Changing the allocation rules for EU greenhouse gas allowances: impact on competitiveness, revenue distribution and economic efficiency

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Abstract

In this paper, we assess four proposals for the future of the EU greenhouse gas Emission Trading Scheme (ETS) – pure grandfathering allocation of emission allowances (GF), output-based allocation (OB), auctioning (AU) and auctioning with border tax adjustments (BTA) – according to their economic efficiency, the competitive distortions they induce vis-à-vis the rest of the world and their distributive impacts. We do not treat the industry as homogenous but use a partial equilibrium model featuring three sectors covered by the EU ETS – cement, steel and electricity – plus the aluminium sector, which is indirectly impacted through a rise in electricity price.

It turns out that competitive distortions are globally low, for all policies and especially under OB or BTA. For a 5% cut in emissions compared to business-as-usual, the production losses are well below the average inter-annual variation in all sectors and for every policy. These losses are mostly due to reductions in consumption rather than to market share losses, except in the steel sector. Impacts of all policies on firms' profits are moderate, even under AU: they are below the average inter-annual variation for a cut in emissions up to 15%. Windfall profits emerge under GF in all sectors covered by the ETS, at different scale however. Under all proposals, consumers bear most if not all the cost of CO2 emission reduction. Concerning the overall cost, OB appears to be the least efficient policy, even when taking into account its ability to prevent CO2 leakage. On the other hand, this policy minimises wealth transfers among stakeholders, which is likely to soften oppositions. The overall cost of GF and AU is close despite the partial regulation of the EU electricity sector, which slightly raises the cost of the former. Finally, the ability of BTA to prevent CO2 leakage makes it the most efficient policy.

Keywords

Industry, leakage, spillover, climate change mitigation, Kyoto Protocol, border-tax adjustment, international trade, transportation cost

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1. Introduction

The EU ETS, created by directive 2003/83/EC and presented in a box below, has started operating in January 2005. It is one of the main EU climate policies and the most important ETS worldwide by the value of allowances (Grubb and Neuhoff, 2006). Moreover it is often seen as the possible core a future international architecture (Stern, 2006) hence its performance is under world scrutiny. The ETS is currently being reviewed by the European Commission (2006), who will make a legislative proposal to revise the directive in the second half of 2007. The changes will take effect in 2013 at the start of the scheme's third trading period. In this context, the main criticisms addressed to the system are the following.

First, many scholars and stakeholders criticise the lack of harmonisation in allowance allocation across Member States and claim for a harmonised or centralised allocation method at the European level (e.g. Buchner et al., 2006). Since there is a general agreement on this point, we will not address it.

Apart from that, three main families of critics have been raised:

⇒ Some features of the allocation methods (updating of allocation every five years based on new information, new entrants reserve and withdrawal of allowances for closing installations) create perverse incentives in production and abatement decisions and jeopardize the economic efficiency of the system (Neuhoff et al., 2005; Neuhoff et al., 2006; Ahman et al., 2006; Schleich and Betz, 2005).

⇒ The EU CO2-intensive industry may suffer from a competitive disadvantage vis-à-vis competitors located in countries without a similar climate policy. Such a competitive distortion vis-à-vis the rest of the world may induce a loss in market shares and employment. It may also entail CO2 leakage, i.e., a part of the emission reductions generated in the EU may be offset by an increase in emissions elsewhere.

⇒ The distributive impact of the ETS is often criticised as unfair. In particular, large electricity consumers claim that utilities benefit from windfall profits, passing the value of CO2 emissions on to prices although they receive allowances for free (Sijm et al., 2006)

Several proposals on the table aim at solving all or some of these problems. Most of them focus on the allocation methodology, which has already been recognised as the Achile's heel of the directive (Boemare and Quirion, 2002). Indeed allocation is not only a distributive issue but may impact economic efficiency and competitive distortions vis-à-vis the rest of the world. The four proposals we assess in this paper are the following.

Output-based allocation (OB). Under this allocation method – also called intensity caps – the amount of free allowances a firm gets is proportional to its current output level. It is promoted by many industrials (EPE, 2005; Eurofer, 2005; Cembureau, 2006) in the context either of the EU ETS or of international sectoral approaches. Demailly and Quirion (2006a) have shown, with a sectoral model of the cement industry, that OB induces no windfall profit and reduces competitive distortions vis-à-vis the rest of the world and CO2 leakage. However it may reduce economic efficiency compared to auctioning or grandfathering (Burtraw et al. 2001, Fisher 2001, Haites, 2003). Whether this remains true when leakage is accounted for is an open question we address in this paper.

Grandfathering (GF). We already stressed that the current allocation method in the EU ETS leads to perverse economic incentives, which would not exist under auctioning or pure grandfathering, i.e., if all allowances were distributed freely without taking account of new information. Hence some authors propose to bring the current allocation method closer to grandfathering in order to improve its efficiency. This is the aim of Ahman et al (2006)'s "ten year rule" or Godard (2005)'s suggestion to suppress the new entrants reserves and the withdrawal of allowances for closing installations. However, such proposals could worsen the competitive distortions – updating, new entrants reserve and closure rules create an incentive against relocation in foreign countries – and increase further windfall profits, as shown by Demailly and Quirion (2006b) with a sectoral model of the steel industry.

Auctioning (AU). Competitive distortions would remain or could even be worsened if allowances were auctioned but windfall profits would disappear and this allocation method is generally considered as the most economically efficient, for two reasons. First and foremost, because the revenue raised through the auction may be used to finance cuts in pre-existing distortionary taxes (e.g. Goulder et al. 1999). Second because AU leads to the full internalisation of emission cost in electricity prices, even in price regulated markets, whereas it might not be the case under GF. Burtraw et al. (2001) highlighted the importance of this effect for a US ETS covering the power sector. In this paper, we assess the magnitude of the latter effect in the EU ETS context.

Auctioning with border-tax adjustments (BTA). In such a system, exporters from the EU would get charges they incur refunded, at least partially, while importers would face a tax based on the emissions embedded in their products. On the one hand, compared with AU, it would solve the competitive distortions issue, particularly leakage, as shown by Hoel (1996) with a theoretical model, by Demailly and Quirion (forthcoming) with a model of the cement sector and by Mathiesen and Maestad (2002) with a model of the steel sector. On the other hand it would increase the impact on EU consumers. Hence its economic efficiency is unclear and we asses it in this paper. It is worth highlighting that the compatibility of BTA with WTO rules is controversial (Ismer and Neuhof, 2004; Biermann and Brohm, 2005) but they recently had the support of the Nobel Prize laureate Joseph Stiglitz (2006), French Prime Minister Dominique de Villepin (2006) or the EU industry commissioner Günter Verheugen (2006).

In this paper, we assess both analytically and numerically the application of these four proposals to the EU ETS, using three criteria: economic efficiency, competitive distortions vis-à-vis the rest of the world and distributive impacts. To our knowledge, such a comprehensive assessment has not been led yet. Bernard and Vielle (2005) and Klepper and Peterson (2006) analyse with general equilibrium models the existing EU ETS but do not assess these proposals. Burtraw et al. (2001) or Haites (2003) analyze some of these proposals but not within the EU ETS context. Moreover, when assessing the economic efficiency of proposals, we take into account the CO2 leakage they would induce and the impact of regulation in the EU electricity sector. This paper required the development of a partial equilibrium model – CASE – featuring four sectors – Cement, Aluminium, Steel and Electricity – linked through electricity and CO2 markets. By using a partial equilibrium model, we know that we do not account for pre-existing distortions or macroeconomic feedbacks – on world energy prices for example. However, when such mechanisms are of importance, we use insights from papers based on general equilibrium models to draw more robust conclusions.

When assessing the impacts of climate policies, it would be misleading to treat the industry as a homogenous sector. Indeed, the industrial sectors differ by their CO2 intensity, their trade exposure or their emissions abatement potentials. CASE features a higher level of disaggregation than most general equilibrium models, which are limited by GTAP or similar databases. It allows us to highlight the contrasted impacts of climate policies among EU sectors. Smale et al. (2006) or Criqui et al. (2005) use detailed partial equilibrium models to study some of the impacts of the EU ETS but they do not compare different allocation methods.

The rest of the paper is organised as follows. In section 2, through a simple analytical framework, we highlight the different incentives provided by the allocation methods as well as their economic efficiency. Section 3 presents the CASE model, whose parameters are gathered in an appendix. Results concerning our three assessment criteria are displayed in sections 4, 5 and 6. Section 7 concludes.

The EU greenhouse gas ETS has started operating in January 2005, following Directive 2003/87/EC. It covers combustion installations over 20 MW – mostly, but not only, in the power sector – oil refineries and the production of steel, cement, glass, lime, bricks, pulp and paper. Currently process emissions from the chemical and aluminium sectors are excluded, as well as other gases than CO_2. Around 11 500 installations emitting 45% of EU CO_2 emissions are concerned.

Most emission allowances are allocated for free. Every Member State draws a National Allocation Plan (NAP) which specifies the amount of allowances received by every installation on its territory. NAPs may be rejected by the European Commission if the latter considers that they violate the Directive or other European laws, especially provisions on State aid. NAPs also precise the way new installations will receive allowances and for how long closing installations will continue to receive them. These provisions differ across Member States.

