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THE 'REST OF THE WORLD' – ESTIMATING THE ECONOMIC STRUCTURE OF MISSING REGIONS IN GLOBAL MULTI-REGIONAL INPUT–OUTPUT TABLES

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Incomplete data for the economic structure of numerous countries hamper the compilation of global multi-regional input–output (MRIO) tables. By themselves, most of these countries are of only limited importance for the global economy and incumbent environmental issues. Hence, in most recent global MRIO tables these countries are either roughly estimated or summarised in one rest of the world (RoW) region. Combining a wide range of countries, this RoW region may play a significant role in global economic and environmental accounts. We conceptualise the importance of RoW in several environmental footprint accounts and present algorithms to estimate the structure of RoW. The approach utilises the information of the economic structure within known parts of the MRIO table to estimate the unknown structure. Using this method, global warming potential and employment footprints remain stable irrespective of the chosen initial estimates, whereas natural land use footprints and individual product impacts vary significantly.

Keywords: Multi-regional input–output tables; Employment; Sensitivity analysis; Emissions embodied in bilateral trade

1. INTRODUCTION

Multi-regional input–output (MRIO) tables describe the global supply chain. They facilitate the tracing of goods and services from the producers to the consumers through different economic stages within and among different countries. Combined with environmental satellite accounts, MRIO tables form the basis of environmentally extended input–output analysis (EEIOA). Therewith, it is possible to attribute pollution and resource use through the whole supply chain to the final consumer and consequently calculate footprint accounts (Peters and Hertwich, 2006, 2008; Wiedmann, 2009).

MRIO tables are built by linking national IO (input–output) tables together into a consistent framework. For the major economies, such IO tables are regularly published by the national statistical agencies (EUROSTAT, 2013). For these countries, compiling the MRIO table breaks down to a problem of (dis)aggregation of products and industrial sectors between countries and satellite accounts (Lenzen, 2011) and balancing the trade between countries (Tukker et al., 2013).

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Countries for which national IO tables are not available or which are outside the focus of the specific EEIOA still need to be represented in an MRIO table to ensure that global supply chains are not cut off. In principle, two approaches exist to deal with lacking country-specific data in the compilation of a global MRIO table: (1) missing country data can be estimated individually by using proxy information from other sources, such as (supposedly) similar countries or (2) countries with poor data can be estimated as an aggregated rest of the world (RoW) region. Eora (Lenzen et al., 2013) and GTAP (Narayanan and Walmsley, 2008) roughly follow the former approach, whilst the latter approach was chosen in four of the other currently available global MRIO databases. Two of these MRIOs (WIOD and EXIOBASE) have a clear focus on European countries and major economies and include almost the same countries (see Section 2 for details).[1] Accordingly, the RoW in both databases possesses only a minor share of the global gross domestic product (GDP) (Streicher and Stehrer, 2012; Tukker et al., 2013). Nevertheless, many countries within the RoW (e.g. Nigeria, Saudi Arabia, and Venezuela) possess large amounts of natural resources and therefore provide an important source of agriculture and/or mining products. In addition, the RoW countries comprise over one-third of the world population, making the RoW countries an important contributor to the global labour force. Hence, when calculating consumption-based footprint accounts, neglecting the RoW could potentially significantly underestimate embodied impact (Xu and Dietzenbacher, 2011).

The importance of including the full international supply chain of goods and services has been studied previously. Andrew et al., (2009) looked at the implication of ignoring the RoW by using the domestic technology assumptions[2] to model the RoW. Whilst the most significant errors clearly occur through ignoring the contribution of imports followed by the use of the domestic technology assumption, they found that including the most important trade partners is of high importance, and that a world-average table provides a reasonable representation of import production. Xu and Dietzenbacher (2011) take this analysis further by concentrating specifically on the RoW in the WIOD database. They model a range of supply-chain cut-offs including ignoring imports; ignoring domestic RoW internal production; ignoring imports to the RoW region; and applying the models with known and average environmental impact coefficients. The authors find that serious bias can occur when unrepresentative countries are used to model the RoW. Further, the trade linkages between the RoW and other countries clearly show where it is important to model the RoW accurately.

During the compilation of a global MRIO the practitioner phases the problem of how to estimate the IO table of a region lacking information on economic structure as the RoW. Here we present an approach which utilises macro-economic information (GDP, industry output, and trade data) for the RoW region in combination with the economic structure given by the other countries in the MRIO model. The presented procedures assume that information about the economic structure for the non-RoW countries (in the form of supply/use tables, SUTs) is available or, in one example, at least expected coefficients are available. Further, imports and exports to/from the RoW are determined beforehand

[1] The two other available global MRIOs with one RoW region, the Asian International Input–Output Table (AIIOT, IDE-JETRO 2006) and the Global Resource Accounting Model (GRAM, Wiebe et al., 2012) focus on a different set of countries and were therefore omitted from the analysis.

[2] The domestic technology assumption models the production of imports assuming that the same technology is employed as that of the domestic economy (Wood and Dey, 2009).

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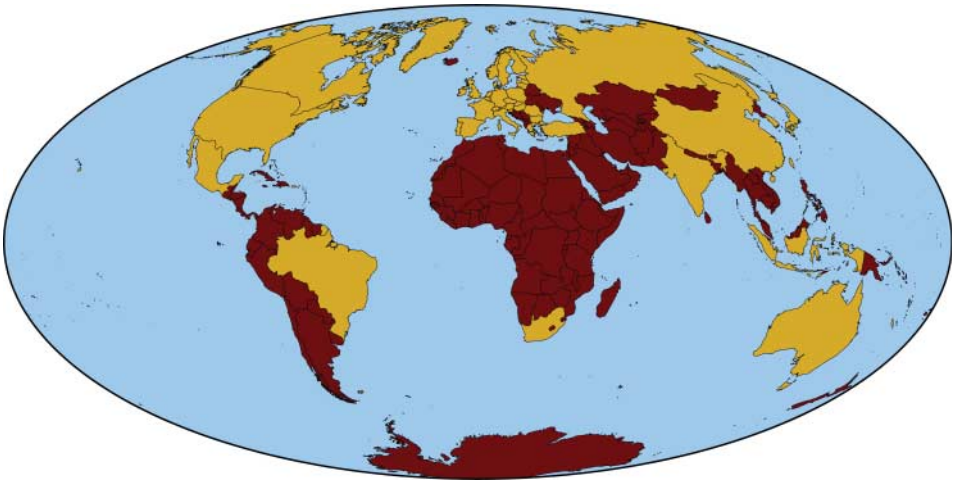
as well as the industry output and GDP of the RoW. Relaxation of this method is clearly possible, but for simplicity of analysing sensitivity of the process, we maintain this method throughout this paper. A crucial point for any global MRIO database with a policy focus is to estimate how assumptions made to estimate the unknown economic structures of a certain region influence the accounts of the countries with robust information. To address this issue we provide a sensitivity analysis of the presented method.

The main objective of the paper is to present a generalised approach to estimate the RoW and to investigate how the choice of assumption for the approach influences the environmental and social accounts for the RoW as well as the footprint results of other countries in the MRIO database. To highlight the importance of the RoW, Section 2 of this article provides background on the RoW definition in MRIO projects and presents environmental and social accounts of the RoW and its differences among MRIO projects. In Section 3 we describe the algorithm to estimate the economic structure of the RoW within an MRIO project. In Section 4 we analyse the sensitivity of the algorithm to different input parameters for the RoW accounts and its consequences for the accounts of the other countries within the MRIO. The article concludes with a discussion of the RoW and the presented algorithm.

2. THE ROW IN MRIO PROJECTS

Several global MRIO projects have been published so far (Wiedmann et al., 2011; Tukker and Dietzenbacher, 2013), of which four make use of an aggregated RoW region. The RoW regions in EXIOBASE and WIOD have comparable coverage due to the MRIO tables containing a similar country set. Two other global MRIO databases (Eora, OPEN:EU based on GTAP) are based on a far more extensive country set. Countries in Eora cover the

FIGURE 1. Available country data in EXIOBASE.



Note: Yellow: countries modelled explicitly in EXIOBASE; Dark colour: the RoW region.

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TABLE 1. Differences in the rest of world region in the EEMRIO models investigated.

Model	RoW region	Changes for analysis
EXIOBASE	1 RoW region World minus EXIOBASE countries	Used as provided
WIOD	1 RoW region World minus WIOD countries	Accounts for Norway, South Africa and Switzerland (based on EXIOBASE data) were subtracted for the RoW account
OPEN:EU	19 RoW regions World minus 94 explicitly modelled countries	Aggregated into one RoW region comparable to EXIOBASE

whole world and the RoW consists of only one sector which serves as a residual in balancing trade flows (statistical discrepancies) of all other countries (Lenzen et al., 2013). OPEN:EU/GTAP includes several minor RoW regions based on geographical location. We used the OPEN:EU/GTAP MRIO table to provide an additional comparison between the two principal approaches for the country coverage in global MRIO databases. For the sake of comparison we harmonised the RoW in all three projects investigated to a common classification (Figure 1, Table 1).

