <math>A</math></b>
Individual Quantities	$q_i^A = \frac{1}{n^A} \left( \frac{\alpha^A(1-1/(n^A\beta^A))}{(c_i^A+\mu_0^A\sigma)+\frac{1}{2\gamma}(c_i'^{A^2}-\sigma^2)} \right)^{\beta^A}$
Emission rate	$\mu_i^A = \mu_0^A - \frac{1}{\gamma}(c_i'^A + \sigma)$
Total Quantities	$Q^A = \left( \frac{\alpha^A(1-1/(n^A\beta^A))}{(c_i^A+\mu_0^A\sigma)+\frac{1}{2\gamma}(c_i'^{A^2}-\sigma^2)} \right)^{\beta^A}$
Price	$P_i^A(Q^A) = \frac{c_i^A+\mu_0^A\sigma+\frac{1}{2\gamma}(c_i'^{A^2}-\sigma^2)}{1-1/(n^A\beta^A)}$

Table 7: Quantities, emission rate and prices in sector  $B$

	Sector $B$
Individual	$q_i^H = (\frac{\alpha^B}{\beta^B})^{\beta^B} \frac{((n^{BF}+n^{BH})\beta^B-1)^{\beta^B} (\beta^B n^{BF} (c^{BF}+\tau) + (1-n^{BF} \beta^B)(c^{BH}+(\mu_i^{BH}-\omega \mu_0^{BH})\sigma))}{(n^{BH}(c^{BH}+(\mu_i^{BH}-\omega \mu_0^{BH})\sigma)+n^{BF}(c^{BF}+\tau))^{\beta^B+1}}$
Quantities	$q_i^F = (\frac{\alpha^B}{\beta^B})^{\beta^B} \frac{((n^{BF}+n^{BH})\beta^B-1)^{\beta^B} (\beta^B n^{BH} (c^{BH}+(\mu_i^{BH}-\omega \mu_0^{BH})\sigma) + (1-n^{BH} \beta^B)(c^{BF}+\tau))}{(n^{BH}(c^{BH}+(\mu_i^{BH}-\omega \mu_0^{BH})\sigma)+n^{BF}(c^{BF}+\tau))^{\beta^B+1}}$
Emission rate	$\mu_i^{BH} = \mu_0^{BH} - \frac{1}{\gamma^B} (c_i^{BH} + \sigma)$ $\mu_0^{BF} = \mu_0^{BH}$
Total Quantities	$Q^{BH} + Q^{BF} = (\frac{\alpha^B}{\beta^B})^{\beta^B} \frac{((n^{BF}+n^{BH})\beta^B-1)}{(n^{BH}(c^{BH}+(\mu_i^{BH}-\omega \mu_0^{BH})\sigma)+n^{BF}(c^{BF}+\tau))}$
Price	$P^B = \beta^B \frac{(n^{BH}(c^{BH}+(\mu_i^{BH}-\omega \mu_0^{BH})\sigma)+n^{BF}(c^{BF}+\tau))}{((n^{BF}+n^{BH})\beta^B-1)}$

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