Cross-border effects of climate change mitigation policies under different trade regimes

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Abstract

In an increasingly globalized world, production chains are ever more fractioned across country borders, increasing the need to trace impacts of structural changes not only within the domestic economy, but also in other parts of the world. Decarbonizing the energy sector in one country can imply an increase in emissions in other countries due to increased production activities of certain technologies, or can create job losses in fossil fuel exporting countries. We implement the technological changes required for a 6-degree (increased mitigation action in the EU and Asia) and 2-degree (global climate mitigation action) warming scenario in a global multi-regional input-output system up to 2030. In light of SDG 13 "climate action", SDG 12 "responsible consumption and production", and SDG 8 "decent work and economic growth", we then analyze the indirect impacts on emissions, material extraction and employment through global value chains under four different trade scenarios based on the OECD "Scenarios for the World Economy". These scenarios are a baseline scenario, i.e. a continuation of current trends, an increased catch-up of the BRIICS countries, accelerated growth in the OECD countries, and decreasing trade openness. The corresponding trade structures at the product level are estimated using a gravity model. Preliminary results show that a global climate mitigation action scenario such as the 2-degree scenario, distributes positive effects on employment better around the world in an increased catch-up scenario, than in the other scenarios. The decreasing trade openness scenario puts most restrictions on the possibilities of climate mitigation action due to restricted access to raw materials.

Note to "IIOA development program" organizers:

We think that this program is a very good opportunity to receive feedback from well-respected scholars in input-output analysis. Unfortunately, we did not yet manage to finish our manuscript, as the main author is moving jobs and the second author currently only has a part time position at the institute. We hope that you will still consider it for the assessment of its suitability for the development program. We will finish a complete draft by mid-May, so that a full version is available to the discussant in time. We have indicated what we plan to do in the respective sections. Thank you!

1 Introduction

The urgent need to restructure the global economy to follow a more sustainable development pathway has just been highlighted in the “IPCC special report on the impacts of global warming of 1.5 °C”. This need for restructuring is mainly brought about by the increased demand for low-carbon technologies and changes in the energy infrastructure. In an increasingly globalized world, production chains are ever more fractioned across country borders, increasing the need to trace impacts of these structural changes not only within the domestic economy, but also in other parts of the world. Decarbonizing the energy sector in one country can imply an increase in emissions in other countries due to increased production activities of certain technologies, or can create job losses in fossil fuel exporting countries. These possibly adverse effects should be identified early, so that corresponding flanking measures can be taken.

International trade is one the major four transfer mechanisms of cross-border effects from climate change (SEI 2017), with the other three being biophysical, people, and finance. The importance of intermediate trade has long been known (Baldwin and Lopez-Gonzalez 2015), but detailed databases reflecting the inter-industry linkages across borders have only become available in the past decade, and are increasingly being picked up in empirical analysis of global trade (Costinot and Rodríguez-Clare 2014; Timmer et al. 2014; Adao et al. 2015; Fajgelbaum and Khandelwal 2016; Rodrik 2018). Examples for such databases are the World Input-Output Database WIOD (Timmer et al. 2015), the OECD’s inter-country input-output tables (Wiebe and Yamano 2016; Yamano and Webb 2018), EXIOBASE (Stadler et al. 2018), and Eora (Lenzen et al. 2013).

Increasing flows of intermediate goods between industries and countries and the trade of final goods across borders since the mid-nineties led to a spatial dissociation of consumption and emissions (Davis and Caldeira 2010; Peters et al. 2011; Wiebe et al. 2012; Lenzen et al. 2012; Peters et al. 2012; Dietzenbacher et al. 2013; Wiebe and Yamano 2016; Wiebe 2018a; Stadler et al. 2018). Considering this need to account for the climate pressures outside national borders makes national climate policies increasingly complex (Ivanova et al. 2016; Wiebe 2016; Wood et al. 2018). However, turning around this argument, for future policy design, the estimation of cross-border effects of expected changes in the production system through international supply chains can be informative (Groundstroem and Juhola 2018; Wiebe 2018b; Wiebe 2018c), and should be increasingly considered in national policy making and international negotiations.

Here, we define cross-border effects to be those that occur in one country, due to changes in the production and/or consumption structure of another country. These effects include e.g. GHG emissions, energy use, material extraction, value added, and employment.

For the analysis of cross-border effects along supply changes of technological and economic structural changes brought about by climate change mitigation and adaptation, trade in intermediate and final goods is most important and the correct modeling of trade is essential. In addition to the large amount of economic parameters to consider, trade relations are heavily dependent on political relations between countries. There is no one possible and correct trade regime going forward. Rather, it is necessary to consider a whole range of possible trade regimes in the short-to-medium term.

In this paper we implement different trade regimes, in line with the OECD “Scenarios for the World Economy” (Guillemette and Turner 2018), into two scenarios of climate change mitigation action. These scenarios are specifically targeted at changes in energy production and energy consumption. The business-as-usual scenario is based on the International Energy Agency’s Energy Technology Perspectives (IEA 2015) 6-degree scenario (IEA ETP 6DS), and the more sustainable alternative “increased climate mitigation” scenario is based on the IEA ETP 2-degree scenario. These scenarios are implemented into a global multi-regional input-output system, with the aim of showing direct and indirect effects of the technological change that comes about with increasing climate mitigation actions. The model is only partially dynamic with respect to the economic feedback of production to final demand. We model the induced effects on investments necessary to change the energy system, as well as the effects of an increasing income on the structure of household demand. However, changes in bilateral trade are implemented exogenously based on Guillemette and Turner (2018), who distinguish between four trade regimes. The differences in institutional reforms and trade openness between these scenarios result in different real GDP per capita growth rates, capital availability, labor efficiency and employment rates.

2 Methodology

The urgency of climate change mitigation and adaptation has been determined by long-run climate and climate-economy models such as integrated assessment models (Nordhaus 1993; Meinshausen et al. 2011; van Vuuren et al. 2011; Nordhaus 2017; O'Neill et al. 2017; Riahi et al. 2017; Tavoni et al. 2017; Nordhaus 2018). The structural changes in the global economy, however, are necessary in the short-to medium term and need to be analyzed at a significantly higher level of industry and regional resolution. Input-output (IO) analysis is very well suited to capture the effects of changes in interdependent global production structures in the context of sustainability analysis (Duchin 2015).

We combine the two climate change mitigation action scenarios with each of the possible developments regarding the global economy, resulting in a total of eight possible combinations. These are implemented in a global multi-regional input-output (GMRIO) system for the year 2030 as follows:

2.1 Implementing climate mitigation actions in an IO-system

The information from the climate change mitigation action scenarios is used to infer about technological changes at the country level. These result in a changing intermediate input structure, e.g. use of energy carriers by industry, use of different sources of electricity, the input structure of the energy industries, and of those industries producing electricity generation technologies. This also requires an alteration the investment structure, captured in the final demand matrix of the IO system. The structure of the different final demand components (household spending, government spending, and gross fixed capital formation) is also altered according to their energy use. These changes are applied to a version of the GMRIO system that is aggregated to the country level, i.e. not distinguishing between domestically sourced and imported goods and services, and also not distinguishing between the different exporters of the imported goods (Wiebe et al. 2018).

The MRIO model is demand-driven without considering induced effects, i.e. the feedback from value added to final demand ($\mathbf{y}$) is not considered. Value added by industry ($\mathbf{v}$) is endogenous, calculated as

$\mathbf{v} = \mathbf{x} - \mathbf{xA}$**,** where $\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-\mathbf{1}}\mathbf{y}$, following the conventional input-output notation.

