WIFO
1030 WIEN, ARSENAL, OBJEKT 20
TEL. 798 26 01 • FAX 798 93 86

ÖSTERREICHISCHES INSTITUT FÜR WIRTSCHAFTSFORSCHUNG

Wegener Center

powered by klima+energie fonds

FFG

ETCLIP – The Challenge of the European Carbon Market: Emission Trading, Carbon Leakage and Instruments to Stabilise the CO2 Price

Effects of Different EU Climate Policy Scenarios on International Trade and Carbon Leakage

Birgit Bednar-Friedl, Veronika Kulmer, Thomas Schinko
(Wegener Center)

August 2011

ÖSTERREICHISCHES INSTITUT FÜR WIRTSCHAFTSFORSCHUNG
AUSTRIAN INSTITUTE OF ECONOMIC RESEARCH

ETCLIP – The Challenge of the European Carbon Market: Emission Trading, Carbon Leakage and Instruments to Stabilise the CO2 Price

Effects of Different EU Climate Policy Scenarios on International Trade and Carbon Leakage

Birgit Bednar-Friedl, Veronika Kulmer, Thomas Schinko (Wegener Center)

August 2011

Austrian Institute of Economic Research

Project co-ordinator: Daniela Kletzan-Slamanig (WIFO) • The project ETCLIP is funded by the Austrian "Klima- und Energiefonds" and is carried out within the research programme "NEUE ENERGIEN 2020".

Abstract

Despite slow progress on international post-2012 climate policy architecture, the EU will expand its emissions trading scheme (the EU ETS) beyond 2020. Three major modifications are planned: 1. auctioning as the initial allocation mechanism (with some exemptions for energy intensive, trade exposed sectors), 2. broader sectoral coverage, and 3. increased stringency of reduction targets. Due to this unilateral approach, emission reductions achieved in the EU might be partially offset by emission increases in non-regulated countries, a phenomenon known as carbon leakage. To contest this claim, we employ a multi-regional Computable General Equilibrium model for Austria and its main trading partners to analyse the consequences for output, international trade and carbon emissions of different unilateral EU climate policy options as well as climate policy architectures which extend towards other Annex I countries. For Austria, we find that any of the unilateral policies affects exports and imports more strongly than domestic production, moreover imports decline more than exports, particularly in energy intensive sectors.

Please refer to: Daniela.Kletzan-Slamanig@wifo.ac.at

2011/338/S/WIFO project no: 1209

Medieninhaber (Verleger), Herausgeber und Hersteller: Österreichisches Institut für Wirtschaftsforschung,
1030 Wien, Arsenal, Objekt 20 • Tel. (+43 1) 798 26 01-0 • Fax (+43 1) 798 93 86 • http://www.wifo.ac.at/ • Verlags- und Herstellungsort: Wien

Verkaufspreis: 40,00 € • Kostenloser Download: http://www.wifo.ac.at/wwa/pubid/43107

Contents

Executive Summary

The Kyoto Protocol is the only international agreement that sets binding greenhouse gas (GHG) emissions targets for 37 industrialized countries and the European Union. These targets require an average of five per cent reduction in greenhouse gas emissions over the five-year period 2008 to 2012 against 1990 levels. However, COP 15 in Copenhagen as well as the subsequent meeting in Cancun failed to bring forward an international agreement on post-2012 climate policy. Nevertheless, the European Union is still willing to play a leading role, by expanding its emissions trading scheme (the EU ETS) beyond 2020, by switching the initial allocation mechanism from grandfathering to auctioning, and by expanding the sectoral coverage and stringency of reduction targets (European Commission, 2008; European Commission, 2009; UNFCCC, 2009). As a consequence of this unilateral commitment, energy intensive, trade exposed industries in the European economies might experience decreased international competitiveness and emissions reductions achieved in the European Union might be partially offset by emissions increases in non-regulated countries, a phenomenon known as carbon leakage.

To contest this claim, this paper aims first to analyze the consequences for sectoral production, international trade and carbon emissions of different forms of unilateral EU climate policy options as discussed after COP15 in Copenhagen, and to compare them to climate policy architectures which extend towards other Annex I countries. We do so at two scales: We focus first on the effects of such policies for a small open economy in the European Union which is strongly linked to other countries by international trade: Austria. Secondly, the paper investigates the economic and environmental ramifications on a global scale – the European Union, its main trading partners and major world regions – and to discuss further the relevance of carbon leakage in this context.

In order to answer the addressed issues we develop a multi-regional Computable General Equilibrium model for Austria and its main trading partners - leading to the selection of France, Germany, Italy, Poland, Russian Federations, China and USA. The remaining member states of the European Union 27 were aggregated to West EU27, Southeast EU27 and North EU27. Further regional aggregates are based on geographical similarity, their common role in climate negotiations as well as the affiliation to certain alliances, like the Commonwealth of Independent States (CIS). On the sectoral level, we differentiate 15 sectors according to their energy intensity and whether they are currently covered by the EU ETS. The model is calibrated for 2004 data based on GTAP 7 and is adjusted by factor productivity, capital and labor growth to the year 2020.

The model is then used to assess the carbon as well as economic impacts of two types of climate policy scenarios - a unilateral EU scenario group, and voluntary commitments by other countries in addition to the EU as stated in Appendix I to the Copenhagen Accord. The unilateral EU policies are reflecting the EU 20-20 targets (European Commission, 2008), and

are differentiated into targets for the energy intensive (ETS) and the non-energy intensive (NETS) sectors. Furthermore we distinguish between different methods of CO_2 permit allocation – grandfathering vs. auctioning, and consider one scenario with additional targets for households. For the Copenhagen Accord scenarios, we distinguish between an EU only scenario (with a 30% reduction target) on the one hand and a more comprehensive one with reduction targets for Annex I countries as stated under the Copenhagen Accord.

These climate policy scenarios are compared to a business as usual (BAU) scenario for 2020. Under BAU 2020, we find that Austrian GDP grows annually at 2.14% (on average for the period 2004 to 2020) and output grows by 29%, predominantly in the non-ETS sectors. Total imports increase by more than total exports, causing Austria's trade balance to improve by 0.5 MUSD (compared to 2004). Austria's main trading partners are to be found within the EU – mainly with neighboring countries Germany and Italy; outside the EU, the US and Russia are the strongest single country trading partners. Austria's CO_2 emissions according to the PBP (production based principle) increase by 15.6% from 2004 (79 Mt CO_2) to 2020 (91 Mt CO_2), with a considerably stronger increase by households than in production. We also find that more than 50% of Austria's CO_2 emissions linked to production activities both in 2004 and 2020 arise within ETS sectors even though the monetary output value of the NETS sectors is almost nine times higher than the ETS output.

The unilateral EU policies are reflecting the EU 20-20 targets which are implemented as emissions trading schemes for ETS and NETS sectors (with international trading in ETS sectors only). In case of auctioning, we find a reduction in Austrian GDP by 0.03 %-points relative to BAU, and Austrian exports and imports decline under auctioning by 2.4% and 1.3% respectively. Partial grandfathering of emission rights to iron and steel, cement and pulp and paper industries has similar effects on GDP but slightly reduces the impact on international trade to -2.3% for exports and -1.4% for imports. When the European Union extends its climate policy also to households but the other Annex I countries still do not reduce their emissions, effects on GDP, exports and imports are more than doubled. Even under the more stringent Copenhagen Accord scenarios either with a 30% target for the EU only or with voluntary reduction commitments also by other Annex I countries, the macroeconomic consequences for GDP remain modest. Moreover, under all scenarios Austrian international trade is affected more strongly than its domestic production.

At the sectoral level, Austrian production in ETS sectors is affected more strongly under all scenarios than NETS sectors. A similar pattern emerges for Austrian exports, with the ETS sectors paper and paper products and iron and steel affected most under all scenarios. Austrian imports are slightly less affected than its exports, and due to the higher openness to trade of the ETS sectors, ETS imports are affected more strongly than non-ETS imports. However, when the EU implements a unilateral policy, imports from all other regions increase relative to BAU, and particularly so in the ETS sector. In contrast, when other Annex I countries are faced with binding reduction targets too, Austrian imports from that regions are lower than under BAU.

Moreover, under all scenarios, Austrian carbon emissions are lower than in the base year

2004, ranging from -3.75% for the least stringent to -19.22% for the most comprehensive scenario. However, the net carbon balance (emission from export minus emissions from import) relative to 2004 and relative to BAU worsens in all scenarios. This implies that emissions from Austrian exports decline more than emissions from its imports, due to a shift of Austrian imports to less regulated and therefore less environmentally friendly production regions. Thus, domestic emission reductions are partly offset by increased emissions from imports.

At the global scale, effects on GDP depend on how universal emission targets are set, both in terms of sectoral and regional coverage. In all unilateral EU policy scenarios, hardly any GDP effects arise for regions and countries outside the EU. When all Annex I regions face constraints, also GDP growth rates of the US and Oceania decline. Regarding worldwide CO_2 emissions, the BAU scenario is characterized by 34.3 Gt CO_2, adjusted for the economic crisis, compared to 27.7 Gt CO_2 in 2004. This increase of 23.7% in global emissions is driven by economic growth, increases in global demand and adjusted for energy efficiency improvements.

When the EU introduces binding targets for ETS and NETS sectors as well as households but all other countries do not commit themselves, only 1/7th of global emissions are regulated (= EU 20-20 target), and hence carbon leakage is more than 75% - of each emission reduction unit achieved in the EU, three quarters are generated elsewhere in compensation. Contrary to the claim that grandfathering of emission rights shields vulnerable industry and reduces carbon leakage, we find that grandfathering leads only to a 1 %-point reduction in carbon leakage. The more stringent and comprehensive the climate policies become, the more declines the fraction of abated CO_2 emissions which is offset in non-abating regions. Even under the more stringent Copenhagen Accord targets for all Annex I countries, every emission reduction in the policy regions is counterbalanced by half an emission increase in non-policy region, since Annex I countries only comprise slightly more than 50% of global emissions (according to the PBP).

Based on this model analysis, several conclusions can be drawn for EU's climate policy. It is of utmost importance, that the EU continues to take the leading role in international climate policy architectures and that they convince other countries to do likewise. These emission targets are not only required for other highly developed countries but in particular for emerging economies, to avoid that imports of emission intensive commodities to the European Union increase. The necessity of emission targets for emerging and developing countries is intensified by the higher growth rates compared to highly developed countries. In regard to the specifics of EU climate policy, it is essential that carbon markets are not limited to firms but cover also households, or otherwise the incentive to import energy intensive commodities is intensified from the demand side. While the consequences of a stand-alone EU policy on energy-intensive trade-exposed sectors are evident in model results, grandfathering of emission rights leads only to a very modest protection and grandfathering is not able to fight carbon leakage, and hence cannot be regard as second-best approach to a more comprehensive, i.e. multilateral, climate policy approach.

1 Introduction

After COP15 in Copenhagen and the subsequent meeting in Cancun, the emergence of internationally binding climate policy agreements seems less and less likely. As a substitute, bottom-up architectures in which countries decide individually on emission reduction targets and abatement policies are gaining prominence. In this new architecture, the European Union is willing to play a leading role, by expanding its emissions trading scheme (the EU ETS) beyond 2020, by switching the initial allocation mechanism from grandfathering to auctioning, and by expanding the sectoral coverage and stringency of reduction targets (European Commission, 2008; European Commission, 2009; UNFCCC, 2009). Thus, the first aim of this paper is to discuss the consequences of different forms of unilateral EU climate policy options as discussed after COP15 in Copenhagen, and to compare them to climate policy architectures which extend towards other Annex I countries. In this analysis, we will focus on Austria, a small open economy in the European Union which is strongly linked to other countries by international trade, and discuss the consequences of these different policy options for Austria's production, exports and imports, and carbon emissions.

A serious consequence of climate policy architectures with a limited regional scope is reduced environmental effectiveness which has been termed carbon leakage. This phenomenon refers to a partial offset of domestically reduced GHG emissions in countries with less stringent environmental requirements as a result of a relocation of production to regions not facing mitigation policies. A related, but distinct, consequence of partial climate policy agreements is the claimed reduction of competitiveness of trade exposed, energy intensive sectors. The second purpose of the present paper is thus to identify the effects of different climate policy architectures differing in regional scope and stringency on carbon emissions and output in the European Union, its main trading partners and major world regions.

The present analysis seeks to delineate the economic and environmental consequences of different options for EU climate policy for the period after 2012, with a focus on Austria, EU member states and major world trade blocks. Thus, a multiregional Computable General Equilibrium model is developed for Austria, its main trading partners (Germany, Italy, France, Poland, Russia, USA, 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, and carbon dioxide emissions embodied in production and consumption processes are considered. The model is calibrated for 2004 data based on GTAP 7 and is adjusted by factor productivity, capital and labor growth to the year 2020. This model is then used to assess the carbon as well as economic impacts of different climate policies: (i) a continuation of the EU's ETS in the energy intensive sectors (-21% reduction target relative to 2005) combined with an additional cap for the European non-ETS sectors (-10% reduction target relative to 2005), with grandfathering for some sectors (ii) the same policy, but the initial allocation is full auctioning, (iii) with an additional emission cap for private households. In addition, two post-Copenhagen proposals will be considered: (iv) a more stringent target for the EU only as envisioned before the Copenhagen Conference (-30%) ,and (v) a global voluntary post-Kyoto agreement with differentiated reduction targets across further Annex I countries (USA, Russia, Australia, Japan etc.). The implications of the policies identified for exports, imports and carbon responsibilities can be regarded as an example for many other small open economies within the group of industrialized countries.

Methodologically, the present paper contributes to the literature on multi-sectoral multi-regional 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). The present model aims to reconcile the trade-off between broad sectoral coverage and detailed country representations, by contrasting the domestic and trade effects of the different climate policies for energy intensive sectors (i.e. the so-called ETS sectors since their emissions are capped by the EU's emissions trading scheme), as well as energy extensive sectors (i.e. the so-called non-ETS sectors) and private households. Apart from energy intensity, theses sectors and agents diverge also in their emission abatement options, since the ETS sectors can comply with their emission reduction requirement by buying permits abroad (at least for EU member states) while non-ETS sectors and households are much more forced to undertake abatement within the country. Moreover, within industrialized countries economic performance of non-ETS sectors is considerably higher than in ETS sectors, leading to significantly higher macroeconomic and trade effects when a policy covers non-ETS sectors and households too.

The structure of this paper is as follows. We start by a description of the structure of the CGE model, while data source used for the modeling and the results for the BAU (Business as usual) 2020 are found in section 3. Section 4 outlines the assumptions for the policy scenarios. Section 5 describes the model findings of the different policy scenarios, namely their impacts for Austria's output, exports and imports, as well as their respective carbon emissions. Section 6 addresses the problem of environmental effectiveness and carbon leakage from the EU perspective. Section 7 summarizes our results and concludes.

2 Model description

We develop a computable general equilibrium (CGE) model to analyze the economic impacts of carbon dioxide emission constraints taken unilaterally or globally, with a focus on the (feedback) effects via international trade and its respective net carbon flows. For that purpose, we construct a CGE model for the Austrian economy, its main trading partners, three regional aggregates for the other EU member states, and 10 larger world regions (see Table 1). The regional (dis)aggregation is based on the importance of individual countries or regions to the climate policy debate as well as on the basis of an analysis of Austria's main trading partners – leading to the selection of France, Germany, Italy, Poland, the Russian

Federation, China and the United States as countries modeled separately. The remaining member states of the European Union 27 were aggregated to West EU27, Southeast EU27 and North EU27. Further aggregates are based on geographical similarity, their common role in climate negotiations as well as the affiliation to certain alliances, like the Commonwealth of Independent States (CIS).

