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**Global Hotspots of the Swedish Footprint: A Multi-model Comparison**

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**Abstract**

Sweden is a country with a high carbon footprint per capita relative to recommended levels for achieving the environmental goals of a stable climate system. Much of that footprint is not exerted directly within the territory of Sweden but rather is embodied in imported goods and leads to environmental impacts abroad. In this study we calculate the total amount and geographical hotspots of the Swedish footprint using multi-regional input output (MRIO) models and survey these results in order to gain a current, comprehensive picture of the present state of knowledge of the Swedish global footprint. We firstly compare a time series of the Swedish carbon footprint calculated by Statistics Sweden with data from EXIOBASE, GTAP, OECD, EORA, and WIOD MRIO databases. We then examine the MRIO-model data in detail and investigate the geographical distribution of the Swedish footprint for carbon dioxide emissions, greenhouse gas emissions, water, materials and employment (depending on data available from each MRIO). From these accounts we identify the most important nations and regions in terms of environmental pressure from Swedish consumption. In doing so we also consider why results may differ between calculation methods and types of environmental pressure. These lessons provide recommendations to guide future research and policy making that will improve the accuracy of national consumption-based accounts. The findings here are thus relevant not just for Sweden but for others seeking to improve national consumption-based accounts.

**Key words**

Footprint, multi-regional input-output databases, environmental pressures, model comparison, consumption-based accounting, hotspots

**Highlights**

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# Introduction

## Environmental footprints

Current consumption patterns and levels in developed countries are unsustainable, using too many raw materials and producing too much waste and pollution (Lorek and Vergragt, 2015), and for countries such as Sweden this is evident in their high ecological or carbon footprints[[1]](#footnote-2) that measure the global impact of Swedish consumption. Sweden is now one among a number of countries that have produced and analysed their environmental impacts of consumption. The Swedish national statistics agency (SCB) has published national consumption-based CO2 emissions accounts (carbon footprint) since the end of the 90s, with current GHG estimates of emissions per product group for 2008–2014 publically available. In addition, a consistent time series from 1995-2009 on the carbon dioxide emissions from Swedish consumption was published by SCB in 2015 (Statistics Sweden, 2015) including a comparison of the calculation methods using two different models. In this study Sweden’s carbon footprint increased from 1995 to 2007, followed by a slight decline to previous 1990s levels in 2009. In similar study to calculate Sweden’s carbon footprint between 1993 and 2014 consumption-based GHG emissions rise to a peak in 2011, after which they decline slightly until 2013 (Sverige Naturvårdsverket, 2015). Earlier pilot studies by Swedish government agencies and research organisations demonstrate comparable footprint findings (Finnveden et al., 2001; Palm et al., 2006; Sverige and Naturvårdsverket, 2008).

Work to develop similar consumption-based accounting for numerous countries has also been ongoing over a number of years, examining a wide range of environmental pressures such as the ‘carbon footprint’ (Hertwich and Peters, 2009; Wiedmann et al., 2010) ‘water footprint’ (Hoekstra and Mekonnen, 2012) , ‘land footprint’ (Hubacek and Giljum, 2003) and ‘material footprint’ (Wiedmann et al., 2015). Footprint results are now publically available for many nations, and an environmentally extended input-output analysis (EE-IOA) approach is becoming a commonly applied and generally accepted technique for national-level footprint account calculations (Tukker et al., 2009; Tukker and Dietzenbacher, 2013; Wiedmann, 2009).

## Consumption-based environmental impact accounting

EE-IOA is based on an established national accounting and analytical method used in economics, representing the structure of the economy in a matrix of transactions between industrial sectors and final consumers (Miller and Blair, 2009). This matrix quantifies the transactions among industries, such as rice production, or services production; factor inputs to production like labour or capital; and deliveries of outputs to the final users (for example for consumption or export) (Duchin, 1998). When compiled at the national level this system provides a representation of the supply chains of an economy and total demand for goods and services. Environmental footprints can then be calculated by extending the monetary tables with environmental data and applying the Leontief model (Leontief, 1970) to reallocate pressures from the industry of production to the products of final demand.

At the international level considerable efforts have been made to expand EE-IOA analysis and calculate footprints for many nations simultaneously using environmentally-extended multi-regional input-output (EEMRIO) models (Lenzen et al., 2013; Timmer et al., 2015; Tukker et al., 2009; Tukker and Dietzenbacher, 2013). The basic methodological principles and structure are the same as EE-IOA, but the models cover a number countries (or country groups, termed regions) in the same matrix, describing the specific production technology for each region and how they are linked via international trade. These global efforts in EEMRIO development mean that there are now numerous databases where consumption-based footprint results for Sweden can be extracted, covering a range of indicators and years. Constructing an EEMRIO for many countries of the world is far from a trivial task, but hence there are a relatively small number of models published and available internationally.

The underlying calculation methods used in all these EE-IOA are essentially the same, however, published studies show differing results *(example of different results, … XXX).* Whilst this can be difficult to interpret it is to be expected as, similarly to any model development, a number of important choices about the structure and data components must be made by the modeller which influence the results. For IOA this includes: the chosen representation of the economy (transactions between industrial sectors and countries or world regions); the matrix of environmental pressures; and final demand by final consumers. Each of these components can vary in the data and methods used to construct and align them, therefore it would not be expected that two studies using different datasets and harmonisation approaches would arrive at exactly the same figure. Recent efforts of the MRIO community to investigate the impact of these choices has been collected and published (see Economic Systems Research Journal, titled: *A Comparative Evaluation of Multi-Regional Input-Output Databases* (Volume 26, Issue 3, 2014, editorial by (Inomata and Owen, 2014)).

## Implications for national environmental policy – the Swedish case

Having a range of similar, but varying results for the same footprint indicator may be confusing for communication purposes. However, there are benefits in examining the outputs of models with varying designs or data sets employed; this variety can be seen as repeated analyses concerned with the same basic set of questions, demonstrating plausibility of a consumption-based accounting approach and raising new policy questions.

This is of particular relevance in Sweden where a number of national policies and strategies are in place to examine and tackle unsustainable consumption. A central component of this effort is the Swedish overarching “generational goal” within its system of environmental goals, which aims to reach the national environmental objectives in Sweden without increasing the environmental pressure in other countries (Brolinson et al., 2010). In addition, Sweden is a signatory to Agenda 2030 and Sustainable Development Goals, with sustainable consumption and production as Goal 12 (United Nations, 2015), and recently launched a national Sustainable Consumption Strategy in December 2016 (Government Offices of Sweden Ministry of Finance, 2016). Thus the understanding of environmental pressure both within and outside of national borders is of great importance and demonstrates the need for regular consumption-based monitoring at the national level.

This research is motivated by this policy objective, aiming to inform the monitoring decision by examining the extent of variation in approaches. The focus will be on the reported global hotspots of environmental pressures from Swedish consumption identified by the different input-output models: SCB, EXIOBASE3, GTAP, Eora and WIOD; with an exploration into the possible underlying causes of any variation. From this analysis the paper aims to provide recommendations future research that will improve the accuracy of national consumption-based accounts and support policy-makers in footprint monitoring discussions.

# Materials and Methods

The Swedish footprint results from five MRIO databases were compiled including – EXIOBASE, WIOD, Eora, OECD and GTAP along with the SCB calculations that employ an import-adjusted single region input-output model. All of the models employ standard input-output analysis to calculate environmental pressures associated with final consumption, this is fully described in (Miller and Blair, 2009). For the methodology behind each of the specific MRIOs please refer to the references listed in the short model descriptions below.

## SCB

The model devised at SCB is a single country IO approach. It uses national economic data from the Swedish National Accounts (at the level of 94 products and industries), along with environmental pressure accounts of emissions to air by at the industry level. The GHG emission footprint is calculated in the current consumption-based accounts; sulphur dioxide, nitrogen oxides and ammonia is being developed . The footprint estimates of Swedish domestic consumption are complemented with data on the estimated environmental pressures (GHG emissions) from the imported goods and services, and the quantity of goods and services imported and exported to/from Sweden. As the model is a single country IO GHG emissions embedded in imported goods must be approximated. Emissions factors of Swedish national goods are employed as a baseline and then adjusted for each country globally using the GHG emissions from the global Edgar database (Emissions Database for Global Atmospheric Research) and GDP per country. These data are also further benchmarked using WIOD.

For model method see: Sverige Naturvårdsverket (2016)

## GTAP

The GTAP (Global Trade Analysis Project) database (or adaptations thereof) is one of the most widely adopted in academic publications. The GTAP database is formulated principally as a representation of the world economy for use in Computable General Equilibrium (CGE) modelling, and while CGE and IO modelling requires a similar foundation of data, the structure of the database is set up for input into a CGE model and a number of processing steps have to be taken to transform this into an IOT for use in consumption-based accounting (Peters et al., 2011). One of the advantages of the GTAP database is that it has existed for a long time and is widely used and, despite a significant time-lag in publication (2011 tables published in 2015), seems able to fund regular updates and consistent publication over time.

For model methods see: Peters et al. (2011)

## EXIOBASE3

EXIOBASE is a global, detailed environmental-extended multi-regional Supply and Use (SUT) / IO database. It was developed by harmonizing and detailing SUTs[[2]](#footnote-3) for a large number of countries, estimating emissions and resource extractions by industry, linking the country EE SUT via trade to a multi-regional EE SUT, and producing an MR EE IOT from this. This international input-output table can be used for the analysis of the environmental impacts associated with the final consumption of product groups. A main strength of EXIOBASE is that it provides a large economic sectoral detail and a wide-range of environmental extensions.

For model methods see: Tukker et al., 2009, 2013; Wood et al. (2015)

## WIOD

The WIOD database is an EU-funded (FP7) database which was released in April 2012 and also based almost entirely on official data sources (Timmer et al., 2015). It includes time series of world input-output tables for forty countries worldwide and a model for the rest-of-the-world, covering the period from 1995 to 2011, in both current and constant prices. The database also has information on air emissions and energy from which it is possible to calculate a variety of footprints.

For model methods see: Erumban et al. (2011)

## Eora

The Eora MRIO project uses extensive automation and a data resolution engine to merge together disparate data sources into a single, composite world MRIO. The database covers 187 countries for each year 1990-2012, and uses a mixed IO table structure so that the IO table of individual countries are each preserved in their original detail. One drawback to this approach is that since different countries are represented in different classifications, inter-country comparison is more difficult. The database includes a number of environmental extensions including GHGs, land use, water use, air emissions, N and P emissions, and biodiversity loss.

