1-15-2009

Changing the Allocation Rules in the EU ETS: Impact on Competitiveness and Economic Efficiency

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NOTA DI LAVORO 89.2008

OCTOBER 2008

CCMP – Climate Change Modelling and Policy

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Summary

We assess five 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), auctioning with border adjustments (AU-BA), and finally output-based allocation in sectors exposed to international competition combined with auctioning in electricity generation (OB-AU). We look at the impact on production, trade, CO_2 leakage and welfare. We use a partial equilibrium model of the EU 27 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. The leakage ratio, i.e. the increase in emissions abroad over the decrease in EU emissions, ranges from around 8% under GF and AU to -2% under AU-BA and varies greatly among sectors. Concerning the overall economic cost, OB appears to be the least efficient policy, even when taking into account its ability to prevent CO_2 leakage. On the other hand, this policy minimises production losses and wealth transfers among stakeholders, which is likely to soften oppositions. GF and AU are the most efficient policies from an EU perspective, even when leakage is accounted for. From a world welfare perspective and whatever the emission reduction, AU-BA is the least costly policy, while OB-AU, AU and GF entail similar costs.

Keywords: Emission Trading, Allowance Allocation, Leakage, Spillover, Climate Policy, Kyoto Protocol, Border Adjustment

JEL Classification: Q5

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1. Introduction

The EU ETS, created by directive 2003/87/EC and presented in a box below, officially 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 of 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 should issue a legislative proposal on January 23rd, 2008. 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[3].

⇒ 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; 2006; Åhman et al., 2007; Schleich and Betz, 2005).

⇒ 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 CO_2 emissions on to prices although they receive allowances for free (Sijm et al., 2006).

⇒ The EU CO_2-intensive industry may suffer from a competitive disadvantage vis-à-vis competitors located in countries without a similar climate policy. This may induce a loss in market shares and employment. It may also entail CO_2 leakage, i.e., a part of the emission reductions generated in the EU may be offset by an increase in emissions elsewhere.

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 Achilles' heel of the directive (Boemare and Quirion, 2002). Indeed allocation is not only a distributive issue but may impact the economic efficiency and the competitive disadvantage vis-à-vis the rest of the world. The five 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 (2006) have shown, with a sectoral model of the cement industry, that OB induces no windfall profit and reduces the competitive disadvantage and CO_2 leakage. However it may reduce economic efficiency compared to auctioning or grandfathering (Burtraw et al. 2001, Fischer 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 Åhman 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 disadvantage – updating, new entrants reserve and closure rules create an

[3] In addition, 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.

incentive against relocation in foreign countries – and increase further windfall profits, as shown by Demailly and Quirion (2008) with a sectoral model of the steel industry.

Auctioning (AU). The competitive disadvantage 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, the revenue raised through the auction may be used to finance cuts in pre-existing distorting taxes (e.g. Goulder et al. 1999). Second, 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; 2002) highlight the importance of this effect for a US ETS covering the power sector. In this paper, we address neither the first effect, which would require a general equilibrium model, nor the second, which will critically depend on the evolution of the deregulation process in the power sector in the next decade.

Auctioning with border-tax adjustments (AU-BTA). In such a system, exporters from the EU would get charges they incurred refunded, at least partially, while importers would face a tax based on the emissions embedded in their products[4]. On the one hand, compared with AU, it would solve the competitive disadvantage 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 Mæstad (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 assess it in this paper. It is worth highlighting that the compatibility of BTA with WTO rules is controversial (Ismer and Neuhoff, 2004; Biermann and Brohm, 2005) but they recently had the support of the Nobel Prize laureate Joseph Stiglitz (2006), of the French current government or of the EU Industry commissioner Günter Verheugen (2006).

Output-based allocation in cement and steel sectors and auctioning in the electricity sector (OB-AU). The rationale of this hybrid variant, which was considered in the Netherlands before the launch of the EU ETS (Kuik and Mulder, 2004), is that cement and steel**,** but not electricity, are exposed to international competition.

In this paper, we assess both analytically and numerically the application of these five proposals to the EU ETS. We look at their impact on production, trade, CO_2 leakage, overall economic cost and revenue distribution. To our knowledge, such a comprehensive assessment has not been led yet. Bernard et al. (2005) and Klepper and Peterson (2006) analyse with general equilibrium models the existing EU ETS but do not assess these proposals. Bernard et al. (2007), Burtraw et al. (2001), Fischer and Fox (2004), Haites (2003) or Kuik and Mulder (2004) analyze some of these proposals but not within the EU ETS context and only the former paper takes into account the CO_2 leakage induced to assess the economic efficiency. The present paper required the development of a partial equilibrium model of the EU 27 featuring four sectors – Cement, Aluminium, Steel and Electricity, hence the name CASE – linked through electricity and CO_2 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 CO_2 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

[4] We only combine BTA with AU and not with GF or OB because the latter two would be politically difficult to defend: EU exporters would receive a subsidy despite paying no allowances for their emissions.

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 are displayed in section 4, and section 5 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 gathering 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.

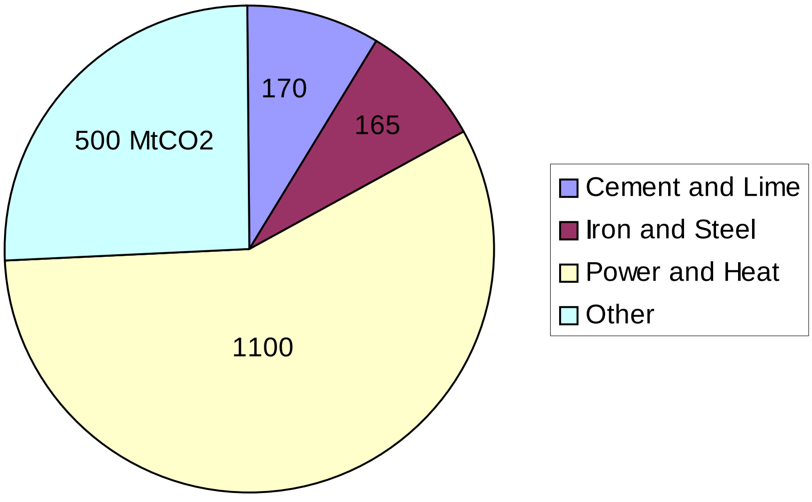

Figure 1. 2005 ETS emissions (source: Kettner et al., 2007)

Box 1: 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[5]. 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 Fischer (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

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, AU-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:

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

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

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:

$$C'[ua] = \lambda \tag{3}$$

$$P = C[ua] + \lambda(ue_0 - ua) \tag{4}$$

Equation (3) shows that the marginal cost of abatement equals the shadow price of the constraint λ 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:

[5] 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".

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

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

$$C'\left[ua\right] = P_{CO_2} \tag{6}$$

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

We get the optimal conditions (3) and (4), with $P_{CO_2} = \lambda$. 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[6].

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:

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

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[6] This assumption is important as it guarantees that OB and GF or AU lead to the same shares for the various technologies in new investments (see for example Neuhoff, 2005). Hence it will allow us to use the same Marginal Abatement Cost Curves for the various policies. It is worth noting however that, in the power sector, we may assume that the operators of non-fossil plants, i.e. nuclear and renewable plants, get no allowance. Indeed, the nuclear and renewable capacity may be seen as unaffected by the ETS, on the ground that it depends on political State-level decisions and/or on State subsidies.

