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The Carbon Content of Austrian Trade Flows in the European and International Trade Context

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Abstract

In this study CO2 emissions embodied in Austrian international trade are quantified employing a 66-region input output model of multidirectional trade. We find that Austria's final demand CO2 responsibilities on a global scale are 38% higher than conventional statistics report (110 Mt-CO2 versus 79 Mt-CO2 in 2004). For each unit of Austrian final demand, currently two thirds of the thus triggered CO2 emissions occur outside Austrian borders. We then develop a 19-region computable general equilibrium model of Austria and its major trading partners and world regions to find that future Austrian climate policy can achieve the EU 20-20 emission reduction targets, but that its carbon trade balance would worsen considerably. Both unilateral EU and internationally coordinated climate policies affect Austrian international trade stronger than its domestic production.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

A INTRODUCTION AND OVERVIEW

Climate change mitigation requires a rapid decrease of global emissions of greenhouse gases (GHGs) from their present value of 8.4 GtC/year to – as of current knowledge –about 1 GtC/year by the end of the century. Facing world economic growth which to date was enhancing emissions this poses a substantial challenge (Grossmann et al., 2009, Meinshausen et al., 2009).

International negotiations and agreements (such as the UNFCC Kyoto Protocol) on greenhouse gas emission reduction have established respective emission accounting systems for countries (or group of countries). This accounting framework is based on the so-called 'Production-Based Principle' (PBP) in which environmental responsibilities are restricted to geographical borders. This means that indicators only capture the environmental impacts linked to the production of national goods and exports. Actual emission responsibility by consumption and investment by individual countries may deviate from the picture drawn by the former accounting systems. Accounting for emissions on basis of the 'Consumption-based Principle' (CBP) implies reattributing embodied environmental impacts associated with exports to foreign countries, and to add to domestic environmental responsibilities those impacts which take place abroad. For more details about PBP and CBP, see Lenzen et al. (2007), Munksgaard et al. (2001) and Wiedmann et al. (2007).

Deviations between PBP and CBP measures can result from international trade and the grey energy and emissions it involves. For countries with very strict domestic objectives and high incentives to meet them, outsourcing of energy and emission intensive production can cause significant deviations, which render the initial policy effort questionable, as we deal with a global pollutant here. Evidence on recent decarbonization has been queried for some countries (see Helm et al., 2007, for UK's case) and the question arises, whether the emissions records really represent a change towards more sustainable societies or whether countries create clean and natural environments within their borders, by merely displacing degrading production beyond their boundaries into other countries with lower environmental standards. Due to the global character of the climate change phenomenon, the countries' environmental responsibilities have therefore to be reconsidered beyond their geographical borders.

While international trade has entered the climate policy agenda only rather recently, there is indeed a strong mutual relationship between international trade and climate policy, along both the lines pointed out above and beyond:

- for a global pollutant like CO_2, international trade can shift carbon intensive production to less developed countries (pollution haven hypothesis); this effect is occurring when raised awareness for pollution in industrialized countries makes them choose binding reduction targets

  in particular:

  - when climate policies are implemented partially (i.e. unilaterally instead of globally), international trade allows for importing carbon intensive products from non-implementing countries (so-called carbon leakage)
  - when climate policies are implemented partially, some sectors, and particularly those very exposed to trade, might experience reduced competitiveness
  - due to international trade, countries which limit their emissions might still import carbon intensive commodities, but these emissions are not counted according to UNFCCC carbon inventories since they are based on production, but not consumption
- international trade enables the transfer of clean technologies from industrialized to developing countries (e.g. via CDM), but also among industrialized countries
- internationally linked carbon markets, such as the EU ETS, can reduce the costs of pollution abatement and thereby are more cost-effective than unilateral solutions

Thus, international trade and climate policy are linked in both supportive and opposing ways – both fields thus necessitate a joint analysis.

The present analysis seeks a quantification of carbon content in Austrian international trade flows with a focus on EU member states and major world trade blocks across time (1992-2004) to have a background evaluation instrument for countries’ Kyoto efforts and achievements. We do so by an enhanced Input-Output analysis of Austrian trade flows and their direct and indirect carbon content.

In our methodological approach, however, we go beyond this enhanced statistical analysis only, by developing also an evaluation tool – a multiregional computable general equilibrium model of Austrian trade with its trading partners across the world, and specified energy balance and carbon emission data for each country and/or world region. We simulate a range of possible post-Kyoto policies with this tool and report results. This tool is now available also for further policy simulations of national or EU climate policy efforts, to evaluate their respective indirect carbon emission impacts via trade flows.

Since the European Council and Parliament approved the EU 2020 targets of the Energy and Climate package in December 2008, a further set of policy measures has to be implemented in Austria. It was thus timely to generate a tool to be able to analyze the indirect emission implications of policy measures developed to achieve the Austrian 2020 targets.

The purpose of the present report is therefore

- to assess the carbon content of Austrian international trade, using the concept of CO_2 embodied in international trade (Peters and Hertwich, 2008)
- to analyze the consequences of envisioned climate policies for the post-Kyoto era (both EU stand alone, but also more global solutions), for Austrian trade, output, transport and carbon emissions, as well as the effects on Austria's main trading partners (Germany, Italy, Russia, USA, China) and other world regions (EU, North America excl. USA, Latin America, different Asian regions, Africa).

To address the first objective, we use a multicountry input output analysis with high sectoral and regional detail (57 sectors and 113 regions). This method is particularly suitable to investigate the carbon emissions along the production chain of the commodities, both domestically and abroad. Moreover, we device and apply a method to consider not only the direct carbon effects of imported and exported products, but also the indirect ones due to imports of factors of production and intermediate products. With this method at hand, we can determine the carbon content of Austrian production, imports and exports and ultimately of Austrian final demand (=consumption). Thus, the main contribution of this method is in the analysis of physical commodity flows and their link to emissions with particularly high detail.

The second objective is directed towards the future, namely the assessment of different climate policy scenarios for the post Kyoto era (climate policy up to 2020). This question can best be addressed within a Computable General Equilibrium (CGE) framework which is also based on input output tables but extended by household and government data (taxes, transfers, expenditures) to construct social accounting matrices. The key characteristic of CGE models is that they allow to analyze the effects of (exogenous) policy changes by requiring that all markets (input, output, international trade) clear, e.g. by means of adjustments in prices and input coefficients (production technologies), at all instances of time.

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, 2008): 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, the database used for carbon emissions varies across GTAP versions and the results are therefore not readily comparable across GTAP versions. Finally, 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 respective sections.

B THE PAST AND CURRENT CARBON CONTENT OF AUSTRIAN TRADE (INPUT OUTPUT ANALYSIS)

This section aims at quantifying the CO_2 emissions embodied in international trade on the basis of the Consumption-Based Principle (CBP) for Austria. At a methodological level, Multi Regional Input-Output (MRIO) models are used in order to account for Austria's CO_2 responsibilities on a global scale. Estimates are carried out for the years 1997 and 2004. This allows assessing effects of the increasing globalization process on carbon reallocation, fostered by unilateral climate change mitigation policies. In order to estimate the relevance of carbon leakage, indicators established from a consumption perspective are compared with standard indicators which are based on the Production-Based Principle (PBP). Results state that during 1997 CO_2 responsibilities based on CBP were 32% larger than those based on PBP; that is, CO_2 emissions based on PBP indicator amounted to 67 million tons of CO_2 (Mt-CO_2), while CO_2 responsibilities based on CBP reported 89 Mt-CO_2. This relation has increased through time: as the CBP indicator of 2004 was 38% larger than the PBP: PBP indicator reported 79 Mt-CO_2 whilst CBP estimates reported 110 Mt-CO_2. Regarding the origin of the emissions embodied in imports, it is estimated that about one-fourth (10 Mt-CO_2) originated in non-Annex I countries in 1997. This proportion increased to one-third (21 Mt-CO_2) by 2004. Due to the divergent magnitude between CBP and PBP indicators as well as the dimensions of carbon leakage, results suggest a re-thinking of the accounting basis in order to properly assign CO_2 responsibilities. Otherwise, the unilateral character of undergoing climate change mitigation policies could partially be undermining emissions responsibilities by reallocating pollution towards those regions without strict environmental commitments.

1 Introduction

The Nature of the climate change phenomenon demands internationally coordinated action in order to mitigate greenhouse gas (GHG) emissions. With regard to the stabilization of greenhouse gas concentration, the United Nations Framework Convention on Climate Change points out that all societies share common but differentiated responsibilities. The largest share of historical and current global emissions of greenhouse gases can be traced back to high income economies while the share of global emissions originating in low and middle income economies are currently at a low per capita level. The latter, however, will inevitably grow during the emerging process.

The Kyoto Protocol, the largest international agreement on climate change mitigation, is aimed at committing a subgroup of high income economies to the reduction of their GHG emissions. The accounting emission system at the Kyoto Protocol is based on the countries' geographical territory, i.e. the environmental responsibilities 'stop' at the respective national borders of the countries (IPCC, 2007). The literature usually refers to this accounting system as the 'Production-Based Principle' (PBP) (Munksgaard and Pedersen, 2001). This means that indicators only capture the environmental pressures which are linked to the production of national goods and exports.

However, the so called 'carbon leakage problem' emerges when emissions inventories are only focused on the PBP and when climate change policies are unilaterally imposed by a group of countries only. There are two core definitions with respect to the carbon leakage problem:

(1) As a policy oriented approach the IPCC defines carbon leakage as "the part of emissions reductions in Annex I countries that may be offset by an increase of the emissions in the non-constrained countries above their baseline levels. This can occur through the relocation of energy-intensive production in non-constrained regions" (IPCC 2007). In other words, the concept relies on the possibility that a unilateral climate change mitigation policy oriented towards reducing domestic emissions in one region can increase emissions in another by the substitution of domestic production due to imports and/or production relocation (for further details see Reinaud, J. 2008; Dröge, S. 2009; IPCC, 2007).

(2) A descriptive approach used to estimate the carbon leakage deals with past and present emission flows that are embodied in imports coming from non-Annex I countries to Annex I countries. The carbon leakage indicator in this context is often defined as the flows of emission embodied in imports coming from non-Annex I countries to an Annex I country divided by the total emissions according the PBP indicator (Peters and Hertwich 2008a). In

this section of our report we will use this latter approach and the country being taken into consideration from Annex I parties is Austria,. In the policy part of this report (part D), however, we will obviously use the policy oriented former definition of carbon leakage.

Due to the carbon leakage problem, recent decarbonization trends for some countries have been queried (see for instance Helm et al 2007 and Minx, et al 2008 for the case of UK). The question arises whether recent evidence of decarbonisation in production in some countries really does represent a change towards more sustainable societies or whether countries are creating clean and natural environments within their borders, while displacing pollution beyond their geographical limits into countries with lower environmental standards and commitments. This shows a rising concern in defining the limits of environmental responsibilities.

In order to overcome the potential environmental leakage problem, solutions suggest setting an emission accounting that relies on the consumption based principle (CPB). This implies the reattribution of embodied environmental pressures associated with exports to foreign countries, and domestic environmental responsibilities should be complemented by those impacts that take place abroad. Thus, by use of CBP it is possible to capture environmental responsibilities across the world, since it takes into account the pollution embodied in the imported commodities. As Peters and Hertwich (2008) suggest some of the advantages of using CBP as the evaluation criterion in GHG inventories are that it reduces the importance of emission commitments for developing countries, increases options for mitigation, encourages environmental comparative advantage, addresses competitiveness concerns, and naturally promotes technology diffusion.

The current report section aims at: (a) estimating the carbon content of Austrian trade for the years 1997 and 2004 on the basis of CPB, and thereby, estimating the corresponding carbon balances between exports and imports for the two years under analysis;(b) comparing Austria's CO_2 responsibilities on the basis of CBP and PBP; (c) providing insights about physical dimensions of the carbon leakage problem between the countries comprising Annex I and non-Annex I.

This part of report is organized as follows: the next section gives an overview of Austria's CO_2 responsibilities (from a production perspective) and related socioeconomic indicators along the last three decades. In section 3, foundations of a Multi-Regional Input-Output model are set out in order to estimate CO2 emissions from CBP. Section 4 shows the results, while section 5 presents a discussion and concluding remarks.

2 Antecedents of the case study

The current section describes Austrian CO_2 emissions and macroeconomic indicators for the period between 1970 and 2006. Nonetheless, the analysis is focused mainly on the time period between the years 1990 and 2006 due to international commitments regarding GHG emissions (Kyoto protocol). The amount of Austria's CO_2 emissions has been steadily increasing. In 1970, Austria's CO2 emissions were 46 Mt-CO_2, while between 1990 and 2006 Austria's CO_2 emissions rose from 56.56 million tons of CO_2 (Mt-CO2) to 72.84 Mt-CO_2[1] (see Figure 2-1). This rise represents an increase of 28% (IEA, 2008). The absolute amount of CO_2 emitted is far above the Kyoto protocol target, where the commitment was to reduce CO_2 emissions by 13% with respect to the levels in 1990 by 2008-12. Furthermore, we see that emissions grew even at an increased rate (at an annual average of 1.3% for the time period 1970-1990, while 2% for 1990-2006 respectively).

For the time period between 1970 and 2006, Austria's economy[2] has grown by about 2.5% percent per year. This means that the GDP has almost doubled twice over the span of 36 years. Furthermore, exports are an important driving force of economic growth, as they show an increase of 150% between the years 1990 and 2006, representing around 65% of the GDP in 2006. Concerning Austrian imports, Figure 2-1 shows a similar development as that of exports between 1970 and 1997; but grew somewhat slower thereafter. Thus, international trade represents a substantial component in production and consumption accounts for the small and open economy of Austria.

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[1] CO_2 figures are based on the IEA because it allows us to observe a longer time period than those figures based on the UNFCCC. However, it is important to emphasize that the UNFCCC's report of Austria's CO_2 emissions – due to a more comprehensive coverage – were on average 4.5 Mt-$C0_2$ higher for each of the years 1990-2006 than those reported by IEA.

[2] Austria is one of the 66 high income economies placed 23th according to the gross national income per capita measured in purchasing power parity (World Bank 2008).

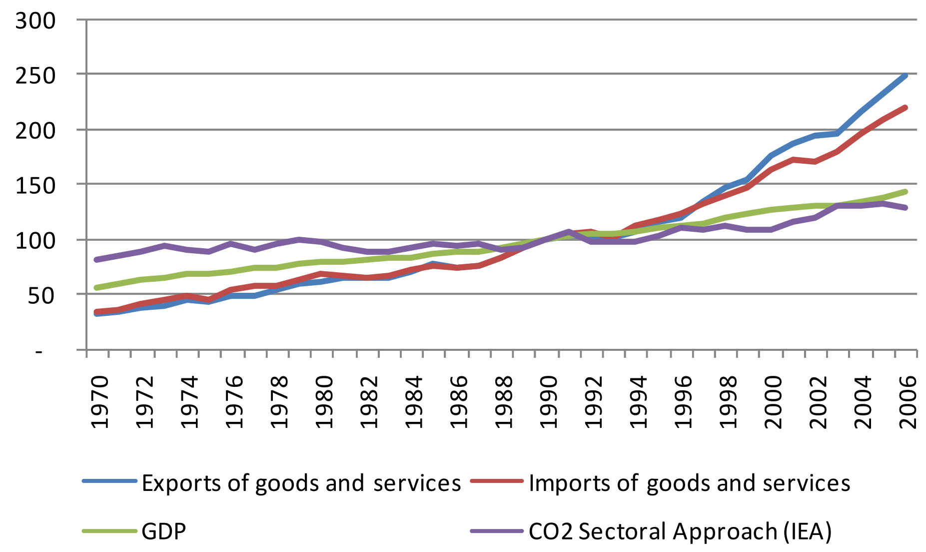


Figure 2-1: CO_2 emissions on the basis of PBP and main macroeconomic aggregates for the years 1970-2006 in Austria (index 1990=100).

Source: IEA (2008) and UNdata (2009).

Note: Original monetary data was expressed in constant 1990 and US dollars.

CO_2 emissions within the Austrian territory have grown at a slower pace than other indicators related to production, such as GDP, exports and imports. Thus, it is possible to observe a tendency towards a relative (but not an absolute) decarbonization of the Austrian economy with respect to GDP in the time period from 1970 to 2006 (See Figure 2-2). Notice that this decarbonization tendency becomes less clear between the years 1990-2006. Furthermore, as can be seen in Figure 2-2, this is partially explained by a relative decrease in the CO_2 emissions per unit of Total Primary Energy Supply (TEPS). Some factors which have contributed to this last decoupling trend refer to the fact that the total amount of coal supplied to the economy has been constant throughout the period under analysis, while the relative participation of gas and, on a smaller scale, of hydropower has increased in total energy supply. In essence, less CO_2 has been emitted per unit of TPES. Concerning CO_2 responsibilities per capita, they have increased over time: in 1970 CO_2 emissions per capita were 6.23 tons of CO_2, in 1990 CO_2 emissions per capita were 8.08 tons CO_2, while in 2006 emissions per capita were 9.33 tons CO_2. It is important to emphasize that the indicators stated above refer to carbon emissions seen from a production perspective only.

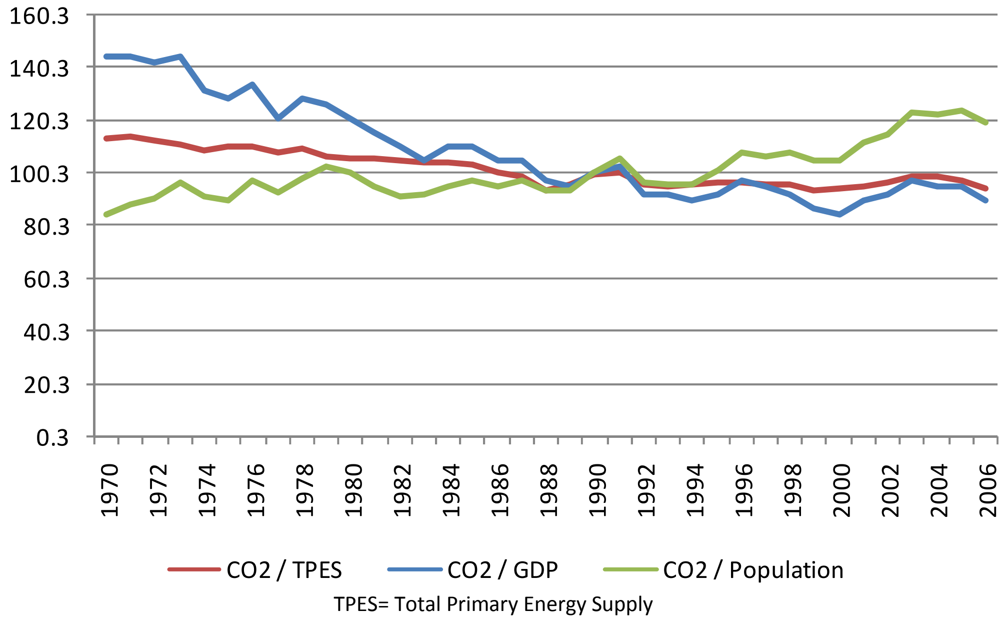


Figure 2-2: Austria's CO_2 intensities for the period 1960-2006 (Index, 1990=100).

Source: IEA (2008)

3 Methodology

A Multi-Regional Input-Output (MRIO) model has been chosen as the framework to be used for accounting CO_2 emissions embodied in the commodity bundle that is needed to satisfy a certain level of consumption for a specific geographic territory. The MRIO competency lies, among others, on the ability of tracing environmental impacts along the production chain, from the consumption side backward to the production side. Thus, one attractive feature of the technique is its ability to establish the production connectedness among sectors and regions.

MRIO models have had a greater appearance in environmental studies done during the last decade[3], for instance see: Ahmad and Wyckoff (2003); Lenzen et al. (2004); Peters and Hertwich (2006); Weber and Matthews (2007); Andrew et al. (2008); Giljum et al. (2008); Peters and Hertwich (2008); Nakano et al. (2008); Wiedmann et al. (2007). In this realm, the above topics mainly refer to: carbon leakage, natural resource use, CO_2 responsibilities, ecological footprint, and household impacts.

MRIO models can, as Lenzen et al. (2004) points out, be classified in three categories: autonomous trade, unidirectional trade, and multidirectional trade models. Autonomous models tend to be – in terms of implementation - the most straightforward approach due to the low data collection requirements; although, they are also the most restrictive types of model considering that the underlying assumption states that the import commodities are produced with the same technology and production structure as that of the importing country. This assumption is considered usually unrealistic given the high degree of heterogeneous trading partners which are involved in the world trade system (see for example Machado, 2001; Muñoz et al., in press; among others).

Alternatively, by means of unidirectional models (see for example Ahmad and Wyckoff, 2003; Peters and Hertwich, 2006; Nakano et al., 2008) it is also possible to trace commodities (and the emissions embodied in them) back to the producing region, which accounts for its own technology and economic structure. However, CO_2 multipliers only consider emissions emitted in the exporter country, and neglect emissions embodied in commodities that stem from of a

[3] For an extensive review about MRIO models, we refer to Wiedmann et al. (2007) and Wiedmann (2009).

third region and that are used as intermediate inputs in export commodities. This model leads, in general, to an underestimation of the CO_2 multipliers.

Finally, a multidirectional trade model considers a full feedback loop trade across world regions induced by the consumer wants of a specific country. Thus, if the domestic consumption increases for a certain quantity (Austrian consumption in this case), domestic CO_2 multipliers and international trade CO_2 multipliers estimate the total CO_2 responsibilities of this change in consumption level along the whole production process, across geographical borders and industries. Domestic CO_2 multipliers account for the environmental impacts in the region where the commodity was produced and consumed. International trade CO_2 multipliers account for the CO_2 responsibilities abroad, due to both production abroad and imports to the country abroad for intermediate use, with the latter further traced back until the ultimate country/region of origin and its specific emissions.

Thus, multidirectional trade models offer the closest representation of the international trade system from all three models above because of the explicit modelling of interregional linkages. The current study has therefore adopted this last concept. The model and data will be presented in the following subsection and the results are summarized in the subsequent section. Annex A, however, contains the outcome for all three models tested at an empirical level for this case study, such that the three modelling approaches and their results can be compared for the case of Austria.

3.1 MRIO Framework

MRIO is presented for the case of the two regions - r and s - that exchange commodities in one period of time. Each region produces a certain level of output (x) of industry i. The resulting output vector represents the total commodities supplied by region r and s. From the demand side, commodities supplied are used by regions for intermediate use (z), in industry j, and/or for final demand (y). Thus, the system can be represented by Eq.1:

$$
(1) \qquad \begin{array}{c} x_1^r \\ \vdots \\ x_n^r \\ x_1^s \\ \vdots \\ x_n^s \end{array} = \begin{array}{ccccccccccc}
z_{11}^{rr}+ & \dots & +z_{1n}^{rr} & + & z_{11}^{rs}+ & \cdots & +z_{11}^{rs} & + & y_1^{rr} & + & y_{11}^{rs} \\
\vdots & \ddots & \vdots & & \vdots & \ddots & \vdots & \vdots & \vdots & & \vdots \\
z_{n1}^{rr}+ & \cdots & +z_{nn}^{rr} & + & z_{11}^{rs}+ & \cdots & +z_{11}^{rs} & + & y_n^{rr} & + & y_n^{rs} \\
z_{11}^{sr}+ & \cdots & +z_{1n}^{sr} & + & z_{11}^{ss}+ & \cdots & +z_{1n}^{ss} & + & y_1^{sr} & + & y_{11}^{ss} \\
\vdots & \ddots & \vdots & & \vdots & \ddots & \vdots & \vdots & \vdots & & \vdots \\
z_{n1}^{sr}+ & \cdots & +z_{nn}^{sr} & + & z_{n1}^{ss}+ & \cdots & +z_{nn}^{ss} & + & y_n^{sr} & + & y_n^{ss}
\end{array}
$$

Equation system (1) allows an understanding of the trade[4] interactions between regions and industries. Additionally, it is possible to define the domestic technical coefficients, a_{ij}^{ss} or a_{ij}^{rr}, and interregional technical coefficients, a_{ij}^{rs} or a_{ij}^{sr}, as in Eq.2 and Eq.3 respectively:

(2) $$a_{ij}^{ss} \equiv z_{ij}^{ss} / x_j^s \qquad a_{ij}^{rr} \equiv z_{ij}^{rr} / x_j^r$$

(3) $$a_{ij}^{sr} \equiv z_{ij}^{sr} / x_j^r \qquad a_{ij}^{rs} \equiv z_{ij}^{rs} / x_j^s$$

i.e. the technical coefficients reflect the specific amount of commodity input i necessary to produce one unit of output x_j in region r (s), taking into account the input precedence as well as the place where the output is produced; region r or s. Furthermore, it is possible to reformulate Eq.1 in terms of the regional and interregional technical coefficients by using block matrix notation as in Eq. 4:

(4) $$\begin{pmatrix} \mathbf{x}^r \\ \mathbf{x}^s \end{pmatrix} = \begin{pmatrix} \mathbf{A}^{rr} & \mathbf{A}^{rs} \\ \mathbf{A}^{sr} & \mathbf{A}^{ss} \end{pmatrix} * \begin{pmatrix} \mathbf{x}^r \\ \mathbf{x}^n \end{pmatrix} + \begin{pmatrix} \mathbf{y}^{rr} + \mathbf{y}^{rs} \\ \mathbf{y}^{ss} + \mathbf{y}^{sr} \end{pmatrix}$$

Expressing the outputs as a function of the final demands, and the regional and interregional technical coefficients, the solution of the system in the matrix notation is shown in Eq. (5):

(5) $$\begin{pmatrix} \mathbf{x}^r \\ \mathbf{x}^s \end{pmatrix} = \left(\begin{pmatrix} \mathbf{I} & \mathbf{0} \\ \mathbf{0} & \mathbf{I} \end{pmatrix} - \begin{pmatrix} \mathbf{A}^{rr} & \mathbf{A}^{rs} \\ \mathbf{A}^{sr} & \mathbf{A}^{ss} \end{pmatrix} \right)^{-1} * \begin{pmatrix} \mathbf{y}^{rr} + \mathbf{y}^{rs} \\ \mathbf{y}^{sr} + \mathbf{y}^{ss} \end{pmatrix}$$

Rewriting (5) once again in matrix block notation and multiplying the final demands of each region by the well-known Leontief inverse Eq.6 is obtained:

(6) $$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1} \mathbf{y}^{\bullet r} + (\mathbf{I} - \mathbf{A})^{-1} \mathbf{y}^{\bullet s}$$

where $(\mathrm{I-A})^{-1}$ provides information about the direct and indirect output changes across regions and industries due to changes in the final demand in r or s. Vectors $y^{\bullet r}$ and $y^{\bullet s}$ represent the 'total' final demand - domestic plus imports - of region r and s respectively. Notice that $(\mathrm{I-A})^{-1}.y^{\cdot r}$ accounts for the change in production in both regions due to a change in the final demand of r. The interpretation is similar for region s.

[4] Note that exports from r to s are conceptually equal to imports of s from r. In practice, the statistics tend to differ not only due to transport and taxes, but also due to innate discrepancies in trade statistics.

