The "windfall profits 2.0" during the third phase of EU-ETS

June 11, 2014

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, whereas energy intensive and trade exposed sectors are granted free allowances, which are calculated based on firms' output. This paper theoretically shows a new type of profit increase in sectors that are not exposed to international competition. The paper also numerically determines the order of magnitude of the profit increase for the third phase of the EU-ETS and shows that profits in the electricity sector may increase by approximately 1.5% when free allowances are given to the other sectors.

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

Classification JEL : F18 ; H2 ; Q5.

1 Introduction

The first two phases of the 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)[2], (2008)[3]; Grubb & Neuhoff (2006)[6]). 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, whereas Energy Intensive and Trade Exposed (EITE) sectors are granted free allowances, which are calculated based on firms' output. 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. Moreover, a new mechanism of allocation entered into effect in 2013; allowances are now given according to firms' production capacity if the variation is sufficiently important.[1] Output-based allocation seems to be a good approximation of this mechanism. Furthermore, pure output-based allocation is one of the various options that are proposed for the EU-ETS post 2020.

The primary difference between the new system and the previous one is that in the previous system with grandfathering, free allowances were lump-sum transfers from the regulator to firms, whereas in the new system, free allowances are determined according to firms' production capacity. Thus, in the new system, free allowances diminish the perceived marginal cost of production and ultimately affect product prices and production. The literature has compared the two systems[2] and analyzed the phenomenon of windfall profits but has not focused, to the best of our knowledge, on how output-based allowances may induce a profit increase.

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

[1]Two thresholds have been defined. For more details, see Ellerman et al. (2010)[4].

[2]See Quirion(2007) [11] for a comparison of various methods of allocation.

because the EU-ETS covers several oligopolistic sectors, such as electricity, cement, and steel.[3] 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)[15] 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 increase may help firms to coordinate an increase in the prices of their products.[4] 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. This assumption is consistent with Fabra & Reguant (2014)[5] 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's firms. Output-based allocation reduces the perceived 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, as 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 1,4% 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

[3]Requate (2006)[14] surveys the different implications on environmental regulation of the presence of imperfect competition in the market for products.

[4]This phenomenon cannot be observed with linear demand.

sector on firms' 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, called A and B, exist. The first sector is not exposed 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 τ. 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 μ_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 β^j be the elasticity of demand in sector j. Firms face a demand given by

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

where α_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

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

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 σ 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 ω be the output-based rate for a firm in sector B. Free allowances are then equal to $\varepsilon_i = \omega\mu_0 q_i$. The allowances depend on the current production and the initial polluting factor. If the free allowances depend on the current polluting factor, the allowances are not anaymore 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, which modifies both the polluting factor and the marginal cost of production. Thus, the cleaner a technology is, the higher its marginal cost is. Meunier & Ponssard (2011)[9] assume that the unit cost of abatement in sector j for firm i is equal to

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

where μ^j is the resulting pollution factor of a firm and μ_0^j is the initial pollution factor in sector j. Moreover, the right-hand side of the above expression represents the marginal cost $c_i^j(\mu)$ of production, and the second part, is the unit cost related to abatement.[5]

[5]As Requate (2005)[13] 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.

3 Output-based allocation and profits 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 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 μ_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 implementing 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

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

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

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

Domestic firms take into account the permit price, whereas foreign firms are not subject to this regulation. The increase in 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

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

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

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. *Granting output-based allocation to the exposed sector's firms improves competitiveness.*

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 ω and adding Assumption 1, we easily find that $\partial Q^{BH}/\partial\omega > 0$. □

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 mechanism of outputbased 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 of 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 the 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) and 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 σ, 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 π_i^A with respect to σ, and we obtain

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

Moreover,

$$\frac{\partial C_i^A}{\partial \sigma} = \mu_i^A q_i^A. \tag{18}$$

By replacing (16) and (18) in (17), we obtain

$$\frac{\partial \pi_i^A}{\partial \sigma} = q_i^A \mu_i^A \left[\frac{1 - \beta^A}{n^A \beta^A - 1}\right]. \tag{19}$$

