Consumption-based carbon emissions in a post-Kyoto regime until 2020

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Abstract

COP17 in Durban revealed once again the general willingness to commit to the 2°-target and the difficulty to reach an international agreement until 2015. There is strong evidence from model-based analysis that economic cost of reaching the 2°-target will be below global GDP growth of one year. Any possible solution has to address global equity, which is explicitly considered in the research on the difference between production-based and consumption-based emissions. Using a multi-regional input-output model (MRIO) extended with carbon intensity coefficients, it is possible to calculate consumption-based carbon emissions. This paper combines these two strands. It uses a scenario of the global GINFORS model in line with the Copenhagen pledges for 2020 to calculate the distribution of future consumption-based carbon emissions around the globe using the Global Resource Accounting Model (GRAM).

GINFORS projections provide GDP development, energy balances and energy-related carbon emissions for 53 countries and two regions (Lutz et al., 2010). Sectoral production structures and trade data are available for all OECD countries, their major trading partners and the large emerging economies. This data is used to project the multi-regional input-output coefficient matrix and the corresponding final demand matrix as well as the energy-intensity coefficient vector of GRAM to calculate consumption-based carbon emissions of a Post-Kyoto regime until 2020. GRAM is a MRIO model with the same sectoral and regional structure as GINFORS (Wiebe et al., 2012).

Production-based emissions will further increase in emerging economies, whereas OECD countries will have to reduce emissions according to their Copenhagen pledges. The results may show that a consumption-based accounting of carbon emissions allocates more emissions to the industrialized countries than production-based accounting. The increasing final demand in the emerging economies may however reduce net-exports and hence also the relative net-emissions embodied in these exports.

Keywords

Multi-regional input-output model, carbon emissions, Post-Kyoto Agreement, scenario analysis

JEL classification

C6, F1, Q5

1. Introduction

The global climate agreement Kyoto-Protocol ends in 2012. COP17 in Durban in December 2011 revealed once again the general willingness to commit to the 2°-target and the difficulty to reach an international agreement until 2015. An international agreement should not only ensure that the global target will be reached, but also a fair burden sharing across countries in the developed and developing world. The industrialized countries are currently responsible for about 60% of the greenhouse gas (GHG) emissions produced in the world (consumption-based accounting), even though the direct emission of greenhouse gases in these countries (production-based) only is 45% of global emissions (compare Wiebe et al. 2012).

There is strong evidence from model-based analysis that economic cost of reaching the 2°-target will be below global GDP growth of one year (IPCC, 2007). Any possible solution has to address global equity, which is explicitly considered in the research on the difference between production-based and consumption-based emissions. Using a multi-regional input-output model (MRIO) extended with carbon intensity coefficients, it is possible to calculate consumption-based carbon emissions. This paper combines these two strands. It implements a scenario in the global GINFORS model, which is in line with the Copenhagen pledges for 2020 to calculate the distribution of future consumption-based carbon emissions around the globe using the Global Resource Accounting Model (GRAM).

2. Combining a static environmentally extended MRIO with a dynamic forecasting model

For the analysis of the impact of a global climate change agreement on the distribution of carbon emissions around the world, we combine the Global Resource Accounting Model (GRAM) with the Global Interindustry Forecasting System (GINFORS). Both models are based on the same sectoral (ISIC Rev. 3) and regional structure (see Wiebe et al, 2012).

2.1 The global energy-environment-economy model GINFORS

The sectorally disaggregated global energy-environment-economy model GINFORS combines econometric-statistical analysis with input-output analysis embedded in a complete macroeconomic framework ensuring the accounting identities of the system of national accounts. GINFORS has recently been applied to various economic questions, ranging from an European environmental tax reform (Lutz et al 2010, Barker et al 2011) and environmental and economic effects of Post-Kyoto regimes (Lutz and Meyer, 2009b) to the impact of higher energy prices through international trade (Lutz and Meyer, 2009a). A detailed description of GINFORS can be found in Lutz et al (2010).

The main difference to neoclassical CGE models is the representation of prices, which are determined from the mark-up hypothesis by unit costs and not specified as long run competitive prices. But this does not mean that the model is demand side driven, as the use of input-output models might suggest. Even though demand determines production, all demand variables depend on relative prices that are given by unit costs of the firms using the mark-up hypothesis, which is typical for oligopolistic markets. The difference between CGE models and GINFORS can be found in the underlying market structure and not in the accentuation of either market side. Firms are setting prices depending on their costs and on the prices of competing imports. Demand is reacting to price signals and thus determining production. Hence, the modelling of GINFORS includes both demand and supply side elements.

