Structural disparities in carbon dioxide consumption and trade in the world economy

Policy Paper no 16

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September 2014

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 290647.

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WWWFOR EUROPE
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THEME SSH.2011.1.2-1

Socio-economic Sciences and Humanities Europe moving towards a new path of economic growth and social development - Collaborative project

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 290647.

Structural disparities in carbon dioxide consumption and trade in the world economy *

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September 3, 2014

Abstract

Social scientists have long argued that developed countries are more and more responsible for climate change because they externalise pollution to less developed countries. This paper offers a way to quantify climate responsibility by calculating carbon footprints and carbon balances between regions by means of an input-output analysis. We find that regions in the center of the world economy are increasingly consuming CO_2 which was emitted in the periphery. Developed countries exhibit a large emission balance deficit with the less developed economies. Furthermore, we decompose carbon footprint developments between 1995 and 2007 into three effects: technical progress, shifts in the global value chain and increasing final demand. Our results show that the effect of technical progress is overcompensated by the effect of increased consumption and value chain shifts. Footprint growth in the center is strongly linked to additional pollution and technical development in the periphery. These findings challenge the prevailing view of the potential of modernisation and globalisation with regard to climate change.

Keywords: Climate responsibility, carbon leakage, carbon footprint, environmental world-system theory, input-output analysis

JEL Codes: C67, F18, F64, Q37, Q56, O13

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* **Acknowledgements:** The research leading to these results has received funding from the European Community's Seventh Framework Programme FP7/2007-2013 under grant agreement n 290647.

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1 Introduction

Climate change is not only a major environmental problem, it has also become ever more important in social sciences. Its main driver, anthropogenic carbon dioxide (CO_2) emissions, are primarily a result of the use of fossil fuels for industrial production and transport. While the impact of other waste materials and emissions is limited to the local environment, the amount of CO_2 emissions has a global dimension.

The distribution of CO_2 emissions across the world is a politically sensitive issue, as the failed attempt to extend the Kyoto protocol has shown. Regional patterns of CO_2 emissions are diverse and continuously changing. Typically, greenhouse gas emissions should decrease with the prosperity (income) of a society, a hypothesis that is illustrated by the Environmental Kuznets Curve (EKC). Technical progress presumably decouples richer economies from the degradation of nature by decreasing emissions per output (World Bank 1992). The EKC hypothesis however has come under severe criticism.[1] Besides its technical and theoretical weaknesses, recent empirical studies failed to find any evidence for an inverted U-relationship between income and different greenhouse gas emissions (Choi, Heshmati, and Cho 2010; Weingärtner 2013).

Some social scientists argue that the emission reduction due to the implementation of new technologies is (over-)compensated by the increase in demand (Schnaiberg 1980). Others, e.g. Cole (2004) and Dasgupta et al. (2002), criticise that the production-based approach of the EKC does not take into account that emissions can be outsourced to other regions. Through imported goods, economies consume natural resources which have never been on domestic land in their pure form. 'Carbon leakage' is possibly triggered by the fact that richer countries introduce stricter environmental standards and thus have higher production costs. Countries with relaxed environmental regulations would consequently have a comparative cost advantage for dirty industries (Cole 2004). International environmental agreements can also be a catalyst for such developments. The Kyoto protocol limits the admissible emission of greenhouse gases of certain countries within their legislative borders by means of binding emission objectives. Such agreements produce incentives to outsource emission-intensive production from industrial economies to developing countries. Theoretically, environmental world-system theory states that peripheral countries increasingly serve as a global waste dump where emissions for the consumption of the center countries are released (Burns, Kick, and Davis 2003; Jorgenson 2003; Wallerstein 1974, 2004). Empirically, a consumption-based approach like the ecological footprint would permit the assessment of the true contribution of certain regions to climate change. The ecological footprint includes all emissions which are caused

[1] For a comprehensive review of the EKC literature see Stern (2004)

by the final consumption of a certain country. Carbon leakages are therefore not omitted. Consumption-based approaches usually do not find any significant negative correlation between high income and emissions (Bagliania, Bravob, and Dalmazzone 2008; Weingärtner 2013).

The aim of our paper is to quantify the contribution of different world regions to global CO_2 emissions, and analyse emission flows between those regions. We thereby intend to assess the hypothesis that the center of the world economy has increasingly outsourced CO_2 emissions into the periphery. Consequently, the center so far has not reduced its emissions and is still primarily responsible for climate change. It is nevertheless increasingly using the periphery as a waste dump for its consumption-oriented lifestyle.

For this purpose, we calculate CO_2 footprints for different world regions by means of an input-output analysis using data from the World Input-Output Database (WIOD). Furthermore, we decompose the changes in the footprint between 1995 and 2007 into the effects of technical progress, shifts in the global value chains and changes in final demand. We find that CO_2 footprints increased both in the center and in the periphery. In absolute terms, the increase in the center outweighs those in the periphery by far. Secondly, we find that technical progress has substantially reduced CO_2 emissions in all regions. Nevertheless, it was not sufficient to decouple economic growth from the degradation of nature. The emission gains from the modernisation process were outweighed by higher consumption. Additionally, by dislocating parts of their production to the periphery, regions in the center increased their footprint, a fact which possibly stems from laxer environmental regulation and therefore dirtier production technologies in peripheric countries.

Furthermore, we calculate emission balances to evaluate the CO_2 flows between regions. We find that regions in the center exhibit large and increasing deficits, which mainly stem from trade with the periphery. This is also reflected in the fact that the imported share of the CO_2 footprint in the center, and particularly in the EU15, is large and has risen markedly since 1995. The EU15 seems to be on top of the 'hierarchy' in terms of emission trade, with negative balances vis-à-vis all other regions. The BRICs on the other hand find themselves in the role of the periphery. The EU12 and other emerging economies appear to be in a semi-peripheric state, with large surpluses with the center on the one side, and deficits with the periphery on the other.