Table 1: Overview of regions

	Aggregated Region	**Model code**	**Comprising GTAP regions**
European Union			
1	Austria	AUT	Austria
2	Germany	GER	Germany
3	Italy	ITA	Italy
4	France	FRA	France
5	Poland	POL	Poland
6	Rest of West EU 27 + Switzerland	WEU	Belgium, Luxemburg, Netherlands, Portugal, Spain, Switzerland
7	Rest of South/-east EU 27	SEEU	Cyprus, Czech Republic, Greece, Hungary, Malta, Slovakia, Slovenia, Bulgaria, Romania
8	North EU 27	NEU	Denmark, Estonia, Finland, Ireland, Latvia, Lithuania, Norway, Sweden, UK
Eastern Europe			
9	Rest of Europe	ROE	Rest of EFTA (Liechtenstein, Iceland), Albania, Croatia, Moldova, Rest of Europe (Bosnia and Herzegovina, Gibraltar,…), Turkey
10	Russian Federation	RUS	Russian Federation
11	Rest of CIS	CIS	Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Rest of former Soviet Union, Ukraine
Asia		ASIA	
12	China	CHN	China
13	Rest of East Asia ("Asian Tigers")	EASI	Hong Kong, Japan, Korea, Taiwan, Rest of East Asia
14	Southeast Asia	SEASI	Cambodia, Indonesia, Lao People's Democratic Republic, Myanmar, Malaysia, Philippines, Singapore, Thailand, Vietnam, Rest of Southeast Asia
15	South Asia	SASI	Bangladesh, India, Pakistan, Sri Lanka, Rest of South Asia

Table 1 (cont.): Overview of regions

	Aggregated Region	Model code	Comprising GTAP regions
North America		NAM	
16	United States of America	USA	United States of America
17	Rest of North America	NAM	Canada, Mexico, Rest of North America
Latin America		LAM	
18	Latin America	LAM	Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela, Rest of South America, Costa Rica, Guatemala, Nicaragua, Panama, Rest of Central America, Caribbean
19	Oceania	OCEA	Australia, New Zealand, Rest of Oceania
Africa			
20	Middle East and North Africa	MENA	Egypt, Morocco, Tunisia, Iran, Rest of West Asia, Rest of North Africa
21	Sub Saharan Africa	SSA	Nigeria, Senegal, Rest of West Africa, Rest of Central Africa, Rest of South Central Africa, Ethiopia, Madagascar, Malawi, Mauritius, Mozambique, Tanzania, Uganda, Zambia, Zimbabwe, Rest of Eastern Africa, Botswana, South Africa, Rest of South African Customs Union

Source: *Based on GTAP (2007)*

On the sectoral level, we differentiate between 15 sectors according to their energy intensity (see Table 2). Sectors with high energy intensity (i.e. the sectors covered by the European Union's Emissions Trading Scheme; European Parliament, 2003; hence referred to as "ETS") are derived energy goods, namely refined oil and coke oven products (P_C), electricity including its distribution (ELY), the iron and steel industries (I_S), the manufacture of non-metallic mineral products like cement, lime and glass (NMM), and the manufacture of paper, pulp and paper products[1] (PPP). Sectors with lower energy intensity (i.e. the non-ETS sectors, NETS) include primary energy extraction coal (COA), oil (OIL) and natural gas (GAS), as well as the non-energy intensive tech industries (TECH) and food and textile industries (FTI), transport (TRN), agriculture (AGRI), other services and utilities (SERV), and capital goods (CGDS).

The remainder of this chapter gives a detailed description of the CGE model structure, which follows in its basic structure the GTAP-E model, as well as the parameters applied for the assessment of different policy scenarios (see chapter 4.5).

[1] According to the GTAP database, the sector paper, pulp and paper products (PPP) also comprises publishing activities, which are actually not included in the EU ETS, but due to lack of data we are not able to disentangle these items. However, publishing activities only amount for a small share in the whole PPP sector.

Table 2: Overview of sectors

Aggregated Sectors	Model Code	Comprising GTAP sectors
ETS sectors		
Refined oil products	P_C	Manufacture of coke oven- and refined oil products (32)
Electricity	ELY	Production, collection and distribution of electricity (43)
Iron and steel	I_S	manufacture of basic iron and steel and casting (35)
Cement, lime, glass etc.	NMM	manufacture of other non-metallic mineral products (34)
Paper, pulp and paper products	PPP	manufacture of paper products and publishing (31)
Non-ETS sectors		
Tech industries	TEC	Chemical industry (33), precious and non-ferrous metals (36), fabricated metal products (37), motor vehicles (38), transport equipment (39), communication equipment (40), machinery (41), other manufacturing & recycling (42)
Food and textile industries	FTI	Textiles (27), wearing apparel (28), leather (29), wood products (30), all food processing sectors (19-26)
Extraction*	EXT	Other mining(18), forestry(13) and fishing(14)
Coal*	COA	Coal Mining (15)
Crude Oil*	OIL	Oil extraction (16)
Natural Gas*	GAS	Natural Gas extraction (17), manufacture of gas, distribution, steam and hot water supply (44)
Transport	TRN	Water (49), air (50), road and rail transport (48)
Agriculture	AGRI	All agriculture sectors (1-12)
Other services and utilities	SERV	Water (45), construction (46), wholesale & retail sale & hotels & restaurant (47), post and telecom (51), financial services (52), insurance (53), real estate & other business (54), Recreational & service activities (55), public administration (56), dwellings (57)
Capital Goods	CGDS	Capital Goods

Source: *Based on GTAP (2007)*

Following the structure of agents used in the social accounting matrix generated by GTAP, the so-called regional household $RegHH_r$ represents total final demand in each of the 21 regions (denoted by r and s). This regional household provides the primary factors capital K_r, labor L_r and natural resources R_r (primary energy commodities, wood, fish) for the 15 sectors, and receives total income including various tax revenues. The regional household redistributes this stream of income between the private household PHH_r and the government GOV_r for private and public consumption, respectively. We model capital and labor as mobile between sectors within a region, but immobile among different regions. The following section provides a description of the production function modeling approach, while the subsequent sections deal with modeling international trade, final demand and carbon emissions and policy.

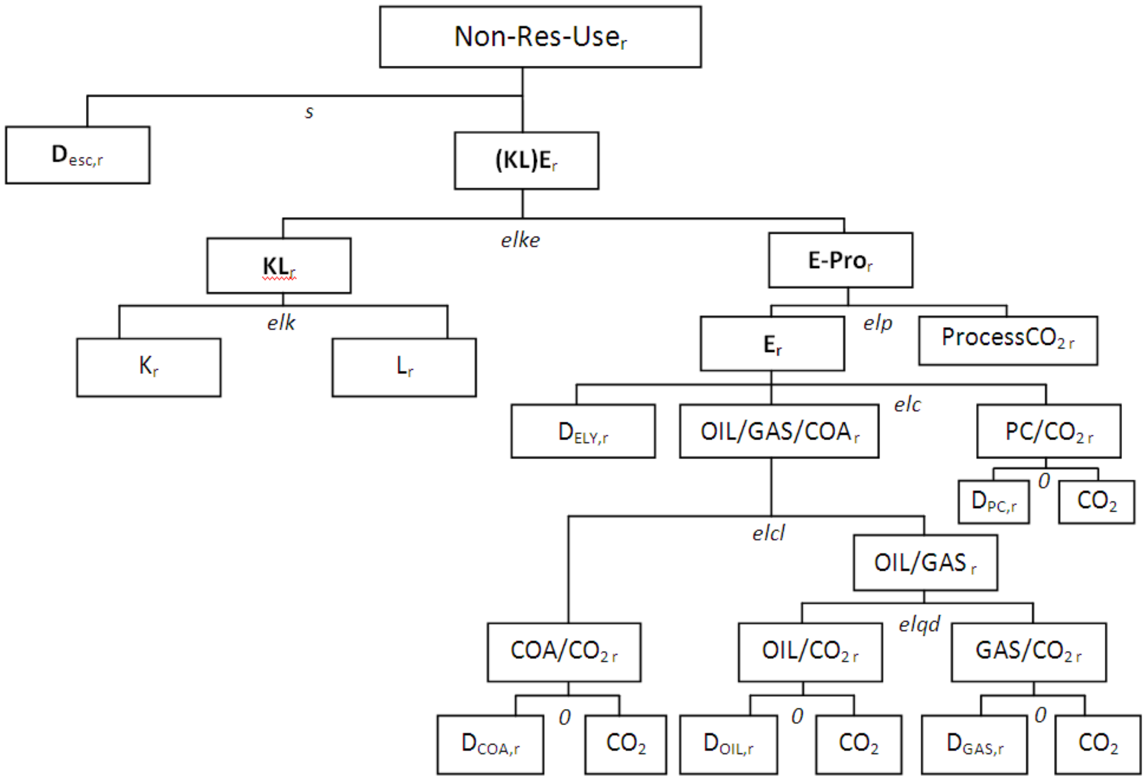
2.1 Production structure

Following the structure of the GTAP social accounting matrix, a specific resource input is used in the production of crude oil, natural gas and coal (i.e. in the extraction of primary energy) as well as in the extraction (EXT) sector (comprising forestry, fishing and other mining). Thus, there are two different groups of production activities which are represented by slightly different production functions in the model: the production of non-resource using commodities, and resource using (primary energy) extraction sectors. For both types of production, nested constant elasticity of substitution (CES) production functions are employed, to specify the substitution possibilities in domestic production between the primary inputs (capital, labor, and natural resources), intermediate energy and non-energy inputs as well as substitutability between energy commodities (primary and secondary).

Figure 1 illustrates the structure of the production of non-natural resource using commodities (Non-Res-Use_r). At the top level the intermediate inputs – the domestic supply $D_{esc,r}$ – from non-energy sectors are employed at a constant, but sectorally differentiated elasticity of substitution (CES) *s* with an aggregate of capital, labor and energy ((KL)E_r). At the second nesting level, a CES composite of capital and labor (KL_r) is again combined under a constant, but sectorally differentiated elasticity (*elke*) with an energy-composite. The composite of capital and labor (KL_r) itself is employed under the constant and sectorally differentiated elasticity *elk*. The energy-composite E_r consists of three main nesting stages. The first one represents a trade off at a constant elasticity *elc* between the domestic supplied secondary energy commodities electricity (ELY) $D_{ELY,r}$ and petroleum products (P_C) $D_{PC,r}$ with an aggregate of primary energy commodities (OIL/GAS/COA_r). At the subsequent level this primary energy-composite is comprised of a CES function (*elcl*) between the domestic supply of coal and another liquid/gaseous CES composite in which oil and gas are utilized under the constant elasticity *elqd*.

The main difference in the production structure of natural resource using extraction activities is that natural resources $NatRes_r$ are the crucial input in the production process. Accordingly, an additional nesting between natural resources and non-resource inputs is introduced at the top level, using a Leontief composite (i.e. a fixed input coefficient). For our analysis, the elasticities of substitution in the production processes (see Table 23 in the Appendix) are based on Okagawa and Ban (2008) as well as Beckman and Hertel (2009).

Figure 1: Nesting of production



2.2 International trade

A common assumption within multi-country CGE models which we also employ here is that goods produced in different regions are not perfectly substitutable. Therefore, trade in goods is described by bilateral trade relationships rather than by an integrated global market (Armington, 1969). An Armington aggregation activity $G_{es,r}$, depicted in Figure 2, corresponds to a CES composite (*tela*) of domestic $X_{es,r}$ and imported goods $IM_{es,s,r}$ as imperfect substitutes. The resulting Armington supply $G_{es,r}$ either enters the domestic supply $D_{es,r}$, satisfying final demand and intermediate demand in production activities, or is exported to other regions $EX_{es,s}$, entering again as an imperfect substitute into the formation of the trading partner's Armington supply. The associated *Armington elasticities (tela$_{es}$)*, different in each sector, are presented in Table 23 in the Appendix.[2]

[2] It is essential to note that, as is typical for CGE models, results are quite sensitive to the magnitude of trade elasticities applied in the model. Since the empirical basis for trade elasticities is comparatively narrow and hence extensive model validation is not possible (at least not within this project), results should be interpreted with caution.

Figure 2: Armington aggregation for country r

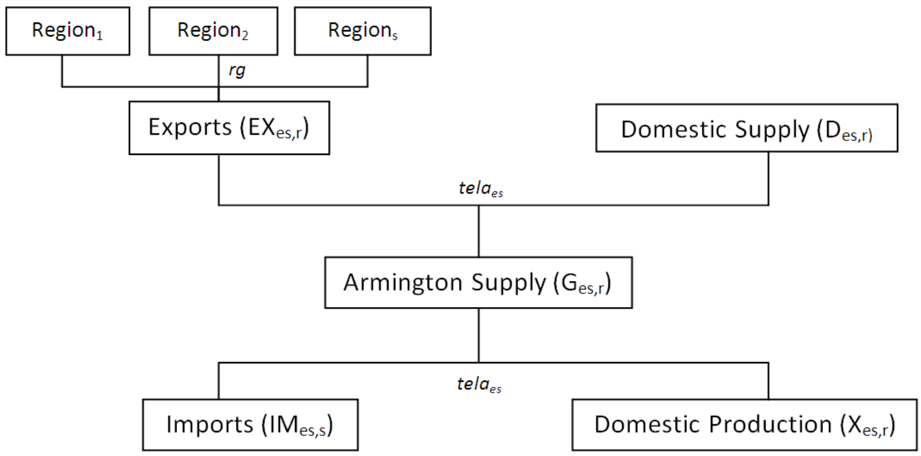
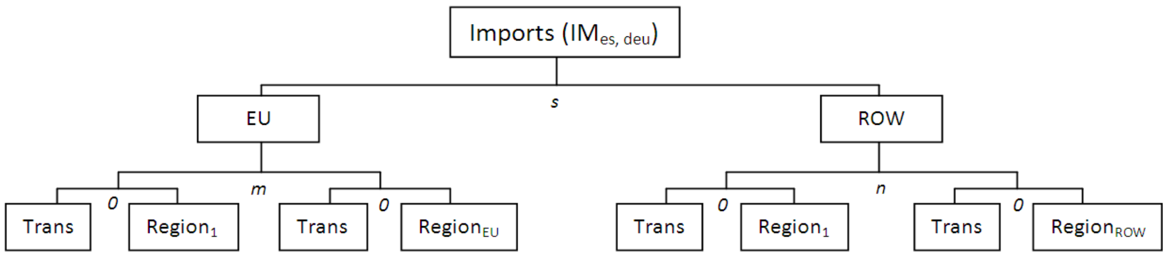


Figure 3: Import structure for EU countries and regions



The imports of any particular non-EU member region $IM_{es,row}$ consist of imports from all other model regions, traded off at a constant but sectorally differentiated elasticity of substitution s. The imports of any particular EU region $IM_{es,deu}$ consist of imports from either the European Union or the Rest of the World (ROW)[3]. 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 (*s*). Imports among EU (ROW) regions are exchanged with a constant elasticity of substitution (*n*). Every bilateral trade flow is linked to a distance dependent amount of transport service *Trans* – which is supplied by a global transport sector – by means of a Leontief production function with an elasticity of substitution equal to zero (see Figure 3). The international transport service activity *TRANS* is assumed to be a Cobb-Douglas composite of domestic

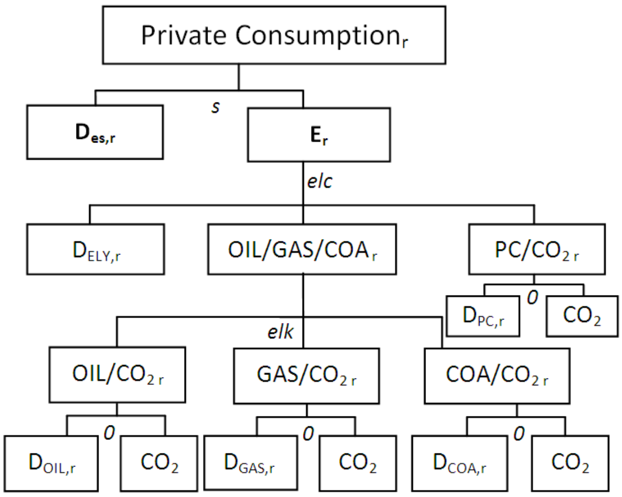
[3] By distinguishing between intra-EU trade and trade by the EU with the rest of the world, we try to rule out certain trade constellations which do not make perfect sense, e.g. electricity trade between continental Europe and Australia.

market activities (TRN) by each region transport goods (provided as an aggregate of water, air and land transport). Values for the elasticities applied in the modeling of imports are presented in Table 24 in the Appendix.

2.3 Final demand

Final demand in each region 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. Disposable income is composed of all factor income and tax revenues. Following the GTAP structure, we differentiate for a broad range of direct taxes (on capital, labor and resource inputs), indirect taxes (intermediate taxes, production taxes or subsidies, consumption taxes, export taxes or subsidies and import tariffs), and we add environmental levies in the form of CO_2 permits.

Figure 4: Final demand of private households for country r



Consumption of private households in each region, depicted in Figure 4, is characterized by a constant elasticity aggregate of a non-energy intermediate consumption bundle $D_{es,r}$ and an energy aggregate E_r (elasticity: *s*). The energy composite itself consists again of two nesting levels – a CES function with an elasticity *elc*, trading off secondary energy (ELY and P_C) with a primary energy fixed proportion composite (*elk*). Public consumption on the other hand is modeled as a Cobb Douglas aggregate of an intermediate consumption bundle $D_{es,r}$.

2.4 CO_2 emissions and carbon policies

As a prerequisite for our climate policy analysis, we model CO_2 emissions as both arising in production and consumption. As depicted in Figure 1, all fossil final energy intermediate inputs in a production process, irrespective at which nesting level, enter as fixed-coefficient composite of an imposed carbon tax linked with an elasticity of substitution equal to zero to the combustion of fossil fuels. This tax – in our case modeled as CO_2 emission permits which prices coincide with the carbon tax – reflects the carbon taxes a GHG emission abating region has to impose on fossil energy consumption in order to achieve an exogenously set reduction target. There is a unique carbon price in all ETS sectors, and within the EU we assume that the permit trading is allowed among all member states such that the carbon price is equalized across member states. Unique in the P_C and the NMM sectors is the inclusion of CO_2 emissions related with industrial processes $ProcessCO_{2\,r}$, which are nested in a Leontief style CES function together with the intermediate energy input composite E_r. The combustion of fossil fuels in the private households in each country is linked in the same way to the generation of CO_2 emissions as in the production sectors. However, we will cap households' emissions only in one climate policy scenario. Due to the absence of an EU-wide permit market for the non-ETS (and household) emission allowances, the price (which in that case can be best described as the carbon shadow price) is not equalized across member states. The revenues of the permit sales are collected by the regional households and redistributed to private households and the government.