Not only does the industry contribute to climate change through its direct emissions of greenhouse gases but it uses electricity whose production also generates GHG emissions – the latter are labelled indirect emissions.

Box 1: The EU ETS

2. Grandfathering, auctioning and output-based allocation: the core differences

The way tradable allowances are allocated (e.g. whether they are auctioned or freely distributed) is sometimes believed to have only a distributional impact[3]. This is true only under some strict assumptions. In particular, if the amount of allowances a firm gets depends on its current behaviour, the firm may alter the latter to get more allowances.

In this section whose aim is pedagogical, we define three allowance allocation methods – auctioning, grandfathering and output-based allocation – and we compare them to the optimal policy with a very simple model, which closely follows Fisher (2001). This allows us to show, from the first-order conditions of profit maximisation, how the different allocation methods impact firms' decision rules, CO_2 price, production and unitary abatement.

2.1. Optimal policy

[3] Tietenberg (2002: 3) makes this case as follows: "Whatever the initial allocation, the transferability of the permits allows them to ultimately flow to their highest valued uses. Since those uses do not depend on the initial allocation, all initial allocations result in the same outcome and that outcome is cost-effective".

Let us assume a one-sector closed economy with perfect competition. Because of the assumption of closed economy, we cannot distinguish in this section AU from our fourth policy option, BTA. This assumption is relaxed in next sections. The benevolent planner chooses the levels of production and unitary abatement that maximise welfare, i.e., the consumers' surplus net of production costs, under a CO_2 emissions constraint:

$$\underset{ua,Q}{Max} W = \int_0^Q P[q]\,dq - C[ua]Q \qquad (1)$$

$$\text{s.t. } (ue_0 - ua)Q \leq E, \qquad (2)$$

where $P[q]$ is the inverse demand function, Q the production level, C the marginal production cost, assumed constant with production but increasing with unitary abatement ua ($C[ua] > 0, C'[ua] > 0$), ue_0 the baseline unitary emissions and E the emission target. Assuming that the latter is binding, the benevolent planner would choose ua and Q according to the first-order conditions:

$$C'[ua] = l \qquad (3)$$

$$P = C[ua] + l\,(ue_0 - ua) \qquad (4)$$

Equation (3) shows that the marginal cost of abatement equals the shadow price of the constraint l and equation (4) that the planner would set the output level such that the marginal benefit of another unit of output (the price) equals the marginal production cost plus the shadow price of the constraint multiplied by unitary emissions ($ue \equiv ue_0 - ua$). In other words, the price includes the value of the emissions embodied in a unit of production.

2.2. Grandfathering (GF) and auctioning (AU)

In these allocation methods, the amount of allowances a firm gets is unaffected by its behaviour. Under auctioning this amount is nil, whereas under grandfathering it is strictly positive.

A representative firm would maximise its profit:

$$\underset{ua,Q}{Max}\, \Pi^{GF/AU} = \left(P - C[ua]\right)Q - P_{CO_2}\left((ue_0 - ua)Q - gf\right), \qquad (5)$$

where gf is the amount of free allowances grandfathered. Under full auctioning, gf equals 0. First-order conditions give:

$$C'[ua] = P_{CO_2} \qquad (6)$$

$$P = C[ua] + P_{CO_2}(ue_0 - ua) \qquad (7)$$

We get the optimal conditions (3) and (4), with $P_{CO_2} = l$. Equation (6) is the classical equalization of the marginal abatement cost with the CO_2 price. In equation (7) we see that the output price equals the sum of the marginal production cost and of the value of the emissions per unit of output: although all allowances are given for free, firms behave as if they had to buy them – allowances have an opportunity cost. Consequently gf does not appear in the first-order conditions, which are identical for AU and GF. It follows, from equation (5), that the profit under GF is higher than that under AU and that the difference amounts to $P_{CO_2} \cdot gf$.

2.3. Output-based allocation (OB)

Under OB, the allocation a firm gets is proportional to its output level. Throughout the present paper, we assume that it does not depend on the technology used[4].

The profit function under OB may be written:

$$\underset{ua,Q}{Max}\,\Pi^{OB} = \left(P - C\left[ua\right]\right)Q - P_{CO_2}\left(ue_0 - ua - ob\right)Q\,, \tag{8}$$

where *ob* is the unitary allocation. First-order conditions of profit maximisation give:

$$C'\left[ua\right] = P_{CO_2} \tag{9}$$

$$P = C\left[ua\right] + P_{CO_2}\left(ue_0 - ua - ob\right) \tag{10}$$

Since for the average firm $ob = ue_0 - ua$, we get:

$$P = C\left[ua\right] \tag{11}$$

For a given CO_2 price, the unitary abatement under OB equals the one under GF or AU (equations 9 and 6). However the output price simply equals the marginal production cost, whereas under GF and AU it equals the sum of the marginal production cost and of the value of the emissions embodied in one unit of production (equations 11 and 7). The product price is thus lower under OB hence (if the demand function is not completely inelastic) the production level Q is higher. Let us now turn to the equilibrium on the allowance market:

$$E = Q\left(ue_0 - ua\left[P_{CO_2}\right]\right), \tag{12}$$

Where $ua\left[P_{CO_2}\right], ua\left[0\right] = 0,\ ua' > 0$ is the unitary abatement expressed as a function of the CO_2 price. This can be rewritten:

$$ua\left[P_{CO_2}\right] = ue_0 - E/Q\,, \tag{13}$$

Since OB leads to a higher Q, it follows that for a given emission target, it also leads to a higher *ua* hence a higher P_{CO2} than GF or AU.

To sum up, GF and AU lead to the optimal levels of production and unitary emissions whereas OB leads to too much production and too much unitary abatement. It also leads to a higher CO2 price than GF and AU[5] for a given emission target.

Given this shortcoming, why is a switch to OB advocated by some stakeholders? OB does also have some pros; first, since production is less impacted, so is employment in the sectors covered. Second, because the product price raises less, the adverse impact on consumers is mitigated. Third, OB may reduce the loss in competitiveness hence CO2 leakage (Haites,

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[4] The only exception is that in the applied model presented below, we assume that in the power sector, operators of non-fossil plants, i.e. nuclear and renewable plants, get no allowance. Indeed, we assume that the nuclear and renewable capacity is unaffected by the ETS, on the ground that it depends on political State-level decisions and/or on State subsidies. Furthermore, since the operating cost of these facilities is lower than that of fossil-fuel power plants, their utilisation rate is unaffected by the ETS.

[5] It is worth noting that OB is, in fine, an output subsidy. That's why, under imperfect competition, OB may offset the under production from firms, and thus increase social welfare (Fisher, 2001). We come back to that point in section 6.

2003). In short, under OB, emissions are mainly reduced through unitary abatement – first of all through technical solutions – which makes it a popular option among industrials. Conversely, under GF and AU, a part of the emissions reduction is due to a decrease in the output of CO2-intensive goods, which may be economically efficient but is for sure unpopular in the industries concerned.

Obviously the very simple model presented above cannot capture many of the interesting features of the EU ETS. First, the latter covers several sectors, which differ e.g. as regards their abatement cost. Second, some sectors are not only impacted directly through the CO_2 price but also indirectly through a possible impact on the electricity price. Third, some sectors are exposed to international competition, hence the need to model the substitution between EU and foreign products. Fourth, some of these sectors are rather concentrated hence firms may have some market power. Fifth, the electricity sector is not completely deregulated, so the electricity price to some residential consumers follows the average production cost and does not include the opportunity cost of allowances (cf. Burtraw et al. 2001). Because of the last three features, an increase in the marginal production cost does not necessarily induce the same increase in the products price, i.e., the pass-through may be incomplete (Smale et al., 2006; Ten Kate and Niels, 2005; Stennek and Verboven, 2001). Taking into account these features requires a numerical model, which is presented in the next section.

3. The CASE model

CASE is a static and partial equilibrium model which represents three sectors covered by the EU ETS, electricity, cement and steel, and one which is not, aluminium. The aluminium sector is electric-intensive: although its direct emissions are not covered by the ETS, it is impacted through the rise in electricity prices.

The two last sectors being not as homogeneous as the two first, it is worth precising their perimeters. Our aluminium sector only covers primary aluminium, international trade occurring mainly at this stage of transformation. We do not consider secondary aluminium, i.e. recycled aluminium, which is around ten times less energy and GHG intensive and whose market is mainly influenced by the scrap availability issue. For the steel sector, we use the definition retained by the European coal and steel community (ECSC and Eurostat 2003). Thus we retain only semi-finished products which constitute the bulk of steel trade.

The three sectors of the EU ETS modelled in CASE represent around 70% of the emissions covered by the system. They were also chosen because they should be impacted quite differently by the ETS given that many determining elements differ across sectors[6]:

- *their CO2 intensity*: cement has the highest direct plus indirect emissions over turnover ratio, followed by Electricity and by far by Aluminium – we do not consider its direct emissions which are not covered – and Steel.

- *their CO2 abatement potential*: for a given CO2 price, power generators and steel manufacturers are able to decrease their unitary emissions at a much higher rate than cement producers.