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

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

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)[15], 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)[15], a stream of environmental economics literature has developed. Kotchen & Salant (2011)[8] consider common-pool resources and show that implementing a tax or a regulatory constraint may increase profits. The condition in the latter article, under which profits increase, is similar to that determined by Seade (1985)[15]. Hepburn et al. (2012)[7] 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)[1] focus on the design of pollution permits and show that the effect of a permit price increase on firms' 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 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, $z\left(\mu_0^A Q_A(0) + \mu_0^B Q_B(0)\right)$ minus free allowances $-\omega Q_B(\sigma)$. Thus, a perfectly competitive permit market clears when supply equals demand, or

$$\mu^A Q_A(\sigma) + \mu^B Q_B(\sigma) = z\left(\mu_0^A Q_A(0) + \mu_0^B Q_B(0)\right) \tag{20}$$

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, the equilibrium perceived marginal cost of sector B depends on the output-based allocation, and

$$\frac{\partial c^B}{\partial \omega} < 0 \tag{21}$$

Output-based allocation decreases the perceived marginal cost; however, production depends on the perceived marginal cost, and on the basis of the first-order conditions (5), we deduce that

$$\frac{\partial Q^B}{\partial \omega} > 0 \tag{22}$$

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., $\partial(\mu^B Q_B)/\partial\omega > 0$. Because total demand increases, the equilibrium permit price also increases with output-based free allowances, and

$$\frac{\partial\sigma^*}{\partial\omega} > 0 \tag{23}$$

On the basis of these results, we can deduce the following lemma:

Lemma 3. *Granting output-based allocation to firms in a given sector induces an increase in the perceived marginal cost in another sector:*

$$\frac{\partial c^A}{\partial\omega} > 0$$

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

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, granting output-based allocation to sector B may increase profits in sector A.*

Proof of Proposition 1. Let us focus on equation (23), 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 $\partial\pi_i^A/\partial\omega > 0$. □

This result is surprising because granting free allowances to a given sector may increase profits in another sector. The two channels are: the permits 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 from the point of view of firms. However, the product price in the non exposed sector increases. In other words, this mechanism may be harmful for the consumers 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)[12], Meunier & Ponssard (2011)[9], and Nicolai (2014)[10].

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 sizes in the 2005, for a BAU scenario (2005 is the base year for the EU-ETS).

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 0,3, 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

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

Sectors	**Electricity**	**Steel**	**Cement**
Market Size (α)	3600	200	250
	Meunier & Ponssard (2011)[9]		
Elasticity (β)	0,4	0,6	0,3
	Meunier & Ponssard (2011)[9]		
Price (p)	47	313	64
	Demailly (2008)[3]	Reinaud (2004)[12]	
Unit cost (c^H)	37	247	46,8
	Nicolai (2014)[10]	Reinaud (2004)[12]	
Impact over unit cost (c')	0,5	4,5	1,5
	Meunier & Ponssard (2011)[9]		
Cost's parameter of abatement (γ)	1017	115	315
	Meunier & Ponssard (2011)[9]		
τ		31	25
		Meunier & Ponssard (2011)[9]	
c^F		247	35
		Meunier & Ponssard (2011)[9]	
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	12

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.[6] 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.

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

4. We determine the cost parameter for abatement by the inverse of the pollution factor solution, i.e., we fix γ on the values observed from $\mu_i^j(\sigma = 30)$, $\mu_0^j(\sigma = 0)$ and the marginal cost in each sector.[7]

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 $\sigma = 4,6$, which is quite close to 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 σ is approximately 2,6%, and when $\omega = 0,5$, the variation is approximately 20%. More important, however, the variation is approximately 52% 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

ω	**0**	**0,1**	**0,2**	**0,5**	**0,8**	**0,9**	**1,0**
σ	4,6	4,72	4,9	5,5	6,3	6,6	7
$\frac{\sigma(\omega)-\sigma(0)}{\sigma(0)}$		2,61%	6,52%	19,57%	36,96%	43,48%	52,17%

