The effectiveness of anti-leakage policies in the European Union: results for Austria

Birgit Bednar-Friedl[1,2], Veronika Kulmer[1,2] and Thomas Schinko[1,2]

Abstract

With the third trading period of the EU emissions trading scheme (EU ETS) starting in 2013, the system of allocating emission allowances will significantly change: In contrast to the previous two trading periods, auctioning of the allowances should now be the rule rather than the exception. Accompanying this policy change, concerns over competitiveness of energy intensive, trade exposed sectors as well as over limited environmental effectiveness via the channel of carbon leakage, have regained prominence. In this paper, we thus explore the impacts of potential EU policies to counter losses in international competitiveness and carbon leakage from the perspective of Austria. Based on numerical simulations with a computable general equilibrium model, we evaluate three policy options: an input subsidy for carbon allowances (thus reflecting the planned partially free allocation mechanism in the third EU ETS phase), a subsidy for domestic production, and an export rebate based on sectoral CO_2 costs. Our results show that each policy has the potential to support domestic production in exposed sectors relative to a full auctioning scenario and thus increase competitiveness. However, none is imperatively effective at reducing Austria's net carbon emissions: while the carbon trade balance is improved and hence leakage declines, the tradability of emission permits within the EU ETS allows CO_2 emissions from Austria's ETS output to increase. A cost benefit analysis indicates that the two policies promoting domestic output and exports are more cost effective than the CO_2 input subsidy.

Keywords: emissions trading, international competitiveness, carbon leakage, anti-leakage policy, grandfathering, computable general equilibrium

JEL Classification: Q54; Q56; H23; C68

Acknowledgments: We thank two anonymous referees for their very helpful comments during the revision of the paper. This research was funded by the Austrian Climate and Energy Fund, carried out within the research programme "New Energies 2020" and by the Austrian Federal Ministry of Economy, Family and Youth as part of the Federal Government's Internationalisation Drive (Research Center International Economics, FIW).

[1] *Wegener Center for Climate and Global Change, University of Graz, Leechgasse 25, 8010 Graz, Austria*

[2] *Department of Economics, University of Graz, Universitätsstr. 15, 8010 Graz, Austria*

1. Introduction

During the recent climate change conference in Durban, Connie Hedegarrd, the EU climate change commissioner, agreed to sign on to a second commitment period of the Kyoto Protocol in order to get an agreement by all Parties to the UN climate change convention and to establish a roadmap for a legally binding framework by 2015 (European Commission 2011c). Until that time, however, the EU has become almost alone among developed countries (The Guardian 2011b) in committing to continue the protocol: Canada withdrew from the protocol (The Guardian 2011a) and Japan as well as Russia announced during the Durban conference that they were also unwilling to sign on to a second period. Therefore, until new emission targets for developed countries participating in the second commitment period of the Kyoto deal are established at the UN climate conference to be held at the end of 2012 in Qatar, the EU will abide by the goal of reducing its 2020 greenhouse gas emissions by at least 20% below 1990 levels. The key instrument of European climate policy is the emissions trading scheme (ETS). In the third trading period of the EU ETS (2013-2010), the system of allocating CO_2 emission allowances will change substantially: In contrast to free allocation of allowances in the first (2005-2007) and second (2008-2012) ETS trading period with just a negligible share of auctioning (0.13% in phase 1 and 3% in phase 2, see Ellerman et al. 2010), in phase 3 the power sector will face full (100%) auctioning of allowances and a considerable share of allowances will be auctioned in other ETS sectors as well (European Parliament and Council 2009). However, the European Commission has decided to grant (sub-)sectors, identified as being exposed to a significant risk of carbon leakage, free allowances based on greenhouse gas performance-based benchmarks (European Parliament and Council 2009; European Commission 2011a). In this paper we compare the consequences of different options for concessions to carbon leakage exposed sectors, namely free initial allocation and carbon measures at the border, by focusing on Austria, a small EU member state which is trade exposed in several sectors.

When climate policies are implemented in some countries only, as is the case with EU ETS, concerns over the environmental effectiveness of such policies arise. Since international trade allows for importing carbon intensive products from non-Union countries, the implementation of unilateral climate policies might lead to higher emissions from imports which partly offset emission reductions within the Union, a phenomenon which has been called *carbon leakage* (e.g. Reinaud 2009 and 2005; IEA 2008; Mani 2007; Copeland and Taylor 2005).

One explanation for carbon leakage is the accounting framework currently used by the UNFCCC which is based on the so-called 'Production-Based Principle' (PBP). According to the PBP, environmental responsibilities are restricted to the production of nationally consumed goods and exports. In contrast, accounting for emissions on the basis of the 'Consumption-based Principle' (CBP) implies reattributing emissions associated with exports to foreign countries, and adding emissions from imports to domestic environmental responsibilities (Peters and Hertwich 2008a and 2008b). Carbon leakage therefore emerges when a unilaterally imposed climate policy reduces emissions on the basis of the PBP but increases the corresponding CBP emissions.

Model based simulations of the EU ETS first commitment period, and of comparable climate policy options in other OCED countries, find rather modest leakage rates in the range of 10% to 30%[1]. One explanation why actual leakage was considerably lower than first feared by industry lobby groups was free allocation of CO_2 allowances (Reinaud 2005; Sijm *et al.* 2004) and that there was even over-allocation (Ellerman and Buchner 2008; Kettner et al. 2008). In the third commitment period with more stringent caps and a considerable role for initial auctioning, the problem of carbon leakage might increase, since CO_2 allowance prices will be substantially higher.[2]

According to EU legislation, a (sub)sector is exposed to a significant risk of carbon leakage if it is trade exposed and/or energy intensive (European

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[1] While some studies focus on specific sectors using partial equilibrium analysis (Lanz et al. 2009; Demailly and Quirion 2004), others apply global trade datasets (e.g. the GTAP database) to conduct input-output analysis (Peters and Hertwich 2008a and 2008b), multi-regional equilibrium analysis (Fischer and Fox 2009), or computable general equilibrium (CGE) analysis (Barker et al. 2007; Paltsev 2001; Babiker 2005; Babiker and Rutherford 2005; McKibbin and Wilcoxen 2008; Ho et al. 2008, Mattoo et al. 2009; Fischer and Fox 2007; Fæhn and Bruvoll 2009).

[2] With increasingly stringent climate policies in the EU, the trend of increasing net imports of energy intensive products in high income countries might be aggravated: A World Bank analysis suggests a gradual increase over the period 1990 to 2004 in the import to export ratio of energy-intensive products in high income countries, and a gradual decline in the ratio in some low and middle income countries (Mani 2007). This trend is particularly strong for small open economies like Austria with a higher openness to trade (Muñoz and Steininger 2010; Giljum et al. 2008).

Commission, 2011). Recent studies on competitiveness effects of the EU ETS find that carbon constrained EU sectors which trade on international markets, are affected negatively in their ability to export goods and services and to retain market shares and profits vis-à-vis unconstrained international competitors (McKinsey and Ecofys 2006, IEA 2008; Reinaud 2009). More specifically, (sub-) sectors might be at risk of a loss in international competitiveness when one or more of the following characteristics apply: they are internationally exposed (i.e. where production can easily relocate), energy is a large share of their total costs, they have high process emissions, they are characterized by some degree of process and product homogeneity, or they face indirect cost increases e.g. via electricity (Reinaud 2009 and 2005; Morgenstern et al. 2007).

Fear of negative impacts of higher carbon prices on certain EU sectors' competitiveness, which in turn may erode political support for the environmental policy regime, results in a call for exemptions of one sector or another (e.g. Bhagwati and Mavroidis 2007; Kraemer *et al*. 2007; Pauwelyn 2007; Stiglitz 2007; Babiker et al. 2000).

The European Commission thus foresees measures to shield itself from carbon leakage. In principal, measures for equalizing carbon prices across countries can utilize several leverages: (i) reducing carbon cost impacts (i.e. grandfathering of emission allowances); (ii) increasing the level of carbon prices in unregulated countries (e.g. by sectoral agreements among Annex I and non-Annex I countries); and (iii) tax adjustments at the border such as import tariffs or export rebates (see e.g. Grubb and Brewer, 2009). The present analysis focuses on (i) and (iii) as policy options that can theoretically be implemented by the EU without the need of coordination with other countries, namely exemptions/subsidies for leakage exposed industries and border cost adjustments for exports of those industries.[3] However, also these options face different potential legal hurdles in both WTO and EU trade law, but an analysis of those is beyond the scope of this paper (see e.g. van Asselt and Biermann 2007).

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[3] As pointed out by one of the reviewers, export rebates could be an option at member state level, while import measures are not, due to the EC trade policy rulings. Moreover, carbon tariffs need to be designed in a non-discriminatory way to avoid appeals to WTO by affected countries (Fischer and Fox 2009).