For model methods see: Lenzen et al. (2013)

## Hotspot comparison approach

The models were all run with a Leontief demand pull model (Miller and Blair, 2009) in order to allocate production based impacts to country specific final demand. All models were run at the original resolution, before aggregating results to a common classification (Steen-Olsen et al., 2014). Such an approach avoids introducing additional aggregation error into the model (de Koning et al., 2015; Wood et al., 2014). The smallest common country classification is identical to the WIOD country classification, and we thus use that aggregation in results forthwith. Of note, is that results are reported then for 40 individual countries, with all other countries aggregated to a “Rest of World” region. In terms of sector aggregation, in this work, we aggregate to country level totals based on the disaggregated calculation. All models are run for maximum number of years of data availability as of 2016, and where a common year (e.g. 2011) is not available for cross-country comparison (this occurs in the environmental extensions of WIOD) we take the latest available year, and explicitly mention the difference in results. We report both the origin of production and the region of final consumption. Environmental accounts of production by region and sector of origin **F** arenormalised by gross output of each sector **x** to give emissions intensities **S.** In this work **F** and **S** is disaggregated row-wise by country, so that country level production based impacts are simply the sum over columns $\sum\_{k2}^{}F\_{k1,k2}$

|  |  |
| --- | --- |
| $S= F\hat{x}^{-1}$ | Eq 1 |

Total emissions caused by final demand **D** (dimension, *k* rows ofregions, *k* columns ofregions), given a Leontief production function is then (substituting above equations and rearranging) given by:

|  |  |
| --- | --- |
| $$D^{}= S\left(I-A^{}\right)^{-1}Y^{}$$ | Eq 2 |

We then obtain two databases of production account: **d** and consumption account: **f** by regionwhere

$$d=\sum\_{k1}^{}D\_{k1,k2}$$

$$f=\sum\_{i}^{}F\_{k1,i}$$

These calculations are done for each year, and each model *m*. A simple aggregation to the common classification of 41 regions is then $d^{cc}=G^{m,cc}\*d$and $f^{cc}=G^{m,cc}\*f$where$G^{m,cc}$is an aggregation matrix of 1’s and 0’s that specifies country aggregation between original country classification of each model *m*, and the common country classification.

## Data analysis

The data from each model were compiled and compared, identifying the countries where Sweden’s consumption-based environmental impacts originate (hotspots). Countries (including Sweden) were ranked and compared for the different environmental indicators, according to the year and indicator available in each model. Where available, data for change in each hotspot over time were analysed to investigate any shifts from one hotspot region to another.

# Results

## Carbon dioxide from fossil fuel combustion emissions – multi-model results

All of the models include an estimate of the Swedish production-based[[3]](#footnote-4) and consumption-based emissions from fossil fuel combustion, so this is a suitable indicator to compare between models and also selected by other model comparison studies (for example (Owen et al., 2014)). For comparability SCB data is shown both including and excluding emissions from processes. Across the models the production-based emissions per capita for Sweden range from 4.8 and 5.7 tonnes per capita and consumption-based emissions from 8.3 to 11.1 tonnes per capita in 2011 (Table 1).

|  |  |  |
| --- | --- | --- |
| **Production based and consumption-based footprints** | **Swedish production-based carbon dioxide (CO2) Fuel combustion** | **Swedish consumption-based carbon footprint (CO2) Fuel combustion** |
| Unit | Tonnes per capita | Tonnes per capita |
| Statistics Sweden (2011)[[4]](#footnote-5) | 6.0 | 10.0 |
| Statistics Sweden (2011)[[5]](#footnote-6) | 5.3 | 8.3 |
| EORA (2011) |  4.8  |  8.8  |
| GTAP (2011) |  5.0  |  8.8  |
| OECD (2011) |  5.5  |  11.1  |
| EXIOBASE3 (2011) |  4.9  |  9.3  |
| WIOD (2009) |  5.7  |  9.3  |

Table 1: Consumption and production-based carbon dioxide emissions from fuel combustion (tonnes per capita)

Figure 1 and Figure 2 present the production-based carbon dioxide emission from fossil fuel production over time to show the basic alignment between the models prior to any hotspot analysis.

All of the models show somewhat similar overall trend over time with increases in earlier years, but steady declines since 1996 (Figure 1). Large differences in level exist however between the models, with the highest level found for SCB, if emissions from processes are included, and the lowest levels found for Eora and EXIOBASE.

 From the consistent base year of 1995 (Figure 2) shows the change in the production based carbon dioxide for each of the models. The models diverge considerable from 2002 onwards as EXIOBASE and Eora reports consistent stronger declines in footprint compared with SCB, WIOD and OECD.

Figure 1: Model variation in production-based carbon emissions from Sweden (carbon dioxide emissions from fossil fuel combustion), 1990-2012, EXIOBASE3, GTAP, OECD, WIOD, SCB[[6]](#footnote-7) and Eora.

Figure 2: Percentage change in carbon dioxide from fossil fuel combustion for Sweden (production-based estimates), 1995-2012, EXIOBASE3, GTAP, OECD, WIOD, SCB[[7]](#footnote-8) and Eora.

The consumption based carbon footprint estimates, (Figure 3 and 4) show similar divergence as the production based estimates, with sharper declines in EXIOBASE and Eora from 2002 onwards. Additional differences between the models can further be seen, with lower levels according to SCB data between 1993 and 2007, in particular if emissions from processes are excluded. If emissions from processes are included an increasing trend from 2007 onwards is seen, taking the estimates over that of both Eora and EXIOBASE. Some of the largest differences are reported between SCB and EXBIOASE and SCB and OECD, with a range of 23-24 Mt difference in some years.

Figure 31: Variation in model estimates of the consumption-based carbon footprint for Sweden (consumption-based carbon dioxide emissions from fossil fuel combustion), 1990-2012, EXIOBASE3, GTAP, OECD, WIOD, SCB[[8]](#footnote-9) and Eora.

Figure 4: Percentage change in estimates of the consumption-based carbon footprint for Sweden (consumption-based carbon dioxide emissions from fossil fuel combustion), 1995-2012, EXIOBASE3, GTAP, OECD, WIOD, SCB and Eora.

## The hotspots of Sweden’s carbon footprints

### Sweden’s footprint of emissions from fossil fuels

For Sweden’s consumption the carbon footprint from fossil fuel consumption hotspots are shown in Table 2 for each MRIO model for the latest year available. All models agree that Sweden itself is the main hotspot for at least one third of the Swedish footprint, with a further between 17 and 27 percent originating in the rest of the EU. There is disagreement between the models in how the remaining third of emissions are distributed between the rest of the world[[9]](#footnote-10), China and Russia. However, all the models indicate that around 20 per cent of the Swedish carbon footprint emissions originate in the rest of the world and China.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Country of origin of fossil fuel emissions footprint**  | **EORA (2011)** | **EXIOBASE3 (2011)** | **GTAP (2011)** | **OECD (2011)** | **WIOD (2009)** |
| Sweden | 31% | 44% | 41% | 54% | 47% |
| Rest of EU total | 27% | 20% | 23% | 17% | 21% |
| Rest of World | 11% | 13% | 11% | 7% | 10% |
| China | 13% | 9% | 10% | 7% | 10% |
| Russia | 5% | 5% | 4% | 7% | 4% |
| USA | 6% | 3% | 4% | 3% | 3% |
| India | 3% | 2% | 2% | 2% | 1% |
| Japan | 1% | 1% | 1% | 1% | 1% |
| South Korea | 1% | 1% | 1% | 1% | 1% |
| Taiwan | 1% | 1% | 1% | 0% | 1% |
| Canada | 0% | 1% | 1% | 0% | 1% |
| Turkey | 0% | 0% | 1% | 0% | 0% |
| Australia | 0% | 0% | 0% | 0% | 0% |
| Indonesia | 0% | 0% | 0% | 0% | 0% |
| Brazil | 0% | 0% | 0% | 0% | 1% |
| Mexico | 0% | 0% | 0% | 0% | 0% |

Table 2: Hotspots of the Swedish carbon footprint from the emissions of fossil fuel combustion

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Country of origin of fossil fuel emissions footprint**  | **EORA26** | **EXIOBASE3 (2011)** | **GTAP (2011)** | **OECD (2011)** | **WIOD (2009)** |
| Sweden | 1 | 1 | 1 | 1 | 1 |
| Rest of EU total | 2 | 2 | 2 | 2 | 2 |
| Rest of World | 4 | 3 | 3 | 5 | 4 |
| China | 3 | 4 | 4 | 4 | 3 |
| Russia | 6 | 5 | 6 | 3 | 5 |
| USA | 5 | 6 | 5 | 6 | 6 |
| India | 7 | 7 | 7 | 7 | 7 |
| Japan | 8 | 8 | 10 | 9 | 9 |
| South Korea | 9 | 9 | 8 | 8 | 10 |
| Taiwan | 10 | 10 | 11 | 10 | 8 |
| Canada | 11 | 11 | 9 | 11 | 11 |
| Turkey | 15 | 12 | 12 | 12 | 13 |
| Australia | 14 | 13 | 13 | 15 | 14 |
| Indonesia | 12 | 14 | 15 | 14 | 15 |
| Brazil | 13 | 15 | 14 | 13 | 12 |
| Mexico | 16 | 16 | 16 | 16 | 16 |

Table 3: Ranking of hotspots of the Swedish carbon footprint from the emissions of fossil fuel combustion

### Sweden’s footprint of greenhouse gas (GHG) emissions

Hotspots of the Swedish carbon footprint including all Kyoto greenhouse gases (CO2, CH4, N20 and SF6 where available using global warming potential from AR4, IPCC 2007) is available for EXIOBASE, GTAP and WIOD and these data are similar to that of the fossil fuel combustion data, with Sweden and the rest of the EU ranked 1 and 2 for the origin of these emissions, followed by the rest of the world, China and Russia (Table 4 and Table 5).

|  |  |  |  |
| --- | --- | --- | --- |
| **Country of origin of GHG footprint**  | **EXIOBASE3 (2011)** | **GTAP (2011)** | **WIOD (2009)** |
| Sweden | 41% | 43% | 44% |
| Rest of EU total | 19% | 21% | 20% |
| Rest of World | 16% | 11% | 13% |
| China | 9% | 9% | 10% |
| Russia | 6% | 5% | 5% |
| USA | 3% | 4% | 3% |
| India | 2% | 2% | 1% |
| Japan | 1% | 1% | 1% |
| South Korea | 1% | 1% | 1% |
| Canada | 1% | 1% | 1% |
| Taiwan | 1% | 0% | 1% |
| Australia | 1% | 1% | 0% |
| Brazil | 1% | 1% | 1% |
| Turkey | 0% | 0% | 0% |
| Indonesia | 0% | 0% | 0% |
| Mexico | 0% | 0% | 0% |

Table 4: Hotspots of the Swedish GHG carbon footprint

|  |  |  |  |
| --- | --- | --- | --- |
| **Country of origin of GHG footprint**  | **EXIOBASE3 (2011)** | **GTAP (2011)** | **WIOD (2009)** |
| Sweden | 1 | 1 | 1 |
| Rest of EU | 2 | 2 | 2 |
| Rest of World | 3 | 3 | 3 |
| China | 4 | 4 | 4 |
| Russia | 5 | 5 | 5 |
| USA | 6 | 6 | 6 |
| India | 7 | 7 | 8 |
| Japan | 8 | 10 | 12 |
| South Korea | 9 | 9 | 11 |
| Canada | 10 | 8 | 10 |
| Taiwan | 11 | 14 | 9 |
| Australia | 12 | 11 | 13 |
| Brazil | 13 | 12 | 7 |
| Turkey | 14 | 13 | 14 |
| Indonesia | 15 | 15 | 15 |
| Mexico | 16 | 16 | 16 |