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 CO_2 price than GF and AU[7].

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 CO_2 leakage (Haites, 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 CO_2-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 links several sectors that differ e.g. as regards their abatement ability and demand elasticity, so some sectors are net buyers and others net sellers of allowances (Fischer, 2001). 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. 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 around 2015[8], i.e. the mid-term of the 3rd phase of the EU ETS, three sectors covered by the EU ETS, electricity, cement and steel, and one which is not, aluminium. The aluminium sector is electric-intensive: whereas its direct emissions are not covered by the ETS, it is impacted through the rise in electricity prices.

The last two sectors being not as homogeneous as the first two, it is worth specifying 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 aggregate long and flat end-products which constitute, until now, the bulk of steel trade.

The three sectors of the EU ETS modelled in CASE represent around 75% of the emissions covered by the system. They were also chosen because they should be impacted quite

[7] 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 might thus increase social welfare (Fischer, 2001).

[8] 2015 because of the Marginal Abatement Cost Curves used which assume a 10 years time horizon.

differently by the ETS given that many determining elements differ across sectors[9]:

- *their CO_2 intensity*: cement has the highest direct plus indirect emissions over turnover ratio, followed by electricity and by far by steel. This ratio is low for aluminium if we do not consider its direct emissions which are not covered, intermediate otherwise.

- *their CO_2 abatement potential*: for a given CO_2 price, power generators and steel manufacturers are able to decrease their unitary emissions at a much higher rate than cement producers according to the PRIMES (Blok et al., 2001) model. For every sector, we fit a linear-quadratic function from the results of the model.

- *the international competition they are subjected to*: trade exposure – defined as exports as a percentage of production, plus imports as a percentage of consumption – equals around 60% for the EU Aluminium sector, 20% for steel, 10% for cement and 0% for electricity.

- *the price elasticity of demand*: aluminium, steel and cement demands are generally considered as more elastic than electricity demand.

In the model, all sectors are first linked through the electricity market (Figure 2). The steel, cement and electricity sectors are also linked through the CO_2 market. The CO_2 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[10]. The steel, aluminium and cement sectors are linked to the rest of the world through product competition. An appendix presents the values and sources for all variables.

To build the BAU scenario, we assume that the growth rates of production and of unitary emissions (emissions/production) remains the same as in the last ten years.

We do not model emissions in the rest of the ETS, nor emissions outside the ETS. These emissions could differ across our scenarios, due to some indirect effects (e.g. substitution between electricity and gas in building heating), but this effect is probably limited.

An important additional assumption is that there is no climate policy in the rest of the world. This is not the most likely scenario, but taking this pessimistic assumption allows assessing the consequences of the EU ETS in the worst case.

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[9] All the following insights and figures are from computation based on the data given in appendix.
[10] We thus neglect CDM, JI hence we overestimate the CO_2 price and competitiveness impact of the ETS. We also neglect banking which has an ambiguous impact on CO_2 price.

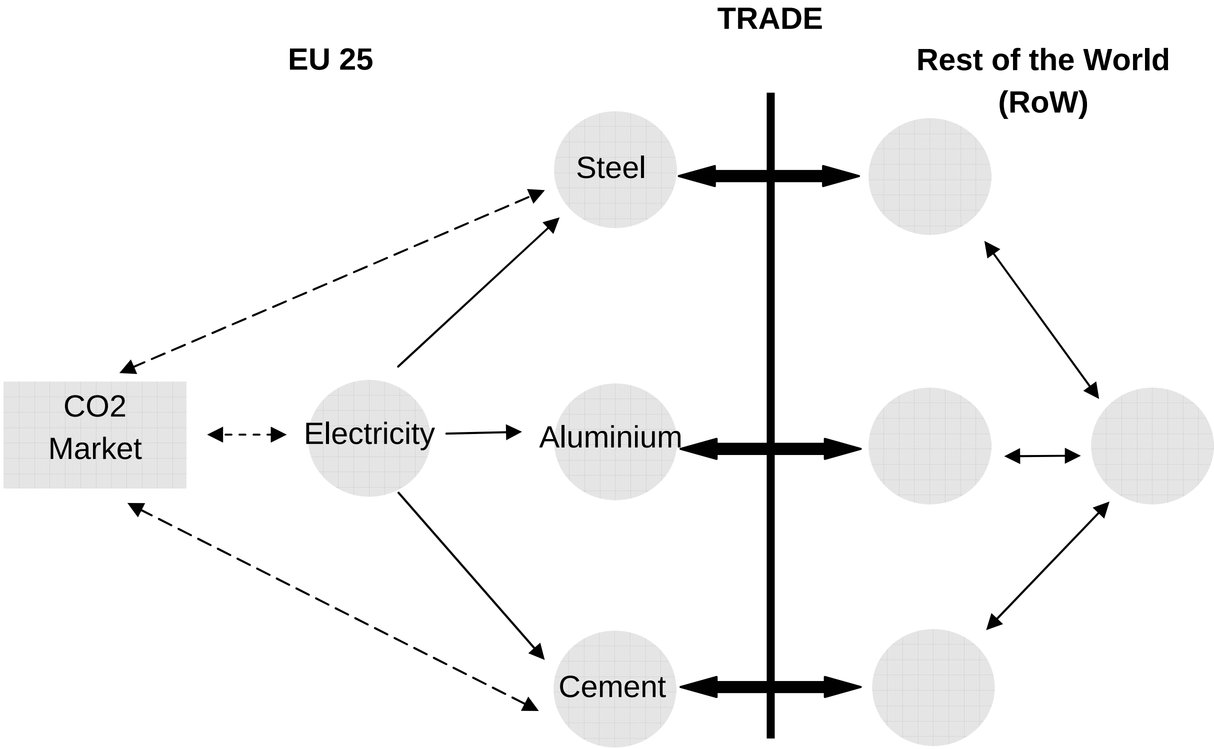

Figure 2: Sectoral links in the CASE model

All sectors are modelled in the same way. The equations of the sectoral sub-models are listed in box 2 and explained below. For EU variables we use the subscript *e*, for RoW variables we use the subscript *r*. A superscript 0 means the value of the variable in BaU.