Impacts ($\mathbf{F}$) on employment, emissions or materials are calculated using the respective stressors $\mathbf{s}$

$$\mathbf{F} = \hat{\mathbf{s}}(\mathbf{I} - \mathbf{A})^{-\mathbf{1}}\mathbf{y} \quad (1)$$

Neither labor markets, nor financial/capital markets are modelled, which is why external scenario assumptions are used to drive the model. The GDP from the scenario determines final demand at the macro-level, using results from simple OLS regressions. The individual final demand components (household consumption, consumption by non-profit organizations serving households, government consumption and gross fixed capital formation) depend on the contemporaneous GDP from the scenario. The coefficients are estimated using EXIBASE data from1995 to2014. The structure of final household demand is determined through a perhaps adequate demand system (PADS), while the structure capital formation is changed for those products that are significantly affected by changes in the investments into the energy infrastructure.

We distinguish two climate change mitigation scenarios, 2 degrees and 6 degrees, which differ in the investment into and use of energy technologies. The energy technologies, represented in the intermediate input structure of each country s in the input coefficient matrix $\mathbf{A}_s$, are adapted accordingly.

The final demand vectors as well as the input coefficient matrices of each country are then disaggregated according to origin of the products by trade partner using the various trade share scenarios.

2.2 Inferring about the macro-economic development from scenario specifications

The data from the OECD scenarios is used to inform the aggregate demand side (final demand) values of the GMRIO system. Based on historical data, Wiebe et al. (2018)have estimated changes in the final demand components given the development of real GDP, see Section 1.2 in the SI of Wiebe et al. (2018). This simple regression analysis approximates the implementation of a Social Accounting Matrix (REFERENCE) or a full System of National Accounts approach (Almon 1991; Almon 2012).

The OECD scenarios (Guillemette and Turner 2018) are

1. Baseline trade – a continuation of current trends: Growth slows down globally, but the emerging markets BRIICS still continue to catch up with OECD economies, resulting in a shift of the center of gravity of world economy to Asia. Living standards continue to improve globally;
2. Increased catch-up by BRIICS through institutional reforms;
3. Accelerated growth in OECD countries through product and labor market reforms; and
4. Decreasing trade openness, back to 1990 levels.

The baseline projections give average annual real GDP per capita growth rates for all OECD and BRIICS countries, as well as Euro-area and World totals, up to 2060. The alternative scenarios are defined in their deviation from the baseline. We have summarized the data in the Supplementary Information (Figure 10).

In Wiebe et al. (2018), the real GDP forecast is based on the IMF projections until 2022 and on average region-specific growth rates from the IEA ETP (2015) scenario for the years from 2022-2030. We use these data for a comparison of the effect of using constant versus using changing trade shares, while we use the OECD scenarios for inferring the effect of different trade regimes on global production and footprint structures.

2.3 Estimating bilateral trade flows using a structural gravity approach

Combining the two sets of scenarios described in the previous sections gives total values for the final demand and value added blocks, as well as the economic structure depending on the level of climate mitigation action. These changes at country level in turn may induce significant shifts in the bilateral trading pattern we observe for the base year. To find a bilateral trade structure that fits these framework requirements, we estimate gravity equations at the industry level (Fally 2015). The structural gravity model from which these equations are derived describes the extent to which any two countries trade with each other, t^{rs}, as a function of supply, S^r, and demand, D^s, of exporting and the importing country, r and s respectively, as well as of further variables describing bilateral trade barriers, φ^{rs}, (Anderson, James;van Wincoop 2001):

$$t^{rs} = G \frac{S^r}{\Omega^r} \frac{D^s}{\Phi^s} \varphi^{rs}, \qquad (2)$$

where G is a constant and Ω^r and Φ^s denote the multilateral resistance terms (MRT) of the exporting and the importing country. The term φ^{rs} is typically a linear combination of variables that describe bilateral barriers to between two countries such as distance, common language, colonial ties or free trade agreements and can be interpreted as trade cost elasticity.

The MRTs take the form of

$$\Omega^r = \sum^{s \neq r} \frac{\varphi^{rs} D^s}{\Phi^s} \qquad (3)$$

and

$$\Phi^s = \sum^{r \neq s} \frac{\varphi^{rs} S^r}{\Omega^r}, \qquad (4)$$

and describe the openness of the exporting and the importing country to trade relative to the average openness of other countries. They were introduced by Anderson and van Wincoop (2001) in order to give the empirically successful classical gravity model of international trade (Tinbergen 1962) a theoretical foundation that explains the spatial allocation of the importing countries expenditures as well as the market clearing conditions for the exporters, arguing that their omission leads to omitted variable bias. For the estimation of model parameters, exporter and importer fixed effects are commonly used as proxies for the MRTs (Fally 2015). In this case the estimation equation for product p can be written as

$$t_{rsp} = exp\left\{f_{rp} + f_{sp} - \theta_p^1 \ln(X_{rs}^1) \dots - \theta_p^N \ln(X_{rs}^N)\right\} * \varepsilon_{rsp}, \tag{5}$$

where f_{rp} and f_{sp} denotes the exporter and the importer fixed effect, respectively, X_{rs}^n denotes the nth independent variable describing bilateral trade barriers with θ_p^n being the corresponding parameter to be estimated and ε_{rsp} is an i.i.d. error term. As independent variables we use average (population weighted) distance, GDP and GDP per capita of the exporting and the importing country as well as dummy variables if the exporter and the importer have a common border, are members of the EU (EUEEA), the Eurozone (EURO), or a another free trade agreement (inFTA) or are the same country (intra-country).

For the base year, 2014, we estimate exporter and importer fixed effects, as well as trade cost elasticities from the GMRIO and CEPII data on different bilateral barriers. Here we follow the estimation strategy of Silva and Tenreyro (2006) and estimate the Equation 4 in its multiplicative form using the Poisson Pseudo Maximum-Likelihood estimator rather than using OLS on the log-transformation. The main reason for this approach is that the log-transformation forces the omission of observations, when two countries do not trade leading to biased results. Since we are estimating Equation 4 at the product level, the case of zero trade flows is likely to occur quite frequently.

Table 1 shows the results of the estimation of the structural gravity model for 2014 for aggregated trade with all products and a summary of the results for the individual products. It can be seen that for aggregate bilateral trade all independent variables except GDP per capita of the exporter and the importer are highly significant. However, at the level of individual products GPD per capita of the exporter and the importer is significant at 10% for at least 41 and 31, respectively, out of 48 products. As expected the parameters for distance are negative in virtually all cases, whereas the parameter for intra-country trade is always positive. The sign of the parameters for the other variables show mixed results across products. Overall the models are all of high explanatory power as shown by the pseudo R^2 between 0.9483 and 0.9997.

Table 1 Results of the estimation of the structural gravity model.