Table 5: Ranking of hotspots of the Swedish GHG carbon footprint

### Insight into the Sweden’s GHG footprint origin in the rest of the EU

As the second largest hotspot for both the GHG and the fossil fuel combustion footprints the rest of the EU data for the GHG carbon footprint are presented in Table 6. All the MRIO models agree that Germany is the largest source of emissions, followed by Denmark. There is disagreement between the third ranked country though as GTAP has Poland as the third largest source, WIOD the Netherlands and EXIOBASE Finland.

|  |  |  |  |
| --- | --- | --- | --- |
| **Country of origin of GHG footprint** | EXIOBASE3 (2011) | GTAP (2011) | WIOD (2009) |
| Germany | 1 | 1 | 1 |
| Denmark | 2 | 2 | 2 |
| Finland | 3 | 5 | 5 |
| UK | 4 | 4 | 4 |
| Netherlands | 5 | 7 | 3 |
| Poland | 6 | 3 | 6 |
| Belgium | 7 | 12 | 7 |
| France | 8 | 6 | 8 |
| Italy | 9 | 8 | 10 |
| Spain | 10 | 9 | 9 |
| Ireland | 11 | 13 | 14 |
| Czech Republic | 12 | 14 | 11 |
| Greece | 13 | 11 | 19 |
| Estonia | 14 | 15 | 12 |
| Austria | 15 | 10 | 15 |
| Hungary | 16 | 17 | 18 |
| Latvia | 17 | 16 | 22 |
| Portugal | 18 | 19 | 13 |
| Lithuania | 19 | 20 | 16 |
| Romania | 20 | 18 | 20 |
| Slovakia | 21 | 22 | 17 |
| Luxembourg | 22 | 24 | 24 |
| Bulgaria | 23 | 21 | 21 |
| Cyprus | 24 | 23 | 25 |
| Slovenia | 25 | 25 | 23 |
| Malta | 26 | 26 | 26 |

Table 6: Ranking of ‘rest of Europe’ hotspots of the Swedish GHG carbon footprint

## The hotspots of Sweden’s social and environmental footprints

This section presents the remaining social and environmental footprints of Swedish consumption and investigates the hotspot countries of origin for each, comparing between models where data are available. This includes global hotspots of the employment footprint from the OECD, EXIOBASE, Eora and WIOD models, the material footprint (domestic extraction including biomass, fossil fuels, metallic and non-metaillic mineral ores, see appendix) from EXIOBASE, Eora and WIOD and water from EXIOBASE and Eora. Comparing both between indicators and models provides insight into both the variation between environmental and social indicators and agreement between models.

### Sweden’s footprint of employment

Figure 4 presents the global hotspots of the Swedish consumption-based employment footprint, showing the differences between the identified hotspots in four MRIO models – EXIOBASE, OCED and WIOD, EORA for 2009. All models agree that Sweden itself is the largest employment footprint hotspot, however there is disagreement as to whether the second largest is the rest of the world or the rest of the EU, with OECD and WIOD ranking rest of the world as 7th and 16th respectively and EXIOBASE and EORA as 2nd and 4th. All of the models agree that the rest of the EU is an important hotspot (ranked 2nd or 3rd by all models), and identify Germany, Poland and the UK as the top EU origins of Sweden’s employment footprint.

Figure 4: Hotspots of Sweden’s employment footprint, 2009

### Sweden’s material footprint

EXIOBASE, EORA and WIOD both provide an estimate of the material footprint and Figure 5 shows the origins of Sweden’s material footprint for the latest year available across the models (2009). WIOD and EORA both report a more even spread of the origin of the material footprint, between Sweden, the rest of the world, the rest of EU and China, than EXIOBASE, where Sweden itself accounts for over half of the material footprint. In agreement with the other footprints considered so far, of the rest of the EU, Denmark, Germany and Poland feature as the main footprint hotspots from the EU countries, and are ranked 1, 2 and 3 by all models.

Figure 5: Hotspots of Sweden’s material footprint, 2009

|  |  |  |  |
| --- | --- | --- | --- |
| **Country of origin of material footprint** | EXIOBASE3 | WIOD | EORA |
| Sweden | 53% | 31% | 26% |
| Rest of World | 16% | 18% | 25% |
| Rest of EU | 12% | 19% | 16% |
| China | 7% | 15% | 12% |
| Russia | 3% | 7% | 9% |
| USA | 3% | 2% | 3% |
| India | 2% | 1% | 3% |
| Brazil | 1% | 2% | 1% |
| Australia | 1% | 1% | 1% |
| Turkey | 1% | 1% | 1% |
| Indonesia | 0% | 1% | 1% |
| Canada | 0% | 1% | 1% |
| South Korea | 0% | 0% | 0% |
| Mexico | 0% | 0% | 0% |
| Japan | 0% | 0% | 0% |
| Taiwan | 0% | 0% | 0% |

Table 7: Hotspots of the Swedish material footprint, 2009

### Sweden’s water footprint

Only EXIOBASE and EORA data were available for the Swedish water footprint hotspots analysis (2011 as the comparison year). This is the only indicator where Sweden is not ranked top as the first hotspot, instead both models identify the rest of the world region as the largest hotspot for Sweden’s water footprint, followed by Sweden and the rest of the EU (Figure 6). EXIOBASE shows a large difference between the rest of the world and Sweden, but Eora reports a similar percentage of the footprint between the rest of the world, Sweden and the rest of the EU. The rest of the EU accounts for only 10 per cent of the footprint in total from EXIOBASE, but Spain is identified as the main footprint hotspot for Sweden within the EU, followed by Italy. However, this is not the same as EORA where Germany and Denmark are ranked highest.

Figure 6: Hotspots of Sweden’s water footprint, 2011

### Hotspots of final demand

A hotspot of environmental or social pressure may arise due to higher environmental pressures in that country or due to the level of consumption of goods and services from that region, or a combination of both. It is therefore interesting to explore the proportions of Swedish final demand from different regions and compare this with the hotspots of environmental and social pressures. Table 8 and Table 9 show the percentage of total Swedish final demand from the different regions in each model. Table 8 includes the ‘rest of EU’ as an aggregate, Table 9 shows the EU countries separately. Only those regions above 0.5 per cent are shown in the tables. Both tables show that Sweden accounts for nearly 90 per cent of final demand, so for the majority of environmental and social hotspots the proportion of impact is greater than the economic expenditures. China for example, accounts for a very small proportion of the Swedish final demand hotspot, but regularly features in the top ranks for the environmental and social hotspots. For the European countries and the rest of the world region, those ranked highest in terms of final demand hotspot tend to also appear higher ranked in the footprint hotspots (for example, rest of world, Germany, Netherlands, Denmark, Finland and the UK).

### Hotspots of value added

It is interesting to explore the footprint of value added to compare economic data with the social and environmental footprints from different regions. Table 8 and Table 9 show the Swedish value added footprint from the different regions in each model. Table 8 includes the ‘rest of EU’ as an aggregate, Table 9 shows the EU countries separately. Only those regions above 0.5 per cent are shown in the tables. Both tables show that Sweden accounts for over 70 per cent of value added, so for the majority of environmental and social hotspots the proportion of value added is greater than the environmental pressures. This appears consistent between models. The ‘rest of the world region’ often accounts for a higher proportion of the environmental pressures, for example, over 10 per cent of the carbon footprints, 16-25 per cent of the material footprint and a large proportion of the water footprint, but a much smaller percentage of the value added at around 4-5 per cent depending on the model selected. For the European countries and the rest of the world region, those ranked highest in terms of value added hotspot tend to also appear higher ranked in the footprint hotspots (for example, rest of world, Germany, Netherlands, Denmark, Finland and the UK).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Year** | **2011** | **2011** | **2011** | **2011** | **2009** |
| **World Region** | **EORA** | **EXIOBASE3** | **GTAP** | **OECD** | **WIOD** |
| Sweden | 87% | 86% | 85% | 83% | 86% |
| Rest of EU | 9% | 9% | 10% | 11% | 10% |
| Rest of World | 2% | 2% | 2% | 2% | 2% |
| USA | 1% | 1% | 1% | 1% | 1% |
| China | 0% | 1% | 1% | 1% | 1% |

Table 8 Swedish final demand, by country/world region, year as specified

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **2011** | **2011** | **2011** | **2009** |
|  | **EXIOBASE3** | **EORA** | **OECD** | **WIOD** |
| Sweden | 74.9% | 71.1% | 70.7% | 72.9% |
| Rest of EU | 13.4% | 18.0% | 16.8% | 15.4% |
| Rest of World | 5.2% | 4.4% | 4.9% | 3.7% |
| USA | 1.6% | 2.0% | 2.6% | 2.4% |
| China | 1.3% | 1.5% | 1.4% | 2.2% |
| Russia | 0.8% | 0.6% | 1.2% | 0.6% |
| Japan | 0.5% | 0.9% | 0.5% | 0.5% |
| India | 0.4% | 0.3% | 0.6% | 0.3% |
| Australia | 0.4% | 0.1% | 0.1% | 0.2% |
| Canada | 0.3% | 0.2% | 0.3% | 0.3% |
| South Korea | 0.3% | 0.2% | 0.2% | 0.3% |
| Brazil | 0.2% | 0.2% | 0.2% | 0.6% |

Swedish footprint of value added, by country/world region, year as specified

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Year** | **2011** | **2011** | **2011** | **2011** | **2009** |
| **World Region** | **EORA** | **EXIOBASE3** | **GTAP** | **OECD** | **WIOD** |
| Sweden | 87% | 86% | 85% | 83% | 86% |
| Germany | 3% | 3% | 3% | 3% | 3% |
| Rest of World | 2% | 2% | 2% | 2% | 2% |
| Netherlands | 1% | 1% | 0% | 0% | 1% |
| Denmark | 1% | 1% | 1% | 1% | 1% |
| UK | 1% | 1% | 1% | 1% | 1% |
| France | 1% | 1% | 1% | 1% | 1% |
| Finland | 1% | 1% | 1% | 1% | 1% |
| Belgium | 1% | 0% | 1% | 0% | 1% |
| Italy | 1% | 0% | 1% | 1% | 0% |
| USA | 1% | 1% | 1% | 1% | 1% |
| China | 0% | 1% | 1% | 1% | 1% |
| Poland | 0% | 0% | 0% | 1% | 1% |
| Spain | 0% | 0% | 0% | 1% | 0% |

Table 9 Swedish final demand, by country/world region with ‘rest of EU disaggregated’, year as specified