The model can be extended to CO_2 impacts in this case (or other variables of interest) by pre-multiplying both sides of Eq.(6) by a diagonalized intensity vector of CO_2, $\hat{\mathbf{f}}$, giving sectoral CO_2 emissions divided by sectoral output. The pre-multiplication of the diagonalized CO_2 intensity vector and the Leontief inverse yields CO_2 multipliers, i.e. the total, direct and indirect, increases in CO_2 emissions among industries and regions due to a change in final demand in region *r* (or *s*). The resulting formulation is shown in Eq.7:

(7)
$$\mathbf{f} \equiv \hat{\mathbf{f}}\mathbf{x} = \hat{\mathbf{f}}\,(\mathbf{I} - \mathbf{A})^{-1}\mathbf{y}^{s} + \hat{\mathbf{f}}\,(\mathbf{I} - \mathbf{A})^{-1}\mathbf{y}^{n}$$

where $\mathbf{f}$ is the vector of total $C0_2$ impacts across regions due to the consumption in $y^{\bullet r}$ and/or $y^{\bullet s}$. Additionally, by multiplying the CO_2 multipliers matrix with a diagonalized vector of final demands, column j^{th} of the resulting matrix would give a comprehensive examination of the CO_2 emissions embodied in industry j^{th} by region and sector. Thus, the impacts abroad due to consumption of one region (imports), as for example the *r* region, are given by the sum rows in the rest of the regions (or *s* in this case), whilst CO_2 impacts on region *r* due to exports would be given by analyzing consumption in region *s*. Therefore, it is possible to assign emissions which take place in other regions to the consumption of one region. The extension of the model to more regions is deducted in a straightforward way (for further details see, for example, Miller and Blair, 2009 or Peters, 2004).

3.2 Data

The data base of the Global Trade Analysis Project (GTAP) was used to construct the MRIO model with full linkages. GTAP provides harmonized Input-Output tables by country or country group (multi-country regions in this case) for the world economy. The current study has used GTAP version 7 and GTAP version 5 which are set for the years 2004 and 1997, respectively. Both GTAP versions are homogenous in terms of sectoral disaggregation, consisting of 57 industries per region (see Table 7-4 for sectoral details). These two GTAP versions, however, present a different regional disaggregation: GTAP version 7 gives details for 113 regions, while GTAP version 5 is comprised of 66 regions. Each GTAP version (and therefore each year under analysis) was treated separately with its own regional disaggregation level in order to avoid aggregation bias. Nonetheless, the purpose of comparing results from the two years, once the findings were obtained for the year 2004, leads to the aggregation of these results at the same regional level as those in 1997 so as to compare CO_2 impacts at a regional level for those two years.

Other important issues refer to the construction of bilateral trade matrices and interregional technical coefficients, i.e. the off-diagonal blocks in Eq (4). Regarding these issues, GTAP supplies vectors of sectoral bilateral trade (c) for each pair of the countries by commodity. However, it does not assist with information about how the bilateral trade imports are used by the industries at the intermediate use level or final demand. Hence, the import matrices which are used to allocate the bilateral imports across the industries and the final demand of the importing country have been utilized.

Thus the off-diagonal block matrix is calculated as follows:

$$Z_{ij}^{rs} = c_i^{rs} \hat{m}_i^{-1} M_{ij}^{ss} \text{ and } Z_{ij}^{sr} = c_i^{sr} \hat{m}_i^{-1} M_{ij}^{rr}$$

where $M_{ij}^{\bullet k}$ is the total import matrix of region k (or s and r at the methodological section) by commodity i and industry j; $\hat{m}_i^{-1}$ is the row sum of M ; and c_i^{lk} is the vector of bilateral trade between region l and k, with k, l= 1,2…113 for GTAP V7 and 1,2…..66 for GTAP V5, and k different than l. Since each pair of regional bilateral trade is represented by a block matrix, it is necessary to construct, in the case of GTAP V7 12,656 off-diagonal blocks (113 regions x 113 regions – 113 diagonal blocks). Notice that the diagonal block is formed by the domestic input-output tables of each region, this amount to 113, in the case of GTAP V7. Finally, it is worth mentioning that this procedure leads us to work with about 41 million of entries ((113 regions x 57 sectors) x (113 regions x 57 sectors)) for the multiregional intermediate use matrix see Eq.4. An analogous process was carried out for the year 1997 based on GTAP V5.

GTAP also provides data of CO_2 by sector and region with which it fulfils the model data requirements presented in the previous section. It is also important to mention, however, that GTAP $C0_2$ data refers only to CO_2 emissions from fuel combustion. CO_2 emissions stemming from industrial processes have also been included, more precisely the CO_2 emissions in the following processes for all countries reported by UNFCCC (2009): minerals products, chemical industry and metal production.

4 Results

Results are presented in three different groups. The first group provides aggregate evidence of the CO_2 responsibilities based on the consumption perspective. These results are compared with those figures derived from applying the production-based principle. Further macro indicators such as emissions embodied in exports, imports, and CO_2 per capita, are also shown. Subsequently, results concerning emissions embodied in trade are disaggregated according to the regions where the CO_2 emissions occurred. A similar analysis is carried out for exports, describing the regions that evoke CO_2 emissions in Austria through international trade. Finally, the analysis given presents and compares both, emissions embodied in the final demand sectors which drive the emissions in the domestic territory as well as abroad, and those sectors more affected by consumption in Austria and other regions across the world.

4.1 A Production-based Principle versus a Consumption-Based Principle

In order to allocate the CO_2 responsibilities according to the level and composition of consumption, it is necessary to reattribute embodied environmental impacts associated with exports to foreign countries, and to add to domestic environmental responsibilities those impacts which take place abroad but satisfy – via imports – the local consumer needs. Results of this procedure carried out for the two years under analysis (1997 and 2004) are presented in Table 4-1. It is interesting to note that the domestic CO_2 emissions embodied in consumption increased by 5% between the years under study. However, the consumption level increased by about 11% between the years 1997 and 2004.

The study allows us to observe a relative decoupling trend between consumption and CO_2 emissions at domestic level. However, the carbon content of imports which are necessary to satisfy consumer needs in Austria represents a large fraction of the total impacts: Imports embodied emissions of 44 Mt-CO_2 in 1997 and 62 Mt-CO_2 in 2004, i.e. if the Austrian final consumption increases by one unit, then, taking the year 2004 as the reference period, around two thirds of the CO_2 impact of this unit would take place abroad. As a result, CO_2 emissions embodied in imports for consumption are a crucial phenomenon for understanding CO_2 responsibilities and decarbonization trends.

Regarding the origin of the emissions embodied in imports, it is important to mention that about one fourth (10 Mt-CO_2) of them were originated in non-Annex I countries in 1997. This proportion increased in the year 2004: emissions emitted in non-Annex I countries and triggered by consumers in Austria reached about one third (21 Mt-CO_2) of the total emissions embodied in imports. These totals are an indicator of the carbon leakage for Austria and a measure of Austria's $C0_2$ responsibilities in countries without emissions constraints. This carbon leakage indicator is usually presented as a percentage of the emissions accounted for under the PBP. In that case, a carbon leakage of 15% and 25% for the years 1997 and 2004, respectively. The difference between the total emissions embodied in imports and those originated in non-Annex I countries were emitted in Annex I countries (see Table 4-1).

Table 4-1: Austria's CO_2 responsibilities: Emissions embodied in different categories (in thousands of tons of CO_2).

Categories and Indicators \Year	1997	2004
Domestic Consumption	44,314	47,780
Consumption in products domestically produced	27,695	29,153
Household (direct consumption)	16,619	18,627
Exports	22,943	31,800
Exports Domestically produced	20,483	27,558
Exports of International Transport	2,460	4,242
Imports (for Austrian Consumption)	44,366	61,988
Imports coming from Annex I countries	34,343	41,408
Imports coming from Non-Annex I countries	10,023	20,581
Imports of International Transport	Not available	Not available
Indicators		
Net Emission Balance (excluding Int. Transport)	- 23,884	- 34,430
Consumption-Based Principle (CBP)	88,680	109,768
Production-Based Principle (PBP)	67,257	79,580
Ratio CBP/PBP	1.32	1.38
CO_2 Emissions per capita based on PBP (*in tons*)	8.44	9.74
CO_2 Emissions per capita based on CBP (*in tons*)	11.13	13.42

Note: Emission data on the PBP in this table is based upon process emission data and fuel combustion emission data, whereas emission data given in section 2 is based on fuel combustion emissions only (IEA, 2008), as IEA supplies a significantly longer time series. Emission data on process emissions is taken from UNFCCC, on fuel combustion emissions from GTAP, with the latter at values between the ones of IEA and UNFCCC.

The export carbon content showed an increase of 9 Mt-CO_2 (39%) from 1997 to 2004, or seen in absolute levels, the emissions embodied in exports (EEE) rose from about 23 Mt-CO_2 to about 32 Mt-CO_2. These changes can be explained by an increase in exports of (international) transport which doubled between 1997 and 2004; while the EEE of commodity production shows an increase of 7 Mt-CO_2 (39%) (see Table 4-1). It is interesting to note that the volume of exports grew by 56% between the years 1997 and 2004 (see Table 4-1).

Furthermore, for the period between 1997 and 2004, Austrian CO_2 emissions increased by about 12 Mt (18%) based on the PBP[5], that is an increase from 67 Mt-CO_2 to 79 Mt-CO_2. If emissions are accounted for from the consumption perspective, it is found that emissions rose from 89 Mt-CO_2 to 110 Mt-CO_2 on the consumption basis, representing this as an increase of 24%. Thus, it does certainly matter in the case of Austria whether emissions are measured on the production or consumption basis. Accounting for emissions on the CBP leads to results which are 32% larger than those derived from PBP in 1997. This share has been increasing over time: in 2004 the ratio was already 38%. Indicators of CO_2 emissions per capita based on a CBP suggest adding up four million tons per capita in comparison with production based indicators. For instance, in 2004 the CO_2 emissions per capita were 9 tons of CO_2 and 13 tons of CO_2 for the PBP and CBP, respectively. Further details are displayed in Table 4-1.

Moreover, the estimates carried out for Austria's CO_2 emissions from a consumption perspective lie in a similar range as the ones of other studies. For example, Peters and Hertwich (2008b) estimated Austrian emissions embodied in consumption to be 95.9 Mt-CO_2 in the year 2001[6], whilst estimates by Nakano et al. (2008) refer to 92 Mt-CO_2 for the year 2000.

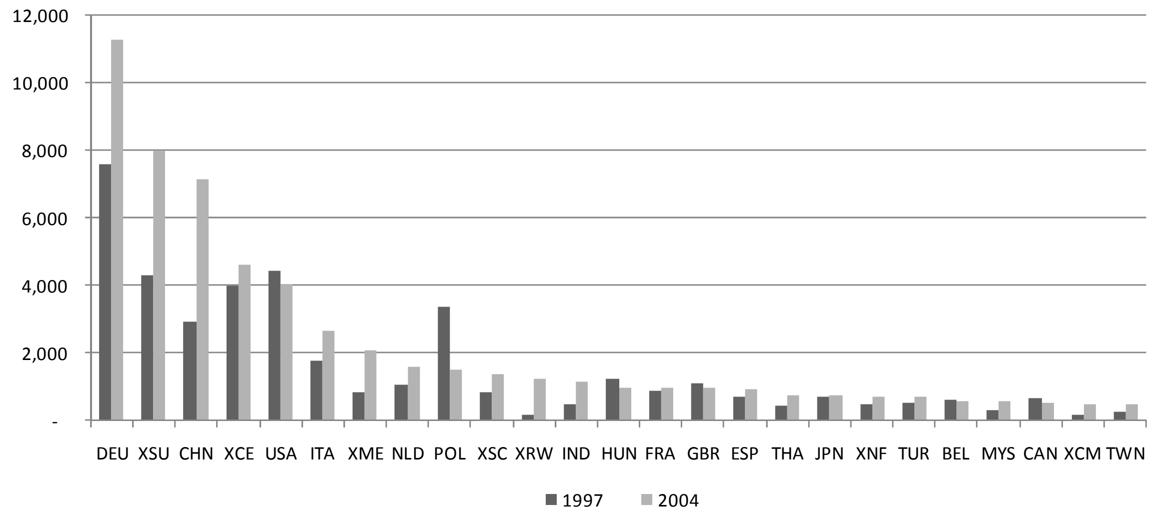
4.2 Geographical Analysis

4.2.1 Regions affected by Austria's consumption

Figure 4-1 shows the top 25 regions where emissions are related to Austrian consumption in the years 1997 and 2004. This represents 90% of all emissions embodied in Austrian imports. In general, the analysis exhibits that the regions which are geographically closer, and especially Germany (DEU), are also the most affected. It is worth mentioning the fast rising trend of the Former Soviet Union (XSU) and China (CHN) representing the top 2 and top 3 origins of the CO_2 emissions. These two regions represent 4% and 3% of all emissions in 1997, while in 2004 they already account for about 12% and 11%, respectively, of the total emissions abroad. Other countries are now listed further down in the ranking of the most impacted regions. The CO_2 emissions assigned to consumption in Austria significantly decreased, as is the case for Poland (POL) and United States (USA) (see Table 7-2 for further details).

[5] This amount is irrespective of source, see UNFCCC (2009) or IEA (2008).

[6] Although this study and Peters and Hertwich (2008b) have used the same data base, GTAP database version 6, differences may originate due to some data replacement with regard to the present work, e.g. different vectors of CO_2 and different input-output tables for some countries as those supplied by GTAP.



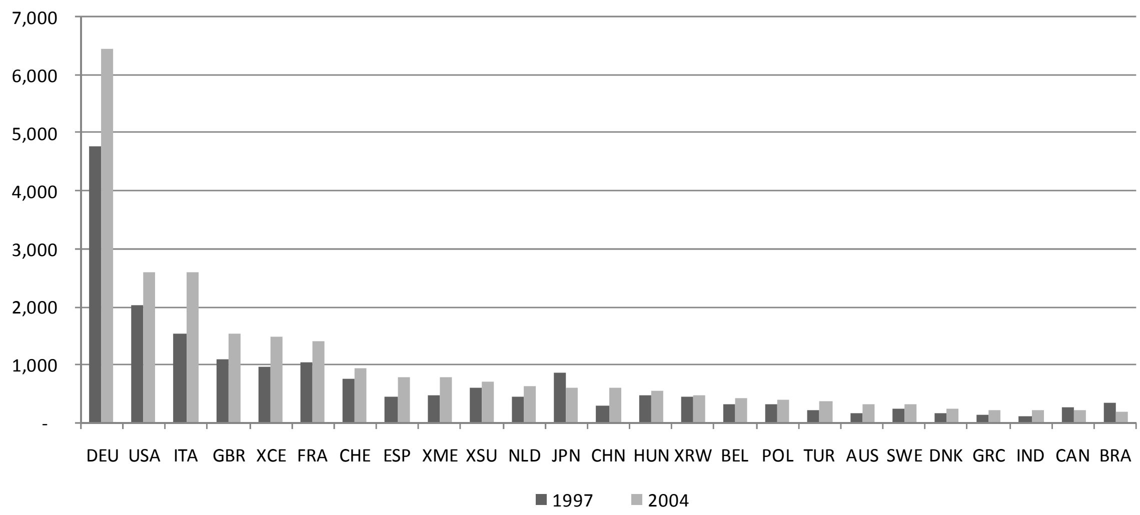
DEU = Germany; XSU = Former Soviet Union; CHN = China; XCE = Rest of Central European Associates; USA = United States of America; ITA = Italy; XME = Rest of Middle East; NLD = Netherlands; POL = Poland; XSC = Rest of South African Customs Union; XRW = Rest of World; IND = India; HUN = Hungary; FRA = France; GBR = United Kingdom; ESP = Spain; THA = Thailand; JPN = Japan; XNF = Rest of North Africa; TUR = Turkey; BEL = Belgium; MYS = Malaysia; CAN = Canada; XCM = Central America and the Caribbean; TWN = Taiwan;

Figure 4-1: CO_2 flows embodied in Austria's imports per region in the year 1997 and 2004 in thousands of tons

Note: The imports of 2004 served as a criterion for the ranking of the different regions.

4.2.1.1 Regional drivers of Austria's CO_2 emissions embodied in exports

The analysis also allows identifying those regions whose consumption mainly induces the discharge in CO_2 emissions within the Austrian borders. The top 25 regions are depicted in Figure 4-2, while the full range of regions is shown in Table 7-3. In general, final CO_2 responsible regions do not change much along the years being studied, apart from an increase in Austrian CO_2 responsibility of Germany, Italy, and China, and the decreases of that of Japan.



DEU = Germany; USA = United States of America; ITA = Italy; GBR = United Kingdom; XCE = Rest of Central European Associates; FRA = France; CHE = Switzerland; ESP = Spain; XME = Rest of Middle East; XSU = Former Soviet Union; NLD = Netherlands; JPN = Japan; CHN = China; HUN = Hungary; XRW = Rest of World; BEL = Belgium; POL = Poland; TUR = Turkey; AUS = Australia; SWE = Sweden; DNK = Denmark; GRC = Greece; IND = India; CAN = Canada; BRA = Brazil.

Figure 4-2 CO_2 flows embodied in Austria's exports per region in the year 1997 and 2004 (in thousands of tons)

Note: The exports of 2004 served as a criterion for the ranking of the different regions.

4.3 Sectoral Analysis

4.3.1 CO_2 drivers at sectoral level

One of the advantages of the MRIO models lies in the ability to estimate CO_2 emissions embodied across industries and regions. Figure 4-3 presents CO_2 emissions embodied in the top 15 commodity groups (or industries) consumed in Austria in the year 2004, distinguishing, at the same time, whether CO_2 emissions took place in Austria or in the rest of the world. These 15 (out of 57) commodity groups explain 82% of the emissions based on the consumption principle, which represents a total amount of 91 Mt-CO_2[7]. Consistent with Table 4-1, the larger part of the impacts takes place abroad at a sectoral level, with the exception of electricity, whose CO_2 emissions dominate of domestic origin (see Table 7-4 for details).

[7] It is worth noting that these figures only account for emissions embodied in products. This implies that it is still necessary to consider the sectoral analysis of those sectors which supply directly to the residential household, as for instance, electricity. Therefore, adding the 91 Mt-CO_2 and the 19 Mt-CO_2 caused by households, the 110 reported by the PBP indicator are obtained (see table 4-1).

By contrast, Figure 4-4 represents the top 15 commodities (81% of emissions embodied in exports (EEE)) which are consumed in the rest of the world but which induce emissions in Austria. Note the much lower absolute levels depicted for exports of sectors.

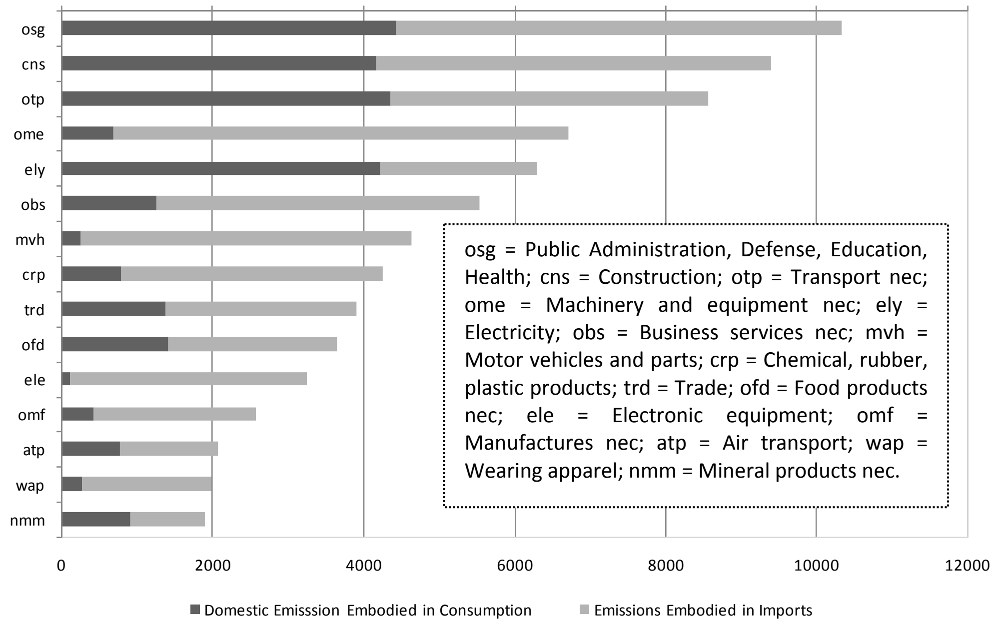


Figure 4-3: Emissions embodied in Austria's final domestic consumption by sectors and place of origin, domestic or foreign territory in 2004 (in thousands of tons)

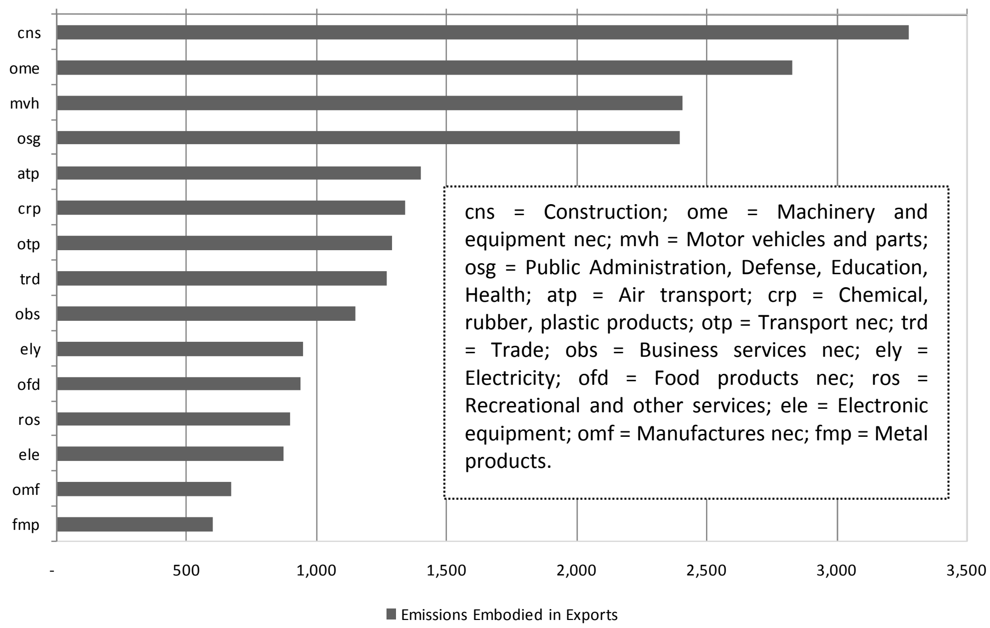


Figure 4-4: Domestic emissions embodied in the top 15 exports in 2004 (in thousands of tons of CO_2)

4.3.2 Affected sectors due to domestic and foreign final demand

We now shed light on those industries in the Austrian economy which are mainly affected by domestic and foreign consumption. First, by focusing on the production side, we can see to which extent sectoral emissions are induced by domestic consumption and exports, respectively. Second, those sectors abroad that are most (emission) burdened by consumption in Austria are depicted.

Figure 4-5 shows the top 15 sectors that are most affected by domestic consumption and export. These 15 industries comprise 93% (53 Mt) of the CO_2 emissions emitted in Austria due to consumption and exports. There is a similar pattern in the sectors affected by domestic consumption and exports. At a sectoral level one can observe that of the CO_2 emissions of the top sector, electricity, the majority (around 61%) are due to domestic needs. Similar patterns are observed for the sectors of public administration, defense, education, health (osg), construction (cns), and food products (ofd). On the other hand, the emissions in the sectors ranked third, fifth, seventh and fifteenth (Ferrous metals (i_s); air transport (atp); chemical, rubber, plastic products (crp); and machinery and equipment (ome)), were predominantly caused in the production of exported goods and services (see Table 7-4 for full details of all sectors).

Finally, Figure 4-6 displays the top 15 industries abroad that are most affected by Austrian consumption, which concentrate 93% of the total emissions embodied in imports (for further details see Table 7-4).

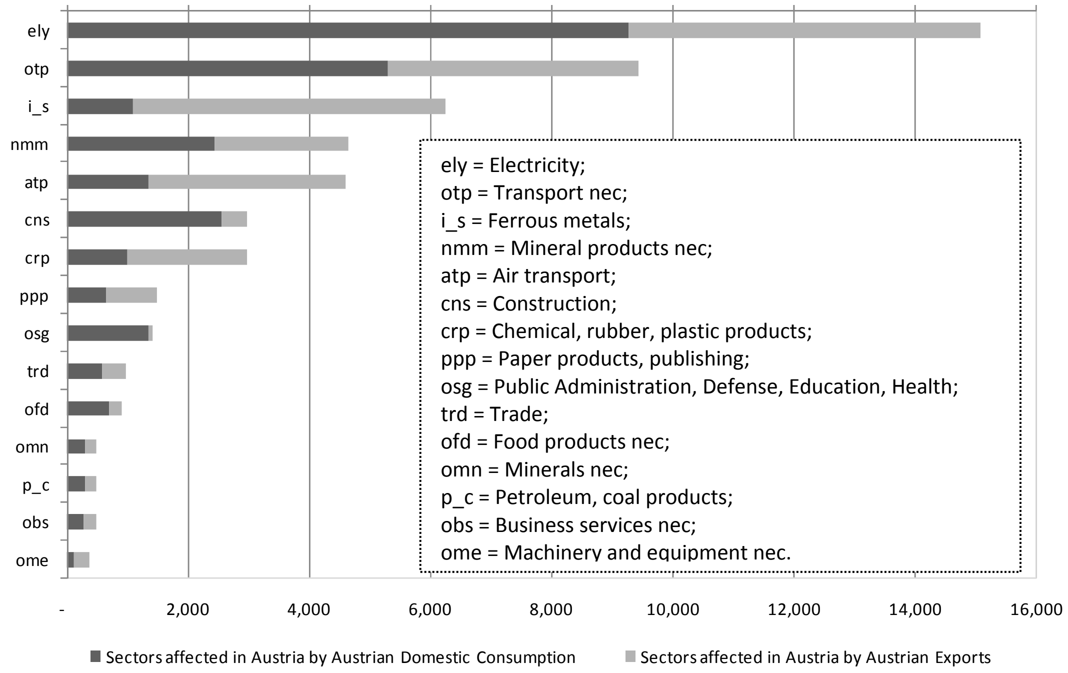


Figure 4-5 Top 15 sectors most affected by domestic consumption and exports (in thousands of tons)

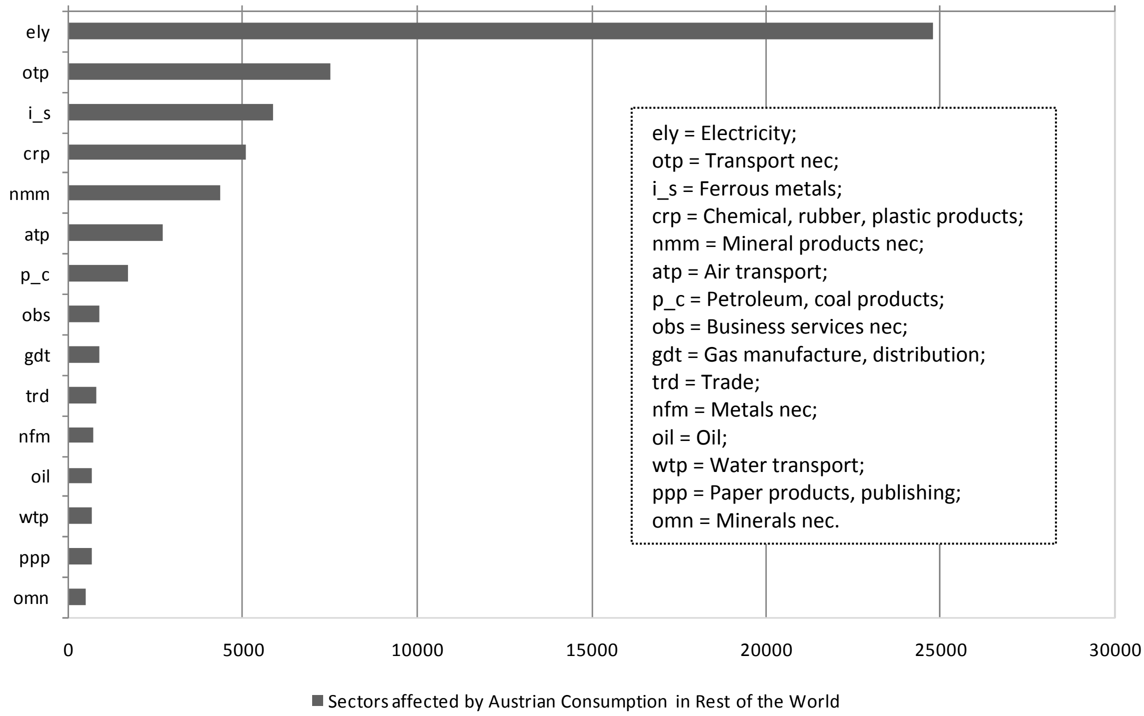


Figure 4-6: Top 15 of the most affected industries abroad due to Austrian final consumption (in thousands of tons)

4.3.3 Global Path Analysis in a Service Sector

So far the commodities which embodied the largest amounts of CO_2 emissions as well as the most affected regions and sectors have been identified. This section additionally analyzes the consumption impact of a specific commodity group in Austria on the rest of the world, differentiating the regional and sectoral level. With regard to the commodity group, the public service sector, 'Public Administration, Defense, Education, Health' (OSG), has been chosen since this is the service sector that embodied the largest amount of CO_2 in imports. One interesting reason for investigating this industry is the fact that a service sector usually has a very low direct CO_2 intensity, however, it may bear large quantities of CO_2 when the complete supply chain is considered, including the indirect effects. The scale effect, i.e. the large share of the OSG sector in the total final demand, is another relevant variable for understanding its large CO_2 impacts.