Throughout the paper, we group the countries under investigation into certain groups, i.e. the 15 old EU member states (Austria, Belgium, Germany, Denmark, Spain, Finland, France, Great Britain, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Sweden), the 12 new EU member states (Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Lithuania, Latvia, Malta, Poland, Romania, Slovakia, Slovenia), mature economies (Australia, Canada, USA, Japan, Korea, Taiwan), emerging economies (Indonesia, Mexico, Turkey), and the BRICs (Brazil, Russia, India, China). This classification roughly resembles the structure of the world-system hierarchy. The EU-15 and the mature economies represent the center, the EU-12 the semi-periphery, and the emerging economies, the BRIC countries, and rest of the world the periphery.

The rest of the paper is structured as follows: In the next section we briefly summarise the empirical literature. Section 3 describes data and methodology. In section 4, we calculate the regional carbon dioxide footprints of the center and periphery of the world economy and decompose their changes between 1995 and 2007 into the effects of technical progress, changes in final demand and shifts in the global value chain. In section 5, CO_2 emission balances are calculated. Finally, we sum up the results and and provide some tentative policy conclusions.

2 Empirical background

This section briefly summarises the empirical background for our analysis. Since the 1970s, the literature about the interaction between trade and the environment is constantly growing. Walter (1973) opened the discussion with his analysis of emissions in the United States embodied in international trade flows. During the last 20 years, trade in emissions was calculated for e.g. Great Britain and Germany (Proops, Faber, and Wagenhals 1993), Japan (Kondo, Moriguchi, and Shimizu 1998), Brazil (Machado, Schaeffer, and Worrell 2001; Tolmasquim and Machado 2003), India (Mukhopadhyay and Chakraborty 2005), Turkey (Tunc, Turut-Asik, and Akbostanci 2006).

These early works assume constant technology throughout the sample due to data weaknesses (Serrano and Dietzenbacher 2010). However, later works with more comprehensive data calculated bilateral emissions in trade, e.g. for Japan and Canada (Hayami and Nakamura 2002). Multinational approaches calculated imported emissions through trade from 6 (Wyckoff 1994) and 24 (Ahmad and Wyckoff 2003) OECD countries. Kratena and Meyer (2009) calculated the CO_2 emissions embodied in Austrian international trade with the rest of the world. Lenzen, Pade, and Munksgaard (2004) calculated trade balances between Denmark, Germany, Sweden, Norway, and the rest of the world. 87 countries were considered in Peters and Hertwich (2008), who calculated CO_2 emissions in international trade, Wilting and Vringer (2009) added two more greenhouse gases and land use, Hertwich and Peters (2009) analysed CO_2 footprints. Serrano and Dietzenbacher (2010) compared two concepts to analyse the international emission responsibility of a country.

A country's responsibility for climate change has to take the regional emission consumption into account. With the publication of the book 'Food First:

Beyond the Myth of Scarcity' Lappé, Collins, and Fowler (1977) presented for the first time measures on how globalised food production and consumption patterns divide the world into two parts, a rich region whose population can satisfy their exotic consumer preferences, and a poor region where poverty, malnutrition and landlessness prevails. The demand of the rich part of the world restrains the demand of poorer countries because land that satisfies exotic consumer demand is no longer available. The biological capacity of land is limited. If a group of people gain the ability to determine how these capacities are used (through their purchasing power), these capacities are no longer available for other groups. The analysis of Lappé, Collins, and Fowler (1977) was limited to the consumption of agricultural goods. By this measure, however, it was possible to determine the average consumption of food and other agricultural products of a citizen and to compare it to inhabitants of other regions or countries (Andersson and Lindroth 2001: p. 114).

Rees (1992), Rees and Wackernagel (1994), and Wackernagel and Rees (1996) expanded the concept of Lappé, Collins, and Fowler (1977) to a comprehensive principal: The Ecological Footprint. Land and sea areas from all regions of the world may be present in the Ecological Footprint of a country, because trading takes place not only in domestic markets but also internationally. In this paper, carbon footprints are defined as the per capita CO_2 embodied in the final consumption of a country or region by using an Environmentally Extended Multi-Region Input-Output (EE-MRIO) analysis.

3 Data and Methodology

3.1 World Input Output Database

For the purpose of this paper, particularly to calculate emissions in trade, national input-output tables do not provide enough data. National accounts statistics give information about flows of production, consumption and income of the domestic market only. However, for analysing flows throughout the world economy, world input-output tables (WIOT) would be required. WIOTs are constructed from national IO tables plus foreign trade data for each country. There are hands full of data records that combine national IO tables with trade data of foreign industries. For this paper the database of the World Input-Output Database (WIOD) project is used. It is funded by the European Commission and contains international trade statistics for 35 industries and 40 countries (EU27, NAFTA, BRIC, Australia, Indonesia, Turkey, Japan, Korea, and Taiwan) which share 85 percent of world's GDP. The list of industries coincides with the industries used in the EUKLEMS dataset. Recently the database was updated with tables for the years 2009 to 2011. Up to date, WIOD provides time series data for 16 years (from 1995 to 2011).

IO tables are constructed from supply and use tables. A national IO table contains a symmetric matrix of intermediates which traces the input of a domestic industry to other domestic industries. Inputs from abroad are indicated by an import vector. The sum of intermediate goods supply, domestic final consumption and exports equals total output of a national economy. The difference between total output and intermediate use plus imports is the value added. Hence, the value added vector indicates values which were added by an economy in the process of production which corresponds to the difference between use and supply of industries.

In national IO tables trade flow information is pooled in the import and export vector. International IO tables, however, provide additional information for trade flows by decomposing import and export patterns of foreign industries. Figure A.1 in the appendix gives a schematic outline of a World Input-Output Table (WIOT) for a three-regions-one-industry set-up. In the WIOD project dataset, however, the intermediate demand and output matrix has a dimension of 1435 x 1435 (that is 41 regions x 35 industries). The final demand matrix has a dimension of 123 x 1435, that is a decomposition of final consumption for households, non-governmental organisations, governments. Additional information is given for investments and changes in inventories and valuables. The sum of rows (sum of total supply of a country) adds up to total output of each country's industry. The difference between the sum of rows and the sum of total intermediates use (column sums) yields in the value added of each industry in each country. For more specific information on the WIOD project see Timmer (2012).