Behavioural parameters of the model are estimated econometrically, and different specifications of the functions are tested against each other, which gives the model an empirical validation. The econometric estimations are based on times series from OECD, IMF and IEA for 1980 to 2006. The modelling philosophy of GINFORS is close to that of INFORUM type modelling (Almon, 1991, EUROSTAT 2008) and to that of the model E3ME of Cambridge Econometrics (Barker et al, 2011b).

Figure 1 displays the basic model structure of GINFORS. The countries's economies are either modelled with input-output models or aggregate macro models (if no OECD input-output table exist). Import demand and export prices are determined within the country models. The bilateral trade model then combines the information and gives export demand and import prices to the countries' economies. The model iterates until the convergence property of the solution is reached, which has to be fulfilled on a yearly basis.

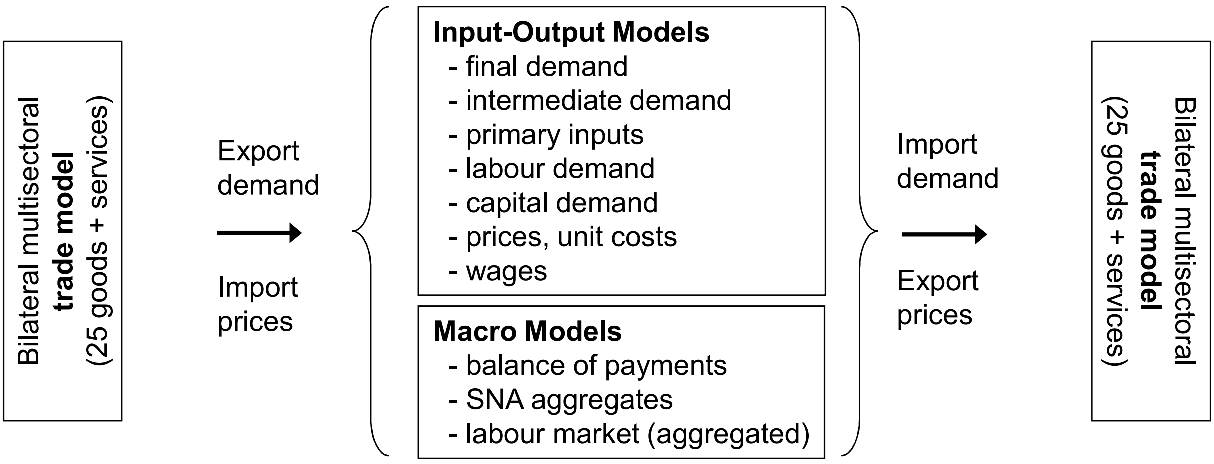

Figure 1: GINFORS structure

2.2 The multi-regional input-output model GRAM

The Global Resource Accounting Model (GRAM) is a multi-regional input-output (MRIO) model that allows for calculating consumption-based emissions and material requirements for 53 countries and 2 regions, disaggregated into 48 sectors, for each year between 1995 and 2005. The countries that are modelled explicitly cover about 95% of world GDP and 95% of global emissions.

GRAM is a "true" MRIO model, as defined by Giljum et al. (2008), incorporating one global input coefficient matrix A. It therefore differs from the other form of MRIO models that include one IO model per country, which is solved separately from the others, and then linked to the other country models via international trade. This method is for example used in Ahmad and Wyckoff (2003) or Nakano et al. (2009). GRAM implicitly includes international trade in the inter-industry requirements matrix, which is calculated from monetary input-output tables and bilateral trade data of the OECD. The two central equations of the model are