Term	**Aggregate**				**Individual Products**		
	Estimate	**SE**	**Statistic**	**p-Value**	**min Est.**	**max Est**	**#p-value<0.1**
Intercept	-19.816	1.227	-16.154	**0.000**	-86.448	5.973	47
log(distance)	-0.736	0.026	-27.977	**0.000**	-1.645	0.008	45
log(GDP_o)	0.701	0.063	11.180	**0.000**	-0.401	4.422	41
log(GDP_d)	0.581	0.063	9.270	**0.000**	-0.811	2.016	43
log(GDPcap_o)	-0.029	0.052	-0.562	0.574	-1.709	1.380	41
log(GDPcap_d)	0.038	0.052	0.737	0.461	-1.320	0.970	31
Contiguity	0.296	0.051	5.814	**0.000**	-0.764	1.108	32
Euro	-0.158	0.065	-2.420	**0.016**	-0.894	2.040	37
EUEEA	-0.201	0.061	-3.274	**0.001**	-1.069	2.019	36
inFTA	0.172	0.050	3.419	**0.001**	-1.140	0.747	29
intra-country	3.715	0.060	62.391	**0.000**	0.950	8.025	48
Pseudo R-sq	0.9921				0.9483	0.9997	

For the year 2030 GMRIO we combine the estimates of the trade elasticities from the base year values with the projected demand and supply of countries the scenario-specific changes in, e.g. trade cost components. Using the resulting import shares, we can disaggregate the intermediate and final demand tables to get the full global multi-regional table, where domestic production and imports by trade partner are distinguished.

2.4 Simultaneous determination of bilateral trade shares and industry output

In the case that product output of the exporter, x_r^p, and demand for product p by the importer, y_s^p, are among the independent factors in the gravity equation, bilateral trade shares and industry output need to be determined simultaneously. In this case we will need to solve system of equations that consists of two parts: First, the trade flow equations, based on the estimated coefficients and all exogenous variables, other than industry output, an, second, the global Leontief equation, where the coefficients in the A-matrix depend on the trade shares calculated from the trade flows. The number of unknowns in the first set of equations are all bilateral trade flows between the C countries for P products, $C \times C \times P$, plus production of P products in C countries, $C \times P$. Hence, $\forall_{r,s \in \boldsymbol{C}}, \forall_{p \in \boldsymbol{P}}$

$$t_{rsp} = exp\{f_{rp} + f_{sp} - \theta_p^x \ln(x_r^p) - \theta_p^y \ln(y_s^p) - \theta_p^1 \ln(X_{rs}^1) \ldots - \theta_p^N \ln(X_{rs}^N)\} * \varepsilon_{rsp} \qquad (6)$$

However, in this first set, there is only one equation per bilateral trade flow for each of the products t_{rsp}, i.e. $N \times N \times P$ equations. The remaining $N \times P$ equations that are necessary to determine all unknowns, are given by the usual input-output equation using the global Leontief inverse, which depends on bilateral import shares by product $m_{rsp} = \frac{t_{rsp}}{\sum_r t_{rsp}}$. Each coefficient in the global input coefficient matrix, a_{rs}^{ij}, is then calculated using these import shares and the country-specific national input coefficients a_s^{ij} for each country s: $a_{rs}^{ij} = m_{rsp} a_s^{ij}$.

3 Results

For the different trade regimes, we compare value added and employment by country and industry, as well as the origin of CO_2 emissions and material extraction between the business-as-usual 6-degree and the “increased climate mitigation” 2-degree scenario.

We are presenting two types of results: First, comparing the assumption of constant trade shares from Wiebe et al. (2018) with changing trade shares according to the gravity model presented here; and second, the differences in between the trade regimes described by the OECD scenarios (Guillemette and Turner 2018).

3.1 Considering the changing center of gravity in the global economy

The importance of considering changing trade structures in demand-driven models becomes visible in the comparison shown in Figure 1. These show the relative changes between the production, employment and CO2 emissions calculated from the demand-driven multi-regional input-output model from Wiebe et al. (2018) with constant (original shares from 2014) and with gravity-based trade shares. For calculating the gravity-based trade shares, we used the same GDP and GDP per capita estimates as in Wiebe et al. (2018) based on the IMF projections until 2022 and the (IEA 2015) projections until 2030.

Figure 1 shows the deviations in the results for value added, employment, and CO_2 emissions by country of using the changed trade shares. The trade shares now reflect that the EU15 and OECD countries grow slower, while other countries are expected to grow faster. This means that more production is allocated to the new EU member states and the non-OECD countries. This has a direct influence on value added, employment and CO2 emissions: Eastern European countries, such as Latvia, Lithuania, Poland or Romania have higher value added and employment, while both employment and value added in Western and Northern European countries is estimated to be lower.

The deviations from the scenario with changing trade shares from constant trade shares are between ±10% for value added and employment. For CO_2 emissions, these changes are significantly larger, indicating that the changes in trade are more substantial for more carbon intense manufactured products which are increasingly produced in countries with less CO_2 efficient production technologies.

Figure 1 Comparison of production-related results using constant and gravity determined trade shares in 2030

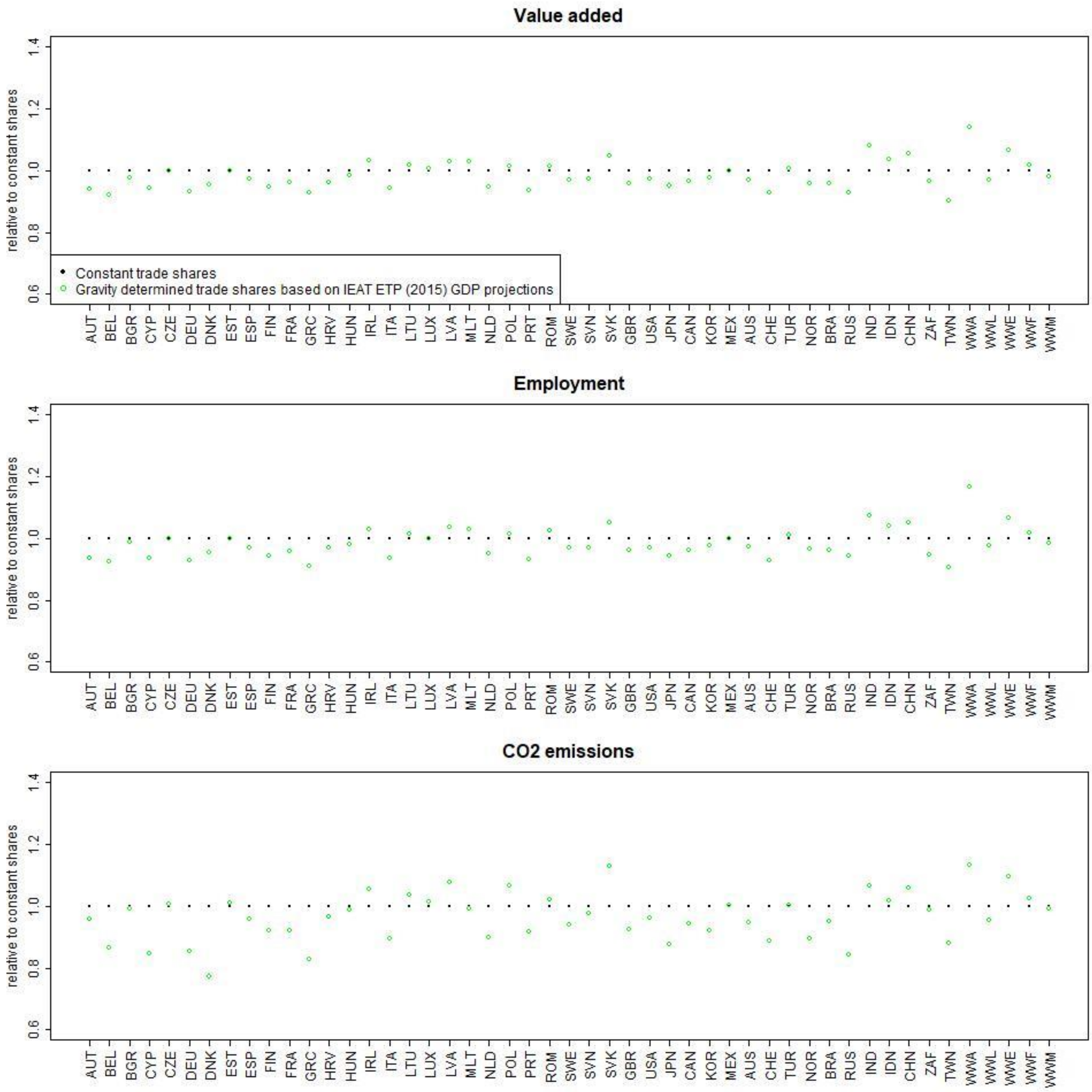


Figure 2 Comparison of EU consumption-based accounts using constant and gravity determined trade shares in 2030