In 2004, the OSG sector embodied 5.9 Mt-CO_2. This is almost 10% of all emissions embodied in Austrian imports (see Table 4-1). The detailed picture of the global path in terms of regions and sectors affected due to final demand of the national OSG is presented in Figure 4-7. The analysis reveals that most of the emissions are explained by the electricity sector which is heavily affected, independent of the region of origin. Other affected industries (albeit at different scale varying across regions) are mainly: Transport, Chemicals, Rubber, Plastic products; Ferrous metals and Mineral products (see Figure 4-7).

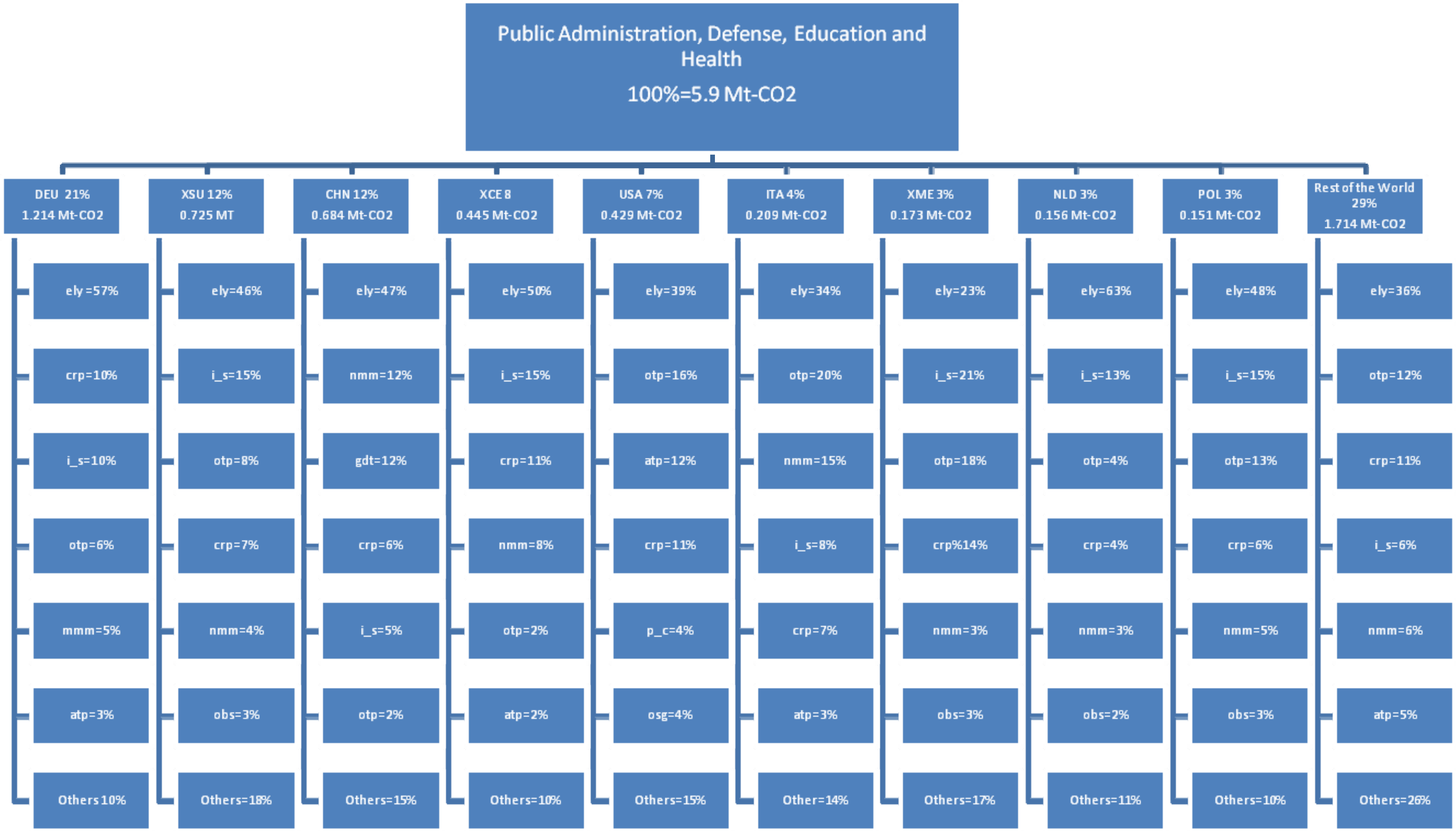


Figure 4-7: Global path at regional and sectoral level for the public service sector, which embodied the largest amount of C0$_2$ of the imported commodities

Note: Regions: DEU = Germany; XSU = Former Soviet Union; CHN = China; XCE = Rest of Central European Associates; USA = United States of America; ITA = Italy; XME = Rest of Middle East; NLD = Netherlands; POL = Poland. Sectors: ely = Electricity; otp = Transport nec; i_s = Ferrous metals; crp = Chemical, rubber, plastic products; nmm = Mineral products nec; atp = Air transport; p_c = Petroleum, coal products; obs = Business services nec; gdt = Gas manufacture, distribution; oil = Oil; wtp = Water transport; ppp = Paper products, publishing; omn = Minerals nec.

5 Discussion and final comments

One of the characteristics of the greenhouse effect refers to the fact that no matter in which geographical region emissions occur, all GHGs contribute to climate and global change. Unilaterally implementing mitigation policies on climate change could partially be causing import substitution or relocating energy intensive firms due to competitiveness loss of domestic producers. This fact should force to assess the effectiveness of domestic climate change mitigation policies beyond the geographical borders of a country.

Present carbon leakage estimates, as accounted for in this part of the report by following the most recent methods to identify emissions embodied in trade, indicate that one-third of the emissions embodied in Austrian imports were originated in non-Annex I countries in 2004. It is important to note that the above carbon leakage indicator is not solely explained by unilateral climate change policies. There may be other factors, such as a lower wages or the availability of specific physical resources in non-Annex I parties, which make the production abroad more profitable. The indicator reflects the amount of emissions which is Austria, an Annex I country, responsible for, but which are not subject to any regulation within the UNFCCC accounting framework yet.

A strong suggestion in this realm refers to a change towards GHG accounting inventories based on a consumption perspective. As Peters and Hertwich (2008a) argue, one way to overcome the carbon leakage problem is to use consumption-based GHG inventories. Other advantages of this approach over production-based inventories are to reduce the importance of emission commitments for developing countries, increase options for mitigation, encourage environmental comparative advantage, address competitiveness concerns, and naturally encourage technology diffusion (Peters and Hertwich 2008a).

Alternatively, a part of the literature has been focused on the idea of introducing a carbon price border adjustment (BA) policy so as to avoid the carbon leakage; i.e. to introduce a tax according to the carbon content of imported goods from countries without strict GHG commitments (non-Annex I parties) (see Reinaud, 2008 and Dröge, 2009). This measure is somehow oriented to protect potential competitive losses in the domestic industry, preventing at the same time from inefficient relocations. A weaker suggestion to avoid the carbon leakage problem has been derived from this approach, which refers to the use of a dual physical border adjustment policy. Border adjustment could not only be used as a policy instrument to correct potential competitive losses, but it can also be used as an instrument to account for the emissions responsibilities of GHG embodied in imports coming from non-Annex I countries. Notice that emissions inventories are still based on the PBP and total CO_2 responsibilities across the world are not fully accounted for while exports are still the responsibility of the exporter country. Nevertheless, this physical border adjustment policy of emission flows is focussed on the carbon leakage as defined in this section of the report. Emissions embodied in commodities coming from non-Annex I are the relevant issue, since their emission responsibilities are not subject to any international regulation yet, although they are actually in the responsibility of an Annex I party (i.e. in the responsibility of an Annex I country consumption). This approach does not focus on the rest of the emissions embodied in imports coming from Annex I countries nor on exports because they are somehow regulated. Therefore, GHG responsibilities would stop once the emissions based on PBP plus emissions embodied from non-Annex I countries are accounted for, which is therefore including carbon leakage.

The currently increasing globalization process, the pervasive character of the climate change phenomenon, the minor historical per capita responsibilities by middle and low income economies, and hence, their limited participation in global environmental commitments, are some of the relevant factors which turn the climate change problem into a complex issue. The figures presented here confirm that unilateral regional initiatives and commitments might fall short of the targets due to the displacement of emissions, using as a reference an indicator based only on production. As it has been shown for Austria, a small and very open economy, the accounting principle used does matter when assigning carbon responsibilities. Therefore, in order to have a better picture of CO_2 responsibilities it is crucial to take into consideration the relevant aspects resulting from a consumption perspective analysis where countries' environmental responsibilities go beyond their geographical borders.

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7 Annex

Table 7-1: Multidirectional, uni-directional, and autonomous models applied to the Austrian case for the year 2004. GTAP V7 was used

Emissions Embodied in Different Final Demand Categories\Models	Multi-Directional Trade (EX)	Uni-Directional Trade (EX)	Autonomous-Trade (EX)
Domestic Consumption	**45,006**	**44,839**	**44,839**
Consumption in products	26,379	26,212	26,212
Household (direct consumption)	18,627	18,627	18,627
Exports	**50,580**	**40,268**	**31,630**
Exports Domestically produced	21,715	22,406	22,406
Exports of International Transport	3,658	3,654	3,654
Exports for Trans. Of other regions	519		
Imports for Exports	24,688	17,862	9,224
Imports	**80,961**	**54,152**	**30,788**
Imports for Austrian Consumption	54,442	36,290	21,564
Imports of International Transport			
Imports for exporting Trans.	1,831	included above	included above
Imports for Exports	24,688	17,862	9,224
PBP	70,898	70,899	70,899
CBP	99,448	84,783	66,403

Table 7-2 CO_2 flows embodied in Austrian imports per region for the years 1997 and 2004 in thousands of tons

Ranking	Regions \CO2 Flows	1997		2004	
		Thousands of tonnes	%	Thousands of tonnes	%
1	Germany	7,580	17.08%	11,294	18.22%
2	Former Soviet Union	4,294	9.68%	8,003	12.91%
3	China	2,917	6.57%	7,142	11.52%
4	Rest of Central European Associates	4,011	9.04%	4,608	7.43%
5	United States of America	4,459	10.05%	4,054	6.54%
6	Italy	1,794	4.04%	2,651	4.28%
7	Rest of Middle East	859	1.94%	2,076	3.35%
8	Netherlands	1,067	2.41%	1,598	2.58%
9	Poland	3,385	7.63%	1,498	2.42%
10	Rest of South African Customs Union	838	1.89%	1,395	2.25%
11	Rest of World	178	0.40%	1,247	2.01%
12	India	502	1.13%	1,177	1.90%
13	Hungary	1,261	2.84%	997	1.61%
14	France	883	1.99%	989	1.60%
15	United Kingdom	1,107	2.50%	964	1.56%
16	Spain	690	1.56%	914	1.48%
17	Thailand	446	1.00%	770	1.24%
18	Japan	721	1.62%	749	1.21%
19	Rest of North Africa	509	1.15%	730	1.18%
20	Turkey	512	1.15%	694	1.12%
21	Belgium	631	1.42%	588	0.95%
22	Malaysia	319	0.72%	566	0.91%
23	Canada	646	1.46%	546	0.88%
24	Central America and the Caribbean	188	0.42%	499	0.81%
25	Taiwan	272	0.61%	499	0.80%
26	Indonesia	280	0.63%	498	0.80%
27	Korea	446	1.00%	449	0.72%
28	Brazil	88	0.20%	417	0.67%
29	Australia	304	0.69%	346	0.56%
30	Finland	263	0.59%	327	0.53%
31	Rest of Sub-Saharan Africa	182	0.41%	276	0.45%
32	Rest of EFTA	136	0.31%	271	0.44%
33	Greece	198	0.45%	251	0.41%
34	Switzerland	175	0.39%	241	0.39%
35	Ireland	130	0.29%	240	0.39%
36	Mexico	212	0.48%	227	0.37%
37	Sweden	198	0.45%	200	0.32%
38	Vietnam	59	0.13%	192	0.31%
39	Argentina	39	0.09%	192	0.31%
40	Portugal	165	0.37%	183	0.30%
41	Hong Kong	53	0.12%	170	0.27%
42	Denmark	271	0.61%	149	0.24%
43	Philippines	177	0.40%	133	0.21%
44	Singapore	400	0.90%	126	0.20%
45	Chile	63	0.14%	125	0.20%
46	Rest of South Asia	69	0.15%	114	0.18%
47	Venezuela	77	0.17%	114	0.18%
48	Morocco	38	0.09%	99	0.16%
49	Luxembourg	36	0.08%	74	0.12%
50	Colombia	39	0.09%	50	0.08%
51	Peru	16	0.04%	42	0.07%
52	Rest of Andean Pact	20	0.04%	42	0.07%
53	New Zealand	45	0.10%	34	0.05%
54	Zimbabwe	26	0.06%	30	0.05%
55	Bangladesh	17	0.04%	29	0.05%
56	Sri Lanka	32	0.07%	23	0.04%
57	Rest of South America	6	0.01%	15	0.02%
58	Other Southern Africa	18	0.04%	12	0.02%
59	Botswana	2	0.01%	11	0.02%
60	Tanzania	3	0.01%	11	0.02%
61	Uruguay	9	0.02%	10	0.02%
62	Uganda	3	0.01%	6	0.01%
63	Mozambique	3	0.01%	5	0.01%
64	Zambia	3	0.01%	4	0.01%
65	Malawi	1	0.00%	2	0.00%
66	Austria	-	0.00%	-	0.00%

Table 7-3: CO_2 flows embodied in Austrian exports per region for the years 1997 and 2004 in thousands of tons

Ranking	Regions \CO2 Flows	1997		2004	
		Thousands of tonnes	%	Thousands of tonnes	%
1	Germany	4,782	23.35%	6,443	23.38%
2	United States of America	2,035	9.94%	2,589	9.39%
3	Italy	1,527	7.45%	2,588	9.39%
4	United Kingdom	1,097	5.35%	1,531	5.55%
5	Rest of Central European Associates	969	4.73%	1,482	5.38%
6	France	1,045	5.10%	1,413	5.13%
7	Switzerland	740	3.62%	933	3.39%
8	Spain	429	2.09%	789	2.86%
9	Rest of Middle East	464	2.27%	784	2.84%
10	Former Soviet Union	602	2.94%	702	2.55%
11	Netherlands	429	2.09%	620	2.25%
12	Japan	859	4.20%	596	2.16%
13	China	280	1.37%	588	2.13%
14	Hungary	472	2.30%	544	1.97%
15	Rest of World	440	2.15%	474	1.72%
16	Belgium	300	1.46%	408	1.48%
17	Poland	299	1.46%	395	1.43%
18	Turkey	196	0.95%	371	1.35%
19	Australia	164	0.80%	315	1.14%
20	Sweden	234	1.14%	301	1.09%
21	Denmark	161	0.78%	225	0.81%
22	Greece	137	0.67%	218	0.79%
23	India	108	0.52%	212	0.77%
24	Canada	255	1.25%	212	0.77%
25	Brazil	340	1.66%	192	0.70%
26	Rest of Sub-Saharan Africa	93	0.46%	173	0.63%
27	Rest of North Africa	143	0.70%	173	0.63%
28	Rest of South African Customs Union	87	0.42%	170	0.62%
29	Central America and the Caribbean	54	0.26%	163	0.59%
30	Rest of EFTA	161	0.79%	147	0.53%
31	Portugal	130	0.64%	140	0.51%
32	Korea	172	0.84%	134	0.49%
33	Hong Kong	116	0.56%	131	0.48%
34	Ireland	61	0.30%	125	0.46%
35	Finland	98	0.48%	121	0.44%
36	Thailand	110	0.54%	121	0.44%
37	Mexico	105	0.51%	106	0.38%
38	Singapore	87	0.43%	105	0.38%
39	Rest of South Asia	23	0.11%	94	0.34%
40	Indonesia	114	0.56%	93	0.34%
41	Taiwan	83	0.40%	90	0.33%
42	Luxembourg	18	0.09%	77	0.28%
43	Malaysia	63	0.31%	58	0.21%
44	Argentina	97	0.47%	53	0.19%
45	Vietnam	15	0.07%	41	0.15%
46	Colombia	35	0.17%	37	0.13%
47	Venezuela	34	0.17%	36	0.13%
48	Morocco	21	0.10%	35	0.13%
49	Philippines	52	0.26%	35	0.13%
50	New Zealand	32	0.16%	30	0.11%
51	Chile	28	0.14%	29	0.10%
52	Peru	16	0.08%	21	0.08%
53	Rest of Andean Pact	12	0.06%	19	0.07%
54	Sri Lanka	3	0.01%	16	0.06%
55	Bangladesh	11	0.06%	16	0.06%
56	Rest of South America	4	0.02%	7	0.03%
57	Tanzania	5	0.03%	7	0.03%
58	Uruguay	8	0.04%	7	0.02%
59	Other Southern Africa	6	0.03%	6	0.02%
60	Botswana	2	0.01%	5	0.02%
61	Zambia	1	0.01%	4	0.02%
62	Mozambique	2	0.01%	3	0.01%
63	Uganda	4	0.02%	3	0.01%
64	Zimbabwe	14	0.07%	2	0.01%
65	Malawi	1	0.01%	1	0.00%
66	Austria	-	0.00%	-	0.00%

Table 7-4: CO_2 drivers at sectoral level and affected sectors due to domestic and foreign final demand in 2004

Cod. Gtap	Regions \CO2 Flows	CO2 Emissions Embodied In						Sectors Affected In					
		Domestic Consumption		Exports		Imports		Austria by Austrian Domestic Consumption		Austria by Austrian Exports		Rest of the World by Austrian Consumption	
		Th. of t.	%	Th. of t.	%	Th. of t.	%	Th. of t.	%	Th. of t.	%	Th. of t.	%
1	Paddy rice	0	0.00%	1	0.00%	1	0.00%	0	0.00%	0	0.00%	7	0.01%
2	Wheat	33	0.11%	27	0.10%	11	0.02%	74	0.25%	116	0.42%	35	0.06%
3	Cereal grains nec	17	0.06%	25	0.09%	30	0.05%	27	0.09%	28	0.10%	49	0.08%
4	Vegetables, fruit, nuts	120	0.41%	116	0.42%	386	0.62%	85	0.29%	23	0.08%	176	0.28%
5	Oil seeds	4	0.01%	8	0.03%	37	0.06%	4	0.01%	6	0.02%	51	0.08%
6	Sugar cane, sugar beet	0	0.00%	2	0.01%	0	0.00%	25	0.09%	9	0.03%	9	0.01%
7	Plant-based fibers	12	0.04%	12	0.04%	97	0.16%	7	0.02%	1	0.00%	44	0.07%
8	Crops nec	102	0.35%	54	0.20%	175	0.28%	127	0.44%	57	0.21%	147	0.24%
9	Bovine cattle, sheep and goats, horses	13	0.05%	18	0.07%	11	0.02%	45	0.16%	23	0.08%	23	0.04%
10	Animal products nec	45	0.15%	46	0.17%	59	0.09%	76	0.26%	36	0.13%	79	0.13%
11	Raw milk	86	0.29%	30	0.11%	63	0.10%	77	0.27%	19	0.07%	27	0.04%
12	Wool, silk-worm cocoons	0	0.00%	3	0.01%	2	0.00%	0	0.00%	0	0.00%	6	0.01%
13	Forestry	40	0.14%	14	0.05%	58	0.09%	81	0.28%	94	0.34%	107	0.17%
14	Fishing	11	0.04%	20	0.07%	28	0.05%	6	0.02%	1	0.00%	64	0.10%
15	Coal	0	0.00%	2	0.01%	7	0.01%	-	0.00%	-	0.00%	174	0.28%
16	Oil	0	0.00%	0	0.00%	0	0.00%	39	0.13%	23	0.08%	671	1.08%
17	Gas	0	0.00%	3	0.01%	0	0.00%	0	0.00%	0	0.00%	420	0.68%
18	Minerals nec	49	0.17%	7	0.03%	124	0.20%	293	1.01%	206	0.75%	495	0.80%
19	Bovine meat products	38	0.13%	110	0.40%	78	0.13%	12	0.04%	11	0.04%	15	0.02%
20	Meat products nec	49	0.17%	150	0.54%	229	0.37%	16	0.05%	18	0.07%	30	0.05%
21	Vegetable oils and fats	14	0.05%	62	0.22%	99	0.16%	10	0.04%	13	0.05%	33	0.05%
22	Dairy products	246	0.84%	312	1.13%	398	0.64%	121	0.41%	62	0.22%	51	0.08%
23	Processed rice	1	0.00%	24	0.09%	16	0.03%	1	0.00%	1	0.00%	8	0.01%
24	Sugar	41	0.14%	35	0.13%	54	0.09%	39	0.13%	17	0.06%	21	0.03%
25	Food products nec	1,420	4.87%	936	3.40%	2,242	3.62%	700	2.40%	205	0.75%	243	0.39%
26	Beverages and tobacco products	201	0.69%	407	1.48%	431	0.70%	73	0.25%	79	0.29%	44	0.07%
27	Textiles	236	0.81%	296	1.07%	1,331	2.15%	98	0.33%	105	0.38%	335	0.54%
28	Wearing apparel	276	0.95%	452	1.64%	1,713	2.76%	45	0.16%	18	0.07%	69	0.11%
29	Leather products	95	0.33%	195	0.71%	886	1.43%	21	0.07%	21	0.08%	67	0.11%
30	Wood products	121	0.41%	298	1.08%	491	0.79%	82	0.28%	179	0.65%	100	0.16%
31	Paper products, publishing	563	1.93%	560	2.03%	840	1.36%	660	2.26%	820	2.98%	628	1.01%
32	Petroleum, coal products	246	0.85%	118	0.43%	1,193	1.92%	312	1.07%	187	0.68%	1,678	2.71%
33	Chemical, rubber, plastic products	794	2.72%	1,339	4.86%	3,471	5.60%	1,006	3.45%	1,975	7.17%	5,084	8.20%
34	Mineral products nec	921	3.16%	389	1.41%	985	1.59%	2,436	8.36%	2,226	8.08%	4,311	6.96%
35	Ferrous metals	34	0.12%	176	0.64%	80	0.13%	1,100	3.77%	5,156	18.71%	5,845	9.43%
36	Metals nec	7	0.02%	58	0.21%	94	0.15%	42	0.14%	226	0.82%	680	1.10%
37	Metal products	264	0.90%	598	2.17%	1,298	2.09%	77	0.26%	108	0.39%	271	0.44%
38	Motor vehicles and parts	267	0.92%	2,407	8.73%	4,380	7.07%	75	0.26%	252	0.92%	166	0.27%
39	Transport equipment nec	69	0.24%	410	1.49%	876	1.41%	33	0.11%	137	0.50%	72	0.12%
40	Electronic equipment	123	0.42%	869	3.15%	3,140	5.06%	12	0.04%	31	0.11%	178	0.29%
41	Machinery and equipment nec	691	2.37%	2,829	10.27%	6,028	9.72%	122	0.42%	259	0.94%	476	0.77%
42	Manufactures nec	441	1.51%	668	2.43%	2,144	3.46%	16	0.05%	7	0.03%	134	0.22%
43	Electricity	4,219	14.47%	947	3.44%	2,086	3.37%	9,272	31.80%	5,825	21.14%	24,743	39.92%
44	Gas manufacture, distribution	42	0.14%	20	0.07%	486	0.78%	92	0.31%	53	0.19%	870	1.40%
45	Water	2	0.01%	52	0.19%	18	0.03%	4	0.01%	2	0.01%	92	0.15%
46	Construction	4,166	14.29%	3,280	11.90%	5,237	8.45%	2,551	8.75%	435	1.58%	68	0.11%
47	Trade	1,378	4.73%	1,269	4.60%	2,542	4.10%	590	2.02%	387	1.40%	779	1.26%
48	Transport nec	4,370	14.99%	1,287	4.67%	4,204	6.78%	5,295	18.16%	4,158	15.09%	7,503	12.10%
49	Water transport	5	0.02%	149	0.54%	44	0.07%	23	0.08%	288	1.04%	667	1.08%
50	Air transport	772	2.65%	1,400	5.08%	1,299	2.10%	1,351	4.63%	3,257	11.82%	2,677	4.32%
51	Communication	207	0.71%	166	0.60%	563	0.91%	91	0.31%	39	0.14%	70	0.11%
52	Financial services nec	32	0.11%	165	0.60%	76	0.12%	22	0.07%	18	0.06%	87	0.14%
53	Insurance	118	0.40%	181	0.66%	413	0.67%	7	0.02%	5	0.02%	33	0.05%
54	Business services nec	1,272	4.36%	1,149	4.17%	4,263	6.88%	284	0.97%	196	0.71%	871	1.41%
55	Recreational and other services	425	1.46%	896	3.25%	1,216	1.96%	161	0.55%	56	0.20%	220	0.36%
56	Public Administration, Defense, Education,	4,429	15.19%	2,396	8.70%	5,901	9.52%	1,337	4.59%	84	0.31%	184	0.30%
57	Dwellings	27	0.09%	113	0.41%	57	0.09%	0	0.00%	0	0.00%	0	0.00%
	Total Sectors	29,153	100%	27,558	100%	61,989	100%	29,153	100%	27,558	100%	61,989	100%

C POST KYOTO CLIMATE POLICIES AND THEIR IMPACT ON CARBON CONTENT OF AUSTRIAN TRADE (COMPUTABLE GENERAL EQUILIBRIUM ANALYSIS)

1 Introduction

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 (Germany, Italy, USA, Russia and China), three regional aggregates for the other EU member states, and 11 larger world regions. On the sectoral level, we differentiate between 11 sectors according to their energy intensity. The model is originally calibrated to the base year 2004. Since, however, the climate political targets discussed at the advent of the UNFCCC Copenhagen meeting are all directed towards the achievement period 2020, our analysis focuses also on this commitment period. Accordingly, we construct a business as usual (BAU) scenario for 2020 and compare the impacts of the different policy scenarios to this BAU trend. In our policy analysis, we discuss three types of scenarios:

- A continuation of a unilateral EU climate policy, analytically differentiated into targets for the ETS sectors only (as the current EU ETS) and with additional targets for non-ETS sectors and households, reflecting the EU 20-20 targets (European Commission, 2008)
- A *voluntary* Post-Kyoto agreement of Annex I countries (characterized by quite weak emission targets for Russia and the US), at the reduction targets stated before the UNFCCC's conference in Copenhagen
- A *compulsory* global agreement of Annex I countries, with reduction targets as identified by the IPCC's 4th Assessment Report to remain within the +2° global temperature target (compared to pre-industrial levels) by 2100

For both, the post-Kyoto and the IPCC scenarios, we distinguish between a 'high' and a 'low' scenario, since reduction targets have been stated in ranges instead of a single number.

