Competitiveness in Unilateral Climate Policy: Border Tax Adjustments or Integrated Emission Trading?

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Abstract

In a world with regionally diverging commitments to climate policy across nations, unilateral carbon abatement induces two problems: It tends to have a detrimental effect on domestic competitiveness, and it fosters increasing carbon emissions abroad (leakage). This paper analyses two policies that have been proposed to mitigate these problems: Border tax adjustments (BTA) and integrated emission trading (IET). The former levies a quantity-based, the latter an emission based duty on imports from non-abating countries. In a stylized two-country model we demonstrate that both policies achieve their double goal. However, BTA is more effective in protecting domestic competitiveness, IET reduces foreign emissions to a larger extent. These results are confirmed by a a computable general equilibrium analysis, where we adopt a unilateral abatement policy that reduces emissions by 20% in the European Union. We conclude that the choice between BTA and IET regimes for the European Union is a matter of priorities for international competitiveness or global environmental effectiveness.

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1 Introduction

While climate change is high on the agenda of the public discourse worldwide, the international disagreement over climate policy persists. This became apparent at the G8 summit in Heiligendamm, Germany, in July 2007, where European governments and the U.S. administration failed to shape a common plan for carbon emission abatement. Despite some progress at the UNCCP climate conference in Bali in December, hitherto no international agreements on emission caps have been reached. In 2007, the European Council has however shaped an ambitious plan for the post-Kyoto era, envisioning a unilateral reduction of carbondioxide emissions in Europe by 20 percent (with respect to baseline emissions in 1990) until 2020 (EU (2007)). To achieve this goal, the European Union builds on the administrative framework of the emission trading system (ETS).

Obviously, more stringent environmental policies raise concerns on competitiveness effects, particularly to those sectors that are energy-intensive, export-oriented and not covered by globally harmonized policies but subject to unilateral actions. Companies from EU member states facing high prices of emission certificates might find it difficult to compete against foreign companies unconstrained by such environmental regulation. As a remedy for this apparent problem border tax adjustments have been proposed (cf. ECCP Working Group (2007) and Neuhoff, Grubb, Hourcade and Matthes (2007)). Border tax adjustments (BTA) are tariffs on imported goods mimicking an (environmental) tax levied on domestic goods (in the absence of a corresponding tax abroad) as well as compensations for the domestic tax on exports. Alternatively, foreign counterparts of sectors participating in the EU ETS could be integrated into European emission trading, buying emission allowances for all imports into the European Union. Correspondingly, European companies exporting their goods abroad would receive emission allowances for free. In other words: While under BTA the environmental duty on imports is quantity-based, under an integrated emission trading (IET) scheme it is emission-based. An IET policy could be implemented as part of international sector agreements. Clearly, IET would require a higher level of international political consensus, as controls of carbon emissions could only be conducted by local authorities (for a discussion of sectoral agreements, cf. Ismer and Neuhoff (2004) and Neuhoff et al. (2007)).

In this paper, we assess the effects of BTA and IET on domestic and foreign economies within a theoretical and numerical framework: In the first part of the paper we present a two-country-model capturing basic features of emissions in production and international trade. Within this framework, we analyse the impact of BTA and IET on key economic variables and discuss to what extend they achieve an improvement in domestic competitiveness vis-a-vis unilateral abatement policy (UAP). Apart from concerns of detrimental competitiveness effects - the main motivation to consider BTA and IET policies - unilateral climate policy can lead to a raise of output and thus increased emissions in countries without climate policy, a phenomenon known as leakage in the literature. Thus we also analyse the effect of BTA and IET on foreign emissions within our theoretical framework. In the second part of this paper, we analyse the impacts of the introduction of BTA and IET regimes into the EU Emission trading scheme within a computable general equilibrium (CGE) framework. The policy scenarios capture the current EU ETS, which divides the economy into participating and non-participating sectors, and implement the EU goal of unilaterally reducing carbon emissions by 20 percent until 2020.

In the literature, the effects of BTA are studied by Bhagwati and Srinivasan (1973), Meade (1974) and Grossman (1980), who examine their role in guaranteeing trade neutrality in a world with differentiated taxation under the origin and the destination principle (i.e. the taxation of production versus the taxation of consumption). Barthold (1994) gives an overview of the insights on BTA for environmental economics. Poterba and Rotemberg (1995) discuss the additional difficulty of assessing the environmental role of intermediate goods in production with pollution.

In the context of the European ETS BTA have been studied by Ismer and Neuhoff (2004) and Peterson and Schleich (2007). Ismer and Neuhoff (2004) present a formal model of a carbon abatement policy with border tax adjustments. They show how BTA can mitigate the productive and allocative inefficiencies of implementing emission certificates only in one region. However, their setup does not allow for a study of differences between BTA and IET, as they do not model an energy efficiency decision of the firm. Peterson and Schleich (2007) quantify the changes in output and trade for the European Union in the computational general equilibrium model PACE-E. They analyse three different regimes of BTA, with border taxes based on average emissions either in the foreign country, in the European Union or on best available technology. An important insight is that since sectors participating in the ETS will increase their production due to a reduced burden on their emissions the other sectors face higher emission reduction targets. We reproduce the qualitative result of Peterson and Schleich (2007) and add the analysis of integrated emission trading (IET) as an alternative policy.

Demailly and Quirion (2006) address the problem of leakage, i.e. the relocation of polluting production to a country without environmental regulation. Leakage can at least partially offset the beneficial effects of carbon abatement efforts in a country by contributing to higher emissions abroad. In their analysis Demailly and Quirion (2006) find that BTA is an efficient remedy for this problem.

Our findings are broadly in line with the literature. Both BTA and IET achieve the double goal of improving competitiveness of the domestic country and reducing carbon emissions of the foreign country. This result follows from the theoretical analysis and is confirmed by the simulations for the European Union and the Rest of the world respectively. Comparing BTA and IET, we add a new insight: While a BTA policy is more effective at mitigating the negative competitiveness effects of unilateral climate policy, a IET policy achieves a stronger reduction of foreign emissions. Both the theoretical and the computational analysis yield this result, which we believe to be helpful for the public discourse on climate policy in the European Union and elsewhere.