2.1. EXIOBASE

The EU-funded project EXIOPOL (A New Environmental Accounting Framework Using Externality Data and Input–Output Tools for Policy Analysis (Tukker et al., 2009, 2013)) aims to support analysis of technologies, policies, and standards in relation to EU sustainability policies. To cope with this environmental focus, the underlying SUTs have been disaggregated to provide higher detail for the agriculture, energy, mining, transport, and waste management sectors. This resulted in IO tables with 129 sectors and 694 environmental extensions for the base year 2000 which is now available as EXIOBASE. This database covers 27 EU countries as well as 16 non-EU countries[3] (Figure 1). These countries generate approximately 89% of the global GDP.

One RoW region summarises all other countries. The RoW SUT was estimated by taking each industry sector and choosing the coefficients of a country which was thought to be an adequate representation of the RoW for that specific sector. Subsequently, these coefficients have been multiplied with the estimated industry output (EXIOBASE, 2000) of the RoW. The resulting RoW SUT table was modified manually to, first, account for peculiarities of the RoW and, second, balance the SUT system (Tukker et al., 2009).

The level of detail in the extension provided by EXIOBASE cannot be found in any other global EEMRIO. In particular compared to the WIOD database, EXIOBASE provides a

[3] Australia (AU, abbreviations following ISO 3166-1), Austria (AT), Belgium (BE), Brazil (BR), Bulgaria (BG), Canada (CA), China (CN), Cyprus (CY), Czech Republic (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Greece (GR), Hungary (HU), India (IN), Indonesia (ID), Ireland (IE), Italy (IT), Japan (JP), Latvia (LV), Lithuania (LT), Luxembourg (LU), Malta (MT), Mexico (MX), Netherlands (NL), Norway (NO), Poland (PL), Portugal (PT), Romania (RO), Russia (RU), Slovakia (SK), Slovenia (SI), South Africa (ZA), South Korea (KR), Spain (ES), Sweden (SE), Switzerland (CH), Taiwan (TW), Turkey (TR), UK (GB), USA (US).

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consistent framework of social and environmental extension also for the RoW region. Due to the extensive detail found in EXIOBASE (especially concerning the unique employment accounts for the RoW region) this database is well suited as a reference point for analysing the global role of the RoW.

2.2. WIOD

WIOD (World Input–Output Database (Timmer et al., 2012)) provides a tool to analyse the effects of globalisation on trade patterns, environmental pressures and socio-economic development at a global level. WIOD consists of a time series (1995–2011) of IOT for 27 EU countries, 13 non-EU countries, and 1 RoW region. WIOD distinguishes 35 industries and 59 products.

The coefficients for the RoW in WIOD were obtained by assuming IO coefficients for an 'average developing country'. This was calculated by the weighted average share of Brazil, Russia, India, China, Indonesia, and Mexico. Macro-economic data (GDP by broad sectors and final demand) for the RoW were collected from the UN National Accounts by summing all countries not included in WIOD. The manufacturing sector was further disaggregated using industrial statistics from the United Nations Industrial Development Organization (UNIDO). Estimates of gross output for industry sectors were based on average ratios of gross output to value added calculated from developing economies (same as above) within WIOD. Finally, the domestic block of the RoW was balanced using the RAS algorithm. Imports and exports were derived from trade residuals of countries within WIOD.

The RoW in WIOD serves first and foremost analytical purposes in the sense that it provides the trade link for the other countries. WIOD includes environmental but not employment data for the RoW region.

EXIOBASE and WIOD use slightly different country classifications. Norway, South Africa, and Switzerland are described explicitly in EXIOBASE whereas they are included in the RoW in WIOD. In order to achieve comparable RoW results as presented in this paper, we subtracted the environmental accounts of Norway, South Africa, and Switzerland (based on the EXIOBASE data) from the RoW accounts of WIOD (Table 1).

2.3. OPEN:EU

The OPEN:EU model is an extended version of an MRIO model constructed from version 7 of the global database published by GTAP (Global Trade Analysis Project) for the year 2004 (Narayanan and Walmsley, 2008). GTAP does not publish a global MRIO database, but their database includes harmonised and balanced data, including domestic IO tables and bilateral trade data for all the regions included, from which an MRIO model can readily be constructed (Peters et al., 2011). The 113 regions include 94 countries that are specifically modelled, whereas the RoW is modelled as 19 composite regions. IO tables for the composite regions were constructed by assigning proxy countries to each of the countries included within it, and subsequently combining these proxy tables after weighting according to GDP shares (Dimaranan and Narayanan, 2008).

The GTAP7 database which forms the basis of the OPEN:EU model features a high level of regional detail. It contains specific data for 94 countries, including all 43 explicitly

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modelled countries in the EXIOBASE. The RoW in GTAP is modelled as an additional 19 composite regions rather than just one 'RoW' region. For the present analysis the results of the 70 GTAP regions (56 countries and 19 composite regions) not explicitly modelled in EXIOBASE were aggregated into a RoW account comparable to that of EXIOBASE.

2.4. The Importance of the RoW in the MRIO Projects

2.4.1. Comparison of Territorial RoW Accounts

Projects compiling MRIO tables differ in their methods to estimate the RoW region. Nevertheless, comparing the calculated territorial accounts (caused by the production within the country) for global warming potential (GWP) of greenhouse gases (GHG) (see Section 3.2) and natural land use among the three MRIO databases shows consistent results. Here we focus on EXIOBASE and WIOD because they have similar RoW definitions and in addition we include a third MRIO with a fundamentally different country set in the comparison (GTAP/OPEN:EU). The RoW in all three databases accounts for around 10% of the global value added (Table 2). The share of territorial GWP varies by only 4% points and the share of natural land use by 11% (Figure 2). This variation could partly be due to different estimates of the global values. The global GWP estimates are in EXIOBASE: 32.2 $GtCO_2$-eq; OPEN:EU 36.5Gt CO_2-eq and WIOD: 32.9 Gt CO_2-eq. For natural land use the global estimate shows a higher variation: EXIOBASE: 89.9 million km^2; OPEN:EU 38.9 million km^2 and WIOD: 58.7 million km^2 (Figure 2).

All three projects indicate that the share of the territorial GWP of the RoW on the world total GWP surpassed the RoW share of the global GDP. On the other side, the territorial GWP clearly lies below the share of the global population. The share of natural land use roughly equals the share of the global population.

The comparison is based on EXIOBASE and WIOD results for 2000 and OPEN:EU for 2004. Since WIOD offers a time series of MRIO we also calculated the impacts during 2004 for WIOD. This changed the relative shares for both accounts by less than 0.4% (Table 2).

In all three projects the RoW region turns out to be a major driver for climate change and natural land use with only minor differences between the projects.

TABLE 2. Comparison of RoW accounts (after adjusting to a common classification) in absolute terms and per cent of global total.

Model (base year)	Value added (Trillion Euro)	GWP (Gt CO_2 eq)	Land use (Million km^2)	Employment (1,000 person years)
EXIOBASE (2000)	3.26 (10%)	5.35 (17%)	35.7 (40%)	698,900 (36%)
WIOD (2000)	3.09 (9%)	6.45 (20%)	25.8 (44%)	n/a
WIOD (2004)	2.91 (9%)	7.25 (20%)	25.7 (44%)	n/a
OPEN:EU (2004)	2.80 (9%)	7.75 (21%)	12.9 (33%)	n/a

Note: n/a, data not available.

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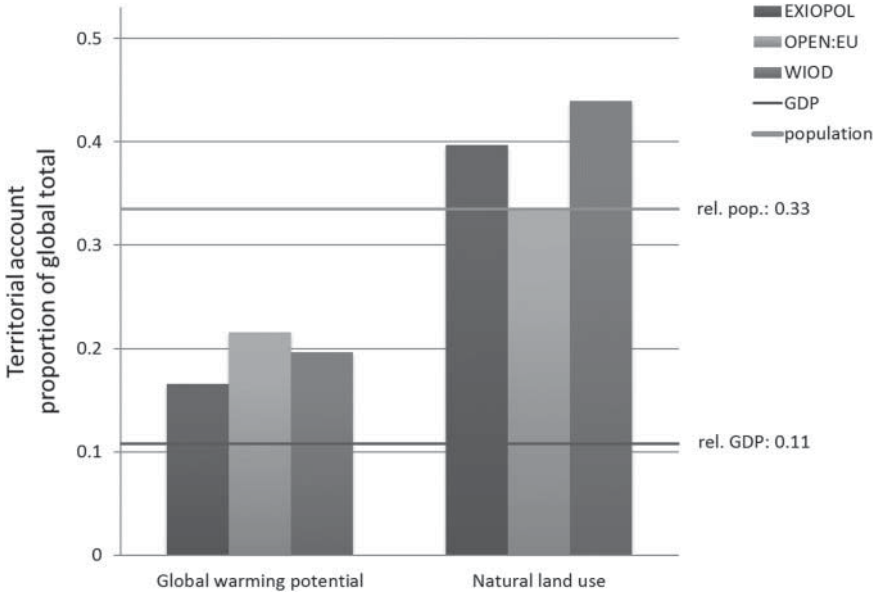
FIGURE 2. Comparison of territorial RoW shares of the global totals for GWP and natural land use among three recent MRIO projects.