Regarding carbon emission inventories, we differentiate between two accounting principles: the production based principle (PBP) and the consumption based principle (CBP). The production based emission inventory represents domestic emissions from economic production within a country and the emissions due to the combustion of fossil fuels in the private sector, while the consumption based approach represents the entity of a country's CO_2 emissions occurring from its economic consumption (final demand). This Consumption Based Principle (CBP) can 'be considered a trade-adjusted version of the production based inventory' (Peters and Hertwich, 2008a), by adding emissions from imports and subtracting emissions attributed to exports. Emissions from imports in a specific sector are thus calculated by taking the CO_2 intensities (CO_2 per unit of output) of the respective sectors in the respective countries, multiplied by import quantities, and aggregating across countries. Emissions from international transport are also differentiated by country of origin and by sector for all international transport flows.

3 Model calibration and baseline

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). Moreover, GTAP-E provides an extension on carbon emissions on a sectoral level for all countries included in GTAP. Despite the impressive scope of the database, it has some limitations (see, e.g., Peters and Hertwich, 2008a): Since data is contributed by GTAP partners voluntarily, some sources are not the most recent ones; more significant for our analysis, however, is the adjustment necessary to ensure internationally consistent input output and trade tables. Moreover, emissions included 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. In our work we had to correct for these shortcomings in the base data as noted in the subsequent sections.

3.1 Economic and emission data

The underlying data base for the analysis of the carbon content of Austria's international trade is GTAP Version 7 (GTAP, 2007), containing the most recent and consistent input output and foreign trade accounts for 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.

The remaining crucial data prerequisite for our analysis is the detailed knowledge of emissions originating from the production processes of various sectors in various countries and regions. Lee (2008) started a first attempt to generate CO_2 emissions data for the GTAP7 database. 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. Therefore, these GHG emissions from industrial processes are added to the two ETS sectors' (P_C and NMM) emissions balances, based on UNFCCC data (UNFCCC, 2011).[4]

[4] 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 (Umweltbundesamt, 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.

3.2 Baseline adjustment and calibration

In our CGE analysis, we examine Austria's international trade and its net carbon flows for the time horizon 2020. The year 2020 was chosen because it reflects the time frame for the EU's proposed 2020 targets – a 20% reduction of GHG emissions below 1990 levels (-30% if there is an international mitigation agreement negotiated with other developed countries) and a 20% share of renewable energies in EU gross final energy consumption until 2020 (European Commission, 2008). Also, many other officially announced reduction strategies by single countries, regions or by the IPCC (IPCC, 2007) refer to the year 2020. Accordingly, we construct a business as usual (BAU) scenario for 2020 and compare the impacts of the different policy scenarios to it.

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. In Poncet (2006) a comprehensive study of the long term growth prospects of the world economy was carried out, providing annual average growth rates for the time span 2005 to 2050 for multi-factor-productivity (MFP), the capital stock and the labor force. For the growth rates which were used to calibrate our model for the 2020 Business As Usual (BAU) scenario, see Table 25 in the Appendix. To account for improvements in energy efficiency over time, we introduce an exogenous autonomous energy efficiency improvement parameter AEEI. The AEEI is a heuristic measure for all non-price driven improvements in technology, which in turn reduces energy intensity. Following Böhringer (1999) or Burniaux et al. (1992) we assume a constant AEEI parameter and set it to 1% per annum. Considering the economic downturn, we decided to apply the annual growth rates by Poncet (2006), which were calculated prior to the advent of the financial crises, not for the whole 16 year time differential between 2004 and 2020, but only for a reduced ten year time span. This procedure should counterbalance the setbacks in growth prevailing from 2008 until 2010.

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.

3.3 The BAU 2020 scenario: Output, final demand and trade

The BAU 2020 scenario is characterized by an average annual GDP growth rate of 2.14% for Austria (over the period 2004 to 2020), resulting in a GDP of 410 billion USD in 2020 (due to the GTAP database, all GDP data is presented in USD, at 2004 real prices). In comparison, the average annual GDP growth rate in Austria for the time period 1999 to 2008 – therefore before the economic crisis – was 2.4%.

Table 3: Output, final demand and trade for Austria for 2004 and BAU-2020

	BASE 2004	BAU 2020	BAU 2020
	in MUSD		% change relative to 2004
GDP	292,312	409,988	+40.26%
Consumption	172,494	241,935	+40.26%
Investment	67,168	93,289	+38.89%
Government	54,933	77,048	+40.26%
Output	604,097	779,148	+28.98%
Imports	144,953	185,810	+28.19%
Exports	142,670	184,063	+29.01%
Trade balance	-2,283	-1,747	-23.46%

Under BAU assumptions, the total output of Austria's economy grows by a total of 29% over these 16 years (see Table 3). Comparing ETS sectors (ELY, I_S, P_C, NMM, PPP) with the rest of the economy – the NETS sectors –, we see that the rise in output is mainly induced by an increase in the NETS sectors by 29%, compared to +25% in the ETS sectors (see Table 4). Table 3 and Table 4 give further insights for the composition and trend of Austrian trade. Austria – being a net importer already in the base year 2004 – enhances its trade balance until the year 2020 by more than 0.5 MUSD. This arises from export volumes increasing relatively stronger than Austria's import volumes. For both exports and imports, trade in NETS (especially the TEC and SERV aggregates) is much larger in quantitative terms than in ETS. Moreover, trade in NETS sectors grows slightly more than in ETS sectors.

Table 4: BAU 2020 scenario for Austria (in million USD = MUSD)

	Output		Exports		Import	
	2004	**2020**	**2004**	**2020**	**2004**	**2020**
	in MUSD (real at 2004 prices)	% change relative to 2004	in MUSD (real at 2004 prices)	% change relative to 2004	in MUSD (real at 2004 prices)	% change relative to 2004
P_C	3,689	+19.45%	274	+21.04%	2,128	+18.99%
ELY	6,558	+18.16%	786	+10.11%	1,030	+38.85%
I_S	7,798	+21.48%	4,202	+21.67%	2,727	+19.07%
NMM	7,233	+22.56%	2,298	+24.50%	1,697	+22.52%
PPP	15,173	+30.76%	5,204	+33.98%	3,613	+23.91%
ETS total	**40,991**	**+24.52%**	**12,764**	**+26.47%**	**11,195**	**+22.96%**
COA	27	+13.99%	0	+70.37%	228	+4.33%
OIL	267	+13.99%	0	+57.14%	1,839	+6.04%
GAS	298	+13.99%	30	+18.72%	859	+8.48%
TEC	122,163	+25.19%	66,088	+24.68%	69,302	+28.99%
EXT	45,937	+34.01%	15,185	+32.05%	15,419	+43.65%
FTI	3,722	+13.95%	409	+23.72%	1,194	+0.91%
TRN	38,328	+32.35%	10,481	+33.95%	5,729	+28.25%
AGRI	5,833	+26.38%	710	+28.60%	2,067	+27.82%
SERV	279,362	+27.90%	29,941	+32.56%	34,445	+23.92%
CGDS	67,168	+38.89%				
non-ETS total	**563,106**	**+29.30%**	**122,846**	**+28.32%**	**131,080**	**+28.58%**
Total	**604,097**	**+28.98%**	**142,670**	**+29.01%**	**144,953**	**+28.19%**

Regarding the country composition of Austrian trade flows in the BAU-2020 scenario, there is clear evidence that its main trading partners, both in 2020 imports and exports, are found within the EU (see Table 5), in particular the neighboring countries Germany and Italy. 44% of all Austrian imports under BAU 2020 originate from these two countries, while 37% of Austria's exports are destined for Germany and Italy. The USA and the Russian Federation are its strongest single country trading partners outside the EU. The USA is particularly important as an export market, being the destination for 6% of Austrian exports under BAU, while China is the source of 3% of total Austrian NETS imports, worth 4.6 billion USD.

Table 5: BAU 2020 scenario for Austrian exports and imports to EU and Non-EU regions (in million USD = MUSD)

	Exports		**Imports**	
	EU	**NON-EU**	**EU**	**NON-EU**
P_C	288	43	2,417	115
ELY	799	66	1,391	39
I_S	4,107	1,005	3,023	223
NMM	1,670	1,191	1,909	169
PPP	5,357	1,616	4,245	232
ETS total	*12,222*	*3,921*	*12,987*	*779*
COA	0	0	219	10
OIL	0	0	2	1948
GAS	22	14	105	827
TEC	61135	21264	73725	15666
FTI	15800	4253	19140	3009
EXT	419	87	859	346
TRN	9,044	4,996	3,984	3,364
AGRI	709	204	2,020	622
SERV	25,975	13,715	28,614	14,071
NETS total	*113,104*	*44,533*	*128,667*	*39,861*
Total	**125,326**	**48,454**	**141,653**	**40,640**

3.4 CO_2 emissions in the BAU 2020 scenario

The analysis of CO_2 emissions embodied in international trade reveals that most industrialized countries (Annex I countries to the Kyoto Protocol) are net importers of CO_2 emissions while most less developed countries are net exporters (Peters and Hertwich, 2008a). Moreover, for many industrialized countries carbon emissions based on domestic production have indeed fallen, or risen at a much slower path, while emissions based on domestic consumption have tended to increase (Baiocchi and Minx, 2010; Helm et al., 2007; Weber and Matthews, 2007). While this trend is typical for almost all industrialized countries, this is particularly true for small open economies with a higher openness to trade like Austria (Munoz and Steininger, 2010; Giljum et al., 2008). Due to the global character of climate change, countries' environmental responsibilities have therefore to be extended beyond their geographical borders according to some scholars (e.g. Peters and Hertwich, 2008a). In the present paper, we therefore analyze how Austria's carbon emissions according to both the so-called Production-based Principle (PBP) and the Consumption-based Principle (CBP) respond to different climate policy scenarios. In particular, we investigate whether the PBP as the UNFCCC's prime indicator for national carbon accounts delivers similar results to the CBP.

For the PBP as an indicator of emissions embodied in domestic production, emissions from production as well as emissions from households (i.e. direct emissions caused by consumption of petroleum and fossil fuels) have to be considered. For the CBP, emissions embodied in exports are subtracted and emissions embodied in imports are added, giving an indicator of emissions embodied in domestic consumption (Peters and Hertwich, 2008b).

Austria's CO_2 emissions under the BAU assumptions are found to increase by 15.6% compared to 2004[5], calculated according to the PBP, corresponding to an absolute increase in Austria's production related and private household's emission by 13 Mt CO_2 from 79 Mt CO_2 in 2004 to 91 Mt CO_2 in 2020 (Table 6). Applying instead the CBP to Austria's CO_2 emissions, we find emissions to be 88 MT CO_2 in 2004 and to rise to 100 Mt CO_2 in 2020 (Table 6), and thus 10% higher than emissions according to the PBP (see CBP-to-PBP ratio). Due to the static nature of the model with exogenous productivity growth rates, the CBP to PBP ratios is changing only slightly from 2004 to 2020 (by -0.02%).

Table 6: CO_2 emissions for Austria according to the PBP and CBP for 2004 and BAU 2020

		BASE 2004	**BAU 2020**	**% Change**
		in Mt CO_2		2004-2020
1	Households	19	25	+32.4%
2	Output	60	67	+10.5%
3	**PBP (1 + 2)**	79	91	+15.6%
4	Imports	26	28	+7.3%
5	Exports	17	19	+13.9%
6	**Net carbon balance (4 -5)**	9.2	8.8	-5.0%
7	**CBP (3 + 6)**	88	100	+13.4%
8	**CBP/PBP ratio (7 ÷ 3)**	1.12	1.10	-0.02%
9	Austrian population (millions)	8.169	8.593	+5.2%
10	CO2 emissions per capita based on PBP	9.7	10.6	+9.8%
11	CO2 emissions per capita based on CBP	10.8	11.6	+7.8%

By comparing the increase in emissions from 2004 to 2020 (Table 6), we see an increase in output related CO_2 emissions by 11%, in households' emissions by 32%. This difference in CO_2 emissions growth in the BAU scenario results from stronger assumed efficiency gains for production sectors than for final demand. Furthermore, Table 6 indicates a slight decrease in emissions embodied in Austria's net carbon balance by 5%. However, when the

[5] While in the base year 2004 global CO_2 emissions were equal to 27,730 Mt CO_2, global CO_2 emissions in 2020 increase, according to our model, to a level of 34,305 Mt CO_2 which is roughly 24% higher than in the base year. Compared to the scenario families presented by the IPCC (Fisher et al., 2007) our model's BAU results would blend in among the medium sphere of the IPCC emission scenario range until 2020.

development of Austria's net carbon balance is compared to the development of its trade balance, one interesting finding arises: While Austria's trade deficit decreases (measured at 2004 real prices) by 24% (see Table 3), its counterpart in terms of CO_2 emissions (i.e. the net carbon balance) decreases only by 5%. This reflects on the one hand a global increase in energy efficiency in all production processes and on the other a shift in the composition of international trade from carbon intensive goods (ETS sectors) to low-carbon products (NETS sectors, e.g. TEC and SERV). In terms of per capita emissions, CBP lies above PBP emissions in both 2004 and 2020 but, due to a slight population growth, the respective emission growth rates are smaller than those for absolute emissions.

50% of Austria's CO_2 emissions linked to production activities both in 2004 and 2020 arise within ETS sectors – predominantly ELY – even though the monetary output value of the NETS sectors – mainly the TRN and SERV sectors – is more than ten times higher than the ETS output. This is caused by relatively high carbon intensities in the ETS industries. The same reasoning also holds for Austria's exports and imports, with trade in NETS sectors being much higher and emissions being much lower than in ETS sectors.

3.5 Definition of policy scenarios

Having described the structure of the CGE model, and before using the model to analyze different climate policy scenarios, we outline the settings of our two different scenario families – a unilateral EU scenario group, and a post-Kyoto agreement with a voluntary commitment by other countries in addition to the EU. The unilateral EU policies are reflecting the EU 20-20 targets (European Commission, 2008), and are differentiated into targets for the ETS and the NETS sectors and with additional targets for households. Furthermore we distinguish between different methods of CO_2 permit allocation – grandfathering vs. auctioning. For the post-Kyoto scenarios, we distinguish between an "EU alone" and a more comprehensive "Annex I" scenario with reduction targets for Annex I countries as stated under the Copenhagen Accord.

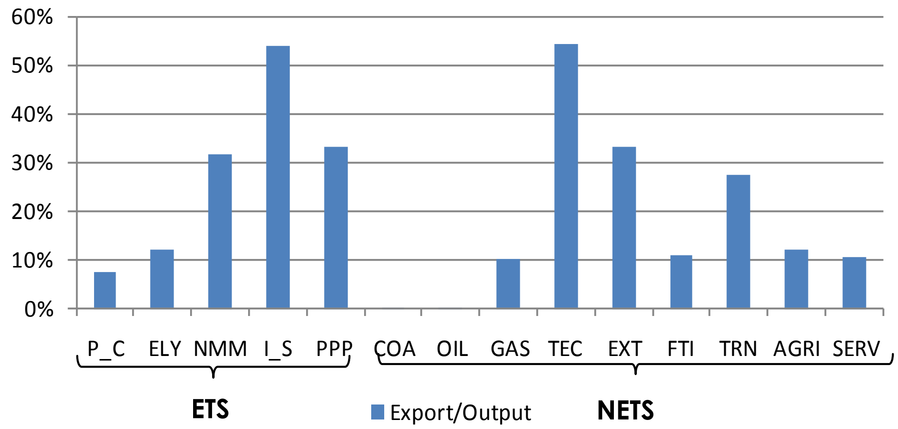
The first three scenarios in Table 8 refer to unilateral EU policies as set up by the EU 20-20 objectives: under EU_2020_g and EU_2020_a, a 21% reduction target relative to 2005 CO_2 emission levels is implemented in all sectors which are included in the current EU ETS, namely the iron and steel industries (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). In addition a 10% reduction target is introduced in the non-EU ETS sectors, again 2020 emission levels compared to 2005 emission levels. In both scenarios, the policies are implemented EU wide. The two scenarios however differ with respect to the allocation method of carbon permits: auctioning vs. grandfathering. For the grandfathering scenario EU_2020_g, we apply grandfathering rates as depicted in Table 7. These rates reflect the share of base year emission permits the ETS sectors at risk of carbon leakage will receive for free.