This discussion paper is organized as follows: Section 2 presents the set-up of the two-country model and formalizes our notion of UAP, BTA and IET. Section 3 compares the equilibrium outcomes under the three policies and discusses the economic implications. Section 4 gives a description of the computable equilibrium model , the policy scenarios and presents the numerical results of our analysis of BTA and IET. Section 5 concludes.

2 A Two-Country-Model

In this section, we introduce a simple model to study the basic differences between carbon abatement policies. The aim is to capture the competitiveness and leakage effects of unilateral abatement policy, an abatement policy with border tax adjustments and one with integrated emission trading. Faced with carbon taxes or carbon certificates producers trade-off a costly improvement of energy efficiency in production and reduction of quantities produced due to price increases. Possible impacts of the policies on government revenues and labor supply are neglected in our framework. With our model we do not intend to do a welfare analysis of the policies which would have to involve a difficult comparison of output gains and global abatement achievements.

2.1 Formal Setup

The model encompasses two countries (commonly denoted by r), the domestic country d and the foreign country f. The representative household in each country disposes of initial wealth w_r, $r \in \{d, f\}$. It derives utility from consumption only. We adopt the Armington assumption (Armington (1969)): The standard goods produced in d and in f are imperfect substitutes in household preferences. Prices for these goods $p_{r_c}^{r_p}$ form on competitive markets, including imports and exports. The representative firm in r chooses the quantity of the good produced for the domestic market q_d^r and for the foreign market q_f^r as well as energy intensity of production μ^r. Quantities and energy intensity determine emissions

$$E = \mu_r(q_f^r + q_d^r)$$

in country r. Costs of production are constant returns to scale with respect to quantity and decreasing and concave in energy intensity

$$C(\mu, q) = c(\mu)q \qquad c'(\mu) < 0 \qquad c''(\mu) > 0$$

The government of the domestic country chooses a climate policy to achieve a certain emission target $\bar{E}$ for its country. It disposes of a carbon tax τ, which - in this simple deterministic setup - is equivalent to an emission trading system with full auctioning of allowances. Furthermore, the domestic government can impose a tariff κ on imported goods and pay a subsidy for exported goods (border tax adjustment), or it can sell off emission allowances abroad (integrated emission trading).

2.2 Household demand

To keep the model tractable, we reduce the household problem and work with a demand function along the following lines. The household maximizes its utility given its initial wealth. This initial wealth can be thought of as a given endowment of labor and of natural resources. However, both features are not explicitly modelled, there is neither a wage nor a price for natural resources in the model.

Instead, we denote Marshallian demand (derived from the household problem, cf. Mas-Colell, Whinston and Green (1995), ch.3) by household in country r_c for the good produced in r_p by

$$q_{r_c}^{r_p} = d_{r_c}^{r_p}(p_{r_c}^d, p_{r_c}^f, w_{r_c}). \tag{1}$$

We restrict the calculations to Cobb-Douglas preferences, the generalisation to CES preferences is discussed subsequently. Utility maximization with Cobb-Doublas utility functions

$$u_{r_c}(q_{r_c}^d, q_{r_c}^f) = k(q_{r_c}^d)^{\alpha_{r_c}}(q_{r_c}^f)^{1-\alpha_{r_c}}$$

leads to the demand functions

$$q_d^d = \frac{\alpha_d w_d}{p_d^d} \qquad q_d^f = \frac{(1-\alpha_d)w_d}{p_d^f},$$

$$q_f^d = \frac{\alpha_f w_f}{p_f^d} \qquad q_f^f = \frac{(1-\alpha_f)w_f}{p_f^f}.$$

The formulae show that relative prices of the domestically produced and of the imported good change their relative demand in an antiproportional manner. As demand functions are separable, however, a unilateral price increase of one good has effect on the absolute demand for the other good. This is a special feature of CD preferences, not present in a CES framework. It means that we exclude the study of wealth effects of (environmental) taxation and concentrate on substitution effects instead. To make the problem interesting we assume that

$$0 < \alpha_d < 1 \qquad\qquad 0 < \alpha_f < 1.$$

Otherwise demand for one of the goods would break down and an analysis of demand effects of the policies would be senseless.

2.3 The firms' problem

In this subsection we formally state the problem of the representative firm in the domestic and in the foreign country: The firm maximizes profits by choosing energy intensity and quantities produced, taking prices for its products as given. As a first benchmark for a later comparison of policies we formulate the firm's problem in the absence of carbon abatement policy ("laissez-faire", LF). The profit function of the domestic firm is

$$\Pi^d = p_d^d q_d^d + p_d^f q_f^d - c^d(\mu^d)(q_d^d + q_f^d),$$

and the one of the foreign firms is

$$\Pi^f = p_d^f q_d^f + p_f^f q_f^f - c^f(\mu^f)(q_d^f + q_f^f).$$

This gives rise to the first order conditions of the domestic firm

$$p_d^d - c^d(\mu^d) = 0 \tag{2}$$
$$p_f^d - c^d(\mu^d) = 0 \tag{3}$$
$$c_1^d(\mu^d) = 0 \tag{4}$$

and the foreign firm

$$p_d^f - c^f(\mu^f) = 0 \tag{5}$$
$$p_f^f - c^f(\mu^f) = 0 \tag{6}$$
$$c_1^f(\mu^f) = 0 \tag{7}$$

We conclude that $p_d^d = p_f^d =: p^d$. The production of goods in the domestic country gives rise to emissions

$$E^{LF} = \mu^d(q_f^d + q_d^d).$$

To make our problem interesting, in the following we assume

Assumption 1 (Emission Cap) *The emission cap $\bar{E}$ imposed by the domestic government is lower than E^{LF}*

$$0 < \bar{E} < E^{LF}.$$

Please note an important feature of our specification of the production technology: Although the standard good is produced for two different markets (home and abroad), the choice of energy efficiency is the same for both quantities. This is an implicit assumption: Production lines in a country are not differentiated according to the targeted market. From this ensues the notion that the choice of energy efficiency is set with respect to the tougher regulation in the two markets for all customers. Although we do not know of a scientific empirical study supporting this view, there clearly is empirical evidence in the wider literature (cf. Shapiro (2007)).