Note: GWP: EXIOBASE: 0.17; OPEN:EU: 0.22; WIOD: 0.20; Natural land use: EXIOBASE: 0.40; OPEN:EU: 0.33; WIOD: 0.44.

2.4.2. The Importance of the RoW for other Countries' Footprints

The previous analysis demonstrates the importance of the RoW for GWP and land use in total global accounts. But how do these territorial accounts influence the accounts of other countries? Such an analysis requires shifting the focus from the territorial account to a more inclusive perspective which takes into account the impacts embodied in imported and exported products. This was done using the emissions embodied in the trade approach (EEBT, Peters 2008). Bilateral trade footprints in this approach are calculated as territorial (emission) accounts plus impacts embodied in imports minus impacts embodied in exports (see Supplemental Data section for methods of the complete algorithm). Accounting with the EEBT algorithm is the method of choice for calculating embodied emissions for the analysis of global trade flows (Peters and Hertwich, 2008). It is consistent with the bilateral agreements between countries and avoids double counting of emissions embodied in trade (Peters, 2008).

The EXIOBASE MRIO table is especially suited for such an analysis as it allows the comparison of environmental accounts (GWP and land use) embodied in products with the amount of embodied employment. From the total GWP embodied in imports globally, 14% are due to exports originating in the RoW (Figure 3). Only China is responsible for a greater part of embodied GWP (15%). Regarding natural land use, exports from the RoW dominate global embodied imports: 38% stem from the RoW, which is more than the sum of the three next biggest contributors (Russia: 14%; Canada: 10%; Australia: 9%). China, the RoW, and India exhibit the highest shares of global employment (for the territorial as well

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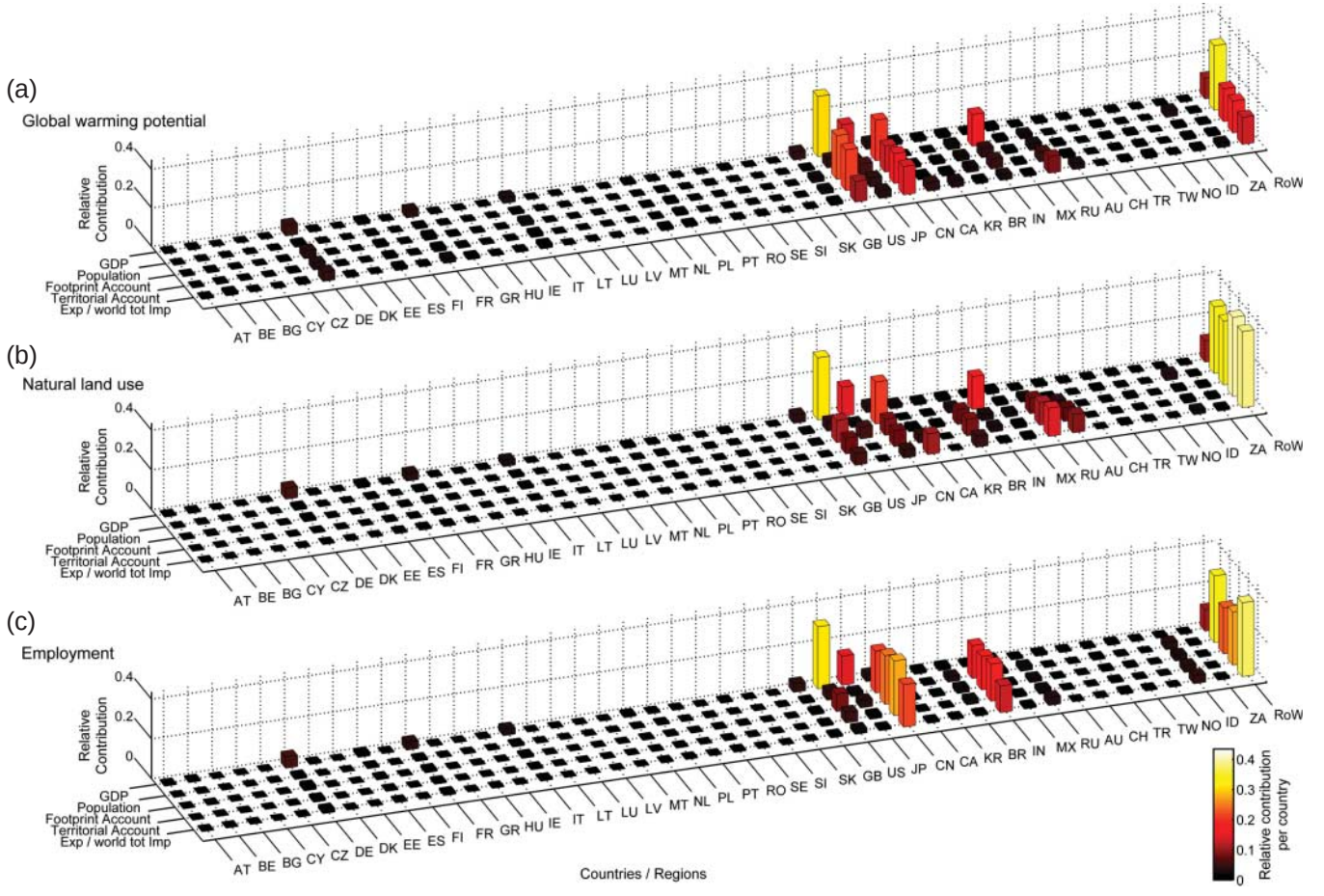
FIGURE 3. EXIOBASE results for two environmental accounts and employment, depicting GDP and population data as well as territorial and footprint accounts.



Notes: All values are shown as shares of the global total. The category 'Exp/world tot imp' indicates how much of the total global imports of the impact category is due to exports of the impact category from the specific country. (a) GWP. The biggest contributors to GWP footprint are the USA (US, 0.23), RoW (0.17) and China (CN, 0.13). Global totals: GDP: 33.93 trillion Euros; Population: 6057 million People: Footprint/Territorial Account: 32.2 Gt CO_2-Eq; (b) Natural land use. The RoW causes almost one-third of the global land transformation (0.32), followed by the USA (US, 0.11), China (CN, 0.08), and Russia (RU, 0.08). Global totals: Footprint/territorial Account: 89.9 million km^2; (c) Employment: China (CN, 0.25), RoW (0.23), and India (IN, 0.17) are the biggest contributors to the global total footprint. Global totals: Footprint/territorial account: 2.6 billion person-years.

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as footprint accounts), mirroring the situation for the shares of total population. Similar to natural land use, employment embodied in global imports is dominated by exports from the RoW (37%), followed by China (21%) and India (13%).

Based on the EXIOBASE MRIO table, the RoW region belongs to the group of countries/regions with the largest climate change and natural land use impacts and is an important contributor to the global labour force.

3. METHODOLOGY

The RoW in global MRIO databases such as WIOD and EXIOBASE accounts for a significant share of the global environmental impacts. Through extensive trade flows, especially for primary products, the economic structure in the RoW is of vital importance for determining the environmental and social footprint accounts in the other countries. However, a lack of economic data on the sectoral level for the RoW requires estimation of this economic structure through other means. Here we present a set of algorithms which allows us to estimate a consistent economic representation of a region lacking economic sector data (such as the RoW) for an MRIO database. This method requires that the economic structure of the other countries and regions included in the database is known.

Since an EEMRIO analysis essentially re-allocates primary (environmental) inputs to final demand categories, it is clear that the estimation of the environmental account will have the greatest impact on results. However, at low time cost, it is generally straightforward to obtain high-quality environmental accounts for the RoW by using information given in databases such as FAOSTAT and the IEA (which already have very good coverage of physical data for the world). Similarly, data for the employment accounts can be found in the database provided by the ILO: LABORSTA (UNdata 2013). As such, we excluded the impact of the estimate of territorial environmental and employment accounts throughout the model runs.

Macro-economic data for the RoW (GDP, industry output) can be obtained from international databases such as UN and the World Bank (The World Bank 2013; UNdata 2013), either by summing all countries assigned to the RoW or by subtracting the economies of the countries contained in the MRIO table from the estimated/given total global estimate. The same data sources give industry statistics in databases such as UNIDO, and value added and final demand statistics in the National Account data. The macroeconomic data serve as constraints for the balancing of the economic structure (see Equation 14).