Table 7: Grandfathering shares for ETS sectors at risk of carbon leakage

Sector		Grandfathering
Refined oil products	P_C	0%
Electricity	ELY	0%
Iron and steel	I_S	67%
Cement, lime, glass etc.	NMM	67%
Paper, pulp and paper products	PPP	67%

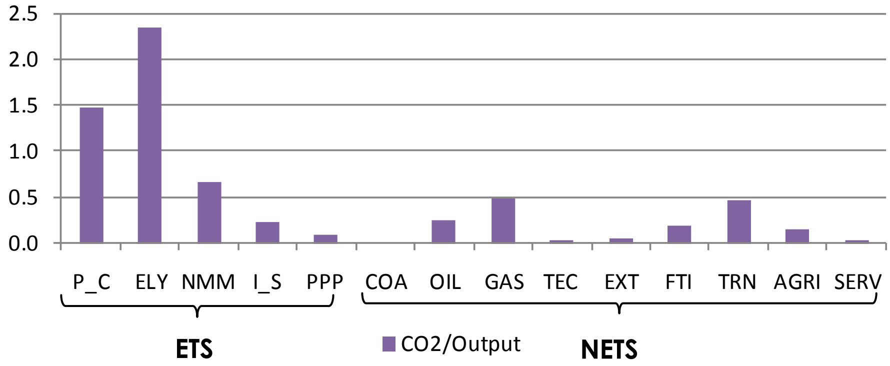
To define the sectoral vulnerability of certain Austrian ETS sectors we refer to their openness to trade as well as their carbon intensities. As visualized in Figure 5 the three ETS sectors NMM, I_S and PPP are characterized by an openness to trade ratio above 30%, and can therefore be considered as being at risk to carbon leakage. The other two ETS sectors P_C and ELY mainly produce for the domestic market and face therefore a smaller risk of carbon leakage. Even though their carbon intensities are substantially higher than those of the other three ETS sectors (see Figure 6), the physical constraints for example in the electricity sector make it unlikely that a substantial share of electricity for domestic consumption can be produced far away from the domestic market.

Figure 5: Non-EU Export to output ratio for Austrian ETS sectors



Considering NETS sectors, their risk to carbon leakage seems to be more or less negligible since they are confronted with relatively low carbon intensities and will therefore not be hit as hard by a carbon policy as certain ETS sectors.

Figure 6: Carbon intensity (t CO_2 per 1,000 USD) of ETS and NETS sectors



The third scenario of the EU-2020 scenario family finally introduces also a -10% cap (again 2020 emission levels compared to 2005 emission levels) for private households, while allocating the emission permits via auctioning. For the ETS sectors we allow for an emission trading scheme with emission permits traded among all EU countries (leading to a common carbon price across Europe for these sectors). For the non-ETS sectors and the private households we do have national targets implying a national shadow price of carbon emission in these sectors that differs across countries.

The two remaining scenarios cover policies in a post-Kyoto context. While scenario PK_EU refers to a scenario where the EU unilaterally increases its reduction effort to -30% until 2020 compared to 2005 GHG emission levels, other world regions are setting reduction objectives in scenario PK_Annex-I (PK_AI) as well, albeit at different stringency levels. This global post-Kyoto scenario presumes that CO_2 emission reduction targets have been set voluntarily by many industrialized countries within a global agreement established at the Copenhagen Conference of the UNFCCC. The reduction targets depicted in Table 8 refer to the most recent, official country specific information on envisioned GHG reduction after the COP15 in Copenhagen.

In order to implement the officially announced GHG emission reduction objectives in our model, we recalculate the emission targets relative to the base year 2004. For example the reduction goal in the EU_2020 scenarios, which was a homogenous -21% reduction for all EU member states, slightly changed by country according to the changes in observed CO_2 emissions between 2004 and 2005, resulting in regional diversified targets for the base year 2004. Moreover, since there are no specific reduction targets announced for the specific regional aggregation adopted within this paper, we generated reduction objectives for the respective regions by weighing the reduction targets for Annex I with the base year emissions for both Annex I and non-Annex I countries within the respective regions.[6] Note that Russia's

[6] For instance, the -12% CO_2 reduction goal for the rest of CIS results since only Belarus and the Ukraine have officially announced CO_2 objectives of -10% and -20%, respectively in a high abatement scenario prior to the Copenhagen climate talks, while emissions in all other CIS countries are allowed to grow without restrictions.

officially announced reduction target in a post-Kyoto agreement would amount to a 15% reduction vis a vis 1990 emissions in a high scenario. By changing the reference year from 1990 to 2004, the target changes from a reduction requirement to an increase in CO_2 emissions since Russia's 1990 CO_2 emissions were substantially higher than in 2004. The same rationale holds for the rest of the CIS region.

Table 8: GHG emission reduction targets for 2020 relative to 2004

Region	**EU 20 20 Targets**			**Copenhagen Accord Targets**	
	EU_2020 grand-fathering	**EU_2020 auctioning**	**EU_2020_HH auctioning incl. households**	**PK_EU (EU only)**	**PK_AI (all Annex I)**
Base year	2005	2005	2005	1990	1990
EU 27 + Switzerland, Norway	-21% in ETS sectors, -10% in non-ETS sectors		-21% in ETS sectors, -10% in non-ETS sectors and for households	-30% (ETS and non-ETS sectors)	
Rest of Europe					+51%
Russia					-15%
CIS					-12%
USA					-4%
North America					-3%
East Asia					-15%
Oceania					-11%
Non-Annex I (Latin America, China, South and Southeast Asia, Middle East and North Africa, South Africa)					

Source: *own calculation based on European Commission (2008); IPCC (2007); UNFCCC (2010)*

4 The economic and carbon effects of climate policy for Austria

4.1 The economic effects of the climate policy scenarios for Austria

Table 9 summarizes the economic effects of the different climate policy scenarios for Austria relative to the business as usual (BAU) scenario for the year 2020. In scenario EU_2020_HH, the emission reduction targets also apply to households. This leads to a reduction in Austrian GDP by 0.9% relative to BAU, and to a reduction in annual economic growth from 2.19 in BAU to 2.08. Austrian exports and imports decline by 3% and 2% respectively. When the European Union applies its climate policy only to ETS and NETS, but households do not need to reduce their emissions, effects on GDP, consumption, exports and imports are substantially weaker.

Considering GDP effects, both climate policy scenarios EU_2020 auctioning as well as EU_2020 grandfathering, lead to similar results. The post Copenhagen scenarios, PK_EU and PK_ AI, have by far the strongest impact regarding the economic consequences for GDP, exports, and imports.

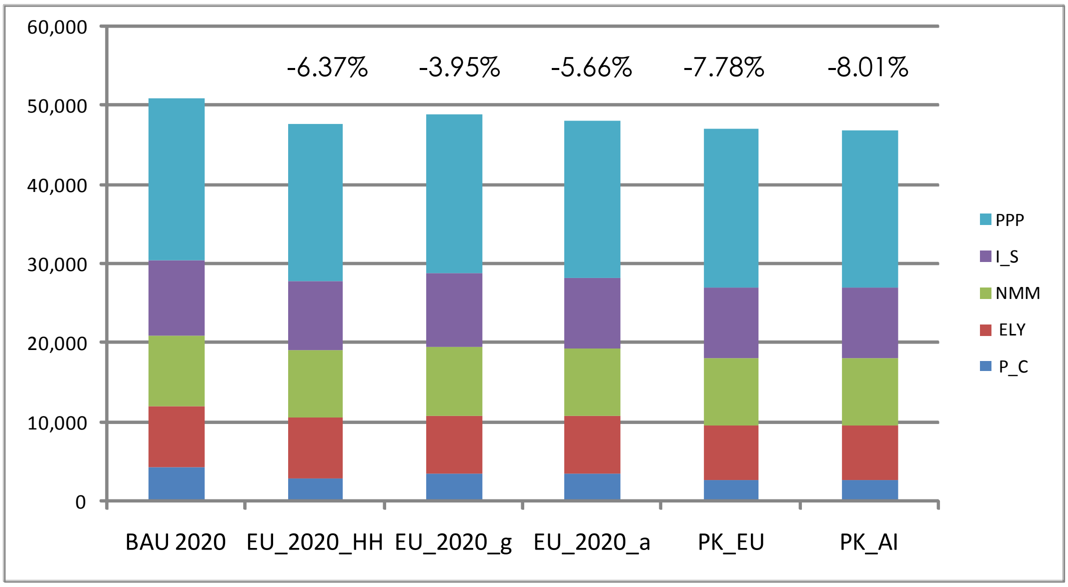
Table 9: GDP effects of climate policy scenarios for Austria relative to BAU 2020

	BAU 2020	**EU_2020 grandfathering**	**EU_2020 auctioning**	**EU_2020_HH auctioning**	**PK_EU**	**PK_AI**
		change relative to BAU 2020 (in %)				
Consumption	241,934	-0.35%	-0.35%	-0.91%	-1.68%	-1.42%
Investment	93,289	-0.34%	-0.35%	-0.88%	-1.64%	-1.38%
Government	77,047	-0.35%	-0.35%	-0.91%	-1.68%	-1.42%
Output	779,148	-1.26%	-1.42%	-2.02%	-3.40%	-3.48%
Exports	184,063	-2.33%	-2.40%	-3.44%	-5.24%	-5.53%
Imports	185,810	-1.36%	-1.34%	-1.84%	-3.38%	-3.03%
GDP	409,988	-0.35%	-0.35%	-0.91%	-1.68%	-1.42%
Annual GDP growth rate	2.14%	2.11%	2.11%	2.08%	2.03%	2.05%

4.2 Effects on Austrian output

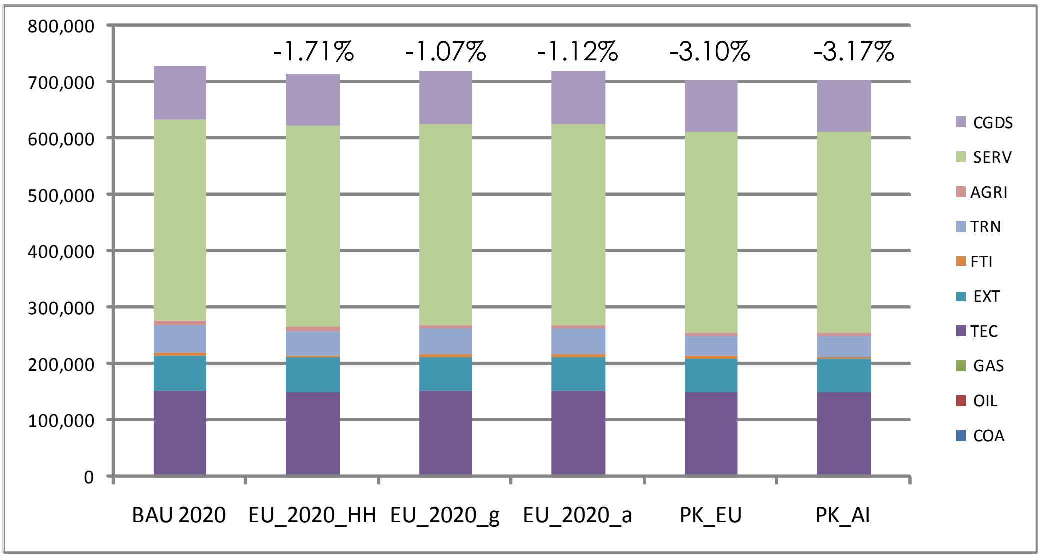
To get a better understanding of the economic effects, we will first discuss the sectoral composition which leads to the fall in GDP (see Table 10). Regardless of the scenario, effects on ETS sectors' output are more severe than on NETS sectors (see also Figure 7 and Figure 8), with the weakest effect for scenario EU_2020 with grandfathering and the strongest for scenario PK_AI (ranging from -4% to -8% relative to BAU 2020).

Figure 7: Sectoral output ETS sectors absolute (in 2004 MUSD) and relative to BAU 2020 (in %)



Thus, the more stringent the reduction target and the broader the regional coverage of climate policy, the more negative are the consequences for Austria's output. Since the ETS sectors only constitute approximately 7% of Austrian output in 2020, total effects range from -1.3% to -3.5% relative to BAU 2020.

Figure 8: Sectoral output NETS sectors absolute (in 2004 MUSD) and relative to BAU 2020 (in %)



Comparing columns EU_2020 auctioning to EU_2020 grandfathering, indicates that the consequences of the partially free initial allocation of permits has an effect on the three exempt sectors iron and steel (I_S), cement (NMM), and pulp and paper (PPP). But the remaining ETS face higher carbon prices which has slightly negative consequences for the petrochemical sector. When the emission reduction targets of NETS are also applied to households (EU_2020_HH), output in ETS and NETS falls slightly more, and this is partly due to lower final demand since consumption falls by -0.9% relative to BAU as compared to -0.4% under the EU_2020 scenarios with auctioning (see Table 9). In case of PK_EU, more stringent emission constraints lead to an even stronger decrease in aggregate ETS and NETS output in Austria. When also other countries agree to binding commitments as in PK_AI, the decrease in aggregate ETS and NETS output is even stronger but some sectors (such as NMM) gain relative to the unilateral policy.

Table 10: Effects of the scenarios on Austrian output by sector relative to BAU 2020

	BAU 2020	**EU_2020 grandfathering**	**EU_2020 auctioning**	**EU_2020_HH auctioning**	**PK_EU**	**PK_AI**
	in MUSD	change relative to BAU 2020 (in %)				
ETS sectors						
P_C	4,407	-21.09%	-21.03%	-31.21%	-36.2%	-36.23%
ELY	7,748	-4.56%	-4.88%	-0.95%	-12.0%	-12.98%
NMM	8,865	-1.47%	-4.97%	-5.44%	-4.78%	-3.22%
I_S	9,473	-1.50%	-5.48%	-6.59%	-4.95%	-6.23%
PPP	20,547	-2.24%	-3.04%	-3.38%	-2.65%	-2.96%
ETS total	***51,041***	***-3.95%***	***-5.66%***	***-6.37%***	***-7.78%***	***-8.01%***
Non-ETS sectors						
COA	31	0.00%	0.00%	0.00%	0.00%	0.00%
OIL	304	0.00%	0.00%	0.00%	0.00%	-32.69%
GAS	340	-0.01%	-0.01%	-36.90%	-33.2%	-95.62%
TEC	152,937	-1.00%	-1.12%	-1.72%	-1.63%	-2.07%
EXT	61,560	-1.33%	-1.22%	-1.60%	-3.51%	-3.80%
FTI	4,242	0.00%	0.00%	+0.01%	+0.01%	+0.01%
TRN	50,730	-8.89%	-9.35%	13.69%	-30.1%	-28.71%
AGRI	7,372	-3.07%	-3.02%	-4.18%	-8.92%	-9.22%
SERV	357,303	-0.12%	-0.12%	-0.18%	-0.09%	-0.17%
CGDS	93,289	-0.34%	-0.35%	-0.88%	-1.64%	-1.38%
non-ETS total	***728,107***	***-1.07%***	***-1.12%***	***-1.71%***	***-3.10%***	***-3.17%***
Output total	**779,148**	**-1.26%**	**-1.42%**	**-2.02%**	**-3.40%**	**-3.48%**

4.3 Effects on Austrian exports

Knowing from Table 9 that exports respond stronger to the policy scenarios than domestic production, we investigate the effects of the climate policy scenarios on Austrian exports in more detail.

Table 11: Effects of the scenarios on Austrian exports by sector relative to BAU 2020

	BAU 2020	EU_2020 grandfathering	EU_2020 auctioning	EU_2020_HH auctioning	PK_EU	PK_AI
	in MUSD	change relative to BAU 2020 (in %)				
ETS sectors						
P_C	332	-27.29%	-26.78%	-35.65%	-39.85%	-42.04%
ELY	865	+20.86%	+19.42%	+25.32%	+18.40%	+17.50%
NMM	2,861	-9.51%	-7.39%	-8.08%	-6.62%	-3.60%
I_S	5,112	-5.28%	-6.58%	-7.90%	-5.87%	-7.57%
PPP	6,973	-4.29%	-4.22%	-4.81%	-3.16%	-4.07%
ETS total	***16,142***	***-4.65%***	***-4.73%***	***-5.39%***	***-4.23%***	***-4.72%***
Non-ETS sectors						
COA	0	+2.21%	+3.60%	+11.72%	+10.46%	-6.39%
OIL	0	+8.33%	+8.48%	+27.27%	+37.53%	-52.69%
GAS	30	+13.03%	+13.30%	-38.18%	-34.06%	-99.02%
TEC	66,088	-1.24%	-1.36%	-2.10%	-1.71%	-2.42%
EXT	15,185	-2.06%	-1.90%	-2.62%	-4.79%	-5.54%
FTI	409	-0.50%	-0.40%	-0.71%	-1.06%	-1.93%
TRN	10,481	-11.29%	-11.92%	-17.30%	-38.92%	-36.22%
AGRI	710	-5.27%	-5.22%	-7.29%	-14.06%	-14.97%
SERV	29,941	-0.04%	+0.08%	+0.10%	+1.95%	1.27%
non-ETS total	***122,846***	***-1.95%***	***-2.02%***	***-3.00%***	***-4.57%***	***-4.99%***
Export TRANS	7,061	-4.42%	-4.60%	-7.10%	-16.97%	-15.15%
Export t total	**142,670**	**-2.33%**	**-2.40%**	**-3.44%**	**-5.24%**	**-5.53%**

As presented in Table 11, effects on exports show a similar pattern as Austrian production: negative effects on total exports double from the least stringent scenario EU_2020 with grandfathering to the most stringent scenario PK_AI, and are more than twice as strong for ETS sectors (in %) than for NETS sectors. Within ETS sectors, I_S and PPP are hit hardest by all policies in absolute terms, while within non-ETS sectors TRN (i.e. transport) is hit hardest (again in absolute terms). In contrast to the effects on Austrian production, where the free allocation of emission permits to certain ETS sectors decreases the climate policy impacts on these sectors' output by almost 2 percentage points (see Table 10), grandfathering has a much less positive effect on ETS exports in general and in particular on the three exempt sectors.