The following subsections discuss the firms' problem under the different policy regimes we want to analyze.

2.4 Unilateral Abatement Policy

The unilateral abatement policy (UAP) is a second benchmark in our comparison of domestic carbon policies that address the problems of competitiveness and leakage in an international context. The government of the domestic country sets a carbon tax (alternatively: auctions off emission allowances) to ensure that total emissions of domestic production do not exceed $\bar{E}$. So goods exported to the foreign country are taxed while goods imported from the foreign country remain tax-free. We state the profit functions and first order conditions of both firms under UAP[1].

Under UAP, the profit function of domestic firm is

$$\Pi^d = p_d^d q_d^d + p_d^f q_f^d - c^d(\mu^d)(q_d^d + q_f^d) - \tau\mu^d(q_d^d + q_f^d).$$

First order conditions (domestic firm):

[1] All variables used in this and the next section should have indices indicating the policy case, as they take different values across the three scenarios. For ease of exposition, this additional index has been dropped here, but will be set in the next section.

$$
\begin{aligned}
p_d^d - c^d(\mu^d) - \tau\mu^d &= 0 && (8)\\
p_f^d - c^d(\mu^d) - \tau\mu^d &= 0 && (9)\\
c_1^d(\mu^d) + \tau &= 0 && (10)
\end{aligned}
$$

Again we conclude that $p_d^d = p_f^d =: p^d$.

The profit function of the foreign firm is

$$\Pi^f = p_d^f q_d^f + p_f^f q_f^f - c^f(\mu^f)(q_d^f + q_f^f).$$

First order conditions of foreign firm:

$$
\begin{aligned}
p_d^f - c^f(\mu^f) &= 0 && (11)\\
p_f^f - c^f(\mu^f) &= 0 && (12)\\
c_1^f(\mu^f) &= 0 && (13)
\end{aligned}
$$

As above $p_d^f = p_f^f =: p^f$.

The government sets τ such that in equilibrium

$$\bar{E} \geq \mu^d(q_d^d + q_f^d). \quad (14)$$

2.5 Border Tax Adjustment

In the second policy scenario the government uses border tax adjustments (BTA) to offset differences in taxation for imported and exported goods. A quantity-based tariff κ is levied on the imported good. It is set to match the tax on average carbon content of the good - as measured by domestic production. Exporters receive a tax refund of κ per quantitiy sold which matches their emission in production. We thus adopt the same BTA scenario in Ismer and Neuhoff (2004) and Peterson and Schleich (2007). The formal setup is as follows:

Profit function of domestic firm

$$\Pi^d = p_d^d q_d^d + p_d^f q_f^d - c^d(\mu^d)(q_d^d + q_f^d) - \tau\mu^d(q_d^d + q_f^d) + \kappa q_f^d$$

First order conditions (domestic firm):

$$
\begin{aligned}
p_d^d - c^d(\mu^d) - \tau\mu^d &= 0 \quad (15)\\
p_f^d - c^d(\mu^d) - \tau\mu^d + \kappa &= 0 \quad (16)\\
c_1^d(\mu^d) + \tau &= 0 \quad (17)
\end{aligned}
$$

Profit function of foreign firm

$$\Pi^f = p_d^f q_d^f + p_f^f q_f^f - c^f(\mu^f)(q_d^f + q_f^f) - \kappa q_d^f$$

First order conditions (foreign firm):

$$
\begin{aligned}
p_d^f - c^f(\mu^f) - \kappa &= 0 \quad (18)\\
p_f^f - c^f(\mu^f) &= 0 \quad (19)\\
c_1^f(\mu^f) &= 0 \quad (20)
\end{aligned}
$$

Again the government sets τ such that in equilibrium

$$\bar{E} \geq \mu^d(q_d^d + q_f^d). \quad (21)$$

To equalize trading conditions in the domestic and the foreign country the tariff on the imported good as well as the tax-refund for the exported good κ is set to

$$\kappa = \tau\mu^d.$$

Note that both τ and κ apply to quantities of goods, not emissions. That is the systematic difference with respect to the third policy scenario.

2.6 Integrated emission trading

The third policy aims at levying an environmental duty on the actual carbon content of imported goods. We call it integrated emission trading (IET): Foreign producers have to purchase emission certificates for their products at the current carbon price country to sell it in the domestic country. In contrast to a emission trading with BTA it is emissions that are targeted by the IET, not quantities. Consequently abatement efforts in the foreign country pay off when goods are imported to the domestic country. Goods exported to the foreign country are exempt from the environmental duty: They receive emission certificates for free.

Formally, the model is as follows

Profit function of the domestic firm

$$\Pi^d = p_d^d q_d^d + p_d^f q_f^d - c^d(\mu^d)(q_d^d + q_f^d) - \tau\mu^d q_d^d$$

First order conditions (domestic firm)

$$\begin{aligned} p_d^d - c^d(\mu^d) - \tau\mu^d &= 0 && (22)\\ p_f^d - c^d(\mu^d) &= 0 && (23)\\ c_1^d(\mu^d)(q_d^d + q_f^d) + \tau q_d^d &= 0 && (24) \end{aligned}$$

Profit function of foreign firm

$$\Pi^f = p_d^f q_d^f + p_f^f q_f^f - c^f(\mu^f)(q_d^f + q_f^f) - \tau\mu^f q_d^f$$

First order conditions (foreign firm)

$$\begin{aligned} p_d^f - c^f(\mu^f) - \tau\mu^f &= 0 && (25)\\ p_f^f - c^f(\mu^f) &= 0 && (26)\\ c_1^f(\mu^f)(q_d^f + q_f^f) + \tau q_d^f &= 0 && (27) \end{aligned}$$

Of course in our deterministic setup, assuming full auctioning of certificates, emission trading is again equivalent to a carbon tax. Thus the government sets τ such that in equilibrium carbon emissions corresponding to domestic consumption are

$$\bar{E} \geq \mu^d(q_d^d + q_f^d). \tag{28}$$

Note that we have choosen to keep the same emission cap across all three policy scenarios. This means that the domestic government sets a cap on domestic emissions, i.e. emissions caused by domestic production.