EU 25	**Rest of the World**
Production Cost	
M1: $c_e = c_e^0 + uac_e + ec_e + P_{CO_2} \cdot ue_e$ M2: $P_{CO_2} = \alpha \cdot ua_e + \beta \cdot {ua_e}^2$ M3: $uac_e = \int_0^{ua_e} \left(\alpha \cdot ua + \beta \cdot ua^2\right) dua$ M4: $ec_e = ec_e^0 + uel_e \cdot \Delta P_{ee}^{elec}$	$c_r = c_r^0$
Manufacturers prices	
M5: $P_{ee} = c_e$ M6: $P_{er} = c_e - s_{BTA}$ M7 (AU, GF, OB & OB-AU): $s_{BTA} = t_{BTA} = 0$ M7 (AU-BTA): $s_{BTA} = t_{BTA} = P_{CO_2} ue_e + \Delta ec_e$	$P_{rr} = c_r^0$ $P_{re} = c_r^0 + t_{BTA}$
Product Market	
M8: $Q_e = \left(a_e - P_e\right) / b_e$ M9: $P_e = \left({\beta_e}^{\sigma} {P_{ee}}^{1-\sigma} + \left(1-\beta_e\right)^{\sigma} {P_{re}}^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$ M10: $D_e = \left(\beta_e \frac{P_e}{P_{ee}}\right)^{\sigma} Q_e$ M11: $M_e = X_r = \left(\left(1-\beta_e\right) \frac{P_e}{P_{re}}\right)^{\sigma} Q_e$	$Q_r = \left(a_r - P_r\right) / b_r$ $P_r = \left({\beta_r}^{\sigma} {P_{rr}}^{1-\sigma} + \left(1-\beta_r\right)^{\sigma} {P_{er}}^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$ $D_r = \left(\beta_r \frac{P_r}{P_{rr}}\right)^{\sigma} Q_r$ $X_e = M_r = \left(\left(1-\beta_r\right) \frac{P_r}{P_{er}}\right)^{\sigma} Q_r$
Consumers' Surplus	
M12: $S_e = \left(a_e - P_e\right) \cdot Q_e / 2$	$S_r = \left(a_r - P_r\right) \cdot Q_r / 2$
CO_2 Emission	
M13: $E_e = \left(D_e + X_e\right) \cdot ue_e$	$E_r = \left(D_r + X_r\right) \cdot ue_r^0$
Sectoral Profit	
M14: $\Pi_e = P_{ee} D_e + P_{er} X_e - c_e\left(D_e + X_e\right) + P_{CO_2} GF + s_{BTA} X_e$	$\Pi_r = P_{rr} D_r + P_{re} X_r - c_r\left(D_r + X_r\right) - t_{BTA} X_r$
State Revenue	
M15 (GF & OB): $R_e = 0$ M15 (AU & AU-BTA): $R_e = P_{CO_2} E_e - s_{BTA} X_e + t_{BTA} X_r$	$R_r = 0$

Box 2: CASE sub-model equations

Equation M1 is similar to equation (10) in the analytical model above. It states that the long-term marginal production cost (c_e) is constant with respect to production and increases, compared to its value in the BaU scenario, by the unitary abatement cost (uac_e), by the rise in electricity cost (ec_e) and by emission cost i.e. the value of emissions minus – under OB – the allowances distributed.

M2 is the usual equalisation of the marginal abatement cost, assumed quadratic, and fitted to the results of the PRIMES model (Blok et al., 2001). M3 follows directly.

M4 states that the increase in electricity cost is simply the rise in electricity price (endogenous) times the unitary electric consumption (uel_e). 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.

M5 and M6 state that the prices set by EU producers at home (P_{ee}) and abroad (P_{er}) increase by the rise in their marginal cost. By this we assume a complete pass-through. Admittedly, these industries are imperfectly competitive, which may entail an incomplete pass-through because such firms may absorb a part of their cost increase in order to maintain output (Dornbusch, 1987). Yet Stennek and Verboven (2001) conclude that in the long run, sales taxes are fully passed on to consumers. A second reason for incomplete pass-through may be international competition, which reinforces the previous effect by increasing the elasticity of each firm's own demand. Unfortunately, whereas there are some estimates of the pass-through rates on exports markets following a cost increase, no such quantification exist for the domestic market. Whatsoever, the partial absorption of marginal cost increase by a firm only makes sense for a low cost increase, i.e. which does not lead to the collapse of the profit margin. For these reasons we do not assume that international competition limits the pass-through: EU firms pass 100% of their cost increase into their prices whatever the cost variation.

M7 states that under AU-BTA, a rebate s_{BTA} covers the emission cost. This rebate, as well as the tax on imports to the EU, equals the value of the average direct plus indirect unitary emissions in Europe. Doing so, we do not model the "pure" BTA system defined in introduction but a system close to the one proposed by Ismer and Neuhoff (2004) which has the advantage, according to the authors, to be compatible with the rules of the World Trade Organization[11].

M8 states that the demand for each good is linear. The price-elasticity of demand in the BaU scenario is taken from Oxera (2004). Note that we do not take into account the cross-price elasticities among the materials impacted by the EU ETS, which are most likely positive: steel, bricks and cement are substitutes in buildings, steel, aluminium and glass in packaging, steel and aluminium in transport materials… Hence we probably overestimate the decrease in demand caused by the EU ETS. For electricity, demand is the sum of the demand from the three other sectors modelled and of a linear demand from the rest of the economy[12].

M9 states that except in the electricity sector, we rely on the Armington (1969) specification, σ being the Armington elasticity[13]. In the electricity sector we assume neither imports nor

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[11] Ismer and Neuhoff tax/subsidize 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, according to some sensitivity tests we made, the differences should not be very significant.

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

[13] The underlying assumption is that goods produced in the EU and in the RoW are imperfect substitutes. Such a

exports because at the EU level they are negligible. We stress that the econometric estimations of Armington elasticities are short to medium run; hence they might not capture long term effects like the partial relocation of capital which becomes mobile in the long run. M10 and M11 derive from M9, they give the market shares of EU and RoW producers in the EU market.

M12 is the consumers' surplus, which derives from M8. The last equations are accounting relationships.

4. Results

In this section, 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 2005 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. CO_2 price and channels to reduce emissions

As we have seen previously, in a closed economy there are two channels to reduce EU emissions:

- the unitary abatement channel, i.e. the reduction in unitary emissions of CO_2-intensive goods;

- the production channel, i.e. the reduction in the production of such goods.

In an open economy the production channel has to be split between the consumption channel, i.e. the drop of EU consumption due to higher prices, and the trade channel, i.e. the relocation of the production of CO_2-intensive goods in the rest of the world. If the latter is efficient to reduce EU emissions, it leads to CO_2 leakage, hence challenges the environmental efficiency of the system. Figure 3 displays for various sectors and policies the share of the channels to reduce the emissions covered by the EU ETS by 15% compared to 2005.

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statement might seem doubtful especially for a product like cement which is seen as homogeneous throughout the world. However, even if one assumes that the cement produced in Turkey is the same as the cement produced in France, the quantity of Turkish cement available in France and its price fluctuate with the economic growth in Turkey, international transportation costs, exchange rate… Therefore, the *service* provided by French cement manufacturers differs from the RoW in the price stability and security of supply. It may also differ in the help provided for the use of their product, in marketing…