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 $\omega = 0,2$,

[7] By Meunier & Ponssard (2011)[9]: $\mu_0^e(\sigma = 0) = 0,37$, $\mu_i^e(\sigma = 30) = 0,34$, $\mu_0^s(\sigma = 0) = 1,3$, $\mu_i^s(\sigma = 30) = 1$, $\mu_0^c(\sigma = 0) = 0,7$ and $\mu_i^c(\sigma = 30) = 0,6$.

the variation of emissions is approximately 0,15% in the steel and 0,37% for the cement sector and approximately -0,2% in the electricity sector. For $\omega = 1$, the percentage of variation in the steel and cement sectors is approximately 0,83% and 2,5%, respectively. The level of emissions for the steel and cement sectors increases with ω. Indeed, increasing ω 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[8] as the increase in emissions in countries that have not ratified Annex B of the Kyoto Protocol after developing countries that have ratified Annex B implemented carbon reduction regulations. Carbon leakage can be interpreted in the short term as a substitution between local and foreign production.

$$L_s = \mu_s(Q_s^F(\sigma) - Q_s^F(\sigma = 0)), \tag{24}$$

$$L_c = \mu_c(Q_c^F(\sigma) - Q_c^F(\sigma = 0)), \tag{25}$$

$$L_T = E_T^F(\sigma) - E_T^F(\sigma = 0). \tag{26}$$

Table 3 shows that when the output-based rate increases, the amount of carbon leakage decreases in the sectors. Then, if we define the carbon leakage according to equation (26), 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 -8,2% for $\omega = 0,1$ and approximately -96% for $\omega = 0,9$. However, we observe the same result for the cement sector, e.g., the variation is -7,5% for $\omega = 0,1$ and -90% for $\omega = 0,9$. Obviously, carbon leakage almost disappears when the output-based rate is 90%.

[8]The United Nations Framework Convention on Climate Change (UNFCCC or FCCC).

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

ω	**0**	**0,1**	**0,2**	**0,5**	**0,8**	**0,9**	**1,0**
E_e	2,038	2,036	2,034	2,026	2,016	2,012	2,007
$\frac{E_e(\omega)-E_e(0)}{E_e(0)}$		-0,08%	-0,19%	-0,58%	-1,09%	-1,28%	-1,53%
E_s	0,839	0,840	0,840	0,842	0,844	0,845	0,846
$\frac{E_s(\omega)-E_s(0)}{E_s(0)}$		0,10%	0,15%	0,37%	0,62%	0,74%	0,83%
E_c	0,969	0,971	0,972	0,978	0,986	0,990	0,993
$\frac{E_c(\omega)-E_c(0)}{E_c(0)}$		0,21%	0,37%	0,99%	1,81%	2,16%	2,52%
L_s	0,009	0,008	0,008	0,005	0,002	0,000	0,000
$\frac{L_s(\omega)-L_s(0)}{L_s(0)}$		-8,16%	-15,95%	-44,05%	-80,87%	-95,94%	-100,00%
L_c	0,016	0,015	0,014	0,010	0,004	0,002	0,000
$\frac{L_c(\omega)-L_c(0)}{L_c(0)}$		-7,45%	-14,54%	-40,54%	-75,41%	-89,99%	-100,00%
L_T	0,025	0,023	0,021	0,015	0,006	0,002	0,000
$\frac{L_T(\omega)-L_T(0)}{L_T(0)}$		-7,70%	-15,05%	-41,80%	-77,37%	-92,12%	-100,00%

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%. 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 -1,8% and -5,17%, respectively.

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

ω	**0**	**0,1**	**0,2**	**0,5**	**0,8**	**0,9**	**1,0**
P_e	48,874	48,929	49,012	49,289	49,657	49,795	49,978
$\frac{P_e(\omega)-P_e(0)}{P_e(0)}$		0,11%	0,28%	0,85%	1,60%	1,88%	2,26%
P_s	323,102	322,580	322,084	320,317	318,051	317,139	316,121
$\frac{P_s(\omega)-P_s(0)}{P_s(0)}$		-0,16%	-0,31%	-0,86%	-1,56%	-1,85%	-2,16%
P_c	68,190	67,879	67,586	66,541	65,205	64,666	64,069
$\frac{P_c(\omega)-P_c(0)}{P_c(0)}$		-0,46%	-0,89%	-2,42%	-4,38%	-5,17%	-6,04%

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 the 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 2,0% in the third phase of the EU-ETS ($\omega = 1$).