Also part of the WIOD dataset are environmental accounts which cover the years 1995 to 2009. Unfortunately the environmental part of the dataset has not been updated in November 2013. For this reason, 2009 is the last covered year of this paper's analysis. However, the environmental dataset split environmental accounts in the same 35 industries (plus households) in all 40 countries. Thus, the environmental accounts can be linked with the rest of the WIOD. Additional data for the rest of the world was constructed from average values from Brazil, China, India, Indonesia and Mexico.

The WIOD environment satellites include data for energy and air emissions as well as materials extraction, land and water use. Emission data are particularly relevant for climate change policy analysis as they have a global rather than a local effect. Due to international guidelines data for CO_2 emissions are broadly available. The advantage of WIOD is that it contains a breakdown of aggregated emission data of standardised NACE sectors. CO_2 emissions are given in kilotons per sector and energy commodity.

3.2 Carbon Footprints and Emission Balances

The Input-Output methodology was introduced by Leontief (1936). He received the 1973 Nobel Memorial Prize in Economic Sciences mostly for developing the framework of equation 1.

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_N \end{bmatrix} \equiv \begin{bmatrix} A_{11} & A_{12} & \cdots & A_{1N} \\ A_{21} & A_{22} & \cdots & A_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ A_{N1} & A_{N2} & \cdots & A_{NN} \end{bmatrix} \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_N \end{bmatrix} + \begin{bmatrix} \sum_j f_{1j} \\ \sum_j f_{2j} \\ \vdots \\ \sum_j f_{Nj} \end{bmatrix}$$

$$y = Ay + f = (I - A)^{-1} f = Lf \tag{1}$$

y represents the gross output vector with dimension CGx1 (C Countries, G Goods), A denotes the output coefficient matrix with dimension CGxCG, f is the CGx1 final demand vector. $L = (I - A)^{-1}$ is the Leontief inverse where I is an identity matrix. Its columns contain the input requirements of an economy, generated by one unit of output.

Following the methodology of Arto et al. (2012), the emission coefficient vector, $v = (\hat{y})^{-1} e$, contains the amount of emissions per unit of output. Thus, equation 2 gives the amount of emissions which are generated in order to satisfy total final demand f. Variables with hats ($\hat{}$) are diagonal matrices.

$$e = \hat{v} y = \hat{v} L f \tag{2}$$

Equation 2 can be rewritten in its partitioned form of a three-country-one-sector example.

$$\begin{bmatrix} e^1 \\ e^2 \\ e^3 \end{bmatrix} = \begin{bmatrix} \hat{v}^1 & 0 & 0 \\ 0 & \hat{v}^2 & 0 \\ 0 & 0 & \hat{v}^3 \end{bmatrix} \begin{bmatrix} L^{11} & L^{12} & L^{13} \\ L^{21} & L^{22} & L^{23} \\ L^{31} & L^{32} & L^{33} \end{bmatrix} \begin{bmatrix} f^{11} + f^{12} + f^{13} \\ f^{21} + f^{22} + f^{23} \\ f^{31} + f^{31} + f^{33} \end{bmatrix} \tag{3}$$

e^1 are emissions of a country 1, $\hat{v}^1$ is the emission coefficient per unit of output of country 1. The first column of the Leontief inverse contains the input requirements of the economy of country 1 on all economies, generated by one unit of output. f^{12} are goods or services for final demand of country 1 which were produced in country 2.

3.2.1 Carbon Footprints

The carbon footprint which is used here is defined as the per capita CO_2 embodied in the final consumption of a country or region. It is the sum of per capita CO_2 contained in the final consumption which was released during the process of production within a region itself and the CO_2 leaked to a region, embodied in imported goods. Equation 4 uses a methodology equivalently to Arto et al. (2012).

$$\text{fp}^r = \frac{\hat{v}^r L f^r + \hat{v}^{-r} L f^r + h^r}{\text{pop}^r} = \frac{\hat{v} L f^r + h^r}{\text{pop}^r} \tag{4}$$

$\hat{v}^r$ is a CGxCG diagonal matrix which contains per output emission values of r on the diagonal an zeros elsewhere. Imports of emissions are marked with superscript $-r$. Hence, $\hat{v}^{-r}$ is a diagonal matrix with per output emission values of all countries but r on the diagonal and zeros elsewhere. L is the Leontief inverse as described above. f^r, however, is a CGx1 vector with final demand accounts at position of country r and zeros elsewhere. Thus, $\hat{v}^r L f^r$ is CGx1 vector of CO_2 emission values which are domestically produced and consumed with entries for country r and zeros elsewhere.

$\hat{v}^{-r} L f^r$ is a CGx1 vector of CO_2 emissions which are domestically consumed but not domestically produced. Hence, $\hat{v}^{-r} L f^r$ indicates the amount of carbon leakage to a region. h^r specifies an CGx1 emission vector with entries for country r and zeros elsewhere. The entries are emissions which are directly released by households i.e. emissions from heating or private transportation. Thus, fp^r is a CGx1 vector of CO_2 emissions that are contained in final demand of a country r (decomposed in abroad and domestic production) plus emissions by households in country r in per capita terms.

3.2.2 Carbon Balances

The carbon balance specifies net carbon leakage from a region. In the general case exports of CO_2 emissions contained in the final demand vector of all other countries can be expressed by $t^r_{\text{CL,X}} = \hat{v}^r L f^{-r}$, where $\hat{v}$ is a diagonal emission coefficient matrix with zeros for all countries but country r. $L = (I - A)^{-1}$ is the Leontief inverse. f^{-r} denotes the final consumption vector of all countries but r. $t^r_{\text{CL,M}} = \hat{v}^{-r} L f^r$ denotes the CO_2 leaked from foreign countries, consumed country r. The difference between imports and exports results in the carbon leakage balance of a region:

$$t^r_{\text{CL,Net}} = t^r_{\text{CL,X}} - t^r_{\text{CL,M}} \tag{5}$$

For the per capita carbon balance, $t^r_{\text{CL,Net}}$ is divided by the population of country r (pop^r).