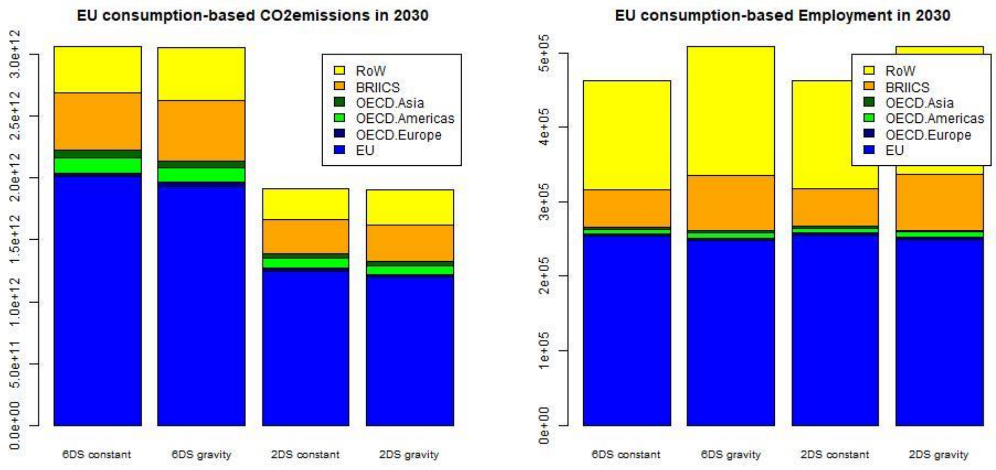


Figure 2 shows European consumption-based CO_2 emissions and employment in 2030 in for the two different trade regimes for the 6-degree and the 2-degree scenarios. For both, emissions and employment, the share of of the BRIICS countries and the Rest of the World (RoW) increases significantly with the gravity-based trade shares, while the EU's share is reduced. Total EU consumption-based emissions, while significantly lower in the 2-degree than in the 6 degree scenario, do not change between the different trade regimes. Emission intense manufacturing products from Europe are replaced by products from BRIICS and RoW.

The number of people employed for producing goods and services that are finally consumed within the EU is significantly larger in the trade regime based on the gravity estimations. While the decrease in jobs in Europe for the EUs consumption is very small, there are significantly more people employed in BRIICS and in RoW under the changing trade shares regime. This is closely related to the manufactured products which are increasingly produced outside Europe, which drive up CO_2 emissions in those countries, but also have a positive net-effect on employment, since labor productivity in these countries is lower than in Europe.

As material efficiency is lower outside European and OECD countries, EU consumption-based extraction of metals, non-metallic minerals and forestry products is higher in scenarios, where more of these materials come from BRIICS and RoW, see Figure 11 in the Supplementary Information. We also need to consider that no price or cost effects are modelled. And if extraction of these materials in BRIICS and RoW is cheaper, the same amount of monetary demand simply translates into more materials.

3.2 The genome of international trade

Shares in global CO_2 emissions and employment, both from the production and consumption perspective are shown in Figure 3 and Figure 4, respectively. The columns represent the regions consumption-based accounts, while the different colors indicate which region has produced the emissions or employed the labor. "constantShares" shows the trade based on the trade shares from 2014.

Note to "IIOA development program" organizers:

While differences between the three different trade scenarios are visible in this graph, the differences between the 6 degree and 2 degree version of the technological change are not significant. It is therefore that we aim to replace these figures by figures with aggregated product trade results.

Both employment and emissions are dominated by the production in the BRIICS region (orange), with the largest part of this being China. For all regions the intra-region trade takes the largest share, i.e. emissions and employment in production for “domestic” consumption. Unsurprisingly, the OECD countries and the EU produce more in the OECD reforms scenario, while the BRIICS produce more in the catch-up scenario. A comparison of the 2 degree and 6 degree scenarios using these graphs is not possible, as the absolute size is not shown.

Figure 3 CO2 emissions by origin and destination region

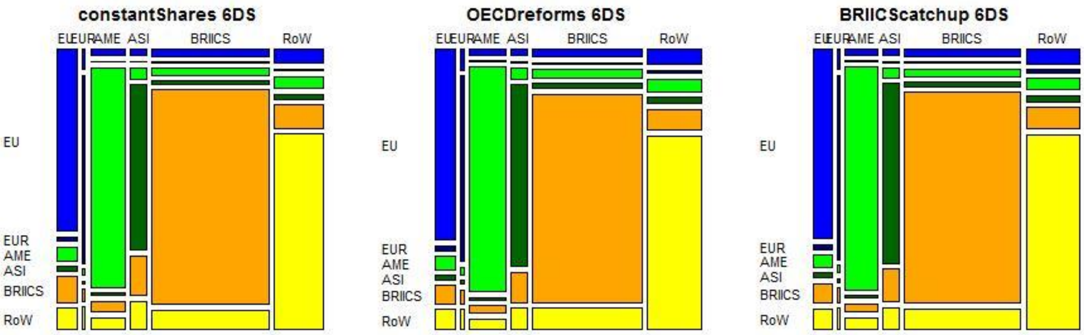


Figure 4 Employment by origin and destination region

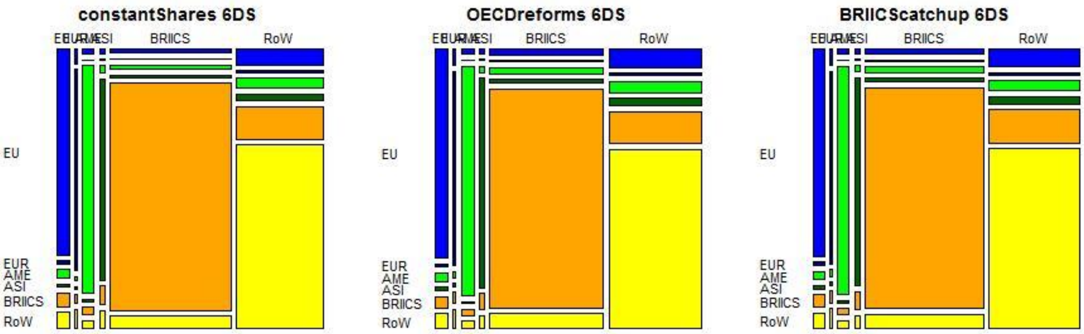


Figure 5 EU consumption-based accounts: Value added by origin country and industry