$$\begin{pmatrix} \hat{\mathbf{x}}_{11} & \hat{\mathbf{x}}_{12} & \cdots & \hat{\mathbf{x}}_{1C} \\ \hat{\mathbf{x}}_{21} & \hat{\mathbf{x}}_{22} & \cdots & \hat{\mathbf{x}}_{2C} \\ \vdots & \vdots & \ddots & \vdots \\ \hat{\mathbf{x}}_{C1} & \hat{\mathbf{x}}_{C2} & \cdots & \hat{\mathbf{x}}_{CC} \end{pmatrix} = \begin{pmatrix} \mathbf{I}-\mathbf{A}_{11} & -\mathbf{A}_{12} & \cdots & -\mathbf{A}_{1C} \\ -\mathbf{A}_{21} & \mathbf{I}-\mathbf{A}_{22} & \cdots & -\mathbf{A}_{2C} \\ \vdots & \vdots & \ddots & \vdots \\ -\mathbf{A}_{C1} & -\mathbf{A}_{C2} & \cdots & \mathbf{I}-\mathbf{A}_{CC} \end{pmatrix}^{-1} \begin{pmatrix} \mathbf{y}_{11} & \mathbf{y}_{12} & \cdots & \mathbf{y}_{1C} \\ \mathbf{y}_{21} & \mathbf{y}_{22} & \cdots & \mathbf{y}_{2C} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{y}_{C1} & \mathbf{y}_{C2} & \cdots & \mathbf{y}_{CC} \end{pmatrix} \quad (1)$$

$$\begin{pmatrix} \mathbf{p}_{11} & \mathbf{p}_{12} & \cdots & \mathbf{p}_{1C} \\ \mathbf{p}_{21} & \mathbf{p}_{22} & \cdots & \mathbf{p}_{2C} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{p}_{C1} & \mathbf{p}_{C2} & \cdots & \mathbf{p}_{CC} \end{pmatrix} = \begin{pmatrix} \mathbf{E}_1 & 0 & \cdots & 0 \\ 0 & \mathbf{E}_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \mathbf{E}_C \end{pmatrix} \begin{pmatrix} \mathbf{I}-\mathbf{A}_{11} & -\mathbf{A}_{12} & \cdots & -\mathbf{A}_{1C} \\ -\mathbf{A}_{21} & \mathbf{I}-\mathbf{A}_{22} & \cdots & -\mathbf{A}_{2C} \\ \vdots & \vdots & \ddots & \vdots \\ -\mathbf{A}_{C1} & -\mathbf{A}_{C2} & \cdots & \mathbf{I}-\mathbf{A}_{CC} \end{pmatrix}^{-1} \begin{pmatrix} \mathbf{y}_{11} & \mathbf{y}_{12} & \cdots & \mathbf{y}_{1C} \\ \mathbf{y}_{21} & \mathbf{y}_{22} & \cdots & \mathbf{y}_{2C} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{y}_{C1} & \mathbf{y}_{C2} & \cdots & \mathbf{y}_{CC} \end{pmatrix} \quad (2)$$

with output vectors $\mathbf{x}_c$, final demand vectors $\mathbf{y}_c$ and input-coefficient matrices $\mathbf{A}_c$, with subscript c corresponding to country c. The global input-coefficient matrix $\mathbf{A}$ (for S×C sectors, where S is the number of sectors per country and C is the number of countries) consists of the domestic input-coefficient matrices $\mathbf{A}_{ii} = \mathbf{A}_{c(dom)}$ and the partitioned import coefficient matrices $\mathbf{A}_{ij} = \mathbf{A}_{ic(imp)}$, with $\mathbf{A}_c = \mathbf{A}_{c(dom)} + \mathbf{A}_{c(imp)} = \mathbf{A}_{c(dom)} + \sum_i \mathbf{A}_{ic(imp)}$. Final demand in this MRIO is displayed in matrix $\mathbf{y}$, which is setup equivalent to matrix $\mathbf{A}$. Output matrix $\hat{\mathbf{x}}$ is estimated using the usual Leontief equation (1).

Calculating embodied emissions $\mathbf{P}$ is done by premultiplying the Leontief inverse (e.g. Peters and Hertwich 2008) with the intensity vector $\mathbf{e}_c$ stored in diagonal matrices $\mathbf{E}_c$. Vectors $\mathbf{p}_{ii}$ represent emissions embodied in domestic production to satisfy domestic demand, and vectors $\mathbf{p}_{ij}$ are emissions embodied in the production of country i to satisfy country j's final demand. Hence, pollution matrix $\mathbf{P}$ contains results for 53 individual countries and two regions, and 48 producing sectors per country/region. Pollution embodied in exports and imports of a country are then simple row and column sums, respectively, in matrix **P**, without the entry on the diagonal, which represents domestic pollution for domestic consumption. Embodied CO_2 exports of country *s* therefore are $\sum_j \langle \mathbf{p}_{sj} \rangle - \langle \mathbf{p}_{ss} \rangle$, where $\langle \mathbf{p}_{ij} \rangle$ denotes the sum of the elements of vector $\mathbf{p}_{ij}$, while the country s' imports are $\sum_i \langle \mathbf{p}_{is} \rangle - \langle \mathbf{p}_{ss} \rangle$. More details of this approach with regard to its application will be given in the following section on GRAM. A more detailed technical description of GRAM can be found in Wiebe et al. (2012).