The structure of the remainder of this chapter is as follows. We start by a description of the data source used for the modeling in section 2. Section 3 describes the structure of the CGE model, while the assumptions for the policy scenarios and the results for the BAU 2020 are given in section 4. Section 5 describes the model findings of the different policy scenarios, namely their impacts for Austria's output, exports and imports, and their respective carbon emissions. The economic and carbon effects of the scenarios on a global scale are discussed in section 5.3, addressing also the problem of carbon leakage due to unilateral policies and the effectiveness of possible policy reactions, such as the impacts of compensation measures like the intensively discussed concept of border tax adjustment.

2 Data sources for the modeling framework

2.1 Economic and trade data and its sectoral and regional aggregation

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.

Table 2-1: Overview of regions

Aggregated Region	Model code	Comprising GTAP regions
Austria	AUT	Austria
Germany	GER	Germany
Italy	ITA	Italy
Rest of West EU 27 + Switzerland	WEU	Belgium, France, Luxemburg, Netherlands, Portugal, Spain, Switzerland
Rest of South/-east EU 27	SEEU	Cyprus, Czech Republic, Greece, Hungary, Malta, Poland, Slovakia, Slovenia, Bulgaria, Romania
North EU 27	NEU	Denmark, Estonia, Finland, Ireland, Latvia, Lithuania, Norway, Sweden, UK
Rest of Europe	ROE	Rest of EFTA (Liechtenstein, Iceland), Albania, Croatia, Moldova, Rest of Europe (Bosnia and Herzegovina, Gibraltar,…), Turkey
Russian Federation	RUS	Russian Federation
Rest of GUS	GUS	Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Rest of former Soviet Union, Ukraine
China	CHN	China
Rest of East Asia ("Asian Tigers")	EASI	Hong Kong, Japan, Korea, Taiwan, Rest of East Asia
Southeast Asia	SEASI	Cambodia, Indonesia, Lao People's Democratic Republic, Myanmar, Malaysia, Philippines, Singapore, Thailand, Vietnam, Rest of Southeast Asia
South Asia	SASI	Bangladesh, India, Pakistan, Sri Lanka, Rest of South Asia
United States of America	USA	United States of America
Rest of North America	NAM	Canada, Mexico, Rest of North America
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
Oceania	OCEA	Australia, New Zealand, Rest of Oceania
Middle East and North Africa	MENA	Egypt, Morocco, Tunisia, Iran, Rest of West Asia, Rest of North Africa
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)

Table 2-1 gives an overview of the regional aggregation used for the CGE analysis. 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 Germany (GER), Italy (ITA), Russian Federation (RUS), China (CHN) and the United States (USA) as single countries modeled separately. The remaining member states of the European Union 27 were aggregated to West EU27 (WEU), Southeast EU27 (SEEU) and North EU27 (NEU) in order to be able to carry out an in depth analysis of Austrian trade with the diverse parts of the EU27. Further aggregates are based on geographical occurrences, their common role in climate negotiations as well as the affiliation to certain alliances, like the Commonwealth of Independent States (CIS/GUS).

Table 2-2: Overview of sectors

Aggregated Sectors	Model Code	Comprising GTAP sectors
Refined oil products	P_C	Manufacture of coke oven- and refined oil products
Electricity	ELY	Production, collection and distribution of electricity
Energy intensive industries	EIS	Chemical industry, non-metallic mineral products, iron and steel, precious and non-ferrous metals, paper products
Non energy intensive industries	NEIS	Textiles, wearing apparel, leather, wood products, fabricated metal products, motor vehicles, transport equipment, machinery, communication equipment
Coal	COA	Coal Mining
Crude Oil	OIL	Oil extraction
Natural Gas	GAS	Natural Gas extraction, manufacture of gas, distribution, steam and hot water supply
Transport	TRN	Water, air, road and rail transport
Food products and agriculture	FOOD	All agriculture and food processing sectors
Other services and utilities	SERV	Water, wholesale, retail sale, hotels, restaurant, construction, financial services, insurance, real estate, public administration, post and telecom
Capital Goods	CGDS	Capital Goods

Source: Based on GTAP (2007)

The sectoral aggregation to be used in the CGE model – depicted in Table 2-2 – was selected according to energy - and therefore GHG emission – intensity. We distinguish between sectors with high and with low energy intensity, respectively. Primary energy extraction is reflected in GTAP by the sectors coal (COA), oil (OIL) and natural gas (GAS), which also incorporates gas, steam and hot water distribution. Derived energy goods include refined oil and coke oven products (P_C) and electricity including its distribution (ELY). The industrial sectors within GTAP7 are split in two groups according to their energy intensities in production. The aggregate Energy Intensive Sectors (EIS) comprises the industries which are responsible for the bulk of a country's production related GHG emissions and its production units are therefore also subject to the EU's Emission Trading Scheme (ETS) (European Parliament, 2003). The most prominent industries within this group are iron and steel, chemicals, cement and paper. The rest of the industries – i.e. the non-energy intensive sectors – which are characterized by a lower CO_2 coefficient in their production processes, are merged in the NEIS aggregate.

2.2 Energy and emissions

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, included in GTAP7, they only take account of combustion based CO_2 emissions. This data therefore is excluding some 10% of global CO_2 emissions which are triggered by 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 sectors (iron and steel, cement, oil refinement) that each are foreign trade intensive and under fierce international competition. We cannot accept to misrepresent the carbon content of these carbon intensive sectors and their trade flows, a misrepresentation that for iron and steel for example can easily concern more than 50% of sectoral CO_2 emissions. While GTAP7 and all international studies based on this data base only do neglect process emissions, we thus had to incorporate these process related emissions in a separate step, thereby relying on UNFCCC data (UNFCCC, 2009). These GHG emissions from industrial processes mainly occur in the cement, chemicals and metal production and are therefore added to the EIS aggregate's emissions balance. 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, since we have detailed knowledge at this level of detail of CO_2 emissions only for Austria, unilateral data reconciliation would artificially worsen Austria's P_C and chemical sectors' international competitiveness in a stricter EU climate policy scenario. 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.

2.3 Economic dynamics

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 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.

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. 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) and Burniaux et al. (1992) we assume a constant AEEI parameter and set it to 1% per annum. Table 2-3 gives an overview of the growth rates which were used to calculate our model for the 2020 Business As Usual (BAU) scenario.

Table 2-3: 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
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
GUS	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)*

***based on IMF (2009)*

3 The model

For our analysis of the carbon content of Austria's international trade in the presence of climate policies, we employ a large-scale multiregional, multisectoral computable general equilibrium model (CGE), programmed and solved in GAMS/MPSGE (Rutherford, 1999) utilizing the solver PATH, which is calibrated to the previously described GTAP7 data base, representing the year 2004. As illustrated in the previous section, we differentiate for 19 world regions/countries and 11 sectors. 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 evaluation of different policy scenarios (see chapter 4).

3.1 Basic model structure

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 19 regions. This regional household provides the primary factors capital K_r, labor L_r and natural resources R_r (primary energy commodities) for the 11 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. Moreover, again 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; therefore those three sectors represent the extraction of primary energy. Thus, there are two different groups of production activities which are represented by slightly different production functions in the model: the production of non-primary energy commodities, and primary energy extraction. The following section provides a description of the production function modeling approach, while the subsequent section deals with modeling trade, taking the form of bilateral trade relationships rather than an integrated global market.

3.2 Production structure

Within the modeling framework MPSGE, 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). There are two groups of produced commodities – primary energy and non-primary energy commodities. Figure 3-1 illustrates the structure of the production of primary energy commodities (PrimNrg). At the top level in the extraction of fossil resources, natural resources and non resource inputs can be exchanged with a constant elasticity of substitution *s*, equaling to zero, which characterizes a Leontief composite.

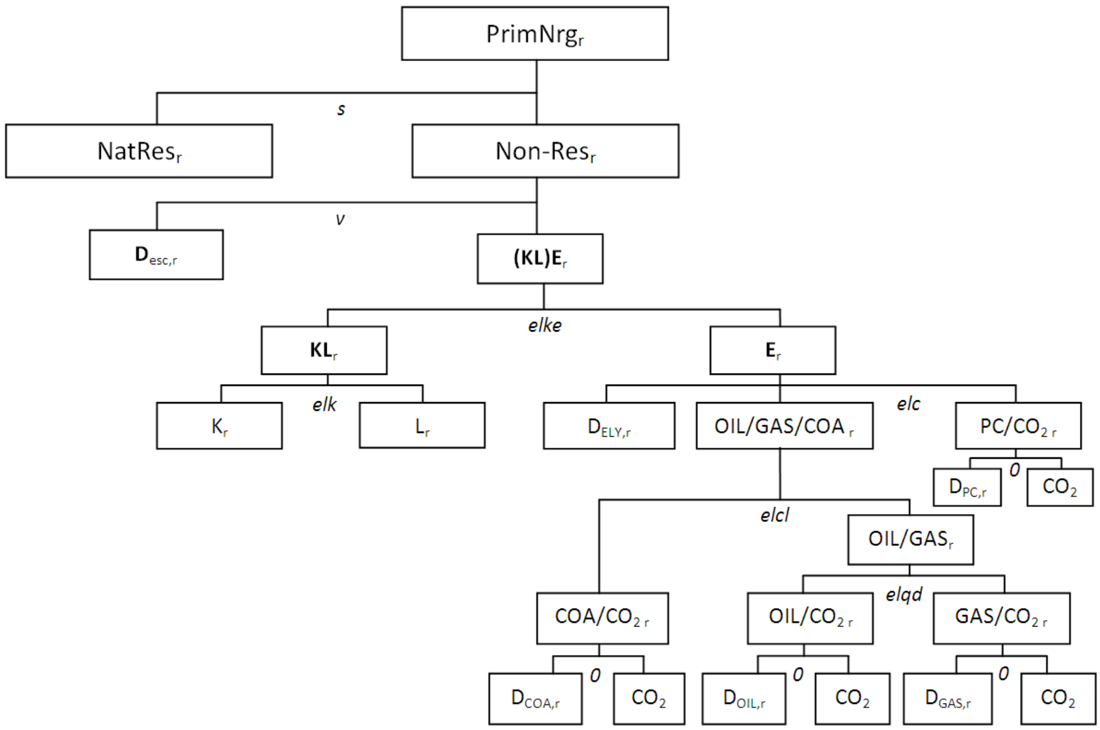

Figure 3-1: Nesting structure of primary energy extraction

At the second level, the Armington aggregation of domestic and imported intermediate inputs – the domestic supply $D_{esc,r}$ – from non-energy sectors are employed in fixed proportions *v* with an aggregate of capital, labor and energy ((KL)E$_r$). At the third nesting level, a CES composite of capital and labor (KL$_r$) is combined in fixed proportions (*elke*) with an energy-composite. 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) PC/$CO_{2\ r}$ 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 in constant proportions (*elqd*).

The final nesting level is a prerequisite for the analysis of climate policy like the EU ETS. All fossil final energy intermediate inputs in a production process, irrespective at which nesting level, enter as fixed-coefficient composite of an adhered carbon tax linked with an elasticity of substitution equal to zero to the combustion of fossil fuels. These reflect the carbon taxes a GHG emission abating region has to impose on fossil energy consumption in order to achieve an exogenously set reduction target. The taxes – in our case modeled as CO_2 emission permits which prices coincide with the carbon tax – can be differentiated between the sectors included in the EU's emissions trading scheme (ETS) and the non-ETS sectors, including private households. The revenues of the permit sales are collected by the regional households and redistributed to private households and the government.

For our analysis, the elasticities of substitution in the production processes (see Table 3-1) are based on Okagawa and Ban (2008) as well as Beckman and Hertel (2009).

Table 3-1: Elasticities in production

Sector	s	v	int	elke	Elk	Elc	elcl	Elqd
COA	0.00	0.73	0.31	0.55	0.14	0.16	0.07	0.25
OIL	0.00	0.73	0.31	0.55	0.14	0.16	0.07	0.25
GAS	0.00	0.73	0.31	0.55	0.14	0.16	0.07	0.25
P_C	0.00	-	0.39	0.26	0.46	0.16	0.07	0.25
ELY	0.00	-	0.39	0.26	0.46	0.16	0.07	0.25
EIS	0.63	-	0.00	0.30	0.32	0.16	0.07	0.25
NEIS	0.56	-	0.49	0.49	0.15	0.16	0.07	0.25
TRN	0.35	-	0.33	0.28	0.31	0.16	0.07	0.25
FOOD	0.36	-	0.00	0.46	0.2	0.16	0.07	0.25
SERV	0.58	-	0.00	0.48	0.29	0.16	0.07	0.25
Final Demand	0.20	-	1.00	-	-	0.50	1.00	-

Source: Okagawa and Ban (2008), Beckman and Hertel (2009)

Figure 3-2 illustrates the production of non-primary energy commodities, like the aggregate energy intensive industries (EIS). In contrast to the production structure of fossil fuel extraction, in these sectors natural resources $NatRes_r$ are not the crucial input in the production process, with the exception of some agricultural activities (incorporated in the FOOD aggregate) using resources as direct intermediate inputs. Accordingly, the top level CES function between natural resources and non-resource inputs is replaced by the originally second nesting level – the constant tradeoff between domestically supplied non-energy intermediate inputs $D_{esc,r}$ and a capital-labor-energy aggregate($(KL)E_r$). The natural resource input $NatRes_r$ (only relevant for FOOD sector production) is moved to the third nesting level, where it is employed in fixed proportion with a capital-labor-natural resource composite at an elasticity *elk*. Unique in the EIS sector 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.

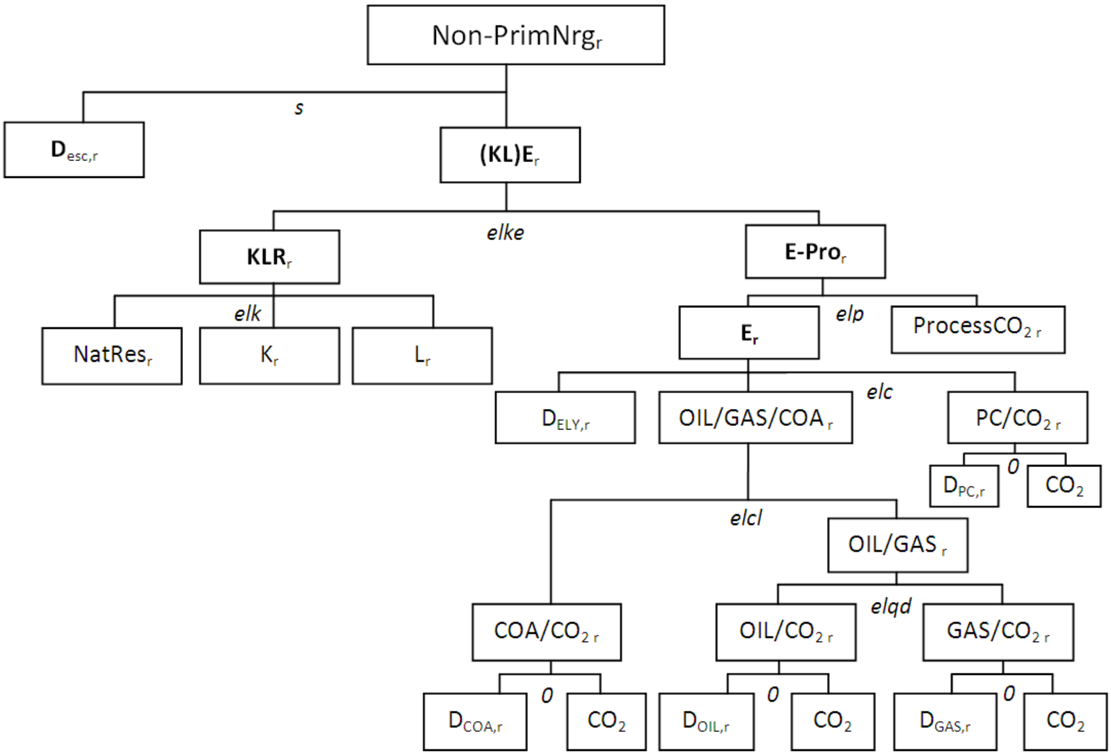

Figure 3-2: Production of non-primary energy commodities

3.3 Trade in the model

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 3-3, corresponds to a CES composite (*tela*) of domestic $X_{es,r}$ and imported goods $IM_{es,s,r}$ as imperfect substitutes.

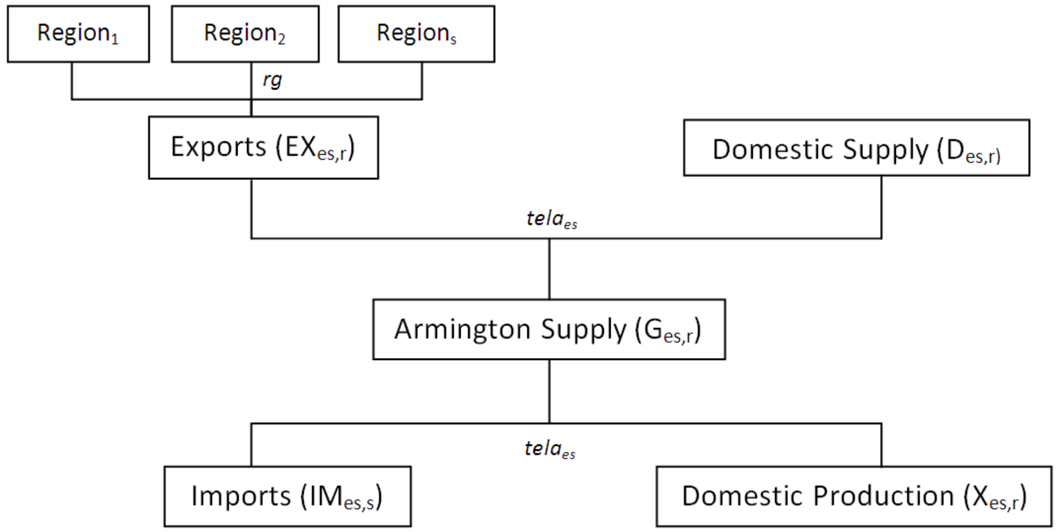

Figure 3-3: Armington aggregation for country *r*

The associated *Armington elasticities* ($tela_{es}$), different in each sector, are presented in Table 3-2. 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 $EX_{es,s,r}$, entering again as an imperfect substitute into the formation of the trading partner's Armington supply.

Table 3-2: Armington elasticities ($tela_{es}$)

Sector	Armington Elasticity
COA	3.05
OIL	5.20
GAS	10.76
P_C	2.10
ELY	2.80
EIS	3.21
NEIS	3.71
TRN	1.90
FOOD	2.39
SERV	1.91

Source: GTAP (2007)

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 3-4). The imports of any particular region $IM_{es,s}$ consist of imports from either the European Union or the Rest of the World (ROW), which are traded off at the top level of the import production block amongst each other at a constant proportion (*elim*).

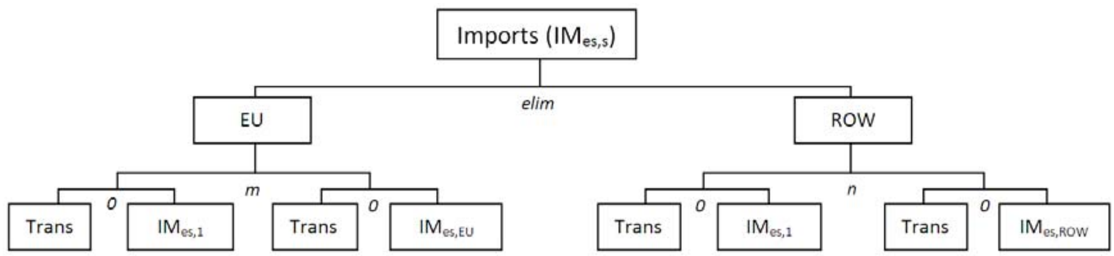

Figure 3-4: Import structure for country *r*

The international transport service activity is assumed to be a Cobb-Douglas composite of transport goods $TRANS_r$ provided as an aggregate of water, air and land transport domestic market activities (TRN) by each region (see Figure 3-5). This global market thereupon delivers the transport services required for imports to the individual regions.

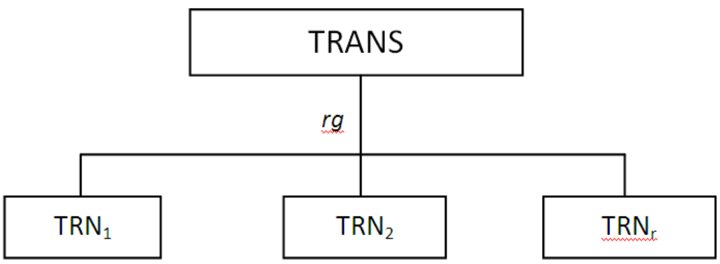

Figure 3-5: International Transport

The parameters *m* and *n* depict the constant elasticity of substitution between EU regions and ROW regions respectively (Figure 3-4). Values for these elasticities applied in the modeling of imports are presented in Table 3-3.

Table 3-3: Elasticities in import structure

Elasticity	value
elim	8
m	4
n	4
rg	4

Source: Rutherford and Paltsev (2000)

3.4 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.

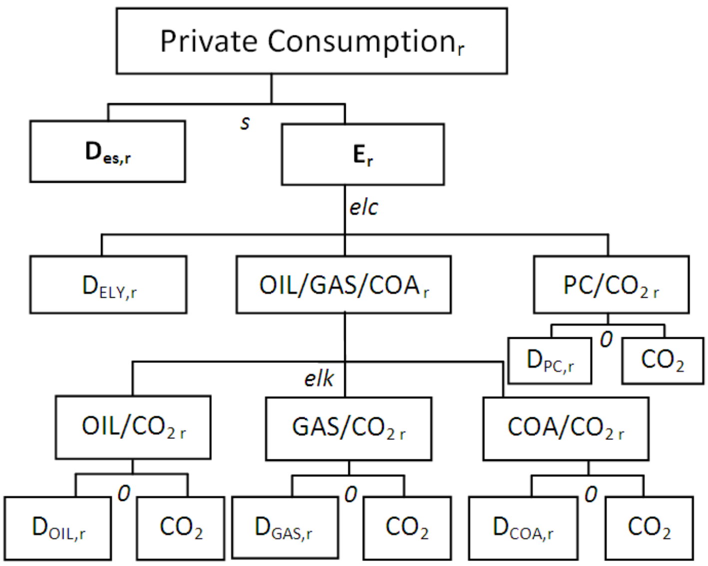

Figure 3-6: Final demand of private households for country *r*

Consumption of private households in each region, depicted in Figure 3-6, 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*). The combustion of fossil fuels in the private households in each country is linked in the same way to CO_2 taxes as it is the case in the production of energy and non-energy commodities.

Having described the structure of the CGE model, and before using the model to analyze different climate policy scenarios, the following section will outline the settings of three different scenario families – a unilateral EU scenario group, a post-Kyoto agreement with a voluntary commitment by other countries in addition to the EU, as well as the spectrum of the IPCC's recommendation on GHG emission reductions for Annex I countries to the Kyoto Protocol.

4 Definition of policy scenarios

4.1 Post-Kyoto climate policies

Table 4-1 presents five different 2020 policy scenarios which are evaluated by means of our CGE model. The first two scenarios, ETS_EU and NETS_EU, refer to unilateral EU policies as set up by the EU20-20 objectives: under ETS_EU 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 energy intensive industries (EIS), the power generation sector (ELY), and the petrochemical industry (P_C). In the NETS_EU setting, an additional 10% reduction target is introduced in the non energy intensive industries and for private households, again 2020 emission levels compared to 2005 emission levels. In both scenarios, the policies are implemented EU wide. 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 remaining scenarios cover global policies with other world regions setting reduction objectives as well, albeit at different stringency levels. The two global post-Kyoto scenarios PK_L and PK_H presume that CO_2 emission reduction targets have been set voluntarily by many industrialized countries within a global agreement established at the upcoming Copenhagen Conference of the UNFCCC. The reduction targets depicted in Table 4-1 refer to the most recent, official country specific information (L is the lower and H the higher bound) on envisioned GHG reduction goals, relative to emissions in the base year 1990. 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 aggregating the available country targets and emissions. For instance, the -8% CO_2 reduction goal for the rest of GUS results since only Belarus and the Ukraine have officially announced CO_2 objectives of -5% and -20%, respectively in a low reduction scenario (-10% and -20% for a high abatement scenario) prior to the Copenhagen climate talks, while emissions in all other GUS countries are allowed to grow without restrictions.

Table 4-1: GHG emission reduction targets for 2020

Region	Unilateral EU Climate Policy		Voluntary post-Kyoto agreement		IPCC requirements 450ppm	
	ETS_EU	NETS_EU	PK_L	PK_H	IPCC_L	IPCC_H
base year	2005	2005	1990	1990	1990	1990
EU	-21% in ETS sectors	-21% in ETS sectors, -10% in non-ETS sectors+ households	-20% in all sectors and households	-30%	-25%	-40%
RUS			-10%	-15%	-25%	-40%
ROE			+52%	+51%	-17%	-28%
GUS			-8%	-8%	-11%	-18%
USA			+/-0%	-4%	-25%	-40%
NAM			-3%	-3%	-14%	-23%
LAM						
CHN						
EASI			-25%	-25%	-15%	-23%
SEASI						
SASI						
OCEA			+10%	-11%	-25%	-40%
MENA						
SSA						

Source: European Commission (2008); IPCC (2007); personal communication Andreas Tuerk (2009)

While the post-Kyoto scenarios are the result of *voluntary* emission reduction targets by Annex I countries, the remaining two IPCC scenarios are based on the recommended -25% to -40% GHG emission cuts in all Annex I countries which are necessary to remain within the crucial +2C° target by 2100 compared to preindustrial periods (IPCC, 2007). While the IPCC acknowledges that a major deviation from baseline emissions will be necessary also within non-Annex I countries, no specific, official reduction targets have been communicated yet. As a consequence, reduction targets of non-Annex I countries will not be considered in the subsequent analysis. As for the post-Kyoto scenarios, emissions reduction objectives for country groups are determined 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.