There is already some literature available on the impact of utilising proxy country coefficients (including using the domestic technology assumption) for a single region (Andrew et al., 2009; Xu and Dietzenbacher, 2011) and they point to a range of data problems. In this paper, we focus exclusively on the most difficult part of the RoW estimate – how to model production technology in the RoW, and purposely exclude the impact of the environmental stressors in order to isolate the impact of applying different types of information on production technology in creating a balanced SUT system.

3.1. Estimation of RoW Based on Representative Countries

We estimated the RoW economy based on the economic structure of each available country SUT within EXIOBASE (for a flow chart overview of the algorithm see Figure S1, see

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Supplemental Data section). In order to do so, industry output $\boldsymbol{g}^{\mathrm{RoW}}$ has to be estimated. Various methods are available for this and are not the focus of this paper. Physical data, value added, and GDP, which are all available in global databases, can be used as proxies to estimate the total production.

Second, expected supply $\mathbf{C}^{\mathrm{RoW}}$ and use $\mathbf{B}^{\mathrm{RoW}}$ coefficients are constructed from a representative country k, such that for each industry j, $\mathbf{C}^{\mathrm{RoW}}_{m,j}$ and $\mathbf{B}^{\mathrm{RoW}}_{m+a,j}$ (with m products and a primary inputs) are estimated from country k's supply $\mathbf{V}^k$ and use $\mathbf{U}^k$ matrices (with industry output g_j) as:

$$\mathbf{C}^{\mathrm{RoW}}_{m,j} = \mathbf{V}^k_{m,j} * (\boldsymbol{g}^k_j)^{-1}, \tag{1}$$

$$\mathbf{B}^{\mathrm{RoW}}_{m+a,j} = \mathbf{U}^k_{m+a,j} * (\boldsymbol{g}^k_j)^{-1}. \tag{2}$$

Note that the same country k is used for each j for the supply and use tables. As such, co-production by industries as shown in the supply matrix is also reflected in the inputs into each industry of the use matrix.

RoW supply and use matrices are then constructed as:

$$\mathbf{V}^{\mathrm{RoW}}_{m,j} = \mathbf{C}^{\mathrm{RoW}}_{m,j} * (\boldsymbol{g}^{\mathrm{RoW}}_j), \tag{3}$$

$$\mathbf{U}^{\mathrm{RoW}}_{m+a,j} = \mathbf{B}^{\mathrm{RoW}}_{m+a,j} * (\boldsymbol{g}^{\mathrm{RoW}}_j). \tag{4}$$

Important constraints for the RoW estimates are the imports and exports from the non-RoW. In this procedure these values are fixed and the RoW economy must provide possibilities to supply the exports and use the imports.[4] Not all representative countries provide this economic structure (e.g. paddy rice production is absent in northern countries, so technical coefficients are zero). In such cases, we used weighted global average coefficients for the particular industry.

Domestic product output $\boldsymbol{q}^{\mathrm{D,RoW}}_m$ can then be calculated as the sum of the estimated supply matrix:

$$\boldsymbol{q}^{\mathrm{D,RoW}}_m = \sum_j \mathbf{V}^{\mathrm{RoW}}_{m,j}. \tag{5}$$

Final demand still needs to be estimated at this stage. In order to do this, an indication of total product supply $\boldsymbol{q}^{\mathrm{RoW}}$ is desired. $\boldsymbol{q}^{\mathrm{RoW}}$ is the sum of domestic products $\boldsymbol{q}^{\mathrm{D,RoW}}$ and imported products $\boldsymbol{q}^{\mathrm{M,RoW}}$.

$$\boldsymbol{q}^{\mathrm{RoW}} = \boldsymbol{q}^{\mathrm{D,RoW}} + \boldsymbol{q}^{\mathrm{M,RoW}}. \tag{6}$$

An estimate of $\boldsymbol{q}^{\mathrm{M,RoW}}$ would be available harmonised international trade data (Tukker et al., 2013).

Various alternatives exist to estimate final demand $\mathbf{Y}^{\mathrm{RoW}}_{m,b}$ based on information on final demand category totals $\boldsymbol{y}^k_b$ for b categories of domestic final demand.

[4] Most MRIO databases estimate trade for the RoW region exogenously in order to keep computational time manageable. An exception is Eora (Lenzen et al., 2013), which builds trade-linking and subsequent SUT balancing into a single balancing algorithm.

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3.1.1. *Final Demand Based on Sales Coefficients (fd sales)*

This approach takes the commodity flow method and applies it solely to final demand. Sales structures, similar to input structures, are obtained from representative countries. In a single step process, sales structures of representative countries are computed and multiplied by estimated product output for the RoW.

$$\mathbf{Y}_{m,b}^{\mathrm{RoW}} = ((\boldsymbol{q}_m^k)^{-1} * \mathbf{Y}_{m,b}^k) * \boldsymbol{q}_m^{\mathrm{RoW}}. \tag{7}$$

3.1.2. *Final Demand Based on Column Coefficients with Estimated Final Demand (fd expected)*

Another possibility is to use column coefficients and shares between the final demand categories to disaggregate the expected overall final demand of the RoW. To do so, first the column coefficients for the final demand block $\mathbf{B}_{m,b}^{\mathrm{Y},k}$ as well as the shares between the final demand categories based on final totals $\boldsymbol{y}_{b\neq\mathrm{exp}}^k = \sum_m \mathbf{Y}_{m,b\neq\mathrm{exp}}^k$ have to be calculated for the representative country excluding the exports.

$$\mathbf{B}_{m,b}^{\mathrm{Y},k} = \mathbf{Y}_{m,b}^k * (\boldsymbol{y}_b^k)^{-1}. \tag{8}$$

In a second step expected final demand $\boldsymbol{y}_{b\neq\mathrm{exp}}^{\mathrm{RoW}}$ per category has to be estimated based on macro-economic data for $\mathrm{gdp}^{\mathrm{RoW}}$, imports $\mathrm{imp}^{\mathrm{RoW}}$ and exports $\mathrm{exp}^{\mathrm{RoW}}$ totals and split into products.

$$\boldsymbol{y}_{b\neq\mathrm{exp}}^{\mathrm{RoW}} = (\mathrm{gdp}^{\mathrm{RoW}} + \mathrm{imp}^{\mathrm{RoW}} - \mathrm{exp}^{\mathrm{RoW}}) * \frac{\boldsymbol{y}_{b\neq\mathrm{exp}}^k}{\sum_b \boldsymbol{y}_{b\neq\mathrm{exp}}^k}, \tag{9}$$

$$\mathbf{Y}_{m,b\neq\mathrm{exp}}^{\mathrm{RoW}} = \boldsymbol{y}_{b\neq\mathrm{exp}}^{\mathrm{RoW}} * \mathbf{B}_{m,b\neq\mathrm{exp}}^{\mathrm{Y},k}. \tag{10}$$

3.1.3. *Final Demand Based on Generic Input Coefficients and Final Demand Based on National Accounts (fd SNA ideal)*

A variant of the approach described above works without the expected final demand and instead uses data from the official national accounts (UNdata, 2013). First the GDP in US$ of all RoW countries is collected from The World Bank (The World Bank, 2013). The sum of these GDPs (3.03 trillion US$) does not sum up to the expected GDP of the RoW (EXIOBASE, 2000) (3.27 trillion US$) which is given by the global GDP minus the GDP of the countries explicitly modelled in the EXIOBASE. To correct for this we scale all entries equally by 1.078 to reach the expected value. In a second step, final demand for each available RoW country is collected from the UNdata – Table 1.1 (Gross domestic product by expenditures at current prices) – and converted to US$ based on the previously estimated GDP (UNdata, 2013). The final demand is then scaled to the expected GDP of the RoW. Obvious inconsistencies (disaggregated values which did not sum up to the aggregate) have been deleted. The final demand per category is then split into products based on ideal/generic coefficients.

$$\mathbf{Y}_{m,b}^{\mathrm{RoW}} = \boldsymbol{y}_b^{\mathrm{RoW_UN}} * \mathbf{B}_{m,b}^{\mathrm{Y,RoW_generic}}. \tag{11}$$

3.1.4. *Final Demand Based on Representative Country Input Coefficients and Final Demand Based on National Accounts (fd SNA repr)*

This method resembles the previous one but uses input coefficients from a representative country to split the final demand categories into products.

$$\mathbf{Y}_{m,b}^{\mathrm{RoW}} = \boldsymbol{y}_b^{\mathrm{RoW_UN}} * \mathbf{B}_{m,b}^{\mathrm{Y},k}. \tag{12}$$

None of the methods used to estimate the final demand can be expected to give reasonable estimates on exports. Instead, these are given explicitly by the trade data (as per imports above).

$$\mathbf{Y}_{m,\mathrm{exp}}^{\mathrm{RoW}} = \mathbf{exp}_m^{\mathrm{RoW}}. \tag{13}$$

This method calculates a full supply/use system. However, it is almost certain that this system is unbalanced due to differing country data used in the different industries and the various methods used to estimate final demand.