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

ω	**0**	**0,1**	**0,2**	**0,5**	**0,8**	**0,9**	**1,0**
π_e	$4,737$	$4,741$	$4,745$	4,762	4,783	4,791	4,801
$\frac{\pi_e(\omega)-\pi_e(0)}{\pi_e(0)}$		0,07%	0,17%	0,51%	0,96%	1,13%	1,35%
π_s	6,883	6,891	6,897	6,919	6,948	6,960	6,972
$\frac{\pi_s(\omega)-\pi_s(0)}{\pi_s(0)}$		0,10%	0,19%	0,52%	0,94%	1,11%	1,29%
π_c	2,159	2,157	2,155	2,149	2,140	2,137	2,133
$\frac{\pi_c(\omega)-\pi_c(0)}{\pi_c(0)}$		-0,08%	-0,17%	-0,47%	-0,86%	-1,02%	-1,20%

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 firms' competitiveness, may, in fact, increase electric companies' profits. The distribution of output-based free allowances in the sensitive 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 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 Table 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

	Sector A
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	$\mu_i^A = \left(\mu_0{}^A - \frac{1}{\gamma}(c_i'^A+\sigma)\right)$
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	$P_i^A(Q^A) = \left(\frac{c_i^A+\mu_0^A\sigma+\frac{1}{2\gamma}(c_i'^{A^2}-\sigma^2)}{1-1/(n^A\beta^A)}\right)$

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

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

References

[1] Christin, C., Nicolaï, J.-Ph. and Pouyet, J. (2013), Pollution permits, abatement technologies and imperfect competition, ETH Working paper.

[2] Demailly, D. and Quirion, P. (2006), CO2 abatement, competitiveness and leakage in the European Cement Industry under the EU ETS: grandfathering versus output-based allocation. Climate Policy 6:93-113.

[3] Demailly, D. and Quirion, P. (2008), Concilier compétitivité industrielle et politique climatique : faut-il distribuer les quotas de CO2 en fonction de la production ou bien les ajuster aux frontières ?, La revue économique 59(3):497-504.

[4] Ellerman, D., Convery, F.J. and de Perthuis, C. (2010), Pricing Carbon: The European Union Emissions Trading Scheme. Cambridge University Press.

[5] Fabra, N and Reguant, M. (2014), Pass-Through of Emissions Costs in Electricity Markets, American Economic Review, forhtcoming.

[6] Grubb, M. and Neuhoff, K. (2006), Allocation and competitiveness in the EU emissions trading scheme: policy overview, Climate Policy 6:7-30.

[7] Hepburn, C., Quah, J. and Ritz, R. (2012), Emissions trading with profit-neutral permit allocations, Journal of Public Economics 98:85-99.

[8] Kotchen M, and Salant S, (2011), A free lunch in the commons. Journal of Environmental Economics and Management 61:245-253.

[9] Meunier, G. and Ponssard, J.P. (2011), A Sectoral Approach Balancing Efficiency and Equity, working paper, Ecole Polytechnique.

[10] Nicolaï, J.Ph. (2014), Conditions for profit-neutral permit allocations, ETH working paper.

[11] Quirion, P. (2007), Comment faut-il distribuer les quotas échangeables de gaz à effet de serre ? Revue française d'économie 22(2):129-164.

[12] Reinaud, J. (2004), Industrial Competitiveness Under The European Union Emissions Trading Scheme, International Energy Agency Information paper.

[13] Requate, T. (2005), Dynamic incentives by environmental policy instruments: a survey, Ecological Economics 54, 175-195.

[14] Requate, T. (2006), Environmental Policy under Imperfect Competition,§ in: Folmer, H. and T. Tietenberg: The International Yearbook of Environmental and Resource Economics 2006/2007, pp. 120-208,Edward Elgar.

[15] Seade, J. (1985), Profitable Cost Increases and the Shifting of Taxation, unpublished University of Warwick Economic Research Paper.