A logical extension of IET would be a cap on emissions caused by domestic consumption: Both domestic producers and importers would have to compete for emission allowances to sell their products in the domestic market. This would change the trade paradigm, abandoning the origin in favor of the destination principle. Consumption, not production, would be the basis for a carbon tax. However, as foreign emissions remain unregulated under BTA and UAP, such an altered version of IET can hardly be compared directly to the other two policies and is therefore not considered here.

2.7 Equilibrium conditions

The previous subsections have presented the household problem, the firm's problem and the emission constraint set by the government under different policy scenarios. Utility maximization by households yields demand functions that specify quantities as function of prices. Profit maximization by firms yields first order conditions that determine prices as function of all other variables. The government sets taxes and tariffs to comply to some rules, in particular, to cap emissions.

Formally, equilibrium conditions take the following form:

1. Zero-Profit (FOCs of the firms)

$$p_{r_c}^{r_p} = P(q_d^{r_p}, q_f^{r_p}, \mu^{r_p}, \tau, \kappa)$$

$$\mu^{r_p} = M(q_d^{r_p}, q_f^{r_p}, \tau, \kappa)$$

2. Utility maximisation (FOCs of the households)

$$q_{r_c}^{r_p} = d_{r_c}^{r_p}(p_{r_c}^d, p_{r_c}^f, w_{r_c})$$

3. Emission cap

$$\bar{E} \geq E(q_d^d, q_f^d, q_d^f, q_f^f, \mu^{r_p})$$

The functional form of the conditions has been derived in the previous subsection. We would like to investigate whether under what conditions equilibria exist. To do so, we make an additional assumption on the marginal cost functions $c^d(.)$ and $c^f(.)$.

Assumption 2 (Inada condition) *The marginal cost functions $c^r(.)$ satisfy*

$$\lim_{\mu \to 0} c_1^r(\mu) \to -\infty.$$

Moreover, there exist unique $\hat{\mu}^d$ and $\hat{\mu}^f$ such that

$$c_1^d(\hat{\mu}^d) = c_1^f(\hat{\mu}^f) = 0.$$

As always, the Inada condition guarantees the existence of equilibria:

Proposition 1 *Under assumptions 1 and 2 equilibria exist in all three scenarios.*

Proof. See appendix. ■

This ends the presentation of the model. The next section presents theoretical results obtained in its framework.

3 Theoretical Results

3.1 Comparison of Policy Outcomes

In this subsection, we will compare the equilibria to study the differences of policy outcomes across policies. We address both competitiveness and leakage. Our central questions are how policies affect production in the domestic and in the foreign country and how they influence emissions in the foreign country (with emissions in the domestic country being capped).

Our first proposition compares the three policies with the laissez-faire scenario. The results are not surprising: They show how domestic economic activity is slowed down by domestic emission reduction.

Proposition 2 (Laissez Faire vs. Abatement Policies) *A comparison of the laissez-faire and the unilateral abatement policy yields*

$$(\mu^d)^{LF} > (\mu^d)^{UAP} \qquad (\mu^f)^{LF} = (\mu^f)^{UAP}$$

$$(p^d)^{LF} < (p^d)^{UAP} \qquad (p^f)^{LF} = (p^f)^{UAP}$$

$$(q_d^d + q_f^d)^{LF} > (q_d^d + q_f^d)^{UAP} \qquad (q_d^f + q_f^f)^{LF} = (q_d^f + q_f^f)^{UAP}$$

A comparison of the laissez-faire and a border tax adjustment policy yields

$$(\mu^d)^{LF} > (\mu^d)^{BTA} \qquad (\mu^f)^{LF} = (\mu^f)^{BTA}$$

$$(p_d^d)^{LF} < (p_d^d)^{BTA} \qquad (p_d^f)^{LF} < (p_d^f)^{BTA}$$

$$(p_f^d)^{LF} < (p_f^d)^{BTA} \qquad (p_f^f)^{LF} = (p_f^f)^{BTA}$$

$$(q_d^d + q_f^d)^{LF} > (q_d^d + q_f^d)^{BTA} \qquad (q_d^d + q_f^d)^{LF} > (q_d^d + q_f^d)^{BTA}$$

A comparison of the laissez-faire and a global emission trading system yields

$$(\mu^d)^{LF} > (\mu^d)^{IET} \qquad (\mu^f)^{LF} > (\mu^f)^{IET}$$

$$(p_d^d)^{LF} < (p_d^d)^{IET} \qquad (p_d^f)^{LF} < (p_d^f)^{IET}$$

$$(p_f^d)^{LF} < (p_f^d)^{IET} \qquad (p_f^f)^{LF} < (p_f^f)^{IET}$$

$$(q_d^d + q_f^d)^{LF} > (q_d^d + q_f^d)^{IET} \qquad (q_d^d + q_f^d)^{LF} > (q_d^d + q_f^d)^{IET}$$

Proof. See appendix ■

From the first proposition we can see the following: Whereas unilateral abatement policy only reduces the economic performance of the domestic country [2], border tax adjustment and global emission trading have consequences for the foreign country as well. The taxation of emissions leads both to an increase in energy efficiency and to an increase in consumer prices of domestic goods and thus to a reduction in demand for them, both in the domestic and in the foreign market.

[2] Remember, though, that our choice of Cobb-Douglas preferences excludes wealth effects from the analysis.

Both border tax adjustment and global emission trading amount to levying an environmental tariff on imports, thus increasing the price for the imported good. One difference between the two policies becomes apparent at this point already: BTA does not affect the energy intensity decision of the foreign producer, whereas his energy intensity is reduced under global emission trading. This highlights the way both policies affect production in the foreign country: Under a BTA policy, a tariff is levied on imports independent of emissions caused by production, under global emission trading the foreign producers has an incentive to increase energy efficiency as he pays for the emissions caused by his imports to the domestic market.

The next step in the analysis of policy outcomes is the comparison of equilibrium energy intensities.