The heart of the model is the multi-regional input-coefficient matrix **A**, which has size 2640×2640. The OECD IOTs distinguish between 48 sectors; given that we model 55 countries or regions, this results in total of 2640 sectors. We can subdivide matrix **A** into 55 by 55 submatrices $\mathbf{A}_{ij}$. For $j=i$ these matrices correspond to the domestic input-coefficient matrices, that is the submatrices $\mathbf{A}_{ii}$ on the diagonal of the $\mathbf{A}$-matrix are the domestic input-coefficient matrices, that can be directly calculated from the OECD input-output tables (OECD, 2009). The OECD input-output tables (IOTs) distinguish between domestic input requirements and imported input requirements, as well as domestic final demand and imported final demand. The virtue of this is that domestic as well as imported input coefficients can be directly calculated from this data, which is the first step in our model. After having calculated the coefficient matrices, the output vectors as given in the OECD IOTs are completely disregarded and the remaining calculations are all based on the input-coefficient matrices $\mathbf{A}_{ij}$ and the final demand data. Sectoral output used in the remaining calculations is estimated by $\hat{\mathbf{x}} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y}$.[1]

To fill the multi-regional input-coefficient matrix $\mathbf{A}$ for the off-diagonal submatrices we need to combine the imported coefficient matrices $\mathbf{A}_{(imp)j}$ from the input-output data with the bilateral trade data from which we have calculated import shares for each sector. The input-output coefficients are calculated from data in basic prices while the import shares are calculated from data in cif. According to Guo et al. (2009) using these trade coefficients is still possible because in the final results the sector of destination is ignored. Let a_{ij}^{mn} be the entry in the m[th] row and n[th] column of matrix $\mathbf{A}_{ij}$, $a_{(imp)j}^{mn}$ be the entry in the m[th] row and n[th] column of the import coefficient matrix $\mathbf{A}_{(imp)j}$, and let m_{ij}^{n} be the import share of country i in country j's imports of good n, i.e. the entry (i,j) in the import share matrix of good n: M^n. Then a_{ij}^{mn} is calculated as

$$a_{ij}^{mn} = m_{ij}^{n} a_{(imp)j}^{mn} \forall n, j \,. \tag{5}$$

Creating the multi-regional final demand matrix $\mathbf{y}$ is done by applying the same method to the imported final demand matrices to disaggregate them according to countries of origin. Note that the final demand vectors do not include export demand, i.e. it is the sum of columns c2 through c7 in the OECD IOT final demand tables. Production necessary to satisfy export demand is implicitly calculated as the sum of the imports of all other countries. Matrix $\mathbf{y}$ has size 2640×55, where the columns represent the countries in which final demand is generated. As the OECD IOTs distinguish between 48 sectors, and each imported final demand vector (which is given in the original data) is disaggregated among 54 countries of origin using the import shares, the resulting columns of matrix $\mathbf{y}$ have 54 times 48 entries (corresponding to imports that satisfy final demand) plus 48 entries (directed at domestic production for final demand), resulting in a total of 2640 entries per column.

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[1] For those years/countries for which input-output tables are available, we do know the "true" output vector $\mathbf{x}$. A quick comparison of the calculated and the original data shows that the sum over all sectors of output $\hat{\mathbf{x}}$ deviates from the OECD data by about 5% in the UK, less than 3% in Germany and not even 1% for the US for 2000. See Appendix in Wiebe et al. (2012) for more detail.