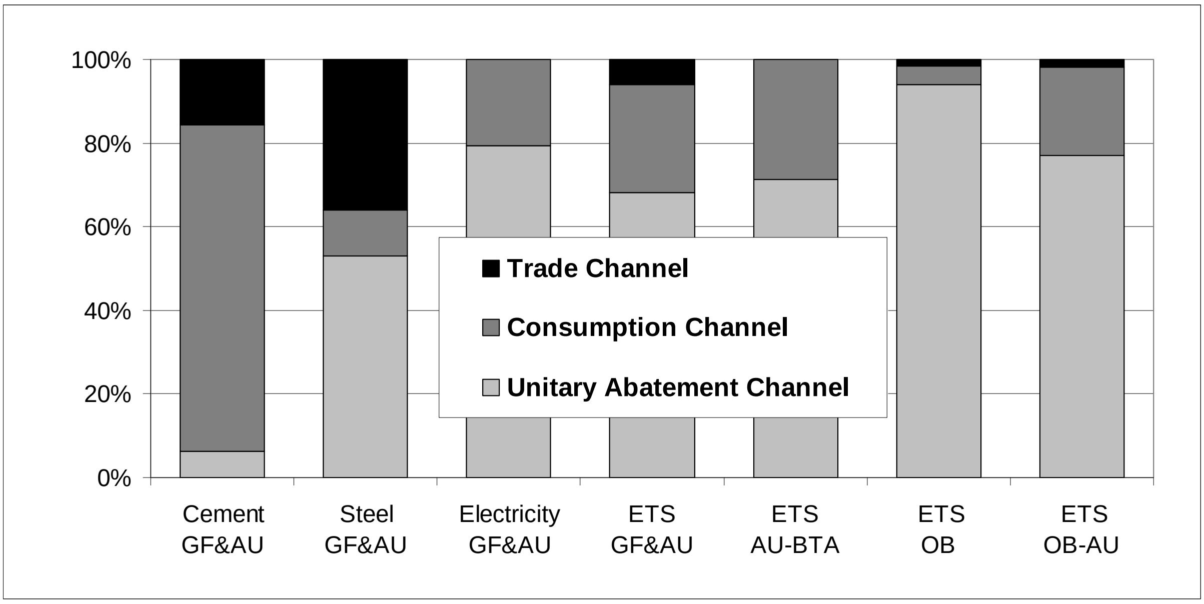

Figure 3. Share of the channels to reduce the emissions covered by the EU ETS by 15% compared to 2005

First, it turns out that the role of every channel varies a lot with sectors. According to PRIMES, the ability of cement manufacturer to reduce emissions is low. Hence, under GF or AU, the unitary abatement channel plays a minor role in this sector, whereas it is predominant in the steel and electricity sectors. Moreover, the production channel is dominated by the consumption channel in the cement sector, given its low trade sensitivity[14], and before all in the electricity sector. Conversely, the trade channel dominates the production channel in the steel sector which is more trade sensitive.

If one aggregates sectors, hence one takes into account the weight of the electricity sector, GF and AU rely at 70% on unitary abatement and at less than 5% on trade to reduce EU ETS emissions. The share of the latter channel drops to 0 under AU-BTA, which thus requires further efforts in unitary abatement to achieve the same emission reduction target. Such efforts are also necessary under OB, the production channel falling to around than 5% because of the low impact of this allocation methodology on all good prices, and under OB-AU, the production channel falling to less than 25% because of the low impact on cement and steel prices.

Further reductions in unitary emissions necessitating higher CO_2 prices, to provide the adequate price signal to firms, the CO_2 price under AU-BTA, OB-AU and before all under OB are higher than under AU or GF: around +10%, +25% and +70% respectively for a 15% ETS emission reduction. CO_2 prices are displayed on the following graph.

[14] A sector is trade sensitive if its trade exposure *and* its Armington elasticities are relatively high.