We seek to delineate the economic and environmental consequences of anti-leakage policies as part of EU climate policy for the period after 2012, with a focus on Austria, as a small open economy. We address three major questions: First, do these anti-leakage measures work as intended for the exposed sector and what are the spillover consequences for the other sectors? Second, how does Austria's carbon balance develop if the EU climate policy deviates from a full auctioning cap-and-trade system by granting concessions to certain sectors? Third, what are the overall economic (and environmental) costs and benefits of anti-leakage policies?

To answer these questions, a multi-regional multi-sector CGE model is developed for Austria, its main trading partners (Germany, Italy, France, Poland, Russia, USA, and China), three EU regional aggregates and 10 further world regions. The model distinguishes 15 sectors according to their energy intensity and whether they are currently covered by the EU ETS (carbon dioxide emissions embodied in production and industrial process emissions not directly linked to the combustion of fossil fuels are considered). This model is then used to assess the carbon as well as economic impacts of different concessions to energy intensive, trade exposed sectors: (i) an input subsidy to reflect free initial allocation of permits to sectors identified at risk of carbon leakage in the third trading phase of the EU ETS, and two alternative redistribution measures namely (ii) an output subsidy, and (iii) an export rebate. Analyzing concession variants (ii) and (iii) should provide answers to the main question of our paper, whether the method chosen to protect EU industries under the EU ETS's third trading phase against competitiveness losses achieves its aim in the most cost efficient way, or if there are superior options available. The implications of the policies identified for Austria's net exports and carbon responsibilities can be regarded as an example for many other small open economies within the group of industrialized countries.

The structure of this paper is as follows: We start with a summary of the main changes in the third trading period of the EU ETS. We then continue in section 3 with a description of the structure of the CGE model. Data sources used for the modeling, the assumptions for the 2020 baseline calibration as well as the characteristics of the full auctioning reference scenario are found in section 4. Section 5 describes the assumptions for the anti-leakage policy scenarios, as well as their specific impacts on Austria's production, trade relations and on the respective carbon emissions. Section 6 summarizes our results and concludes.

2. The EU ETS in the third phase

The EU ETS, which was launched in January 2005, is the key instrument for a cost effective reduction of industrial GHG emissions in the EU. Currently it covers approximately 11,000 installations from power generation and other energy intensive industries across 30 countries, the 27 Member States as well as Norway, Iceland and Liechtenstein as non-EU members of the European Economic Area. This sample accounts for approximately 50% of total EU CO_2 emissions, and 40% of total EU GHG emissions. From the start of 2012 in addition, emissions from all domestic and international flights that arrive at or depart from an EU airport will be covered by the EU ETS (European Commission 2008).

Table 1: Main differences between EU-ETS in phases I and II versus phase III. Source: European Commission (2011b, p. 7)

phase I and II	**phase III**
• National caps defined in national allocation plans (NAPs)	• EU-wide cap defined in Community-wide implementation measures (CIMs), translated into National Implementation Measures (NIMs)
• Fixed cap	• Annually decreasing cap (1.74% / year)
• 3 and 5 years trading period	• 8 years trading period
• Limited auctioning (max. 5% phase I, 10% phase II)	• Substantial auctioning
• Free allocation based on historical emissions at installation level for industry and electricity generation	• Transitional free allocation for industry and heat-related emissions (not for electricity generation) based on emission benchmarks at product level

In the first (2005-2007) and second (2008-2012) ETS trading period the CO_2 emission allowances were allocated to regulated firms for free, based on countries' individual national allocation plans (NAPs). The allocation was thus left to the individual Member States; however, the NAPs were subject to approval by the European Commission. With the third trading period starting in 2013, National Allocation Plans will cease to exist and the allocation will be harmonized at the European Union. Furthermore in phase 3, auctioning of emission allowances should become the norm rather than an exception, as was the case in the first two trading periods, where auctioning was limited by the European Directive to at most 5% and 10% for phases one and two respectively. From 2013 onwards, the EU27 power sector will face full auctioning of allowances (with only limited and temporary options to derogate from this rule for some Eastern European countries such as Poland) and a considerable share of allowances is to be auctioned in other ETS sectors as well (European Parliament and Council, 2009). The main differences between phase I & II versus phase III with respect to the EU ETS are summarized in Table 1.

Instead of grandfathering emission allowances based on historic emissions, the European Commission will grant free allowances for ETS industries and heating sectors (not for power generation which will still face full auctioning, except in some Eastern European countries, see above) based on greenhouse gas performance-based benchmarks (European Commission, 2011a): While installations meeting the benchmark will receive their allowances for free, other installations will have a shortage of emission allowances and thus either abate their excess emissions or purchase additional allowances from other installations. Industrial sectors which are exposed to a significant risk of carbon leakage will receive a higher share of free allowances than those which are not at the risk of carbon leakage. According to § 15 of Article 10a of Directive 2003/87/EC (European Parliament, 2003), a sector or subsector is acknowledged as being exposed to a significant risk of carbon leakage if its direct and indirect cost of the EU ETS in phase III would increase production cost by at least 5% *and* if the intensity of trade with non-EU countries (sum of exports and imports) make up at least 10% of market size within the EU. If a (sub)sector does not fulfill both criteria, it can still be eligible if either its production costs increase by at least 30%

or if its extra-Union trade intensity is at least 30% (§ 16 of Article 10a of Directive 2003/87/EC).

Table 8 in the Appendix lists those carbon leakage exposed sectors in accordance with § 15 at NACE-2 level (and whether they also fulfill one of the criteria in § 16). The full list (at NACE-4 level) is much longer as many additional subsectors classify according to the criteria in § 16, extending towards e.g. food, textiles, wood, non-metallic mineral products, machinery, electrical and optical equipment, transport equipment (European Commission, 2009). In total, the EU commission expects about half of the total allowances to be auctioned from the start of the third trading period in 2013 (European Commission, 2011a).

Thus, with the exception of power generation and electricity consumption as well as gas flaring where full auctioning applies, the annual (free) allocation of allowances to installations in ETS covered sectors is determined by (European Commission, 2011b):

Allocation = Benchmark x Historical activity level x Carbon leakage exposure factor x Cross sectoral correction factor OR linear factor

The *benchmarks* are developed on a per-product basis and reflect the average greenhouse gas performance of the top 10 % of best performing installations in the EU producing a certain product, in terms of metric tons of CO_2 emitted per ton of product produced at the European level in the years 2007-2008. These product benchmarks are then multiplied by the *historical activity level* [tons of product] of the relevant installation. For the carbon leakage exposed sectors, the free allocation defined by the benchmark will be multiplied by a *carbon leakage exposure factor* (CLEF) of 1 while for other sectors the free benchmark based allocation will be phased out over the third trading period and therefore multiplied by a lower CLEF (0.80 in 2013, and reduced every year to reach 0.30 in 2020). The *cross sectoral correction factor* ensures that the total amount of free allocation to non-electricity sectors does not exceed the maximum amount of emissions under the EU cap. The quantity of allowances issued each year starting in 2013 will be decreased by a *linear factor* of 1.74 % per year, and this also applies to the total amount of allowances issued for free (European Parliament and Council, 2009; European Commission, 2011b).

3. Model structure

In this section we lay out a non-technical model summary underlying our core assumptions. We construct a multi-region, multi-sector CGE model of global trade and energy use. Methodologically, the present paper thus contributes to the literature on multi-sector multi-region CGE models analyzing climate policies and carbon leakage (e.g. Böhringer 2000; Burniaux and Martins 2000; Paltsev 2001; Kuik and Gerlagh 2003; Babiker 2005; Fischer and Fox 2007; Fæhn and Bruvoll 2009).

On the regional level, we model the Austrian economy, its main trading partners, three regional aggregates for the other EU member states, and 12 larger world regions (see Table 2).

Table 2 Regional dimension of the CGE model

Aggregated Region	**Model code**	**Aggregated Region**	**Model code**
Austria	AUT	China	CHN
Germany	GER	Rest of East Asia ("Asian Tigers")	EASI
Italy	ITA	Southeast Asia	SEASI
France	FRA	South Asia	SASI
Poland	POL	United States of America	USA
Rest of West EU 27 + Switzerland	WEU	Rest of North America	NAM
Rest of South/-east EU 27	SEEU	Latin America	LAM
North EU 27	NEU	Oceania	OCEA
Rest of Europe	ROE	Middle East and North Africa	MENA
Russian Federation	GUS	Sub Saharan Africa	SSA
Rest of CIS	CIS		

On the sectoral level, we differentiate between 15 sectors according to their energy intensity (see Table 3). Sectors with high energy intensity include all sectors covered by the European Union's Emissions Trading Scheme (European Parliament, 2003; hence referred to as "ETS"), such as refined oil and coke oven products. Sectors with lower energy intensity (i.e. the non-ETS sectors, NETS) include primary energy extraction as well as other non-energy intensive industries such as food and textile industry.