- *the competition they are subjected to, hence their ability to pass their cost increase to consumers*: trade exposure – defined as exports as a percentage of production, plus imports as

[6] All the following insights and figures are from computations based on the data given in appendix.

a percentage of consumption – equals around 60% for the EU Aluminium sector, 30% for the EU steel sector, 10% for cement and 0% for electricity.

- *the elasticity of the demand*: aluminium and steel demands are around 3 times more elastic than electricity and cement demands.

In the model, all sectors are first linked through the electricity market. The steel, cement and electricity sectors are also linked through the CO2 market. The CO2 price clears the market: thanks to unitary abatement and production drop, the sum of the emissions from these sectors equals the total amount of allowances given for free or auctioned[7]. The steel, aluminium and cement sectors are linked to the rest of the world through product competition. We assume no climate policy in the rest of the world. An appendix presents the values and sources for all variables.

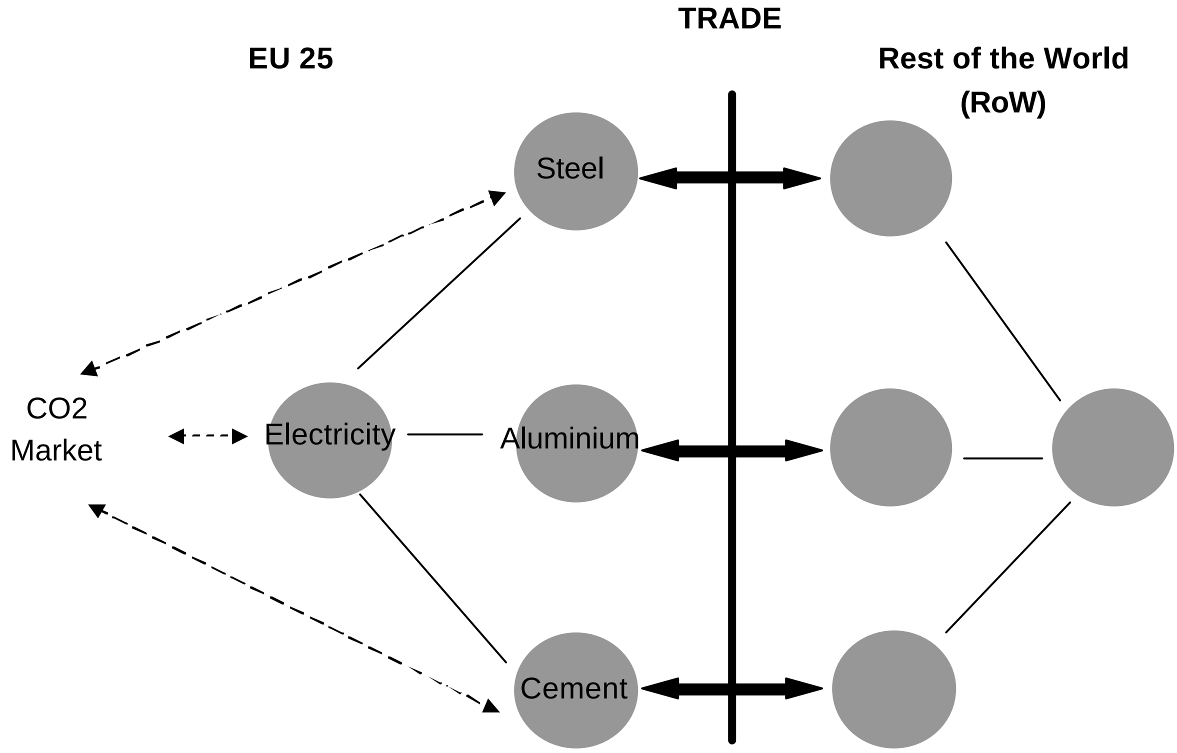

Figure 1: Sectoral links in the CASE model

All sectors are modelled in the same way: below we comment the equations of the sectoral sub-models including the international competition. Equations are provided in box 1. For EU variables we use the subscripts e, for RoW variables we use the subscript r.

[7] We thus neglect CDM, JI and banking.

EU 25	**Rest of the World**
Production Cost	
$c_e = c_e^0 + uac_e + ec_e + P_{CO_2}\left[dereg \cdot \left(ue_e^0 - ua_e\right) - ob\right]$ $Electricity \;\&\; GF \quad dereg = 0.7$ $else \quad dereg = 1$ $P_{CO_2} = a \cdot ua_e + b \cdot ua_e^{\,2}$ $uac_e = \int_0^{ua_e} \left(a \cdot ua + b \cdot ua^2\right) dua$ $ec_e = ec_e^0 + uec_e\left(P_{ee}(elec) - P_{ee}^0(elec)\right)$	$c_r = c_r^0$
Manufacturers prices	
$P_{ee} = c_e^0 + PT_e \cdot \Delta c_e$ $P_{er} = c_e^0 + PT_e \cdot \left(\Delta c_e - s_{BTA}\right)$ where $BTA: \quad s_{BTA} = P_{CO_2} ue_e$ ~~BTA~~ $: \quad s_{BTA} = 0$	$P_{rr} = c_r^0$ $P_{re} = c_r^0 + PT_r \cdot t_{BTA}$ where $BTA: \quad t_{BTA} = P_{CO_2} ue_r$ ~~BTA~~ $: \quad t_{BTA} = 0$
Product Market	
$P_e = \left(b_e^{\,s} P_{ee}^{\,1-s} + (1-b_e)^s \; P_{re}^{\,1-s}\right)^{\frac{1}{1-s}}$ $Q_e = (a_e - P_e)/b_e$ $D_e = \left(b_e \dfrac{P_e}{P_{ee}}\right)^s Q_e$ $M_e = X_r = \left((1-b_e)\dfrac{P_e}{P_{re}}\right)^s Q_e$	$P_r = \left(b_r^{\,s} P_{rr}^{\,1-s} + (1-b_r)^s \; P_{er}^{\,1-s}\right)^{\frac{1}{1-s}}$ $Q_r = (a_r - P_r)/b_r$ $D_r = \left(b_r \dfrac{P_r}{P_{rr}}\right)^s Q_r$ $X_e = M_r = \left((1-b_r)\dfrac{P_r}{P_{er}}\right)^s Q_r$
Consumers' Surplus	
$S_e = (a_e - P_e) \cdot Q_e / 2$	$S_r = (a_r - P_r) \cdot Q_r / 2$
CO2 Emission	
$E_e = \left(D_e + X_e\right) \cdot ue_e$	$E_r = \left(D_r + X_r\right) \cdot ue_r^0$
Sectoral Profit	
$\Pi_e = P_{ee} D_e + P_{er} X_e - c_e\left(D_e + X_e\right) + P_{CO_2} GF + s_{BTA} X_e$	$\Pi_r = P_{rr} D_r + P_{re} X_r - c_r\left(D_r + X_r\right) - t_{BTA} X_r$
State Revenue	
$GF / OB \quad R_e = 0$ $AU / BTA \quad R_e = P_{CO_2} E_e - s_{BTA} X_e + t_{BTA} X_r$	$R_r = 0$

Box 2: CASE sub-model equations

Average Cost Pricing (in BaU)

In a given sector we assume perfect competition in BaU. The prices set by EU producers home (P_{ee}) and abroad (P_{er}) equal their long term marginal cost, i.e. their average cost (C_e). The same applies for the producers of the RoW. This average cost pricing assumption may seem debatable for the electricity sector. Indeed, in deregulated markets, marginal pricing is the rule. However, free entry and exit guarantee that, in the long term, marginal pricing leads to the same price as average cost pricing[8].

ETS impact on production cost

With the implementation of the EU ETS, the CO2 price triggers – in the sectors covered by the ETS – abatements in unitary emissions (ue_e). The levels (ua_e) and costs (uac_e) of abatement are given by Marginal Abatement Cost Curve (MACC). Moreover, all EU industrials – covered or not – see their electricity cost (ec_e) increase because of the rise in electricity price. We assume that this increase equals their unitary electric consumption (uec_e) multiplied by the electricity price rise. Hence, we do not take into account the fact that some industrials produce their own electricity – around 20% of EU aluminium producers for example (Carbon Trust, 2004) – and the role of long term power supply contracts. Moreover, we do not consider electricity abatement opportunities. Finally, production costs also increase because of the introduction of an emission cost, $P_{CO2}\left(ue_e - ob_e\right)$, which depends on the allocation methodology.

As we have seen previously, the former "emission cost" is theoretically the same under GF and AU. However, the partial regulation in the EU electricity sector may differentiate these two allocation methodologies. Indeed, in the EU, there is not a unique electricity market but national markets more or less linked. Some national markets are regulated whereas others are deregulated. It does not only depend on the country considered but also on the type of consumers (industrials, large-scale commercial, households). Moreover even in some deregulated markets, governments keep on playing a major role in pricing decision. That is why some electricity generators may well be prevented from making windfall profits, i.e. from adding to their cost the opportunity cost of CO2 emissions under GF. The building of a detailed EU electricity model being far beyond the scope of this paper, we take that characteristic into account by assuming – according to experts of this sector – that 30%[9] of the EU electricity consumption is or will be in a near future "protected" from the pass through of the opportunity cost under GF. That is why we have introduced a parameter *dereg*, which equals 0.7 under GF for the electricity sector and 1 elsewhere. Obviously, this rate is much debatable, especially within the moving context of the EU electricity market, but it remains worthy to test roughly the implication of this "protection", which may turn out to be significant (Burtraw, 2001). We also assume that all industrial consumers buy their electricity on deregulated markets, what is and will be more and more reasonable in a near future.