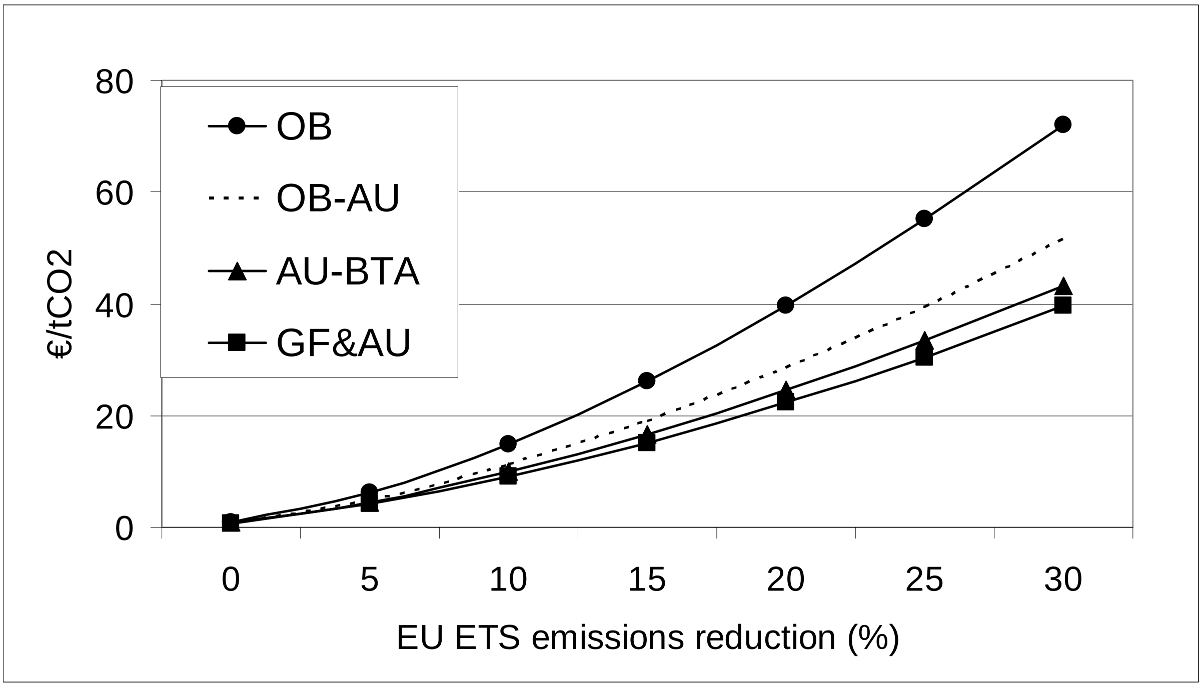

Figure 4: CO_2 price for the five policy options

4.2. Impact on Production

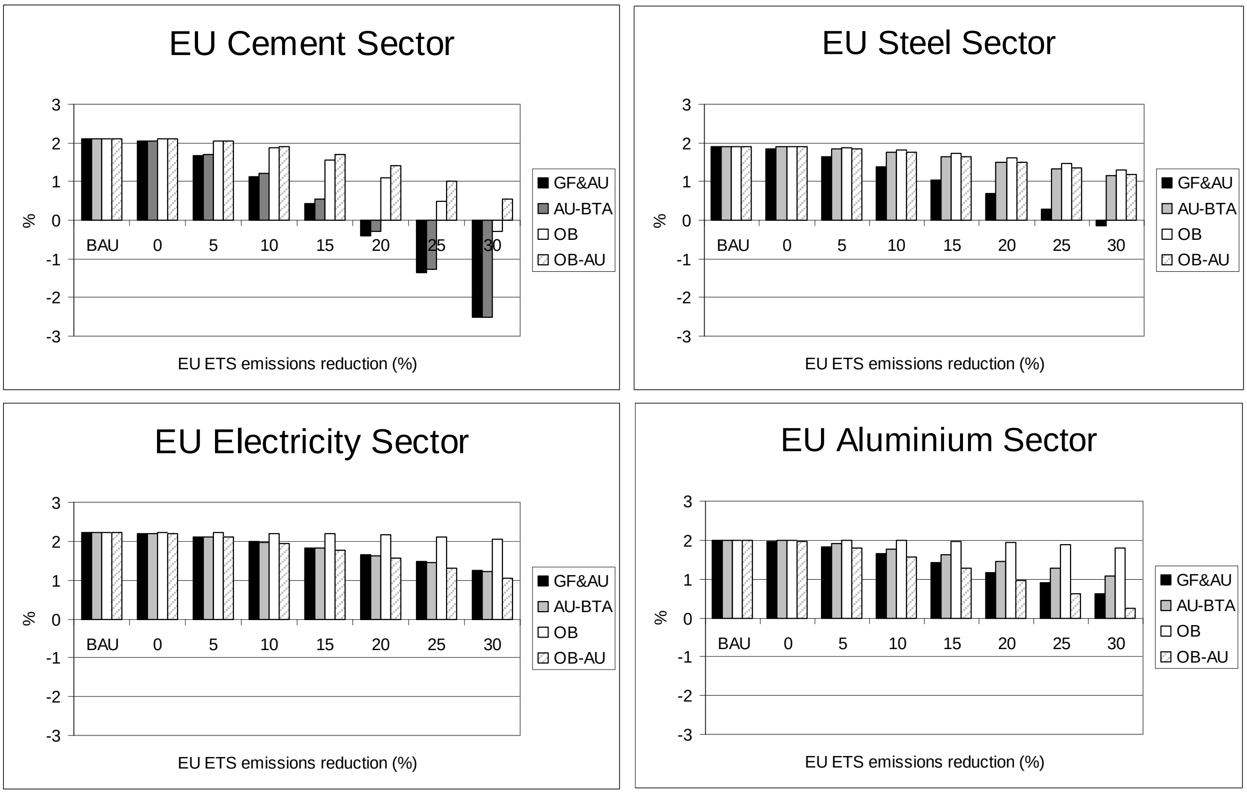

Figure 5: Average annual production growth ratio from 2005 to 2015

4.2.1. Sectoral production losses under AU or GF

The cement sector is not particularly trade sensitive and neither is its demand especially elastic to price. However, its high CO_2-intensity leads it to be the sector with the highest production drop under AU or GF. For a 15% ETS emission reduction, a sound target for 2015[15], its average production growth is close to nil whereas it is around 2% under BAU. Nevertheless, the sector's production keeps on increasing and higher targets would be required to make it drop. Moreover, it is worth noting that around 15% of production losses compared with BAU are due to market share losses vis-à-vis foreign competitors. Production losses are mainly due to a reduction in EU cement consumption. Hence, the production and related employment issues in the cement sector are not that much a matter of competitive disadvantage vis-à-vis foreign producers.

The slowdown of the production growth in the other sectors is lower. In the steel sector, the growth ratio falls "only" from around 2 to 1% for a 15% cut in the EU ETS emission, in spite of its relatively high price demand elasticity and to its trade exposure. It is due to its relatively low CO_2-intensity. In this sector around 3/4 of the production drop is due to market share losses. The picture is quite similar for the aluminium sector. Concerning the electricity sector, its CO_2 intensity is offset by a relatively inelastic demand and because it is sheltered from the competition of non EU producers.

4.2.2. Impacts on production of the different policies

As seen previously, AU-BTA leads to slightly higher CO_2 prices than AU or GF, hence a higher price increase and a lower consumption in the electricity sector. Moreover, in the other sectors opened to trade, prices are higher because non EU products are taxed at the border. Conversely, almost all the production losses through trade vanish. Finally, these sectors incur slightly lower losses than under AU, the latter effect dominating.

OB has the same kind of impact as AU-BTA on trade flows: roughly speaking, the relative price of EU vs. foreign producers increases only marginally, at least for low targets. Conversely, 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 for all sectors and low targets. For high targets however, the production growth in the steel and before all the cement sectors is significantly reduced. Indeed, both sectors and especially the latter have to buy allowances (to the electricity sector) to compensate their relatively low ability to decrease their unitary emissions. Hence their production cost and their prices significantly increase.

Compared with OB, the auction of allowances to electricity generators under OB-AU reduces the emission cost of cement and steel manufacturers – as the CO2 price is lower – but raises their electricity cost. Depending on the relative size of the emission and electricity cost, the manufacturers see their production cost increasing and their production slowing (steel), or the opposite (cement). For the electricity and the aluminium, the impact on production is clearer: it is similar as under AU or GF and even increased as the CO2 price raises.

4.3. CO_2 leakage

As we have just seen, the EU ETS leads to market share losses in the sectors which are trade

[15] The EU has recently announced a 20% unilateral emission reduction target for 2020 compared with 1990, whereas it is supposed to reduce its emissions by 8% around 2010.

sensitive. These losses induce CO_2 leakage, i.e. an increase in CO_2 emissions from non EU countries, where production is globally more CO_2-intensive. We label this source of leakage the "competitiveness channel"[16]. The leakage ratio of a sector is defined as the increase in the direct and indirect emissions from this sector in the RoW over the decrease in direct and indirect emissions in the EU.