In order to implement the officially announced GHG emission reduction objectives depicted in Table 4-1 in our model, we recalculate the emission targets relative to the base year 2004 (see Table 4-2). Depending on the development of the regions' CO_2 emissions relative to the scenarios' respective base years (2005 for ETS_EU and NETS_EU, all other scenarios 1990), these reduction targets deviate in some cases substantially from the ones presented in Table 4-1. For example the reduction goal in the ETS_EU scenario, 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.

Table 4-2: GHG emission reduction targets for 2020 relative to 2004

Region	ETS_EU	NETS_EU	PK_L	PK_H	IPCC_L	IPCC_H
sectors	ETS	ETS+NETS	ETS+NETS	ETS+NETS	ETS+NETS	ETS+NETS
AUT	-20%	-14%	-36%	-44%	-40%	-52%
GER	-24%	-17%	-6%	-18%	-12%	-29
ITA	-21%	-13%	-29%	-38%	-33%	-47%
WEU	-20%	-11%	-35%	-43%	-39%	-51%
SEEU	-21%	+11%	-7%	-19%	-13%	-30%
NEU	-23%	-17%	-20%	-30%	-25%	-40%
RUS			+48%	+39%	+23%	-2%
ROE			+4%	+3%	-44%	-51%
GUS			+22%	+22%	+18%	+9%
USA			-16%	-19%	-37%	-50%
NAM			-16%	-3%	-26%	-34%
LAM						
CHN						
EASI			-30%	-30%	-20%	-28%
SEASI						
SASI						
OCEA			-18%	-11%	-44%	-55%
MENA						
SSA						

By comparing the reduction targets in Table 4-1 and Table 4-2, crucial information can be attained from the comparison of Russia's reduction goals. Russia's 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. Only in the strongest IPCC scenario – representing a 40% reduction of GHG in Annex I countries – Russia would be confronted with a minor effective reduction objective of 2% compared to 2004 CO_2emissions. The same rationale holds for the rest of the GUS region, while one can see the rise in the ROE region's CO_2

emissions reflected in the more stringent reduction target compared to the base year 2004 instead of 1990.

4.2 The BAU 2020 scenario

In the subsequent analysis all results will be compared to a business as usual scenario (BAU) for 2020, since this is the period for which both at the UNFCCC and European level reduction targets are negotiated. To develop the BAU scenario for 2020, we combine the economic data for 2004 with data on growth in multifactor productivity, labor force and capital stock discussed in section 2.3. By applying these (exogenous) annual growth rates to the model, which was initially calibrated for the GTAP7 base year 2004, we develop an economic structure for the year 2020 – representing a possible future scenario based on 2009 knowledge about future economic growth in presence of the ongoing economic crises. Considering the current 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 in 2008 and 2009 and which will not – again based on the most recent information by EUROSTAT and others – come to a halt earlier than 2011.

This adjustment procedure allows us to generate a BAU scenario for the year 2020, which will be used as a benchmark in our analysis of the consequences of climate policies for the Austrian economy, especially focusing on the (changing) carbon content of Austria's international trade relationships. To get a better understanding of this benchmark by introducing the 'crises adjusted' growth prospects, let us look at a few numbers. The scenario is characterized by an average annual GDP growth rate of 2.2% for Austria (over the period 2004 to 2020), resulting in a GDP of 413.3 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 downswing – was 2.4% (see Table 2-3).

Table 4-3: BAU 2020 scenario for Austria (in million USD, below: MUSD)

	2004	2020	% change 2020 relative to 2004
	in MUSD (real at 2004 prices)		in %
GDP			
Consumption	172,494	247,414	+43%
Investment	67,168	101,964	+52%
Government	54,933	78,793	+43%
Trade balance	-2,283	-14,843	+550%
Total	292,312	413,328	+41%
annual average growth rate	2.41	2.19	
Output			
P_C	3,689	4,363	+18%
ELY	6,557	7,617	+16%
EIS	58,932	71,641	+22%
ETS total	69,179	83,621	+21%
COA	27	31	+14%
OIL	267	304	+14%
GAS	298	340	+14%
NEIS	118,850	147,779	+24%
TRN	38,328	50,380	+31%
FOOD	30,617	41,402	+35%
SERV	279,362	360,201	+29%
CGDS	67,168	101,964	+52%
non-ETS total	534,918	702,401	+31%
Output total	604,097	786,022	+30%
Export			
P_C	274	334	+22%
ELY	786	890	+13%
EIS	26,285	32,461	+23%
ETS total	27,345	33,684	+23%
COA	0	0	+28%
OIL	0	0	+85%
GAS	30	36	+19%
NEIS	61,503	77,146	+25%
TRN	10,481	13,642	+30%
FOOD	6,309	8,634	+37%
SERV	29,941	38,231	+28%
non-ETS total	108,265	137,689	+27%
Export TRANS	7,061	10,343	+46%
Export total	142,670	181,716	+27%

Table 4-4 (cont.): BAU 2020 scenario for Austria (in million USD, below: MUSD)

	2004	2020	% change 2020 relative to 2004
	in MUSD (real at 2004 prices)		in %
Import			
P_C	2,128	2,560	+20%
ELY	1,030	1,400	+36%
EIS	24,891	32,694	+31%
ETS total	28,049	36,654	+31%
COA	228	238	+4%
OIL	1,839	1,932	+5%
GAS	859	932	+9%
NEIS	63,443	88,673	+40%
TRN	5,729	7,635	+33%
FOOD	7,684	11,016	+43%
SERV	34,445	45,824	+33%
non-ETS total	114,226	156,249	+37%
Import TMG	2,678	3,656	+36%
Import total	144,953	196,558	+36%

Under BAU assumptions, the total output of Austria's economy grows by a total of 30% over these 16 years. Comparing ETS sectors (ELY, EIS, P_C) 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 31%, compared to +21% in the ETS sectors. Since the NETS output volume already in 2004 is almost eight times the level of that of the ETS output, the increase of the NETS output in absolute terms is considerably higher than that of the ETS output. Table 4-3, which presents the effects of the transition from 2004 to 2020 under the previously illustrated BAU growth assumptions, gives further insights for the composition of Austrian trade in the years 2004 and 2020. Austria – being a net importer already in the base year 2004 – worsens its trade balance until the year 2020 by some 13 MUSD. This arises from import volumes increasing relatively stronger than Austria's export volumes. For both exports and imports, trade in NETS (especially the NEIS 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 4-5 focuses on Austrian trade flows in the BAU-2020 scenario, distinguishing ETS and non-ETS sectors. The first two columns give a detailed account of Austria's imports from the other 18 model regions, while the third and fourth columns analyze Austria's export structure. Clear evidence is that Austria's main trading partners, both in 2020 imports and exports, are found within the EU, in particular the neighboring countries Germany and Italy. The USA and Russia are its strongest single country trading partners outside the EU. The USA is particularly important as an export market, while China is the source of NETS imports worth 5.3 billion USD.

Table 4-5: Austrian trade flows in the BAU 2020 scenario (in MUSD)

	Imports 2020 (MUSD)		Exports 2020 (MUSD)	
	ETS	NETS	ETS	NETS
GER	17,172	53,784	8,434	38,299
ITA	2,791	13,983	3,139	11,915
WEU	6,644	21,162	6,117	19,840
SEEU	3,685	15,157	6,232	17,035
NEU	3,084	11,036	2,332	11,971
ROE	432	2,551	1,159	4,210
RUS	347	2,053	436	1,680
GUS	158	1,019	289	1,235
CHN	263	5,331	270	2,903
EASI	468	7,872	693	2,831
SEAS	314	5,884	333	3,459
SASI	40	1,068	174	1,845
USA	691	7,253	1,855	10,365
NAM (excl. USA)	97	1,266	391	1,517
LAM	169	1,934	358	1,929
OCEA	38	441	197	1,253
MENA	104	3,317	1,071	3,804
SSA	156	1,136	206	1,597
Total	***36,654***	***156,249***	***33,684***	***137,689***

4.3 CO_2 emissions in the BAU 2020 scenario

Turning to CO_2 emissions, Austria's CO_2 emissions under the BAU assumptions are found to increase of 14.8% compared to 2004, calculated according to the Production Based Principle (PBP) and thus based on emissions from domestic production. This increase of 14.8% corresponds to an absolute increase in Austria's production related and private household's emission by 12 Mt CO_2 from 79 Mt CO_2 in 2004 to 91 Mt CO_2 in 2020 (Table 4-6).

Table 4-6: CO_2 emissions for Austria according to the PBP and CBP for 2004 and BAU-2020

	2004	2020	% Change
	in Mt CO_2		2004-2020
PrivHH	18.63	23.34	+25.3%
Output	60.42	67.43	+11.6%
PBP	79.05	90.77	+14.8%
Import	27.27	31.25	+14.6%
Export	19.31	22.09	+14.4%
IM-EX	7.96	9.16	+15.1%
CBP	87.01	99.93	+14.9%

Following Peters and Hertwich (2008), we move beyond the production based emission inventory – representing domestic emissions from economic production within a country and the emissions due to the combustion of fossil fuels in the private sector – to the broader concept of a consumption based emission inventory. This Consumption Based Principle (CBP) can 'be considered a trade-adjusted version of the production based inventory' (Peters and Hertwich, 2008), therefore representing the entity of a country's CO_2 emissions occurring from its economic consumption. Applying this CBP concept to Austria's CO_2 emissions, we find emissions to be 87 MT CO_2 in 2004 and to rise to 100 Mt CO_2 in 2020 (Table 4-6and Figure 4-1), and thus to be considerably higher than emissions according to the PBP. Thus, taking account of all emissions which are necessary to fulfill Austrian consumption (i.e. final demand), by adding emissions from imports and subtracting emissions attributed to exports, leads to a higher amount of carbon emissions according to the CBP than the PBP. This is a typical pattern which is found for the lion's share of industrialized countries, while developing countries in general have a reverse pattern (for a country comparison, see Peters and Hertwich, 2008).

By comparing the increase in emissions from 2004 to 2020, we see an increase in emissions according to the PBP by 14.8% while emissions according to the CBP increase by 14.9%. Compared to 2004 output related CO_2 emissions increase by 12%, household's emissions by 25% and emissions embodied in Austria's net carbon trade flow increase by 15% (Table 4-6). However, when the development of Austria's net carbon trade flows are compared to the development of its trade balance in monetary terms, one interesting finding arises: While Austria's trade deficit increases almost sixfold, its counterpart in terms of CO_2 emissions increases only by 15%. 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 imports from carbon intensive goods (EIS sectors) to low-carbon products (NEIS and SERV sectors).

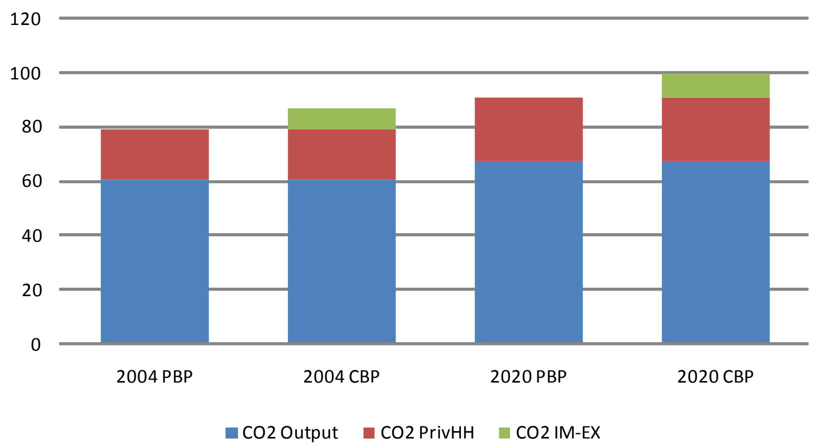

Figure 4-1: PBP vs. CBP in 2004 and 2020 (in Mt CO_2)

Note that almost 50% of Austria's CO_2 emissions linked to production activities both in 2004 and 2020 arise within ETS sectors – mainly EIS and ELY – even though the monetary output value of the NETS sectors – predominantly the NEIS and SERV sectors – is almost nine 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 (Table 4-3 and Table 4-7).

Table 4-7: BAU-2020 scenario – Sectoral CO_2 emissions for output, exports and imports for Austria (in Mt CO_2)

	2004	2020	% Change
	in Mt CO2		2004-2020
Private Households	18.63	23.34	+25%
Output			
P_C	0.54	0.58	+6%
ELY	15.33	16.18	+5%
EIS	15.24	15.67	+3%
ETS total	31.12	32.42	+4%
COA	0.00	0.00	+0%
OIL	0.07	0.06	-7%
GAS	0.15	0.15	+3%
NEIS	2.22	2.43	+9%
TRN	18.10	21.70	+20%
FOOD	2.44	3.04	+25%
SERV	6.33	7.63	+21%
CGDS	0.00	0.00	+0%
non-ETS total	29.30	35.01	+19%
Output total	60.42	67.43	+12%
Export			
P_C	0.04	0.04	+10%
ELY	1.84	1.89	+3%
EIS	6.80	7.10	+4%
ETS total	8.68	9.03	+4%
COA	0.00	0.00	+0%
OIL	0.00	0.00	+51%
GAS	0.01	0.02	+7%
NEIS	1.15	1.27	+10%
TRN	4.95	5.88	+19%
FOOD	0.50	0.63	+26%
SERV	0.68	0.81	+19%
non-ETS total	7.29	8.60	+18%
Export TRANS	3.33	4.46	+34%
Export total	19.31	22.09	+14%
Import			
P_C	0.20	0.21	+5%
ELY	4.72	5.60	+19%
EIS	8.90	9.94	+12%
ETS total	13.82	15.75	+14%
COA	0.05	0.05	-5%
OIL	0.26	0.23	-11%
GAS	1.45	0.81	-44%
NEIS	1.61	2.02	+25%
TRN	6.12	7.44	+22%
FOOD	0.61	0.79	+29%
SERV	0.96	1.23	+28%
non-ETS total	11.06	12.56	+14%
Import TMG	2.39	2.93	+23%
Import total	27.27	31.25	+15%

A fraction of Austria's imports and exports consists of trade services – air, water and land based – which are causally linked to import and export activities and which are responsible for a certain amount of emissions, determined by the transport technology used by the transport arranging trade partner. As was explained earlier (see section 3), in our modeling framework each region exports a certain amount of transport services (TRANS) to a global transport market, which further redistributes the transport services as Import Trade Margins (TMG) linked to imports. Since within the GTAP database these trade services are attributed in total and not for each sector separately, the final entries within exports and imports are TRANS and TMG respectively (see Table 4-7). Within this globally balanced transport market, Austria is – based on the GTAP7 database – a net exporter of transport services and its respective CO_2 emissions.

5 The economic and global carbon effects of climate policy for Austria as an internationally trading economy

5.1 The economic effects of the climate policy scenarios for Austria

Table 5-1 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 ETS_EU, the European Union implements an emissions trading scheme in the energy intensive sectors (ETS sectors, namely P_C, ELY, EIS) only, but the other countries do not limit their emissions. This leads to a reduction in Austrian GDP by 0.4% relative to BAU, and to a reduction in annual economic growth from 2.19 in BAU to 2.16. Austrian exports and imports decline by 1.1% and 0.9% respectively. When the European Union extends its climate policy also to the non-ETS sectors (as in the NETS_EU scenario; this separation is only done for analytical reasons, as the EU has a single climate policy focusing on both ETS and NETS) but the other countries still do not reduce their emissions, effects on GDP, exports and imports are more than doubled. The post Kyoto scenarios PK_L and PK_H with voluntary reduction commitments also by other Annex I countries (see Table 4-1), further intensify the economic consequences for GDP, exports, and imports. However, these effects are even higher under the IPCC scenarios which constitute, according to the IPCC Fourth Assessment Report, the necessary reduction targets for Annex I countries to remain within the +2 ° temperature target (compared to pre-industrial levels) by 2100.

Table 5-1: GDP effects of climate policy scenarios for Austria relative to BAU 2020

	BAU 2020	ETS_EU	NETS_EU	PK_L	PK_H	IPCC_L	IPCC_H
	in MUSD	change relative to BAU 2020 (in %)					
Consumption	247,414	-0.4%	-1.6%	-3.6%	-5.3%	-4.5%	-8.0%
Investment	101,964	-0.4%	-0.9%	-2.3%	-3.9%	-3.1%	-6.4%
Government	78,793	-0.4%	-0.7%	-1.9%	-3.3%	-3.1%	-6.2%
Export	181,716	-1.1%	-4.0%	-7.1%	-9.1%	-8.4%	-12.5%
Imports	196,558	-0.9%	-2.1%	-3.9%	-5.5%	-5.1%	-8.6%
GDP	413,328	-0.4%	-1.6%	-3.6%	-5.3%	-4.5%	-8.0%
Annual GDP growth rate	2.19	2.16	2.01	1.89	1.76	1.82	1.55

5.1.1 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 5-2, Figure 5-1 and Figure 5-2). Under ETS_EU, output in ETS sectors drops by 3.5% and in non-ETS sectors by 0.4%. Under NETS_EU, output falls more strongly: in non-ETS sectors by 1.6% and in ETS sectors by 5.6%. When Austria's carbon constraint becomes more stringent (see Table 4-2), but at the same time also other countries agree to binding commitments as in PK_L or IPCC_L, output in ETS sectors falls just slightly more: by 6.4% and 6.6%. The reason is that ETS sectors in Austria become more competitive if other countries as trading partners also have to reduce their carbon emissions. This favorable effect on Austria's ETS competitiveness is counterbalanced by even more stringent emission constraints in the PK_H and IPCC_H scenarios, leading to a stronger decrease of ETS output in Austria, namely by 8.8% and 10.2%. Non-ETS sectors, in contrast, are much more affected under the internationally coordinated scenarios PK_L and IPCC_L than under the unilateral EU policies ETS_EU and NETS_EU. This is due to the fact that non-ETS sectors are required to curb carbon emission as much as in ETS sectors under PK and IPCC scenarios while they are required to curb less under the NETS scenario (see Table 4-1). Moreover, the sector P_C is hardly affected under ETS_EU while it is affected much more under all other scenarios in which the non-ETS and private households – which are major consumers of petroleum products (especially in the transport sector) – have to cut emissions.

Table 5-2: Sectoral output effects of climate policy scenarios for Austria, 2020 with policy relative to BAU 2020

	BAU 2020	ETS_EU	NETS_EU	PK_L	PK_H	IPCC_L	IPCC_H
	in MUSD	change relative to BAU 2020 (in %)					
ETS sectors							
P_C	4,363	-2.9%	-26.0%	-42.8%	-50.1%	-46.5%	-56.8%
ELY	7,744	-5.3%	-5.9%	-3.5%	-5.8%	-3.6%	-8.1%
EIS	70,353	-3.4%	-4.3%	-4.5%	-6.6%	-4.5%	-7.6%
ETS total	83,621	-3.5%	-5.6%	-6.4%	-8.8%	-6.6%	-10.2%
Non-ETS sectors							
COA	31	+0.0%	-0.0%	-0.0%	-0.0%	-0.0%	-0.0%
OIL	304	+0.0%	+0.0%	-81.8%	-88.1%	-86.0%	-93.8%
GAS	340	+0.0%	-65.3%	-90.8%	-94.2%	-99.0%	-100.0%
NEIS	147,779	-0.6%	-1.1%	-1.5%	-2.4%	-2.6%	-4.9%
TRN	50,380	-0.2%	-13.3%	-26.6%	-33.8%	-28.4%	-40.0%
FOOD	41,402	-0.2%	-2.0%	-4.9%	-6.7%	-5.9%	-9.6%
SERV	360,201	-0.3%	-0.4%	-1.0%	-1.8%	-1.6%	-3.5%
CGDS	101,964	-0.4%	-0.7%	-1.9%	-3.3%	-3.1%	-6.2%
non-ETS total	702,401	-0.4%	-1.6%	-3.4%	-4.8%	-4.3%	-7.2%
Output total	**786,022**	**-0.7%**	**-2.1%**	**-3.7%**	**-5.2%**	**-4.5%**	**-7.5%**

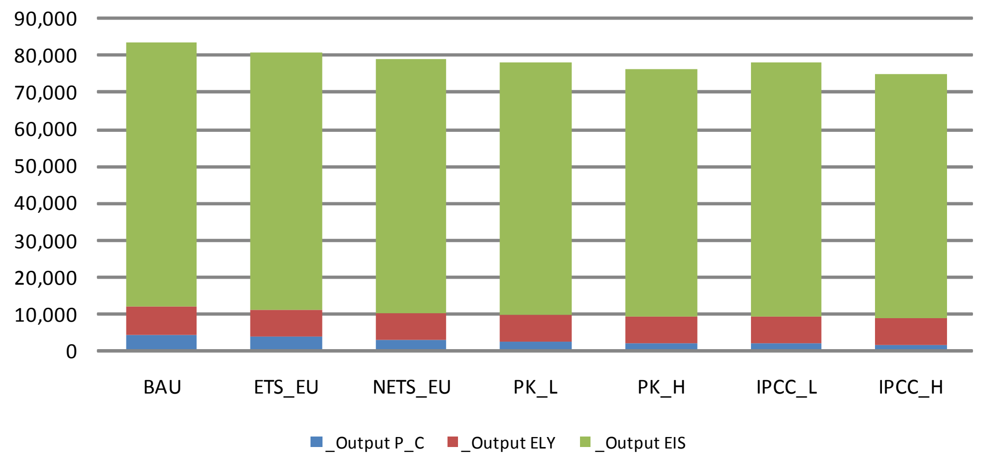

Figure 5-1: Output of ETS sectors for 2020 (in MUSD)

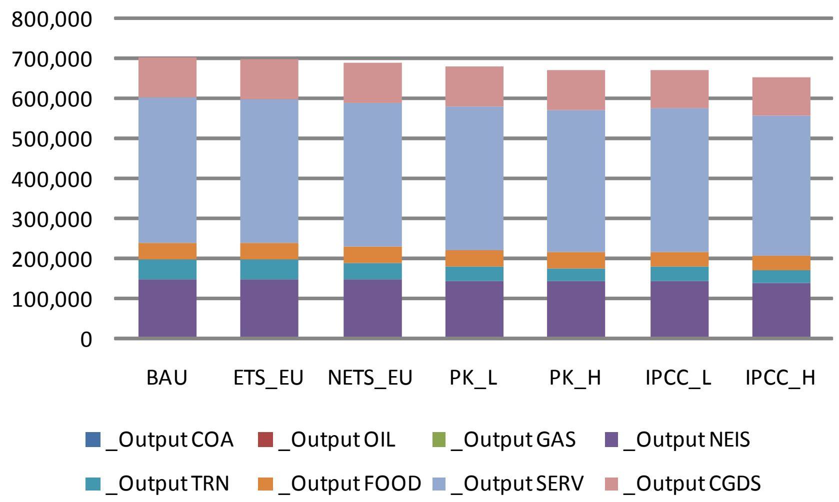

Figure 5-2: Output of non-ETS sectors for 2020 (in MUSD)

5.1.2 Effects on Austrian exports

Knowing from Table 5-1 that exports and – to a slightly lesser extent – imports, respond stronger to the policy scenarios than domestic production, we investigate the effects of the climate policy scenarios on Austrian exports and imports in more detail.

Regarding exports, presented in Table 5-3, we see a similar pattern as for Austrian production: ETS sector exports are already significantly affected by unilateral EU policy scenarios (ETS_EU, NETS_EU), while non-ETS sector exports are affected stronger by internationally coordinated policies (both PK and IPCC scenarios), since emissions by the non-ETS sectors are only then equally strong regulated as ETS emissions. This is also due to the fact that the lion's share of Austrian exports goes to the European Union where ETS reduces output and consumption, too. Within ETS sectors, EIS is hit hardest by all policies in absolute terms, while within non-ETS sectors NEIS and TRN (i.e. transport) are hit hardest (again in absolute terms).

Table 5-3: Effects of the scenarios on Austrian exports by sector relative to BAU 2020

	BAU 2020	ETS_EU	NETS_EU	PK_L	PK_H	IPCC_L	IPCC_H
	in 2004 MUSD	change relative to BAU 2020 (in %)					
ETS sectors							
P_C	334	-4.5%	-18.6%	-30.8%	-39.3%	-35.3%	-48.0%
ELY	890	+3.6%	+4.6%	+7.9%	+9.1%	+12.3%	+13.3%
EIS	32,461	-4.6%	-6.2%	-7.1%	-9.8%	-6.9%	-10.5%
ETS total	33,684	-4.4%	-6.1%	-7.0%	-9.6%	-6.7%	-10.2%
Non-ETS sectors							
COA	0	-22.1%	-29.2%	-57.0%	-66.3%	-61.9%	-74.9%
OIL	0	+4.0%	+38.4%	+36.7%	+48.0%	+54.8%	+83.7%
GAS	36	-5.5%	-24.0%	-49.8%	-55.1%	-31.8%	-11.1%
NEIS	77,146	-0.5%	-2.0%	-4.2%	-5.3%	-6.2%	-9.9%
TRN	13,642	-0.1%	-18.0%	-33.9%	-42.5%	-33.8%	-46.6%
FOOD	8,634	-0.1%	-3.7%	-8.4%	-10.7%	-10.0%	-14.8%
SERV	38,231	-0.1%	-0.2%	-0.7%	-0.7%	-1.7%	-2.8%
non-ETS total	137,689	-0.3%	-3.2%	-6.4%	-8.1%	-7.9%	-11.9%
Export TRANS	10,343	-0.1%	-8.1%	-16.4%	-21.6%	-19.4%	-28.2%
Export total	**181,716**	**-1.1%**	**-4.0%**	**-7.1%**	**-9.1%**	**-8.4%**	**-12.5%**

Analyzing the countries where Austrian exports are directed to (Table 5-4, Figure 5-3 and Figure 5-4), we find that under the IPCC climate policy scenarios we observe an increase of ETS sectors' exports to NAM (North America) and Eastern Europe compared to the unilateral EU policies, since the US and Russia are required to limit their emissions more strongly under IPCC. Note, however, that a similar effect does not result for non-ETS sectors.