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[8] Because of this assumption, one will not see the auctioning paradox (Burtraw et al., 2002), i.e. the fact that electricity producers may be better off paying for CO2 allowances than having them for free through OB, because rents for low CO2-intensive plants are captured by the entry of new such plants.

[9] To check the robustness of the results, we ran CASE with a *dereg* parameter of 0.4 (60% of the EU electricity market is regulated). The outcomes, not displayed here, show that the qualitative conclusion of this paper hold under this assumption.

Pass-through of the cost increase to price

The ability of manufacturers to pass their cost increase to their price depends on every sector.

In the long term, free entry and exit of firms must lead to complete pass-through (PT_e) to guarantee zero profit. We do not assume free entry and exit: in this shorter term that we consider, pass-through may be incomplete not only because of the competition of non EU firms which are not subjected to a CO2 constraint, but also because of the market power of EU firms (Stennek and Verboven, 2001; Ten Kate and Niels, 2005). These two effects must lead pass-through to fall, but to what extent?

For the electricity sector, (Sijm et al., 2006) has shown that the pass-through may be almost complete in deregulated markets, so we assume a 100% pass-through. To our knowledge[10], conclusive works do not exist yet for the other sectors covered.

That's why, for our pass-through estimates, we rely on the methodology developed by Smale et al. (2006) for the UK. This methodology relies on the Cournot model with linear demand. This model leads to a N/(N+N'+1) pass-through, where N and N' are the numbers of domestic and foreign firms respectively (Ten Kate and Niels, 2005). These numbers are calibrated to make the outcome of the Cournot model fit with real production and trade data[11]. In CASE we apply this methodology to the EU 25 and we do not assume constant pass-through: pass-through is made endogenous. It evolves with trade flows, following the Smale methodology: when imports to the EU increase, the pass-through of EU producers tends to decline. Finally, we have to distinguish the BTA case: under BTA, foreign firms are also subjected to the climate policy when exporting to the EU. Then, following the Cournot model, we assume a (N+N')/(N+N'+1) pass-through of EU producers at home.

Initial PT (dP/dc)	Electricity	Steel	Cement	Aluminium
GF/AU/OB	100%	67%	78%	31%
BTA	100%	78%	83%	72%

Table 1: Sectoral pass-thourgh rates

We stress that the pass through rates are uncertain: theoretical literature provides no clear-cut answer on that topic, neither does empirical literature although it leads to significant values (Stennek and Verboven, 2001). For an interesting discussion on the ability of various industries to pass a cost increase to consumers, see (Carbon Trust, 2004). We also note that the pass-through issue turns out to be of major importance when assessing the competitiveness impacts of climate policies, highlighted by Demailly and Quirion (2006b).

Impact on trade flows

To assess the impact on trade, we rely on the Armington (1969) specification to assess these impacts, s being the Armington elasticity (0 for electricity because at the EU level, imports and exports of electricity are negligible).

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[10] A preliminary but not conclusive econometrical work has been led to assess the PT of cement manufacturers in the EU ETS context (Walker, 2006)

[11] N=bD/(P-C), N'=bX/(P-C), where P=a-bQ.

Impact on demand

For cement, steel and aluminium, we assume a linear demand for a composite of imported and domestic good (Armington good). The initial price-elasticity of demand is taken from Oxera (2004). For electricity demand is the sum of the demand from these three sectors and of a linear demand from the rest of the economy[12].

CASE is used to assess the four climate policies defined before. Concerning the BTA, we do not assume that products imported from the RoW are taxed according to the direct and indirect CO2 emissions induced by their production process, but according to the average emissions induced by the EU process[13]. In the three following sections, we assess their performance according to three criteria. First, we will use the "competitive distortions" criterion: to what extent the climate policies considered induce production losses, and lead to employment losses and CO2 leakage. Then, we will assess their distributive impacts: how is shared the burden between firms and consumers. Finally, we will compare the economic efficiency of the four policies, in other words assess their economic cost for a given emission reduction. Moreover, in the two first sections we do not only compare the four policies but also the impacts on the four sectors modelled of AU – this policy being generally considered as the most efficient and as the one having the most severe competitive and distributive impacts.

4. The Competitive distortions

In this section and in the following ones, we assume that the rates of unitary allocation under OB or of free allocation under GF are the same across all sectors of the ETS. In other words, if the cement sector receives under OB a unitary allocation which equals 95% of its unitary emission under BaU, all sectors receive the same rate. If it receives for free an amount of allowances accounting for 95% of its BaU emissions under GF, all sectors receive the same rate. It is worth noting that, in the real world, the electricity sector tends to receive much less than others, at least in most of the EU countries (Buchner et al., 2006).

4.1. CO2 price

In this paper, results are presented with respect to the reductions in the emissions covered by the EU ETS. Because readers may be used to graphs with respect to CO2 price, the dual variable, we first plot below the CO2 price with respect to EU ETS emission reductions.

[12] For simplicity, we do not display this equation in box 2.

[13] Such a system is different from a proposal by Ismer and Neuhoff (2004) – to tax products as if they were produced with the best and widely available technologies in the EU – to make BTA compatible with WTO rules. Testing this BTA would require a detailed technological analysis of sectors, what is beyond the scope of this paper. However, the relative performances of these BTA is close (see Demailly and Quirion, forthcoming).

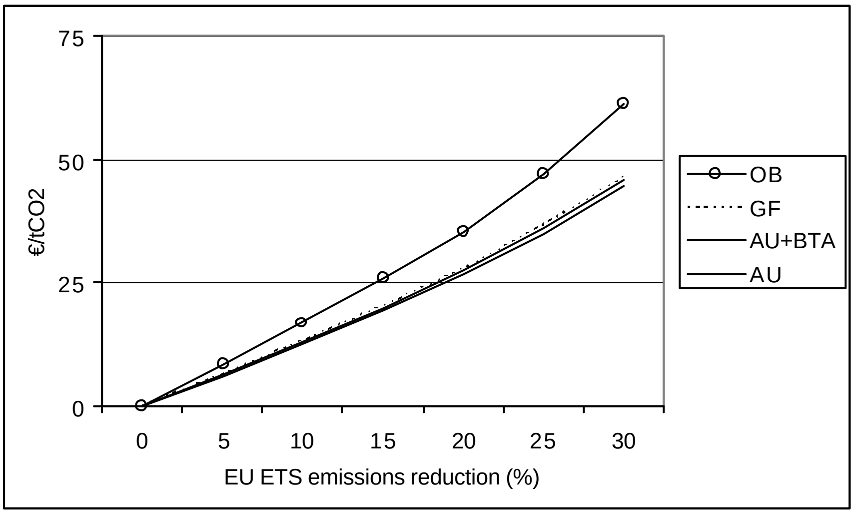

Figure 2: CO2 price

As expected, the CO2 price is higher (around +30%) under OB than under AU the former leading to less output reduction. In-between is GF: the output reduction is lower than under AU, regulated electricity firms being prevented by governments to internalize the opportunity cost of emissions in their price. However, it turns out that the difference is small (around 5%)[14]. The same stands for BTA which prevents emission reduction through the trade channel: without BTA, a part of the emission reduction in the EU ETS is achieved through relocation of the production of CO2-intensive goods in the rest of the world; with BTA, more abatement – hence a higher CO2 price – is needed to get the same emission reduction in the EU ETS.

4.2. Impact on Production

[14] A regulation rate *dereg* of 60% in the electricity sector would lead to a CO2 price under GF only 10% higher than under AU: the difference between the two allocation methodologies remains small.