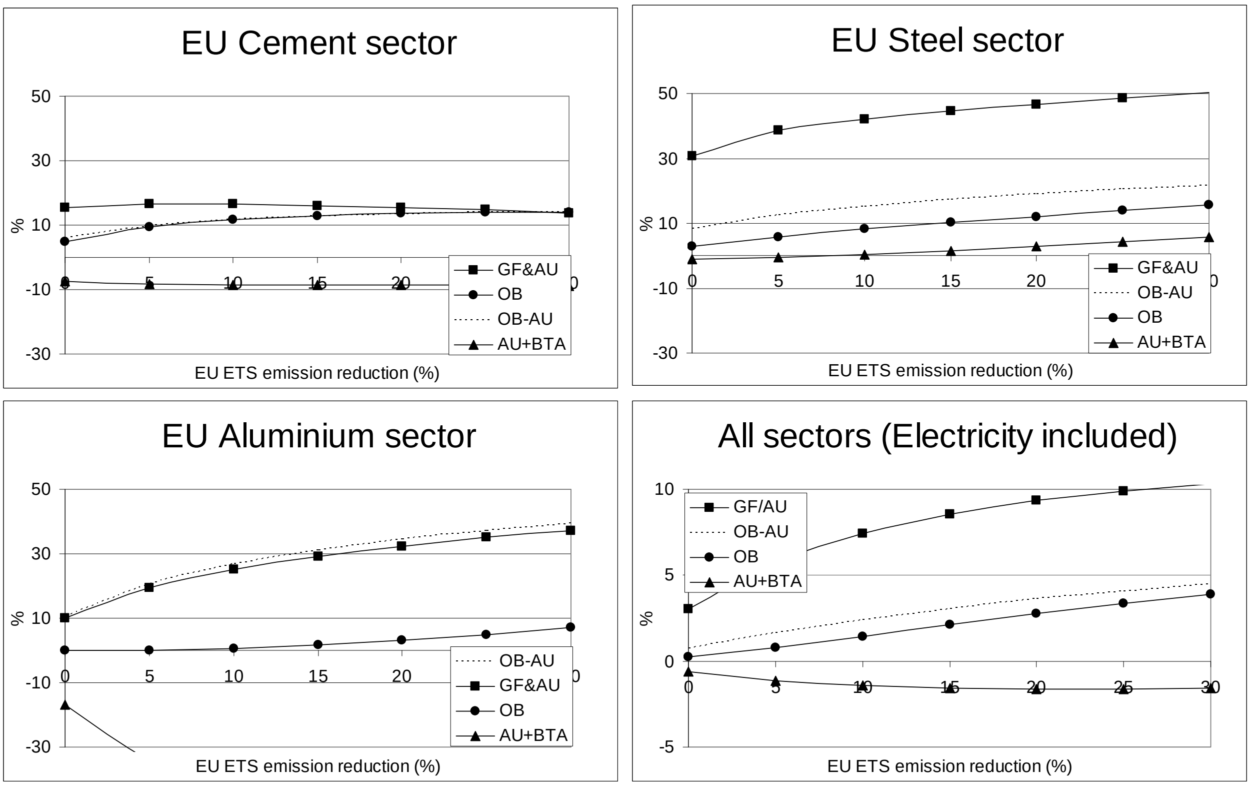

Figure 6: CO_2 leakage

4.3.1. Sectoral CO_2 leakage under AU or GF

Being not subjected to international competition, the leakage ratio of the electricity sector equals zero and is not displayed here. It does not mean that the electricity sector in the RoW does not increase its emissions. Actually, it does because its production increases to satisfy the rise in demand of the other sectors from the RoW, which gain some market shares. However, in our sectoral leakage estimates, indirect emissions are assigned to the electricity consumers.

As we have seen previously, the EU Aluminium sector is trade sensitive: around 40% of its drop in production is due to trade, hence is offset by a rise in production abroad which is more CO_2 intensive. Moreover, being not covered by the ETS, EU aluminium manufacturers do not have an incentive to decrease their unitary emissions. These two elements should lead to a

[16] 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 across sectors the leakage ratios we have to be aware that we only compare their different contribution to the competitiveness channel, what remains worthy.

very high leakage ratio. However, indirect emissions of the sector, which represent around 2/3 of its total emissions, decrease thanks to the important improvements made in the electricity generation: finally, the leakage rate is around 30% for a 15% emission reduction.

In the cement sector, we have seen that around 15% of the production drop in the EU is offset by a rise abroad. The – low – improvements in unitary emissions just offset the higher CO_2 intensity of cement production in the ROW and the leakage ratio is around 20%.

The fact that the improvements in direct unitary emissions are not so expensive for steel manufacturers – they are responsible for more than half of the CO_2 emissions reduction in this sector, partially offset their trade sensitivity highlighted previously. Hence, the leakage ratio in the EU steel sector is the highest, around 45%, but is lower than one may have feared.

In aggregate, the leakage ratio of the EU ETS is low, around 8%, what traduces the weight of the electricity sector.

4.3.2. EU ETS CO_2 leakage for the different policies

Globally, leakage ratios are much lower under OB, OB-AU and AU-BTA. It drops to around 2% under OB: as highlighted in Demailly and Quirion (2006) OB is an efficient tool to prevent leakage. Unsurprisingly, leakage ratios under OB-AU are close to the ratio under AU for the aluminium sector, and to the ratios under OB for the cement and steel sectors. Finally, it prevents leakage almost as much as OB.

Under AU-BTA, the leakage ratio is negative, around -2%, because net imports tend to decrease with AU-BTA. This drop is not due to the fact that EU producers gain market shares at home, the non EU producers being taxed in accordance with the CO_2 intensity of EU producers while experiencing no abatement costs. For the same reason, neither do the formers gain market shares abroad. The drop in net imports is due to the decrease in consumption of EU consumers, which more than offset the gains in market shares of foreign firms.

4.7. Overall economic cost

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 CO_2 emissions. Neither does it include the dynamic cost due to workers retraining for example. The economic cost of the five policy options is defined as the loss in welfare they entail in 2015 compared to business-as-usual.

A caveat is that we do not take into account pre-existing distortions and the impact of our five policies on them when ranking the latter: 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 CO_2 leakage and the impacts of these policies on the RoW.

4.7.2. From the EU point of view

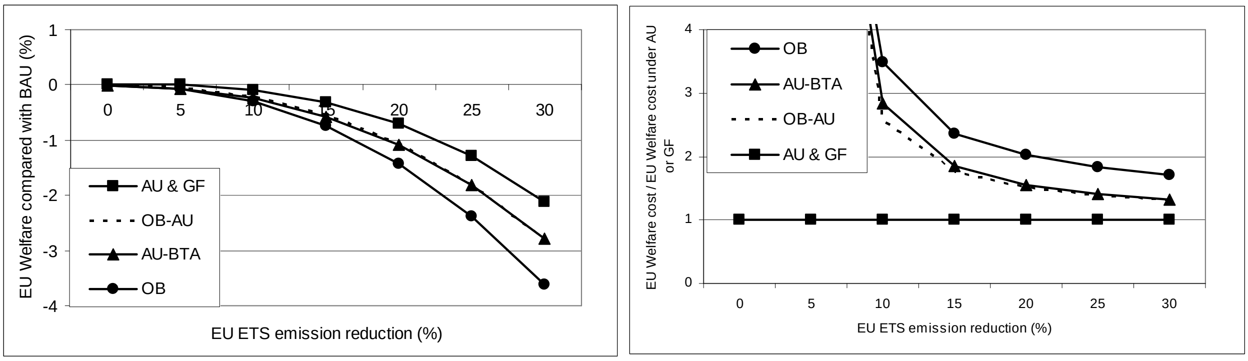

Figure 7:Impact on EU Welfare of the five policy options. Left panel: as a percentage of BAU welfare. Right panel: as a proportion of the welfare cost of AU or GF

Unsurprisingly, AU or GF lead to the lowest welfare losses for the EU, followed by OB-AU and AU-BTA, which are close, and by OB. The first explanation has already been presented above: for a given target, OB entails too much production and too much unitary abatement; so does OB-AU in the cement and steel sectors; AU-BTA entails too much production as it does not use the trade channel, which is efficient as long as we do not take into account the CO_2 emissions increase in the RoW. A second explanation is that AU and GF create a significant wealth transfer from the RoW to the EU, whereas the other three policies do not, or only to a much lower extent.

Indeed, under AU or GF, the increase in price paid by foreign consumers for traded EU products – cement, steel and aluminium directly, electricity indirectly – entails a wealth transfer from foreign consumers to the EU budget (under AU) or to EU firms (under GF). This 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, which can be hardly seen on the graph: this is why these policies are so cost efficient for low targets compared to the others. 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.

Under OB, the increase in price for EU products paid by foreign consumers – hence the wealth transfer – is much lower, although it becomes significant for high targets – steel and before all cement manufacturers buying allowances to the electricity producers to compensate their lower ability to reduce unitary emissions.

Under OB-AU, a part of the wealth transfer which occurs under AU is conserved, as the increase in prices of aluminium and electricity is preserved. This part is significant but small as the main sectors which benefits from this transfer under AU are cement and steel.

Under AU-BTA, the wealth transfer from the RoW is due to the fact that the EU budget benefits from a transfer from foreign firms, through the tax on imports. However, this remains marginal.