Proposition 3 (Comparison of energy intensities) *In equilibrium, energy intensities chosen in the domestic and the foreign country compare as follows*

$$(\mu^d)^{UAP} > (\mu^d)^{BTA} \qquad (\mu^f)^{UAP} = (\mu^f)^{BTA}$$

$$(\mu^d)^{UAP} = (\mu^d)^{IET} \qquad (\mu^f)^{UAP} > (\mu^f)^{IET}$$

$$(\mu^d)^{BTA} < (\mu^d)^{IET} \qquad (\mu^f)^{BTA} > (\mu^f)^{IET}$$

The results of proposition 3 for the energy intensity of the foreign country are straightforward: Neither UAP nor BTA affect the production decision of the foreign firm, so energy intensity remains at its maximum laissez-faire level. In contrast, by levying a duty on the carbon content of the import good, the domestic country exerts an abatement influence on the foreign country, leading it to an increase in energy efficiency.

Concerning the domestic country, the proposition states that energy intensity is equal under UAP and IET, and lower under BTA. This is a somewhat surprising result. From proposition 3.1 we have learnt that carbon abatement leads to an increase in energy efficiency - this is part of the economic answer to making emissions costly. Both BTA and IET limit that pressure to the output produced for the domestic country. This makes the energy efficiency/quantity reduction trade-off more pronounced which explains why energy efficiency under BTA increases vis--vis UAP. The same influence exists in the case of

IET, however, it is exactly offset by the lowered price pressure on the export good.

The equilibrium choice of energy intensity is important for the understanding of the policy outcome in general. The next proposition presents a comparison of equilibrium prices and quantities under the three policies. While the comparison of UAP on the one hand and BTA and IET on the other hand is rather straightforward, comparing BTA and IET turns out to be somewhat difficult. This is because the duty levied on the import good depends on the domestic production function in the case of BTA and on the foreign production function in the case of IET. Thus, with some variables being comparable directly, a full comparison requires an additional assumption on the two cost functions. We assume that they are identical.

Assumption 3 (Cost Symmetry) *The marginal cost function is equal for both countries* $c^d(.) \equiv c^f(.)$.

We will see that this is a sufficient condition to obtain a clear result. The inequalities that require assumption 3 are labelled by an index s.

Proposition 4 (Comparison of prices and quantities) *In equilibrium, quantities and prices chosen under UAP and under BTA compare as follows*

$$(p_d^d)^{UAP} < (p_d^d)^{BTA} \qquad (p_f^f)^{UAP} = (p_f^f)^{BTA}$$

$$(p_f^d)^{UAP} > (p_f^d)^{BTA} \qquad (p_d^f)^{UAP} < (p_d^f)^{BTA}$$

$$(q_d^d + q_f^d)^{UAP} < (q_d^d + q_f^d)^{BTA} \qquad (q_d^f + q_f^f)^{UAP} > (q_d^f + q_f^f)^{BTA}$$

Under UAP and IET, the comparison yields

$$(p_d^d)^{UAP} < (p_d^d)^{IET} \qquad (p_f^f)^{UAP} < (p_f^f)^{IET}$$

$$(p_f^d)^{UAP} > (p_f^d)^{IET} \qquad (p_d^f)^{UAP} < (p_d^f)^{IET}$$

$$(q_d^d + q_f^d)^{UAP} = (q_d^d + q_f^d)^{IET} \qquad (q_d^f + q_f^f)^{UAP} > (q_d^f + q_f^f)^{IET}$$

Under BTA and IET equilibrium prices and quantities compare as follows

$$(p_d^d)^{BTA} < (p_d^d)^{IET} \qquad (p_f^f)^{BTA} < (p_f^f)^{IET}$$

$$(p_f^d)^{BTA} > (p_f^d)^{IET} \qquad (p_d^f)^{BTA} <_s (p_d^f)^{IET}$$

$$(q_d^d + q_f^d)^{BTA} > (q_d^d + q_f^d)^{IET} \qquad (q_d^f + q_f^f)^{BTA} >_s (q_d^f + q_f^f)^{IET}$$

Proposition 4 states the central results on competitiveness effects of the three policies. From the comparison of BTA and IET with UAP, we can see that both policies achieve one central aim in mitigating the detrimental effect of abatement policy on competitiveness: (gross) prices of imports increase, (gross) prices of exports decrease. Moreover, both policies lead to a net reduction of foreign output. The BTA policy also increases overall production of the domestic country, while under IET overall domestic production remains unaltered. This somewhat surprising result can be explained by the change in domestic abatement. As exports are exempt from the emission duty, the pressure on domestic consumption increases: gross prices of output sold in the domestic market are raised by both BTA and IET. While the raising energy efficiency under BTA leaves domestic producers with a net increase of production, under IET the increase of exports and the decrease of domestic sales offset each other.

The comparison of BTA and IET gives us a general result for production in the domestic country: Both the price increase on the domestic market and the price decrease of exports vis-á-vis UAP are more pronounced under IET than under BTA. The net effect of output is unambigious, too: Under BTA domestic output is higher than under IET. As for production in the foreign country, we need assumption 3 to derive results - except for the price of foreign products sold at home. They are higher under IET, as this policy induces an increase of energy efficiency. With symmetric cost functions, gross prices for the import good are also higher under IET than under BTA and overall production in the foreign country is lower. A look at the proof of proposition 4 shows that the latter result also holds if marginal costs in the foreign country are higher than in the domestic country. It is reversed only if marginal costs in the foreign country are much lower than in the domestic country, so that the abatement efforts of foreign producers lead to only small costs.

From proposition 4 we learn that BTA is more effective in protecting domestic competitiveness than IEP. What about leakage? The next proposition gives an answer.