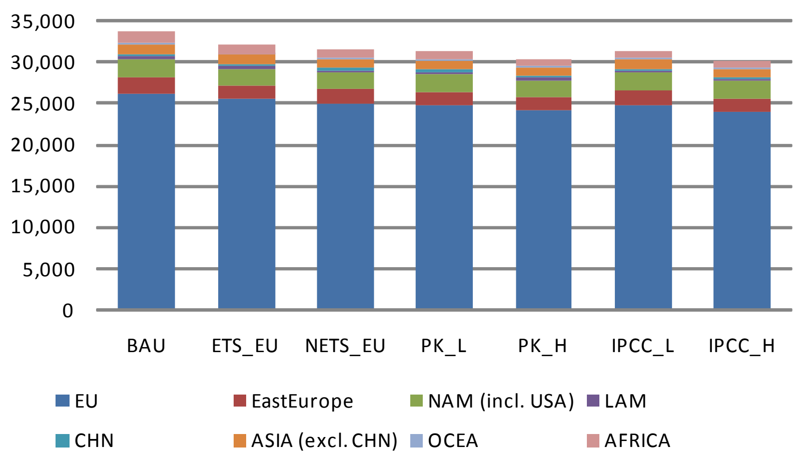

Figure 5-3: Austrian exports of ETS sectors by region for 2020 (in MUSD)

Table 5-4: Impacts of climate policy scenarios on Austrian exports in ETS and non-ETS sectors by world region (in MUSD)

	BAU	ETS_EU	NETS_EU	PK_L	PK_H	IPCC_L	IPCC_H
	in 2004 MUSD	change relative to BAU 2020 (in %)					
ETS sectors							
EU	26,255	-2.8%	-4.4%	-5.4%	-7.6%	-5.4%	-8.6%
EastEurope	1,884	-8.3%	-12.0%	-16.4%	-19.9%	-11.0%	-13.0%
NAM (incl. USA)	2,245	-10.4%	-10.3%	-3.8%	-8.6%	-1.0%	-5.3%
LAM	358	-11.8%	-12.5%	-13.6%	-18.2%	-13.7%	-19.8%
CHN	270	-11.6%	-12.1%	-8.7%	-15.1%	-13.2%	-24.1%
ASIA (excl. CHN)	1,200	-11.0%	-11.8%	-6.0%	-11.7%	-10.9%	-19.6%
OCEA	197	-10.7%	-10.5%	-7.4%	-9.9%	-4.5%	-10.7%
AFRICA	1,277	-10.2%	-15.4%	-28.9%	-32.4%	-28.7%	-33.6%
Export ETS total	33,684	-4.4%	-6.1%	-7.0%	-9.6%	-6.7%	-10.2%
Non-ETS sectors							
EU	99,060	-0.7%	-2.8%	-5.4%	-7.2%	-6.5%	-10.5%
EastEurope	7,125	+0.3%	-4.0%	-8.9%	-9.3%	-14.0%	-18.3%
NAM (incl. USA)	11,881	+0.5%	-3.3%	-6.1%	-7.7%	-10.1%	-17.4%
LAM	1,929	+1.0%	-4.6%	-10.1%	-10.7%	-9.9%	-9.1%
CHN	2,903	+0.9%	-3.4%	-6.3%	-7.6%	-7.4%	-10.7%
ASIA (excl. CHN)	8,136	+0.8%	-3.7%	-5.9%	-7.4%	-7.1%	-9.9%
OCEA	1,253	+0.0%	-7.5%	-11.9%	-15.9%	-14.8%	-24.3%
AFRICA	5,402	-0.0%	-7.1%	-21.8%	-21.8%	-20.6%	-18.2%
Export non-ETS total	137,689	-0.3%	-3.2%	-6.4%	-8.1%	-7.9%	-11.9%

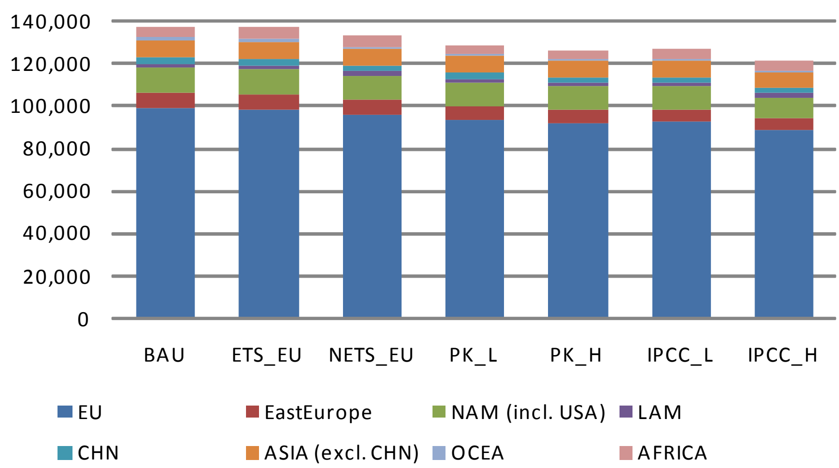

Figure 5-4: Austrian exports of non-ETS sectors by region for 2020 (in MUSD)

5.1.3 Effects on Austrian imports

With respect to imports, we find that Austrian imports of ETS sectors decline by 2.5% under ETS_EU relative to BAU and decline by up to 14.9% under IPCC_H. Imports of non-ETS sectors decline by 0.5% under ETS_EU and by up to 7.1% under IPCC_H. Thus, overall imports are slightly less declining under all climate policy scenarios than exports (but both more than Austrian output). One explanation for the higher impact in 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. Among non-ETS sectors, the imports of COA (coal) and GAS decline sharpest which is also a consequence of the incentive provided by ETS to reduce carbon emissions. All other non-ETS sectors are affected much less. In ETS sectors, ELY (electricity) and P_C (petroleum- and coke oven products) are affected much stronger than EIS under all climate policy scenarios (Table 5-5); again a feedback effect from reduced energy demand in all sectors.

Table 5-5: Effects of climate policy scenarios on Austrian imports by sector relative to BAU 2020

	BAU 2020	ETS_EU	NETS_EU	PK_L	PK_H	IPCC_L	IPCC_H
	in 2004 MUSD	change relative to BAU 2020 (in %)					
ETS sectors							
P_C	2,560	-1.7%	-25.2%	-37.1%	-43.9%	-40.2%	-51.7%
ELY	1,400	-26.0%	-26.5%	-26.6%	-34.9%	-32.5%	-45.2%
EIS	32,694	-1.6%	-2.2%	-4.0%	-6.2%	-5.6%	-10.7%
ETS total	36,654	-2.5%	-4.7%	-7.2%	-10.0%	-9.0%	-14.9%
Non-ETS sectors							
COA	238	-15.1%	-28.2%	-34.5%	-42.4%	-38.2%	-49.7%
OIL	1,932	-2.6%	-28.5%	-34.9%	-42.0%	-38.2%	-47.9%
GAS	932	-17.3%	-20.4%	-19.6%	-27.7%	-19.3%	-29.8%
NEIS	88,673	-0.4%	-1.3%	-3.9%	-5.4%	-5.4%	-9.1%
TRN	7,635	-0.2%	+0.1%	+5.5%	+7.1%	+2.4%	+4.3%
FOOD	11,016	-0.1%	-1.0%	-2.0%	-3.5%	-3.0%	-6.6%
SERV	45,824	-0.4%	-0.7%	-1.1%	-2.3%	-1.0%	-2.7%
non-ETS total	156,249	-0.5%	-1.5%	-3.0%	-4.4%	-4.1%	-7.1%
Import TMG	3,656	-0.8%	-2.9%	-5.8%	-8.0%	-7.6%	-12.9%
Import total	**196,558**	**-0.9%**	**-2.1%**	**-3.9%**	**-5.5%**	**-5.1%**	**-8.6%**

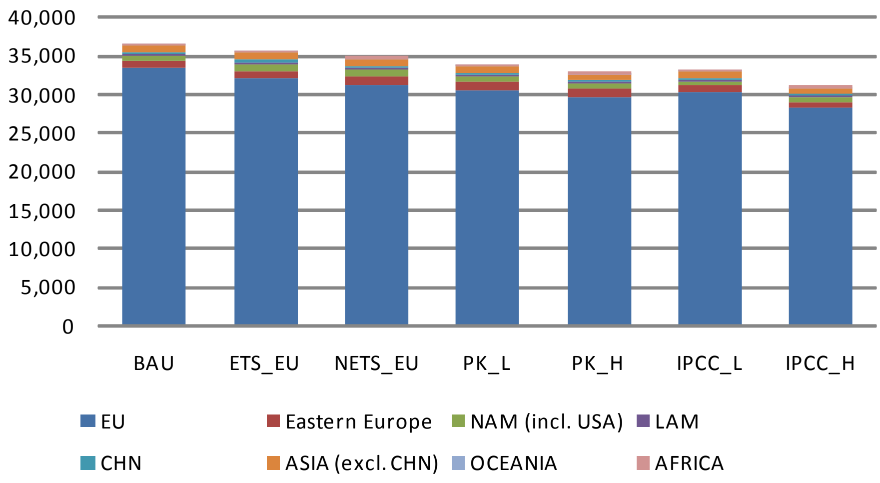

Figure 5-5: Austrian imports of ETS sectors by region for 2020 (in MUSD)

Austrian imports by region are summarized in Table 5-6, Figure 5-5 and Figure 5-6. Again, the main trading partner of Austria is the European Union, and hence the effects are strongest, and roughly proportionally increasing with the strength of the policy, in absolute terms for imports from other European countries. For other trading partners, there is however a remarkable difference across scenarios: under the IPCC climate policy scenarios, both the US and Russia are required to limit their emissions more strongly and hence imports from North America (NAM, including US) and Eastern Europe drop under these scenarios much more than under the other scenarios. A similar, but less pronounced effect is evident for CHN (China), the rest of Asia, and Oceania.

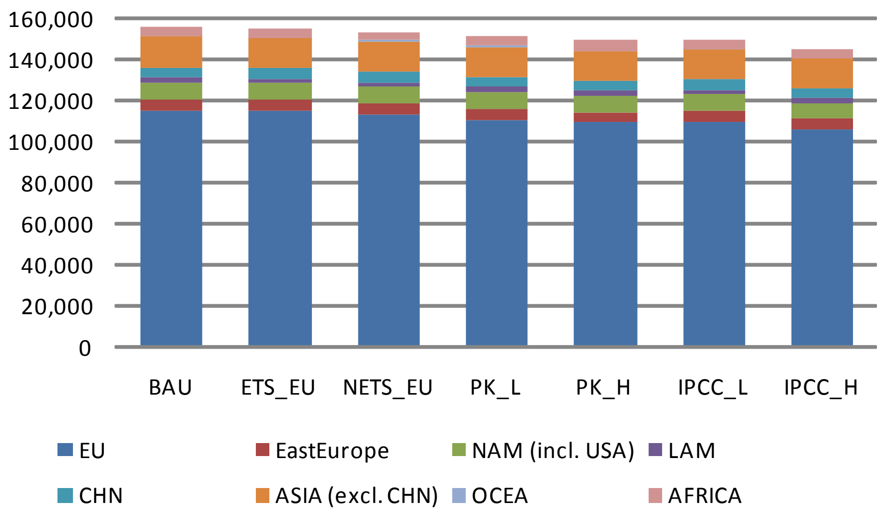

Figure 5-6: Austrian imports of non-ETS sectors by region for 2020 (in MUSD)

Table 5-6: Effects of the scenarios on Austrian imports in ETS and non-ETS sectors by world region (in MUSD)

	BAU 2020	ETS_EU	NETS_EU	PK_L	PK_H	IPCC_L	IPCC_H
	in 2004 MUSD	change relative to BAU (in %)					
ETS sectors							
EU	33,376	-3.9%	-6.2%	-8.2%	-11.4%	-9.4%	-15.1%
Eastern Europe	937	+12.0%	+14.8%	+17.0%	+17.8%	-3.2%	-20.1%
NAM (incl. USA)	788	+10.8%	+7.1%	-9.6%	-8.6%	-21.3%	-31.1%
LAM	169	+13.9%	+10.8%	+9.6%	+13.6%	+7.9%	+12.3%
CHN	263	+11.9%	+7.8%	+1.7%	+5.2%	+1.6%	+6.4%
ASIA (excl. CHN)	821	+11.3%	+8.3%	-7.1%	-5.0%	-4.6%	-5.6%
OCEANIA	38	+14.0%	+10.3%	-6.1%	-12.1%	-22.3%	-31.2%
AFRICA	260	+13.9%	+14.3%	+24.0%	+26.8%	+20.6%	+21.1%
Import ETS total	36,654	-2.5%	-4.7%	-7.2%	-10.0%	-9.0%	-14.9%
Non-ETS sectors							
EU	115,124	-0.1%	-1.4%	-3.6%	-4.9%	-4.7%	-7.8%
Eastern Europe	5,623	-3.3%	-4.1%	-5.4%	-7.4%	-6.5%	-10.6%
NAM (incl. USA)	8,519	-1.4%	-1.1%	-4.2%	-6.2%	-3.4%	-5.4%
LAM	1,934	-2.0%	+1.6%	+8.7%	+9.1%	+8.6%	+8.7%
CHN	5,331	-1.2%	-0.4%	-1.2%	-2.0%	-1.5%	-3.4%
ASIA (excl. CHN)	14,824	-1.3%	-1.0%	-3.0%	-4.3%	-3.7%	-6.2%
OCEA	441	-1.2%	+1.7%	-4.1%	-7.4%	-7.4%	-10.4%
AFRICA	4,453	-2.1%	-5.5%	+8.3%	+6.5%	+5.0%	-0.0%
Imports Non-ETS total	156,249	-0.5%	-1.5%	-3.0%	-4.4%	-4.1%	-7.1%

5.2 The carbon effects of the scenarios for Austria

The carbon emissions of the different scenarios are summarized in Table 5-7 and Figure 5-7 and Figure 5-8. Emissions fall under all scenarios both according to the PBP and CBP, with emissions (according to CBP) under IPCC_H almost halved compared to BAU. Moreover, while carbon emissions under ETS_EU are reduced mainly by production, in all other scenarios households also reduce their emissions, such that their share of total carbon emissions is reduced from 24% in BAU to 19% in IPCC_H.

Table 5-7: CO_2 effects according to the PBP and CBP of the scenarios relative to BAU 2020

	Base 2020	ETS_EU	NETS_EU	PK_L	PK_H	IPCC_L	IPCC_H
	Mt CO_2	change relative to BAU 2020 (in %)					
CO_2 PrivHH	23.34	+3.8%	-24.3%	-39.6%	-45.0%	-42.7%	-51.1%
CO_2 Output	67.43	-12.1%	-28.9%	-37.1%	-44.7%	-40.5%	-52.1%
PBP	90.77	-8.0%	-27.7%	-37.7%	-44.8%	-41.1%	-51.8%
CO_2 Import	31.25	-11.0%	-12.3%	-9.5%	-12.4%	-14.9%	-22.0%
CO_2 Export	22.09	-9.9%	-29.1%	-38.8%	-46.6%	-41.7%	-53.2%
CO_2 IM-EX	9.16	-13.8%	+28.1%	+61.3%	+70.0%	+49.9%	+53.1%
CBP	99.93	-8.6%	-22.6%	-28.7%	-34.3%	-32.7%	-42.2%

Moreover, the carbon trade balance improves for ETS_EU relative to BAU, but worsens in all other 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 as depicted in Table 5-6.

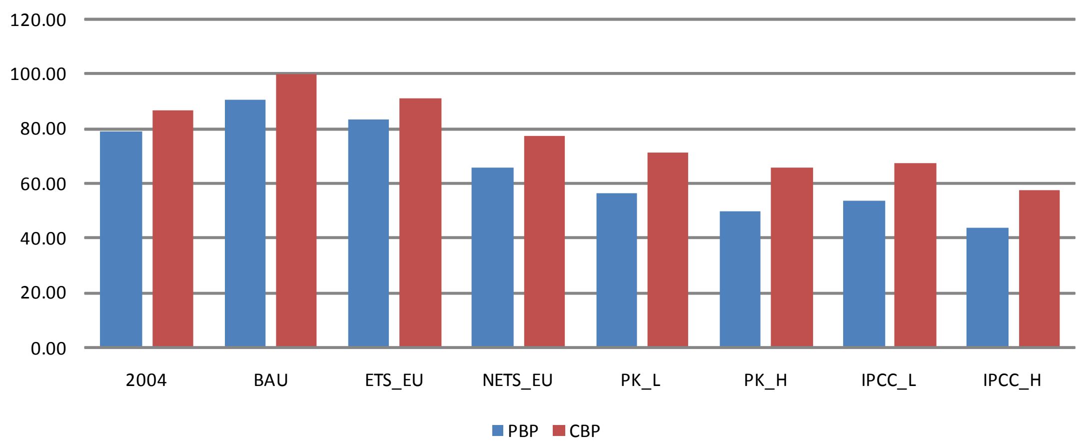

Figure 5-7: PBP vs. CBP CO_2 emissions for Austria 2020 (Mt CO_2)

Additionally, 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 11% to 22% below BAU levels. Figure 5-9 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 35.5% in IPCC_H relative to BAU, see Table 5-8). 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 unilateral EU scenarios ETS_EU and NETS_EU to more comprehensive climate policy scenarios, Austria's ETS import related CO_2 emissions tend to go down even stronger, since also CO_2 coefficients in the ETS production processes outside the EU are improved, caused by putting a price tag on CO_2 emissions.

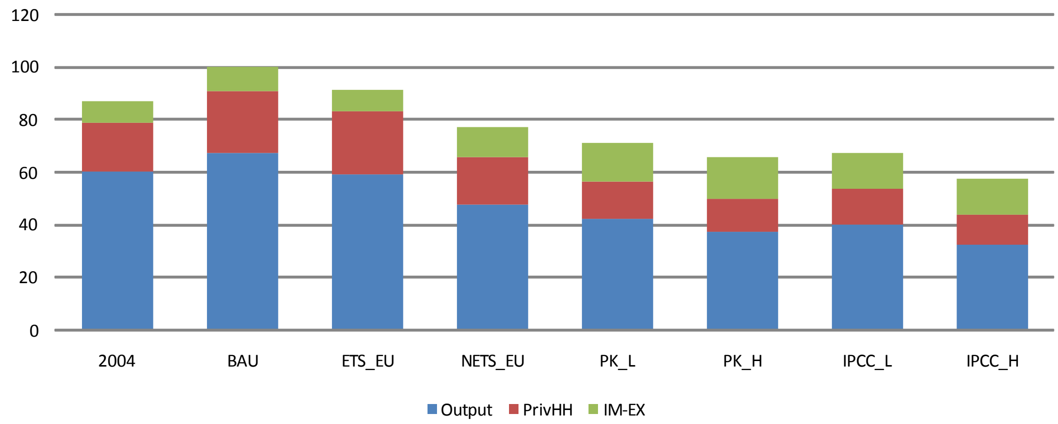

Figure 5-8: CO_2 according to CBP for Austria 2020 (Mt CO_2)

As mentioned earlier, the imported emissions embodied in NETS imports hardly change compared to BAU even under the most stringent IPCC scenarios. This is caused by the fact that a CO_2 price does not put ancillary high pressure on the corresponding 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.

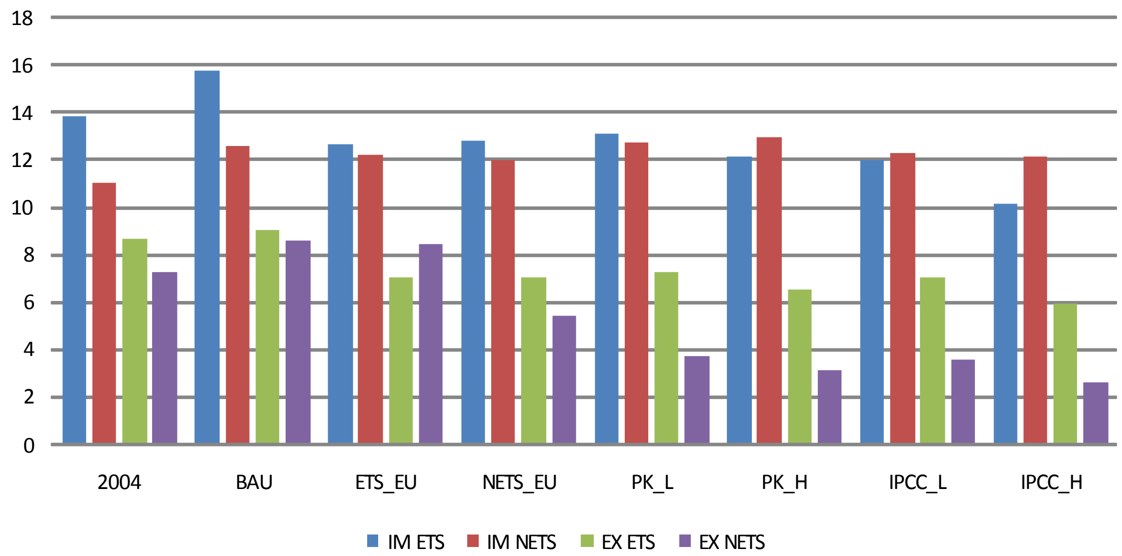

Figure 5-9: CO_2 emissions in AUT trade 2020 (Mt CO_2)

Table 5-8: Sectoral CO_2 effects of the scenarios relative to BAU 2020 (Mt CO_2)

	Base 2020	ETS_EU	NETS_EU	PK_L	PK_H	IPCC_L	IPCC_H
	Mt CO_2	Change relative to BAU 2020 (in %)					
CO_2 Output							
P_C	0.58	-25.0%	-44.9%	-59.8%	-68.2%	-64.1%	-75.3%
ELY	16.18	-22.8%	-23.2%	-20.1%	-27.4%	-23.2%	-34.3%
EIS	15.67	-23.1%	-22.4%	-19.0%	-27.7%	-22.8%	-36.4%
ETS total	32.42	-23.0%	-23.2%	-20.3%	-28.3%	-23.7%	-36.0%
COA	0.00	-	-	-	-	-	-
OIL	0.06	-1.6%	-61.3%	-95.7%	-97.7%	-97.1%	-99.1%
GAS	0.15	-0.3%	-84.6%	-97.4%	-98.6%	-99.7%	-100.0%
NEIS	2.43	-5.0%	-38.8%	-55.4%	-62.1%	-59.5%	-69.6%
TRN	21.70	-0.6%	-32.4%	-51.7%	-59.3%	-54.7%	-65.9%
FOOD	3.04	-2.9%	-40.9%	-58.7%	-65.0%	-62.3%	-71.7%
SERV	7.63	-5.0%	-33.6%	-50.8%	-58.2%	-55.1%	-66.2%
CGDS	0.00	-	-	-	-	-	-
non-ETS total	35.01	-2.0%	-34.1%	-52.6%	-60.0%	-56.1%	-66.9%
Output total	67.43	-12.1%	-28.9%	-37.1%	-44.7%	-40.5%	-52.1%

Table 5-8 (cont.): Sectoral CO_2 effects of the scenarios relative to BAU 2020 (Mt CO_2)

	Base 2020	ETS_EU	NETS_EU	PK_L	PK_H	IPCC_L	IPCC_H
	Mt CO_2	Change relative to BAU (in %)					
CO_2 Exports							
P_C	0.04	-26.3%	-39.4%	-51.3%	-61.3%	-56.6%	-70.4%
ELY	1.89	-15.5%	-14.7%	-10.7%	-15.9%	-10.6%	-18.9%
EIS	7.10	-24.1%	-24.0%	-21.2%	-30.3%	-24.7%	-38.3%
ETS total	9.03	-22.3%	-22.1%	-19.2%	-27.4%	-21.9%	-34.4%
COA	0.00	-	-	-	-	-	-
OIL	0.00	+2.3%	-46.4%	-68.0%	-71.7%	-67.6%	-72.4%
GAS	0.02	-5.8%	-66.3%	-85.7%	-89.3%	-82.4%	-82.8%
NEIS	1.27	-4.9%	-39.4%	-56.6%	-63.3%	-61.0%	-71.2%
TRN	5.88	-0.5%	-36.1%	-56.5%	-64.7%	-58.1%	-69.6%
FOOD	0.63	-2.7%	-42.0%	-60.2%	-66.5%	-64.0%	-73.3%
SERV	0.81	-4.9%	-33.4%	-50.6%	-57.7%	-55.1%	-66.0%
non-ETS total	8.60	-1.7%	-36.8%	-56.3%	-64.0%	-58.7%	-69.8%
CO_2 TRANS	4.46	-0.5%	-28.4%	-45.0%	-51.8%	-49.0%	-59.2%
Exports total	22.09	-9.9%	-29.1%	-38.8%	-46.6%	-41.7%	-53.2%
CO_2 Imports							
P_C	0.21	-20.8%	-41.4%	-56.9%	-65%	-62%	+600%
ELY	5.60	-38.8%	-39.4%	-38.8%	-46.2%	-44.8%	-37.6%
EIS	9.94	-8.6%	-6.7%	-3.8%	-9.2%	-11.5%	-47.9%
ETS total	15.75	-19.5%	-18.8%	-17.0%	-23.1%	-24.0%	-35.5%
COA	0.05	-26.0%	-52.2%	-62.3%	-71.1%	-67.4%	-78.6%
OIL	0.23	-0.0%	-22.7%	-34.6%	-41.7%	-38.6%	-53.8%
GAS	0.81	-20.7%	-29.3%	-27.8%	-32.2%	-34.5%	-53.5%
NEIS	2.02	-4.2%	-17.8%	-27.5%	-33.7%	-33.7%	-33.1%
TRN	7.44	-0.3%	+6.0%	+21.1%	+28.2%	+19.5%	+25.2%
FOOD	0.79	-3.3%	-26.4%	-34.5%	-42.3%	-40.9%	-57.7%
SERV	1.23	-3.3%	-13.3%	-19.7%	-25.4%	-24.6%	-43.9%
non-ETS total	12.56	-2.8%	-4.8%	+1.3%	+3.0%	-2.0%	-3.1%
CO_2 IM TMG	2.93	-0.6%	-9.9%	-15.6%	-20.7%	-20.6%	-31.1%
Imports total	31.25	-11.0%	-12.3%	-9.5%	-12.4%	-14.9%	-22.0%

5.3 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 respectively. In the subsequent sections we are going to refocus our analysis by taking a look at 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 the Annex I countries. Since our analysis is based on plausible developments, none of the scenarios is of global scope with binding agreements also for developing countries. Another distinctive feature of the scenarios is the sectoral scope of the emission reduction obligations, with EU_ETS being limited to ETS sector emissions while all other scenarios require limitations for non-ETS sectors too. Obviously, both the limited regional and the limited sectoral scope might lead to inefficiencies, discussed under the heading of competitiveness and carbon leakage. 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.

Table 5-9: Annual GDP growth rates for 2020 for the scenarios

	1999-2008	BAU 2020	ETS_EU	NETS_EU	PK_L	PK_H	IPCC_L	IPCC_H
AUT	2.40	2.19	2.16	2.09	1.95	1.84	1.90	1.66
GER	1.49	2.39	2.36	2.27	2.31	2.24	2.28	2.12
ITA	1.22	1.81	1.78	1.73	1.64	1.54	1.60	1.37
WEU	2.41	2.36	2.34	2.27	2.12	2.01	2.07	1.84
SEEU	4.18	2.83	2.75	2.73	2.68	2.56	2.61	2.34
NEU	2.74	2.59	2.57	2.48	2.46	2.37	2.42	2.23
RUS	6.85	2.52	2.50	2.44	2.35	2.33	2.34	2.22
ROE	3.94	2.57	2.57	2.58	2.45	2.43	1.67	1.37
GUS	7.72	3.09	3.08	3.06	2.97	2.93	2.90	2.63
USA	2.62	2.57	2.57	2.57	2.46	2.44	2.28	2.02
NAM	2.95	2.91	2.91	2.92	2.70	2.69	2.58	2.44
LAM	3.50	1.32	1.32	1.32	1.31	1.31	1.31	1.28
CHN	9.76	5.90	5.91	5.90	5.90	5.89	5.89	5.85
EASI	1.89	2.43	2.43	2.43	2.23	2.22	2.30	2.23
SEAS	5.02	5.38	5.39	5.39	5.39	5.37	5.37	5.32
SASI	6.72	4.14	4.15	4.15	4.17	4.17	4.17	4.15
OCEA	3.18	2.99	2.99	2.99	2.84	2.69	2.53	2.22
MENA	5.10	1.78	1.79	1.77	1.69	1.68	1.69	1.65
SSA	4.16	1.16	1.16	1.15	1.12	1.11	1.11	1.07

5.3.1 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 5-9. 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 current economic downturn. China's predicted economic growth is 3.86 percentage points lower (5.90%) than in the comparison period (9.76%). Also Latin American and African economies, which are already facing hard times in the globalized world economy due to lack of capital and productivity drawbacks (reflected by low MFP, capital and labor force growth rates in Table 2-3), will be substantially affected by the crises ramifications. 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 1.35 percentage points to a level of 2.83%.