Using equation (1), we can calculate output matrix $\hat{\mathbf{x}}$ which has the exact same dimension as the final demand matrix **y**. For calculating $\hat{\mathbf{x}}$ we assume that we know final demand **y** and the input coefficient matrix **A**, but not the true **x.** By using the calculated output $\hat{\mathbf{x}}$ only, we make sure that the model is consistent. The column total (of column *s*) gives worldwide production that is necessary to satisfy final demand in country *s*. Subdividing column *s* into 55 vectors, explicitly shows the sector and country in which production to satisfy final demand in country *s* occurred. $\hat{\mathbf{x}}_{21}$ for example is the sectoral production in country 2 to satisfy country 1's final demand. Note that by calculating $\hat{\mathbf{x}}$ we also implicitly calculate value added of the IO system. This implicit calculation of value added ensures that the system is balanced, but the calculated value added does not necessarily correspond to the "real" value added. By using this approach we do not need to RAS the global input-output matrix as explained in Wiebe et al (2012).

Carbon emissions data for fossil fuel combustion (coal & peat, gas, oil, and others) is taken from the International Energy Agency (IEA 2008c). The data is only available for highly aggregated economic sectors, not corresponding to the IOT sectoral classification. The IEA also publishes energy balances (EB) for all countries that are explicitly modeled (IEA 2008a,b). The EBs contain physical data on the use of different energy carriers on a sectoral level that almost corresponds to the sector structure of the OECD data. This physical data is used to split emissions, which are available for four energy carriers, but only on more aggregated economic sector level, according to the sectoral classification of the OECD data. Emission intensities $\mathbf{e}_c$ are then calculated for each sector by dividing total emissions, i.e. the sum over all energy carriers, of this sector by total output of the sector, which is calculated within the model as $\hat{\mathbf{x}}$.

2.3 Combining GRAM and GINFORS

The economic cores of GINFORS and GRAM are based on the same historical data: input-output tables and bilateral trade data from the OECD STAN database. GINFORS additionally includes data on the system of national accounts, sectoral prices and employment. The energy-environment module of GINFORS incorporates both energy balances and emissions data of the International Energy Agency (IEA). The same data is used in GRAM to calculate the emission intensity coefficients.

While GRAM is a static historical calculation model, GINFORS is a dynamic projection model. The projections calculated in GINFORS give forecasts of the data that is needed for GRAM, i.e. the input-output tables, the bilateral trade data, energy balances and carbon emissions. Using the projected GINFORS data, it is therefore possible to fill the multi-regional coefficient matrix **A**, the multiregional final demand matrix **y**, and the energy intensity coefficient vectors **e**. The projections are calculated in the form of scenarios, a reference scenario and a global climate change agreement scenario. These will be introduced in the next section.

There are, however, limitations in the GINFORS data: on the one hand the import coefficient matrices are assumed to be constant, i.e. no structural/technical change with respect to the import structure of intermediate demand is considered. On the other hand, the total import vector does change, but is not separated according to intermediate and final demand. The total import vector is separated among intermediate and final demand using the historical ratio from the last year for which this data is available (2005). This results in an inconsistency of the flow matrix of intermediate demands, calculated in GRAM from the constant import coefficient matrix multiplied by the output vector that has been projected in GINFORS, with the total import vector that has been projected in GINFORS independently of the input-output system. These shortcomings will be improved in the future.

3. Results

3.1 The implemented scenarios

Different scenarios have been implemented in GINFORS, a baseline scenario and global climate change agreement scenarios that differ in the international participation in such a global agreement. The baseline scenario assumes that the EU unilaterally implements a post-Kyoto regime in the form of the 20-20-20 targets. All scenarios are described in detail in Lutz and Wiebe (2012) based on a study for the German Ministry of Economy and Technology (Lutz et al. 2010b). For the analysis at hand one scenario (Inter IV) has been selected, in which the EU cuts emissions by 30% in 2020 compared to 1990 and the other industrialised countries and the major emerging economies realize the maximum emission reductions as stated in the Copenhagen Accord (UNFCCC, 2009).

The baseline scenario assumes an EU wide 20% reduction in greenhouse gas (GHG) emissions in 2020 compared to 1990, few CDM (clean development mechanism) measures, i.e. at most 25%, and expansion of renewable energies according to national action plans (NAP). The rest of the world follows business-as-usual, that is the Copenhagen Accord will not be met.