Proposition 5 (Comparison of foreign emissions) *Emissions in the foreign country relate to each other as follows*

$$(E^f)^{UAP} > (E^f)^{BTA}$$

$$(E^f)^{UAP} > (E^f)^{IET}$$

$$(E^f)^{BTA} >_s (E^f)^{IET}$$

Proposition 5 shows that both BTA and IET lead to a reduction of foreign emissions in comparison to the case of UAP. In the case of BTA, this is a mere quantity effect: A decrease in imports to the domestic country leads to a decrease in output. In the case of IET, higher energy efficiency adds up with reduced sales abroad. As for the comparison of foreign emissions under BTA and IET, we need assumption 3 to obtain an unambigious result, which is that under a IET policy in the domestic country, the induced abatement in the foreign country is larger. As before, though, symmetry of cost functions is only a sufficient condition: As long as marginal costs are higher abroad, the results holds. This is plausible, because under IET foreign producers increase their energy efficiency, which under BTA they do not. Only if their costs of doing so are very small, much smaller than in the domestic country, the (then) larger output under IET could offset the effect of increased energy efficiency and foreign emissions would be higher than under BTA.

At the end of the subsection we can thus broadly summarize our findings: Both BTA and IET achieve the target of mitigating negative competitiveness effects of unilateral climate policy and leakage. While BTA is more effective in the former, IET tends to be more effective in the latter.

4 Computable General Equilibrium (CGE) Analysis: Evaluating Policy Impacts

4.1 Modelling approach

For the numerical analysis, we adopt a standard multi-sector, multi-region CGE model of international energy use and global trade. Figure 1 provides a diagrammatic structure of the open-economy CGE model used for the comparative-static impact analysis of border tax adjustments and integrated emission trading[3]. A representative agent RA_r in each region r is endowed with three primary factors: labour $\bar{L}_r$, capital $\bar{K}_r$, and fossil-fuel resources $\bar{Q}_r$ (used for fossil fuel production). The representative agent maximizes utility from consumption of a composite good C_r which combines demands for energy and non-energy commodities at a constant-elasticity-of-substitution (CES). Production Y_{ir} of commodities i in region r is captured by nested separable CES functions that describe the price-dependent use of capital, labour, energy and material in production. Carbon emissions are linked in fixed proportions to the emissions-relevant use of fossil fuels with carbon coefficients differentiated by the specific carbon content of fuels. Carbon abatement thus can take place by fuel switching or energy savings in production and final consumption. Trade is specified using the Armington approach of product heterogeneity (Armington (1969)), so that domestic and foreign goods of the same variety are distinguished by origin. All goods used on the domestic market in intermediate and final demand correspond to a CES composite A_{ir} that combines the domestically produced variety Y_{ir} and imports M_{ir} of the same variety from other regions. Domestic production Y_{ir} either enters the formation of the Armington good A_{ir} or is exported (X_{ir}) to other regions to satisfy their import demand. Trade with other regions is represented by a set of horizontal export demand and import supply functions at exogenous world import and export prices. A balance of payment constraint, which is warranted through flexible exchange rates, incorporates the benchmark trade deficit or surplus.

The model is based on consistent accounts of national production and consumption, trade and energy flows for 2001 as provided by the

[3]For details and an algebraic formulation of the core model see Böhringer and Lange (2005).

GTAP 6 database (Dimaranan and McDougall (2006)). The forward calibration of the 2001 economies to the target year 2020 is based on energy trends for EU Member States (EU (2003)) and on international energy projections for non-European economies (US Department of Energy (2005)). Table 1 summarizes the regional and sectoral aggregation of the model. The regional aggregation of the GTAP database includes ten regions that are central in the climate policy debate on competitiveness and leakage. The sectoral aggregation in the model has been chosen to distinguish carbon-intensive sectors from the rest of the economy. It captures key dimensions in the analysis of greenhouse gas abatement, such as differences in carbon intensities and the degree of substitutability across carbon-intensive goods. The primary and secondary energy goods identified in the model are coal, natural gas, crude oil, refined oil products, and electricity. Important carbon-intensive non-energy industries that are potentially most affected by carbon abatement policies are specified as energy-intensive sectors. The remaining manufacturers and services are aggregated to a composite industry that produces a non-energy-intensive macro good. The primary factors in the model include labor, physical capital, and fossil-fuel resources.

4.2 Emission reduction targets

In January 2008, the European Commission has adopted a Proposal to amend the current EU ETS Directive (EU (2003)). This Proposal is part of draft legislation implementing the Integrated Energy Climate Change Package, endorsed by the European Council in March 2007 to limit the rise in global average temperature to no more than 2 Celsius above pre-industrial levels. To achieve cost-effectively the commitment of the EU to at least a 20 percent in greenhouse gas emissions below 1990 levels, the Proposal foresees the uniform emission reduction of 21 percent below 2005 emissions for the EU ETS sectors (ETS sectors) in all Member States (EU (2008a)). Commission's Climate Action and Renewable Energy Package of January 2008 contains furthermore the Proposal for a Decision on the commitments of Member States to reduce the greenhouse gas emissions up to 2020 (the so-called "Effort Sharing Decision") (EU (2008b)). This Proposal determines heterogeneous contributions of Member States to meeting the EU greenhouse gas emission reduction commitment up to 2020 (in relation to the 2005 emissions level) in sectors not covered under the

EU ETS Directive (NETS sectors). Table 2 reports effective emission reduction targets that apply to the ETS and NETS sectors in new and old EU Member States. The effective emission reduction targets are derived using the data from the Commission's Impact Assessment for the years 1990, 2005 and 2020 (EU (2008c)). A uniform emission reduction target of 21 percent for the ETS sectors (compared to the 2005 emissions level) corresponds to an emissions reduction target of about 27.8 and 26.8 percent versus business-as-usual levels (BaU) in 2020 for the EU15 and EU12, respectively. Table 2 further depicts that burden imposed on the EU NETS sectors is rather moderate in terms of effective emission reductions requirements in 2020. The resulting total aggregate commitments versus BaU level imply comparable effective reduction targets for old and new EU Member States in 2020 (22 and 20.4 percent respectively). In our calculations, the EU27 is however expected to commit to total emissions reduction of 17.8 percent versus 1990 levels in 2020. This effective requirement is obviously slightly below the European Council objective to achieve at least a 20 percent reduction of greenhouse gas emissions by 2020 compared to 1990 (EU (2007)). Finally, all non-EU regions are assumed to not having committed to binding emissions reduction targets in 2020.