Figure 9: ETS sectors' exports – absolute (in 2004 MUSD) and relative (in %) to BAU 2020

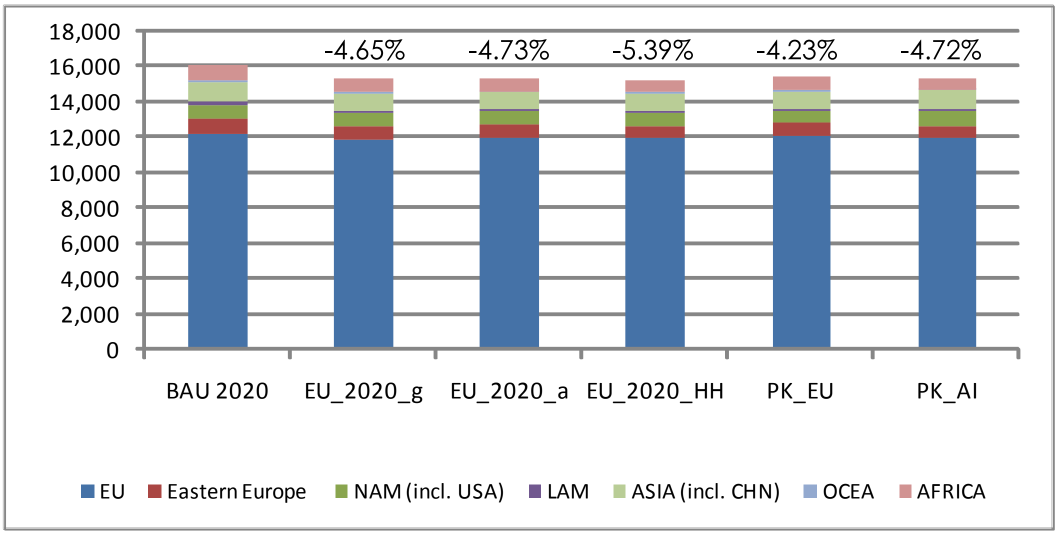
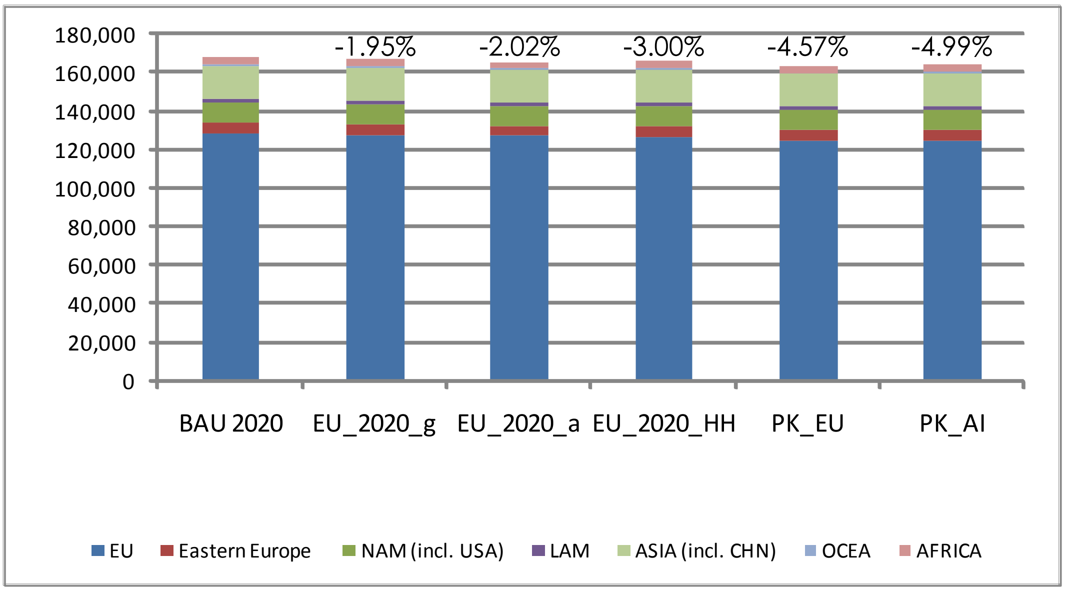


Figure 10: NETS sectors' exports – absolute (in 2004 MUSD) and relative (in %) to BAU 2020



Analyzing the world regions where Austrian exports are directed to (Figure 9, Figure 10 and Table 12), we find that the lion's share of Austria's exports is directed to other EU countries and that the effect on these exports is negligible (ranging from -1.1% for PK_EU to -2.7% for EU_2020 grandfathering, relative to BAU 2020). In contrast, unilateral EU climate policy has consequences for Europe's competitiveness and hence Austria's ETS exports to North America, Eastern Europe and Asia fall in the range of -10% to almost -20% (a similar, but less pronounced effect is visible for NETS exports). However, under the PK_AI (all Annex I) scenario we observe an increase of ETS sectors' exports to North America and Asia compared to the unilateral EU policies, since the US and other Annex I countries are required to limit their emissions, too. Furthermore, the free allocation of emission permits to certain ETS sectors seems to be beneficial for Austria's ETS exports to non-EU countries, which decrease under EU_2020 with grandfathering by less compared to BAU than under EU_2020 with auctioning.

Table 12: Effects of the scenarios on Austrian exports by region relative to BAU 2020

	BAU 2020	**EU_2020 grandfathering**	**EU_2020 auctioning**	**EU_2020_HH auctioning**	**PK_EU**	**PK_AI**
	in 2004 MUSD	change relative to BAU 2020 (in %)				
ETS sectors						
EU	12,222	-2.7%	-1.6%	-2.1%	-1.1%	-1.8%
Eastern Europe	815	-8.8%	-11.2%	-13.0%	-10.9%	-17.6%
NAM (incl. USA)	822	-9.9%	-14.6%	-15.1%	-12.9%	-2.6%
LAM	168	-15.9%	-18.8%	-19.4%	-17.3%	-18.8%
ASIA (incl. CHN)	1,136	-12.4%	-17.2%	-17.5%	-15.9%	-9.2%
OCEANIA	106	-8.7%	-11.7%	-11.6%	-9.7%	-17.7%
AFRICA	873	-11.3%	-13.9%	-16.6%	-14.8%	-25.6%
ETS total	**16,142**	**-4.7%**	**-4.7%**	**-5.4%**	**-4.2%**	**-4.7%**
Non-ETS sectors						
EU	113,104	-1.5%	-1.6%	-2.3%	-4.0%	-3.7%
Eastern Europe	8,635	-3.4%	-3.1%	-5.3%	-5.1%	-11.0%
NAM (incl. USA)	10,455	-2.8%	-2.7%	-4.1%	-5.7%	-4.6%
LAM	2,249	-3.5%	-3.5%	-5.4%	-7.4%	-9.0%
ASIA (incl. CHN)	15,159	-2.2%	-2.1%	-3.2%	-4.9%	-3.2%
OCEANIA	1,377	-5.9%	-5.9%	-8.3%	-12.6%	-10.3%
AFRICA	6,659	-5.3%	-5.1%	-8.5%	-8.8%	-21.3%
Non-ETS total	**157,638**	**-2.0%**	**-2.0%**	**-3.0%**	**-4.6%**	**-5.0%**

Thus, while unilateral EU climate policy has an effect on exports to other EU countries due to declining final demand there, there is a considerably stronger impact for Austria's export to non-EU countries. Table 13 gives a more comprehensive sectoral representation of effects for Austrian exports to non-EU regions.

Table 13: Effects of the scenarios on Austrian exports to non-EU by sector relative to BAU 2020

	BAU 2020	EU_2020 grandfathering	EU_2020 auctioning	EU_2020_HH auctioning	PK_EU	PK_AI
	in MUSD	change relative to BAU 2020 (in %)				
ETS sectors						
P_C	43	-33.84%	-32.43%	-35.57%	-38.57%	-46.02%
ELY	66	-71.33%	-69.21%	-71.37%	-73.67%	-69.68%
I_S	1,005	-11.82%	-18.03%	-20.12%	-18.56%	-20.07%
NMM	1,191	-13.44%	-19.91%	-20.82%	-19.59%	-10.16%
PPP	1,616	-5.36%	-5.83%	-6.50%	-3.59%	-9.61%
ETS total	**3,921**	**-10.90%**	**-14.60%**	**-15.76%**	**-13.85%**	**-13.87%**
NETS sectors						
COA	0	-	-	-	-	-
OIL	0	-	-	-	-	-
GAS	14	+84.15%	+84.68%	+18.21%	+10.86%	-99.01%
TEC	21,264	-2.14%	-2.10%	-3.48%	-2.81%	-5.52%
FTI	4,253	-3.54%	-2.94%	-4.91%	-6.87%	-11.40%
EXT	87	+1.55%	+3.60%	+4.17%	+5.00%	+1.43%
TRN	4,996	-20.32%	-20.69%	-30.71%	-50.92%	-45.28%
AGRI	204	-7.88%	-7.44%	-11.59%	-18.12%	-24.09%
SERV	13,715	+1.43%	+1.75%	+2.33%	+5.48%	+2.21%
NETS total	**44,533**	**-10.90%**	**-14.60%**	**-15.76%**	**-13.85%**	**-13.87%**
Total	48,454	-3.83%	-4.00%	-5.77%	-6.72%	-8.72%

4.4 Effects on Austrian imports

With respect to imports, we find that the impacts of all policy scenarios on Austrian imports are similar to the effects on domestic production: ETS sectors are hit harder than NETS sectors (see Table 14). However, imports are declining less (in relative terms) under all climate policy scenarios than exports, which might be the consequences of substitution of domestic production by imports, particularly in energy intensive sectors.

One explanation for the higher impact on ETS sectors relative to non-ETS sectors is the higher openness to trade in ETS sectors as well as the higher carbon intensity of these sectors which lead to higher effects on relative prices compared to the non-ETS sectors. Furthermore, as Austria's main trading partner – the rest of the EU – is subject to CO_2 emission caps as well, the import prices for ETS products from these countries tend to increase as well, due to the pricing of carbon emissions. Within ETS, imports of ELY decline sharpest under all climate policy scenarios. This is due the effect, that the lion's share of ELY is imported from the EU, which is subject to CO_2 emission caps as well. Among non-ETS sectors, the imports of COA (coal) and GAS decline sharpest. This is the result of a relatively strong decline of the domestic P_C (the energy transformation sector, e.g. refineries) output (see Table 10), triggered by less secondary fossil energy demand due to autonomous energy efficiency improvements. Therefore the decline in P_C output, ranging from -21% to -36% depending on the strictness of the climate policy scenarios, is proportionate to the decrease in primary energy imports. Associated with the decline in total imports is a decreasing demand for transport services from the international transport market (see line "Import TMG" in Table 14).

Table 14: Effects of climate policy scenarios on Austrian imports by sector relative to BAU 2020

	BAU 2020	**EU_2020 grandfathering**	**EU_2020 auctioning**	**EU_2020_HH auctioning**	**PK_EU**	**PK_AI**
	in MUSD	change relative to BAU 2020 (in %)				
ETS sectors						
P_C	2,532	-6.71%	-7.52%	-19.54%	-23.13%	-16.96%
ELY	1,430	-30.19%	-29.68%	-26.86%	-40.05%	-42.07%
NMM	2,079	-8.65%	-2.08%	-2.40%	-5.49%	-7.17%
I_S	3,247	-5.01%	-2.35%	-3.03%	-4.82%	-4.88%
PPP	4,478	-0.95%	+0.17%	+0.21%	-3.09%	-2.98%
ETS total	**13,765**	**-7.17%**	**-5.28%**	**-7.39%**	**-11.39%**	**-10.70%**
Non-ETS sectors						
COA	238	-19.65%	-19.51%	-25.22%	-31.81%	-32.90%
OIL	1,950	-23.03%	-23.01%	-34.43%	-40.23%	-34.99%
GAS	932	-24.27%	-24.59%	-27.60%	-27.93%	-1.38%
TEC	89,390	-0.75%	-0.90%	-1.25%	-2.87%	-2.87%
EXT	22,149	-0.12%	-0.18%	-0.15%	-1.34%	-1.44%
FTI	1,205	-0.05%	-0.39%	-0.40%	-0.60%	-0.32%
TRN	7,347	+1.42%	+1.58%	+2.66%	+12.45%	+8.94%
AGRI	2,642	+0.78%	+0.84%	+1.17%	+2.25%	+2.10%
SERV	42,685	-0.42%	-0.65%	-0.94%	-3.60%	-2.46%
non-ETS total	**168,538**	**-0.88%**	**-1.02%**	**-1.37%**	**-2.70%**	**-2.37%**
Import TMG	3,507	-1.83%	-1.61%	-2.34%	-4.36%	-4.59%
Imports total	185,810	-1.36%	-1.34%	-1.84%	-3.38%	-3.03%

Austrian imports by region are summarized in Table 15 for ETS (Figure 11) and for non-ETS sectors (Figure 12). As for exports, the main trading partner of Austria is the European Union (which is subject to emission constraints as well), and hence the effects are strongest, and roughly proportionally increasing with the strength of the policy, in absolute terms for imports

ETCLIP

from other European countries. For other trading partners, there is however a remarkable difference across scenarios: for example imports from NAM and OCEANIA are subject to a steep decline (more pronounced for ETS than for NETS sectors) by comparing scenarios PK_EU and PK_AI, since the US and other Annex I countries are required to limit their emissions, too.

Figure 11: ETS imports – absolute (in 2004 MUSD) and relative (in %) to BAU 2020

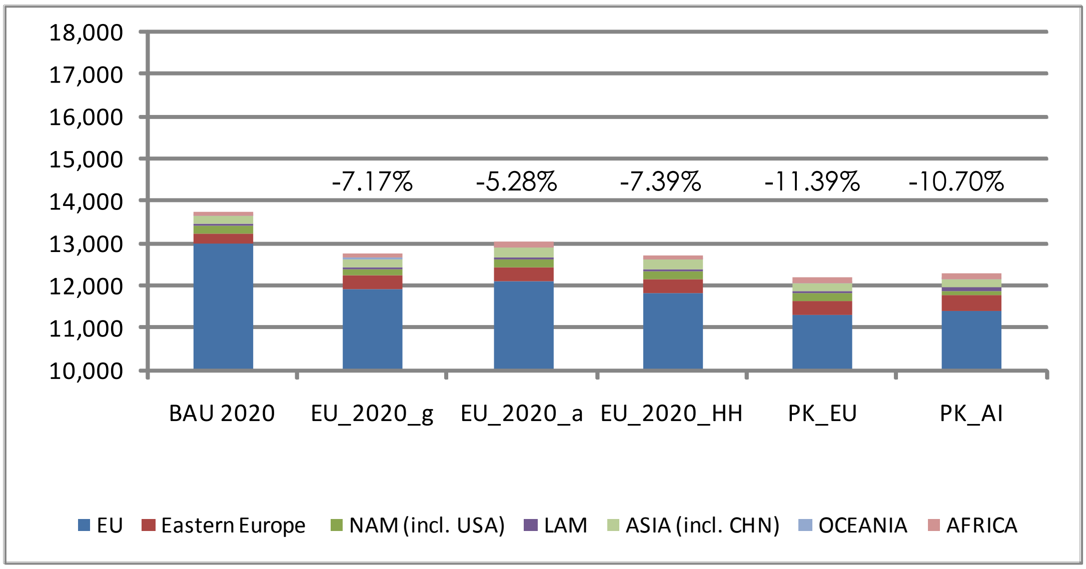
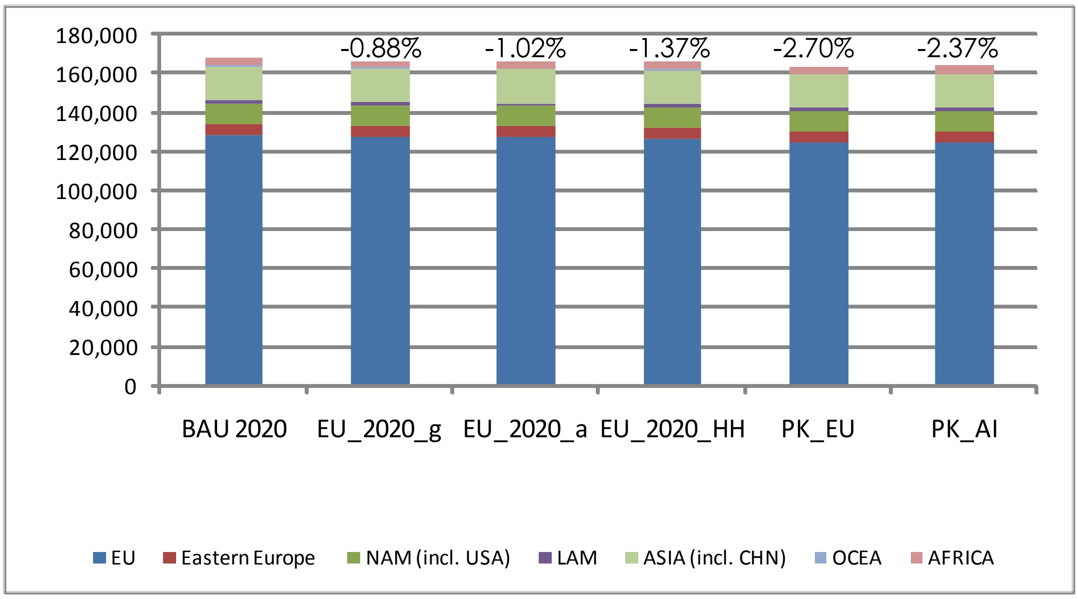


Figure 12: NETS imports – absolute (in 2004 MUSD) and relative (in %) to BAU 2020



Focusing on the effects of grandfathering emission permits to certain ETS sectors, it can be seen that such a (partial) free allocation scheme reduces the impacts on Austrian ETS sectors' international competitiveness. Austria's ETS imports from other EU member countries decrease by more (and its imports from non-EU countries increase by less) in EU_2020_g than under EU_2020_a. The lower ETS imports under the grandfathering scenario are opposed by relatively high NETS imports, which in contrast decrease by more under EU_2020 with auctioning than EU_2020 with free allocation of carbon permits.