3.3 Decomposition Techniques

This paper aims to identify changes in the global emission structures between different periods. Decomposition techniques intend to split up the changes in variables to changes of their components. In an input-output analysis decomposition is often done in an additive form. In the process a value of a former period is subtracted from a value of a later period and then decomposed in their constituent parts. Equation 6 gives an example of a decomposition with two components.

$$
\begin{aligned}
a_1b_1 - a_0b_0 &= (a_1b_1 - a_0b_1) + (a_0b_1 - a_0b_0) \\
&= (a_1b_0 - a_0b_0) + (a_1b_1 - a_1b_0)
\end{aligned} \tag{6}
$$

The first term on the right side of the equation indicates the change in component a using component b of period 1 as a weight. The second term indicates the change in b weighted by a of period 0. The second line uses weights of the period 0 for b and period 1 for a. As there is no reason to choose one form over the other, usually the arithmetic average is used.

$$
\begin{aligned}
a_1b_1 - a_0b_0 &= \frac{1}{2}(a_1 - a_0)(b_0 + b_1) + \frac{1}{2}(a_0 + a_1)(b_1 - b_0) \\
&= \frac{1}{2}(\Delta a)(b_0 + b_1) + \frac{1}{2}(a_0 + a_1)(\Delta b)
\end{aligned} \tag{7}
$$

Changes of a are weighted with the sum of b of both periods, while the changes of b is weighted by the sum of the a component (Dietzenbacher, Lahr, and Los 2004).

Here, however, the intertemporal change of footprints will be decomposed in three components: units per output ($\hat{v}$), technological divergence (L), and final demand (f). The change of $\hat{v}$ indicates increases in emission efficiency of production and hence technological progress. The change of L shows if a shift in the supply chain (if goods or services are produced elsewhere) leads to additional emissions. An increase in f displays emission growth of additional consumption.

4 Carbon Footprints

In order to evaluate the true contribution of a certain world region to climate change, we need to calculate carbon footprints. This concept permits to quantify the total amount of CO_2 emissions caused by the consumption in this region (see Sections 1 and 3). We usually limit our analysis to the time period from 1995 to 2007, the last year before the financial and economic crisis. Thereby we focus on long-term trends and exclude the distorting effect of the crisis.

Carbon footprints evolved heterogeneously across groups (see table A.1 in the appendix and figure 1). Although they increased in all regions under investigation, the highest rises were exhibited by the regions in the center of the world economy. In absolute terms, the carbon footprint per capita in the mature economies increased from 15.71 tons in 1995 to 17.47 tons in 2007 (1.76 tons, 11.2 percent). In the EU15, they rose by almost one ton per capita (8.87 percent). The BRIC countries on the other hand were falling behind with an increase of just 0.76 tons per capita. In relative terms however, their footprint skyrocket and increased by around 40 percent. They were only outpaced by the emerging economies whose footprint rose by 42 percent, or 0.87 tons. In total, the center expanded their per capita carbon footprint by 1.22 tons. In the periphery, the consumption of embedded CO_2 amounted to 0.49 tons. These findings emphasise that the countries in the center of the world economy are still primarily responsible for global warming, even though peripheral countries are relatively catching up.

The high increases in the carbon footprints of the center however did not correspond with a similar increase in their own CO_2 emissions. In the EU, the own contribution to the footprint declined markedly. In the mature countries it still increased, albeit only moderately. Imports of CO_2 emissions however increased substantially in both regions. In contrast, both their own contributions and their imports rose in the BRICs and the emerging economies.

The fact that the import share rose in all regions reflects the ongoing globalisation process. Nevertheless, its increases were particularly strong in the EU15, where it had already been highest at the beginning of the period, and in the EU12. In 2007, the import share amounted to 34 percent in the EU15 and 29 percent in the EU12. In the mature economies, it rose moderately to 20 percent and in the BRICs to only 8 percent. The emerging economies on the other hand exhibited a high import share in 2007 (25 percent), but a less dynamic development than in the EU.

Where did the imports of CO_2 emissions originate? In mature economies and the EU15 countries, the CO_2 imports mainly stemmed from the emerging economies and BRIC countries, as well as from the rest of the world. The import share of the carbon footprint from the EU12 countries stagnated or fell. In the EU12, imports rose substantially from the EU15 (0.33 tons, 145 percent), the BRIC countries (0.42 tons, 84 percent), and the rest of the world (0.35 tons, 291 percent). Imports from mature economies and other emerging countries rose sharply in relative terms, but accounted for only 0.19 tons CO_2 in absolute terms. All in all, the countries in the center of the world economy increased their carbon imports from the periphery and are therefore partly responsible for the increase in the CO_2 emissions in the periphery.

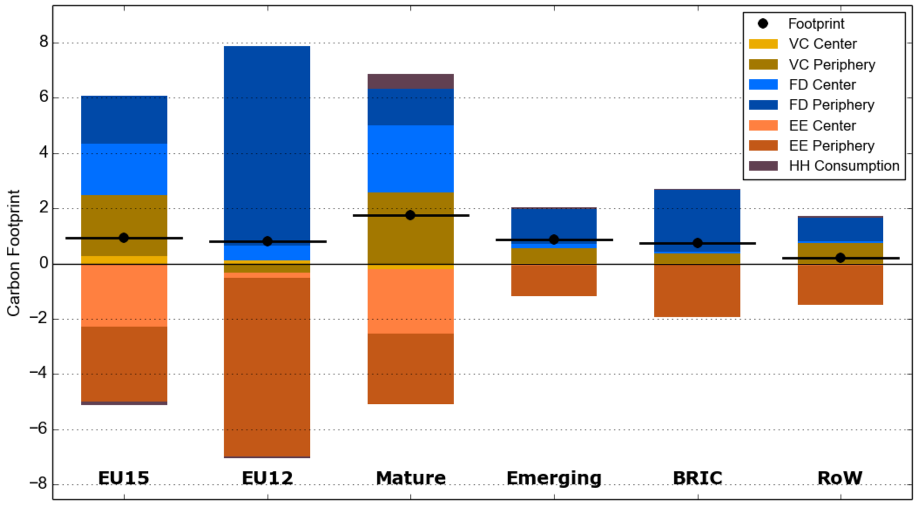
Decomposition

Another way to look into the underlying factors which drive the developments of regional carbon footprints is to decompose their changes between 1995 and

Figure 1: Evolution of Footprints and Footprint imports

Notes: EU15: Austria, Belgium, Germany, Denmark, Spain, Finland, France, Great Britain, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Sweden. EU12: Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Lithuania, Latvia, Malta, Poland, Romania, Slovakia, Slovenia. Mature: Australia, Canada, USA, Japan, Korea, Taiwan. Emerging: Indonesia, Mexico, Turkey. BRIC: Brazil, Russia, India, China.
Source: Authors' calculations based on the World Input-Output Database, April/May 2012.