The assumptions for the scenario InterIV are first that the EU reduces total emissions by 30% (Germany by 40%); Second, CDM measures are allowed to be up to 50% of total emission reduction. The price of these measures is 90% of the lowest CO2-certificate price in industrialised countries (Lutz et al, 2010); and third, transfers to low income countries for adaptation measures excluding GHG reduction increase from 10 billion Euros in 2012 to 35 billion Euro in 2020. Furthermore, it aims at a more equal burden sharing by adapting CO2 prices for the non-ETS sectors in selected EU and non-EU countries in a way that their GDP-loss compared to the baseline is comparable to the macroeconomic costs borne by Germany. And last, it calculates CO2 certificate costs necessary to reach a global emission path that is equivalent to the 450ppm scenario from the 2009 World Energy Outlook (IEA 2009), ensuring the attainment of the 2° target. The maximum pledges for selected countries are (UNFCCC, 2009):

- EU: 30% (compared to 1990)
- US: 17% (compared to 2005)
- Japan: 25% (compared to 1990)
- China: 45% (carbon intensity compared to 2005)
- India: 25% (carbon intensity compared to 2005)
- Brazil: 38.9% (compared to business as usual)
- South Africa: 34% (compared to business as usual)
- Russia: 25% (compared to 1990)

3.2 Production- versus consumption-based carbon emissions

The projections of the input-output tables, the bilateral trade data, the energy balances and carbon emissions of these two scenarios have been included in GRAM to calculate consumption based carbon emissions in 2020 for both scenarios. The aim of this scenario analysis is not to give a perfect prediction about what future carbon emissions are going to be exactly, rather a comparison of these scenarios shows the difference of a unilateral carbon reduction action of the EU compared to a global climate protection agreement. Table 1 displays the final solution, that is the **P**-matrix, for three aggregated regions OECD, BRICSA (Brazil, Russia, India, China, South Africa and Argentina) and the rest of the world (RoW). The top left matrix of the Table corresponds to the baseline scenario, the bottom left matrix to the InterIV scenario and those on the right display the differences (absolute and in % of the baseline) between the scenarios. Emissions globally decreased in the reduction scenario. The highest absolute reduction took place within the OECD countries production and consumption, the top left entry within the trade matrices, closely followed by the reduction within the BRICSA countries (entry in the centre of the matrices). In absolute and percentage terms the highest decrease regarding the production of carbon emissions can be achieved in the BRICSA countries (second row of the matrices), while the highest decrease in consumption is achieved for the OECD countries. Production in RoW changes little, because most of the countries in this aggregate do not have explicit reduction targets.

Table 1: Carbon trade matrix in 2020

Baseline

mt CO2	OECD	BRICSA	RoW
OECD	8940	330	190
BRICSA	2804	7108	446
RoW	1739	588	2852

Difference (absolute)

mt CO2	OECD	BRICSA	RoW
OECD	-913	-29	-22
BRICSA	-377	-722	-66
RoW	-22	-6	-7

InterIV

mt CO2	OECD	BRICSA	RoW
OECD	8026	301	168
BRICSA	2427	6386	380
RoW	1718	581	2845

Difference (percent)

mt CO2	OECD	BRICSA	RoW
OECD	-10%	-9%	-11%
BRICSA	-13%	-10%	-15%
RoW	-1%	-1%	0%

The carbon trade balances of the two scenarios for selected countries are displayed in Table 2. The results clearly show that on both scenarios the OECD countries are net-importers of embodied carbon emissions, while the non-OECD countries, including the BRICSA countries Brazil, Russia, India, China, South Africa and Argentina and the rest of the world (RoW) are net-exporters of embodied carbon emissions.