One option to reconcile this difference is to fix row and column sums, and to RAS balance any difference. This has the following two disadvantages: (1) it puts a high certainty on very uncertain industries and product outputs relative to the technical coefficients and, more practically, (2) it allows for variation in the import and export data.

An alternate approach is to use a flexible mathematical programming approach where information gain is minimised, subject to (1) balancing constraints (GDP); (2) import data $\boldsymbol{q}^{\mathrm{M,RoW}}$; and (3) export data $\mathbf{EXP}^{\mathrm{RoW}}$. To do so a final estimate of the supply/use system $\mathbf{Z}_{m,j,t}$ ($\mathbf{Z}_{m,j,1} = \mathbf{V}_{m,j}^{\mathrm{RoW}}$; $\mathbf{Z}_{m,\mathrm{imp},1} = \boldsymbol{q}^{\mathrm{M,RoW}}$; $\mathbf{Z}_{m+a,j,2} = \mathbf{U}_{m+a,j}^{\mathrm{RoW}}$; $\mathbf{Z}_{m,b,2} = \mathbf{Y}_{m,b}^{\mathrm{RoW}}$; $\mathbf{Z}_{m,\mathrm{exp},2} = \mathbf{exp}_m^{\mathrm{RoW}}$) is created from minimising differences (the objective value $o(\mathbf{Z}, \mathbf{Z}^0)$) from the initial estimate of the supply/use system $\mathbf{Z}_{m,j,t}^0$

$$o(\mathbf{Z}, \mathbf{Z}^0) = \sum_{m,j,t} \mathbf{W}_{m,j,t} * (\mathbf{Z}_{m,j,t} - \mathbf{Z}_{m,j,t}^0)^2. \tag{14}$$

A QP target function was chosen to minimise $o(\mathbf{Z}, \mathbf{Z}^0)$. This deals with conflicting information from a variety of data sources (Robinson et al., 2001) and allows flexibility in estimation of inter-regional trade accounts (Canning and Wang, 2005) as well as reconciliation of large databases (Müller et al., 2009; Wood 2011). Weights $\mathbf{W}_{m,j,t}$ for the weighted sums of least squares (Morrison and Thumann, 1980) were defined as:

$$\mathbf{W}_{m,j,t} = \begin{cases} \frac{1}{|\mathbf{Z}_{i,j,t}^0|} & \text{if } |\mathbf{Z}_{i,j,t}^0| > 0.001, \\ 1{,}000 & \text{if } |\mathbf{Z}_{i,j,t}^0| \leq 0.001. \end{cases} \tag{15}$$

Total GDP of the RoW ($\mathrm{gdp}^{\mathrm{RoW}}$), exports $\mathbf{Z}_{m,\mathrm{exp},2}$ as well as total imports $\mathbf{Z}_{m,\mathrm{imp},1}$ were set as constraints.

At this stage a fully balanced supply/use system is available, but in the use table, no distinction is made between imported and domestically produced products. In order for this to happen, a ratio of imported goods to total goods is constructed, assuming, without further knowledge, that all industries consume the same proportion of imported to domestically

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produced products.

$$\boldsymbol{q}^{\text{Ratio}} = \frac{\boldsymbol{q}^{\text{M,RoW}}}{\boldsymbol{q}^{\text{RoW}}}. \tag{16}$$

And applied to the use matrix to construct the import use matrix $\mathbf{U}_{m,j}^{\text{M,RoW}}$:

$$\mathbf{U}_{m,j}^{\text{M,RoW}} = \widehat{\boldsymbol{q}^{\text{Ratio}}} * \mathbf{U}_{m,j}^{\text{RoW}}. \tag{17}$$

And the domestic use matrix $\boldsymbol{U}_{m,j}^{\text{D,RoW}}$

$$\mathbf{U}_{m,j}^{\text{D,RoW}} = \widehat{(1 - \boldsymbol{q}^{\text{Ratio}})} * \mathbf{U}_{m,j}^{\text{RoW}}. \tag{18}$$

This now gives a full supply/use system with the use of imports distinguished from domestically produced products. Various methods exist to convert SUTs into an IO framework. We use the industry technology assumption (EUROSTAT, 2008). Here a symmetric IO table **T** and extensions **F** of the product by product IO table are (where **K** are the accounts in industry classification):

$$\mathbf{T} = \mathbf{U} * \hat{\boldsymbol{g}}^{-1} * \mathbf{V}, \tag{19}$$

$$\mathbf{F} = \mathbf{K} * \hat{\boldsymbol{g}}^{-1} * \mathbf{V}. \tag{20}$$

Input coefficient matrices (monetary **A** and extensions **S**) can be derived from these by dividing the columns by the total domestic output of products.

$$\mathbf{A} = \mathbf{T} * \widehat{\boldsymbol{q}^{\text{D}}}^{-1}, \tag{21}$$

$$\mathbf{S} = \mathbf{F} * \widehat{\boldsymbol{q}^{\text{D}}}^{-1}. \tag{22}$$

The presented approach can be extended to use a representative country specific to every industry sector of the RoW ('blueprint country approach (blue)'). For that, we use the classification which was also used in EXIOPOL (Table S1 a,b, see Supplemental Data section). Further, a set of 'generic coefficients' is used based on various data sources including country-specific SUTs, life-cycle data, and other engineering data (Wood et al., 2010). We constructed two versions of 'generic coefficients', one based on disaggregated country data (exio1), the other also incorporating life-cycle data (exio2).

3.2. Environmental and Employment Accounts

We investigate two major environmental accounts as readily available in EXIOBASE: GWP and natural land use. GWP of GHG is calculated by converting the amount of CO_2, CH_4, and N_2O pollution into CO_2 equivalents (multiplication factors of 1, 25, and 298, respectively) and summing for each country (EXIOBASE, 2000). This gives the amount of GHG emissions in kg CO_2 equivalents. Natural land use is the combined area used for crops, pastures, and forests (EXIOBASE, 2000) and measured in m^2.

In addition, we analyse the employment per country and product. For that, we use labour data (in terms of 1,000 person years) from the ILO/LABORSTA (UNdata, 2013) database and disaggregate the data into EXIOBASE classification (EXIOBASE, 2000; Wood et al., forthcoming).

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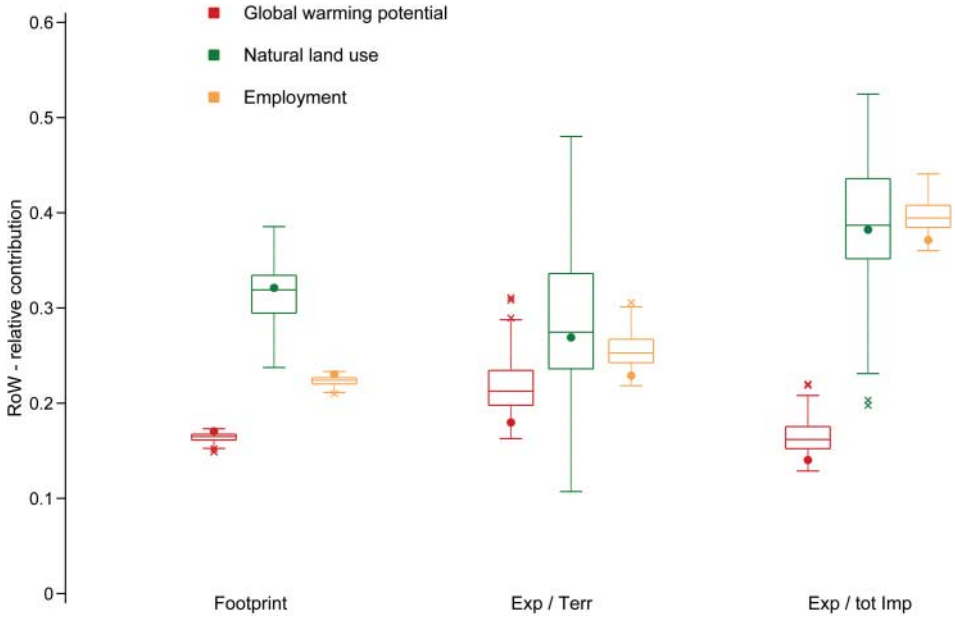
FIGURE 4. Relative changes of various parameters based on multiple representative countries and final demand calculations for the RoW.