Figure 2: Decomposition of change in carbon footprint, in (metric) tons CO_2 per capita, 1995-2007



Notes: Center: EU15 and mature economies. Periphery: EU12, emerging economies, and BRICs.
Source: Authors' calculations based on the World Input-Output Database, April/May 2012.

2007 into the effects of technical progress, shifts in the global value chain and changes in final demand. The results are presented in figure 2, which for simplicity separate the world economy into center and periphery. Table A.2 in the appendix provides detailed results for all regions.

The final demand effect (FD effect) of a certain region represents the additional CO_2 footprint caused by increasing domestic demand. The emissions can nevertheless be released in the causative region itself or abroad. From figure 2, we see that the additional CO_2 emissions due to changes in final consumption were substantial in all regions. Nevertheless, the countries in the center could partly increase their consumption without a similar increase in their own footprint. In the EU15 countries, almost half of the emissions caused by additional final demand were emitted in the periphery. In mature economies, two thirds of its CO_2 emissions were imported. Additional CO_2 emissions caused by rising final demand in all other groups were not or only marginally released in the center. Increasing final demand in the center caused more CO_2 emissions in the periphery but not vice versa.

Furthermore, CO_2 consumption in the center has risen due to supply chain shifts to the periphery. The value chain effect (VC effect) is the change in the footprint of a certain region due to shifts in the global value chains. Just like final demand, the reorganisation of global production networks can cause a change in the footprint both in the domestic and the foreign economy. It is striking that changes in the global value chains increased the CO_2 footprint in the EU15 (+2.47 tons) and in the mature economies (+2.38 tons). The major part of this increase was released in the periphery. It seems that dirty industries were to some extent outsourced to peripheral regions. This reallocation was responsible for a major increase in the footprints of the center.

Technical progress in general reduces CO_2 consumption in all regions of the world economy. Nevertheless, this effect is compensated to a large extent by the increase in final demand. Differences between center and periphery were substantial. Technical progress in the periphery reduces consumption in the center, but not vice versa. All in all, the developments of the footprints in the periphery were dependent on structural developments in the periphery alone, whereas those in the center were strongly interrelated with additional emissions and technical development in the periphery.

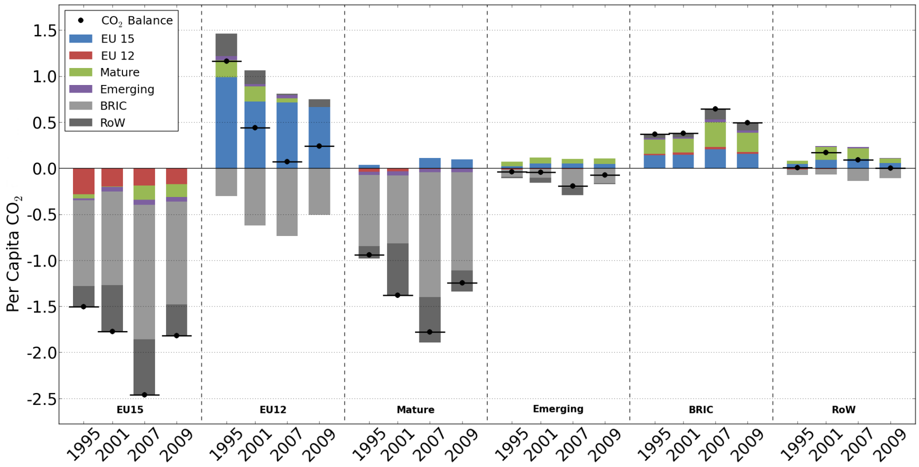
5 Carbon Emission Balances

In the previous section we have shown that the share of imported CO_2 emissions is increasing, particularly in the center of the world economy. Here, we further look into the amount of carbon leakage by calculating emission balances. The latter are the difference between CO_2 exports and imports. Exports are the sum of emissions which are produced in a certain country or region as a result of foreign final demand. Imports on the other hand are the emissions that domestic final demand generates in foreign countries. A negative carbon emission balance therefore reflects a situation where a region causes more CO_2 emissions abroad by its own domestic demand than vice versa. Figure 3 and figure 4 present the balances per capita and in Gigatons, respectively.

In absolute terms, the carbon emission balance of the EU15, of the mature economies and to a lesser extent also of the emerging economies was negative, whereas the EU12 and the BRIC countries exhibited a small surplus. It is noticeable that especially the EU12 and the emerging countries showed little evidence for emission trading in absolute terms. Interestingly, although the negative balance of the EU15 and other mature economies was substantial, it was outrun by the surplus of the BRICs. Per capita however, the surpluses of the BRICs were by far smaller than the deficits of the center.

Looking into bilateral emission balances, we see that almost all of the deficit of the EU15 and the mature economies stemmed from trade with the BRICs and the rest of the world. The EU15 had negative balances even with the mature economies and the EU12. Thus, the EU15 can be seen as being at the 'top of the hierarchy' of the world system in terms of CO_2 consumption. The EU12 and the emerging economies on the other hand show the typical pattern of semi-

Figure 3: Carbon balances in per capita CO_2 consumption



Source: Authors' calculations based on the World Input-Output Database, April/May 2012.