Table 15: Effects of the scenarios on Austrian imports by region relative to BAU 2020

	BAU 2020	EU_2020 grandfathering	EU_2020 auctioning	EU_2020_HH auctioning	PK_EU	PK_ AI
	in MUSD	change relative to BAU 2020 (in %)				
ETS sectors						
EU	12,987	-8.1%	-6.6%	-8.8%	-12.7%	-12.1%
Eastern Europe	273	+13.1%	+20.2%	+21.9%	+15.9%	+27.5%
NAM (incl. USA)	151	+7.3%	+14.1%	+11.2%	+4.9%	-15.1%
LAM	61	+0.5%	+4.5%	+3.2%	-3.1%	+3.7%
ASIA (incl. CHN)	176	+7.3%	+17.2%	+15.2%	+10.7%	+6.0%
OCEANIA	6	-2.9%	+0.8%	-1.0%	-7.8%	-18.1%
AFRICA	112	+7.7%	+13.4%	+14.2%	+8.9%	+26.3%
ETS total	**13,765**	**-7.2%**	**-5.3%**	**-7.4%**	**-11.4%**	**-10.7%**
Non-ETS sectors						
EU	128,667	-0.8%	-0.8%	-1.3%	-2.8%	-2.5%
Eastern Europe	6,215	-3.2%	-14.9%	-5.1%	-4.7%	-8.3%
NAM (incl. USA)	10,150	-0.6%	-0.9%	-0.8%	-2.4%	-2.8%
LAM	1,760	+1.4%	+1.1%	+2.9%	+4.5%	+15.3%
ASIA (incl. CHN)	17,269	+0.5%	+0.2%	+0.7%	-0.2%	-1.4%
OCEANIA	444	+2.2%	+1.9%	+3.2%	+5.1%	-5.5%
AFRICA	4,022	-6.2%	-26.2%	-8.6%	-9.0%	+3.1%
Non-ETS total	**168,528**	**-0.8%**	**-1.8%**	**-1.3%**	**-2.7%**	**-2.3%**
Import total	185 810	-1.36%	-1.34%	-1.84%	-3.38%	-3.03%

Furthermore, we can learn from Table 15 that in scenarios where only the EU is taking climate policy measures (all scenarios except of PK_AI), ETS as well as NETS imports from other EU member states are decreasing while they are generally increasing from non-EU countries. Focusing specifically on imports from non-EU regions, Table 16 shows the sectoral distribution of changes in imports from countries other than EU member states.

Table 16: Effects of the scenarios on Austrian imports from non-EU regions by sector relative to BAU 2020

	BAU 2020	EU_2020 grandfathering	EU_2020 auctioning	EU_2020_HH auctioning	PK_EU	PK_AI
	in MUSD	change relative to BAU 2020 (in %)				
ETS sectors						
P_C	115	+27.80%	+24.68%	+15.58%	+7.37%	+18.74%
ELY	39	-30.64%	-30.11%	-27.41%	-40.54%	-41.99%
I_S	223	+14.19%	+25.39%	+29.19%	+24.83%	+36.76%
NMM	169	+9.42%	+27.60%	+27.83%	+24.34%	+6.42%
PPP	232	+0.38%	+1.97%	+0.75%	-5.14%	-2.02%
ETS total	***779***	***+8.80%***	***+16.01%***	***+15.57%***	***+9.94%***	***+12.00%***
NETS sectors						
COA	10	0.00%	0.00%	0.00%	0.00%	0.00%
OIL	1,948	-23.05%	-99.91%	-34.45%	-40.25%	-35.01%
GAS	827	-36.73%	-37.03%	-57.11%	-44.50%	-2.84%
TEC	15,666	+0.48%	+0.35%	+0.71%	-1.32%	-4.14%
FTI	3,009	-0.17%	-0.82%	-0.32%	-2.54%	-1.95%
EXT	346	-1.97%	-3.60%	-4.46%	-5.61%	-5.72%
TRN	3,364	+15.28%	+15.27%	+25.94%	+46.34%	+39.90%
AGRI	622	+2.81%	+2.37%	+4.42%	+5.97%	+6.24%
SERV	14,071	-1.73%	-2.08%	-2.91%	-6.96%	-4.43%
NETS total	***39,861***	***+8.80%***	***+16.01%***	***+15.57%***	***+9.94%***	***+12.00%***
Total	40,640	-0.82%	-4.61%	-1.10%	-1.87%	-1.43%

4.5 The carbon effects of the policy scenarios for Austria

As a basis to set reduction targets for the individual participants under the Kyoto Protocol and to monitor their progress on greenhouse gas emission reduction, emission accounting systems have been established based on the so called 'Production-Based Principle' (PBP) in which environmental responsibilities are restricted to geographical borders. This indicator thus captures only the carbon impacts linked to the domestic production of goods (for own consumption and exports). Actual emission responsibility by consumption (the Consumption-Based Principle, CBP) may deviate from the picture drawn by the former accounting system. A serious consequence of the PBP accounting principle is that unilateral emission reduction policies like the European Union's emissions trading scheme may lead to carbon leakage, i.e. emissions are "exported" to less regulated countries and commodities are re-imported but the embodied emissions are not accounted for in the policy implementing country.

While the question of carbon leakage will be addressed in more detail in the following section, in this section we investigate the claim that more stringent EU climate policy may lead to lower emissions from domestic production but to higher emissions from consumption.

Austria's carbon emissions resulting in the different scenarios are summarized in Table 17. Emissions fall under all scenarios both according to the PBP and CBP with emissions (according to CBP) under PK_EU almost reduced by one third compared to BAU 2020. By applying the NETS 2020 targets also to households, we reach similar emission reductions as under the Copenhagen targets (PK_EU and PK_AI). In contrast, EU_2020 grandfathering and auctioning – i.e. applying the EU2020 objectives, solely for production sectors (comprising of manufacturing and (secondary) energy generation) – have a substantially lower impact in terms of emission reduction. Thus, restricting all economic activities in an economy is important or otherwise a stabilization of emissions is hard to achieve at the national scale.

Table 17: CO_2 effects (in Mt CO_2) according to the PBP and CBP of the scenarios

	BASE 2004	BAU 2020	EU_2020 grand-fathering	EU_2020 auctioning	EU_2020_ HH auctioning	PK_EU	PK_AI
	Mt CO_2	In % changes relative to BASE 2004					
PrivHH	19	+32.42%	+34.88%	+34.85%	+1.35%	+33.92%	+43.95%
Output	60.41	+10.3%	-15.7%	-16.2%	-21.3%	-35.6%	-35.6%
Imports	26.09	+7.2%	-9.1%	-8.2%	-9.3%	-10.9%	-9.5%
Exports	16.87	+13.9%	-12.0%	-12.3%	-18.7%	-35.0%	-34.3%
PBP	79.04	+15.55%	-3.75%	-4.16%	-15.93%	-19.22%	-16.82%
CBP	88.25	+13.41%	-3.75%	-3.80%	-13.46%	-13.73%	-11.31%
Net Carbon Balance	9.22	8.76	8.87	9.15	9.93	12.29	12.52
CBP to PBP ratio	1.12	1.10	1.12	1.12	1.15	1.19	1.19
PBP per capita	9.7	10.6	8.9	8.8	7.7	7.4	7.7
CBP per capita	10.8	11.5	9.7	9.7	8.7	8.7	9.0

Relative to Base 2004, the net carbon balance (defined as CO_2 incorporated in imports minus CO_2 incorporated in exports) worsens for PK_EU, PK_AI and EU_2020_HH, but improves in the two other scenarios. For the former three scenarios this implies that emissions from exports decline relative to emissions from imports due to decreasing domestic output in combination with improved energy efficiency in domestic production as well as a shift to imports from less regulated and therefore less environmentally friendly producing regions.

While CO_2 emissions caused by Austrian exports drop by 12% to 35% (compared to BASE 2004) depending on the scenario, CO_2 emissions caused by Austrian imports fall considerably less (see Table 17): A shift in the sectoral composition of imports to more non-ETS and less ETS commodities leaves the imported CO_2 emissions at levels only about 9% to 11% below BASE 2004 levels.

Table 18 illustrates that emissions embodied in imported non-ETS commodities hardly change in the policy scenarios compared to BAU, while the CO_2 emissions linked to ETS imports decrease substantially (by more than 20% in EU_2020 scenarios relative to BAU). This is due to generally reduced ETS imports and the, due to environmental regulations, lower CO_2 intensities in ETS production of Austria's main trading partners in the EU. Moving from the EU_2020 scenarios to more comprehensive climate policy scenarios like PK_AI, Austria's ETS import related CO_2 emissions tend to decrease even stronger, since also CO_2 intensities in the ETS production processes outside the EU are reduced, caused by putting a price tag on CO_2 emissions. The reason why the emissions embodied in non-ETS imports hardly change compared to BAU even under the most stringent scenarios, is that a higher CO_2 price does not sufficiently alter total production costs, since the non-ETS sectors are reflected – by definition – by relatively low energy inputs in their production processes. Furthermore the increasing CO_2 emissions associated with imports of transport services counterbalance the decreasing CO_2 emissions from all other NETS sectors. Austria tends to source out a substantial part of its transport sector – which is highly reactive to changes in fossil fuel prices – to less regulated regions.

Table 18: Sectoral CO_2 effects for imports of the scenarios relative to BAU 2020 (Mt CO_2)

	BASE 2004	**BAU 2020**	**EU_2020 grandfathering**	**EU_2020 auctioning**	**EU_2020_HH auctioning**	**PK_EU**	**PK_AI**
	Mt CO_2	Change relative to BAU (in %)					
CO2 Imports							
P_C	2.20	+8.2%	-1.8%	-2.5%	-15.2%	-18.1%	-13.2%
ELY	4.84	+20.7%	-36.2%	-35.3%	-33.5%	-46.2%	-47.7%
NMM	1.64	+8.4%	-14.1%	-4.7%	-4.7%	-9.0%	-11.0%
I_S	1.02	-10.2%	-30.7%	-26.5%	-25.3%	-28.8%	-21.3%
PPP	0.27	+7.3%	-5.8%	-4.3%	-4.3%	-8.9%	-6.9%
ETS total	9.98	+12.4%	-23.6%	-21.3%	-23.1%	-31.1%	-30.2%
COA	0.05	-12.7%	-39.7%	-39.3%	-55.2%	-67.0%	-66.7%
OIL	0.26	-8.8%	-23.9%	-23.9%	-31.1%	-38.6%	-33.1%
GAS	1.45	-62.4%	-73.5%	-73.7%	-79.0%	-76.0%	-54.7%
TEC	3.62	+5.7%	-1.5%	-1.6%	-4.5%	-10.0%	-10.8%
EXT	0.72	+19.2%	-0.8%	-0.9%	-7.9%	-13.3%	-15.3%
FTI	0.28	-10.7%	-17.7%	-18.6%	-21.1%	-24.0%	-26.7%
TRN	6.11	+12.8%	+18.2%	+18.3%	+23.3%	+36.4%	+37.3%
AGRI	0.29	+18.6%	-0.3%	-0.3%	-7.6%	-14.9%	-17.3%
SERV	0.96	+13.3%	+2.1%	+1.9%	-1.5%	-8.1%	-9.9%
non-ETS total	13.74	+2.5%	-0.9%	-1.0%	-1.1%	+2.5%	+4.7%
CO2 IM TMG	2.37	+13.1%	+4.7%	+4.9%	+0.7%	-3.5%	-4.4%
Imports total	26.09	+7.2%	-9.1%	-8.2%	-9.3%	-10.9%	-9.5%

5 The economic and carbon effects of the scenarios on a global scale

In the previous sections we have dealt with the repercussions of climate policies on the Austrian economy in the EU context as well as in a broader post-Kyoto context. In this section we are going to refocus our analysis on the global effects of the different scenarios. Obviously, one distinctive feature of the different scenarios is the regional scope – reaching from 'unilateral' EU policies to broader ones which cover all Annex I countries. Since our analysis is based on currently conceivable policy developments, none of the scenarios is of global scope with binding agreements also for developing countries. We will thus investigate the economic as well as the environmental ramifications on a global scale and illustrate our findings on the relevance of carbon leakage in this context.

5.1 The effects on GDP

The first part of our analysis of the global effects of different climate policy scenarios focuses on the economic impacts. As a measure for the economic performance of a region we utilize the GDP growth rate, which is presented for all regions and all scenarios in Table 19. The first column represents the regions' average annual GDP growth rates over the period 1999 to 2008, derived from IMF (2009) data. The second column shows our model results for the GDP growth rate under BAU assumptions, therefore without any climate policy measures. Compared to the 1999-2008 average growth rates, these 2020 GDP growth rates are in most cases lower, representing the highly visible impacts of the economic crisis. China's predicted economic growth is 3.9 percentage points lower (5.9%) than in the comparison period (9.8%). Also Latin American and African economies, which are already facing hard times in the globalized world economy due to a lack of capital and productivity drawbacks (reflected by low multi factor productivity (MFP), capital and labor force growth rates in Table 25), will be substantially affected by the crisis' implications. Within the EU, South Eastern European countries will be mostly affected by the economic downswing, the average annual GDP growth rates falling in BAU by 1.4 percentage points to a level of 2.7%.

The impacts of climate policies may alter these effects, as our model results illustrate. In all scenarios but PK_AI, only the EU is faced by binding emission constraints leading to a small reduction in annual growth rates for EU countries and to slight positive effects in some other Annex I countries, like the US, and also in Eastern Europe. Whether households face binding constraints and whether some sectors receive emission permits for free has no economic consequences for regions outside the EU, with the latter not even affecting EU growth rates.

Only when CO_2 emissions in all Annex I regions are affected by a more comprehensive global climate agreement (PK_AI), countries like the USA, Oceania and Russia have to face lower GDP growth rates. This is triggered by increased costs of production due to permit allocation, but also by a shrinking demand for their exports by the other regulated regions.

Table 19: Annual GDP growth rates for 2020 for the scenarios (2004-2020 average)

	1999-2008*	BAU 2020	EU_2020 grandfathering	EU_2020 auctioning	EU_2020_HH auctioning	PK_EU	PK_AI
AUT	2.40	2.14	2.11	2.11	2.08	2.03	2.05
GER	1.49	2.40	2.36	2.36	2.29	2.36	2.38
ITA	1.22	1.78	1.76	1.76	1.72	1.70	1.73
FRA	2.03	2.06	2.04	2.04	2.00	1.99	2.01
POL	4.22	3.01	2.94	2.94	2.93	2.91	2.95
RUS	6.85	3.04	2.88	2.88	2.77	2.80	2.43
USA	2.62	2.53	2.53	2.53	2.54	2.54	2.51
CHN	9.76	5.89	5.89	5.89	5.89	5.89	5.92
WEU	2.41	2.31	2.29	2.29	2.26	2.19	2.21
SEEU	4.18	2.74	2.71	2.71	2.71	2.71	2.75
NEU	2.74	2.62	2.55	2.55	2.50	2.49	2.46
ROE	3.94	2.46	2.49	2.49	2.52	2.51	2.51
CIS	7.72	3.01	2.95	2.95	2.93	2.91	2.84
EASI	1.89	2.41	2.42	2.42	2.43	2.42	2.42
SEAS	5.02	5.43	5.42	5.42	5.42	5.41	5.44
SASI	6.72	3.91	3.93	3.94	3.95	3.95	4.07
NAM	2.95	2.94	2.93	2.93	2.92	2.92	2.80
LAM	3.50	1.45	1.43	1.43	1.43	1.42	1.38
OCEA	3.18	3.09	3.07	3.07	3.08	3.07	2.90
MENA	5.10	2.41	2.28	2.28	2.19	2.20	1.67
SSA	4.16	1.57	1.49	1.49	1.45	1.45	1.22

* Source: IMF (2009)

5.2 Global carbon emissions

The development of global CO_2 emissions under the different scenario assumptions is presented in Table 20 (relative to Base 2004) and Figure 13 (relative to 2004). In the base year 2004, global CO_2 emissions were equal to 27.7 Mt CO_2, which is 23.7% below CO_2 emissions in 2020. Compared to the scenario families presented by the IPCC (Fisher et al., 2007) our model's BAU results would blend in among the scenario families A1, A2 and A1f, thus representing the medium to upper sphere of the IPCC emission scenario range.