Table 3 Sectoral dimension of the CGE model

Aggregated Sectors	**Model Code**	**Aggregated Sectors**	**Model Code**
ETS sectors	**ETS**	**Non-ETS sectors**	**NETS**
Refined oil products	P_C	*(a) Primary energy extraction:*	*EXT*
Electricity	ELY	Other extraction	OXT
Iron and steel	I_S	Coal	COA
Cement, lime, glass etc.	NMM	Crude oil	OIL
Paper, pulp and paper products	PPP	Natural gas	GAS
		(b) Other non-ETS sectors:	*ONETS*
		Tech industries	TEC
		Food and textile industries	FTI
		Transport	TRN
		Agriculture	AGRI
		Other services and utilities	SERV
		Capital goods	CGDS

Figure 1 illustrates the diagrammatic structure of the model. Following the structure of agents used in the social accounting matrix generated by GTAP, the so-called "Regional Household" is an aggregate of private and public households and thus represents total final demand in each region r. This regional household provides the primary factors capital (K_r), labor (L_r), and natural resources (R_r) for the 15 sectors, and receives total income including various tax revenues. The regional household redistributes this stream of income with a unitary elasticity of substitution between the private household and the government for private and public consumption, respectively. Moreover, labor and capital are intersectorally mobile within a region but immobile between regions. The specific resource input is used in the extraction of primary energy (COA, OIL, GAS) and other extraction (OXT). There are two types of production activities Y_{ir} which differ slightly in their production functions: (i) resource using (primary energy) extraction sectors, and (ii) non-resource using commodity production (comprising ETS and other non-ETS sectors). For all types of production activities, nested constant elasticity of substitution (CES) production functions with several levels are employed, to specify the substitution possibilities in domestic production between the primary inputs (capital, labor, and natural resources), intermediate energy and material inputs as well as substitutability between energy commodities (primary and secondary).

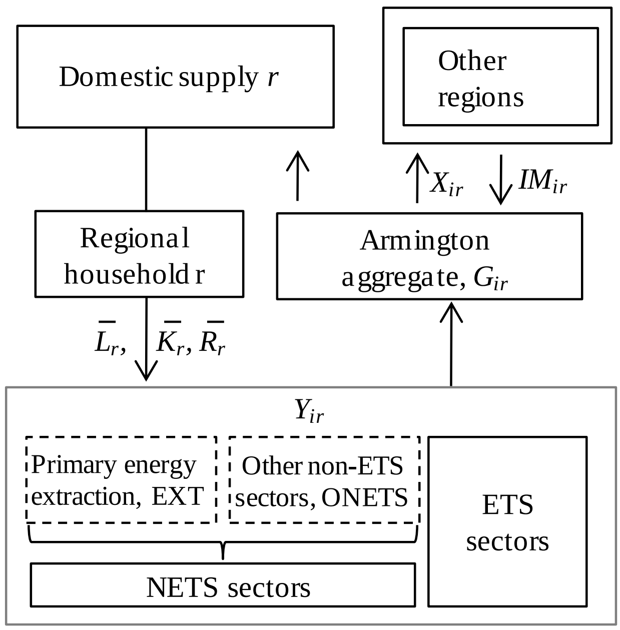

Fig. 1 Diagrammatic overview of the model structure

Following the Armington hypothesis (Armington 1969), goods produced in different regions are not perfectly substitutable. The Armington aggregation activity G_{ir}, corresponds to a CES composite of domestic output and imported goods IM_{ir} as imperfect substitutes. The resulting Armington supply G_{ir} either enters the domestic supply satisfying final demand and intermediate demand in production activities, or is exported to satisfy the import demand of other regions X_{ir} (see Figure 1). Further, the imports of any particular non-EU member region consist of imports from all other model regions, traded off at a constant but sectorally differentiated elasticity of substitution. The imports of any particular EU region consist of imports from either the European Union or the Rest of the

World (ROW).[4] At the top level of the import production block, imports from EU regions and from ROW are traded off amongst each other at a constant proportion. Imports among EU (ROW) regions are exchanged with a constant elasticity of substitution.

Final demand in region *r* is determined by consumption of the private household and the government. Both the private household and the government maximize utility subject to their disposable income received from the regional household. Consumption of private households in each region is characterized by a constant elasticity of substitution between a material consumption bundle and an energy aggregate. Public consumption is modeled as a Cobb Douglas aggregate of an intermediate material consumption bundle.

As a prerequisite for our climate policy analysis, we model CO_2 emissions as both arising in production and consumption. CO_2 emissions are linked in fixed proportions to the use of fossil fuels differentiated by the specific carbon content of fuels. In particular, fossil fuel intermediate inputs in the production process enter as fixed-coefficient composite of a carbon permit price linked to the combustion of fossil fuels. Furthermore, in the P_C and the NMM sectors we include industrial process emissions which are nested in a Leontief style CES function together with the intermediate energy input composite. The combustion of fossil fuels by private households is linked to the generation of CO_2 emissions in the same way as in the production sectors.

The price of CO_2 emission permits is endogenously determined in order to achieve an exogenously set reduction target. Since within ETS sectors permit trading is allowed among all member states, there is a single ETS carbon price across member states. Due to the absence of an EU-wide permit market for non-ETS emission allowances, there is a specific non-ETS carbon price (for all non-ETS sectors) in each EU region.

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[4] By distinguishing between intra-EU trade and trade by the EU with the rest of the world, we try to rule out certain trade constellations which do not make perfect sense, e.g. electricity trade between continental Europe and Australia.

4. Model calibration and the full auctioning reference scenario

4.1 Economic and emission data

For our analysis we use the GTAP database (GTAP 2007) which is unique in its sectoral and regional coverage of consistent input output and trade tables (113 countries and 57 commodities for the base year 2004). Furthermore the data base provides information on international energy markets derived from the International Energy Agency's (IEA) energy volume balances, again for the year 2004 (McDougall and Lee 2006; McDougall and Aguiar 2007; Rutherford and Paltsev 2000). GTAP7 relies on updated energy prices for the year 2004 – using price indices and exchange rates from the year 2000 – to add information about the monetary energy input values to the physical energy quantities.
Despite the impressive scope of the database, it has some limitations with regard to emissions which are solely based on combustion processes (Lee 2008), while process related emissions (which can be substantial for some sectors like refineries) are not part of the emissions data in GTAP.[5] To include also process related emissions, which are particularly relevant for coke oven products and clinker production and somewhat less relevant for the chemical industry, we add GHG emissions from industrial processes to the emissions in the two ETS sectors' P_C and NMM, based on UNFCCC data (UNFCCC 2011).[6]

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[5] Since these CO_2 emissions are derived from the IEA energy balances, they only take account of combustion based CO_2 emissions. This data therefore is excluding some 10% of global CO_2 emissions which are related to industrial processes. While 10% might seem negligible, it is not in our context of analysis, because it is 10% of global emissions originating from basically three economic activities (coke ovens, clinker production, and to a smaller extent in the chemical industry) that each are foreign trade intensive and under intense international competition.

[6] Another flaw of Lee's CO_2 emissions calculation lies in the misinterpreted treatment – at least for Austria – of fuels used as feedstock in the chemical and petrochemical industry (P_C). This leads to an underestimation of these industries' CO_2 emissions compared to more detailed data for Austria (Anderl et al. 2008). Based on this additional information and on our own work in this field (Steininger et al. 2009), a reconciliation of the Austrian CO_2 data is possible in principle. However, to keep global consistency within the GTAP7 data set and to avoid implausible model results at the expense of Austrian industrial sectors, we thus stick to the initial CO_2 data base by Lee, but augmented by industrial process related emissions, yet without correction for feedstock use in these sectors.

4.2 Baseline adjustment and calibration

In our CGE analysis, we examine Austria's international trade and its net carbon flows for the time horizon 2020, an important date in international and European climate policy. Accordingly, we calibrate the model for 2020, where no climate policies are in place. Since the GTAP7 data base is consistent for the reference year 2004 and we apply a static general equilibrium model calibrated for this base year, we have to factor in the economic developments until the year 2020 by growth rates. Based on a comprehensive study of the long term growth prospects of the world economy, annual average growth rates for the time span 2005 to 2050 for multi-factor-productivity (MFP), the capital stock and the labor force were calculated (Poncet 2006). For the growth rates which were used to calibrate our model for 2020, see Table 9 in the Appendix.