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 2011 | 2011 | 2011 | 2009 |
|  | **EXIOBASE3** | **EORA** | **OECD** | **WIOD** |
| Sweden | 74.9% | 71.1% | 70.7% | 72.9% |
| Rest of World | 5.2% | 4.4% | 4.9% | 3.7% |
| Germany | 3.3% | 5.3% | 4.1% | 3.9% |
| USA | 1.6% | 2.0% | 2.6% | 2.4% |
| UK | 1.3% | 1.9% | 2.1% | 1.8% |
| China | 1.3% | 1.5% | 1.4% | 2.2% |
| Denmark | 1.2% | 1.5% | 1.7% | 1.6% |
| France | 1.2% | 1.6% | 1.4% | 1.1% |
| Netherlands | 0.9% | 1.5% | 0.7% | 1.3% |
| Italy | 0.9% | 1.2% | 1.2% | 0.8% |
| Russia | 0.8% | 0.6% | 1.2% | 0.6% |
| Finland | 0.8% | 1.0% | 1.2% | 0.9% |
| Belgium | 0.7% | 0.9% | 0.5% | 0.9% |
| Poland | 0.6% | 0.5% | 0.7% | 0.8% |
| Spain | 0.5% | 0.6% | 0.9% | 0.6% |
| Japan | 0.5% | 0.9% | 0.5% | 0.5% |
| India | 0.4% | 0.3% | 0.6% | 0.3% |
| Ireland | 0.4% | 0.3% | 0.4% | 0.4% |
| Australia | 0.4% | 0.1% | 0.1% | 0.2% |
| Canada | 0.3% | 0.2% | 0.3% | 0.3% |
| Austria | 0.3% | 0.4% | 0.3% | 0.3% |
| South Korea | 0.3% | 0.2% | 0.2% | 0.3% |
| Czech Republic | 0.2% | 0.3% | 0.2% | 0.2% |
| Brazil | 0.2% | 0.2% | 0.2% | 0.6% |

Swedish footprint of value added, by country/world region with ‘rest of EU disaggregated’, year as specified

## Change in Sweden’s footprint hotspots over time

By running time series data for each of the models where available it was possible to investigate if and how the global hotspots of Sweden’s footprints have changed over time. The findings show that for a number of indicators they have indeed changed, indicating a gradual outsourcing of the Swedish footprints over time. The GHG footprint is clearly demonstrates this, in both EXIOBASE and the WIOD MRIOs (see Figure 7 and Figure 8 for the top six global hotspots of Sweden’s GHG footprint). The percentage of the GHG footprint originating in Sweden has decreased from around 60 per cent to 40 per cent in both models, with increases reported in China and the rest of the world in both models and also in the rest of the EU in EXIOBASE.

Figure 7: Change in hotspots of Sweden’s GHG footprint, EXIOBASE model 1995-2011

Figure 8: Change in hotspots of Sweden’s GHG footprint, WIOD model 1995-2011

This trend is similar for the Swedish water footprint in the EXIOBASE model, showing a decline in the water footprint originating in Sweden and an increase in China and India. Interestingly, the top hotspot for the water footprint – the rest of the world – has remained relatively stable (Figure 9). For employment (also from the EXIOBASE model) the change in footprint hotspots over time is less pronounced, with a slight decline in the Swedish component and small increases in the hotspot of China and the rest of the world (Figure 10).

Figure 9: Change in hotspots of Sweden’s water footprint, EXIOBASE model 1995-2011

Figure 10: Change in hotspots of Sweden’s employment footprint, EXIOBASE model 1995-2011

# Discussion

## The global hotspots of Swedish environmental and social footprints

All consumption requires resources and the various stages of production often cause adverse impacts on the local and global environment, particularly when the energy system is driven by fossil fuels. With the development of global supply chains these adverse impacts can happen in locations very distant from the consumer and from the legislation in the country where the products are consumed. The results from this study demonstrate that MRIO analysis can provide insight into the global hotspots of consumption-based environmental and social footprints, and the rapid development of a number of increasingly sophisticated global models allows in-depth comparison and analysis of different calculations for Sweden.

The Swedish environmental and social footprints have been shown to not only originate in a range of countries globally, but to also in some cases be shifting from Sweden to abroad over time. This presents a challenge for both policy makers and consumers when making efforts to reduce their footprint impacts. Environmental pressures vary according to production methods, fuel use and environmental protection standards in different countries and a large number of actors including government, transporters, manufactures, retailers and consumers are involved in each of these aspects in every product supply chain. From the perspective of the consumers – becoming increasingly distant from the environmental and social pressures of production, combined with the increasing complexity of supply chains and the vast range of products available reduces the potential for improvements and change driven by consumer pressure and feedback. Similarly, governments have the capacity to directly impact the component of the footprint that originates within their own countries, but less influence over the environmental and social conditions in others. Despite this the awareness of these interactions is gradually increasing, and the discussion about the ways to influence the supply chains and the types of consumption has started (Persson et al., 2015).

## MRIO model variations in findings

The principle aim of this work was to investigate the agreement or otherwise between the different MRIO and IO models available globally in order to provide insight into their potential policy applications. Considerable differences in the results of the models would restrict the potential for their findings to be interpreted, used and acted upon by policy makers.

In this study we can identify the following findings on which all of the MRIO models agree:

* The consumption-based per capita carbon footprints (carbon dioxide from combustion of fossil fuels only) for Sweden remain considerably higher than a per capita share of the global budget for limiting 2 degrees of warming (Larsson, 2015).
* The consumption-based per capita carbon footprint of Sweden is almost double that of the production-based carbon footprints in all of the models.
* For the Swedish carbon (both from fossil fuels and GHGs), employment and material footprints the Sweden is the largest hotspot of environmental pressure in all of the models for which the data are available, but the size of the Swedish component varies between models.
* For all footprints except water, the rest of the world, the rest of the EU and China feature as the dominant hotspots of environmental pressure from Sweden’s consumption-based footprint.
* The WIOD and EXIOBASE models agree that the domestic share of Sweden’s component of the GHG carbon footprint has declined overtime as the hotspots in other parts of the world (notably China and the rest of the world) have increased.
* All models agree that the majority (nearly 90 per cent) of final demand comes from Swedish demand for domestic goods and services, but the footprint hotspots show that Sweden only often only accounts for 40-60 per cent of the impacts, with larger hotspot pressures elsewhere.
* All models agree that the majority of the Swedish value added footprint (over 70 per cent) occurs in Sweden, with the rest of the EU accounting for between 13 and 18 per cent followed by the rest of the world (4-5 per cent). In contrast, the environmental and social footprint hotspots show that Sweden often only accounts for 40-60 per cent of the impacts, with larger hotspot pressures elsewhere.

Despite this agreement, there are also variations between the models, one of the most major being whether the Sweden’s carbon dioxide footprint from the combustion of fossil fuels has increased or declined over time. In addition, individual models disagree on the extent to which the footprint pressures occur domestically or externally to Sweden. One particular example is the OECD model which reports Sweden as a much larger hotspot of pressure, particularly compared to the rest of the world, for both emissions from the combustion of fossil fuels and employment. In comparison, the other models identify larger hotspots in the rest of the world. Why these variations may occur have important implications future MRIO development and policy applications. Section 4.3 summarises some of these reasons for variations below.

## Reasons for MRIO model variation

### The approach to MRIO development

Some common factors of model variation are relatively straight forward to identify, while others require assessment of the input data or internal workings of the model which can be more time intensive to complete and often requires specialist knowledge of the model being investigated. Due to the number of data points, assumptions and calculations involved in generating a single total consumption-based footprint figure, it can also be difficult to disentangle individual factors that cause variations in results. The purpose of this paper is not to test or examine in detail the differences between the MRIO models, but instead investigate the impacts and main findings from each for a case study country to support policy and decision-making. As mentioned previously, a number of studies that investigate the impact of these specific model development choices has been collected and published in Economic Systems Research Journal, titled: *A Comparative Evaluation of Multi-Regional Input-Output Databases* (Volume 26, Issue 3, 2014, editorial by (Inomata and Owen, 2014)). This section discusses conclusions of these papers and others that have made similar studies in relation to the results and findings presented for Sweden in this study.

As a first step to understanding the similarities and variations in the models it is important to consider the how they are constructed and the data on which they are based. Work by (Owen et al., 2014, Table 1) shows the main features of the EORA, GTAP and WIOD databases. Here we expand on this to include OECD, SCB and EXBIOASE (Table 10) highlighting the main differences in input data and calculation method of each model. One major different to note is that the SCB model is a single-region IO model meaning that the economic structure is based on Swedish IO data; there is no representation of the production structures and international economic flows between other sectors and other countries.

### Macroeconomic data

To see one of the possible impacts of the data choices and approaches highlighted in Table 10 Table 11 summarises the global and national totals in the macroeconomic and environmental pressure data for each of the models. There is reasonable agreement between the models, however there are variations and if the global and national input data totals vary then the footprint results will undoubtedly vary following the calculations made to estimate the consumption-based footprints. However, there is some disagreement in the literature about whether the input data or the calculation methods are more important. Moran and Wood (2014) identified variance in environmental input data as one of the principle factors; whereas Hoekstra et al. (2013) identified issues in the compilation of the databases that gave rise to differences between carbon footprint results from Statistics Netherlands and WIOD[[10]](#footnote-11).Owen et al., (2014)reports that the total final demand vector is an important source of the variation between the Eora database and GTAP and WIOD, but that GTAP and WIOD were more similar in their total final demand and composition. For Sweden the total final demand is higher in EXIOBASE and EORA, with WIOD and OECD both using lower and very similar figures NEED TO COMPARE WITH SCB HERE DATA ARE MISSING. This is however consistent with global final demand which is higher in EXIOBASE and EORA resulting in Sweden having a very similar percentage of global final (around 0.7%) demand in all of the MRIO models except WIOD which is closer to 0.6%.

### Environmental and social data

The limited environmental data consistently available for the different models restricts the possibility for detailed comparisons between environmental pressures at this time. However, studies such as (Moran and Wood, 2014) found that there was substantial variability in the way the carbon emissions accounts were compiled in the four MRIOs they compared in this study (EORA, WIOD, EXIOBASE, and an MRIO model developed as part of a EU funded project OPEN:EU[[11]](#footnote-12) see (Hertwich and Peters, 2010)). For example, how total impacts are allocated amongst particular sectors, which of the GHGs are included, which emissions sources are included/excluded, how sectoral inventories are estimated if empirical data are not available, and if included there are non-CO2 GHGs included and converted into CO2 equivalents, the assumed global warming potential of each of the gases. National footprints and hotspots will consequently vary due to any discrepancies in total emissions, the emissions databases selected for the analysis, the emissions included, and the assumptions made in linking these to monetary flows. This may be a main reason behind the variation in the trends of Swedish carbon footprint from the combustion of fossil fuels. For 2011 Table 11 shows that there is a 5 million tonne difference in the production-based carbon dioxide emissions from the combustion of fossil fuels of Sweden between the OECD and Eora databases, whereas GTAP, Eora and EXIOBASE are much more closely aligned. This is not the same for global emissions however, where the differences are smaller. ADD IN SWEDISH COMPARISON PLUS EORA FOR 2011 WOULD BE BETTER THAN 2012 FOR THESE COMPARISONS.