Table 20: Change in emissions (in %) relative to BASE 2004

	BASE 2004	**BAU 2020**	**EU_2020 grandfathering**	**EU_2020 auctioning**	**EU_2020_HH auctioning**	**PK_EU**	**PK_AI**
	Mt CO_2	Change relative to 2004 (in %)					
EU	4,376	+17.9%	-4.5%	-4.6%	-15.9%	-14.0%	-11.8%
Eastern Europe	3,051	+18.0%	+22.4%	+22.6%	+24.6%	+23.6%	+26.6%
NAM (incl. USA)	7,294	+20.9%	+23.7%	+23.7%	+25.5%	+25.1%	-2.5%
LAM	1,087	+4.2%	+7.2%	+7.3%	+9.3%	+9.3%	+22.1%
ASIA (incl. CHN)	8,913	+37.8%	+40.9%	+40.9%	+41.9%	+41.9%	+44.2%
OCEA	434	+21.2%	+24.7%	+24.7%	+26.0%	+26.1%	-22.3%
AFRICA	2,573	+8.2%	+12.2%	+12.3%	+14.5%	+13.9%	+26.0%
Total	**27,729**	**+23.7%**	**+22.9%**	**+23.0%**	**+22.5%**	**+22.5%**	**+17.5%**

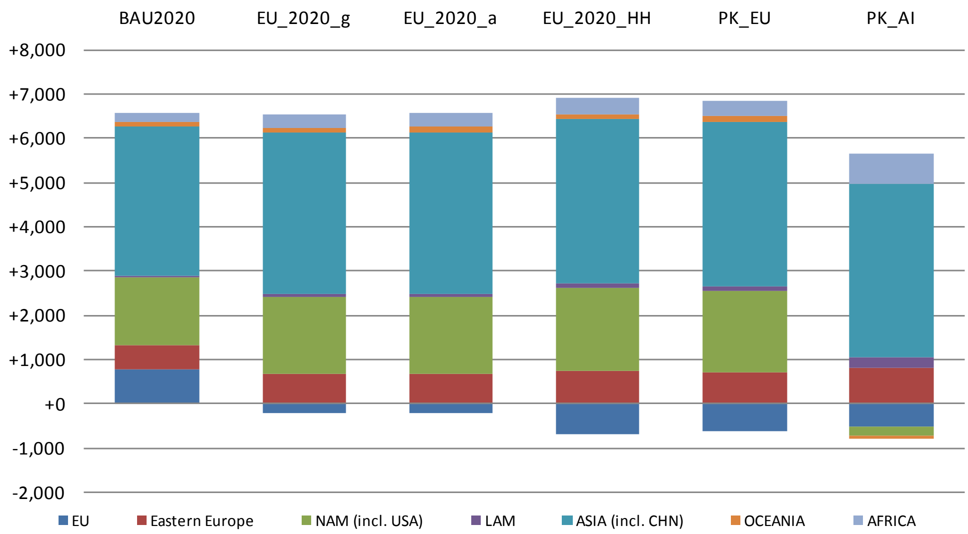
As revealed by Table 20, total emissions in the presence of climate policies fall compared to BAU but are higher than in BASE 2004. While within the EU emissions decrease below 2004 levels, emissions in most other countries increase even above BAU levels. Only under scenario PK_ AI emissions are also reduced in NAM and OCEA compared to BASE 2004. For Asia, which comprises the two big, but uncapped emerging economies China and India, CO_2 emissions would be subject to an even more accelerated growth than under BAU premises, fostering emission growth by 6.4 percentage points in the PK_ AI scenario compared to BAU. For Africa and Latin America these carbon leakage induced CO_2 effects are even stronger, though these regions are starting from substantially lower CO_2 emissions in the base year 2004 – 1,087 Mt CO_2 for LAM and 2,573 Mt CO_2 for Africa compared to 8,913 Mt CO_2 for Asia (Table 20).

As a consequence, total global CO_2 emissions growth can be slowed down by introducing climate policies aiming at a reduction in CO_2 emissions; but even in the most stringent PK_AI scenario, emissions in 2020 cannot be reduced below the level of 2004. This fact is also illustrated in Figure 13 where the global carbon effects of the different policy scenarios relative to 2004 are compared. One reason for this result is that this scenario still covers only about 50% of global emissions in 2004.

In the least stringent scenario (EU_2020_g), 2020 emissions in the EU are only 19% below BAU 2020 levels. This follows from a relative stronger increase in CO_2 emissions in the not regulated private households, which outweigh emission reductions in production sectors. These higher household emissions in the EU can be overcome by incorporating private households into the EU's abatement efforts as in scenario EU_2020_HH. When all Annex I regions are subject to emission constraints (scenario PK_ AI) climate policies become more successful in reducing emissions on a global scale. A major contribution originates from the regulation of North America's (incl. USA) CO_2 emissions, though these efforts are still outperformed by Asia's (most prominently China's) CO_2 emissions increase. In total, however, the decrease of CO_2

emissions in abating regions compared to 2004 is still more than counterbalanced by CO_2 emission increases in non-abating regions even in the most stringent policy analyzed in this paper. While CO_2 emissions in policy implementing regions (EU, NAM and OCEANIA) can be reduced under PK_AI by 797 Mt CO_2 compared to 2004, emissions in uncapped regions (mainly Asia) tend to increase by 5,658 Mt CO_2, leading to a net global CO_2 emissions increase of 4,861 Mt CO_2.

Figure 13: Change in CO_2 emissions (in Mt CO_2) per region and per scenario relative to 2004



5.3 Carbon leakage

One obvious argument why all scenarios studied fail to achieve the goal of reducing global carbon emissions below 2004 levels is the phenomenon of carbon leakage. If carbon emissions are not regulated on a global scale, GHG emission reductions in some countries may be partially offset by emission increases elsewhere. It is argued that carbon leakage occurs on account of a relocation of production to regions not facing mitigation policies. In this section, we will address the scope of this problem.

We start by comparing the carbon emissions in GHG abating countries – the policy-regions – to those in non-abating or non-policy regions. In all EU_2020 and the PK_EU scenarios, the policy region is the EU, while in PK_AI the policy regions comprise also other industrialized countries which stated reduction objectives under the Copenhagen Accord (UNFCCC, 2010) (i.e. USA, Australia, Japan etc.). Table 21 reveals the difference between policy regions' and non-policy regions' 2020 emissions in the respective scenarios and their respective CO_2 emissions in BAU 2020. The first important conclusion from Table 21 (upper half) is that in the unilateral EU policies only about one seventh of the world's 2020 CO_2 emissions under BAU assumptions would be regulated by climate policies.

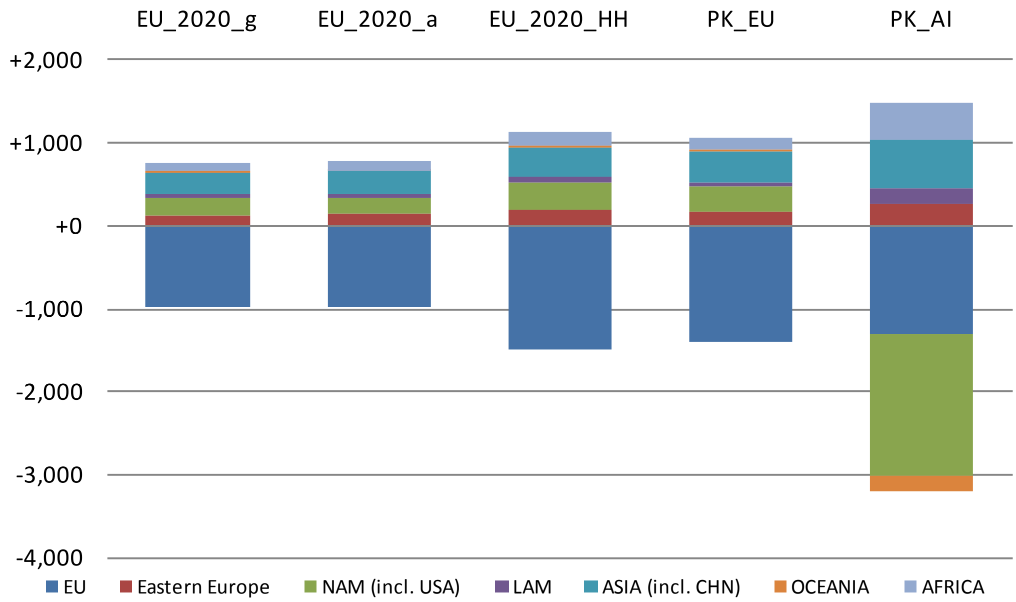
Table 21: Climate policies and carbon leakage - Global CO_2 effects relative to 2020 (in Mt CO_2)

	BAU 2020	EU_2020 grand-fathering	EU_2020 auctioning	EU_2020_ HH auctioning	PK_EU	BAU 2020	PK_AI
CO_2 emissions							
policy regions	5,161	4,178	4,176	3,680	3,764	20,357	16,935
non-policy regions	29,145	29,909	29,923	30,281	30,205	13,948	15,655
Total	34,306	34,087	34,099	33,961	33,969	34,305	32,590
Change relative to BAU 2020							
policy regions		-982	-984	-1480	-1,396		-3,422
non policy regions		+764	+778	+1,135	+1,060		+1,706
2020 Total		-219	-206	-345	-336		-1,715
Leakage rate 2020		*78%*	*79%*	*77%*	*76%*		*50%*

In addition to the absolute levels of emission effects in policy and non-policy regions, we are interested in the amount of carbon emissions leaking by production shifts to other regions, hence counteracting the emission reductions in the abating countries. Figure 14 compares the abating regions' CO_2 reduction achievements relative to BAU 2020 to the increase of CO_2 emissions in the regions not facing GHG emission constraints. Following the 'strong' definition of carbon leakage, the rate of carbon leakage can be calculated as the ratio of the increase of CO_2 emissions beyond BAU in non-abating regions to the emission reductions in the abating regions (see bottom line of Table 21), which thus can be interpreted as the relocation effects of production due to the regulation of emissions in the policy region. The derived carbon leakage rates are particularly high in all unilateral EU scenarios (above 75%). Thus, due to the fact that only a small fraction of global CO_2 emissions is under control in these unilateral EU scenarios, more than three quarters of the emission reduction within the EU is counteracted by ancillary emission increases above BAU in non-abating countries. Contrary to the claim that grandfathering of emission rights shields vulnerable industry and reduces carbon leakage, we find that grandfathering leads only to a 1 %-point reduction in carbon leakage.

The more stringent and comprehensive the climate policies become, the more declines the fraction of abated CO_2 emissions which is offset in non-abating regions. But even in the most stringent and comprehensive climate policy scenario PK_AI, in which also other Annex I regions are subject to emission constraints, carbon leakage amounts to 50%.

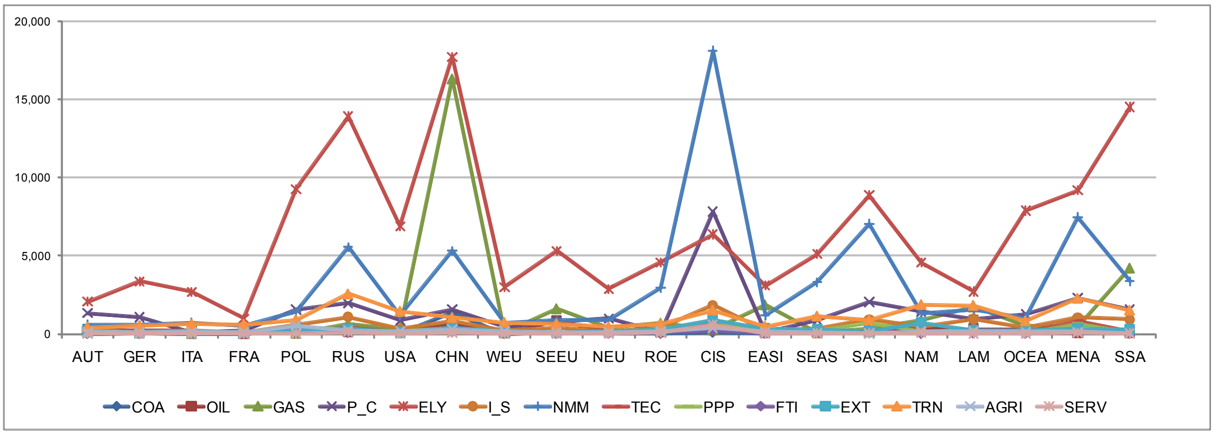
Figure 14: CO_2 effects (in Mt CO_2) in policy and non-policy regions relative to BAU 2020



5.4 Development of carbon intensities

Figure 15 compares the carbon intensities, or the CO_2 coefficients, per country and sector for the year 2020 under BAU. They were calculated as the total carbon input in the various production processes divided by total monetary output of the respective sector. These CO_2 coefficients differ quite substantially across regions, with the highest differences in ELY and NMM. By a comparison among regions it is striking that CO_2 intensities in these sectors are by far highest in CIS, followed by China, the Russian Federation and the developing countries in Asia and Africa, reflecting the disproportionally high CO_2 intensities in these countries production methods. While Austria's I_S sector for example emits 181 tCO_2 per MUSD output in 2020, the CIS region emits 10 times as much CO_2 for the same amount of output.

Figure 15: CO_2 coefficients for BAU 2020 across countries and sectors (t CO_2/MUSD)



More stringent mitigation efforts in the sense of stricter carbon emission constraints also trigger a more efficient use of fossil fuels in production. By pricing the release of CO_2 due to combustion of fossil fuels or those related to industrial processes, industries as well as private households have an incentive to reduce their carbon emissions either by directly reducing the fossil fuel consumption or by raising energy efficiency. This decarbonization effect can reduce sectoral country specific CO_2 coefficients by a quite substantial amount.

Figure 16: CO_2 coefficients for BAU 2020 and PK_AI in sector ELY (t CO_2/MUSD)

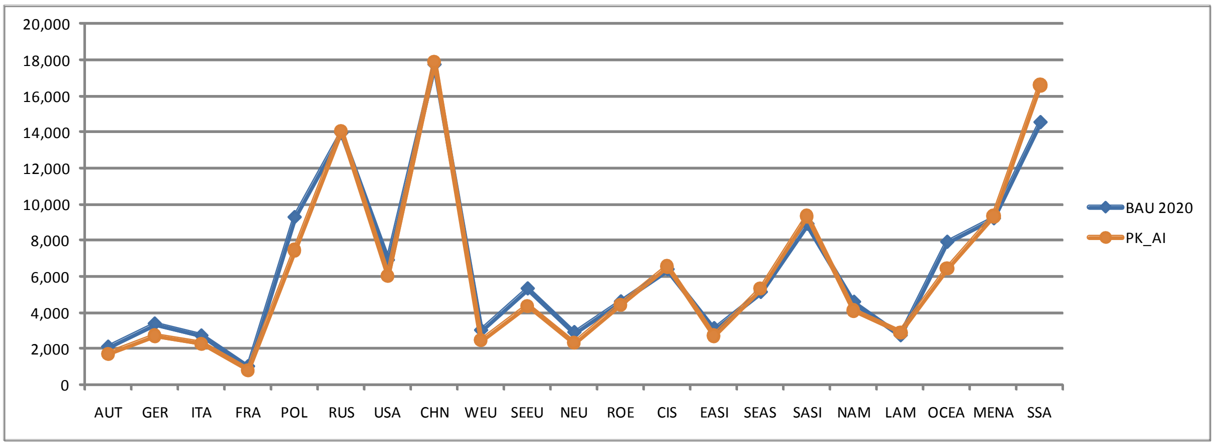


Figure 16 compares the emissions intensities in sector ELY between BAU 2020 and the most stringent climate policy scenario PK_AI for the 21 model regions. Austria's emission intensity in the power generation sector (ELY) for example would be reduced by 348 t CO_2/MUSD, thus representing a shift to more renewable energy as well as an increase in energy efficiency in fossil fueled power plants (see also Table 22). The same holds true for other climate policy implementing countries, while carbon intensities in the uncapped regions' electricity sectors tend to increase even stronger than under BAU. This is mainly based on a reduction of international primary energy prices: Due to a decrease in demand for fossil fuels by regions facing a carbon cap, international fossil fuel prices fall, creating disincentives for uncapped regions to raise energy efficiency standards in their ELY sectors or to foster the shift to less carbon intensive technologies.