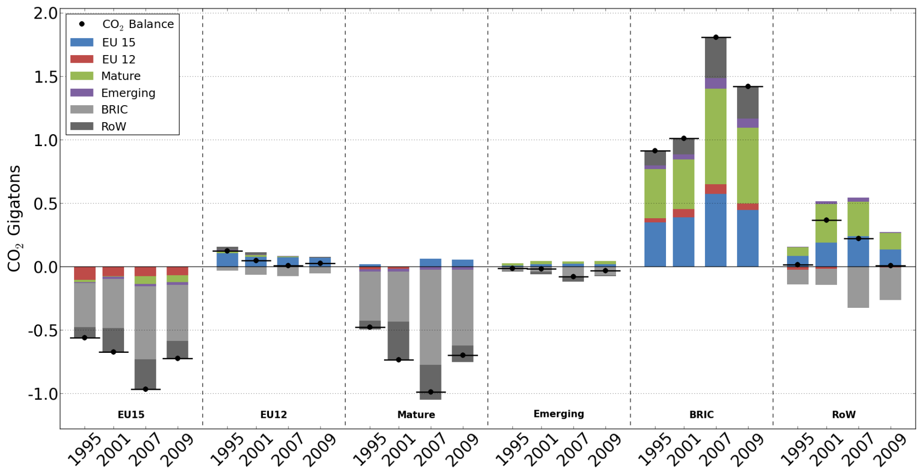
peripheric regions. While they exhibit surpluses with the EU15 and the mature economies, they feature significant negative balances with respect to the BRICs and the rest of the world. The BRICs on the contrary had emission surpluses with all other regions.

Table A.3 and table A.4 in the appendix show how carbon balances changed between 1995 and 2007, both in terms of per capita and in CO_2 Megatons. Carbon balances deteriorated substantially in the EU15 (per capita: -0.96 t, absolute: -407 Mt), the EU12 (-1.09 t, -116 Mt) and the mature economies (-0.84 t, -511 Mt), and moderately in the emerging economies (-0.15 t, -66 Mt). Carbon balances in BRIC countries (0.27 t, 896 Mt) and the RoW (0.08 t, 205 Mt) made up for the decrease of the former regions. Whereas the EU15 exhibited a decline in their balances with all regions but the EU12, and the EU12 with all regions, the mature economies and the emerging economies exhibited decreases in their balances with the BRICs and the rest of the world.

Overall emission trade increased between 1995 and 2007. World emission imports and exports respectively increased by 0.36 tons in per capita CO_2 or 3,070 CO_2 Mt. A large share of CO_2 exports to all countries, 1,428 Mt, came from the BRIC countries which increased their carbon balance by 896 Mt. EU15 and other mature economies increased their total balance deficit by 407 Mt and 511 Mt. Almost the entire CO_2 balance deficit increase of center regions is composed by fast increasing imports from peripheral regions, i.e. BRIC countries and RoW.

To summarise, our analysis of the carbon emission trade between different

Figure 4: Carbon balances in CO_2 Gigatons



Source: Authors' calculations based on the World Input-Output Database, April/May 2012.

regions of the world economy gives some insights into the world-system hierarchy. Mature economies stand on the top, the EU12 show characteristics of the semi-periphery, and emerging economies and BRICs of the periphery. We find that peripheral countries increasingly export CO_2 to core regions. Almost the entire CO_2 balance deficit increase of the center is a result of increasing imports from the periphery. Countries with low CO_2 footprints are major CO_2 exporters. Such countries show small shares of footprint imports, especially from the center. Countries of the center increased their consumption without a similar increase in emission production at the expense of the periphery. Emissions to satisfy additional demand in center countries are more and more emitted in the periphery.

6 Conclusion

This paper aims at quantifying the contribution of different world regions to global CO_2 emissions, and at analysing emission flows between those regions. Thereby we intend to assess two interrelated hypotheses: First, other than what the Environmental Kuznets Curve states, countries in the center of the world economy so far have not reduced their emissions and are still primarily responsible for climate change. Second, the center has increasingly outsourced CO_2 emissions into the periphery, using the latter as a waste dump for its consumption-oriented lifestyle.

For this purpose, we calculated CO_2 footprints for different world regions.

Furthermore, we decomposed the changes in the footprint between 1995 and 2007 into the effects of technical progress, shifts in the global value chains and changes in final demand. We find that CO_2 footprints increased both in the center and in the periphery. In absolute terms, the increase in the center outweighs those in the periphery by far. Secondly, we find that technical progress has substantially reduced CO_2 emissions in all regions. Nevertheless, it was not sufficient to decouple economic growth from the degradation of nature. The emission gains from the modernisation process were outweighed by higher consumption. Additionally, by dislocating parts of their production to the periphery, regions in the center increased their footprint, a fact which possibly stems from laxer environmental regulation and therefore dirtier production technologies in peripheric countries.

Furthermore, we calculated emission balances to evaluate the CO_2 flows between regions. We find that regions in the center exhibit large and increasing deficits, which mainly stem from trade with the BRICs and the rest of the world. This is also reflected in the fact that the imported share of the CO_2 footprint in the center, and particularly in the EU15, is large and has risen markedly since 1995. The EU15 seems to be on top of the 'hierarchy' in terms of emission trade, with negative balances vis-à-vis all other regions. The BRICs on the other hand find themselves in the role of the periphery. The EU12 and the emerging economies appear to be in a semi-peripheric state, with large surpluses with the center on the one side, and deficits with the periphery on the other.

All in all, our findings challenge the potential of the modernisation process with regard to climate change as well as the hypothesis of the Environmental Kuznets Curve. The economies in the center still bear the main responsibility for climate change and were only able to reduce their own emission production by an ever larger import share from the periphery.

Different environmental regulations and technologies create structural disparities in the world economy which provide incentives to shift production to countries with lower emission efficiency. These shifts increase the global CO_2 footprint. There is a need to reduce these structural disparities by forcing technology transfer to the periphery and opening up patent law for green technology. Furthermore, international coordination is necessary to overcome the danger of climate change. Production-based agreements like the Kyoto protocol encourage carbon leakage. Future environmental agreements should pursue a consumption-based approach and e.g. implement measures to tax CO_2 consumption.