Notes: Footprint: Estimates of the RoW accounts (in relation to the global total). Exp/Terr: Share of total territorial account which gets exported. Exp/tot Imp: Share of total global imported account which is due to exports from the RoW. Circle: EXIOBASE original results.

3.3. Statistics

In the depicted box-plots (Figures 4–8), the top and bottom of the boxes correspond to the 25th and 75th percentiles of the underlying data. The central line indicates the median, the drawn whiskers span over all data points except outliers, defined as data points outside the upper/lower quartile plus/minus 1.5 times the inter-quartile range. Circles in some of the box-plots indicate original EXIOBASE values.

4. RESULTS

The method presented for estimating the economic structure of the RoW relies on the availability of a representative country data set. Here we analyse how sensitive final results are to the choice of one particular representative country.

In total we calculated 186 different RoW tables based on all countries available in EXIOBASE combined with various methods to estimate the final demand. In addition we tested several alternative approaches for obtaining an initial estimate of economic structure of the RoW. Appendix Table A1 (see Supplemental Data section) lists all used approaches.

For all model runs the industrial output, GDP, and import/exports were fixed, while the rest of the values were subject to the balancing routine.

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Recalculating the RoW based on the different representation methods caused the RoW share of the global GWP footprint to vary from 0.14 to 0.17 (Figure 4). In contrast, the proportion of exported GWP in relation to the territorial GWP ranged from 0.16 to 0.31. The share of the world's total GWP embodied in imports which are due to exports from the RoW varied from 0.12 to 0.22. The original EXIOBASE results lay well within that range (0.17, 0.18, and 0.14, respectively). Outliers in the plots are due to model runs with Switzerland and Sweden as representative countries (all with final demand estimates based on input coefficients).

For natural land use (Figure 4), the different model runs caused higher variation. The proportion of the natural land use footprint varied from 0.23 to 0.38. The exported share of total territorial stressors ranged from 0.11 to 0.48 and the share of the RoW exports on the global imported natural land use varied from 0.20 to 0.52. Again, original EXIOBASE results lay well within that range (0.32, 0.27 and 0.41, respectively). The blueprint country approach with final demand calculations based on input coefficients produced the two single outliers.

Employment footprint (Figure 4) results varied from 0.21 to 0.23 (original EXIOBASE value: 0.23). As for the other two accounts, the variation of exported account to the total territorial showed a higher variation (0.22 to 0.31, original EXIOBASE value: 0.23). The share of global employment embodied in imports which are due to exports from the RoW varied from 0.36 to 0.44 (original EXIOBASE value: 0.37). Outliers were due to model runs based on Switzerland (with final demand estimates based on input coefficients: fd expected and fd SNA repr).

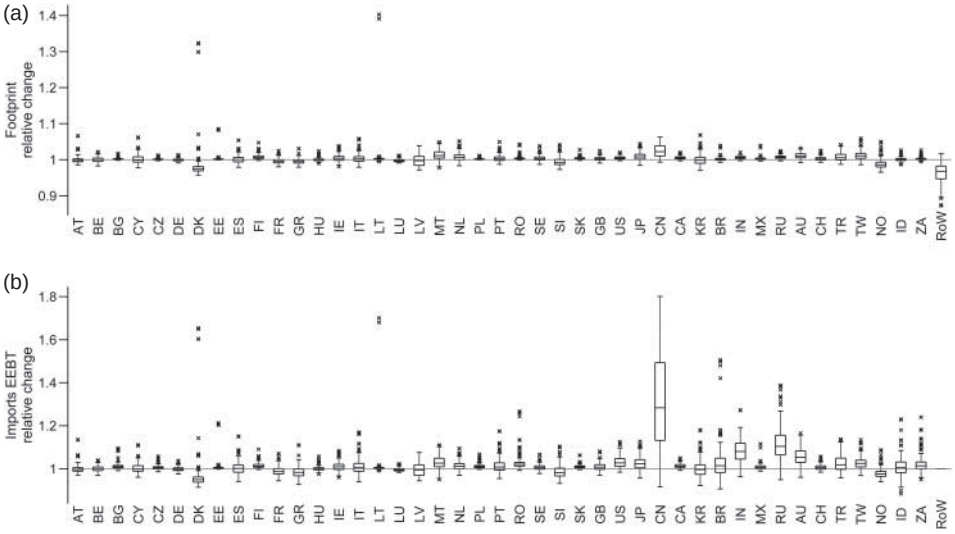
Using different representative countries to estimate the RoW economy resulted in comparable GWP and employment footprints for the RoW but highly affected the natural land use footprint.

How does the choice of one particular representative country alter the EXIOBASE results for all countries? To analyse that, we compared the outcome of each model run for all EXIOBASE countries as well as for the RoW region to the original EXIOBASE results (EXIOBASE, 2000).

For non-RoW countries the GWP footprint stayed mostly within a ±5% range around the original results (Figure 5(a)). Most of the outliers were produced by RoW estimates based on Luxembourg, Switzerland, and Sweden (Appendix Table A2, see Supplemental Data section). Some representative countries produced footprint results quite similar (within 1%) to the original EXIOBASE results: choosing Portugal as representative country (with a final demand estimate based on sales coefficients) matched the original EXIOBASE footprint in 41 of 44 cases (Appendix Table A3, see Supplemental Data section). Only the blueprint country approach, on which the EXIOBASE results were originally based, performed equally well. The amount of imported stressors resembles the footprint except for some significant changes for China, India, Russia, and Australia (Figure 5(b)).

Regarding natural land use the changes were in general much higher than for GWP (Figure 6(a) and 6(b)). Footprint calculations for the RoW estimate based on the Netherlands as the representative country produced most of the outliers (Appendix Table A4, see Supplemental Data section). None of the model approaches matched the original EXIOBASE results as often as for the GWP footprint (Appendix Table A5, see Supplemental Data section). Most frequently Indonesia, with final demand estimates based on sales coefficients, gave footprints similar to the original results. Again, a good match

FIGURE 5. Variation of GWP country footprints (based on the EEBT method) for different estimates of the RoW compared to the EXIOBASE original results.



Notes: Grey line: EXIOBASE original results. (a) Deviation of the estimated footprint and (b) deviation of the GWP embodied in imports.

could also be obtained based on the 'blueprint country' approach, but this time with a final demand estimate based on macro-economic data from international databases.

Variation of employment footprints for non-RoW countries due to different RoW estimates stayed mostly within ±10% (Figure 7(a)). Only Luxembourg appeared to be highly influenced by the RoW estimates. Luxembourg also produced the majority of outliers (20%) followed by Switzerland and Malta (both 10%, Appendix Table A6, see Supplemental Data section). Results similar to the original EXIOBASE were obtained most often by the 'blueprint country' approach based on sales coefficient (39 of 44 cases, Appendix Table A7, see Supplemental Data section). In general, the fraction of employment embodied in imports for each country varied more than the actual footprint (Figure 7(b)).

Except for some outliers, estimating the RoW based on representative countries had only a minor effect on the GWP footprint of the other countries. However, natural land use and in some cases employment footprints were much more sensitive to the underlying RoW estimates.

Multipliers for the environmental impact of specific products varied substantially (Table S2, see Supplemental Data section). Regarding GWP, the highest variation occurred in the waste sector (Collection and treatment services of sewage, incineration of waste . . .), energy sector (nuclear fuel, electricity by wind . . .), and some agriculture products (paddy rice, cattle). Besides the high variation in the waste sector, the amount of natural land use variation resembled the variation of GWP. Employment multipliers varied the most for electricity and agriculture products as well as for the recycling and service sectors.

Over 50% of the RoW exports in monetary terms are based on 10 products (Table S2, see Supplemental Data section). Major changes in the embodied environmental impacts of