Table 22: Regional ELY CO_2 coefficients for the policy scenarios (t CO_2/MUSD)

	2004	BAU 2020	EU_2020 grand-fathering	EU_2020 auctioning	EU_2020_HH auctioning	PK_EU	PK_AI
				in t CO_2/MUSD			
AUT	2,338	2,067	1,743	1,752	1,740	1,707	1,719
GER	3,812	3,350	2,742	2,757	2,737	2,710	2,714
ITA	3,012	2,688	2,295	2,305	2,294	2,259	2,282
FRA	1,117	984	804	809	803	789	798
POL	10,511	9,255	7,564	7,587	7,549	7,476	7,470
RUS	15,514	13,921	13,982	13,981	13,988	13,973	14,058
USA	8,146	6,880	6,957	6,956	6,957	6,960	6,035
CHN	21,464	17,725	17,780	17,777	17,751	17,766	17,895
WEU	3,463	2,989	2,494	2,506	2,492	2,447	2,464
SEEU	6,033	5,301	4,417	4,433	4,408	4,359	4,367
NEU	3,421	2,877	2,338	2,350	2,338	2,304	2,315
ROE	5,200	4,579	4,679	4,677	4,702	4,694	4,434
GUS	7,219	6,366	6,485	6,483	6,542	6,504	6,560
EASI	3,688	3,093	3,148	3,147	3,160	3,155	2,712
SEAS	5,933	5,106	5,156	5,155	5,187	5,165	5,327
SASI	10,757	8,888	8,994	8,992	9,000	8,997	9,333
NAM	5,236	4,559	4,612	4,611	4,631	4,622	4,118
LAM	3,044	2,704	2,737	2,737	2,758	2,747	2,900
OCEA	9,505	7,887	8,033	8,030	8,031	8,044	6,431
MENA	10,228	9,191	9,235	9,234	9,269	9,241	9,342
SSA	16,595	14,523	14,974	14,967	14,948	15,015	16,595

6 Discussion and conclusions

Within our CGE model of the Austrian economy and its main trading partners, we analyzed the consequences of two types of climate policy scenarios relative to a business as usual (BAU) scenario for 2020, namely four different unilateral EU climate policies, analytically separating three variants for EU's 20-20 targets – one with auctioning (EU_2020 auctioning), one with partial grandfathering (EU_2020_grandfathering), and one which also includes emission targets for households (EU_2020_HH); and in addition two voluntary Copenhagen targets: one -30% target for the EU only (PK_H EU only) and one for all Annex I countries (PK_H all Annex I). Our main findings can be summarized as follows.

Under BAU 2020, Austrian GDP grows annually at 2.14% (on average for the period 2004 to 2020) and output grows by 29%, predominantly in the non-ETS sectors. Total imports increase by more than total exports, causing Austria's trade balance to improve by 0.5 MUSD (compared to 2004). Austria's main trading partners are to be found within the EU – mainly with neighboring countries Germany and Italy; outside the EU, the US and Russia are the strongest single country trading partners.

Austria's CO_2 emissions according to the PBP (production based principle) increase by 15.6% from 2004 (79 Mt CO_2) to 2020 (91 Mt CO_2), with a considerably stronger increase in the household sector than in production. According to the CBP (consumption based principle), Austria's emissions increase from 88 Mt CO_2 in 2004 by 13.4% to 100 Mt CO_2 in 2020, which is due to a higher increase in emissions from imports than from exports. As a result, the net carbon deficit of Austria increases by 2% relative to 2004. Finally, more than 50% of Austria's CO_2 emissions linked to production activities both in 2004 and 2020 arise within ETS sectors – mainly Iron and steel and electricity – even though the monetary output value of the NETS sectors – predominantly the non-energy and service sectors – is almost nine times higher than the ETS output.

In scenario EU_2020, the European Union implements an emissions trading scheme in the energy intensive and non-energy intensive sectors, but the other countries do not limit their emissions. This leads to a reduction in Austrian GDP by 0.03 %-points relative to BAU, and Austrian exports and imports decline under auctioning by 2.4% and 1.3% respectively. Partial grandfathering of emission rights to iron and steel, cement and pulp and paper industries has similar effects on GDP but slightly reduces the impact on international trade to -2.3% for exports and -1.4% for imports. When the European Union extends its climate policy also to households but the other Annex I countries still do not reduce their emissions, effects on GDP, exports and imports are more than doubled. Even under the more stringent post Copenhagen scenarios either with a 30% target for the EU only or with voluntary reduction commitments also by other Annex I countries, the macroeconomic consequences for GDP remain modest.

Regarding international trade we find that exports and imports are affected more strongly than domestic production. While under all scenarios the effects on exports to the EU are negligible, there is a considerable strong impact on Austrian exports to non-EU countries. Moreover, imports are declining less (in relative terms) under all climate policy scenarios than exports, which might be the consequences of substitution of domestic production by imports, particularly in energy intensive sectors

At the sectoral level, Austrian production in ETS sectors is affected more strongly under all scenarios than non-ETS sectors. A similar pattern emerges for Austrian exports, with the ETS sectors paper and paper products and iron and steel affected most under all scenarios.

Austrian imports are slightly less affected than its exports and due to the higher openness to trade of the ETS sectors, ETS imports are affected more strongly than non-ETS imports. However, when the EU implements a unilateral policy, imports from all other regions increase relative to BAU, and particularly so in the ETS sector. In contrast, when other Annex I countries are faced with binding reduction targets too, Austrian imports from that regions are lower than under BAU.

Moreover, under all scenarios, Austrian carbon emissions are considerably lower than in the base year 2004, ranging from -3.75% under EU_2020 to -30% under PK_H EU_only according to the production based principle (PBP). However, the net carbon balance (emission from export minus emissions from import) worsens. This implies that emissions from Austrian exports decline more than emissions from its imports, due to a shift of Austrian imports to less regulated and therefore less environmentally friendly production regions. Thus, while emissions according to the consumption based principle (CBP) are lower in all scenarios than under BAU, the reduction is considerably smaller than according to the PBP since domestic emission reductions are partly offset by increased emissions from imports.

At the global scale, effects on GDP depend on how universal emission targets are set, both in terms of sectoral and regional coverage. In all unilateral EU policy scenarios, hardly any GDP effects arise for regions and countries outside the EU. When all Annex I regions face constraints, also GDP growth rates of the US and Oceania decline. Regarding worldwide CO_2 emissions, the BAU scenario is characterized by 34.3 Gt CO_2, adjusted for the economic crisis, compared to 27.7 Gt CO_2 in 2004. This increase in global emissions is driven by economic growth, increases in global demand and despite energy efficiency improvements.

When the EU introduces binding targets for ETS and non-ETS sectors and households but all other countries do not commit themselves, only $1/7^{th}$ of global emissions are regulated (= EU 20-20 target), and hence carbon leakage is more than 75% - for each emission reduction unit achieved in the EU, 0.75 units are generated elsewhere in compensation. Even under the more stringent Copenhagen Accord targets for all Annex I countries, every emission reduction in the policy regions is counterbalanced by an increase of half an emission unit in non-policy region, since Annex I countries only comprise slightly more than 50% of global emissions (according to the PBP). Thus, unless emissions are limited for all countries, following the UNFCCC principle of common but differentiated responsibilities, stabilization of global carbon emission might not be attainable.

Based on this model analysis, several conclusions can be drawn for EU's climate policy. It is of utmost importance, that the EU continues to take the leading role in international climate policy architectures and that they continue their effort to convince other countries to do likewise. These emission targets are not only required for other highly developed countries but in particular for emerging economies, to avoid that imports of emission intensive commodities to the European Union increase compared to Business as Usual. The necessity of emission targets for emerging and developing countries is intensified by the higher growth rates compared to highly developed countries. In regard to the specifics of EU climate policy, it is essential that carbon markets are not limited to firms but cover also households, or otherwise the incentive to import energy intensive commodities is intensified from the demand side. While the consequences of a stand-alone EU policy on energy-intensive trade-exposed sectors are evident in model results, grandfathering of emission rights leads only to a very modest protection (negative consequences are shifted to other sectors which then face a larger burden). In addition, and in contrast to frequently heard claims, grandfathering is not able to fight carbon leakage, and hence cannot be regard as second-best approach to a more comprehensive, i.e. multilateral, climate policy approach.

7 Literature

Armington, P. (1969). “A theory of demand for products distinguished by place of production”. IMF staff papers, 16, 1969, 159-178.

Babiker, H. (2005). Climate change policy, market structure, and carbon leakage. *Journal of International Economics* 65: 421-445.

Baiocchi, G., Minx, J., 2010. Understanding changes in the UK CO2 emissions: a global perspective. *Environmental Science & Technology* 44, 1177–1184.

Beckman, J.F. and T.W. Hertel (2009). “Why Previous Estimates of the Cost of Climate Mitigation are Likely Too Low.” GTAP Working Paper No.54, Purdue University.

Böhringer, C. (1999). PACE – Policy Assessment based on Computable Equilibrium. Ein flexiblles Modellsystem zur gesamtwirtschaftlichen Analyse von wirtschaftspolitischen Maßnahmen. ZEW Dokumentation, Centrefor European Economic Research. Mannheim, Germany.

Böhringer, C. (2000), Cooling down hot air: A global CGE analysis of post-Kyoto carbon abatement strategies, *Energy Policy*28: 779-789.

Burniaux, J.M., J.P. Martin, G. Nicoletti and J. Oliveira (1992). GREEN – A Multi-Regional Dynamic General Equilibrium Model for Quantifying the Costs of Curbing CO2 Emissions: A Technical Manual. Working Paper 116, Economics and Statistics Department, OECD, Paris.

Burniaux, J.-M., J.O. Martins (2000), “Carbin emission leakages: a general equilibrium view”, OECD Economics Department Working Papers, 242, OECD publishing, doi:10.1787/41053555

Centre for Global Trade Analysis, Purdue University (2007). Global Trade, Assistance and Production: The GTAP 7 Data Base. West Lafayette.

European Commission (2008). “20 20 by 2020. Europe’s climate change opportunity.” Communication from the European Commission to the European Parliament, the council, the European economic and social committee and the committee of the regions. Brussels.

European Commission (2009). Towards a comprehensive climate change agreement in Copenhagen. Communication from the Commission to the Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Brussels.

European Parliament (2003). “Directive 2003/87/EC of the European Parliament and the Council. Establishing a Scheme for Greenhouse Gas Emissions Allowance Trading within the Community and amending Council Directive 96/61/EC.” Brussels.

Fæhn, T., A. Bruvoll (2009), Richer and cleaner-at others’ expense? *Resource and Energy Economics* 31: 103-122.

Fischer, C., A.K. Fox (2007). Output-based allocation of emissions permits for mitigation tax and trade interactions, *Land Economics* 83(4): 575-599.

Fisher, B.S., N. Nakicenovic, K. Alfsen, J. CorfeeMorlot, F. de la Chesnaye, J.-Ch. Hourcade, K. Jiang, M. Kainuma, E. La Rovere, A. Matysek, A. Rana, K. Riahi, R. Richels, S. Rose, D. van Vuuren, R. Warren, (2007): Issues related to mitigation in the long term context, In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Inter-governmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge.

Helm, D., Smale, R., Phillips, J., 2007. Too Good To Be True? The UK's Climate Change Record. 10th December 2007. New College Oxford, Vivid Economics and School of Oriental and African Studies.

IMF (2009). World economic and financial surveys. World economic outlook database. International Monetary Fund. Available at: http://www.imf.org/external/pubs/ft/weo/2009/02/weodata/download.aspx.

IPCC (2007). 4th Assessment report, Climate Change 2007: Synthesis report, Intergovernmental Panel on Climate Change. Cambridge, Cambridge University Press.

Kuik, O., R. Gerlagh (2003). Trade liberalization and carbon leakage. *Energy Journal* 24(3), 97-120.

Lee, H.-L. (2008). The Combustion-based CO_2 Emissions Data for GTAP Version 7 Data Base. Department of Economics, National Chengchi University, Taiwan. Available at: https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=1143.

Lenzen, M., J. Murray, F. Sack, T. Wiedmann (2007). Shared producer and consumer responsibility — Theory and practice. *Ecological Economics* 61(1): 27-42.

Lenzen, M., L.L. Pade and J. Munksgaard (2004). CO_2 multipliers in multi-region input-output models. *Economic Systems Research* 16(4): 391–412.

McDougall, R. and A. Aguiar (2007). "Initial Preparation of Energy Volume Data for GTAP 7." GTAP Research Memorandum No. 10. Center for Global Trade Analysis, Purdue University.

McDougall, R. And H.-L. Lee (2006). "An energy data base for GTAP." In *Global Trade, Assistance and Production: The GTAP 6 Data Base*, chapter 17. Center for Global Trade Analysis, Purdue University.

Muñoz, H., K.W. Steininger (2010), Austria's CO_2 responsibility and the carbon content of its international trade. *Ecological Economics* 69(10): 2003-2019.

Okagawa, A. and Ban, K. (2008), Discussion Paper 08—16: Estimation of Substitution Elasticities for CGE Models, Graduate School of Economics and Osaka School of International Public Policy (OSIPP) Osaka University, Toyonaka, Osaka 560-0043, Japan.

Paltsev, S.V. (2001). The Kyoto Protocol: Regional and sectoral contributions to the Carbon Leakage. *Energy Journal* 22(4), 53-79.

Peters, G., E. Hertwich (2008a). CO_2 Embodied in International Trade with Implications for Global Climate Policy. *Environmental Science and Technology* 42(5): 1401-1407.

Peters and Hertwich (2008b). Post-Kyoto greenhouse gas inventories: production versus consumption. *Climatic Change* 86, 51-66.

Poncet, S. (2006). The Long Term Growth Prospects of the World Economy: Horizon 2050. WorkingPaper 2006–16. Centre d'Etudes Prospectives et d'Informations Internationales.

Rutherford, T.F. (1999). Applied General Equlibrium Modeling with MPSGE as a GAMS Subsystem: AN overview of the modeling framework and syntax. *Computational Economics* 14 (1-2): 1-46.

Rutherford, T.F. and S.V. Paltsev (2000). "GTAP-Energy in GAMS." University of Colorado, Working Paper 00-2 2000. http://debreu.colorado.edu/download/gtap-eg.pdf.

Steininger, K., S. Schleicher, B. Gebetsroither, T. Schinko, A. Tuerk (2009). Klimaschutzplan Steiermark, Teilbericht 1: Emissionen, Sektorale Zurechung und EU 2020 Ziele.

UMWELTBUNDESAMT (2008): Muik, B.; Anderl, M.; Freudenschuß, A.; Kampel, E.; Köther, T.; Poupa, S.;Schodl, B.; Schwaiger, E.; Seuss, K.; Weiss, P.; Wieser, M.; Winiwarter, W. &Zethner, G.: Austria's National Inventory Report 2008. Submission under the United Nations Framework Convention on Climate Change. Reports, Bd. REP-0152. Umweltbundesamt, Wien.

UNFCCC (2009). Decision -/CP.15. The Conference of the Parties takes note of the Copenhagen Accord of 18 December 2009. Bonn.

UNFCCC (2010). Information provided by Parties to the Convention relating to the Copenhagen Accord. http://unfccc.int/home/items/5262.php . [last accessed 18 February 2010].

UNFCCC (2011)."Greenhouse Gas Inventory Data" United Framework Convention on Climate Change. http://unfccc.int/di/DetailedByParty.do [last accessed 16 May 2011]

Weber, C.L., Matthews, H.S., 2007. Embodied Environmental Emissions in U.S. International Trade. *Environmental Science & Technology* 41, 4875-4881.

8 Appendix

Table 23: Elasticities in production

Sector	*s*	*int*	*elke*	*elk*	*elc**	*elcl**	*elqd**	*$tela_{es}$***
COA	0.73	0.31	0.55	0.14	0.16	0.07	0.25	3.05
OIL	0.73	0.31	0.55	0.14	0.16	0.07	0.25	5.20
GAS	0.73	0.31	0.55	0.14	0.16	0.07	0.25	10.76
P_C	0.00	0.39	0.26	0.46	0.16	0.07	0.25	2.10
ELY	0.00	0.39	0.26	0.46	0.16	0.07	0.25	2.80
I_S	1.17	0.25	0.66	0.22	0.16	0.07	0.25	2.95
NMM	0.31	0.19	0.41	0.36	0.16	0.07	0.25	2.90
TEC	0.60	0.49	0.32	0.23	0.16	0.07	0.25	3.71
PPP	0.19	0	0.21	0.38	0.16	0.07	0.25	2.95
FTI	0.58	0.24	0.49	0.21	0.16	0.07	0.25	2.91
EXT	0.73	0.31	0.55	0.14	0.16	0.07	0.25	1.38
TRN	0.35	0.33	0.28	0.31	0.16	0.07	0.25	1.90
AGRI	0.39	0	0.52	0.02	0.16	0.07	0.25	2.45
SERV	0.58	0.5	0.48	0.29	0.16	0.07	0.25	1.91
Final Demand	0.20	1.00	-	-	0.50	1.00	-	

Source: *Okagawa and Ban (2008), * Beckman and Hertel (2009); ** GTAP (2007)*

Table 24: Elasticities in import structure

Sector	***s***	***m***	***n***
COA	6.1	6.1	6.1
OIL	10.4	10.4	10.4
GAS	32.4	32.4	32.4
P_C	4.2	4.2	4.2
ELY	0	5.6	5.6
I_S	5.9	5.9	5.9
NMM	5.8	5.8	5.8
TEC	7.5	7.5	7.5
PPP	5.9	5.9	5.9
FTI	6.4	6.4	6.4
EXT	2.2	2.2	2.2
TRN	3.8	3.8	3.8
AGRI	4.9	4.9	4.9
SERV	3.8	3.8	3.8

Source: *GTAP (2007)*

Table 25: 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)*