The production-based employment figures for EORA, WIOD, OECD and EXIOBASE are quite consistent, but WIOD appears to be an outlier as it is considerably larger than the others. Further investigation into the data sources and approaches would be required in order to establish the possible reasons for this. Similarly, when examining the footprint hotspot results for employment WIOD showed higher totals than the other models, but the spread between different regions was consistent with the other models.

### Model construction and data processing

The basic conceptual principles and building blocks for an IO analysis are similar; all require data on flows between industries within each country – in the form of supply-and-use tables (SUTs) or IO tables (IOTs) – along with data on international trade in goods and services. MRIOs must however use whatever data is available at national level, and each country has its own national standards. The modellers must therefore make some decisions and assumptions when combining them into MRIOs. These are as follows:

1. **The data prioritised in the MRIO model construction** – the models are constructed from different datasets which often report the same thing (e.g. imports of products from one country to another) and the figures can vary between the data sources. This means that one data source may have to be prioritised over another as the correct value to assume. EXIOBASE, WIOD, EORA and OECD prioritise staying as close as possible to the numbers collected and presented by national governments in their SUTs or IO tables in official national statistics (Hoekstra et al., 2013), but others such as GTAP focus on ensuring that the values of reported trade data remain as close to the source trade data as possible and adjust other components to match.
2. **Data processing decisions and standards** – variable quality of the input data means that a number of processing decisions must be taken, which can also lead to differences in models. SUTs and IOTs are commonly published by national statistics agencies within their national accounts and standard accounting practices guide their formulation. These are compiled in international databases such as those maintained by the United Nations, OECD and Eurostat (Hoekstra et al. 2013). However, despite the standardisations, the availability and quality of these data can still vary – European countries publish SUTs in accordance with the System of National Accounts (SNA) and the Eurostat standard; however, other countries publish IOTs or SUTs following different standards (Wood et al., 2014).

When developing the model a number of decisions such as dealing with asymmetries in reported trade data, the level of sectoral aggregation and handling with missing data must be taken. There are also a number of factors that must be taken into account when creating global IO tables (MRIO tables) from national SUTs and IOTs, this includes: the overall balancing of the tables (ensuring total inputs are equal to total outputs), dealing with transport and trade costs, taxes and subsidies in the economic data and converting tables into the most appropriate form (either representing industries or products for example). While there is a relatively long list of specific modelling choices to be made, previous studies such as that by (Arto et al., 2014) and (Moran and Wood, 2014) have found that disagreement across models is often highly localized, occurring in just a few countries and sectors) and a few sections of the model.

ADD anything here? What does this mean for this paper?

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Variable Category** | **Variable** | **Statistics Sweden (SCB model)** | **GTAP Database** | **EORA** | **EXIOBASE** | **World Input Output Database (WIOD)** | **OECD (2015)** | **Assessment of similarity/importance as source of variation? (Highlight a few publication refs which have explored each part?)** |
| **Source Data** | **Overview** | Official IO data from Statistics Sweden; Macro-economic data from the World Bank to adjust environmental pressures of imports from other countries. Main focus national statistics and time series | Macro-economic data from World Bank, OECD and EUROSTAT; Regional IO tables from individual GTAP contributors, following guidelines on definitions and sector classificationMain focus; trade and agriculture issues | To be filled inMain focus: National statistics with high level of mathematical modelling | National Statistics Offices; Eurostat; Macro-economic data from UNSTAT (economic); International energy agency, SERI/WU Global Material Flows Database, FAOSTAT (extensions)Main focus environmental pressure from product groups | To be filled inMain focus: economic analyses, time series | National and international statistical data sources are used to generate harmonized IO tablesMain focus: trade and value added  | Different purposes with the models result in different priorities made when creating, balancing and analyzing the data |
|  |  |  |  |  |  |  |  |  |
|  | **Bilateral trade data** | Trade in goods and services from Statistics Sweden , collected and disseminated by Statistics Sweden | Trade in goods from UN Comtrade database. Trade in services from UN Service trade database | Trade in goods from UN Comtrade database. Trade in services from UN Service trade database | Trade in goods from UN Comtrade database, also used harmonized version of UN Comtrade BACI (from CEPII). Trade in services from UN Service trade database | Trade in goods from UN Comtrade database. Trade in services from UN, Eurostat and OECD | Trade in goods from UN Comtrade, trade by end-use category from OECD BTDIXE) and Trade in services (EBOPS classification) | Similar sources in all MRIOs. Differences in adjustments and balancing can however be of importance.  |
|  | **Environmental accounts** | National calculated emissions according to the environmental accounts standars.  | Sector-based CO2 emissions derived from IEA energy data | EDGAR and IEA | Material use and extraction: SERI/WU Global Material Flows DatabaseEnergy and emissions: IEA data and emission coefficients (consortium data)Land use: FAOSTAT | Emissions according to environmental accounts standards,  | CO2 emissions from fuel combustion derived from IEA energy data  | Important source of variation according to Moran and Wood (2014) and … (REFs). Differences exist in how transportation and bunkring is treated between sources using environmental accounts data and sources using IEA data  |
|  |  |  |  |  |  |  |  |  |
| **Structure** | **Product/Sector Detail** | 97 products-by-products  | 57 industrial sectors | Varies by country; ranges from 26 to 511 sectors | 200 products, 163 industrial sectors | 35 (industry-by-industry) | 34 sectors (industry by industry) | Quite considerable variation on paper.Considerable differences in aggregation level used. Differences in assumption made in creating product x products and industry x industry tables. See Mark de Haan (doktorsavhandling) ´counting goods and bads |
|  |  |  |  |  |  |  |  |  |
|  | **Classification Scheme** | Disaggregated version of NACE 2 digit level. Version: NACE rev 2. 2008 SNA | GTAP classification scheme which combines International Standard Industry Classification (ISIC) with UN Central Product Classification (CPC)1993 SNA? | Own classification system1993 SNA? | Disaggregation of NACE 2-digit levelVersion: NACE rev 1.1.1993 SNA | Aggregated version of NACE 2-digit levelVersion: NACE rev 1.11993 SNA | Aggregated version of NACE 2-digit level. 2015 edition: NACE rev 2.2016 edition: 1993 SNA  | Large difference in classification scheme and version used between Statistics Sweden and MRIOs |
|  | **Countries or Regions**  | A single regional model with bilateral trade with 201 countries +ROW  | 139+ RoW in latest year (minimum 66 in earlier years) | 187 countries (??) | 43 regions+5 RoW | 40 + RoW (including all EU27) | 61 countries + RoW | Considerable difference here, possibly source of variation. The difference between single-region (SCB model) and MRIO will be examined in the paper. |
|  | **Monetary units** | Million SEK | USD ($) |  | Million EUR | Million USD | Million USD |  |
| **System construction** |  |  |  |  |  |  |  |  |
|  | **Harmonisation of sectoral classifications in different region IOTs or SUTs** | Uses original classification from national accounts | To disaggregate a country’s non-agricultural sectors the structure from other IO tables within regional groupings is used. For agricultural sectors data from the FAO is employed | Uses original classification from national accounts. | Based on mapping between national classification and EXIOBASE classification, original data was disaggregated and aggregated (rarely occurred). Disaggregation based on the available physical data (see sources for extensions) | Uses original classification from national accounts plus aggregation. | Uses original classification from national accounts plus aggregation |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
| **For the practicality of use, the following rows present the availability of the models currently, historically and in the future:** |
| **Accessibility** |  | Free downloadable SIOT as Excel files at 64 products level. Footprint is calculated on commission. | Licence fee payable (~£3000); data contained within proprietary software but extractable to Excel |  | Free; downloadable as txt files | Free, downloadable as Excel files | ?? |  |
| **Latest Available Year** |  | 2013 | 2011 | 2012 | 2011 | 2011 | 2011 |  |
| **Availability of economic data** |  | 2008-2013 | In GTAP 9 three reference years are available 2004, 2007 and 2011 | 1990–2011 (economic data) | 1995 to 2014 | 1995–2011  |  2008-2011 |  |
| **Availability of****environmental data** |  | 2008-2013 | 2004, 2007 and 2011 (energy data) | 1990–2010 (environmental extensions) |  | 1995–2009  | 2008-2011 |  |
| **Historical results time series** |  | 1993-2008 in NACErev1.1 2008-2013 in NACErev2. | 1990, 1992, 1995, 1997, 2001, 2004, 2007 (all years are not comparable). Harmonised 2004, 2007 and 2011 for comparison | 1990-2011 | 1995-2011 | Yearly 1995-2009 | 1995, 2000, 2005, 2008-2011 |  |
|  |  |  |  |  |  |  |  |  |
| **Main sources:** |  |  | [[12]](#footnote-13) | [[13]](#footnote-14) | [[14]](#footnote-15) | [[15]](#footnote-16) | [[16]](#footnote-17) |  |

Table 10 MRIO and IO model features, adapted from (Owen et al., 2014; West et al., 2013).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Measurement Units** | Statistics Sweden MISSING | **EORA (2012)** | **WIOD (2009)** | **GTAP (2011)** | **OECD (2011)** | **EXIOBASE3 (2011)** |
| Total Swedish final demand | US$ apart from EXIOBASE in Euros??? | 0 | 513,275  | 350,589  | 463,837 | 461,210  | 536,569  |
| Total global final demand | US$ apart from EXIOBASE in Euros??? | 0 | 72,827,610  | 56,840,290  | 67,902,360  | 66,650,850  | 72,738,020  |
| Total Swedish final demand, as % of global total |  | 0 | 0.70% | 0.62% | 0.68% | 0.69% | 0.74% |
| Total global GHG emissions  | Kilograms (Kg) | 0 | N/A | 39,616,080,000,000  | 41,489,770,000,000  | N/A | 42,271,140,000,000  |
| Total global CO2 emissions  | Kilograms (Kg) |  | 37,295,430,000,000  | 27,199,720,000,000  | N/A | 29,588,390,000,000 | 33,099,770,000,000  |
| **Total Swedish production-based impacts, by indicator** |  | 0 |  |  |  |  |  |
| Employment | 1000 people | 0 | 4,159  | 7,147  | N/A | 4,594  | 4,604  |
| Domestic Extraction | Kilo tonnes (Kt) | 0 | 122,988  | 192,130  | N/A | N/A | 209,546  |
| Water Consumption Blue – Total|Mm3|| | Million cubic meters (Mm3) | 0 |  623  |  N/A | N/A | N/A |  469  |
| GHG emissions (GWP100)|kg CO2 eq.|Problem oriented approach: baseline (CML, 2001)|GWP100 (IPCC, 2007) | Kilograms of carbon dioxide equivalents (Kg CO2 eq) | 0 | N/A | 71,978,010,000  | 68,843,640,000  | 52,095,870,000  | 56,699,670,000  |
| Swedish domestic carbon dioxide emissions IPCC categories 1 to 4 and 6 to 7 (excl land use, land use change and forestry) | Kilogams of carbon dioxide (Kg CO2) | 0 | 49,551,080,000  | 53,082,150,000  |  | N/A | 48,781,080,000  |
| Methane (CH4) IPCC categories 1 to 4 and 6 to 7 (excl land use, land use change and forestry) | Kg CO2 eq | 0 |  | 6,791,751,000  | 13,392,700,000  | N/A | 4,296,780,000  |
| Nitrous Oxide (N2O) IPCC categories 1 to 4 and 6 to 7 (excl land use, land use change and forestry)|Kg CO2-eq|| | Kg CO2 eq | 0 |  | 7,333,892,000  | 7,216,258,000  | N/A | 3,464,605,000  |
| Carbon dioxide from fuel combustion  | Kg CO2 | 0 | 43,724,640,000 (2012)46,270,020,000 (2011 for comparison)  | 53,082,150,000  | 47,020,060,000  | 52,095,870,000  | 46,239,800,000  |
| Value Added|M.USD|| |  | 0 | 492,039  | 353,702  |  | 489,329  |  |
| Value Added|M.EUR|| |  | 0 |  |  |  |  | 529,905  |