To account for improvements in energy efficiency over time, we introduce an exogenous autonomous energy efficiency improvement parameter AEEI (Nordhaus 1992; Manne and Richels 1992). The AEEI is a heuristic measure for all non-price driven improvements in technology, which in turn reduce energy intensity. Following Böhringer (1999) or Burniaux et al. (1992) we assume a constant AEEI parameter and set it to 1% per annum.

To adjust for the financial crisis, we decided to apply the annual growth rates by Poncet (2006), which were calculated prior to the crisis, only for a reduced ten year time span. This procedure should counterbalance the setbacks in growth prevailing from 2008 until 2010. See Table 10 in the Appendix for the numerical values generated by our no-policy 2020 forward projection, with respect to Austria's economic output, its trade relations and associated GHG emissions.

For our analysis of the effects of different EU climate policy scenarios on international trade and carbon leakage, the CGE model is programmed and solved in GAMS/MPSGE (Rutherford 1999) utilizing the solver PATH (Ferris and Munson 2000).

4.3 Full auctioning reference scenario – definition and results

In our numerical analysis the full auctioning scenario characterizes the reference case to which the impacts of different alternatives for concessions to ETS sectors at risk of carbon leakage (i.e. anti-leakage policies) on international competitiveness and on overall environmental effectiveness are compared to. The scenario is based on the unilateral EU climate policy as set up under the EU "20-20-20" targets – a 20% reduction of GHG emissions below 1990 levels (-30% if there is an international mitigation agreement negotiated with other developed countries), a 20% increase in energy efficiency (i.e. a 20% reduction in primary energy use compared with projected levels), and a 20% share of renewable energies in total EU energy consumption by 2020 (European Commission 2008). To achieve the GHG reduction target, different targets are set for those sectors which are currently covered under the EU ETS and those which are not, 21% and 10% respectively (for 2020 relative to 2005 CO_2 emission levels). For non-ETS sectors, the EU wide reduction target is differentiated across countries (e.g. -16% for Austria). Private household emissions are not capped.

The full auctioning reference scenario (*FullAuct*) achieves the EU-wide emission reduction target by an EU wide cap-and-trade scheme for the ETS sectors (in our model, the iron and steel industries (I_S), the non-metallic mineral production (NMM), the paper, pulp and paper products industry (PPP), the power generation sector (ELY), and the petrochemical industry (P_C)).[7] In contrast, non-ETS sectors are restricted by national cap-and-trade systems. For both ETS and non-ETS sectors, all allowances are auctioned and resulting revenues are collected by the regional households and redistributed to private households and the government.

Table 4 illustrates the economic and environmental results of the full auctioning scenario for Austria. As in the base year, a substantial share of Austrian output (93%) derives from non-ETS sectors. Compared to the non-policy case (see Table 10 in the Appendix for comparison), the emission reduction targets under *FullAuct* lead to a 5.7% decline of output levels in the ETS sectors and a 1.1% decline in non-ETS sectors. The higher impact on ETS sectors relative to non-ETS sectors is caused by the higher openness to trade and the higher carbon intensity, which lead to higher effects on relative prices compared to the non-ETS sectors. Furthermore, ETS sectors face a 21% reduction target below 2005 emission levels while non-ETS sectors in Austria are subject to a 16% emission reduction target.

[7] Note that the characterization of ETS sectors here follows the classification in phase I and II. Compared to phase III, aviation and parts of the chemical industry fall into non-ETS sectors.

Table 4 Economic and environmental results for Austria for the full auctioning scenario

Production, exports and imports [MUSD]			
	Production	Export	Import
P_C	3,484	243	2,344
ELY	7,372	1,033	1,006
NMM	8,424	2,649	2,036
I_S	8,953	4,775	3,171
PPP	19,921	6,677	4,486
ETS total	*48,154*	*15,377*	*13,043*
ETS Intra EU	N.A.	12,029	12,139
ETS Extra EU	N.A.	3,348	903
non-ETS total	*719,982*	*164,297*	*170,272*
Total	**768,136**	**179,673**	**183,315**
CO_2 emissions [$MtCO_2$]			
	CO_2 production	CO_2 export	CO_2 import
P_C	4.5	0.3	2.1
ELY	12.9	1.8	3.1
NMM	3.5	1.1	1.6
I_S	1.2	0.7	0.8
PPP	1.4	0.5	0.3
ETS total	*23.6*	*4.4*	*7.9*
ETS Intra EU	N.A.	0.7	1.5
ETS Extra EU	N.A.	3.7	6.4
non-ETS total	*27.1*	*10.5*	*16.1*
Total	**50.7**	**14.9**	**23.9**

In terms of international trade, Austria's main trading partner is the EU (primarily Germany and Italy) and thus a significant share of Austria's imports (93%) as well as exports (78%) originate from other EU countries. Trade outside the EU, mainly with US and China, is negligible for Austria. Compared to the non-policy case we find a similar pattern for Austria's exports and imports as for Austrian production: Negative effects on ETS sectors are stronger than those on non-ETS sectors. While Austria's ETS exports decrease by 4.7% compared to the non-policy case, non-ETS exports decrease only by about half that number, namely

2.2%. One important exception is the electricity sector where Austrian exports increase despite the cost increase caused by the EU ETS. This increase is due to the fact that Austria has lower CO_2 emissions in electricity generation (high share of hydropower) compared to the neighboring countries and hence Austrian electricity becomes relatively less expensive as a consequence of the policy.

In case of imports, Austria's ETS imports decrease by 5.2% more than its non-ETS imports, amounting to -1.0%. This stronger impact on ETS imports is due to the fact that almost all imports are coming from within the EU while the EU share of exports is approximately three quarters, and that all EU countries face CO_2 emission caps, thus leading to higher import prices for ETS products. The import decline is particularly strong for electricity because Austria's electricity becomes relatively cheaper. Among non-ETS sectors, the imports of COA (coal) and GAS decline the most sharply. This is the result of a relatively strong output decline in the energy transformation sector (e.g. refineries; P_C), which is in turn triggered by less secondary fossil energy demand due to autonomous energy efficiency improvements. Therefore the decline in P_C output, amounting to -21.0% under *FullAuct*, is proportionate to the decrease in primary energy imports.

Turning to CO_2 emissions, we see that Austrian ETS as well as non-ETS sectors succeed in reducing their production related CO_2 emissions. In total, Austria's production causes 52 Mt CO_2, which is 23.9% lower than in the non-policy case. On the one hand, this results from the decrease in Austrian production and on the other hand from increasing energy efficiency in Austrian production, triggered by the cost pressure from carbon pricing. CO_2 emissions incorporated in Austrian exports decrease by 19.9% in ETS sectors and by 24.0% in non-ETS sectors. Again, the total 22.9% reduction of exported CO_2 emissions results from decreasing domestic output and decreasing CO_2 intensities in domestic production.

In terms of imports we find a shift in the sectoral composition of imports to more non-ETS and less ETS commodities and hence a fall in imported CO_2 emissions compared to the non-policy case. The CO_2 emissions from ETS imports decrease substantially due to reduction in ETS imports and the lower CO_2 intensities in ETS production of Austria's main trading partners in the EU.

5. Anti-leakage policy simulations

5.1 Characterization of anti-leakage policy scenarios

In contrast to the full auctioning case, the anti-leakage policy scenarios are characterized by alternatives to free allocation of CO_2 allowances to exposed sectors. In order to define sectoral vulnerability of certain Austrian ETS sectors according to the GTAP aggregation, we follow the European Commission's approach (European Commission 2009) and refer to the criteria of openness to extra-EU trade. Based on the highly disaggregated list of exposed sectors identified by the European Commission (for a condensed version, see Table 9 in the Appendix), we select those ETS sectors which fulfill the vulnerability criteria overall: NMM, I_S and PPP. Thus, two ETS sectors remain as facing full auctioning: P_C[8] and ELY.

In all anti-leakage policy scenarios, concessions to firms in the three exposed sectors are calculated following the formula for free allocation presented in section 2. The scenarios differ therefore in the way these concessions are granted, either by initial free allocation (scenario input subsidy *InSub*), as a lump sum subsidy (scenario ouput subsidy *OutSub*), or as an export rebate (scenario *ExReb*). Thus, in contrast to the full auctioning case where the revenues of the permit sales are collected by the regional households and redistributed to private households and the government, in the anti-leakage policy scenarios, permit sales are used to finance subsidies to the firms instead and hence the potential for redistribution is reduced. More specifically, these scenarios are characterized according to their refund approach as follows:

(i) Input subsidy - InSub

Those ETS sectors which have been identified as being at risk of carbon leakage, namely I_S, NMM, and PPP, receive 67% of their historical 2004 emissions as free CO_2 allowances in the year 2020.[9] Additional allowances have to be

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[8] Even though there are some subsectors within the P_C sector which are also classified as leakage exposed by the Commission, we treat the P_C sector as a whole not as leakage exposed.