The impacts of climate policies may alter these effects, as our model results illustrate. In the ETS_EU and NETS_EU scenarios, only the EU is faced by binding emission constraints. In the ETS_EU scenario, almost no consequences on GDP growth rates arise for all other countries (reducing only EU's annual average GDP growth rate slightly compared to BAU due to EU wide emissions trading). In the NETS_EU scenario, where the EU restricts GHG emissions to a level of 20% below 2005 levels, stronger consequences for worldwide economic growth arise. These reduced growth rates are mostly triggered by high carbon prices in the NETS sectors. Moreover, while the ETS sector is responsible of approximately 13% of output and 80% of carbon emissions in the EU, the inclusion of the NETS sectors and households implies a much stronger reduction of final demand. Additionally, emissions reductions within these sectors and by households cannot be traded within the EU as in the ETS sectors, additionally increasing the carbon price compared to the ETS sector. Despite the strong economic consequences within the EU, the non-abating regions outside the EU are not affected by these slowdowns of economic growth within the EU, or may even benefit, as was shown in section 5.1.3 by means of increasing imports especially from non-EU ETS sectors.

Only when all Annex I regions' CO_2 emissions are affected by a more comprehensive global climate agreement (PK and IPCC scenarios), countries like the USA, Japan or Ukraine have to face lower GDP growth rates. This is triggered by increased costs of production due to CO_2 taxes, but also by a shrinking demand for their exports by the other regulated regions. Even China, which carries no emission reduction obligation within any of our scenarios, looses in the IPCC_H scenario 0.05 percentage points due global feedbacks of reduced demand even for Chinese exports.

5.3.2 The carbon markets: emissions, prices and decarbonization

The development of global CO_2 emissions under the different scenario assumptions is presented in Figure 5-10 and Table 5-10. While in the base year 2004 global CO_2 emissions were equal to 27,734 Mt CO_2, CO_2 emissions in 2020 increase, according to our model, to a level of 34,163 Mt CO_2 which is roughly 23% higher than in the base year. Recall, however, that these results already incorporate the economic slowdown caused by the current financial and economic crises. 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.

Table 5-10: CO_2 emissions (in Mt CO_2) per region

	2004	BAU 2020	ETS_EU	NETS_EU	PK_L	PK_H	IPCC_L	IPCC_H
Total Emissions								
EU	4,381	5,156	4,507	3,679	3,495	3,062	3,277	2,629
Eastern Europe	3,051	3,601	3,721	3,798	3,822	3,844	3,470	2,929
NAM (incl. USA)	7,294	8,893	8,946	9,065	6,127	5,939	4,710	3,815
LAM	1,087	1,132	1,141	1,167	1,303	1,319	1,328	1,380
CHN	4,853	6,830	6,882	6,908	7,243	7,255	7,232	7,265
ASIA (excl. CHN)	4,060	5,286	5,339	5,426	4,819	4,841	5,027	4,954
OCEANIA	434	528	536	542	356	287	243	196
AFRICA	2,573	2,736	2,818	2,900	3,227	3,278	3,305	3,500
Total	27,734	34,163	33,890	33,484	30,392	29,827	28,593	26,668

As can be further concluded from Table 5-10, total global CO_2 emissions growth can be slowed down by introducing climate policies aiming at a reduction in CO_2 emissions. However, only in the most stringent IPCC_H scenario, representing a 40% GHG emission cut in Annex I regions (about 50% of global emissions), emissions in 2020 can be reduced below the level of 2004. By widening the scope of regulated regions, as depicted by the transition from NETS_EU to PK_L and further on to IPCC_H, the effectiveness of climate policies can be substantially increased.

However, as more regions beyond the EU have to reduce their CO_2 emissions, the countries still not included within an emission mitigation agreement increase their emissions compared to 2004 by far more than the abating regions reduce their emissions. For instance, China's CO_2 emissions in the IPCC_H scenario increase by 2,400 Mt CO_2 by 2020, while the EU's CO_2 emissions can only be reduced by 1,750 Mt CO_2.

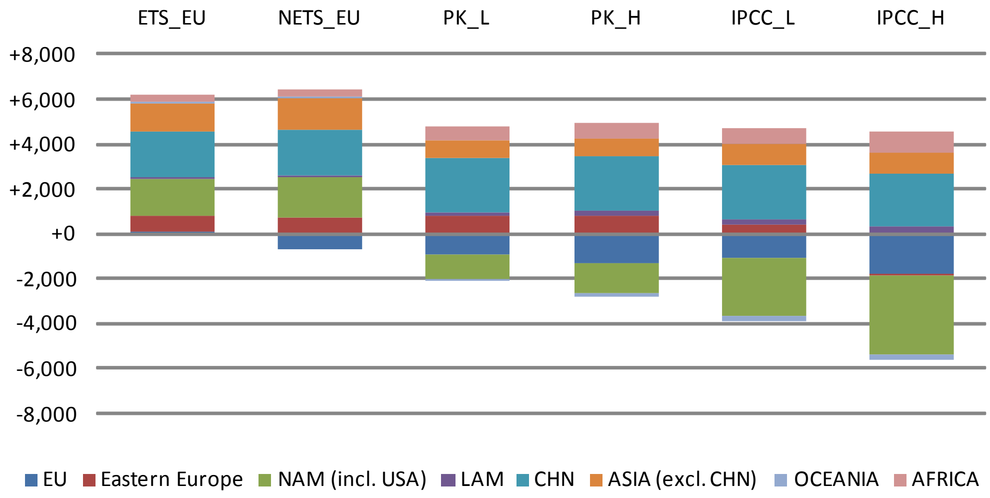

Figure 5-10: Change in CO_2 emissions (in Mt CO_2) per region and per scenario relative to 2004

Figure 5-10 illustrates the global carbon effects of the different policy scenarios, with a focus on how emissions change in the different regions. As argued above, the decrease of CO_2 emissions in abating regions compared to 2004 is more than counterbalanced in any scenario – except of IPCC_H – in this paper. In the least stringent scenario (ETS_EU), 2020 emissions increase in all regions compared to base year 2004, including the abating region (EU). This follows from a relative stronger increase in CO_2 emissions in the not regulated NETS sectors and the private households, which outweigh emission reductions in the ETS sectors. These higher NETS emissions in the EU can be overcome by incorporating the NETS sectors and the private households into the EU's abatement efforts. When all Annex I regions are subject to emission constraints (starting with PK_L) 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 China's CO_2 emissions increase.

The CO_2 permit prices associated with the various CO_2 emission reduction scenarios are presented in Table 5-11. It can be seen that in all scenarios the ETS permit prices are equal across the EU, representing the implementation of an emissions trading scheme (ETS) in the European Union.

Table 5-11: CO_2 price in ETS sectors per region (in USD/tCO_2)

	ETS_EU	NETS_EU	PK_L	PK_H	IPCC_L	IPCC_H
ETS sectors						
AUT	130	124	100	166	135	282
GER	130	124	100	166	135	282
ITA	130	124	100	166	135	282
WEU	130	124	100	166	135	282
SEEU	130	124	100	166	135	282
NEU	130	124	100	166	135	282
RUS	-	-	-	-	13	35
ROE	-	-	36	38	245	310
GUS	-	-	-	-	4	12
USA	-	-	84	95	229	410
NAM	-	-	120	119	184	251
LAM	-	-	-	-	-	-
CHN	-	-	-	-	-	-
EASI	-	-	195	188	112	162
SEAS	-	-	-	-	-	-
SASI	-	-	-	-	-	-
OCEA	-	-	63	130	209	338
MENA	-	-	-	-	-	-
SSA	-	-	-	-	-	-

When NETS sectors' as well as private households' CO_2 emissions are regulated too (NETS_EU), the EU wide CO_2 permit price for ETS sectors decreases to 124 USD/tCO_2, due to reduced production triggered by the falling demand by the henceforth constrained NETS sectors and private households. The CO_2 shadow prices for these agents, depicted in Table 5-12 , are notably higher than the ETS permit prices. This is not only due to the absence of an EU-wide market for the NETS emission allowances, as can be concluded from comparing non-EU prices for ETS and NETS permits (which are in every region higher); this result confirms the more difficult reduction of CO_2 emissions found in reality for private households and non-energy intensive sectors – most prominently emissions related to transport. When moving from scenarios in which emission constraints are introduced only in an EU context, to semi-universal post-Kyoto scenarios, the EU ETS-permit prices experience another drop from the above mentioned 124 USD/tCO_2 to 100 USD/tCO_2. This effect is triggered on the one hand by more efficient production processes as a response to stricter emission constraints and on the other hand by a shrinking foreign demand from countries which were previously not affected by climate policies. As more ambitious reduction targets are introduced in the scenarios, emission permits become more expensive – both in the ETS and the NETS sectors.

Table 5-12: CO_2 price in non-ETS sectors per region (in USD/tCO_2)

	NETS_EU	PK_L	PK_H	IPCC_L	IPCC_H
AUT	395	1065	1507	1300	2246
GER	449	332	521	442	874
ITA	341	847	1276	1030	1972
WEU	368	1117	1569	1342	2282
SEEU	71	228	381	310	638
NEU	426	550	827	692	1280
RUS	-	-	-	12	58
ROE	-	226	239	1381	1760
GUS	-	25	23	40	56
USA	-	329	366	808	1439
NAM	-	250	245	345	437
LAM	-	-	-	-	-
CHN	-	-	-	-	-
EASI	-	756	744	502	688
SEAS	-	-	-	-	-
SASI	-	-	-	-	-
OCEA	-	480	872	1351	2136
MENA	-	-	-	-	-
SSA	-	-	-	-	-

Eastern European regions (ROE and GUS) and Russia can be identified as the cheapest destination for emission reduction, since these countries are characterized by highly carbon intensive production processes in the base year 2004, leaving enough space for efficiency improvements for 2020. This conjecture can be confirmed by an analysis of CO_2 intensities in the different regions and sectors and leads to the question whether the introduction of climate policies accelerates the decarbonization of societies.

Table 5-13 presents the carbon intensities, or the CO_2 coefficients, per country and sector for the year 2020 under BAU, which were calculated as the total carbon input in the various production processes divided by total output of the respective sector.

Table 5-13: CO_2 coefficients (in t CO_2 per MUSD) per country and sector for BAU 2020

	P_C	ELY	EIS	COA	OIL	GAS	NEIS	TRN	FOOD
CO_2 coefficient	in t CO_2 per 2004 MUSD								
AUT	132	2,124	219	0	205	444	16	431	73
GER	15	3,410	204	16	202	65	10	519	45
ITA	5	2,758	188	23	203	14	21	635	72
WEU	166	2,288	174	19	74	66	15	694	76
SEEU	166	6,718	456	205	847	1,395	27	725	108
NEU	502	2,949	162	55	153	430	18	440	57
RUS	345	13,832	2,036	198	147	590	90	2,508	185
ROE	38	4,765	915	16	132	756	74	661	160
GUS	416	6,561	7,603	91	269	297	481	1,580	324
USA	561	7,087	336	26	265	292	26	1,519	124
NAM	922	4,630	395	444	340	896	48	1,932	79
LAM	399	2,696	754	118	267	1,690	62	1,817	108
CHN	28	17,805	1,302	1,343	667	16,328	77	1,039	290
EASI	64	3,089	231	38	85	1,875	16	479	92
SEAS	376	5,107	591	110	64	106	35	1,124	103
SASI	151	9,139	1,990	243	212	374	65	937	85
OCEA	188	8,055	416	174	307	552	48	842	83
MENA	2,075	9,189	2,396	170	69	452	209	2,261	156
SSA	237	14,618	964	14	85	4,271	93	1,502	54

These CO_2 coefficients differ quite substantially across regions, with the highest differences in the electricity, and energy intensive sectors. By a comparison among regions – visualized in Figure 5-11 – it is striking that CO_2 intensities in these sectors are by far highest in China, followed by Southeast Europe, Russia and the developing countries in Asia and Africa, reflecting the disproportionally high CO_2 intensities in these countries production methods. While Austria's EIS sector for example emits 219 tCO_2 per MUSD output, the GUS region emits 34 times as much CO_2 for the same amount of output.

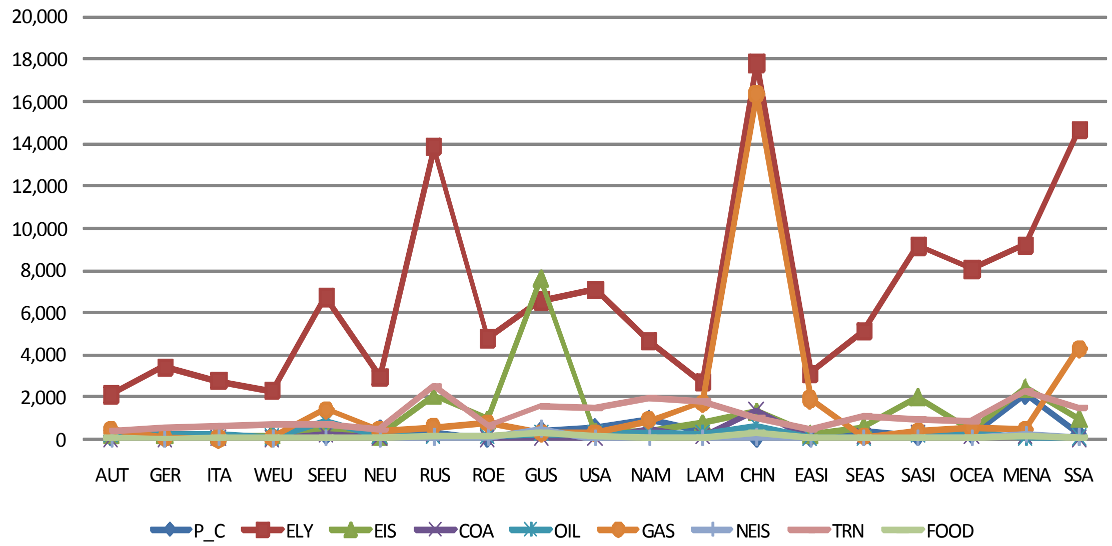

Figure 5-11: CO_2 coefficients for BAU 2020 across countries and sectors (t CO_2/MUSD)

Comparing Table 5-13 to Table 5-14 shows that more stringent mitigation efforts in the sense of stricter carbon emission constraints also trigger a more efficient usage of fossil fuels in production. By taxing the release of CO_2 due to combustion of fossil fuels or in 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. Austria's emission intensity in the power generation sector (ELY) for example would be reduced by 605 tCO_2/MUSD, thus representing a shift to more renewable energy as well as an increase in energy efficiency in fossil fueled power plants.

The important issue of power generation is analyzed in more detail in Figure 5-12. There we see that both the PK and IPCC scenarios lead to improvements in energy efficiency in power generation in all Annex I countries, namely USA, the remaining North America, Oceania (i.e. Australia, New Zealand), East Asia (i.e. Japan), and all EU countries. In contrast, all other countries, namely Russia China and the remaining American, Asian and African regions do not experience any considerably improvements compared to BAU 2020. In Sub-Saharan African countries the CO_2 intensity of the power generation sector even tends to increase, compared to BAU, since this region does not face any carbon price induced incentives to increase energy efficiency. The effect of the NETS_EU scenario on improved energy efficiency is only apparent for the EU countries, showing the limited scope of solving a global problem unilaterally.

Table 5-14: CO_2 coefficients (in tCO_2 per MUSD) per country and sector for IPCC_H

	P_C	ELY	EIS	COA	OIL	GAS	NEIS	TRN	FOOD
CO_2 coefficient	in t CO_2 per 2004 MUSD								
AUT	76	1,519	151	0	31	86	5	245	23
GER	8	2,456	151	7	41	35	5	382	21
ITA	3	2,055	143	0	36	5	8	398	27
WEU	95	1,629	137	8	22	23	4	439	23
SEEU	95	4,988	293	79	317	0	11	488	47
NEU	294	2,079	120	22	28	120	7	301	23
RUS	257	13,309	1,834	128	103	408	74	2,251	154
ROE	20	3,571	648	6	30	0	24	431	59
GUS	381	6,446	7,403	72	207	289	416	1,448	292
USA	356	5,448	221	7	65	87	8	981	38
NAM	645	3,769	276	132	134	398	22	1,426	38
LAM	382	2,861	804	136	303	1,894	68	1,943	120
CHN	25	17,824	1,353	1,374	742	16,296	81	1,112	312
EASI	41	2,484	194	12	21	795	8	321	46
SEAS	374	5,304	650	147	77	126	40	1,193	117
SASI	130	9,404	2,072	304	193	343	70	1,022	94
OCEA	100	5,893	246	41	43	133	12	489	23
MENA	2,020	9,355	2,606	194	80	521	240	2,424	176
SSA	241	15,870	1,059	15	113	5,536	109	1,633	63

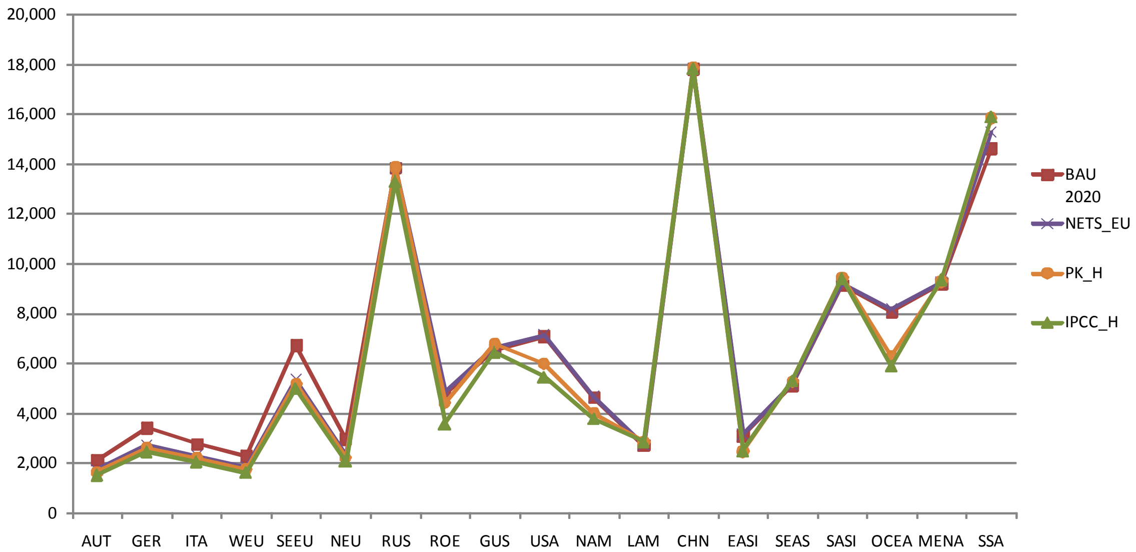

Figure 5-12: CO_2 coefficients for ELY sectors across countries and scenarios (t CO_2/MUSD)

5.3.3 Carbon Leakage

A fiercely discussed issue in the climate policy debate is the carbon leakage phenomenon – 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.

Table 5-15 presents the implications of climate policies on GHG abating countries – the policy-regions – as well as on non-abating or non-policy regions. Two different policy region groupings for the base year 2004 are necessary, since the two unilateral EU scenarios embrace fewer regions than the post-Kyoto and the IPCC scenarios. The changes in CO_2 emissions in the respective scenarios were calculated as the difference between the policy regions' and the non-policy regions' 2020 emissions and their respective CO_2 emissions in the base year 2004. Thus e.g. in the NETS_EU scenario the change in CO_2 emissions of -703 Mt CO_2 results from an emission reduction in abating regions from 4,381 Mt CO_2 in 2004 to 3,679 Mt CO_2 in 2020. However, the net change in total global CO_2 emissions for the NETS_EU setting is still significantly positive – due to increasing emissions in the non abating regions by 6,452 Mt CO_2.

Table 5-15: CO_2 effects (in Mt CO_2) of climate policies relative to 2004

	2004	ETS_EU	NETS_EU	2004	PK_L	PK_H	IPCC_L	IPCC_H
CO_2 emissions								
policy regions	4,381	4,507	3,679	17,263	15,316	14,649	13,412	11,124
Non-policy regions	23,353	29,382	29,805	10,471	15,076	15,178	15,180	15,544
Total	27,734	33,890	33,484	27,734	30,392	29,827	28,593	26,668
Change relative to 2004								
policy regions		+126	-703		-1,948	-2,615	-3,851	-6,139
non policy regions		+6,029	+6,452		+4,605	+4,707	+4,710	+5,073
Total		*+6,155*	*+5,750*		*+2,658*	*+2,093*	*+858*	*-1,066*

The first salient conclusion that can be drawn from Table 5-15 is that in the ETS_EU as well as the NETS_EU settings only about one sixth of the world's 2020 CO_2 emissions under BAU assumptions would be regulated by climate policies. Therefore even under the successful implementation of the EU 20-20 targets in the NETS_EU scenario, thereby reducing the EU's CO_2 emissions by 20% compared to 2005 emissions (European Commission, 2008), the global effect would be a substantial increase of CO_2 emissions compared to 2004 by 5.8 Gt CO_2. The total global emissions in 2020 under the NETS_EU scenario would still be boosted to 33.5 Gt CO_2, only 0.4 Gt CO_2 below BAU.

Under a more comprehensive climate policy agreement comprising all Annex I countries of the UNFCCC Kyoto Protocol – represented by the two post-Kyoto and IPCC scenarios – more fundamental reduction achievements could be obtained, since more than 50% of global 2004 CO_2 emissions would be regulated in such a policy framework. However, only in the most stringent policy scenario – IPCC_H with a reduction of Annex I regions' emissions by 40% until 2020 compared to 1990 levels – the global net effect would be a decline in emissions compared to 2004 levels, since non-abating regions' emissions would grow by 1 Gt CO_2 less than the reduction in Annex I countries (see bottom row of Table 5-15). Under these circumstances carbon leakage is very likely to occur.

Following a 'strong' definition of carbon leakage, the increase of CO_2 emissions beyond BAU in non-abating regions is divided by the emission reduction relative to BAU in the abating regions to get a measure for the amount of carbon emissions which is leaking by production shifts to other regions and hence counteract the emission reductions in the abating countries. These shares are depicted for our scenarios in the bottom line of Table 5-16 (which contains the same information as Table 5-15, with the difference that the scenarios' results are compared to BAU 2020 and not the base year 2004).

Table 5-16: Climate policies and carbon leakage - Global CO_2 effects relative to 2020 (in Mt CO_2)

	BAU	ETS_EU	NETS_EU	BAU	PK_L	PK_H	IPCC_L	IPCC_H
CO2 emissions								
policy regions	5,156	4,507	3,679	20,556	15,316	14,649	13,412	11,124
non-policy regions	29,007	29,382	29,805	13,607	15,076	15,178	15,180	15,544
Total	34,163	33,890	33,484	34,163	30,392	29,827	28,593	26,668
Change relative to 2020								
policy regions		-649	-1,478		-5,241	-5,907	-7,144	-9,432
non policy regions		+375	+799		+1,469	+1,571	+1,574	+1,937
2020 Total		-274	-679		-3,771	-4,336	-5,571	-7,495
Leakage rate 2020		*-58%*	*-54%*		*-28%*	*-27%*	*-22%*	*-21%*

Figure 5-13 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, again relative to BAU. By comparing the CO_2 effects in this figure (as well as in Table 5-16) to the 2020 emissions under BAU presumptions, the ancillary CO_2 effect on non-abating regions triggered by not globally set emission constraints can be deducted. It turns out that part of the policy induced CO_2 emissions reductions are offset by emission increases in non-policy regions, ranging from -21% for IPCC_H to -58% for ETS_EU. Thus, under ETS_EU more than half of the emission reduction within the EU is counteracted by ancillary emission increases above BAU in non-abating countries.

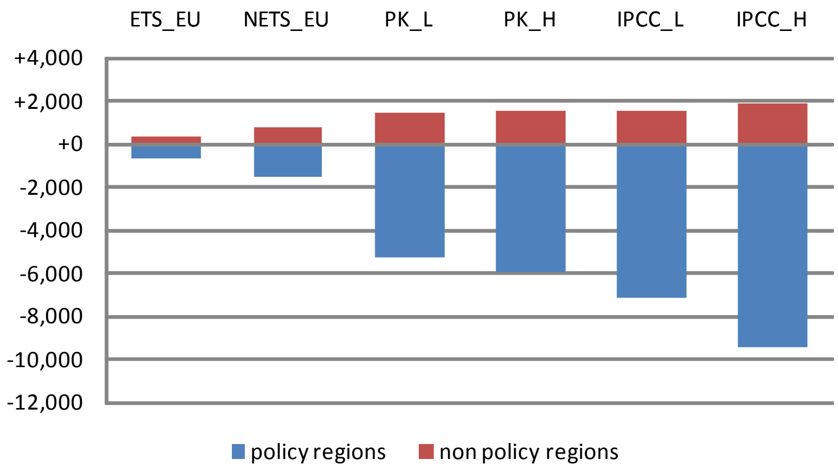

Figure 5-13: CO_2 effects (in Mt CO_2) in abating and non-abating regions relative to BAU-2020

The derived carbon leakage rates amount to -58% in the ETS_EU scenario and -54% in the NETS_EU scenario respectively. This is due to the fact, which has already been pointed out earlier, that only a small fraction of global CO_2 emissions is under control in these unilateral EU scenarios. The fraction of abated CO_2 emissions, offset in non-abating regions, declines, the more stringent and comprehensive the climate policies become. But even in the most stringent and comprehensive climate policy scenario IPCC_H, carbon leakage amounts to -21%.