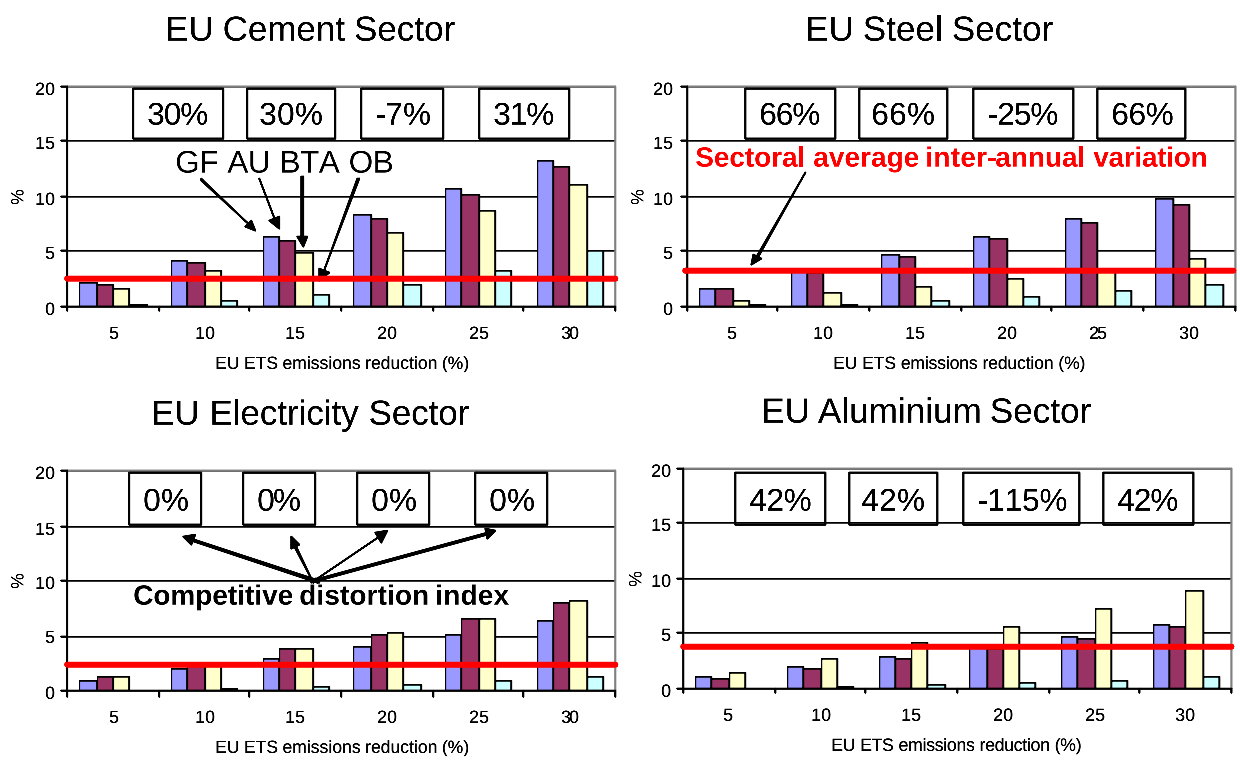

Figure 3: Production losses compared with BaU

4.2.1. Sectoral production losses under AU

The cement sector is not particularly trade sensitive and its demand is relatively inelastic to price. However, its high CO2-intensity leads it to be the sector with the highest production drops under AU. Nevertheless, this drop may be considered as moderate: for a 15% ETS emission reduction, a target whose implementation is a matter of years, the production drop is of the order of magnitude of twice the average inter-annual production variation in this sector[15] (red line on Figure 3). Moreover, it is worth noting that only 30% of production losses are due to market share losses vis-à-vis foreign competitors (see the *competitive distortions indexes* displayed on the graph). Production losses are mainly due to a reduction in EU cement consumption. Hence, the production and employment issues in the cement sector are not that much a matter of competitive distortion vis-à-vis foreign producers.

For a 15% cut in the EU ETS emission, the production drops in the other sectors are of the order of magnitude of average annual production variation. Thus the production drop is moderate in the steel sector in spite of its relatively high price elasticity of demand and of its trade exposure. It is due to its relatively low CO2-intensity. Competitive distortions vis-à-vis non EU countries are significant as around 2/3 of its production drop is due to market share losses. Concerning the electricity sector, its CO2 intensity is offset by a relatively inelastic demand and it is sheltered from the competition of non EU producers.

Although the aluminium sector is the most exposed to trade, its demand is the most price elastic and it is more CO2-intense than the steel sector, its production is less impacted than the

[15] Inter-annual production variation of the EU15 cement sector from 1990. Own computation using the ENERDATA database. The same computation has been realised for the other sectors. For electricity, we used UE25 data.

latter, and the less impacted among all sectors. It is mostly due to the fact that its PT is by far the lowest among all sectors, hence its price rise is limited. The role of competitive distortions is important however: around 40% of the drop in aluminium production is due to market share losses vis-à-vis non EU competitors.

4.2.2. Impacts on production of the different policies

Compared with AU, GF leads to a significantly lower average price in the electricity sector and to lower production losses (-20%). However, because of a higher CO2 price, the deregulated price faced by industrial consumers is higher under GF. That is why the cement, steel and aluminium sectors incur larger production losses under GF, although only by a small extent (+5%).

As seen previously, BTA leads to slightly higher CO2 prices than AU, hence a higher price increase and a lower consumption in the electricity sector. Moreover, in the other sectors opened to trade, two other effects lead to higher prices: higher pass-through for EU producers and higher price of non EU products, taxed at the border. Conversely, almost all the production losses through trade vanish. The cement and above all the steel sectors finally incur significantly lower losses than under AU, the latter effect dominating. On the other hand, counter-intuitively, the aluminium sector suffers from higher losses with BTA. It is worth noting that BTA leads to negative competitive distortions index. This is due to the fact that net imports of EU tend to decrease with BTA, because of a lower consumption. The two last facts highlight the predominance of consumption considerations on trade.

OB has the same kind of impact as BTA on trade flows: roughly speaking, the relative price of EU vs. foreign producers increases only through the rise in marginal production cost due to abatement. Conversely, compared to BTA, the absolute price for EU consumers hardly rises compared with BAU, so consumption is almost not impacted. Finally, OB leads to almost negligible production losses.

4.3. CO2 leakage

As we have just seen, the EU ETS leads to market share losses in the sectors which are trade sensitive. These losses induce CO2 leakage, i.e. an increase in CO2 emissions from non EU countries, where production is globally more CO2-intensive. We label this source of leakage the "competitiveness channel".[16]

[16] The leakage ratio is defined as the increase in RoW emissions over the decrease in EU emissions. We stress that our estimates of the leakage ratio do not include one of the main leakage channels, the increase in RoW emissions due to the international drop in world fuel prices induced by climate policies (Sijm et al. 2004). However this "trade in energy channel" is similar for the four policies assessed, they only differ in the competitiveness channel for leakage, so we are able to compare the leakage ratios across policies. Conversely this channel may vary across sectors because their energy intensities and fuel mixes differ, hence when we compare the leakage ratios across sectors we have to be aware that we only compare their different contribution to the competitiveness channel, what remains worthy.

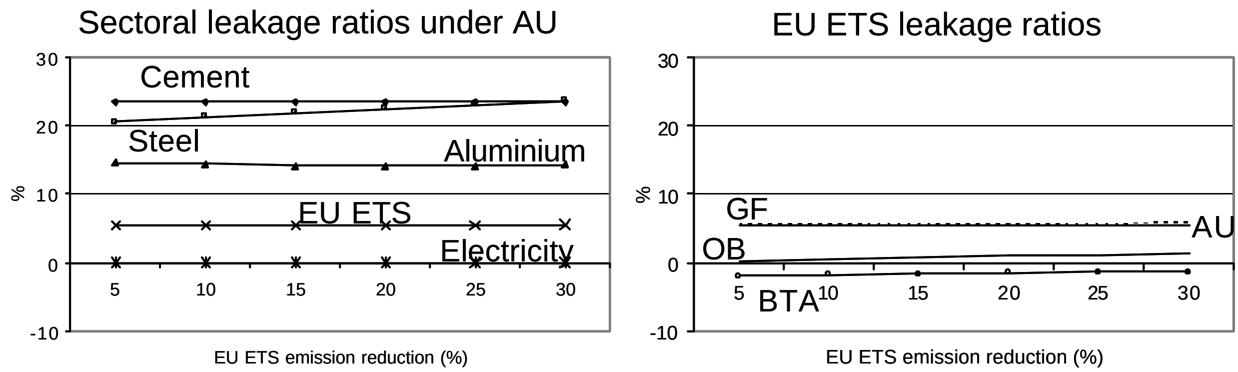

Figure 4: CO2 leakage

4.3.1. Sectoral CO2 leakage rates under AU

The ability of electricity producers to decrease their unitary emissions is relatively high, as it has been highlighted before. Hence, CO2 emissions reductions of the electricity sector under AU are achieved for around ¾ through improvements in unitary emissions and for only ¼ through a drop in production. This sector being not subjected to international competition, its leakage rate equals zero. It does not mean that the non EU electricity sector does not increase its emissions. In fact, it does because its production increases to satisfy the rise in demand of the other industrial sectors from the RoW, which gain some market shares. However, in our sectoral leakage estimates, indirect emissions are assigned to the electricity consumers.

The EU Aluminium sector is relatively trade sensitive. Moreover, being not covered by the ETS, EU aluminium manufacturers do not have an incentive to decrease their direct unitary emissions. These two elements should lead to a high leakage rate (high numerator and low denominator). However, indirect emissions of the sector – remember that direct emissions are not covered – decrease thanks to the important improvements made in the electricity sector, what allow a relatively low leakage rate (15%).

The role of unitary emissions improvements in the electricity sector is less important when considering the cement and steel sectors, where indirect emissions are minor. Moreover, in the EU cement sector, direct unitary emissions improvements are expensive to achieve, what may lead to a very high leakage ratio. However, trade losses are low. Finally emissions reductions are low but mostly due to the consumption drop, what leads to a leakage rate around 25%.