[9] The value of 67% reflects an average value of grandfathered CO_2 allowances during the third trading period, since not all EU companies within the exempt EU ETS sectors will achieve the benchmark emission intensities. Furthermore the overall cap will decrease each year by 1.74% of

purchased by auction or can be traded on the ETS carbon market. In principle, this scenario comes closest to the EU ETS grandfathering in phase I and II except that the grandfathering rate is set here below 100%.

(ii) Output subsidy - OutSub

This scenario reflects a transfer of a fraction of CO_2 allowance auctioning revenues, again to those ETS sectors which have been identified as being at risk of carbon leakage. These sectors receive subsidies up to the same amount as the value of the grandfathered CO_2 permits under the scenario *InSub*, namely the value of 67% of base year carbon allowances.

(iii) Export rebate - ExReb

This scenario introduces export rebates as a policy measure to level the international playing field in the highly competitive ETS sectors' trade. The EU ETS sectors at risk of carbon leakage, which have to purchase the required CO_2 allowances by auctioning, receive export subsidies equal to the value of CO_2 emissions incorporated in their exports.

5.2 Competitiveness effects of anti-leakage policies

Economic analyses of measures to shield a region that is implementing unilateral climate policies from negative consequences for its international competitiveness and environmental effectiveness usually focus on different indicators. Competitiveness indicators encompass domestic economic indicators, like production, as well as changes in trade flows while environmental effectiveness is measured e.g. by carbon leakage (Reinaud 2005; Fischer and Fox 2009). We follow Fischer and Fox (2009) here by investigating production changes, more precisely the production losses avoided through concessions to exposed sectors (anti-leakage policies taking the form of input or output subsidies or export rebates) compared to full auctioning. In addition, we assess (net) trade effects of the anti-leakage scenarios, again relative to full auctioning. The effects for full auctioning are displayed relative to the baseline without climate policy.

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the average annual total quantity of allowances issued by the Member States in 2008-2012. Applying the cross sectoral correction factor and the linear factor reduces the preliminary allocation based on the benchmarks and the carbon leakage exposure factor to secure that the overall, annually reduced cap is satisfied. Therefore free allowances amounting to 100% of base year emissions are not possible in 2020.

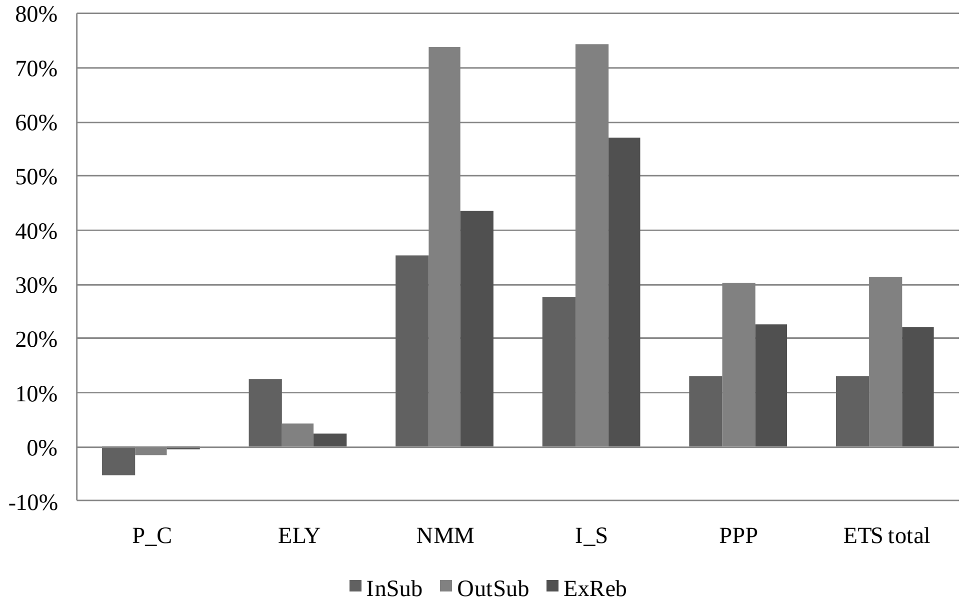

Fig. 2 ETS production loss avoided by anti-leakage policies (relative to *FullAuct* in %)

As Figure 2 points out, all three scenarios *InSub*, *OutSub* and *ExReb* are able to increase these sectors' output compared to *FullAuct*. However, the effectiveness of the policies differs substantially. This results from the different channels via which the three exempt sectors NMM, I_S and PPP are supported. In scenario *InSub*, 13.2% of the output losses under full auctioning can be avoided by allocating the three exempt ETS sectors two thirds of their emission allowances for free. The policy implemented in *OutSub* achieves ETS output loss avoidance of 31.3% instead, even though it redistributes the same amount of money to the three exempt sectors as in *InSub*, however not via an input subsidy on CO_2 permits but via an output subsidy. The *ExReb* scenario, which directly aims at subsidizing EU ETS exports by the amount of money these sectors have to pay for CO_2 permits necessary for the production of exports, results in a 22.1% output loss avoidance of EU ETS sectors compared to the full auction climate policy scenario.

Among the three exempt sectors, the two highly carbon intensive sectors NMM and I_S profit more strongly than sector PPP from any of the three anti-leakage policies. By examining the impacts on the two non-exempt sectors ELY and P_C, we encounter diverging effects: while the output loss avoided in sector ELY amounts to 12.6%, 4.3% and 2.4% respectively in the three scenarios, the output loss in sector P_C actually increases under *InSub* by 5.3%, under *OutSub* by 1.7% and by 0.4% in scenario *ExReb* because there is, compared to the *FullAuct* scenario, a shift of production to the exempt ETS sectors. Sector ELY's adjustment to higher CO_2 permit prices under all anti-leakage scenarios (relative to full auctioning) is a switch to less carbon intensive power generation (e.g. via fuel switch or increasing utilization of RES) represented by decreasing carbon intensities (see Figure 3). Even though ELY is not an exempt sector from full auctioning of CO_2 permits, it can partially circumvent the increasing cost pressure through higher CO_2 prices and can increase its output to satisfy the increasing domestic and foreign demand (from nearby EU countries). The P_C sector instead has no potential to substitute away from fossil fuel inputs (whose international prices tend to increase compared to *FullAuct*) and is therefore prone to additional output losses and increasing P_C imports from non-EU countries.

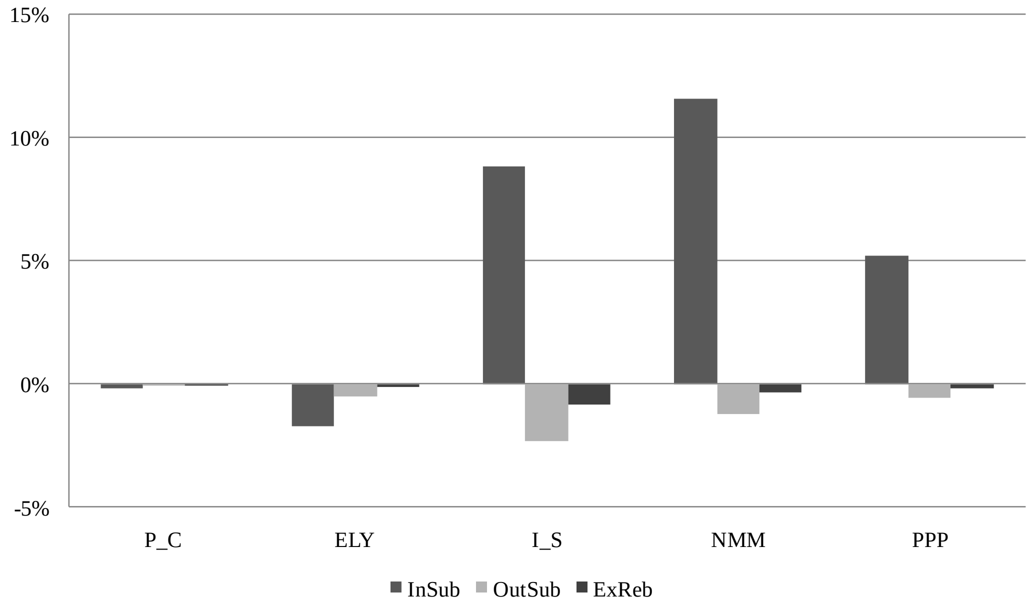

Fig. 3 Effects of anti-leakage policies on ETS sectors' CO_2 emission intensities (relative to *FullAuct* in %)

By referring to changing trade flows as an additional measure for the effectiveness of policies to shield EU ETS sectors from negative competitiveness effects, Table 5 demonstrates that all of the three policies achieve the anticipated purpose. The first column reports the absolute gains or losses in million USD (MUSD) under our full auctioning reference scenario *FullAuct*, compared to a no-policy scenario (see Table 10 in the Appendix), which have already been discussed in detail in the previous section. Columns two to four of Table 5 present the effectiveness of different anti-leakage (i.e. anti-competitiveness loss) policies to improve international competitiveness, especially of energy intensive industries.