Table 5-17: Change in emissions (in %) relative to BAU

	2004	BAU 2020	ETS_EU	NETS_EU	PK_L	PK_H	IPCC_L	IPCC_H
EU	4,381	5,156	-12.6%	-28.7%	-32.2%	-40.6%	-36.5%	-49.0%
Eastern Europe	3,051	3,601	+3.3%	+5.5%	+6.1%	+6.8%	-3.6%	-18.7%
NAM (incl. USA)	7,294	8,893	+0.6%	+1.9%	-31.1%	-33.2%	-47.0%	-57.1%
LAM	1,087	1,132	+0.8%	+3.1%	+15.1%	+16.6%	+17.3%	+21.9%
CHN	4,853	6,830	+0.8%	+1.1%	+6.0%	+6.2%	+5.9%	+6.4%
ASIA (excl. CHN)	4,060	5,286	+1.0%	+2.6%	-8.8%	-8.4%	-4.9%	-6.3%
OCEA	434	528	+1.5%	+2.6%	-32.6%	-45.7%	-53.9%	-63.0%
AFRICA	2,573	2,736	+3.0%	+6.0%	+18.0%	+19.8%	+20.8%	+28.0%
Total	27,734	34,163	-0.8%	-2.0%	-11.0%	-12.7%	-16.3%	-21.9%

The more parties are being held responsible for their CO_2 emissions, the less room is left for emissions leaking to non-regulated regions. As can be seen in Figure 5-14, CO_2 emissions in the post-Kyoto and the IPCC scenarios are only increasing relative to BAU in Latin America, China and Africa – regions which are not facing any emission constraints in any of the scenarios and whose emissions can therefore grow without bounds. The more stringent the reduction objectives become, the higher the CO_2 reduction achievements in regions like North America or Eastern Europe become.

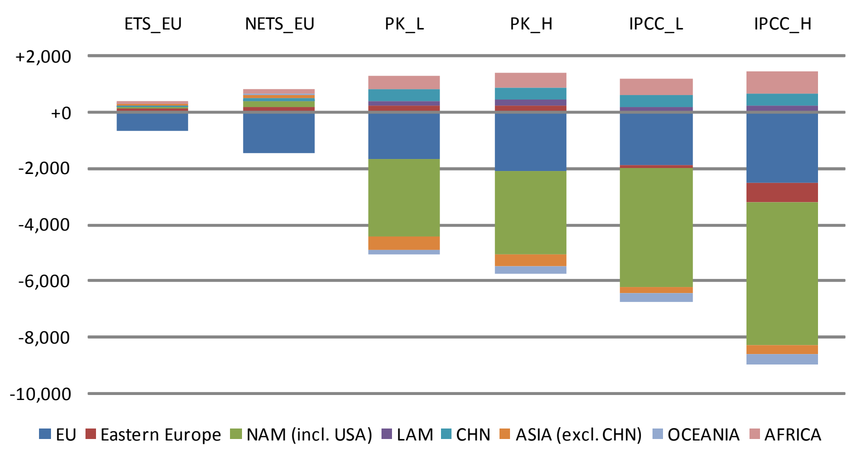

Figure 5-14: Change in CO_2 emissions (in Mt CO_2) relative to BAU

Table 5-17 gives a more detailed account of CO_2 emission trajectories in the presence of climate policies. While emissions compared to BAU in most regions fall quite significantly, moving from the least to the most stringent scenario, the picture in China, Latin America and Africa is quite different. The EU's CO_2 emissions reduction would increase from -13% in the

ETS_EU scenario to -49% compared to 2020 BAU assumptions. Even in North America (including USA), where emissions would rise in the two EU scenarios due to carbon leakage even more than under BAU, CO_2 emissions would fall by 57% in the strict IPCC_H setting compared to BAU. For China on the other hand, CO_2 emissions would be subject to even a more accelerated growth than under BAU premise, fostering emission growth by 6.4% in the IPCC_H scenario relative 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 4,853 for CHN (Table 5-17).

Table 5-18: Sectoral CO_2 effects and carbon leakage (in Mt CO_2) relative to BAU

	BAU	ETS_EU	NETS_EU	BAU	PK_L	PK_H	IPCC_L	IPCC_H
in Mt CO_2		relative to BAU 2020				relative to BAU 2020		
policy regions								
ETS sectors								
P_C	71	-18	-27	409	-167	-181	-221	-268
ELY	1552	-525	-526	7243	-1,674	-1,911	-2,395	-3,193
EIS	735	-155	-144	2765	-220	-311	-474	-885
Non-ETS sectors								
COA	2	-1	-1	9	-4	-5	-5	-6
OIL	14	+1	-9	88	-46	-49	-56	-66
GAS	18	+0	-12	132	-65	-68	-79	-98
NEIS	97	-7	-36	336	-135	-148	-164	-199
TRN	1023	-8	-290	3712	-1,161	-1,283	-1,519	-1,935
FOOD	197	-8	-70	584	-244	-268	-297	-358
SERV	279	-19	-98	1204	-448	-489	-552	-687
Private households	1167	+89	-264	4075	-1,079	-1,195	-1,380	-1,737
non-policy regions								
ETS sectors								
P_C	717	+9	+22	379	+49	+56	+63	+98
ELY	11,072	+204	+235	5381	+331	+346	+330	+384
EIS	5,254	+121	+203	3224	+402	+411	+396	+433
Non-ETS sectors								
COA	101	+1	+1	94	+4	+4	+3	+3
OIL	163	+1	+4	89	+11	+11	+11	+13
GAS	256	+3	+6	142	+9	+9	+9	+11
NEIS	637	+4	+12	399	+38	+34	+30	+16
TRN	4,135	+10	+236	1447	+474	+553	+578	+835
FOOD	866	+4	+19	479	+47	+46	+46	+42
SERV	1,346	+7	+21	421	+32	+31	+32	+30
Private households	4,459	+12	+42	1551	+72	+71	+74	+72
Total	34,163	-274	-679	34,163	-3,771	-4,336	-5,571	-7,495

Another interesting issue to look at in more detail – after analyzing regional structure of the leakage effects –, is the sectoral disaggregation of the carbon leakage phenomenon. Table 5-18 presents the CO_2 effects of the six climate policy scenarios on the sector aggregates within our model. Again, there are two dissimilar fragmentations of the BAU results, depending on the respective differentiation of policy and non-policy regions relevant for the various scenarios.

It can be seen that the sectors most affected (in absolute terms) by emission constraints are the two ETS sectors ELY and EIS as well as the non-ETS sector TRN and in the more stringent/comprehensive scenarios also the SERV sector. By analyzing the effects of the ETS_EU scenario we can see that the ETS emissions in the abating region (here the EU) fall quite significantly by 525 Mt CO_2 (ELY), 155 Mt CO_2 (EIS) and 18 Mt CO_2 (P_C) as well as due to feedback effects of not restricted sectors' emissions growing less strong than under BAU. Only the private household's emissions grow in this scenario, since they are not confronted with an emission constraint and the benefit from the revenue recycling of the emission permit sales. The non-abating regions' emissions on the other hand react in the exact opposite way. Part of the ETS production relocates to non abating regions, depicted by higher emissions compared to BAU in the P_C (+9Mt CO_2), the ELY (+204 Mt CO_2) and the EIS sector (+121 Mt CO_2).

Table 5-19: Sectoral carbon leakage rates

	ETS_EU	NETS_EU	PK_L	PK_H	IPCC_L	IPCC_H
	Leakage rate relative to BAU 2020					
Sectors						
P_C	-50%	-79%	-29%	-31%	-29%	-36%
ELY	-39%	-45%	-20%	-18%	-14%	-12%
EIS	-78%	-141%	-183%	-132%	-83%	-49%
COA	-115%	-45%	-90%	-78%	-63%	-44%
OIL	136%	-47%	-24%	-22%	-20%	-19%
GAS	736%	-46%	-14%	-13%	-12%	-12%
NEIS	-52%	-32%	-28%	-23%	-18%	-8%
TRN	-128%	-81%	-41%	-43%	-38%	-43%
FOOD	-51%	-27%	-19%	-17%	-15%	-12%
SERV	-35%	-21%	-7%	-6%	-6%	-4%
Total	**-58%**	**-54%**	**-28%**	**-27%**	**-22%**	**-21%**

These movements of CO_2 emissions are reflected in the sectoral leakage rates presented in Table 5-19. In the ETS_EU case the TRN sector corresponds to a leakage rate of 128%, followed by the EIS sector with 78% and the P_C sector with 50%. The high leakage rates in the TRN sector as well as the primary energy sectors (COA, OIL, GAS) can be traced back to the intermediate input character of theses commodities in the ETS production. Therefore lower

ETS production in abating regions triggers lower intermediate inputs, resulting in lower emissions also within these intermediate sectors (and in opposite direction in non-abating regions).

The more stringent and comprehensive emission reduction objectives are obtained in the scenarios, the smaller not only the total leakage rate becomes but also the lower the sectoral leakage rates tend to be. For instance, the leakage rate of the EIS sector in the IPCC_H scenario is only 49%, compared to 141% in the NETS_EU scenario. This is due to the fact that for both PK and IPCC scenarios all Annex I regions are subject to CO_2 emission constraints and that therefore domestically reduced emissions cannot be shifted across borders in such high volumes anymore as with the EU unilateral scenarios.

6 Alternative policy scenarios

As a final section, we will discuss two aspects of climate policy which are of particular interest for EU countries. The first is the efficiency gains obtained by an EU wide ETS instead of country specific systems which are not linked. The second is the question of compensating policies in case that the EU is faced with the failure of a post Kyoto agreement in Copenhagen. One such approach discussed is border tax adjustment to reduce competitiveness effects for European industries.

The first alteration abandons the idea of a uniform carbon price in the EU, in other words the EU ETS is adjourned. This setting will, when compared to the emission trading case, reflect the efficiency losses in the absence of a common emission permit market. The second variation introduces the concept of border tax adjustment (e.g. import taxes or export subsidies) as a remedy to the arising carbon leakage phenomenon in the lack of a global agreement on emissions reduction. In our scenario, we model border tax adjustment (BTA) as the doubling of import taxes in those sectors which are faced with emission constrains in all abating countries (the ETS sectors in ETS_EU and all sectors in NETS_EU). Border tax adjustment will only be investigated within the two unilateral EU policy scenarios.

Table 6-1: CO_2 price in ETS sectors in Europe

	ETS_EU	ETS_EU non-uniform
AUT	130	132
GER	130	160
ITA	130	104
WEU	130	157
SEEU	130	78
NEU	130	183

An interesting finding of the model under a non-uniform ETS_EU can be derived from the diverse CO_2 permit prices across the EU (see Table 6-1). As was noted in earlier analysis of the EU ETS, emission abatement is cheapest in South East European countries (78 USD/tCO_2) compared to the 243 USD/tCO_2 in Northern European areas. Therefore the introduction of an EU wide CO_2 permit market enhances the efficiency of climate policies by allowing CO_2 emissions reductions to take place where they are cheapest. This equalizes CO_2 permit prices across the EU in 2020 at 181 USD/tCO_2 under ETS_EU. In contrast, the non-uniform prices range from 108 USD/tCO_2 in South Eastern EU to 243 USD/tCO_2 in the Northern EU. Austria's price ranges in the middle field.

The effects of both a non-uniform ETS_EU and of BTA are summarized in Table 6-2. We find that, compared to ETS_EU, the relative changes to BAU 2020 of Austria's economic activity increase with a non-uniform carbon price. Output in Austria's ETS sectors is reduced additionally by 0.06 percentage points, ETS imports by 0.7 percentage points and ETS exports by 0.61 percentage points relative to BAU; reflecting the efficiency loss from an abolishment of the EU ETS.

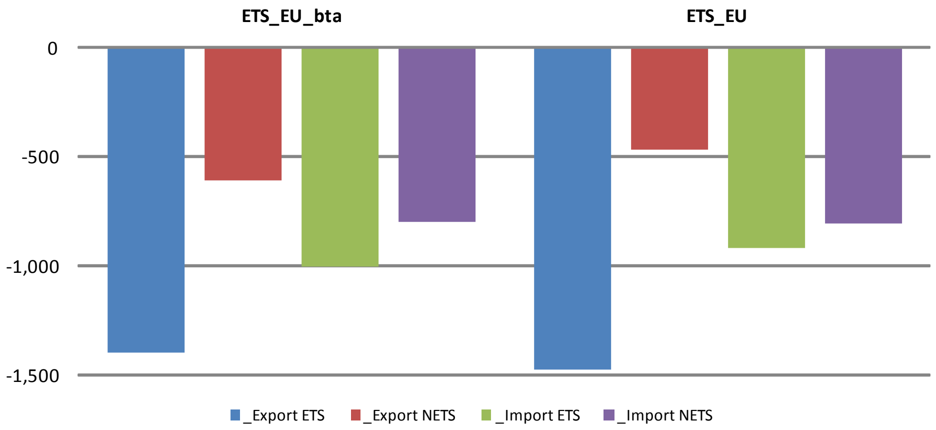

Figure 6-1: Trade effects of BTA in the ETS_EU scenario (in MUSD) relative to BAU

Regarding BTA, we find that ETS output and exports are protected, leading to lower reductions compared to BAU than the scenarios without BTA. Figure 6-1 as well as Table 6-2 depict these BTA effects. ETS output under protective measures would be reduced – relative to BAU - by 3.32% only (instead of 3.54% if no BTA policies would be implemented). While Austria's ETS exports would benefit from the introduction of BTA, NETS exports would be reduced stronger under ETS_EU with BTA than under ETS_EU, reflecting the general shift from NETS production to ETS production. Austria's import structure would react in the exact opposite way – the import of ETS commodities could be reduced since domestic production can satisfy a greater share of domestic demand, while the decline in domestic NETS production is partly offset by increasing NETS imports.

Table 6-2: Output and trade effects of BTA and a non-uniform carbon price for Austria

	BAU 2020	ETS_EU	ETS_EU with BTA	ETS_EU non-uniform	NETS_EU	NETS_EU with BTA
	in MUSD	change relative to BAU 2020 (in %)				
GDP						
Consumption	247,414	-0.37%	-0.36%	-0.39%	-0.86%	-0.84%
Investment	101,964	-0.35%	-0.36%	-0.34%	-0.70%	-0.72%
Government	78,793	-0.37%	-0.36%	-0.39%	-0.86%	-0.84%
Trade balance	-14,843	+1.35%	+1.37%	+1.06%	+20.96%	+21.52%
total	413,328	-0.43%	-0.42%	-0.43%	-1.60%	-1.61%
growth rate	2.19	2.16	2.16	2.16	2.09	2.08
Output						
ETS total	83,621	-3.54%	-3.32%	-3.60%	-5.58%	-5.58%
non-ETS total	702,401	-0.38%	-0.40%	-0.39%	-1.64%	-1.62%
Output total	786,022	-0.71%	-0.71%	-0.73%	-2.06%	-2.04%
Export						
ETS total	33,684	-4.38%	-4.15%	-4.99%	-6.09%	-6.44%
non-ETS total	137,689	-0.34%	-0.44%	-0.31%	-3.21%	-3.65%
Export TRANS	10,343	-0.14%	-0.29%	-0.07%	-8.12%	-9.32%
Export total	171,249	+4.97%	+4.92%	+4.88%	+1.85%	+1.35%
Import						
ETS total	36,654	-2.50%	-2.73%	-3.20%	-4.73%	-4.99%
non-ETS total	156,249	-0.52%	-0.51%	-0.49%	-1.51%	-1.91%
Import TMG	3,656	-0.82%	-0.95%	-0.72%	-2.88%	-4.40%
Import total	196,558	-0.89%	-0.93%	-1.00%	-2.13%	-2.53%

For emissions linked to Austrian output and consumption, however, the effects of doubling import taxes on ETS goods from ROW to the EU are almost negligible. As can be seen from Table 6-3, CO_2 emissions in Austrian ETS production decrease by 0.05 percentage points less (compared to BAU) than in ETS_EU. In combination with a slightly stronger CO_2 emission reduction (by 0.02 percentage points) in the NETS sectors compared to ETS_EU – as mentioned earlier due to decreasing output quantities – Austria's domestic output related CO_2 emissions are almost not affected by the BTA policy.

By analyzing the BTA effects on Austria's trade related CO_2 emissions in Table 6-3 and Figure 6-2, it follows that CO_2 emissions embodied in Austria's exports are subject to a negligible decrease – by 0.02 percentage points compared to ETS_EU without BTA measures. The slightly increasing exported ETS emissions compared to ETS_EU are counterbalanced by the diminishing non-ETS emissions as well as diminishing emissions delivered to the global transport market (TRANS), indicated in Austria's CO_2 emission balance (Table 6-3). For emissions embodied in Austrian imports, the extra emission reduction of protective measures can mainly be attributed to decreasing CO_2 imports connected to ETS commodities.

Table 6-3: CO_2 effects of BTA and a non-uniform carbon price for Austria

	BAU 2020 Mt CO_2	ETS_EU	ETS_EU with BTA	ETS_EU unilateral	NETS_EU	NETS_EU with BTA
			change relative to BAU 2020 (in %)			
CO2 PrivHH	23.34	+3.79%	+3.87%	+3.97%	-24.30%	-24.16%
CO2 Output	67.43	-12.12%	-12.10%	-12.21%	-28.87%	-28.92%
PBP	90.77	-8.03%	-8.00%	-8.05%	-27.69%	-27.69%
CO2 IM-EX	9.16	-13.84%	-14.81%	-12.59%	+28.12%	+28.74%
CBP	99.93	-8.56%	-8.62%	-8.47%	-22.58%	-22.52%
CO_2 Output						
ETS total	32.42	-22.99%	-22.94%	-23.20%	-23.20%	-23.20%
non-ETS total	35.01	-2.05%	-2.07%	-2.03%	-34.11%	-34.21%
total	67.43	-12.12%	-12.10%	-12.21%	-28.87%	-28.92%
CO_2 Exports						
ETS total	9.03	-22.28%	-22.18%	-23.46%	-22.12%	-22.37%
non-ETS total	8.60	-1.72%	-1.79%	-1.65%	-36.83%	-37.18%
CO_2 TRANS	4.46	-0.48%	-0.60%	-0.40%	-28.39%	-29.24%
total	22.09	-9.87%	-9.89%	-10.32%	-29.11%	-29.52%
CO_2 Imports						
ETS total	15.75	-19.54%	-20.18%	-19.48%	-18.82%	-18.79%
non-ETS total	12.56	-2.81%	-2.70%	-2.79%	-4.78%	-4.52%
CO_2 IM TMG	2.93	-0.60%	-0.77%	-0.42%	-9.86%	-12.27%
total	31.25	-11.04%	-11.33%	-10.98%	-12.33%	-12.44%

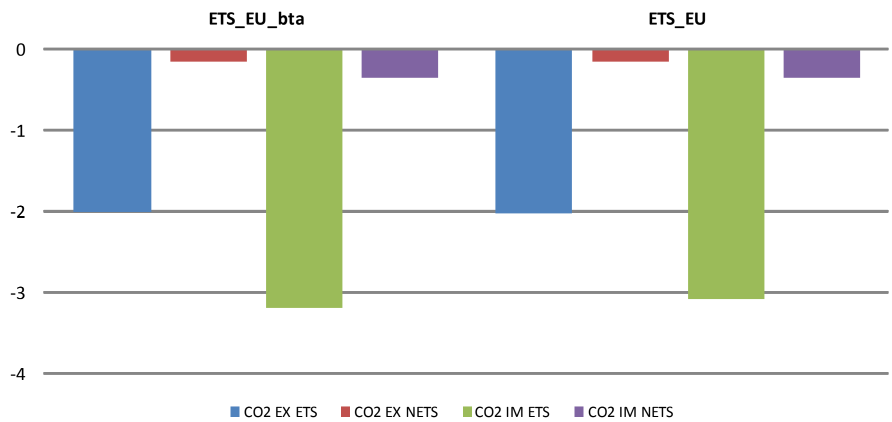

Figure 6-2: CO_2 effects of BTA in the ETS_EU scenario (in MUSD) relative to BAU

Finally, in our analysis of BTA measures it can be concluded that a doubling of import taxes related to imports from non-EU regions' ETS sectors has a quite insignificant effect on the Austrian economy. While in monetary values a movement of Austrian production and trade activities in the anticipated way can be observed, favorable CO_2 effects from the net carbon balance of Austrian trade are partly counterbalanced by increasing private household emissions. Therefore Austria's emissions measured by the CBP approach can be reduced by 8.62% relative to BAU under ETS_EU with BTA, slightly more than without BTA policies (-8.56%).

Table 6-4: Global CO_2 effects of BTA (in Mt CO_2)

	BAU	ETS_EU	ETS_EU_bta
CO_2 emissions			
policy regions	5,156.	4,507	4,507
non-policy regions	29,006	29,382	29,380
Total	34,163	33,889	33,887
Change relative to 2020			
policy regions		-649	-649
non policy regions		+375	+373
Total		-274	-276
Leakage rate 2020		-57.8%	-57.5%

Since the debate on carbon leakage in combination with compensation measures has a strong global dimension – because it is widely assumed that import tariffs set by the EU on commodities from regions facing less stringent environmental regulations have in addition to their positive effects on the EU economy ancillary positive effects on global CO_2 emissions – Table 6-4 presents the model results for the ETS_EU scenario compared to the same scenario augmented with the previously described protective policy. While the CO_2 emissions in the policy implementing regions can be hold constant at a level of 4,507 Mt CO_2, even though output in the EU is increasing due to protective measures in the ETS sectors, the CO_2 emissions in non-abating regions can only be slightly reduced, namely by 2 Mt CO_2. Therefore, the carbon leakage rate in the ETS_EU scenario can be reduced only by 0.3 percentage points. If the quite substantial trade intervention – a 100% increase of the initial 2004 GTAP7 import tariff values – is weighed against its negligible effect on global CO_2 emissions, the appropriateness of BTA measures have to be questioned. Thus, one of the claims held by proponents of trade measures that BTA reduces carbon leakage cannot be confirmed within our current model strucuture. To derive necessary characteristics of BTA to ensure their effectiveness, would need further investigation which is however beyond the scope of this report.

7 Conclusions

Within our CGE model of the Austrian economy and its main trading partners, we analyzed the consequences of three types of climate policy scenarios relative to a business as usual (BAU) scenario for 2020, namely two unilateral EU climate policies, analytically separating a policy for the ETS sectors only (ETS_EU) or also non-ETS sectors and households (NETS_EU); a voluntary post Kyoto agreement of Annex I countries (PK_L, PK_H); and a compulsory global agreement for Annex I countries, with reduction targets as identified by the IPCC's 4th Assessment Report to reach the +2° temperature target by 2100 (IPCC_L, IPCC_H). Our main findings can be summarized as follows.

The BAU 2020: Austrian consumption based carbon emissions almost 40% higher than in 2004

Under BAU 2020, Austrian GDP grows annually at 2.2% (on average for the period 2004 to 2020) and output grows by 30%, predominantly in the non-ETS sectors. Total imports increase 36% while total exports only increase by 27%, causing Austria's trade balance to worsen by 13 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 14.8% from 2004 (79 Mt CO_2) to 2020 (91 Mt CO_2), with a considerably stronger increase by households than in production. According to the CBP (consumption based principle), Austria's emissions increase from 87 Mt CO_2 in 2004 by 15% 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 CO_2 trade deficit of Austria increases by 15% relative to 2004, despite a much stronger increase in Austria's trade deficit which increases almost eightfold. This decoupling of emissions from trade flows 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 imports from carbon intensive goods (EIS sectors) to low-carbon products (NEIS and SERV sectors). Finally, more than 50% of Austria's CO_2 emissions linked to production activities both in 2004 and 2020 arise within ETS sectors – mainly EIS and ELY – even though the monetary output value of the NETS sectors – predominantly the NEIS and SERV sectors – is almost nine times higher than the ETS output.

Both unilateral EU and internationally coordinated climate policies affect Austrian international trade stronger than its domestic production

In scenario ETS_EU, the European Union implements an emissions trading scheme in the energy intensive sectors (ETS sectors, namely P_C, ELY, EIS) only, but the other countries do not limit their emissions. This leads to a reduction in Austrian GDP by 0.4% relative to BAU, and Austrian exports and imports decline by 1.1% and 0.9% respectively. When the European Union extends its climate policy also to the non-ETS sectors and households but the other Annex I countries still do not reduce their emissions, effects on GDP, exports and imports are more than doubled. The post Kyoto scenarios PK_L and PK_H with voluntary reduction commitments also by other Annex I countries, further intensify the economic consequences for GDP, exports, and imports. Finally, under the IPCC emission reduction scenarios which constitute, according to the IPCC Fourth Assessment Report, the necessary reduction targets for Annex I countries to remain within the +2° temperature target (compared to pre-industrial levels) by 2100, GDP is up to 8.0% lower than under BAU and exports and imports fall by up to 12.5% and 8.6% respectively. Thus, under all scenarios Austrian international trade is affected more strongly than its domestic production.

At the sectoral level, Austrian production in ETS sectors is hit relatively hard under the unilateral EU policies, while the non-ETS sectors are affected more strongly under the internationally coordinated scenarios (post Kyoto and IPCC). For Austrian exports, a similar pattern emerges as for its production; moreover, ETS exports to North America and Eastern Europe are highest under the IPCC scenarios, since the US and Russia are subject to much more stringent emission targets than under all other scenarios. Austrian imports are slightly less affected than its exports. Due to the higher openness to trade of the ETS sectors, ETS imports are affected more strongly than non-ETS imports. Since Austria’s main trading partners are within the EU, reductions in imports from the EU are the result of binding emission targets for all member states. 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.

Austria can achieve the EU 20-20 emission reduction targets, but its carbon trade balance worsens considerably

Under all scenarios, Austrian carbon emissions are considerably lower than under BAU 2020, ranging according to the production based principle (PBP) from 8.0% under ETS_EU to 51.8% under BAU. These emission reductions are sufficient to reach the EU 20-20 targets, except for ETS_EU where the non-ETS sectors and the households are not committed to reduction targets. However, the carbon trade balance (emission from export minus emissions from import) worsens – emissions from Austrian exports decline more than emissions from its imports, due to a shift in trade partners and a shift from imports of ETS to non-ETS commodities. It is striking, that the emissions embodied in imported non-ETS commodities hardly respond to the different climate policies while the CO_2 emissions linked to ETS commodities change considerably. 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.

To achieve a stabilization of global CO_2 emissions, a global agreement including non-Annex I countries is needed

At the global scale, effects on GDP depend on how universal emission targets are set, both in terms of sectoral and regional coverage. In both 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 34.2 Gt CO_2, already adjusted for economic slowdown due to the current economic crisis, compared to 27.7 Gt CO_2 in 2004.

When the EU introduces binding targets for ETS and non-ETS sectors and households but all other countries do not commit themselves, only $1/6^{th}$ of global emissions are regulated (= EU 20-20 target) and global emissions still rise by 5.8Gt CO_2 above 2004 levels. Even under the more stringent post Kyoto (PK_L and PK_H) and the IPCC_L scenarios global emissions cannot be reduced under 2004 levels: emissions increase by 0.9 Gt CO_2 to 2.7 Gt CO_2 compared to 2004, since Annex I countries only comprise slightly more than 50% of global emissions (according to the PBP). Only in the most stringent policy scenario that we analyzed within this paper – IPCC_H, where Annex I countries are constrained to reduce their CO_2 emissions by 40%

compared to 1990 levels by 2020 – global CO_2 emissions can be mitigated strong enough to fall by 1 Gt CO_2 under the 2004 level (which was at 27.7 Gt CO_2).

Carbon leakage from non-abating to abating regions occurs in all scenarios, ranging from 58% (EU_ETS) to 21% (IPCC_H). Thus, the more countries, and in particular other major economies like the US (and the rest of North America), Russia and Oceania, commit themselves to binding emission targets, the lower the rate of leakage and the less carbon intensive are domestic production and the imports from those countries. This argument can be extended to non-Annex I countries: in a post Kyoto agreement, developing countries, in particular China, have to play a substantial role to halt carbon leakage and to thereby achieve a stabilization of carbon emissions on a global scale.

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