Table 2: Carbon trade balances

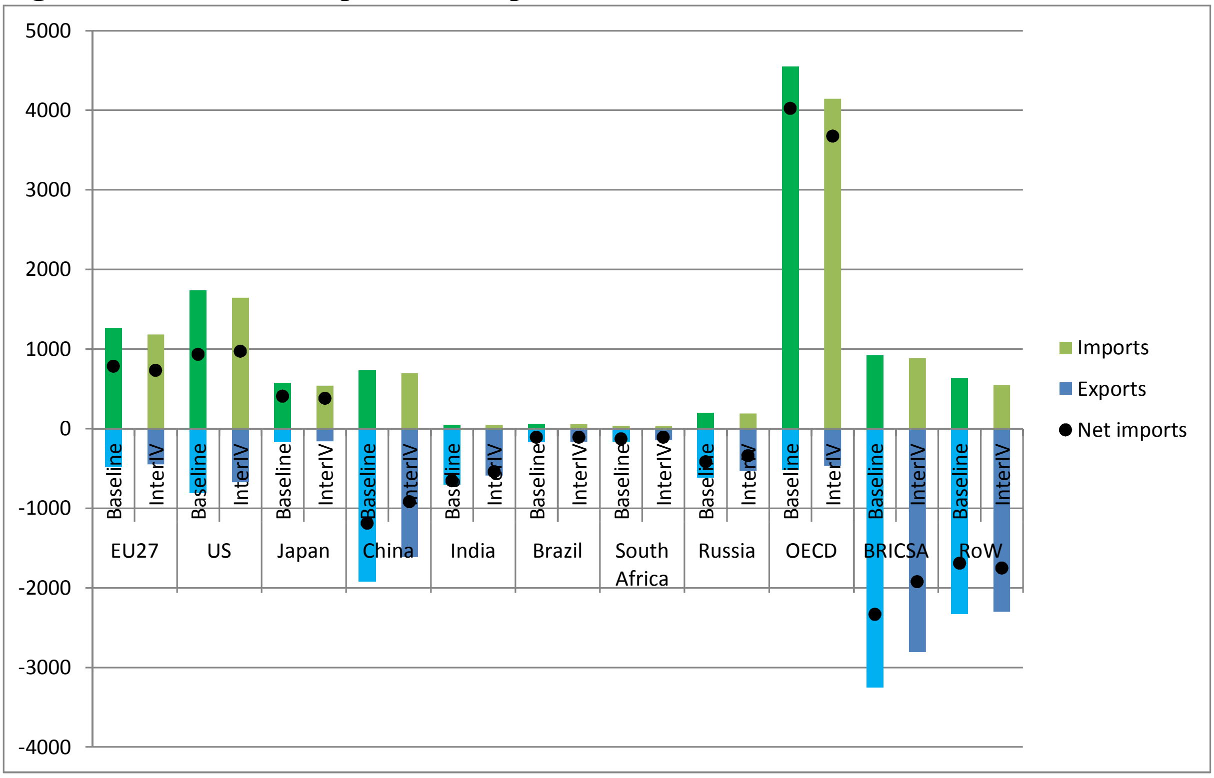
	Million t CO2	EU27	US	Japan	China	India	Argentina	Brazil	South Africa	Russia	OECD	BRICSA	RoW
Baseline	Domestic P & C (DD)	1726	3242	812	4272	720	93	308	135	883	**8940**	**7108**	**2852**
	Exports (DX)	484	803	166	1921	702	66	170	161	614	**520**	**3250**	**2327**
	Imports (MD)	1267	1736	574	731	47	14	60	31	198	**4544**	**918**	**635**
	Domestic Production (DD + DX)	2211	4045	978	6193	1422	159	478	296	1498	**9460**	**10358**	**5179**
	Domestic Consumption (DD + MD)	2993	4978	1386	5003	766	108	368	166	1081	**13483**	**8026**	**3487**
	Imports - Exports	782	933	408	-1190	-656	-52	-110	-129	-416	**4024**	**-2332**	**-1692**
	Net-Imports oder -exports?	I	I	I	E	E	E	E	E	E	**I**	**E**	**E**
InterIV	Domestic P & C (DD)	1625	2920	769	3830	636	92	293	120	807	**8026**	**6386**	**2845**
	Exports (DX)	450	674	160	1615	588	65	164	140	530	**469**	**2807**	**2299**
	Imports (MD)	1180	1647	540	696	45	13	57	30	190	**4145**	**883**	**548**
	Domestic Production (DD + DX)	2074	3594	928	5445	1224	157	457	259	1337	**8496**	**9192**	**5144**
	Domestic Consumption (DD + MD)	2805	4567	1309	4526	682	106	350	150	998	**12171**	**7268**	**3393**
	Imports - Exports	730	972	381	-919	-543	-52	-107	-110	-339	**3675**	**-1924**	**-1751**
	Net-Imports oder -exports?	I	I	I	E	E	E	E	E	E	**I**	**E**	**E**
InterIV / Baseline	Domestic P & C (DD)	0.94	0.90	0.95	0.90	0.88	0.99	0.95	0.89	0.91	**0.898**	**0.898**	**0.998**
	Exports (DX)	0.93	0.84	0.96	0.84	0.84	0.99	0.96	0.87	0.86	**0.903**	**0.864**	**0.988**
	Imports (MD)	0.93	0.95	0.94	0.95	0.97	0.95	0.94	0.95	0.96	**0.912**	**0.961**	**0.862**
	Domestic Production (DD + DX)	0.94	0.89	0.95	0.88	0.86	0.99	0.96	0.88	0.89	**0.898**	**0.887**	**0.993**
	Domestic Consumption (DD + MD)	0.94	0.92	0.94	0.90	0.89	0.98	0.95	0.90	0.92	**0.903**	**0.906**	**0.973**
	Imports - Exports	0.93	1.04	0.93	0.77	0.83	1.00	0.97	0.85	0.82	**0.913**	**0.825**	**1.035**
	Net-Imports oder -exports?	I	I	I	E	E	E	E	E	E	**I**	**E**	**E**