Table 5 Export and import effects of anti-leakage policies on Austrian trade

	FullAuct	InSub	OutSub	ExReb
	gains/losses relative to no policy (in MUSD)	losses avoided (or additional gains) relative to FullAuct (in %)		
Exports				
P_C	-89	-8.0%	-2.5%	-0.7%
ELY	+168	+21.9%	+7.0%	+1.9%
NMM	-212	+34.6%	+71.2%	+105.4%
I_S	-338	+27.2%	+70.2%	+74.0%
PPP	-294	+12.8%	+28.6%	+42.5%
ETS total	-765	+30.5%	+63.0%	+78.6%
ETS Intra EU	-191	+56.3%	+113.5%	+212.6%
ETS Extra EU	-574	+21.9%	+46.2%	+34.1%
non-ETS total	-3,626	-1.6%	-3.4%	-5.0%
Exports total	-4,391	+4.0%	+8.1%	+9.6%
Imports				
P_C	-188	+17.2%	+5.5%	+2.3%
ELY	-424	-7.7%	-2.1%	-0.3%
NMM	-43	+10.3%	+20.2%	+215.9%
I_S	-76	-1.4%	+51.4%	+80.7%
PPP	+8	-76.5%	-93.1%	+387.2%
ETS total	-723	-0.4%	+5.8%	+25.9%
ETS Intra EU	-848	+2.5%	+11.9%	+25.6%
ETS Extra EU	+126	-19.6%	-47.1%	-23.6%
non-ETS total	-1,770	+2.9%	+14.2%	+10.4%
Imports total	-2,493	+1.9%	+11.8%	+14.9%
Trade balance	-1,898	+6.7%	+3.4%	+2.6%

As for output loss avoided, the two scenarios, *OutSub* and *ExReb*, granting CO_2 permit rebates to the three exempt ETS sectors via output and/or export subsidies, perform better in terms of export loss avoided than the scenario with direct input

subsidies (*InSub*). The export rebate scenario *ExReb* achieves the highest percentage of export loss avoided, compared to *FullAuct.* In total, under the three anti-leakage scenarios 30.5%, 63.0% and 78.6% of Austria's ETS sectors' export losses due to the full auctioning climate policy can be regained (see Table 5). Again, the greatest positive impact results for NMM and I_S, followed by the third exempt sector PPP. The non-exempt sector ELY which is already increasing its export activity under *FullAuct* (due to lower carbon intensity than the surrounding EU neighbor countries), benefits especially under *InSub* from reduced fuel prices and increasing domestic and EU electricity demand.
Table 5 furthermore reports that also imports, which have been initially reduced under *FullAuct*, tend to increase, and particularly so in scenario *ExReb*. This can be attributed to an "EU effect": since by assumption all EU countries implement anti-leakage policies in their ETS sectors and therefore try to increase their international competitiveness, part of import reduction triggered by a full auctioning EU climate policy is restored. Table 5 displays that in all three scenarios, imports from EU countries tend to increase compared to *FullAuct*, and substitute thereby for imports from non-EU countries, which decrease even stronger than under the reference case. In total, the two anti-leakage policies *OutSub* and *ExReb* trigger a regain of ETS imports by 5.8% and 25.9% respectively, while under *InSub* ETS imports are reduced by 0.4%.[10]

5.3 Effects of anti-leakage policies on environmental effectiveness

Table 6 reports the impacts of the anti-leakage scenarios on environmental effectiveness relative to full auctioning. In correspondence to increasing output in Austria's ETS sectors, also their production related CO_2 emissions tend to increase compared to the full auctioning scenario, namely by 2.0%, 0.3% and 0.4% in the anti-leakage scenarios *InSub*, *OutSub* and *ExReb*, respectively. This increase in emissions is possible since the Austrian ETS sectors can buy additional allowance at the EU-wide ETS market and hence other EU countries have to reduce their emissions accordingly so that the overall EU emission target is achieved. In non-ETS sectors, emission allowances cannot be traded across

[10] One should not be confused by the extremely high rates of regained imports in sectors NMM and PPP under *ExReb*. Table 5 reveals that the absolute import reductions under *FullAuct* compared to BAU have been small.

borders and hence emissions remain in all anti-leakage policies at the full auctioning level.

Table 6 Environmental effects of anti-leakage scenarios relative to full auctioning

	BAU	FullAuct	InSub	OutSub	ExReb
	$MtCO_2$	$MtCO_2$	Change relative to FullAuct (in %)		
PrivHH	*24.7*	*25.1*	*-0.1%*	*+0.0%*	*+0.0%*
Output	*66.7*	*50.7*	+0.9%	+0.1%	+0.2%
ETS	30.6	23.6	+2.0%	+0.3%	+0.4%
non-ETS	36.1	27.1	0.0%	0.0%	0.0%
PBP	**91.4**	**75.8**	**+0.6%**	**+0.1%**	**+0.1%**
Export					
ETS	5.4	4.4	+6.5%	+1.8%	+2.9%
Intra EU	4.2	3.7	+5.1%	+0.3%	+2.1%
Extra EU	1.2	0.7	+14.1%	+9.4%	+7.5%
non-ETS	13.8	10.4	+0.0%	-0.1%	-0.1%
Total	*19.2*	*14.8*	+1.9%	+0.5%	+0.8%
Import					
ETS	11.2	7.9	-0.9%	-1.9%	-0.1%
Intra EU	9.9	6.4	-0.1%	-0.4%	+0.9%
Extra EU	1.3	1.5	-4.1%	-8.2%	-4.1%
non-ETS	16.8	16.1	+0.0%	+0.2%	+0.2%
Total	*28.0*	*24.0*	*-0.3%*	*-0.5%*	*+0.1%*
CO_2 trade balance					
ETS	-5.8	-3.5	+10.0%	+6.4%	+3.8%
Intra EU	-5.7	-2.7	+7.1%	+1.4%	+0.7%
Extra EU	-0.1	-0.8	+20.0%	+23.6%	+14.3%
non-ETS	-3.0	-5.6	+0.1%	-0.7%	-0.6%
Total	*-8.8*	*-9.1*	+3.9%	+2.0%	+1.1%
CBP	**100.2**	**84.9**	**+0.1%**	**-0.1%**	**+0.0%**

As Figure 4 points out, the three exempt ETS sectors NMM, I_S and PPP increase their production related CO_2 emissions the most strongly under *InSub*, even though in this scenario the relative output loss avoided compared to *FullAuct* is the lowest among all three carbon rebate policies (see Figure 2). This outcome is also reflected in increasing EU ETS sectors' carbon intensities relative to full auctioning (see Figure 3). Thus, a direct subsidy of carbon input in ETS production does not create strong enough incentives for the three exempt ETS sectors to increase energy efficiency. The two policies *OutSub* and *ExReb*, aiming at redistributing CO_2 permit revenues to ETS firms via an output subsidy or an export rebate, create a higher incentive for reducing carbon intensities in production processes. In that case, since carbon as a production input is not directly subsidized, the cost increase triggered by rising CO_2 prices relative to *FullAuct* is more relevant for ETS sectors. In total, Austria's CO_2 emissions according to the PBP increase compared to full auctioning by 0.1% under *OutSub* and *ExReb* and by 0.6% under *InSub* (see Table 6).

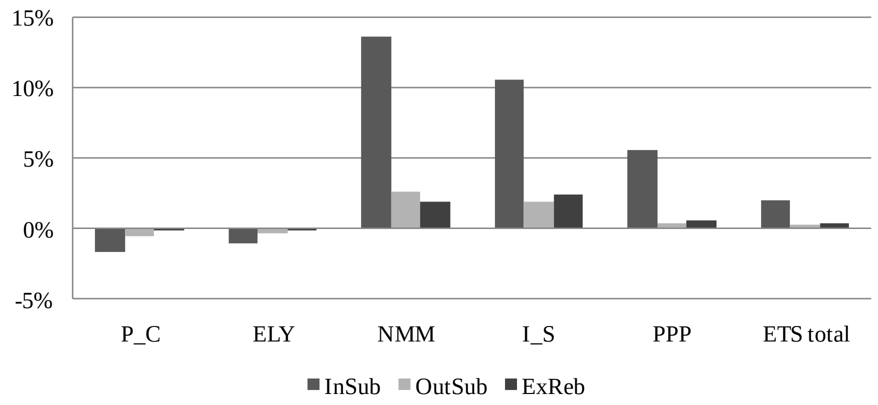

Fig. 4 Effects of anti-leakage policies on CO_2 emissions from ETS output (relative to *FullAuct* in %)

The same picture as for output related CO_2 emissions arises when investigating the CO_2 emissions incorporated in Austrian exports (Figure 5). The three subsidized ETS sectors NMM, I_S and PPP regain international competiveness and can increase their exports. The total increase relative to *FullAuct* in CO_2 emissions linked to total exported Austrian ETS production amounts to 1.8% under *OutSub*, 2.9% under *ExReb*, and 6.5% under *InSub* (see Table 6).