Thus, the various climate policies differ according to their "wealth transfer effect" and to their "channels effect", i.e. their different use of emission reduction channels. It turns out that the former dominates for low emission targets. Indeed, as one may see on Figure 8, when one takes into account both effects, OB, OB-AU and AU-BTA are around 70%, 30% and 30%

more costly than AU or GF respectively for the most stringent target considered. These gaps more than double for a 15% emission reduction target. If one abstracts from the wealth transfer effect by taking into account welfare losses from the RoW, relative gaps among policies are much lower (and stable): OB is 30% more costly than AU or GF, 10% more for AU-BTA and less than 10% more for OB-AU, for a 15% emission reduction.

It is worth noting that OB-AU and AU-BTA yield almost the same cost in terms of EU welfare: the low use of the production channel in the former for the cement and steel sectors is offset by a higher wealth transfer and the fact that the latter does not use at all the trade channel.

4.7.2. Adopting a global perspective

If one wants to assess the cost efficiency of various climate polices from a global perspective, it is fair to take into account the CO_2 leakage which deteriorates the environmental effectiveness of some climate policies. That is why we compute the cost of the various policies including leakage: 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 10-0.05*10=9.5%. Results are displayed on the figure above.

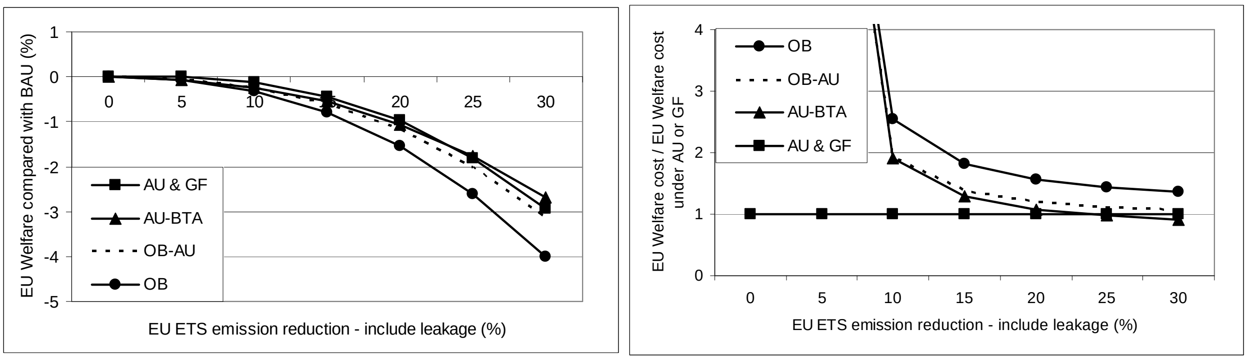

Figure 8: EU welfare loss from the five policy options, including leakage. Left panel: as a percentage of BAU welfare. Right panel: as a proportion of the welfare cost of AU or GF

Including leakage, the cost efficiency of AU, GF, OB and OB-AU deteriorate, especially the two former as they entail higher leakage ratios. AU-BTA, which leads to a slight spillover, improves. Given the globally low CO_2 leakage, AU or GF remain the best option for low to intermediate targets, although the gaps with the other policies decrease For the most stringent target considered here, AU-BTA is slightly more efficient than AU or GF, and OB-AU slightly less efficient.

However, adopting a global perspective, it is fair not only to consider CO_2 leakage but also the impact of EU policies on the world welfare, i.e. to add to the EU welfare losses the losses from the RoW (Figure 9).

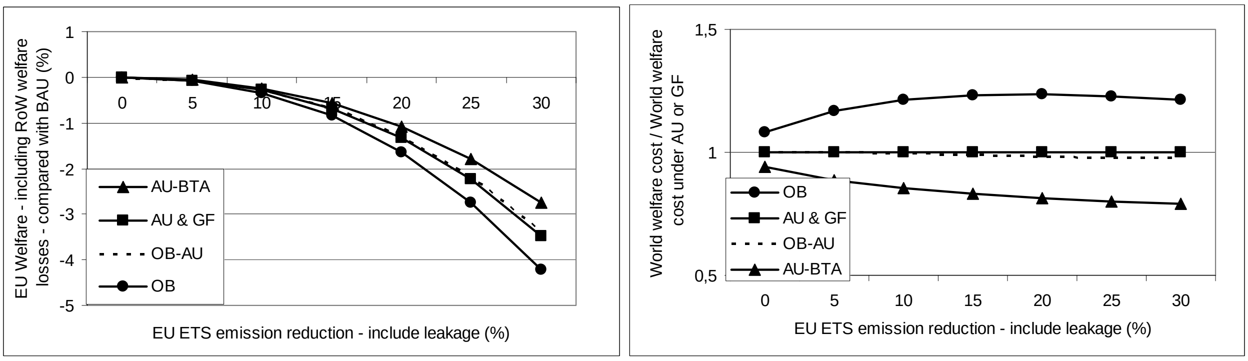

Figure 9: World welfare loss from the five policy options, including leakage. Left panel: as a percentage of BAU EU welfare. Right panel: as a proportion of the welfare cost of AU or GF

Factoring out the wealth transfer effect from the various policies, OB-AU, OB and even more AU-BTA improve compared with AU or GF as they induce lower wealth transfer. Finally, from this global perspective, AU-BTA is the most efficient policy whatever the emission reduction: it is around 20% less costly than AU or GF. OB-AU turns to be roughly as efficient as AU or GF while OB remains around 20% more costly.

How would the previous rankings be impacted if we had taken into account pre-existing distortions? Literature, using general equilibrium models, has shown that “policies that raise revenues and use these revenues to finance cuts in pre-existing distorting taxes have lower costs than policies that do not generate and recycle revenues in this way.” (Bovenberg et al., 2005). Hence, if the auction revenue were used to cut taxes, the performance of GF would deteriorate vis-à-vis revenue-raising policies.

Output-based allocation does not raise revenue hence does not allow to reduce pre-existing taxes. However, it partly reduces the negative impact of such taxes on production, since it constitutes an implicit production subsidy. In Goulder et al. (1999), the introduction of pre-existing distorting taxes does not change the relative cost of AU and OB, but it dramatically raises the cost of GF compared to the other policies. Hence, one may consider that pre-existing distorting taxes would not change the relative costs of AU, AU-BTA, OB-AU and OB while severely deteriorating GF.

It is fair to stress that the implicit production subsidy when allowances are output-based may be beneficial in imperfectly competitive industry, where firms underprovide output. However, as stressed by Fischer (2001), gains are uncertain for various reasons, in particular because quantifying market power is difficult[17].

[17] As it has been enhanced by various authors when comparing GF, AU and OB (Goulder et al., 1999), the cost differences among policies depend importantly on the emission reduction target. However, according to CASE, the Goulder et al. (1999)'s result that the higher the target, the lower the difference, does not hold. If it is true that the costs converge for very high targets not displayed here (for a zero emission target, all unitary emissions must equal zero, hence the production channel is nil), it is the opposite for the lower targets presented in this subsection. Actually, the evolution of the relative cost of OB and the other policies with the target depends on the relative evolutions of the unitary abatement and production channels. For example, by just modifying the form of the electricity MACC one may get the opposite conclusion.