Recall, that in the baseline scenario the EU cuts carbon emissions by 20% in 2020 compared to 1990, while the other industrialised and emerging economies do not follow a similar climate protection policy. In the InterIV scenario these countries' climate protection policy is assumed to be a commitment to the maximum mitigation possibilities stated in the Copenhagen Accord. The results show that global emissions in the InterIV scenario are about 10% lower than in the baseline scenario. Generally emissions produced or consumed and embodied in exports or imports, including net-imports and net-exports are lower in InterIV than in the baseline, as can be seen in the lower part of Table 2. There are two notable exceptions: the US net-imports of embodied emissions in InterIV are 4% higher than in the baseline and net-exports of CO2 are 3.5 higher for the rest of the world (RoW). This might be an indication of carbon leakage, while the US reduces domestic emissions, it imports relatively more. The rest of the world, whereof most countries are not participating in the global climate change agreement, exports relatively more CO2.

The BRICSA countries do realize significant carbon reductions in InterIV. Interestingly, in Argentina, which did not commit to a reduction, emissions embodied in domestic production are also reduced by 1%. On average domestic carbon production in the BRICSA countries is reduced by more than 11%, while consumption of embodied emissions is reduced by almost 10%. Net-exports of embodied emissions from the BRICSA countries are reduced by 17%, showing a relative redistribution of embodied carbon net outflows from the BRICSA countries to the rest of the world, that is the OECD countries import relatively more embodied

emissions from the rest of the world compared to the BRICSA countries. This is on the one hand due to lower carbon intensities of production and on the other hand to a redistribution of trade flows. EU net-imports of carbon are reduced by 7%. The reason why the EU's domestic production and consumption of embodied carbon emissions is only lowered by 6% is that the EU already unilaterally cuts its GHG-emissions by 20% in 2020 in the baseline scenario.
Figure 1 displays carbon imports (green), exports (blue) and net-imports (black dots) for the two scenarios (baseline left with strong colours, InterIV right with pale colours). The results clearly show that the EU27, USA and Japan are net carbon importers and the BRICSA countries are net carbon exporters. The graph nicely displays that both carbon exports and carbon imports decrease for all regions, as do carbon net-imports and net-exports. One exception is the rest of the world, for which net exports increase, capturing part of the reduced carbon trade between the BRICSA and the OECD countries.

Figure 1: Carbon imports and exports



4. Conclusion

This paper presents some preliminary results from implementing scenario results of the dynamic global energy-environment-economy model GINFORS in the static multi-regional input-output model GRAM. It is a first attempt of combining the growing literature on MRIO-based analysis of consumption-based emissions with the field of 3e (energy-environment-economy) projection and simulation models. These show a relative redistribution of carbon emission production to those countries without a reduction target, whereas carbon emissions embodied in consumption change relatively less. The net-imports of embodied emissions into

the OECD countries are smaller, but while the net-exports of the BRICSA countries also decrease, the net-exports of embodied emissions from the rest of the world even increases.
The model is still work-in-progress and has some methodological limitations. The results presented here are not yet fully analysed. They, however, give a first indication of the redistribution of production- and consumption-based carbon emissions around the globe resulting from a global climate change agreement. Future work will include an update of the databases of both GINFORS and GRAM to overcome the discrepancies, a further development of the treatment of exports in GRAM and the consideration of changing coefficients in the technical import matrix.

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