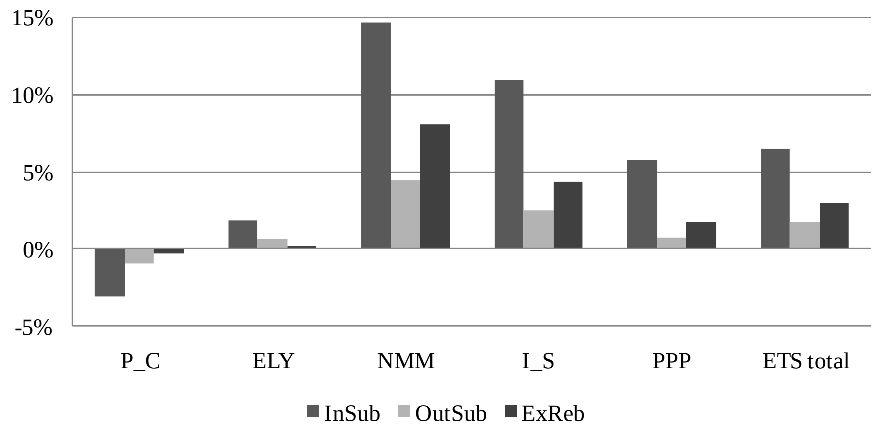

Fig. 5 Effects of anti-leakage policies on CO_2 emissions from ETS exports (relative to *FullAuct* in %)

Turning to CO_2 emissions incorporated in ETS imports to Austria, we find that even though imports of ETS products increase in all three scenarios (see Table 5), the corresponding CO_2 emission imports do not (see Table 6). This reflects the fact of a change in trade patterns again away from less energy efficiently producing regions to the now gaining EU regions, which are characterized by lower ETS carbon intensities than many international competitors. These changing trade patterns and international carbon flows demonstrate the effectiveness of carbon leakage policies in leveling out the cost of carbon in the EU ETS sectors.

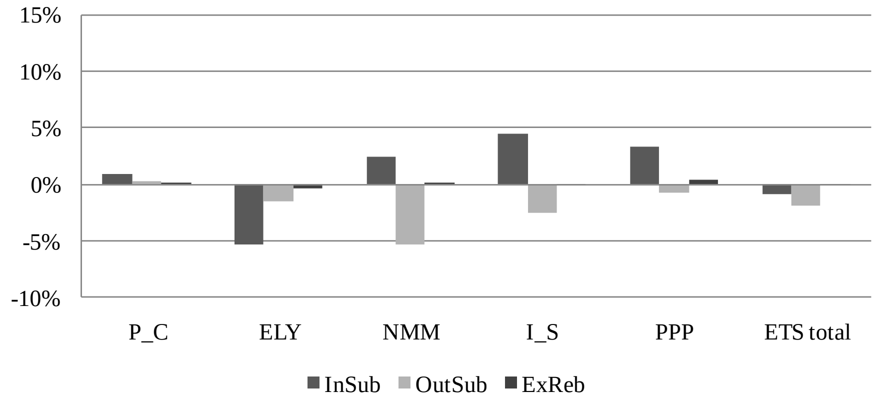

Fig. 6 Effects of anti-leakage policies on CO_2 emissions from ETS imports (relative to *FullAuct* in %)

Furthermore, Figure 6 reveals that, depending on the anti-leakage policy, some ETS sectors have lower but others higher total imported CO_2 emissions than under *FullAuct*. The sign and magnitude of the change in imported ETS CO_2 emissions depends on the anti-leakage policies' incentives to reduce emission intensities in Austria's main trading partners', the EU countries', exempted ETS industries. As described earlier, *InSub* does provide lower incentives for NMM, I_S and PPP to increase energy efficiency in production than the other two policies, which are not directly subsidizing CO_2 as a production input. Therefore, CO_2 emissions associated with imports of these three exempted sectors' products increase in scenario *InSub* compared to *FullAuct*. In total, however, all three anti-leakage policies achieve their goal of reducing CO_2 emission imports.

Summing up these effects on CO_2 incorporated in trade flows, the net carbon balance (defined as CO_2 exported minus CO_2 imported) improves for Austria's ETS sectors relative to *FullAuct* in the range of 3.8% to 10.0% and also for the whole Austrian economy by 1.1% to 3.9% and hence all three anti-leakage policies are effective in reducing carbon leakage (see Table 6). However, the net effect of an improved carbon trade balance and an increasing domestic CO_2 output is almost zero – the increasing domestic production cancels out the reduced carbon leakage and renders the policies' effects on environmental effectiveness negligible. Put differently, and in contrast to PBP emissions, CPB emissions in all scenarios remain roughly constant at the full auctioning level.

5.4 Cost-benefit analysis of anti-leakage policies

We have shown that the three anti-leakage policies work as intended with respect to the anticipated effects on Austria's ETS sectors' international competitiveness and carbon leakage. However, since this paper intends to assess the cost effectiveness of anti-leakage policies, it is important to ask, at which cost the regained international competitiveness of Austrian ETS sectors and reduced carbon leakage is achieved. Table 7 reports the results of a cost-benefit analysis of the three anti-leakage policies in which the output gains (and environmental benefits) are contrasted to the costs of the policies, which are higher for *InSub* and *OutSub* than for *ExReb*. It is interesting to see that despite the same level of subsidies under scenario *InSub* and *OutSub* the latter scenario achieves much higher output gains relative to *FullAuct*. Under *ExReb,* the overall output gain compared to *FullAuct* is lower than under *OutSub,* however this comes at much lower costs: only about one fourth of the subsidies under *InSub* and *OutSub*. The benefit-cost ratio reveals that per every US Dollar redistributed to ETS sectors, the export rebate scenario achieves the highest benefits, namely at a factor of 1.40. By granting output subsidies to certain EU ETS sectors, scenario *OutSub* achieves a benefit-cost ratio of 1.18. Scenario *InSub*, however, only achieves a benefit-cost ratio of 0.35, meaning that only 35% of every USD granted in form of free emission allowances actually results in an output gain.

Table 7 Cost benefit analysis of anti-leakage scenarios

	InSub	OutSub	ExReb
	Change relative to FullAuct (in MUSD)		
(1) Subsidies for ETS	-653.4	-686.7	-271.6
(2) Output gain/loss ETS	+380.1	+902.6	+636.8
(3) Output gain/loss NETS	-149.0	-92.6	-257.3
Anti-leakage policy net gain (excl. CO_2 avoided) (1)+(2)+(3)	**-422.4**	**+123.3**	**+107.9**
Benefit-cost ratio [(2)+(3)]/(1)	**0.35**	**1.18**	**1.40**
(4) Additional CO_2 costs from higher ETS production	-66.8	-7.7	-11.9
Anti-leakage policy net gain incl. CO_2 avoided (1)+(2)+(3)+(4)	**-489.2**	**+115.6**	**+96.1**
Benefit/cost ratio incl. CO_2 [(2)+(3)]/[(1)+(4)]	**0.32**	**1.17**	**1.34**

By including additional costs for CO_2 (i.e. due to higher PBP emissions relative to *FullAuct*), we aim at augmenting the cost-benefit analysis by an environmental component. In order to derive the additional CO_2 costs triggered by the anti-leakage policies, we apply the CO_2 prices derived from our CGE model to the additional output related carbon emissions in Austria. The model's result for the EU wide ETS carbon price of 120 USD/t CO_2 under the scenario *FullAuct* increases to 140 USD/t CO_2 for scenario *InSub*, 126 USD/t CO_2 for scenario OutSub, and 122 USD/t CO_2 for scenario *ExReb*, respectively[11].