Leakage rate in the EU steel sector is similar, in spite of its much higher trade sensitivity. This is due to the fact that, conversely to the cement case, improvements in direct unitary emissions are not so expensive for steel manufacturers: they are responsible for around ¾ of the CO2 emissions reduction.

Hence, except for the electricity sector, the leakage ratios turn out to be similar in the three other sectors, different effects compensating. In aggregate, the leakage ratio of the EU ETS is low, around 5%, what traduces the weight of the electricity sector.

4.3.2. EU ETS CO2 leakage for the different policies

The ETS leakage ratio under GF is only very slightly higher than under AU, because of higher market share losses as we have seen above. Conversely, leakage ratios are very different under OB and BTA. It drops to around 1% under OB: as highlighted in (Demailly and

Quirion, 2006a) OB is an efficient tool to prevent leakage. Under BTA, the leakage ratio is negative, around -2%. This spillover is not due to the fact that EU producers gain market shares at home, the non EU producers being taxed in accordance with the CO2 intensity of EU producers while experiencing no abatement costs. Neither do the formers gain market shares abroad, the subsidy to export covering only the cost of auctioned allowances, not the abatement costs. The spillover is due to the fact that, following the drop in consumption of EU consumers and in spite of some gains in market shares for foreign firms, non EU exports – hence production – decrease.

5. Distributive issues

The recent debate about windfall profits in the electricity sector has highlighted the distributive issue surrounding the EU ETS: in deregulated countries, power generators turn out to pass almost all the opportunity cost of their emission to consumers (Sijm et al., 2006), despite the fact that allowances were freely allocated. In other words, electricity generators make profit and consumers pay. Contrarily to what other industrials claim, studies show that large windfall profits may also emerge in the other sectors covered by the ETS (Smale, 2006; Demailly and Quirion, 2006a). The distributive issue deserves important attention: at a CO_2 price of €20/t CO_2, the average price in the first semester of 2006[17], the value of the annual allowances given to the electricity, cement and steel sectors represents around ¼ of their cumulated EBITDA[18] (Earnings Before Interest, Tax, Debt and Amortization).

In this section we address the distributive issue by first analysing the impacts of the four climate policies tested on firms EBITDA, then their impact on consumers' surplus.

5.1. Impact on firms' EBITDA

In the graph below, we first present the EBITDA losses by sector under AU. Then we present the total EBITDA variations for the various policies. We neglect the dynamic costs which could emerge from prematurely scrapping capital and which may be avoided through timely strengthening of climate policies.

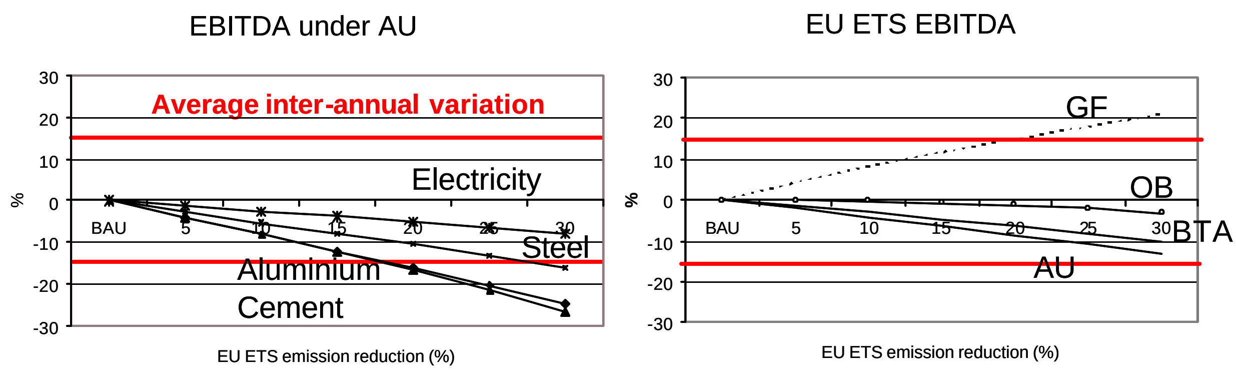

Figure 5: Impact on EBITDA compared with BaU

5.1.1. Sectoral EBITDA losses under AU

[17] Own calculation from Powernext data: http://www.powernext.fr/
[18] From a computation using data in appendix.

For power generators, within our hypothesis of 100% pass-through of cost increase, the investor's return rate maintains. The EBITDA only declines with production, at the same relatively low rate: 4% for a 15% cut in emissions. This figure may be compared to the average inter-annual variation in EBITDA in euro countries[19]: around 15% in average for our four sectors, ranging from 11% for electricity to 45% for basic metals (including steel and aluminium).

The picture is quite different for the other sectors whose ability to pass their cost increase to consumers is lower. In the cement sector the pass-through, although relatively high, is incomplete and the production drop much higher. Finally, the EBITDA drop is the highest among all sectors, -12% for a 15% cut in ETS emissions[20]. Yet it is of the order of magnitude of inter-annual variations: almost 15% in the non-metallic minerals sector. The steel sector experiences a lower pass-through but a lower drop in production than cement. The latter effect dominates so the EBITDA decreases twice less. The impact of international competition is of major importance for the aluminium producers: their ability to pass their cost increase to consumers is the lowest. It leads to a low production drop, but their EBITDA drops almost as much as in the cement case.

We note it would be enough to rebate 30% of the auction revenue to EU industrials, notably aluminium, to maintain their EBITDA and overcome industry's opposition to AU. As highlighted by Bovenberg et al. (2005), the key basis for this low rate is that "CO2 abatement policies have the potential to generate rents that are very large in relation to the potential loss of profit", the latter being limited thanks to the ability of producers to pass on to consumers an important part of their cost increase. Such a low rebating rate allows using most of the auction revenue for other purpose, notably to finance cuts in distortionary taxes as we will see in the next section.

5.1.2. Total EBITDA losses for the different policies

BTA allowing all EU firms to raise their pass-through, it benefits significantly to the trade sensitive sectors. However, they keep on loosing profits and, in aggregate, the impact of BTA compared with AU is limited. EBITDA losses under BTA are around 25% lower than under AU and the compensating rate of rebating falls to 20%. Having low impacts on prices and production, OB leads to EBITDA losses ten times lower than AU. Losses are low in every.

When allowances are grandfathered, windfall profits emerge in all the sectors covered by the ETS. It is worth having a sectoral focus however. The electricity sector benefits the most from GF – its EBITDA increases by 20% for a 15% ETS emissions reduction. Because of a lower pass-through and higher production drop, the rise in EBITDA of the cement sector is halved compared with electricity. Given its much lower CO2 intensity and the relative importance of the rise in its electricity cost, the steel sector sees its EBITDA rising marginally. For the sector not covered, aluminium, there is no significant difference between GF and AU.

5.2. Impact on the consumers' surplus

To assess the impact of climate policies on consumers we analyze their total surplus,

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[19] All the figures of EBITDA inter-annual variations were computed using the (deflated) operating surplus data from the OECD STAN database, using countries and years for which this information was available.

[20] In CASE, we assume that no EU firm exits the markets despite the drop in investors' return. In the long term however, such exit may happen to maintain EU investor's return to a normal rate, leading to complete pass-through, lower EBITDA losses for every sector, hence even lower losses for every remaining firm.

consumers' surplus being defined as in section 3.

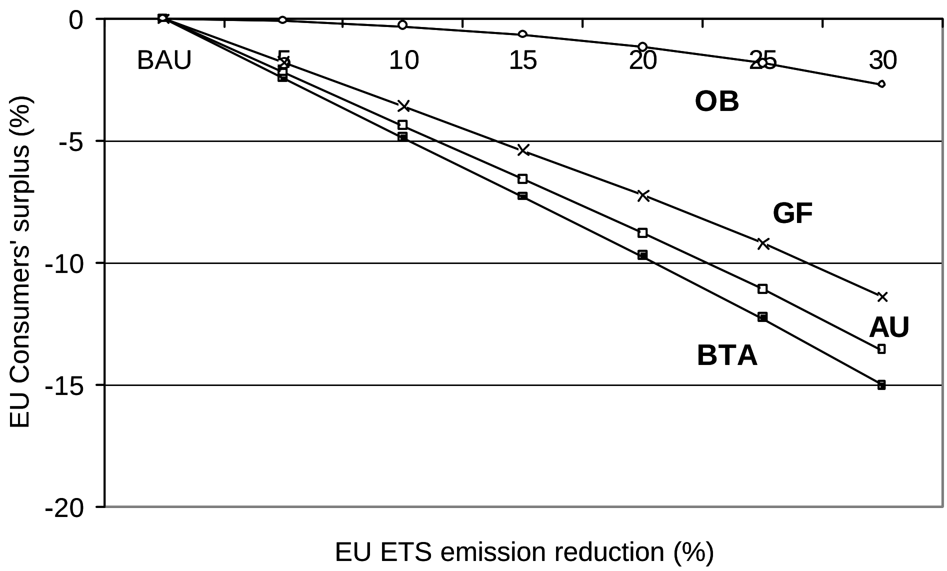

Figure 6: ETS impact on EU Consumers' surplus

By preventing the trade effect, BTA leads to higher output prices for EU consumers. First and foremost, without BTA, trade lowers the pass-through rates applied by EU producers and offers an alternative to the expensive EU products; BTA prevents trade from playing this role. Second, by blocking the competitiveness channel for CO2 leakage, BTA prevents to cut CO2 emissions in the EU through trade in CO2-intensive goods. All in all, the impact on consumers increases by 10% because of BTA compared to AU. Conversely, GF mitigates this impact by around 20% since it leads to a lower increase in electricity prices on regulated markets. OB leads to the lowest impact on consumers: compared with AU, its divides by around ten the losses of surplus for EU consumers.