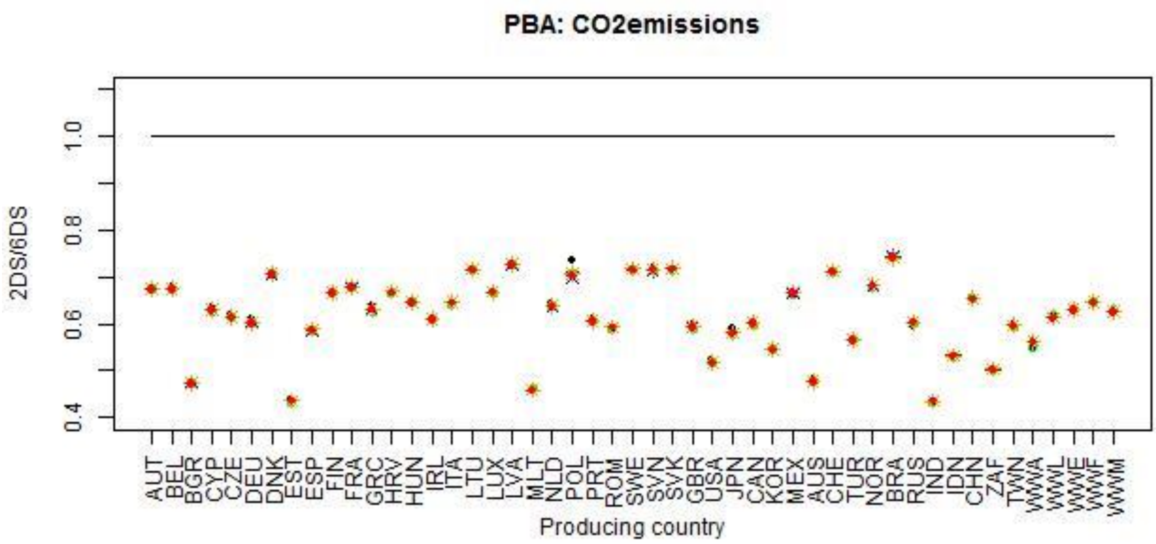
Figure 6 EU consumption-based accounts: CO2 emissions by origin country and industry

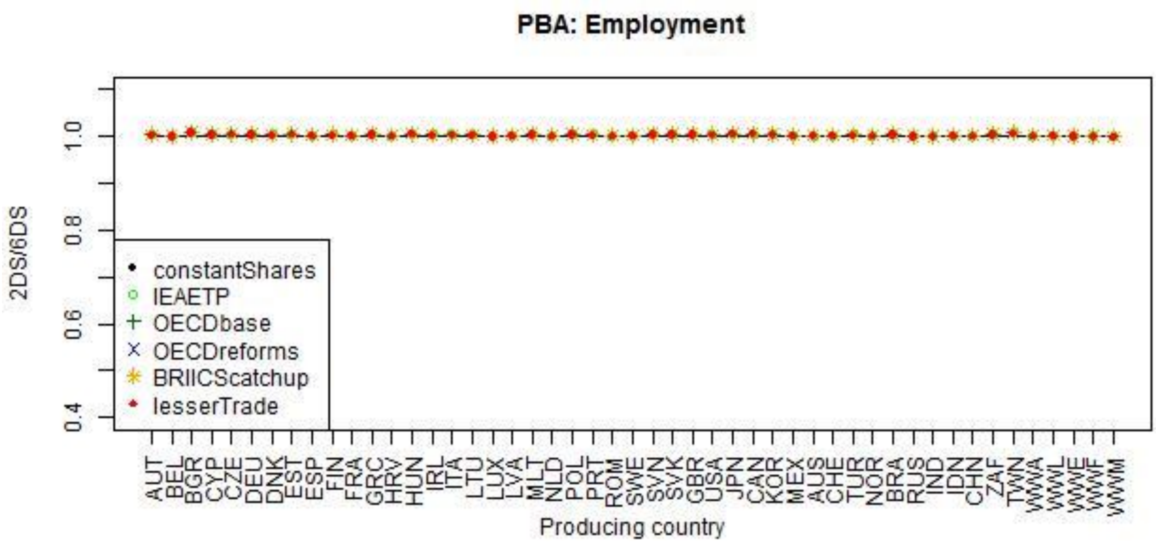
Figure 7 EU consumption-based accounts: Employment by origin country and industry

3.3 Sensitivity to changing technology

CO_2 emissions are significantly lower in the 2-degree scenario than in the 6-degree scenario, while employment remains almost unchanged. With the exception of oil and gas producing countries, employment effects are positive. The two graphs in Figure 8 show the ratio of emissions and employment, respectively, between the two technology scenarios for all trade scenarios.