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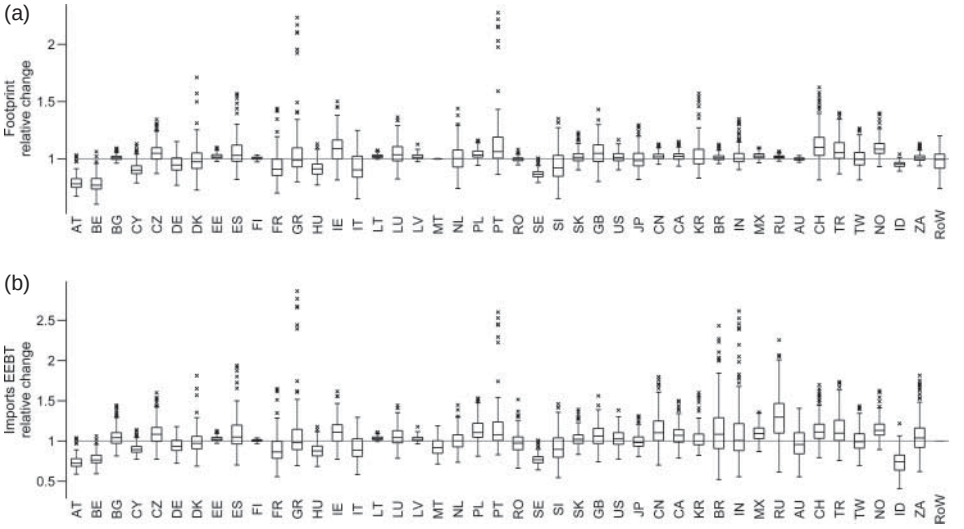
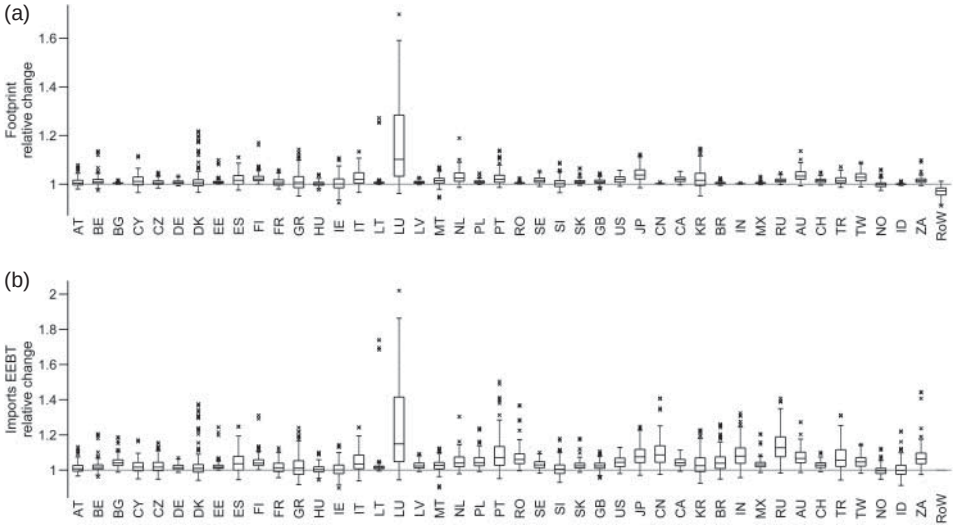
FIGURE 6. Variation of natural land use country footprints (based on the EEBT method) for different estimates of the RoW compared to the EXIOBASE original results.



Notes: Grey line: EXIOBASE original results. (a) Deviation of the estimated footprint and (b) deviation of the natural land use embodied in imports.

FIGURE 7. Variation of employment footprints (based on the EEBT method) for different estimates of the RoW compared to the EXIOBASE original results.



Note: Grey line: EXIOBASE original results. (a) Deviation of the estimated footprint and (b) deviation of the employment embodied in imports.

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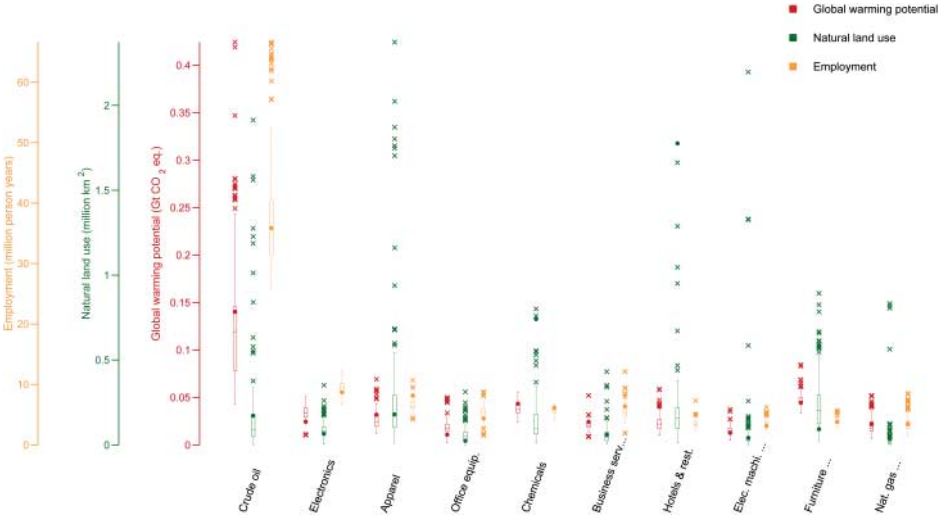
FIGURE 8. GWP, natural land use and employment embodied in the exports of RoW products.



Notes: Ten most exported products in monetary terms: Crude oil: crude petroleum and services related to crude oil extraction, excluding surveying; Electronics: Radio, television and communication equipment and apparatus; Apparel: Wearing apparel; furs; Office equip.: Office machinery and computers; Chemicals: Chemicals, chemical products and man-made fibres; Business serv.: Other business services; Hotels & rest.: Hotel and restaurant services; Elec. machi.: Electrical machinery and apparatus n.e.c.; Furniture: Furniture; other manufactured goods n.e.c.; Nat. gas: Natural gas and services related to natural gas extraction, excluding surveying). Circles: EXIOBASE original results.

these products (Figure 8) occurred especially for the most exported product of the RoW: 'Crude petroleum and services related to crude oil extraction, excluding surveying'. For the other products, variation in natural land use impact was generally higher than for GWP. Changes in the employment embodied in exports generally mirrored the variation for GWP.

Choosing a specific representative country gave an initial estimate for the SUT structure of the RoW. These were then subject to the optimisation routine which balanced the SUT given various external constraints. Depending on the representative country chosen for the initial estimates the degree of change needed to balance the system varied. The objective value measures the amount of this change (see methods). The representative countries with the lowest amount of change were Austria, Mexico, and Poland. However, simply adding all available representative countries for the initial estimate outperformed all single representative country model runs (see for a summary Appendix Table A7, see Supplemental Data section; all results are given in Table S3, see Supplemental Data section). The 10 model runs with the lowest objective value are characterised by using a final demand estimation based on sales coefficients. On the other side of the scale, initial RoW estimates based on Estonia and Italy required the highest amount of change to balance the SUT, irrespective of the final demand estimate used.

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5. DISCUSSION

Two recently published global MRIO databases, WIOD and EXIOBASE (EXIOPOL), focus on European countries and major global economies. In both databases, one RoW summarises all other countries. Due to the common country focus the RoW is comparable between these databases: it exhibits only a minor share of the global GDP (around 10%), but comprises over one-third of the world population. The RoW in both databases includes several countries which play an important role in providing primary products for the world economy (e.g. most of the Middle Eastern countries). Accordingly, based on an emissions/accounts embodied in trade analysis for EXIOBASE, a majority of natural land use and employment in traded products originate from the RoW region. For greenhouse gas emissions (measured in GWP) only products exported from China surpasses the RoW in terms of embodied emissions.

All attempts to assemble an MRIO table representing the global economy face the problem of data shortage. This holds especially for the RoW regions and projects differ in their method to handle this problem. Nevertheless, comparing the estimated territorial accounts for GWP and natural land use among the two databases shows consistent results. In addition, also the OPEN:EU/GTAP database estimates qualitatively similar accounts for the regions corresponding to the RoW in EXIOBASE/WIOD. All databases estimate that the share of territorial impacts of the RoW exceeds the share of the RoW on the global GDP. Comparing the results of EXIOBASE (base year 2000) and the GTAP-based OPEN:EU (base year 2004) as well as WIOD for 2000 and 2004 showed that for both indicators the relative importance of the RoW did not change.

In this paper, we presented a set of algorithms which use available macroeconomic data such as GDP and industry output as well as trade data to derive a coherent RoW representation within a given MRIO framework. The method requires an initial estimate of the economic and final demand structure of the RoW which can be obtained by choosing one 'representative' country from the available countries in the MRIO. In order to test the sensitivity of the method to different initial estimates/representative countries we (re)calculated GWP, natural land use, and employment accounts based on the new method. We chose the EXIOBASE system as background since only this global MRIO makes use of one RoW region and also provides employment data for the RoW.

The sensitivity analysis showed that the GWP and employment footprint of the RoW varied only marginally, independent of the chosen representative country. Greater differences occurred for the natural land use footprint. For all accounts, the change in the proportion of exported stressor to territorial account exceeded the variation of the footprint account. The greater variation of the natural land use accounts compared to the two other accounts can be explained by the more restricted sector set which contributes to the total land use. Thus, whereas GWP (as a consequence of energy use) and employment accounts are influenced by all sectors, the natural land use is mainly determined by the efficiency of the agriculture sectors. Countries vary in their specialisation of exporting certain product groups. The variations in the relative exports (thus comparing the share of exports to the total territorial account) reflect these different degrees of specialisation. Not surprisingly, we again found the highest variation for natural land use, as the source of variation is mainly restricted to agriculture products.