Table 11 Macro economic and environmental pressure data global totals and Swedish domestic (production-based) data per model

## Policy implications

* The follow-up needs to decide what model to use and understand the implications of the choice.
* What can be taken from the results comparison: trends similar, the decision of which model to use, the usefulness of MRIO, more accessible information about MRIO and how they are developed/can be developed in-house by statistics agencies?
* Data and indicators currently available, difficulties faced by policy-makers when models show different results, limited comparisons available as different models have been developed in different places independently
	+ What can we say about consumption-based indicators and their uses
	+ What can be done with these indicators

*The choice of appropriate MRIO is not always simple, and depends on the aims of the project (Hoekstra et al. 2013). As Table 11 showed, there is reasonable agreement between the data used in the models, however it is clear from this and numerous other studies (REFS) that efforts must be made to support consistent data collection and reporting internationally in order for models such as MRIO to draw on consistent input datasets.*

* How this information helps in targeting policies or targeting future research
* Plans in Sweden for development and application of indicators in the future

## Limitations

* Data and model restrictions
* More streamlined approaches, collaboration and data sharing mean that we can complete comparisons, but reasons for variations are difficult to unpick as the models are large and complex, with many data sources and transformations

# Conclusion

* Next steps, what this implies for future MRIO development and country-level analysis generally (not just Swedish case)

Acknowledgements: This work was funded by the Swedish EPA under the PRINCE project, grant #XXX.

# Annex

The composition of each of the environmental and social footprints:

## Material Footprint

|  |  |
| --- | --- |
| **Material** | **Units** |
| Domestic Extraction Used - Crop residues - Feed | Kt |
| Domestic Extraction Used - Crop residues - Straw | Kt |
| Domestic Extraction Used - Fishery - Aquatic plants | Kt |
| Domestic Extraction Used - Fishery - Inland waters fish catch | Kt |
| Domestic Extraction Used - Fishery - Marine fish catch | Kt |
| Domestic Extraction Used - Fishery - Other (e.g. Aquatic mammals) | Kt |
| Domestic Extraction Used - Fodder crops - Alfalfa for Forage and Silage | Kt |
| Domestic Extraction Used - Fodder crops - Beets for Fodder | Kt |
| Domestic Extraction Used - Fodder crops - Cabbage for Fodder | Kt |
| Domestic Extraction Used - Fodder crops - Carrots for Fodder | Kt |
| Domestic Extraction Used - Fodder crops - Clover for Forage and Silage | Kt |
| Domestic Extraction Used - Fodder crops - Forage Products nec | Kt |
| Domestic Extraction Used - Fodder crops - Grasses nec for Forage and Silage | Kt |
| Domestic Extraction Used - Fodder crops - Green Oilseeds for Fodder | Kt |
| Domestic Extraction Used - Fodder crops - Leguminous nec for forage and Silage | Kt |
| Domestic Extraction Used - Fodder crops - Maize for Forage and Silage | Kt |
| Domestic Extraction Used - Fodder crops - Other grasses | Kt |
| Domestic Extraction Used - Fodder crops - Rye Grass, Forage and Silage | Kt |
| Domestic Extraction Used - Fodder crops - Sorghum for Forage and Silage | Kt |
| Domestic Extraction Used - Fodder crops - Swedes for Fodder | Kt |
| Domestic Extraction Used - Fodder crops - Turnips for Fodder | Kt |
| Domestic Extraction Used - Fodder crops - Vegetables and Roots, Fodder | Kt |
| Domestic Extraction Used - Forestry - Coniferous wood - Industrial roundwood | Kt |
| Domestic Extraction Used - Forestry - Coniferous wood - Wood fuel | Kt |
| Domestic Extraction Used - Forestry - Kapok Fruit | Kt |
| Domestic Extraction Used - Forestry - Natural Gums | Kt |
| Domestic Extraction Used - Forestry - Non-coniferous wood - Industrial roundwood | Kt |
| Domestic Extraction Used - Forestry - Non-coniferous wood - Wood fuel | Kt |
| Domestic Extraction Used - Forestry - Raw materials other than wood | Kt |
| Domestic Extraction Used - Fossil Fuels - Anthracite | Kt |
| Domestic Extraction Used - Fossil Fuels - Coking coal | Kt |
| Domestic Extraction Used - Fossil Fuels - Crude oil | Kt |
| Domestic Extraction Used - Fossil Fuels - Lignite/brown coal | Kt |
| Domestic Extraction Used - Fossil Fuels - Natural gas | Kt |
| Domestic Extraction Used - Fossil Fuels - Natural gas liquids | Kt |
| Domestic Extraction Used - Fossil Fuels - Oil shale and oil sands | Kt |
| Domestic Extraction Used - Fossil Fuels - Other bituminous coal | Kt |
| Domestic Extraction Used - Fossil Fuels - Other hydrocarbons | Kt |
| Domestic Extraction Used - Fossil Fuels - Peat | Kt |
| Domestic Extraction Used - Fossil Fuels - Sub-bituminous coal | Kt |
| Domestic Extraction Used - Grazing | Kt |
| Domestic Extraction Used - Metal Ores - Bauxite and aluminium ores | Kt |
| Domestic Extraction Used - Metal Ores - Copper ores | Kt |
| Domestic Extraction Used - Metal Ores - Gold ores | Kt |
| Domestic Extraction Used - Metal Ores - Iron ores | Kt |
| Domestic Extraction Used - Metal Ores - Lead ores | Kt |
| Domestic Extraction Used - Metal Ores - Nickel ores | Kt |
| Domestic Extraction Used - Metal Ores - Other non-ferrous metal ores | Kt |
| Domestic Extraction Used - Metal Ores - PGM ores | Kt |
| Domestic Extraction Used - Metal Ores - Silver ores | Kt |
| Domestic Extraction Used - Metal Ores - Tin ores | Kt |
| Domestic Extraction Used - Metal Ores - Uranium and thorium ores | Kt |
| Domestic Extraction Used - Metal Ores - Zinc ores | Kt |
| Domestic Extraction Used - Non-Metallic Minerals - Building stones | Kt |
| Domestic Extraction Used - Non-Metallic Minerals - Chemical and fertilizer minerals | Kt |
| Domestic Extraction Used - Non-Metallic Minerals - Clays and kaolin | Kt |
| Domestic Extraction Used - Non-Metallic Minerals - Gravel and sand | Kt |
| Domestic Extraction Used - Non-Metallic Minerals - Limestone, gypsum, chalk, dolomite | Kt |
| Domestic Extraction Used - Non-Metallic Minerals - Other minerals | Kt |
| Domestic Extraction Used - Non-Metallic Minerals - Salt | Kt |
| Domestic Extraction Used - Non-Metallic Minerals - Slate | Kt |
| Domestic Extraction Used - Primary Crops - Kapokseed in Shell | Kt |
| Domestic Extraction Used - Primary Crops - Honey | Kt |
| Domestic Extraction Used - Primary Crops - Beeswax | Kt |
| Domestic Extraction Used - Primary Crops - Abaca | Kt |
| Domestic Extraction Used - Primary Crops - Agave Fibres nes | Kt |
| Domestic Extraction Used - Primary Crops - Almonds | Kt |
| Domestic Extraction Used - Primary Crops - Anise, Badian, Fennel | Kt |
| Domestic Extraction Used - Primary Crops - Apples | Kt |
| Domestic Extraction Used - Primary Crops - Apricots | Kt |
| Domestic Extraction Used - Primary Crops - Arecanuts | Kt |
| Domestic Extraction Used - Primary Crops - Artichokes | Kt |
| Domestic Extraction Used - Primary Crops - Asparagus | Kt |
| Domestic Extraction Used - Primary Crops - Avocados | Kt |
| Domestic Extraction Used - Primary Crops - Bambara beans | Kt |
| Domestic Extraction Used - Primary Crops - Bananas | Kt |
| Domestic Extraction Used - Primary Crops - Barley | Kt |
| Domestic Extraction Used - Primary Crops - Beans, dry | Kt |
| Domestic Extraction Used - Primary Crops - Beans, green | Kt |
| Domestic Extraction Used - Primary Crops - Berries nec | Kt |
| Domestic Extraction Used - Primary Crops - Blueberries | Kt |
| Domestic Extraction Used - Primary Crops - Brazil nuts, with shell | Kt |
| Domestic Extraction Used - Primary Crops - Broad beans, horse beans, dry | Kt |
| Domestic Extraction Used - Primary Crops - Buckwheat | Kt |
| Domestic Extraction Used - Primary Crops - Cabbages | Kt |
| Domestic Extraction Used - Primary Crops - Canary Seed | Kt |
| Domestic Extraction Used - Primary Crops - Carobs | Kt |
| Domestic Extraction Used - Primary Crops - Carrots | Kt |
| Domestic Extraction Used - Primary Crops - Cashew nuts, with shell | Kt |
| Domestic Extraction Used - Primary Crops - Cashewapple | Kt |
| Domestic Extraction Used - Primary Crops - Cassava | Kt |
| Domestic Extraction Used - Primary Crops - Cassava leaves | Kt |
| Domestic Extraction Used - Primary Crops - Castor oil seed | Kt |
| Domestic Extraction Used - Primary Crops - Cauliflower | Kt |
| Domestic Extraction Used - Primary Crops - Cereals nec | Kt |
| Domestic Extraction Used - Primary Crops - Cherries | Kt |
| Domestic Extraction Used - Primary Crops - Chestnuts | Kt |
| Domestic Extraction Used - Primary Crops - Chick peas | Kt |
| Domestic Extraction Used - Primary Crops - Chicory Roots | Kt |
| Domestic Extraction Used - Primary Crops - Chillies and peppers, dry | Kt |
| Domestic Extraction Used - Primary Crops - Chillies and peppers, green | Kt |
| Domestic Extraction Used - Primary Crops - Cinnamon | Kt |
| Domestic Extraction Used - Primary Crops - Citrus Fruit nec | Kt |
| Domestic Extraction Used - Primary Crops - Cloves | Kt |
| Domestic Extraction Used - Primary Crops - Cocoa Beans | Kt |
| Domestic Extraction Used - Primary Crops - Coconuts | Kt |
| Domestic Extraction Used - Primary Crops - Coffee, Green | Kt |
| Domestic Extraction Used - Primary Crops - Coir | Kt |
| Domestic Extraction Used - Primary Crops - Cotton Lint | Kt |
| Domestic Extraction Used - Primary Crops - Cottonseed | Kt |
| Domestic Extraction Used - Primary Crops - Cow peas, dry | Kt |
| Domestic Extraction Used - Primary Crops - Cranberries | Kt |
| Domestic Extraction Used - Primary Crops - Cucumbers and Gherkins | Kt |
| Domestic Extraction Used - Primary Crops - Currants | Kt |
| Domestic Extraction Used - Primary Crops - Dates | Kt |
| Domestic Extraction Used - Primary Crops - Eggplants | Kt |
| Domestic Extraction Used - Primary Crops - Fibre Crops nes | Kt |
| Domestic Extraction Used - Primary Crops - Figs | Kt |
| Domestic Extraction Used - Primary Crops - Flax Fibre and Tow | Kt |
| Domestic Extraction Used - Primary Crops - Fonio | Kt |
| Domestic Extraction Used - Primary Crops - Fruit Fresh Nes | Kt |
| Domestic Extraction Used - Primary Crops - Fruit, tropical fresh nes | Kt |
| Domestic Extraction Used - Primary Crops - Garlic | Kt |
| Domestic Extraction Used - Primary Crops - Ginger | Kt |
| Domestic Extraction Used - Primary Crops - Gooseberries | Kt |
| Domestic Extraction Used - Primary Crops - Grapefruit and Pomelos | Kt |
| Domestic Extraction Used - Primary Crops - Grapes | Kt |
| Domestic Extraction Used - Primary Crops - Groundnuts in Shell | Kt |
| Domestic Extraction Used - Primary Crops - Hazelnuts | Kt |
| Domestic Extraction Used - Primary Crops - Hemp Fibre and Tow | Kt |
| Domestic Extraction Used - Primary Crops - Hempseed | Kt |
| Domestic Extraction Used - Primary Crops - Hops | Kt |
| Domestic Extraction Used - Primary Crops - Jojoba Seeds | Kt |
| Domestic Extraction Used - Primary Crops - Jute and Jute-like Fibres | Kt |
| Domestic Extraction Used - Primary Crops - Kapok Fibre | Kt |
| Domestic Extraction Used - Primary Crops - Karite Nuts | Kt |
| Domestic Extraction Used - Primary Crops - Kiwi Fruit | Kt |
| Domestic Extraction Used - Primary Crops - Kolanuts | Kt |
| Domestic Extraction Used - Primary Crops - Leeks and other Alliac. Veg. | Kt |
| Domestic Extraction Used - Primary Crops - Leguminous vegetables, nes | Kt |
| Domestic Extraction Used - Primary Crops - Lemons and Limes | Kt |
| Domestic Extraction Used - Primary Crops - Lentils | Kt |
| Domestic Extraction Used - Primary Crops - Lettuce | Kt |
| Domestic Extraction Used - Primary Crops - Linseed | Kt |
| Domestic Extraction Used - Primary Crops - Lupins | Kt |
| Domestic Extraction Used - Primary Crops - Maize | Kt |
| Domestic Extraction Used - Primary Crops - Maize, green | Kt |
| Domestic Extraction Used - Primary Crops - Mangoes, mangosteens, guavas | Kt |
| Domestic Extraction Used - Primary Crops - Mate | Kt |
| Domestic Extraction Used - Primary Crops - Melonseed | Kt |
| Domestic Extraction Used - Primary Crops - Millet | Kt |
| Domestic Extraction Used - Primary Crops - Mixed Grain | Kt |
| Domestic Extraction Used - Primary Crops - Mushrooms | Kt |
| Domestic Extraction Used - Primary Crops - Mustard Seed | Kt |
| Domestic Extraction Used - Primary Crops - Natural Rubber | Kt |
| Domestic Extraction Used - Primary Crops - Nutmeg, mace and cardamoms | Kt |
| Domestic Extraction Used - Primary Crops - Nuts, nes | Kt |
| Domestic Extraction Used - Primary Crops - Oats | Kt |
| Domestic Extraction Used - Primary Crops - Oil Palm Fruit | Kt |
| Domestic Extraction Used - Primary Crops - Oilseeds nec | Kt |
| Domestic Extraction Used - Primary Crops - Okra | Kt |
| Domestic Extraction Used - Primary Crops - Olives | Kt |
| Domestic Extraction Used - Primary Crops - Onions | Kt |
| Domestic Extraction Used - Primary Crops - Onions, dry | Kt |
| Domestic Extraction Used - Primary Crops - Oranges | Kt |
| Domestic Extraction Used - Primary Crops - Other Bastfibres | Kt |
| Domestic Extraction Used - Primary Crops - Other melons | Kt |
| Domestic Extraction Used - Primary Crops - Papayas | Kt |
| Domestic Extraction Used - Primary Crops - Peaches and Nectarines | Kt |
| Domestic Extraction Used - Primary Crops - Pears | Kt |
| Domestic Extraction Used - Primary Crops - Peas, Green | Kt |
| Domestic Extraction Used - Primary Crops - Peas, dry | Kt |
| Domestic Extraction Used - Primary Crops - Pepper | Kt |
| Domestic Extraction Used - Primary Crops - Peppermint | Kt |
| Domestic Extraction Used - Primary Crops - Persimmons | Kt |
| Domestic Extraction Used - Primary Crops - Pigeon peas | Kt |
| Domestic Extraction Used - Primary Crops - Pineapples | Kt |
| Domestic Extraction Used - Primary Crops - Pistachios | Kt |
| Domestic Extraction Used - Primary Crops - Plantains | Kt |
| Domestic Extraction Used - Primary Crops - Plums | Kt |
| Domestic Extraction Used - Primary Crops - Pome fruit, nes | Kt |
| Domestic Extraction Used - Primary Crops - Poppy Seed | Kt |
| Domestic Extraction Used - Primary Crops - Potatoes | Kt |
| Domestic Extraction Used - Primary Crops - Pulses nec | Kt |
| Domestic Extraction Used - Primary Crops - Pumpkins, Squash, Gourds | Kt |
| Domestic Extraction Used - Primary Crops - Pyrethrum, Dried Flowers | Kt |
| Domestic Extraction Used - Primary Crops - Quinces | Kt |
| Domestic Extraction Used - Primary Crops - Quinoa | Kt |
| Domestic Extraction Used - Primary Crops - Ramie | Kt |
| Domestic Extraction Used - Primary Crops - Rapeseed | Kt |
| Domestic Extraction Used - Primary Crops - Raspberries | Kt |
| Domestic Extraction Used - Primary Crops - Rice | Kt |
| Domestic Extraction Used - Primary Crops - Roots and Tubers, nes | Kt |
| Domestic Extraction Used - Primary Crops - Rye | Kt |
| Domestic Extraction Used - Primary Crops - Safflower Seed | Kt |
| Domestic Extraction Used - Primary Crops - Sesame Seed | Kt |
| Domestic Extraction Used - Primary Crops - Sisal | Kt |
| Domestic Extraction Used - Primary Crops - Sorghum | Kt |
| Domestic Extraction Used - Primary Crops - Sour Cherries | Kt |
| Domestic Extraction Used - Primary Crops - Soybeans | Kt |
| Domestic Extraction Used - Primary Crops - Spices nec | Kt |
| Domestic Extraction Used - Primary Crops - Spinach | Kt |
| Domestic Extraction Used - Primary Crops - Stone Fruit nec, | Kt |
| Domestic Extraction Used - Primary Crops - Strawberries | Kt |
| Domestic Extraction Used - Primary Crops - String beans | Kt |
| Domestic Extraction Used - Primary Crops - Sugar Beets | Kt |
| Domestic Extraction Used - Primary Crops - Sugar Cane | Kt |
| Domestic Extraction Used - Primary Crops - Sugar Crops nes | Kt |
| Domestic Extraction Used - Primary Crops - Sunflower Seed | Kt |
| Domestic Extraction Used - Primary Crops - Sweet Potatoes | Kt |
| Domestic Extraction Used - Primary Crops - Tallowtree Seeds | Kt |
| Domestic Extraction Used - Primary Crops - Tang. Mand Clement. Satsma | Kt |
| Domestic Extraction Used - Primary Crops - Taro | Kt |
| Domestic Extraction Used - Primary Crops - Tea | Kt |
| Domestic Extraction Used - Primary Crops - Tea nes | Kt |
| Domestic Extraction Used - Primary Crops - Tobacco Leaves | Kt |
| Domestic Extraction Used - Primary Crops - Tomatoes | Kt |
| Domestic Extraction Used - Primary Crops - Triticale | Kt |
| Domestic Extraction Used - Primary Crops - Tung Nuts | Kt |
| Domestic Extraction Used - Primary Crops - Vanilla | Kt |
| Domestic Extraction Used - Primary Crops - Vegetables Fresh nec | Kt |
| Domestic Extraction Used - Primary Crops - Vetches | Kt |
| Domestic Extraction Used - Primary Crops - Walnuts | Kt |
| Domestic Extraction Used - Primary Crops - Watermelons | Kt |
| Domestic Extraction Used - Primary Crops - Wheat | Kt |
| Domestic Extraction Used - Primary Crops - Yams | Kt |
| Domestic Extraction Used - Primary Crops - Yautia | Kt |

## Water Footprint

TO ADD

## Carbon footprint of fossil fuel combustion

TO ADD

## Carbon footprint of greenhouse gases

Global warming potentials are used across the databases based on AR4, IPCC 2007

|  |  |  |
| --- | --- | --- |
| CO2 | 1 |  |
| CH4 | 25 |  |
| N20 | 298 |  |
| SF6 | 22800 |  |

EXIOBASE:

|  |
| --- |
| CO2 - combustion - air|air|kg |
| CH4 - combustion - air|air|kg |
| N2O - combustion - air|air|kg |
| CH4 - non combustion - Extraction/production of (natural) gas - air|air|kg |
| CH4 - non combustion - Extraction/production of crude oil - air|air|kg |
| CH4 - non combustion - Mining of antracite - air|air|kg |
| CH4 - non combustion - Mining of bituminous coal - air|air|kg |
| CH4 - non combustion - Mining of coking coal - air|air|kg |
| CH4 - non combustion - Mining of lignite (brown coal) - air|air|kg |
| CH4 - non combustion - Mining of sub-bituminous coal - air|air|kg |
| CH4 - non combustion - Oil refinery - air|air|kg |
| CO2 - non combustion - Cement production - air|air|kg |
| CO2 - non combustion - Lime production - air|air|kg |
| SF6 - air|air|kg |
| CH4 - agriculture - air|air|kg |
| CO2 - agriculture - peat decay - air|air|kg |
| N2O - agriculture - air|air|kg |
| CH4 - waste - air|air|kg |
| CO2 - waste - biogenic - air|air|kg |
| CO2 - waste - fossil - air|air|kg |