Figure 8 2DS versus 6DS: Production-based accounts

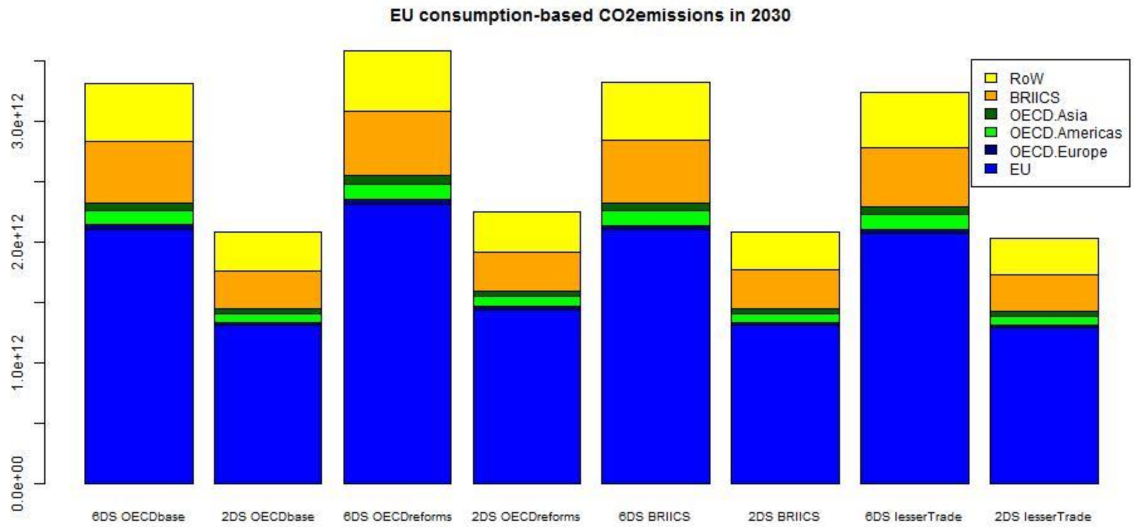


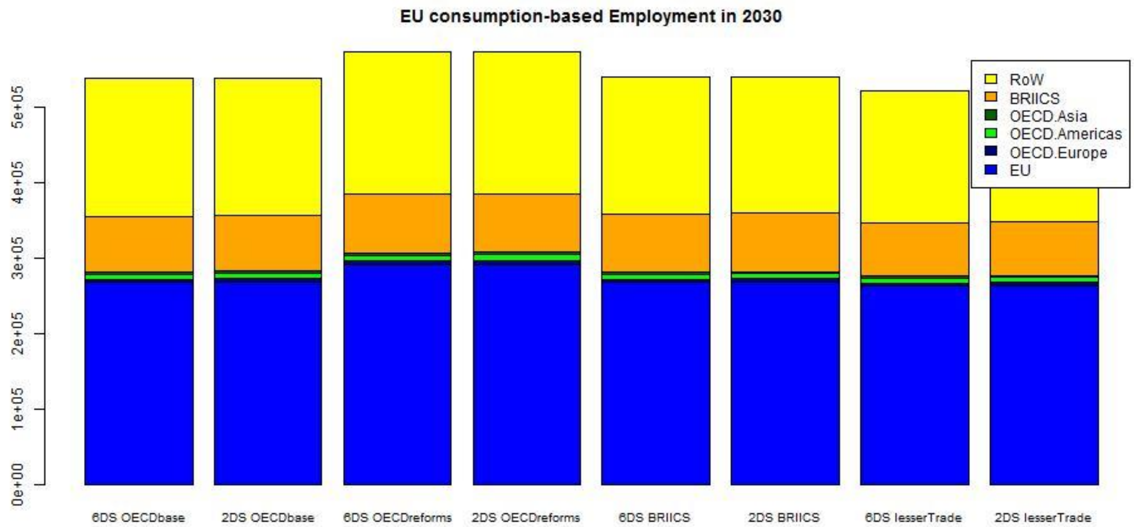


The two panels in Figure 9 show where CO_2 is emitted and people are employed along global value chains for the EU's consumption. Here we compare the four OECD trade scenarios, as well as the two technology scenarios. CO_2 emissions embodied in European consumption are significantly lower in the 2-degree scenarios than in the 6-degree scenarios, while global employment for EU consumption is slightly higher. Recall that total final demand is the same for the 2-degree and the 6-degree scenarios, but different for the different trade scenarios. The EU's final demand in the baseline and the BRIICS catch-up scenario are the same. Consumption-based emissions and employment are largest in the OECD reforms scenario and lowest in the low trade scenario. This is mainly due to the size of the EU's final demand, but the trade patterns have some influence: In the BRIICS catch-up scenario, consumption-based emissions and employment are higher than in the baseline. This is due to the fact that the BRIICS countries have a larger share in global trade, i.e. there is more trade between EU and BRIICS. Both, emission as well as labor productivity are lower in the BRIICS than in the EU. Thus, with a higher share of BRIICS products in the total final demand of the EU, both consumption-based accounts increase.

Comparing employment effects in the 2-degree and 6-degree scenarios for OECD reforms and BRIICS catch-up, we find that the additional employment in BRIICS and the Rest-of-the-World (RoW) from going from 6-degree to 2-degree is higher in the BRIICS catch-up than in the OECD reforms. A global climate mitigation action scenario such as the 2-degree scenario, distributes positive effects on employment better around the world in an increased catch-up scenario, than in the other scenarios.

Figure 9 EU footprints under different trade regimes: 2DS versus 6DS





<u>Note to "IIOA development program" organizers:</u>

We might want to include a statistical analysis here.

3.4 Linking SDGs across borders

In the further analysis of the results, we will specifically consider SDG target 12.2 "By 2030, achieve the sustainable management and efficient use of natural resources", and its relation with SDG 13 "Climate Action" and SDG 8 "Decent work and economic growth".

<u>Note to "IIOA development program" organizers:</u>

This section is unfortunately not finalized yet, but we will do so before mid-May.

- ERL Connecting the sustainable development goals by their energy inter-linkages (McCollum et al. 2018) McCollum et at 2018
- (Wackernagel et al. 2017)
- (Jacob 2016) "International trade is an engine for inclusive economic growth and poverty reduction, and contributes to the promotion of sustainable development."
- (Jacob 2017) Mind the Gap: Analyzing the Impact of Data Gap in Millennium Development Goals' (MDGs) Indicators on the Progress toward MDGs
- SDG 7 'Ensure access to affordable, reliable, sustainable and modern energy for all' with its sub-targets 1) By 2030, ensure universal access to affordable, reliable and modern energy services, 2) By 2030, increase substantially the share of renewable energy in the global energy mix, and 3) By 2030, double the global rate ofimprovement in energy efficiency, is generally found to have a positive impact on other SDGs. Negative spillovers may occur, when the implementation of the policies is not considering the adverse effects (McCollum et al. 2018)

4 Discussion and conclusion

<u>Note to "IIOA development program" organizers:</u>

This section is unfortunately not finalized yet, but we will do so before mid-May.

5 References

Adao R, Costinot A, Donaldson D (2015) Nonparametric Counterfactual Predictions in Neoclassical Models of International Trade. NBER Work Pap 21401 107:633–689. doi: 10.3386/w21401

Almon C (1991) The Inforum Approach to Interindustry Modeling. Econ Syst Res 3:1–8. doi: 10.1080/09535319100000001

Almon C (2012) The Craft of Economic Modeling - Part I.

Anderson, James;van Wincoop E (2001) Gravity with gravitas: a solution to the border puzzle.

NBER Work Pap Ser 3:1–37. doi: 10.1257/000282803321455214

Baldwin R, Lopez-Gonzalez J (2015) Supply-chain Trade: A Portrait of Global Patterns and Several Testable Hypotheses. World Econ 38:1682–1721. doi: 10.1111/twec.12189

Costinot A, Rodríguez-Clare A (2014) Trade Theory with Numbers: Quantifying the Consequences of Globalization. Handb Int Econ 4:197–261. doi: 10.1016/B978-0-444-54314-1.00004-5

Davis SJ, Caldeira K (2010) Consumption-based accounting of CO2 emissions. Proc Natl Acad Sci U S A 107:5687–92. doi: 10.1073/pnas.0906974107

Dietzenbacher E, Los B, Stehrer R, et al (2013) The construction of world input-output tables in the WIOD project. Econ Syst Res 25:71–98. doi: 10.1080/09535314.2012.761180

Duchin F (2015) The Transformative Potential of Input–Output Economics for Addressing Critical Resource Challenges of the Twenty-First Century. In: Baranzini ML, Rotondi C, Scazzieri R (eds) Resources, Production and Structural Dynamics. Cambridge University Press, pp 136–154

Fajgelbaum PD, Khandelwal AK (2016) Measuring the Unequal Gains from Trade. Q J Econ 131:1113–1180. doi: 10.1093/qje/qjw013

Fally T (2015) Structural gravity and fixed effects. J Int Econ 97:76–85. doi: 10.1016/j.jinteco.2015.05.005

Groundstroem F, Juhola S (2018) A framework for identifying cross-border impacts of climate change on the energy sector. Environ Syst Decis 1–13. doi: 10.1007/s10669-018-9697-2

Guillemette Y, Turner D (2018) The Long View: Scenarios for the World Economy to 2060. OECD Econ Policy Pap. doi: https://doi.org/10.1787/b4f4e03e-en

IEA (2015) Energy Technology Perspectives 2015: Mobilising Innovation to Accelerate Climate Action. Paris

Ivanova D, Stadler K, Steen-Olsen K, et al (2016) Environmental Impact Assessment of Household Consumption. J Ind Ecol. doi: 10.1111/jiec.12371

Jacob A (2016) Trade and the new global development framework.

Jacob A (2017) Mind the Gap: Analyzing the Impact of Data Gap in Millennium Development Goalsâ€™ (MDGs) Indicators on the Progress toward MDGs. doi: 10.1016/j.worlddev.2016.12.016

Lenzen M, Kanemoto K, Moran D, Geschke A (2012) Mapping the structure of the world economy. Environ Sci Technol 46:8374–8381. doi: 10.1021/es300171x

Lenzen M, Moran D, Kanemoto K, Geschke A (2013) Building Eora: a Global Multi-Region Input-Output Database At High Country and Sector Resolution. Econ Syst Res 25:20–49. doi: 10.1080/09535314.2013.769938

McCollum DL, Echeverri LG, Busch S, et al (2018) Connecting the Sustainable Development Goals by their energy inter-linkages.