4.5. Distributive impacts

The previous section has focused on the overall economic cost of policies. This one deals briefly with the sharing of the burden among EU stakeholders – firms, consumers and state – when one does not take into account leakage[18].

Given our assumption of 100% pass-through, firms make no profit with the implementation of climate policies, except under GF. Under GF, firms' profit equals the value of the allowances given to them for free. This value increases with the strengthening of the emission reduction target, i.e. the reduction in the amount of allowances is more than compensated by the rise of the CO_2 price. For a 15% emission reduction, firms' profit is close to 20 billion €, of which 15 for electricity generation, 2.5 for steel and 2.5 for cement. This means that the net profit margin (profit/total production cost) increases by 7 percentage points. This gain is in the detriment of the consumers whose surplus drops by almost 10% for the same target. Such a policy option thus entails a huge wealth transfer from consumers to producers.

Under AU and AU-BTA, the State instead of firms benefit from the ETS. Hence, the impact on the consumers and the burden sharing depends on how policy makers will use the auction revenue. If it is all rebated to consumers, the surplus of the latter is marginally impacted. If it is not, the impact is high, as under GF.

Under OB-AU, consumers benefit from the output-based allocation to steel and before all to cement producers compared with AU, although this benefit remains modest in aggregate State revenue only slightly deteriorates for low targets: if on the one hand the amount of allowances auctioned is lower, on the other hand the CO_2 price is higher.

Under OB, neither the State nor the firms benefit from the ETS. The impact on EU consumers is negative but low.

5. Conclusion

In this paper, we assess five proposals for the future of the EU ETS: pure grandfathering allocation of emission allowances (GF), output-based allocation (OB), auctioning (AU), auctioning with border tax adjustments (AU-BTA) and finally output-based allocation in sectors exposed to international competition and auctioning in electricity generation (OB-AU). 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.

For an emission reduction of up to 15% in 2015 compared to 2005, production still increases, although less than in the BAU scenario, in all four sectors and for all policy proposals. This is not true anymore for more stringent targets in the cement sector under GF, AU or AU-BTA. Emission reduction is mostly due to unitary abatement, except in the cement sector under GF, AU and AU-BTA, in which case the drop in consumption is the main factor. The leakage ratio, i.e. the increase in emissions abroad over the decrease in EU emissions, goes from around 8% under GF and AU to -2% under AU-BTA. At the sectoral level, these ratios vary greatly from 0 for the electricity sector to almost 50% for steel.

In the light of our results, which policy option is the most attractive? Firstly, although GF

[18] In the end, all the costs are unavoidably distributed to households in their various capacities as workers, consumers, investors and taxpayers. A general equilibrium model would be needed to assess how firms' profits would be distributed to households. See Dinan and Rogers (2002).

performs well in terms of overall economic cost, its distributive consequences are highly regressive since it creates huge windfall profits, in particular for electricity producers, at the expense of consumers. Moreover, it is well-know that pre-existing distorting taxes (not included in our model) raise the cost of GF compared to the other options. Secondly, OB is more costly than the other options, even accounting for its ability to reduce CO_2 leakage. This higher cost is due to its inefficient balance between the two main mechanisms to reduce emissions: the decrease in unitary emissions and the decrease in production. OB leads to too much of the former and too little of the latter.

This leaves the policy-maker with three options: AU, OB-AU and AU-BTA. According to our results, if we only take into account EU welfare, AU is the most efficient option. If one accounts for CO_2 leakage, it remains true for low targets but, for more stringent ones, the three options leads to similar costs. If the metric is the world welfare, AU-BTA is the most efficient and the other two options yield a similar, slightly higher, cost whatever the emission reduction target. Hence the choice among these three options may rely more on political acceptability and feasibility considerations than on the relative cost of the options. There is no doubt that AU will be fiercely opposed by most of the CO_2-intensive industry, especially those exposed to international competition. OB-AU and AU-BTA could be more acceptable since they would drastically mitigate the competitive disadvantage of these industries vis-à-vis the rest of the world. As we have seen, in our model both options yield a rather similar overall cost so the choice should rely on other arguments.

Indeed, both options have pros and cons not taken into account in our model. Output-based allocation, on the positive side, allows emancipating from uncertain production growth projections during the process of allocation negotiation, 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. Moreover this definition may have drastic consequences when intermediary CO_2 intensive products which may be traded internationally enter the manufacturing process. Turning to AU-BTA, border adjustment may be challenged in front of the WTO with an uncertain outcome, but would give an incentive to non EU countries, and more precisely non Kyoto ratifying countries, to engage more in the fight against climate change, as highlighted by Stiglitz (2006).

Appendix: data used in the CASE model

Sectors	**Electricity**[19] MWh	**Steel**[20] tonne	**Cement** tonne	**Aluminium** tonne
Prices = production costs				
Prices (€)	47	313	64	1600
Source	Reinaud (2004)			
Trade and Demand elasticities				
Armington elasticity	-	6	2	2
Source	Average values in Donnelly et al. (2004), Gallaway and McDaniel (2003), Reinert and Roland-Holst (1992), Shiells and Reinert (1993), Bishop (2004), Romali (2004)			
Price elasticity of demand at the BAU equilibrium[21]	0.4	0.6	0.8	0.8
Source	Best guess in Hepburn et al. (2006)			Oxera (2004)
CO_2 Emissions				
2005 EU direct unitary emissions (tCO_2)	0.370	0.880	0.800	3.5
Source	ETS Emission from Knetter et al. (2007) over production			Reinaud (2004)
Yearly improvement (%)	2	1.3	1.3	-
Source	Computations from ENERDATA and EEA data			-
2005 RoW Direct unitary emissions (tCO_2)	0.560	0.980	0.880	3.5
Source	CAIT	Reinaud (2004) + computation[22]	Batelle (2002)	Reinaud (2004)
2005 unitary electric	-	0.4	0.103	15.2

[19] 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.
[20] 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).
[21] Since demand curves are linear rather than isoelastic, the elasticity is endogenous. Yet it remains very close to its BAU value in every case.
[22] = 2005 EU unitary direct emission * RoW unitary direct emission from Reinaud / EU unitary direct emission from Reinaud (2004).

consumption (MWh)				
Source	Reinaud (2004)			
Yearly improvement in the EU (%)	-	- 0.9	0.4	-
MACC	PRIMES	PRIMES	PRIMES[23]	-
10^{-6} x (Production / Imports / Exports / Consumption)				
EU 2005	3000/0/0/3000	187/20/21/186	211/15/8/218	2.9/3.9/0/6.8
Row 2005	-	943/21/20/944	1729/8/15/1722	-
Source	Eurelectric (2006)	McKinsey (forthcoming) / IISI (2006)	Cembureau, (2004)	EAA (2005)
EU / RoW yearly consumption growth (%)[24]	2.2 / -	1 / 7.8	2 / 4.7	2 / 3
Source	Computation from Eurostat	IISI (2006)	Cembureau (2005) / Freedonia (2006)	Roskill (2003)

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[23] It is worth noting the MACC 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).
[24] We assume that markets shares remain unchanged until 2015, hence from consumption projections follow estimates for production, imports and exports.

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