4.3 Policy scenarios

In order to assess the competitiveness impacts of BTA and IET on energy-intensive sectors, we introduce climate policy scenarios for the year 2020. Across all scenarios, an international emission trading system is restricted to eight energy-intensive sectors (electricity, oil refineries, iron and steel, non-ferrous metals, mineral industries, paper and pulp production, air transportation and chemicals) as foreseen under the Proposal to amend the current EU emissions trading scheme (EU (2008a)). Within the EU ETS, the covered (ETS) sectors are assumed to be allocated tradable allowances, while the remaining (NETS) industries have to be regulated via domestic abatement measures (here: unilateral carbon taxation) in order to meet the national emissions reduction targets in 2020. The regulation stringency in the EU is represented by the underlying regional effective emissions reduction targets as presented in the previous section. As a reference case, scenario UAP reflects the upcoming European emission trading scheme in 2020, thereby abstaining from any complementary measures to mitigate negative competitiveness on covered energy-intensive industries. In scenarios BTA and IET, we introduce border tax adjustments and integrated emission trading into the European emissions trading scheme. Under the former, both tax compensation for the EU exports and tariffs for the EU importers are quantity-based, while the sector-specific level of BTA is determined by the EU average carbon content in the production of the respective energy-intensive goods. Under the latter, the EU exporters and the EU importers face the allowance price which is applied to the actual carbon content of the respective energy-intensive industry. Subject to the BTA and IET scheme are four energy-intensive and export oriented sectors, i.e. iron and steel, non-ferrous metals, mineral industries and paper and pulp production.

4.4 Results

This subsection presents the simulation results of our model-based assessment: We start our analysis by reporting the impacts of alternative policy options on the market for emissions permits (Figure 2) and the associated macroeconomic effects for the EU and non-EU regions (Table 3 and Table 4), before addressing the issues of international carbon leakage (Table 5). Figure 2 depicts the impacts on the market for emissions permits imposed by the exogenous carbon emission constraint on the ETS sectors in 2020 across our scenarios. Under UAP, the allowance price amounts to roughly 31 US$ per ton CO_2. This price originates from the allowance allocation implying effective emissions reduction requirements for the ETS sectors of 27.8 and 26.8 percent in old and new EU Member States, respectively. The introduction of the BTA scheme (yielding scenario BTA) and the IET scheme (yielding scenario IET) into the EU ETS has a rather limited impact on the allowance price: Under BTA, the international CO2 value decreases by roughly one percent compared to the reference case. Being consistent with our theoretical findings, this result is due to the increase in the production levels in the ETS sectors which are exclusively covered by the BTA scheme (DIR_POL). On their part, ETS sectors outside the BTA scheme (DIR_NPOL) slightly decrease production levels to comply with the sectoral emission reduction target.

In contrast, the introduction of the IET scheme into the EU ETS causes the allowance price to drop by roughly two percents compared to the UAP scenario. Although not being consistent with the expectations from our theoretical model, this finding may be explained by the choice of the Cobb-Douglas preferences in the theoretical framework which excludes welfare effects from the analysis. The decrease in the production level of the sectors which are covered by the IET scheme (DIR_POL) outweighs the output increase of the non-covered sectors (DIR_NPOL) and puts more downward pressure on the allowance price, which falls to roughly 30 US$. The macroeconomic implications - measured as changes in production and welfare level - for both EU and non-EU regions are summarized in the Table 3. For the EU-27, it reports negative production and welfare impacts, which amount to roughly 0.38 and 0.1 percent of the BaU level, respectively (scenario UAP). While the introduction of the BTA and IET scheme into the EU ETS may slightly reduce EU welfare losses, the sectoral and total production impacts of alternative instruments are rather heterogeneous. Referring to central theme of our theoretical framework, we find that DIR_POL sectors in the EU are best off under the BTA regime: For these industries, the decrease in the production level in BTA scenario is much less pronounced than under alternative scenarios. Vice versa, the DIR_POL sectors in non-EU regions are worst off under the BTA scenario as this (quantity-based) regime does not allow the respective industries to adjust the energy intensity in production process. We conclude that DIR_POL sectors in the EU are least exposed to international competition under the BTA regime. We finally turn to the impacts on global environmental effectiveness that constitutes - from the perspective of the European Union - the central trade-off with pure competitiveness considerations: Under UAP, the unilateral abatement policy leads to an increase in emissions in non-abating regions by 9 percent, reducing the global environmental effectiveness (Table 5). Although both instruments (i.e. BTA and IET) occur to be a suitable strategy to reduce the leakage rate, Table 5 illustrates the central reasoning behind the superiority of the IET scheme as compared to the BTA scheme in terms of global environmental effectiveness (leakage). The most important insight from our numerical analysis is that the IET scheme induces - at both global and regional level - a considerably lower leakage rate than the BTA scheme. Except for Russia, all model regions face the lowest regional leakage rate under the IET scheme. Thus, the attractiveness of the BTA and IET regimes for the European Union is a matter of priorities for international competitiveness or global environmental effectiveness.

5 Conclusion

In 2007, the European Council has shaped an ambitious plan for the post-Kyoto era, envisioning a unilateral reduction of CO_2 emissions in Europe by 20 percent (compared to the 1990 level) until 2020. Obviously, such unilateral environmental policy raises concerns on competitiveness effects, particularly on the European energy-intensive industries. This paper analyses two policies that have been proposed to mitigate these problems: Border tax adjustments (BTA) and integrated emission trading (IET). Referring to central theme of our theoretical framework, we find that energy-intensive sectors in the EU are best off under the BTA regime, while the impacts of the IET regime on global environmental effectiveness constitutes - from the perspective of the European Union - the central trade-off with pure competitiveness considerations: The IET scheme induces a considerably lower leakage rate than the BTA scheme. We conclude that the choice between the BTA and the IET regimes for the European Union is a matter of priorities for international competitiveness or global environmental effectiveness.