Meinshausen M, Smith SJ, Calvin K, et al (2011) The RCP greenhouse gas concentrations and their extensions from 1765 to 2300. Clim Change 109:213–241. doi: 10.1007/s10584-011-0156-z

Nordhaus WD (2018) Evolution of modeling of the economics of global warming: changes in the DICE model, 1992–2017. Clim Change 148:623–640. doi: 10.1007/s10584-018-2218-

y

Nordhaus WD (2017) Revisiting the social cost of carbon. Proc Natl Acad Sci U S A 114:1518–1523. doi: 10.1073/pnas.1609244114

Nordhaus WD (1993) Rolling the "DICE": an optimal transition path for controlling greenhouse gases. Resour Energy Econ 15:27–50. doi: 10.1016/0928-7655(93)90017-O

O'Neill BC, Kriegler E, Ebi KL, et al (2017) The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century. Glob Environ Chang 42:169–180. doi: 10.1016/j.gloenvcha.2015.01.004

Peters GP, Davis SJ, Andrew RM (2012) A synthesis of carbon in international trade. Biogeosciences 9:3247–3276. doi: 10.5194/bg-9-3247-2012

Peters GP, Minx JC, Weber CL, Edenhofer O (2011) Growth in emission transfers via international trade from 1990 to 2008. Proc Natl Acad Sci U S A 108:8903–8. doi: 10.1073/pnas.1006388108

Riahi K, van Vuuren DP, Kriegler E, et al (2017) The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. Glob Environ Chang 42:153–168. doi: 10.1016/j.gloenvcha.2016.05.009

Rodrik D (2018) New Technologies, Global Value Chains, and the Developing Economies.

SEI (2017) Transnational climate change impacts.

Silva JMCS, Tenreyro S (2006) The Log of Gravity. Rev Econ Stat 88:641–658. doi: 10.1162/rest.88.4.641

Stadler K, Wood R, Bulavskaya T, et al (2018) EXIOBASE 3: Developing a Time Series of Detailed Environmentally Extended Multi-Regional Input-Output Tables. J Ind Ecol 22:502–515. doi: 10.1111/jiec.12715

Tavoni M, Hasegawa T, Masui T, et al (2017) Future air pollution in the Shared Socio-economic Pathways. Glob Environ Chang 42:346–358. doi: 10.1016/j.gloenvcha.2016.05.012

Timmer MP, Dietzenbacher E, Los B, et al (2015) An Illustrated User Guide to the World Input-Output Database: the Case of Global Automotive Production. Rev Int Econ 23:575–605. doi: 10.1111/roie.12178

Timmer MP, Erumban AA, Los B, et al (2014) Slicing Up Global Value Chains. J Econ Perspect 28:99–118. doi: 10.1257/jep.28.2.99

Tinbergen J (1962) An Analysis of World Trade Flows. In: Shaping the World Economy. Twentieth Century Fund, New York,

van Vuuren DP, Edmonds J, Kainuma M, et al (2011) The representative concentration pathways: an overview. Clim Change 109:5–31. doi: 10.1007/s10584-011-0148-z

Wackernagel M, Hanscom L, Lin D (2017) Making the Sustainable Development Goals Consistent with Sustainability. Front Energy Res 5:1–5. doi: 10.3389/fenrg.2017.00018

Wiebe KS (2018a) Identifying emission hotspots for low carbon technology transfers. J Clean Prod 194:243–252. doi: 10.1016/j.jclepro.2018.05.003

Wiebe KS (2016) The impact of renewable energy diffusion on European consumption-based emissions. Econ Syst Res 28:1–18. doi: 10.1080/09535314.2015.1113936

Wiebe KS (2018b) Cross-border effects of climate change mitigation in a multi-regional input-output framework, presented at: UNFCCC SBSTA 48: In-forum training workshop on the use of economic modelling tools related to the areas of the work programme. UNFCCC, Bonn. https://unfccc.int/sites/default/files/resource/20180501 Wiebe MRIO crossbordereffects_replacement.pdf.

Wiebe KS (2018c) Cross-border effects of climate change mitigation in a multi-regional input-output framework. Presented at: UNFCCC African region awareness creation workshop to maximize the positive and minimize the negative impacts of implementation of response measure. https://unfccc.int/topics/mitigation/workstreams/response-measures/african-region-awareness-creation-workshop-response-measures.

Wiebe KS, Bjelle EL, Többen J, Wood R (2018) Implementing exogenous scenarios in a global MRIO for the estimation of future environmental footprints. J Econ Struct. doi: 10.1186/s40008-018-0118-y

Wiebe KS, Bruckner M, Giljum S, Lutz C (2012) Calculating Energy-Related CO2 Emissions Embodied in International Trade Using a Global Input–Output Model. Econ Syst Res 24:113–139. doi: 10.1080/09535314.2011.643293

Wiebe KS, Yamano N (2016) Estimating CO2 Emissions Embodied in Final Demand and Trade Using the OECD ICIO 2015. OECD Publishing

Wood R, Moran DD, Stadler K, et al (2018) Prioritizing Consumption-Based Carbon Policy Based on the Evaluation of Mitigation Potential Using Input-Output Methods.

Yamano N, Webb C (2018) Future Development of the Inter-Country Input-Output (ICIO) Database for Global Value Chain (GVC) and Environmental Analyses. J Ind Ecol 22:487–488. doi: 10.1111/jiec.12758

6 Supplementary information (SI)

Figure 10 GDP per capita in 2030 compared to baseline for the EXIOBASE countries/regions and selected OECD scenarios

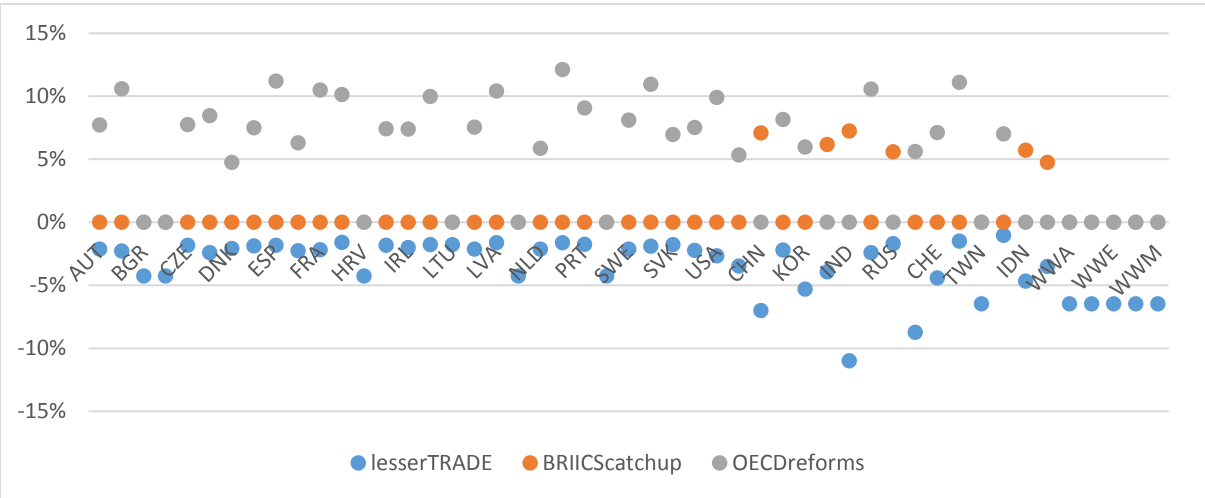


Figure 11 Additional EU consumption-based accounts using constant and gravity determined trade shares in 2030