Turning to the burden sharing under OB, consumers bear 90% of the cost defined as the sum of the impacts on consumers' surplus and firms' profit. However these impacts are low, compared with the three other policies. Under GF, only consumers are negatively impacted: GF leads to a significant wealth transfer from consumers to firms. Under AU and BTA both consumers and firms loose wealth, but the burden's share of the former is high: 90% under AU, 95% under BTA. However, this loss partially benefits to the State which raises funds through the allowances auction, funds which may be redistributed to consumers to some extent. To asses the overall economic impact of emission reduction, these funds have to be considered with firms' profit and consumers' surplus losses, what is done in the next section.

6. Economic efficiency

In this paper, welfare is defined as the sum of consumers' surplus, firms' profit and State revenue (when allowances are auctioned). It does not include the impacts of CO2 emissions neither does it include the dynamic cost due to workers retraining. The economic cost of the four policy options is defined as the loss in welfare they entail compared to business-as-usual.

A caveat is that we do not take into account pre-existing distortions and the impact of our four policies on them: distortions due to taxes on the one hand, due to the difference between price and marginal cost – imperfect competition – what is common in the industry considered, on the other hand. These distortions being of importance, especially the former, we use insights from papers analysing their impacts to draw more robust conclusions.

In this section, we first analyze the economic cost of the four policies from the EU point of view only. That is, we compute the EU welfare losses for the various policies as a function of the emission reduction in the EU only. Then, we enlarge our vision to assess the efficiency of the policies from a more global point of view: we take into account the impacts of these policies on the RoW welfare and the CO2 leakage.

6.1. EU economic cost of the EU ETS

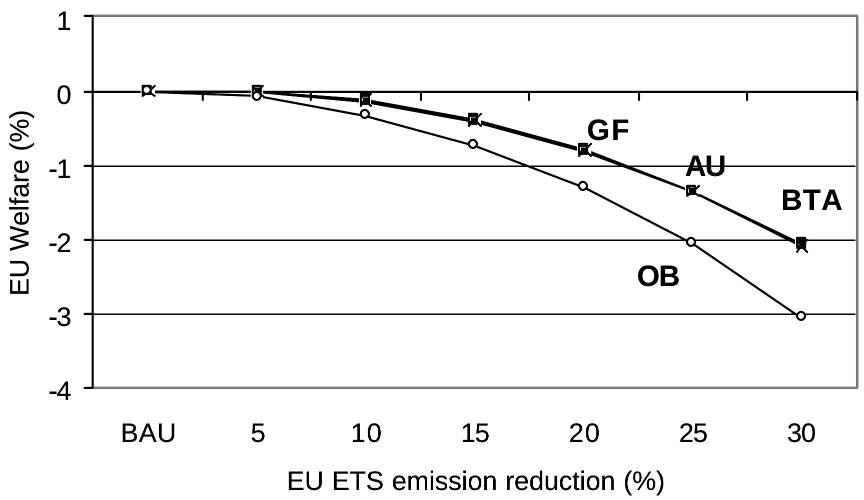

Figure 7 : ETS Impact on EU Social Welfare

First, OB leads to welfare losses much higher than the other three policies. The main explanation is presented in section 2 above: for a given target, OB entails too much production and too much unitary abatement. A second explanation is that OB does not create a significant wealth transfer from the RoW to the EU, whereas the other three policies do, as highlighted below.

This wealth transfer occurs through different channels. The main channel under BTA is that the EU budget benefits from a transfer from foreign firms, through the tax on imports. Under GF and AU, the increase in price paid by foreign consumers for EU products entails a wealth transfer from foreign consumers to the EU budget (under AU) or to EU firms (under GF). This last mechanism is labelled "*terms of trade effect*" in the literature. In CASE and for low emission reductions – around 5% – this effect is strong enough to improve the EU welfare under AU and GF, as can be hardly seen on the graph. Note that the same phenomenon occurs in Bernard and Vielle (2003) general equilibrium model. In their paper as in ours, for more stringent targets the negative impact on EU consumers dominates and this "double dividend" disappears.

The impact of AU, GF and BTA are so close that it is hardly possible to distinguish these three policies on the graph. There are many effects which tend to differentiate these policies but which finally turn out to be low or to compensate. In particular:

- Compared with AU, GF leads to a higher terms of trade effect, because it entails a higher CO2 price; however, GF does not lead to the internalization of the emission cost in electricity prices for regulated consumers, what is suboptimal (see section 2).

- Compared with AU, BTA has a low term of trade effect. In addition, the reduction of emissions through a loss of market shares is not used to reduce emissions whereas it is efficient as long as we do not take into account the CO2 emissions increase in the RoW. On the other hand, under BTA, the EU budget benefits from a transfer from foreign firms as explained above, and the internalization of the emission cost in prices is more complete thanks to higher pass through rates.

How would this ranking be impacted if we had taken into account the existence of pre-existing distortionary taxes? Goulder et al. (1999) have shown that AU and GF compound the distortions because they lead to important rise in prices, but that this negative effect (tax-interaction effect) may be partly offset under AU if the auction revenue is recycled through cuts in marginal tax rates. Such compensation may not occur under GF what put this policy at an important disadvantage relative to AU (and BTA), especially for low levels of emission reduction. Moreover, the authors state that the net impact of tax-interaction and revenue recycling effects is proportional to primary cost, primary cost being the economic cost we have considered until now without taking into account pre-existing distortionary taxes. Hence, the ranking of OB – whose tax-interaction effect is low and revenue-recycling effect is nil – and the two revenue raising polices, AU and BTA, may not be modified if the auction revenue is used to cut marginal tax rates. The fact that OB leads to lower prices may also be beneficial in imperfectly competitive industry, where firms underprovide output. However, as stressed by Fisher (2001), such gains are uncertain for various reasons. Concerning the ranking of AU and BTA with pre-existing distortionary taxes, the two effects considered above are higher under BTA, the latter raising 5% more revenue and leading to higher prices, hence the conclusion is not straightforward and would require deeper analysis.

6.2. World economic cost of the EU ETS

In this subsection, we adopt a global perspective by considering the impact of EU policies on the world welfare. Moreover, it would be unfair not to take into account CO2 leakage which deteriorates the environmental effectiveness of the climate policies. Then from now on we compute the world welfare losses as a function of the "effective" emission reduction in the EU ETS, i.e. we take leakage into account[21]. For example, if a 10% decrease in EU ETS emissions entails a 5% leakage, we consider that the effective emission reduction in the EU ETS is 9.5%.

Below, we plot the social cost of the various policies compared with the cost under AU, with respect to emission reduction in the EU taking into account leakage.

[21] As highlighted before, we do not take account one of the main sources of leakage, i.e. the "trade in energy channel". However since it is similar for the four policies assessed, it would not change their ranking.

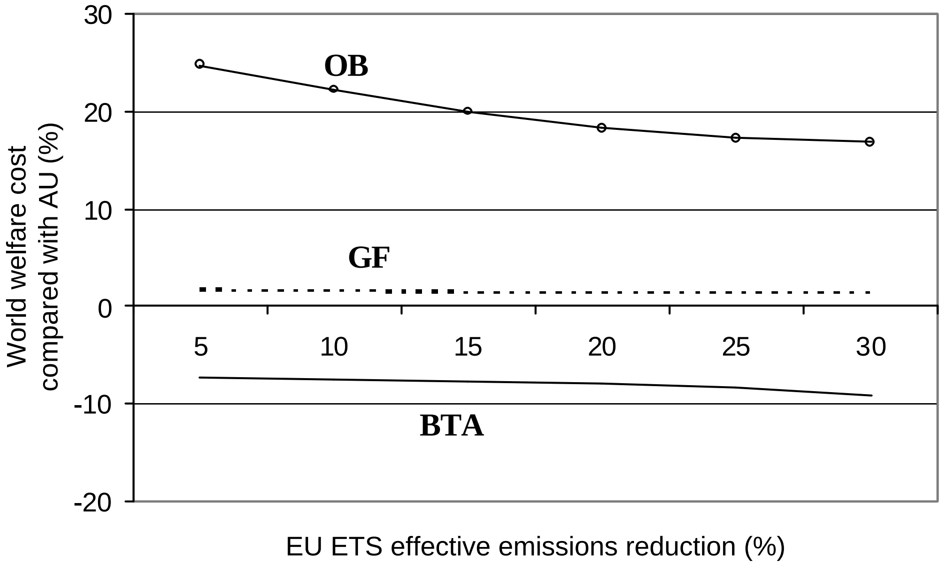

Figure 8: World Welfare cost of GF, BTA and OB compared with AU

Since OB and BTA reduce the leakage occurring through the competitiveness channel compared to AU, their relative economic cost (i.e. compared to the latter) diminishes when we consider effective emission reductions. Conversely, because GF leads to a slightly higher leakage than AU, its relative cost raises.