Further research in the field of CO_2 emission trade would be important to trace back structural inequalities between center and periphery in a world-system perspective. In particular, the role of the EU12 as a semi-periphery should be analysed in more detail. The usefulness of the WIOD database for world-system analysis is however limited. Important data, e.g. for peripheral and extracting regions such as the Sub-Saharan countries are missing. The inclusion of other environmental indicators such as a full set of greenhouse gases and waste flows would further also broaden our analysis.

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Appendix

Figure A.1: Structure of World Input-Output Tables (WIOT), hypothetical example with two countries and rest of the world

		Country A Intermediate *Industry*	Country B Intermediate *Industry*	Rest of World Intermediate *Industry*	Country A Final domestic	Country B Final domestic	Rest of World Final domestic	Total
Country A	*Industry*	Intermediate use of domestic output	Intermediate use by B of exports from A	Intermediate use by RoW of exports from A	Final use of domestic output	Final use by B of exports from A	Final use by RoW of exports from A	Output in A
Country B	*Industry*	Intermediate use by A of exports from B	Intermediate use of domestic output	Intermediate use by RoW of exports from B	Final use by A of exports from B	Final use of domestic output	Final use by RoW of exports from B	Output in B
Rest of World (RoW)	*Industry*	Intermediate use by A of exports from RoW	Intermediate use by B of exports from RoW	Intermediate use of domestic output	Final use by A of exports from RoW	Final use by B of exports from RoW	Final use of domestic output	Output in RoW
		Value added	Value added	Value added				
		Output in A	Output in B	Output in RoW				

Notes: Squares in blue are of domestic concern, squares in red are of foreign concern.
Source: Timmer (2012).

Table A.1: Evolution of the Carbon Footprint

Group	Origin	Year				Δ 95-07	
		95	01	07	09	Rel.	Abs.
EU15	Total	10.68	11.24	11.63	10.13	8.87%	0.95
	Own contrib.	8.08	8.16	7.63	6.92	-5.58%	-0.45
	Imports	2.60	3.08	4.00	3.21	53.81%	1.40
	EU12	0.35	0.30	0.33	0.29	-3.39%	-0.01
	Mature	0.46	0.54	0.62	0.51	33.92%	0.16
	Emerging	0.06	0.11	0.12	0.11	96.90%	0.06
	BRIC	1.03	1.14	1.66	1.31	60.91%	0.63
	RoW	0.70	0.99	1.26	0.98	81.16%	0.56
EU12	Total	6.83	6.77	7.65	6.71	11.95%	0.82
	Own contrib.	5.92	5.31	5.46	4.99	-7.76%	-0.46
	Imports	0.91	1.46	2.19	1.72	139.93%	1.28
	EU15	0.23	0.36	0.55	0.46	145.09%	0.33
	Mature	0.06	0.10	0.20	0.17	226.41%	0.14
	Emerging	0.01	0.02	0.05	0.05	577.83%	0.05
	BRIC	0.50	0.74	0.91	0.69	83.52%	0.42
	RoW	0.12	0.24	0.47	0.35	290.82%	0.35
Mature	Total	15.71	17.02	17.47	15.40	11.20%	1.76
	Own contrib.	13.63	14.37	14.03	12.63	2.93%	0.40
	Imports	2.09	2.65	3.45	2.77	65.29%	1.36
	EU15	0.31	0.38	0.33	0.26	7.79%	0.02
	EU12	0.05	0.05	0.05	0.03	-12.06%	-0.01
	Emerging	0.13	0.19	0.18	0.16	42.19%	0.05
	BRIC	0.90	0.95	1.72	1.45	89.82%	0.81
	RoW	0.69	1.08	1.17	0.87	68.78%	0.48
Emerging	Total	2.05	2.38	2.92	2.70	42.23%	0.87
	Own contrib.	1.69	1.87	2.19	2.12	29.24%	0.49
	Imports	0.36	0.51	0.73	0.57	103.60%	0.37
	EU15	0.05	0.06	0.07	0.06	37.20%	0.02
	EU12	0.02	0.01	0.02	0.01	30.53%	0.00
	Mature	0.14	0.20	0.20	0.15	46.17%	0.06
	BRIC	0.10	0.13	0.25	0.21	159.50%	0.15
	RoW	0.06	0.12	0.19	0.13	215.48%	0.13
BRIC	Total	1.95	1.89	2.70	3.09	39.03%	0.76
	Own contrib.	1.86	1.77	2.49	2.87	33.84%	0.63
	Imports	0.08	0.12	0.21	0.22	154.19%	0.13
	EU15	0.02	0.02	0.03	0.03	85.63%	0.01
	EU12	0.01	0.00	0.01	0.01	-23.24%	0.00
	Mature	0.03	0.04	0.07	0.08	161.34%	0.04
	Emerging	0.00	0.00	0.01	0.01	242.37%	0.01
	RoW	0.03	0.05	0.10	0.11	223.06%	0.07

Notes: In per capita CO_2 consumption, metric tons.

Table A.2: Evolution of the Carbon Footprint from 1995 to 2007, decomposition

		EU15	EU12	Mature	Emerg	BRIC	RoW	Total
EU15		-0.45	-0.01	0.16	0.06	0.63	0.56	0.95
	ΔFD	1.65	0.25	0.21	0.04	0.94	0.52	3.61
	ΔVC	0.21	0.16	0.06	0.05	1.20	0.80	2.47
	ΔEE	-2.16	-0.42	-0.11	-0.02	-1.52	-0.76	-4.99
	ΔHH	-0.14						-0.14
EU12		0.33	-0.46	0.14	0.05	0.42	0.35	0.82
	ΔFD	0.41	5.89	0.13	0.03	0.95	0.35	7.76
	ΔVC	0.07	-0.82	0.04	0.02	0.25	0.21	-0.24
	ΔEE	-0.15	-5.47	-0.03	-0.01	-0.78	-0.21	-6.65
	ΔHH		-0.05					-0.05
Mature		0.02	-0.01	0.40	0.05	0.81	0.48	1.76
	ΔFD	0.09	0.02	2.34	0.03	0.95	0.29	3.73
	ΔVC	0.05	0.03	-0.25	0.08	1.54	0.93	2.38
	ΔEE	-0.12	-0.06	-2.23	-0.06	-1.68	-0.74	-4.89
	ΔHH			0.54				0.54
Emerg		0.02	0.00	0.06	0.49	0.15	0.13	0.87
	ΔFD	0.03	0.02	0.11	1.00	0.17	0.09	1.41
	ΔVC	0.01	0.02	0.00	0.21	0.20	0.13	0.56
	ΔEE	-0.02	-0.03	-0.04	-0.79	-0.21	-0.09	-1.18
	ΔHH				0.08			0.08
BRIC		0.01	0.00	0.04	0.01	0.63	0.07	0.76
	ΔFD	0.02	0.01	0.04	0.00	2.17	0.06	2.30
	ΔVC	0.00	0.00	0.01	0.00	0.31	0.05	0.37
	ΔEE	-0.01	-0.01	-0.01	0.00	-1.86	-0.05	-1.93
	ΔHH					0.01		0.01
RoW		0.02	0.00	0.01	0.01	0.15	0.03	0.14
	ΔFD	0.03	0.01	0.03	0.01	0.16	0.67	0.90
	ΔVC	0.02	0.01	0.00	0.01	0.21	0.49	0.75
	ΔEE	-0.04	-0.03	-0.02	0.00	-0.22	-1.20	-1.51
	ΔHH						0.08	0.08