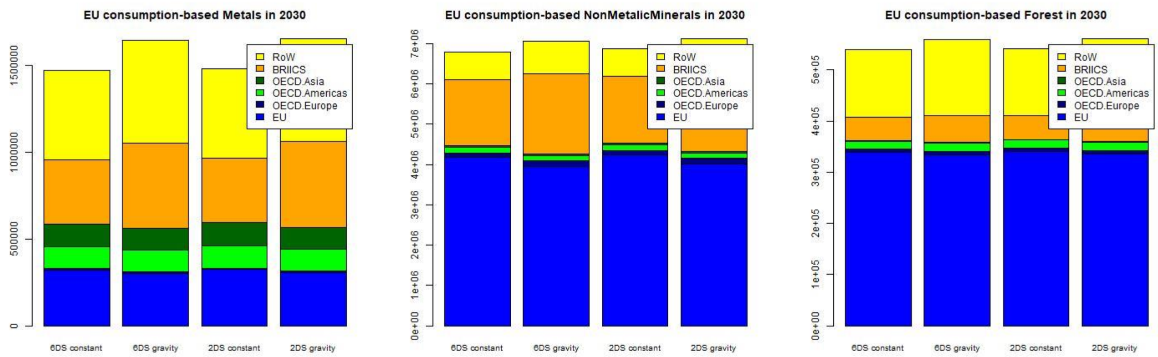
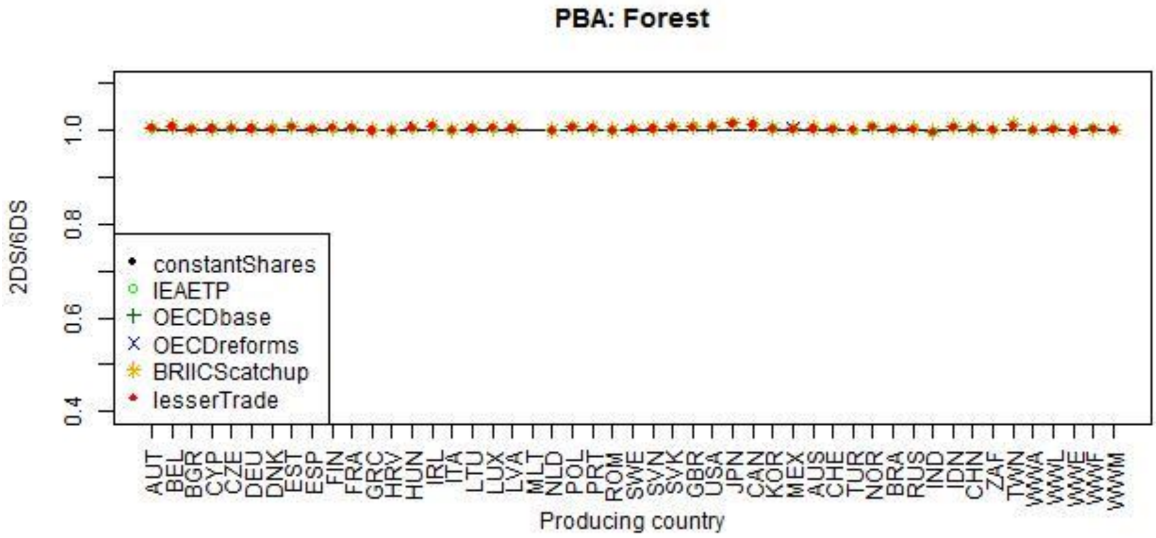
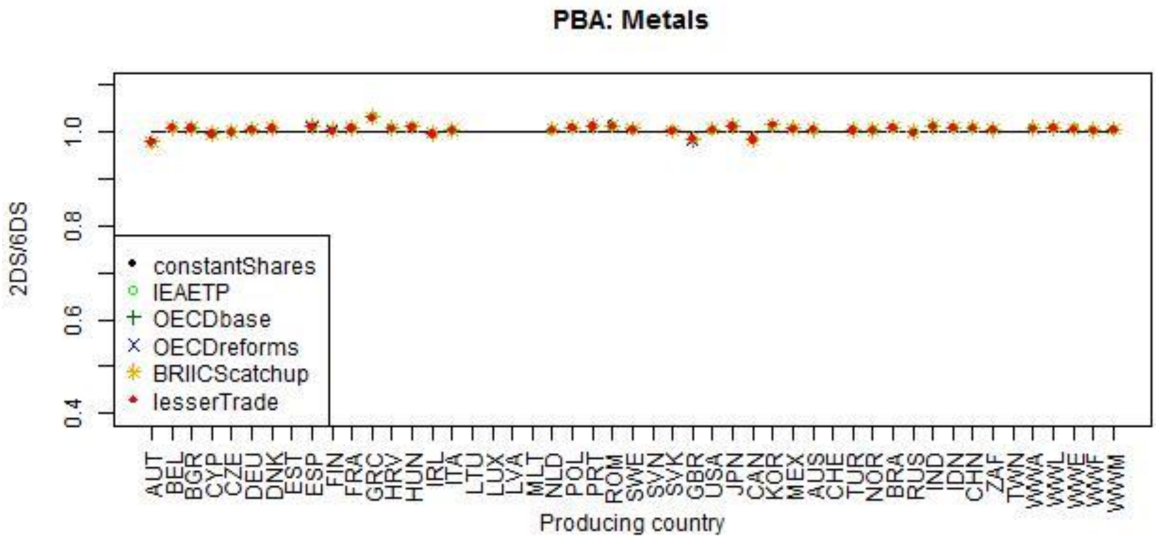


Figure 12 *Additional 2DS versus 6DS: Production-based accounts*





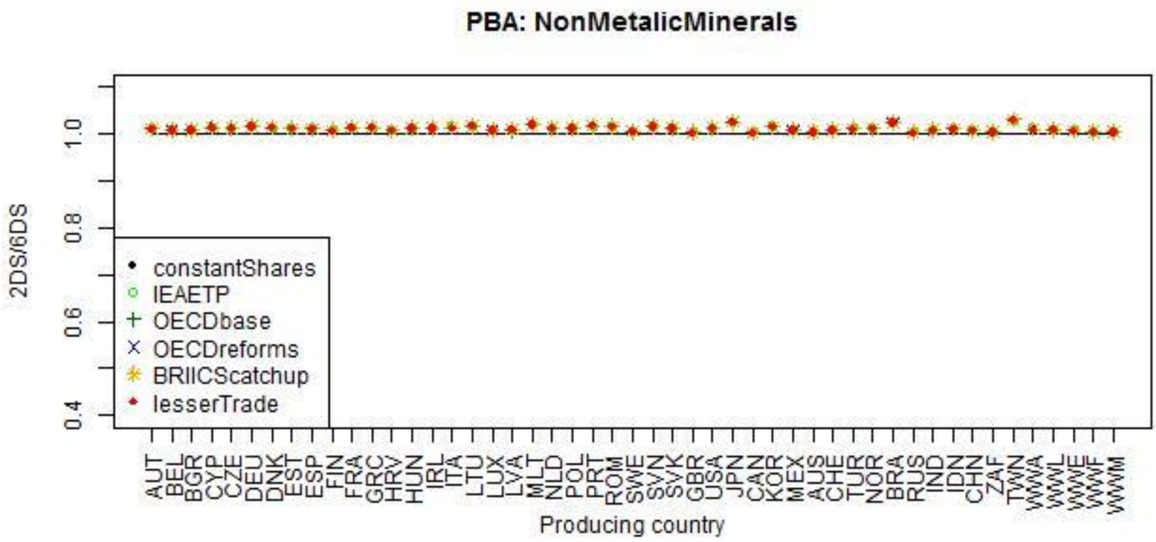


Figure 13 *Additional EU footprints under different trade regimes: 2DS versus 6DS*