OB improves but not enough to compensate its lower performance due to excessive efforts in unitary abatement: its cost remains around 20% higher than AU. Much higher trade sensitivities would be required to make OB less costly than AU: twice the highest elasticities found in the literature (Donnelly et al., 2004) according to our calculations.

BTA is the least costly policy from a global perspective: like OB, it prevents leakage and like AU, it allows a more optimal mix of the two emission reduction channels: unitary abatement and output reduction. The implementation of BTA reduces the cost of auctioning alone by almost 10%.[22]

[22] Note that BTA would not necessarily be less costly than AU if RoW emissions per unit of output were lower than in the UE, since production relocation might be an effective way to reduce world emissions. Yet this is not the case.

7. Conclusion

In this paper, we assess both analytically and numerically the application of four proposals for the future of the EU ETS: pure grandfathering allocation of emission allowances (GF), output-based allocation (OB), auctioning (AU) and auctioning with border tax adjustments (BTA). This assessment is based on three criteria which are of major importance according to stakeholders and economic literature: economic efficiency, competitive distortions vis-à-vis the rest of the world and distributive impacts. To our knowledge, such a comprehensive assessment has not been led yet. Moreover, when assessing the economic efficiency of proposals, we take into account the CO2 leakage they induce and the impact of regulation in the EU electricity sector. The CASE model, developed for this paper, represents four industries: Cement, Aluminium, Steel and Electricity. This high level of disaggregation allows us not to treat the industry as homogenous but to highlight the diversity of the sectors and the contrasted impacts of the EU ETS on them.

When comparing the four policies tested – AU, GF, OB and BTA – it first appears that, according to CASE, OB increases the cost for the EU by around 30% compared to the other policies. Indeed it leads to a suboptimal mix of the two channels for emission reduction: unitary abatement and output reduction. An interesting feature of OB, which is generally not taken into account when assessing its efficiency, is its ability to prevent CO2 leakage due to competitive distortions vis-à-vis foreign producers. Nevertheless, since leakage is globally low, it turns out that this ability is far from offsetting the above-mentioned inefficiency[23]. This being said, economic efficiency may well not be the most important economic criteria in policymaking as shown by Keohane et al. (1998). An interest of OB is that its implementation may be less controversial as it softens all the impacts of the ETS on firms' EBITDA or consumers and leads to insignificant production losses: fears of massive employment losses or relocation vanish.

Contrarily to what most industrials claim, production hence employment losses appear to be globally moderate under AU and the role of competitive distortions is globally of minor importance compared with the reduction in consumption. Thus, the most sensitive sector is cement, which is little exposed to trade and the production drop is of the order of magnitude of twice the average inter-annual production variation for a 15% ETS emission reduction. Moreover, CO2 leakage due to competitive distortions is low in aggregate (around 5%) and remains moderate for all sectors (around 25% at worst). That is why BTA does not lead to drastic differences with AU. Differences are visible for the production losses of the most trade exposed sectors, steel and aluminium. However, surprisingly, production of the latter decreases with BTA, what traduces one more time the predominance of consumption considerations in production drops. The other noticeable difference when implementing BTA is the shift from a slight leakage to a slight spillover (around 2%). Concerning GF, it turns out that the partial regulation of the EU electricity sector has no significant effect, contrarily to the US case analysed by Burtraw et al. (2001): GF and AU have similar impacts on

[23] It is worth noting that OB raises practical questions. On the positive side, it allows emancipating from production growth projections during the process of allocation negotiation, whose definition is problematic and which may be used to negotiate or to justify high emission caps. On the other hand, the development of such benchmarks is far from simple. In particular, the definition of an output is problematic, even for a relatively homogenous product like cement and may have drastic consequences when intermediary CO2 intensive products which may be traded internationally enter the manufacturing process (Demailly and Quirion, 2006a).

production and leakage.

Turning to distributive issues, AU leads to moderate EBITDA losses: for a 15% cut in EU emissions, the EBITDA loss is below the average inter-annual variation for every sector. Cement and aluminium are the most sensitive sectors, although for different reasons, the former because of its production loss, the latter due to its low ability to pass the cost increase on to consumers because of international competition. BTA allowing firms to raise their pass-through, it benefits significantly to the sectors exposed to trade which might be its best promoters. In both cases, a rebate of the auction revenue may be required to overcome the opposition of industrials. Interestingly, as in Bovenberg et al. (2005), only a low rate of the auction revenue (30% under AU and 20% under BTA) would have to be rebated to maintain firms EBITDA. However, all sectors except for aluminium may prefer GF, as they incur windfall profits, especially the two most CO2-intensive and less trade exposed sectors, electricity and cement. Turning to consumers, they support all the burden of the emission reduction under GF and most of it under AU and BTA. May we expect strong oppositions from non industrials consumers however? Indeed, the impact of these policies on the latter, though important in the aggregate, remains small for each individual. Firms on the other hand may be much more willing to incur the costs of “political mobilization” (Olson, 1965).

GF, AU and BTA entail approximately the same cost for the EU economies, different effects compensating. This conclusion would not hold if one assumed that the auction revenue were used to cut pre-existing distortionary taxes, what would make AU and BTA more efficient than GF. Moreover, as only a small share of the auction revenue would be required to compensate firms and then lower their opposition to auctioning, the rest may be used to finance cut in taxes: there is a way of overcoming the tension between political acceptability and economic efficiency.

BTA raising slightly higher revenue than AU, and requiring lower rebate to compensate firms, it may improve its economic efficiency compared with the latter. A general equilibrium model would be required to assess the difference. However, from CASE, it already appears that the ability of BTA to prevent leakage makes it 10% more efficient than AU from a world perspective. This leakage argument may be used to defend BTA in front of the WTO, as it puts forward not the protection of EU industry but the environmental effectiveness of the EU ETS. However, it is fair to note that the interest of BTA may not reside that much in its ability to prevent competitive distortions of auctioning vis-à-vis the rest of the world, which are low whatever. It may rather be to allow a deeper emission reduction in the EU ETS – by addressing the fears of competitive distortions – and to give an incentive to non EU countries, and more precisely non Kyoto ratifying countries, to engage more in the fight against climate change.

Appendix : CASE Data

Sectors	**Electricity**[24] MWh	**Steel**[25] tonne	**Cement** tonne	**Aluminium** tonne
Prices and production costs				
Prices (€)	47	538	80	1600
Source	Reinaud (2004)	Quirion and Demailly (2006b)	Reinaud (2004) + transport Demailly and Quirion (2005)	Reinaud (2004)
Variable cost (€)	27	292 [26]	21	820
Investment cost (€)[27]	20	246	59	780
Source	Computation[28]	Reinaud (2004)		
Trade and Demand elasticities				
Armington elasticity	-	3.5	1.3	1.8
Source	-	Bishop (2004)	Average value in Donnelly et al. (2004), Gallaway and McDaniel (2003), Reinert and Roland-Holst (1992), Shiells and Reinert (1993)	
Demand elasticity	0.25	0.62	0.27	0.8
Source	Oxera (2004)			
CO2 Emissions				
EU / RoW Direct unitary emissions (tCO_2)	0.385 / 0.564	1.2 / 1.4	0.85 / 0.94	3.5
Source	Reinaud (2004) / CAIT	Reinaud (2004)	Batelle (2002)	Reinaud (2004)
Unitary electric consumption (MWh)	-	0.4	0.103	15.2
Source	Reinaud (2004)			

[24] Electricity generation requires the use of much diverse technologies than in other industries. That's why we stress that the data for this sector are average values.
[25] Reinaud distinguishes the BOF and EAF routes for steel making. We aggregate the data by summing them, weighted by their shares in total production capacity of EU and non EU countries (IISI, 2006) .
[26] Production costs from Reinaud (2004) have been increased proportionally to make them correspond with the steel price used from (Demailly and Quirion, 2006b).
[27] Investment Cost = Price – Variable Production Cost, except for electricity.
[28] Using investment and production cost data for nuclear, gas and coal generation (DGEMP/DIGEC, 1997) as well as their share in EU 25 production (from Eurostat), we separate average production and investment costs.

EU / RoW Indirect unitary emissions (tCO2)	-	0.15 / 0.21	0.04 / 0.06	5.9 / 8.6
MACC	PRIMES	PRIMES	PRIMES [29]	-
10^{-6} x (Production / Imports / Exports / Consumption)				
EU	3000/0/0/3000	187/24/37/174	211/15/8/218	2.9/3.9/0/6.8
Row	-	943/36/24/955	1729/8/15/1722	-
Year	2004	2004	2003	2003
Source	Eurelectric (2006)	IISI (2006)	Cembureau, (2004)	EAA

Box 3: CASE data

[29] It is worth noting the MAC used for the cement sector is conservative because it does not take into account reduction in process emissions, whereas the potential is considerable (Prebay et al, 2006).

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