Due to the variation of the RoW exports, the footprint of the other countries also varied depending on the chosen approach. For GWP, choosing different 'representative' countries

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only had a minor effect on the footprint of the other countries. In particular, the footprint of the biggest contributor to the global GWP, the USA, stayed within close range (±2%). In contrast, the footprint of the next biggest single country contributor, China, showed a higher variation (−1% to +7%), caused by the high variability in the import accounts of the footprint. This reflects the needs of the growing Chinese economy on imports from RoW countries.

In general, natural land use footprints varied more than GWP footprints. Nevertheless, the largest contributors to the natural land use footprint besides the RoW (USA, China, Russia, and Brazil) showed small variations despite the high input variation of the footprint for some of those countries. In particular, Brazil and Russia exhibited the highest range of imported natural land use footprint of all countries (disregarding some outliers). However, the natural land use footprint of these countries remained relatively stable due to the large contribution of the domestic production to the natural land use footprint in addition to the high amount of exported land use, an effect also observed for China and India in the employment analysis. It is also clear that supply chains of traded goods that have a more disparate structure will have a greater impact on results. For GWP, electricity generally had the highest GHG intensity, but relatively low direct trade, whilst for land use, agricultural products had large direct land impacts, and were also directly traded in high proportions. Thus the variation found in the RoW per se combined with the variation due to the more direct trade of agriculture products.

When considering the footprints estimates of all countries, some representative countries gave estimates quite similar to the original EXIOBASE estimates (Indonesia, Mexico, Portugal, 'sum of all countries', 'blueprint country') whereas Luxembourg, Switzerland, Sweden, the Netherlands, and Taiwan led to the highest deviations. This may be due to the high development level of the latter countries and their lack of natural resources. In addition, the final demand structure in these countries differs significantly from most countries included in the RoW.

The multiplier factors for environmental impact per product were highly sensitive to the chosen 'representative' country. The highest variation occurred mainly in products with a minor share of the total exports of the RoW. Focusing on the most exported products, impacts embodied in the trade of crude petroleum showed the highest variation. In general the amount of embodied natural land use varied more than for GWP and employment, reflecting the variation found for the country accounts. Regarding the variation for specific products, the lowest variation was found for products with dispersed supply chains. The variations in the requirements for producing electronics or office equipment were quite similar across countries, which led to smaller variation observed here. In contrast, the efficiency for mining crude oil could vary significantly. For most of the products and impacts, the original EXIOBASE results lay well within the model results with the exception of 'Chemicals, chemical products and man-made fibres' and 'Hotel and restaurant services' where almost all model runs led to embodied impacts lower than the original results.

The major obstacle for assessing the quality of estimated SUT for the RoW is the lack of a reference table. So far, we compared the models estimates with estimates obtained with the original EXIOBASE procedure. Alternatively, the objective value measures how much the initial given economic structure has to be modified by the balancing routine in order to meet the required constraints (given implicitly by the supply/use system and externally by the macroeconomic data).

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Ranking the RoW estimates based on this measure (a summary is given in Appendix Table A8, see Supplemental Data section; all results are given in Table S3, see Supplemental Data section) showed that the scaled average of all available countries in EXIOBASE needed the least amount of change. In this sense it can be considered the best guess for the economic structure of the RoW. This may be due to the good representation of the world economy within EXIBOASE which includes the main producers of agricultural products (Brazil, India, Russia) as well as countries with large mining sectors (Australia, China, Russia). Surprisingly, the next best estimate was Austria. Speculatively, the combination of a large agriculture sector together with some oil production could have led to this. In the SUT estimation routine, sectors which were not present in one 'representative' country but which were necessary for the RoW economy were taken from the world average. For Austria this was the case, for example, for production of paddy rice, all metal mining industries, and nuclear energy production. This pushed the RoW estimate of Austria closer to the RoW estimate based on the average of all countries and may further explain the low objective value for Austria. Only the third best estimate was based on a country traditionally (Timmer et al., 2012) thought to be a good representation of the RoW: Mexico.

Interestingly, the EXIOBASE approach with input coefficients chosen for each industry separately out of the available EXIOBASE countries did not result in a small objective value: the first model run based on the EXIOBASE approach in the objective value list ranked 12th with an objective value nearly 40% higher than the lowest one. 'Representative' country model runs which had a low objective value and also resulted in footprint accounts quite similar to the original EXIOBASE included Mexico and Poland.

The presented approach is not restricted to estimating the accounts for the RoW. It can easily be generalised to estimate the economic structure of any region/country. However, several prerequisites have to be met to do so. First, macroeconomic data (GDP, industry output) for the region in question must be available, including imports and export at the used sector classification. Second, the stressor matrix/territorial accounts for the unknown region must be determined by other means. Third, an adequate sample of possible economic structures (the 'representative' countries) must be available. Assuming that no further information about the economic structure is known, the quantity of the objective value obtained from the balancing routine can then serve as an indicator for the best representation in the available country set for the unknown region.

6. CONCLUSION

Global MRIO tables are compiled to provide information for policymakers regarding environmental and globalisation issues (Tukker and Dietzenbacher, 2013). In order to do so they have to describe the world economy, and often focus on a specific set of countries, either roughly estimating or aggregating the other countries into an RoW. Some of the recently published global MRIO tables (WIOD and EXIOBASE) make use of one RoW region which has comparable macroeconomic and environmental characteristics.

All MRIO models that quantify the impact of the RoW, either directly through one single region or indirectly through the estimation of multiple RoW regions/countries, rely on proxy information for this structure of production and consumption. Here we present a

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method which results in a coherent description of the RoW within a global MRIO table. The approach utilises macro-level information about the RoW (GDP, industry output) and the trade links within the MRIO table. Proxy information about the economic structure is then obtained from the available countries within the MRIO table.

For defining policies on the basis of the results of the EEMRIO analysis, assessing the robustness of the accounts is crucial, especially for the focal countries of the MRIO table. Here, we employ a sensitivity analysis across proxy information which can be used for the RoW estimate. The results show that for impacts that are broadly distributed across many sectors of the economy (greenhouse gas emissions, employment) the presented approach yields robust estimates for all countries within the MRIO table. However, for environmental impacts that occur in very specific sectors of the economy (land use) the choice of the proxy information to estimate the RoW has a major influence on the accounts of almost all countries. On the sector level, the variability is significant enough to impact trust in results at the level of individual products, especially for primary products. The question of how to further improve the presented method to account for this represents a rich area for further research.

In terms of practicability in estimating production structures for the RoW our results show that a proxy production structure based on the global average provides a reasonable and simple basis for this estimation of the economic structure of the RoW.

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SUPPLEMENTAL DATA

Supplemental material for this article is available via the supplemental tab on the article's online page at http://dx.doi.org/10.1080/09535314.2014.936831

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APPENDIX. MATHEMATICAL NOTATION

Index	Description
m	Products
j	Industries
a	Primary inputs
t	Table index for the supply/use system $\mathbf{Z}$ ($t = 1\ldots$ supply, $t = 2\ldots$ use)
r, k	Countries
RoW	Rest of the world region
b	Final demand categories
M	Superscript indicating imports
D	Superscript indicating domestic production/use

Variable	Description
$\mathbf{V}^k_{m,j}$	Supply matrix, showing production of commodity m by industry j of country k.
$\mathbf{U}^k_{m,j}$	Use matrix, showing flows of commodity m to industry j of country k.
$\mathbf{C}^k_{m,j}$	Supply coefficient matrix, showing production of commodity m by industry j of country k.
$\mathbf{B}^k_{m,j}$	Use coefficient matrix, showing flows of commodity m to industry j of country k.
$\mathbf{Y}^{\mathrm{k}}_{\mathrm{m,b}}$	Final demand for each commodity m per category b of country k.
$\mathbf{Z}_{m,j,t}$	Supply use system, showing flows of commodity m to industry j in table t.
g	Industry output
q	Product output
y_b	Final demand totals per category b
$\mathbf{imp}^k$, $\mathbf{exp}^k$	Imports and export totals of country k
$\mathbf{TR}^{k,r}$	Trade flow of products from country k to country r
$\mathbf{W}_{m,j,t}$	Weights for the balancing routine
o	objective value of the balancing routine
$\mathbf{T}$	Symmetric input/output table (products $\times$ products)
$\mathbf{F}$	Environmental extensions of the IO table
$\mathbf{K}$	Environmental accounts in industry classification
$\mathbf{A}$	Technical coefficient table (products $\times$ products)
$\mathbf{S}$	Environmental extension coefficients
$\mathbf{e}^k_{\mathrm{terr}}$	Territorial accounts of country k
$\mathbf{e}^k_{\mathrm{imp}}$	Total imported accounts of country k
$\mathbf{e}^k_{\mathrm{exp}}$	Total exported accounts of country k
$\mathbf{e}^k_{\mathrm{f}}$	Footprint accounts of country k
$\mathbf{Q}^k$	Multipliers for impacts per product of country k

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