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Table 1: Model dimensions

Production sectors		Countries and Regions	
Energy		*EU regions*	
COA	Coal	EU15	Old Member States
CRU	Crude oil	EU12	New Member States
GAS	Natural gas		
OIL	Refined oil products		
ELE	Electricity		
Energy-intensive sectors		*Non-EU countries and regions*	
ORE	Ferrous metals	USA	United States
PPP	Paper products and publishing	OOE	Rest of OECD
NMM	Mineral products nec	RUS	Former Soviet Union
NFM	Metals nec	SMA	Rest of South and Middle America
ATP	Air transport	CHN	China (including Hongkong)
CRP	Chemicals, rubber and plastics	SEA	Rest of South and East Asia
Non-energy-intensive sectors		OPC	OPEC
ROI	Rest of industry	XRW	Rest of the World
CGD	Savings good		

Table 2: Effective emission reduction targets [% vis-à-vis BaU in 1990, 2005 and 2020]

	ETS			NETS			TOTAL		
	1990	2005	2020	1990	2005	2020	1990	2005	2020
EU15	-17.6	-21.0	-27.8	-8.5	-13.8	-16.1	-12.9	-17.3	-22.0
EU12	-43.2	-21.0	-26.8	-16.5	13.2	-11.0	-33.6	-8.4	-20.4
EU27	-24.9	-21.0	-27.6	-10.0	-10.2	-15.3	-17.8	-15.7	-21.7

Source: EU (2008c): Commissions Staff Working Document, Impact Assessment, own calculations

Table 3: Output effects [% vis-à-vis BaU]

	DIR_POL			DIR_NPOL			NDIR			TOTAL		
	UAP	BTA	IET	UAP	BTA	IET	UAP	BTA	IET	UAP	BTA	IET
EU15	-0.836	-0.042	-0.780	-2.168	-2.272	-2.140	-0.385	-0.414	-0.386	-0.392	-0.422	-0.393
EU12	-1.334	-0.547	-1.203	-3.393	-3.470	-3.335	-0.175	-0.212	-0.176	-0.197	-0.232	-0.197
EU27	-0.912	-0.119	-0.845	-2.304	-2.405	-2.273	-0.368	-0.398	-0.369	-0.378	-0.406	-0.378
CHN	0.068	-0.087	0.061	0.177	0.201	0.167	0.039	0.050	0.037	0.040	0.051	0.038
XRW	1.070	0.381	0.875	1.571	1.512	1.498	0.079	0.124	0.094	0.088	0.131	0.102
USA	0.024	-0.040	0.031	0.211	0.231	0.206	0.008	0.012	0.008	0.009	0.012	0.009
RUS	0.753	0.275	0.647	0.812	0.788	0.791	0.151	0.167	0.151	0.163	0.175	0.161
OOE	0.056	-0.178	0.069	0.476	0.517	0.465	-0.002	0.007	-0.002	0.000	0.008	0.000
SMA	0.249	-0.099	0.229	0.616	0.660	0.606	0.038	0.050	0.038	0.040	0.052	0.041
SEA	0.169	-0.464	0.224	0.556	0.581	0.549	0.036	0.054	0.036	0.040	0.056	0.039
OPC	1.433	0.885	1.181	1.560	1.569	1.533	0.127	0.149	0.133	0.137	0.158	0.142

EU15 Old Member States, **EU12** New Member States**, USA** United States, **OOE** Rest of OECD, **RUS** Former Soviet Union, **SMA** Rest of South and Middle America, **CHN** China (including Hongkong), **SEA** Rest of South and East Asia, **OPC** OPEC, **XRW** Rest of the World.

DIR_POL energy-intensive sectors to which BTA and IET may be applied (ORE, PPP, NMM and NFM), **DIR_NPOL** energy-intensive sectors to which BTA and IET may not be applied (ATP, CRP, ELE and OIL), **NDIR** non-energy intensive sectors (ROI).

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Table 4: Welfare impacts (in % of HEV)

	UAP	BTA	IET
EU15	-0.064	-0.062	-0.063
EU12	-0.075	-0.071	-0.066
EU27	-0.065	-0.063	-0.064
CHN*	0.024	0.027	0.026
XRW*	-0.034	-0.035	-0.034
USA*	0.014	0.014	0.015
RUS*	-0.044	-0.049	-0.043
OOE*	-0.001	-0.004	0.000
SMA*	-0.045	-0.049	-0.044
SEA*	0.040	0.048	0.039
OPC*	-0.055	-0.055	-0.052

Table 5: Leakage rate (% vis-à-vis BaU)

	UAP	BTA	IET
CHN	1.800	1.745	1.649
XRW	0.612	0.510	0.430
USA	2.212	2.222	2.208
RUS	0.941	0.808	0.819
OOE	0.803	0.776	0.760
SMA	0.638	0.605	0.577
SEA	1.235	1.181	1.179
OPC	0.896	0.807	0.715
TOTAL	9.136	8.655	8.337

* For the sake of completeness, the welfare impacts of the non-EU regions are listed in Table 4. The direct comparison of the welfare impacts would however be misleading as environmental effectiveness of alternative policy options for these regions differs across three scenarios (see Table 5).

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Figure 1: Diagrammatic overview of the model structure

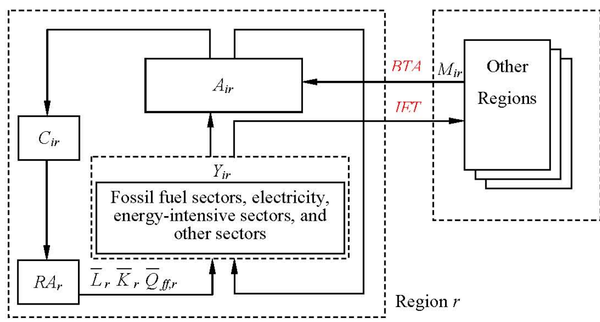
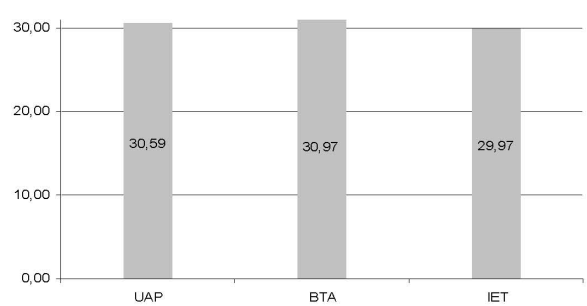


Figure 2: CO2 value in ETS sectors (in $US per ton of CO2)



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