Notes: In per capita CO_2 consumption, metric tons.
Footprint of regions in rows, origin in columns.
FD: Final Demand. VC: Value Chain. EE: Energy Efficiency. HH: Household consumption.

Table A.3: Evolution of the Carbon Footprint balances from 1995 to 2007

		EU15	EU12	Mature	Emerg	BRIC	RoW	Total
EU15	ΔEB	0.00	0.09	-0.11	-0.04	-0.53	-0.38	-0.96
	ΔX	0.11	0.08	0.05	0.02	0.10	0.19	0.55
	ΔI	0.11	-0.01	0.16	0.06	0.63	0.56	1.51
EU12	ΔEB	-0.27	0.00	-0.14	-0.01	-0.44	-0.23	-1.09
	ΔX	0.06	0.12	0.00	0.03	-0.02	0.12	0.30
	ΔI	0.33	0.12	0.14	0.05	0.42	0.35	1.40
Mature	ΔEB	0.07	0.03	0.00	0.00	-0.58	-0.36	-0.84
	ΔX	0.10	0.02	0.04	0.05	0.23	0.12	0.57
	ΔI	0.02	-0.01	0.04	0.05	0.81	0.48	1.40
Emerg	ΔEB	0.03	0.01	0.00	0.00	-0.12	-0.07	-0.15
	ΔX	0.05	0.01	0.06	0.01	0.03	0.06	0.22
	ΔI	0.02	0.00	0.06	0.01	0.15	0.13	0.38
BRIC	ΔEB	0.06	0.01	0.11	0.02	0.00	0.07	0.27
	ΔX	0.08	0.01	0.15	0.02	0.05	0.14	0.45
	ΔI	0.01	0.00	0.04	0.01	0.05	0.07	0.18
RoW	ΔEB	0.06	0.01	0.08	0.01	-0.08	0.00	0.08
	ΔX	0.07	0.01	0.09	0.02	0.08	0.00	0.27
	ΔI	0.02	0.00	0.01	0.01	0.15	0.00	0.19
Total	ΔEB	0.05	0.02	0.06	0.01	-0.11	-0.03	0.00
	ΔX	0.07	0.02	0.10	0.02	0.07	0.08	0.36
	ΔI	0.02	0.00	0.04	0.01	0.19	0.11	0.36

Notes: In per capita CO_2 consumption, metric tons.
Emission balance of regions in rows, origin in columns.
EB: Emission Balance. X: Emission Exports. I: Emission Imports

Table A.4: Evolution of the absolute emission balances from 1995 to 2007

		EU15	EU12	Mature	Emerg	BRIC	RoW	Total
EU15	ΔEB	0	31	-43	-14	-227	-154	-407
	ΔX	65	33	28	11	41	83	261
	ΔI	65	2	71	25	268	236	668
EU12	ΔEB	-31	0	-15	-2	-44	-25	-116
	ΔX	2	12	-1	3	-3	11	25
	ΔI	33	12	14	5	42	36	141
Mature	ΔEB	43	15	0	-2	-361	-206	-511
	ΔX	71	14	63	35	133	93	409
	ΔI	28	-1	63	37	494	299	920
Emerg	ΔEB	14	2	2	0	-55	-29	-66
	ΔX	25	5	37	2	15	29	113
	ΔI	11	3	35	2	71	58	180
BRIC	ΔEB	227	44	361	55	0	208	896
	ΔX	268	42	494	71	141	413	1428
	ΔI	41	-3	133	15	141	205	532
RoW	ΔEB	154	25	206	29	-208	0	205
	ΔX	236	36	299	58	205	0	834
	ΔI	83	11	93	29	413	0	629
Total	ΔEB	407	116	511	66	-896	-205	0
	ΔX	668	141	920	180	532	629	3070
	ΔI	261	25	409	113	1428	834	3070

Notes: In metric megatons.
Emission balance of regions in rows, origin in columns.
EB: Emission Balance. X: Emission Exports. I: Emission Imports

Project Information

Welfare, Wealth and Work for Europe

A European research consortium is working on the analytical foundations for a socio-ecological transition

Abstract

Europe needs change. The financial crisis has exposed long-neglected deficiencies in the present growth path, most visibly in the areas of unemployment and public debt. At the same time, Europe has to cope with new challenges, ranging from globalisation and demographic shifts to new technologies and ecological challenges. Under the title of Welfare, Wealth and Work for Europe – WWWforEurope – a European research consortium is laying the analytical foundation for a new development strategy that will enable a socio-ecological transition to high levels of employment, social inclusion, gender equity and environmental sustainability. The four-year research project within the 7th Framework Programme funded by the European Commission was launched in April 2012. The consortium brings together researchers from 34 scientific institutions in 12 European countries and is coordinated by the Austrian Institute of Economic Research (WIFO). The project coordinator is Karl Aiginger, director of WIFO.

For details on WWWforEurope see: www.foreurope.eu

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