In all three anti-leakage scenarios the redistribution of CO_2 permit auctioning revenues to ETS sectors results in increasing Austrian ETS output and therefore a higher demand for CO_2 permits, which itself triggers higher permit prices. By directly subsidizing carbon permits, the policy scenario *InSub* reduces the incentives for ETS industries to increase efficiency in production processes and hence CO_2 emissions from domestic ETS output increase the most. By valuing CO_2 emissions with the corresponding ETS and non-ETS prices, respectively, we find the additional environmental costs of this policy amounting to 66.8 MUSD. The net loss of this grandfathering policy is therefore further reduced to 489.2 MUSD, resulting in a benefit-cost ratio of 0.32. The other two scenarios lead to an increase of CO_2 emissions as well, but due to the difference in the base of the subsidy (the subsidy is linked to the output value rather than on a single input, such as CO_2 permits), permit prices remain a viable cost incentive to increase energy efficiency in production processes. In total, additional costs of CO_2 avoided reinforce the net gains from production losses avoided, such that the benefit-cost ratio is still highest with 1.34 for *ExReb*, followed by 1.17 for *OutSub*. Thus, the export rebate is the most efficient anti-leakage policy.

6. Discussion and conclusions

With the third trading period of the EU ETS starting in 2013, the system of allocating emission allowances will significantly change. The power sector will face full auctioning of allowances and a considerable share of allowances is to be auctioned in other ETS sectors as well, with the share of free allocation contingent on sectoral exposure to carbon leakage. In this paper, we compare this form of concession (input subsidy, *InSub*) to two alternative options: an output subsidy (*OutSub*) and an export rebate (*ExReb*).

[11] Note that there is a single ETS CO_2 price for all EU member states (due to the tradability of EU ETS emission allowances in these sectors). For non-ETS sectors, a different CO_2 price emerges in each modeled EU region, spanning e.g. for *FullAuct* from 15 USD/t CO_2 for SEEU to 356 USD/t CO_2 for NEU. These price differentials represent the differences in countries' specific mitigation potentials, i.e. their marginal abatement costs.

While our analysis for Austria indicates that all three anti-leakage policies achieve the expected regain of ETS sectors' international competitiveness, it also indicates that they may not be very effective at reducing overall consumption based GHG emissions in Austria. While in all three scenarios the net carbon balance (defined as CO_2 exported minus CO_2 imported) improves for Austria's ETS sectors relative to a full auctioning reference scenario (*FullAuct*), the increasing domestic production related CO_2 emissions cancel out the reduced carbon leakage and renders the policies' effects on environmental effectiveness negligible.

Even though all anti-leakage scenarios effectively avoid the loss in international competiveness which would occur under full auctioning, they differ substantially with respect to the level of cost effectiveness. While the level of subsidies granted to the exempt ETS sectors is the same under scenario *InSub* and *OutSub*, the latter scenario achieves much higher output gains relative to *FullAuct*. *ExReb* achieves output gains in between the two other anti-leakage policies, but at much lower costs: about one fourth of the subsidies necessary under *InSub* and *OutSub*. The benefit-cost ratio reveals that per every USD redistributed to ETS sectors, the export rebate scenario achieves the highest benefits, followed by the output subsidy scenario. The scenario reflecting the grandfathering policy under the EU ETS, however, only achieves a benefit-cost ratio of 0.5, meaning that only 50% of every USD granted in form of free emission allowances actually results in an output gain.

In the cost benefit analysis, additional carbon costs of the anti-leakage policy scenarios, relative to the full auctioning scenario, are included. In the anti-leakage policy scenarios, these additional costs arise because CO_2 prices are higher than in the full auctioning scenario and because Austrian firms are buying additional allowances from other EU member states. In all three scenarios the redistribution of CO_2 permit auctioning revenues to ETS sectors results in increasing ETS output and therefore a higher demand for CO_2 permits and higher permit prices. The direct subsidy for carbon permits under the input subsidy (*InSub*) policy scenario reduces the incentives for ETS industries to increase efficiency in production processes and thus fosters emissions at home considerably. Due to the different subsidy base in the other two anti-leakage scenarios (the subsidy is linked to the output value rather than to a single input value, such as CO_2 permits), the price signal remains an incentive to curb domestic emissions. The inclusion of an environmental component thus reinforces the ranking of the three policies. Thus, in terms of cost-effectiveness, the export rebate policy, followed by the output subsidy, tend to be the more efficient anti-leakage policies, compared to the input subsidy (i.e. grandfathering). It should therefore be in the European Commission's best interest to reform the ways in which exempt sectors are supported in order to achieve both policy goals of increased international competiveness and reduced carbon leakage at minimal cost.

While this paper has focused on the differences in economic and environmental effects across policies, there is also an international trade law dimension because the export rebate reduces the prices of exported goods in leakage exposed sectors relative to the domestic prices. Export rebates could thus conflict with GATT/WTO provisions, in particular with the Agreement on Subsidies and Countervailing Measures and GATT Articles I and III (non-discrimination) and XX (exemptions for measures necessary to protect nature and exhaustible resources). At least three criteria are important for an export rebate to confirm with WTO legislation: first, the measure has to be motivated by environmental objectives (reduced carbon leakage); second, the input on which the rebate is based needs to be incorporated in the product; and third, the subsidy rate needs to be imposed based on an appropriate carbon allowance price (Tamiotti 2011; Fischer and Fox 2009, WTO and UNEP 2009, von Asselt and Biermann 2007).

In addition to questions of legal compatibility and political feasibility, there are several issues of design and implementation which could be addressed in future modeling, such as alternative options for export rebates (based on a subsidy rate or on allowances). Moreover, export rebates and national anti-leakage policies could be compared to and combined with different forms of carbon-based import tariffs or sectoral agreements among Annex I and non-Annex I countries. Finally, in our analysis the selection of leakage exposed sectors was treated as given (by the European Commission), but the influence of the scope of targeted sectors and commodities for policy effectiveness and costs should be analyzed as well.

Appendix

Table 8 Subsectors at significant risk of carbon leakage (for 2013 and 2014) (based on European Commission, 2009)

Nace-2 Level	Description	§15 and § 16	§ 15
10.1	Mining and agglomeration of hard coal	x	
14.3	Mining of chemical and fertilizer minerals	x	
15.6	Manufacture of grain mill products, starches and starch products		x
15.8	Manufacturing of other food products		x
15.9	Manufacture of beverages	x	x
17.1	Preparation and spinning of textile fibers	x	
18.1	Manufacture of leather clothes	x	
21.1	Manufacture of pulp, paper and paperboard		x
23.1	Manufacture of coke oven products	x	
23.2	Manufacture of refined petroleum products		x
24.1	Manufacture of basic chemicals	x	
26.1	Manufacture of glass and glass products		x
26.3	Manufacture of ceramic tiles and flags		x
27.1	Manufacture of basic iron and steel and of ferro-alloys	x	
27.3	Other first processing of iron and steel production and production of non-ECSC ferro-alloys	x	
27.4	Manufacture of basic precious and non-ferrous metals	x	x
29.3	Manufacture of agricultural and forestry machinery	x	

Table 9 Annual Growth rates 2004 – 2020

Regions	MFP*	Capital stock*	labor force*
AUT	1.30	1.40	-0.20
GER	1.50	1.60	-0.10
ITA	1.30	1.10	-0.50
FRA	1.20	1.40	0.10
POL	1.60	2.60	-0.30
WEU	1.40	1.60	-0.03
SEEU	1.40	2.00	-0.40
NEU	1.40	2.50	0.20
ROE	1.50	1.80	0.30
RUS	1.50	1.80	0.30
CIS	1.50	1.80	0.30
CHN	2.60	5.70	0.10
EASI	1.50	2.20	-0.30
SEAS	2.70	5.20	0.60
SASI	2.10	4.40	0.80
USA	1.50	2.60	0.70
NAM	1.60	2.60	0.50
LAM	0.50	1.40	0.70
OCEA	1.60	3.00	0.50
MENA	0.90	1.10	1.00
SSA	0.50	0.90	0.50

*based on Poncet (2006)

Table 10 Economic and environmental results for Austria for the 2020 no-policy baseline projection

Production, exports and imports [MUSD]			
	Production	Export	Import
P_C	4,407	332	2,532
ELY	7,747	865	1,430
NMM	8,866	2,861	2,078
I_S	9,474	5,113	3,247
PPP	20,545	6,971	4,478
ETS total	*51,039*	*16,142*	*13,765*
ETS Intra EU	N.A.	12,220	12,987
ETS Extra EU	N.A.	3,922	778
non-ETS total	*728,105*	*167,923*	*172,043*
Total	**779,143**	**184,065**	**185,808**
CO_2 emissions [$MtCO_2$]			
	CO_2 production	CO_2 export	CO_2 import
P_C	5.9	0.4	2.4
ELY	16.0	1.8	5.8
NMM	5.3	1.7	1.8
I_S	1.7	0.9	0.9
PPP	1.7	0.6	0.3
ETS total	*30.6*	*5.4*	*11.2*
ETS Intra EU	N.A.	1.2	1.3
ETS Extra EU	N.A.	4.2	9.9
non-ETS total	*36.1*	*13.8*	*16.8*
Total	**66.6**	**19.2**	**28.0**

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