GTAP:

|  |
| --- |
| 'CO2 -coa' |
| 'CO2 -oil' |
| 'CO2 -gas' |
| 'CO2 -p\_c' |
| 'CO2 -gdt' |

WIOD:

|  |
| --- |
| CO2;HCOAL () |
| CO2;BCOAL () |
| CO2;COKE () |
| CO2;CRUDE () |
| CO2;DIESEL () |
| CO2;GASOLINE () |
| CO2;JETFUEL () |
| CO2;LFO () |
| CO2;HFO () |
| CO2;NAPHTA () |
| CO2;OTHPETRO () |
| CO2;NATGAS () |
| CO2;OTHGAS () |
| CO2;WASTE () |
| CO2;BIOGASOL () |
| CO2;BIODIESEL () |
| CO2;BIOGAS () |
| CO2;OTHRENEW () |
| CO2;ELECTR () |
| CO2;HEATPROD () |
| CO2;NUCLEAR () |
| CO2;HYDRO () |
| CO2;GEOTHERM () |
| CO2;SOLAR () |
| CO2;WIND () |
| CO2;OTHSOURC () |
| CO2;NonENERGY () |
| CO2;StatDiff () |
| AIR;CH4 () |
| AIR;N2O () |

Eora:

|  |
| --- |
| CO2 (Gg) - Public electricity and heat production |
| CO2 (Gg) - Other Energy Industries |
| CO2 (Gg) - Manufacturing Industries and Construction |
| CO2 (Gg) - Domestic aviation |
| CO2 (Gg) - Road transportation |
| CO2 (Gg) - Rail transportation |
| CO2 (Gg) - Inland navigation |
| CO2 (Gg) - Other transportation |
| CO2 (Gg) - Residential and other sectors |
| CO2 (Gg) - Fugitive emissions from solid fuels |
| CO2 (Gg) - Fugitive emissions from oil and gas |
| CO2 (Gg) - Memo: International aviation |
| CO2 (Gg) - Memo: International navigation |
| CO2 (Gg) - Production of minerals |
| CO2 (Gg) - Cement production |
| CO2 (Gg) - Lime production |
| CO2 (Gg) - Production of chemicals |
| CO2 (Gg) - Production of metals |
| CO2 (Gg) - Production of pulp/paper/food/drink |
| CO2 (Gg) - Production of halocarbons and SF6 |
| CO2 (Gg) - Refrigeration and Air Conditioning |
| CO2 (Gg) - Foam Blowing |
| CO2 (Gg) - Fire Extinguishers |
| CO2 (Gg) - Aerosols |
| CO2 (Gg) - F-gas as Solvent |
| CO2 (Gg) - Semiconductor/Electronics Manufacture |
| CO2 (Gg) - Electrical Equipment |
| CO2 (Gg) - Other F-gas use |
| CO2 (Gg) - Non-energy use of lubricants/waxes (CO2) |
| CO2 (Gg) - Solvent and other product use: paint |
| CO2 (Gg) - Solvent and other product use: degrease |
| CO2 (Gg) - Solvent and other product use: chemicals |
| CO2 (Gg) - Solvent and other product use: other |
| CO2 (Gg) - Enteric fermentation |
| CO2 (Gg) - Manure management |
| CO2 (Gg) - Rice cultivation |
| CO2 (Gg) - Direct soil emissions |
| CO2 (Gg) - Manure in pasture/range/paddock |
| CO2 (Gg) - Indirect N2O from agriculture |
| CO2 (Gg) - Other direct soil emissions |
| CO2 (Gg) - Solid waste disposal on land |
| CO2 (Gg) - Wastewater handling |
| CO2 (Gg) - Waste incineration |
| CO2 (Gg) - Other waste handling |
| CO2 (Gg) - Fossil fuel fires |
| CO2 (Gg) - Other sources |
| GHG-CH4 (Gg) - Public electricity and heat production |
| GHG-CH4 (Gg) - Other Energy Industries |
| GHG-CH4 (Gg) - Manufacturing Industries and Construction |
| GHG-CH4 (Gg) - Domestic aviation |
| GHG-CH4 (Gg) - Road transportation |
| GHG-CH4 (Gg) - Rail transportation |
| GHG-CH4 (Gg) - Inland navigation |
| GHG-CH4 (Gg) - Other transportation |
| GHG-CH4 (Gg) - Residential and other sectors |
| GHG-CH4 (Gg) - Fugitive emissions from solid fuels |
| GHG-CH4 (Gg) - Fugitive emissions from oil and gas |
| GHG-CH4 (Gg) - Memo: International aviation |
| GHG-CH4 (Gg) - Memo: International navigation |
| GHG-CH4 (Gg) - Production of minerals |
| GHG-CH4 (Gg) - Cement production |
| GHG-CH4 (Gg) - Lime production |
| GHG-CH4 (Gg) - Production of chemicals |
| GHG-CH4 (Gg) - Production of metals |
| GHG-CH4 (Gg) - Production of pulp/paper/food/drink |
| GHG-CH4 (Gg) - Production of halocarbons and SF6 |
| GHG-CH4 (Gg) - Refrigeration and Air Conditioning |
| GHG-CH4 (Gg) - Foam Blowing |
| GHG-CH4 (Gg) - Fire Extinguishers |
| GHG-CH4 (Gg) - Aerosols |
| GHG-CH4 (Gg) - F-gas as Solvent |
| GHG-CH4 (Gg) - Semiconductor/Electronics Manufacture |
| GHG-CH4 (Gg) - Electrical Equipment |
| GHG-CH4 (Gg) - Other F-gas use |
| GHG-CH4 (Gg) - Non-energy use of lubricants/waxes (CO2) |
| GHG-CH4 (Gg) - Solvent and other product use: paint |
| GHG-CH4 (Gg) - Solvent and other product use: degrease |
| GHG-CH4 (Gg) - Solvent and other product use: chemicals |
| GHG-CH4 (Gg) - Solvent and other product use: other |
| GHG-CH4 (Gg) - Enteric fermentation |
| GHG-CH4 (Gg) - Manure management |
| GHG-CH4 (Gg) - Rice cultivation |
| GHG-CH4 (Gg) - Direct soil emissions |
| GHG-CH4 (Gg) - Manure in pasture/range/paddock |
| GHG-CH4 (Gg) - Indirect N2O from agriculture |
| GHG-CH4 (Gg) - Other direct soil emissions |
| GHG-CH4 (Gg) - Savanna burning |
| GHG-CH4 (Gg) - Solid waste disposal on land |
| GHG-CH4 (Gg) - Wastewater handling |
| GHG-CH4 (Gg) - Waste incineration |
| GHG-CH4 (Gg) - Other waste handling |
| GHG-CH4 (Gg) - Fossil fuel fires |
| GHG-CH4 (Gg) - Indirect N2O from non-agricultural NOx |
| GHG-CH4 (Gg) - Indirect N2O from non-agricultural NH3 |
| GHG-CH4 (Gg) - Other sources |
| GHG-N2O (Gg) - Public electricity and heat production |
| GHG-N2O (Gg) - Other Energy Industries |
| GHG-N2O (Gg) - Manufacturing Industries and Construction |
| GHG-N2O (Gg) - Domestic aviation |
| GHG-N2O (Gg) - Road transportation |
| GHG-N2O (Gg) - Rail transportation |
| GHG-N2O (Gg) - Inland navigation |
| GHG-N2O (Gg) - Other transportation |
| GHG-N2O (Gg) - Residential and other sectors |
| GHG-N2O (Gg) - Fugitive emissions from solid fuels |
| GHG-N2O (Gg) - Fugitive emissions from oil and gas |
| GHG-N2O (Gg) - Memo: International aviation |
| GHG-N2O (Gg) - Memo: International navigation |
| GHG-N2O (Gg) - Production of minerals |
| GHG-N2O (Gg) - Cement production |
| GHG-N2O (Gg) - Lime production |
| GHG-N2O (Gg) - Production of chemicals |
| GHG-N2O (Gg) - Production of metals |
| GHG-N2O (Gg) - Production of pulp/paper/food/drink |
| GHG-N2O (Gg) - Production of halocarbons and SF6 |
| GHG-N2O (Gg) - Refrigeration and Air Conditioning |
| GHG-N2O (Gg) - Foam Blowing |
| GHG-N2O (Gg) - Fire Extinguishers |
| GHG-N2O (Gg) - Aerosols |
| GHG-N2O (Gg) - F-gas as Solvent |
| GHG-N2O (Gg) - Semiconductor/Electronics Manufacture |
| GHG-N2O (Gg) - Electrical Equipment |
| GHG-N2O (Gg) - Other F-gas use |
| GHG-N2O (Gg) - Non-energy use of lubricants/waxes (CO2) |
| GHG-N2O (Gg) - Solvent and other product use: paint |
| GHG-N2O (Gg) - Solvent and other product use: degrease |
| GHG-N2O (Gg) - Solvent and other product use: chemicals |
| GHG-N2O (Gg) - Solvent and other product use: other |
| GHG-N2O (Gg) - Enteric fermentation |
| GHG-N2O (Gg) - Manure management |
| GHG-N2O (Gg) - Rice cultivation |
| GHG-N2O (Gg) - Direct soil emissions |
| GHG-N2O (Gg) - Manure in pasture/range/paddock |
| GHG-N2O (Gg) - Indirect N2O from agriculture |
| GHG-N2O (Gg) - Other direct soil emissions |
| GHG-N2O (Gg) - Savanna burning |
| GHG-N2O (Gg) - Solid waste disposal on land |
| GHG-N2O (Gg) - Wastewater handling |
| GHG-N2O (Gg) - Waste incineration |
| GHG-N2O (Gg) - Other waste handling |
| GHG-N2O (Gg) - Fossil fuel fires |
| GHG-N2O (Gg) - Indirect N2O from non-agricultural NOx |
| GHG-N2O (Gg) - Indirect N2O from non-agricultural NH3 |
| GHG-N2O (Gg) - Other sources |

## Employment footprint

TO ADD

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# Ecological Economics Guidelines

Abstract

A concise and factual abstract is required. The abstract should state briefly the purpose of the research, the principal results and major conclusions. An abstract is often presented separately from the article, so it must be able to stand alone. For this reason, References should be avoided, but if essential, then cite the author(s) and year(s). Also, non-standard or uncommon abbreviations should be avoided, but if essential they must be defined at their first mention in the abstract itself.

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Immediately after the abstract, provide a maximum of 6 keywords, using British spelling and avoiding general and plural terms and multiple concepts (avoid, for example, 'and', 'of'). Be sparing with abbreviations: only abbreviations firmly established in the field may be eligible. These keywords will be used for indexing purposes.

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Formatting of funding sources

List funding sources in this standard way to facilitate compliance to funder's requirements:

Funding: This work was supported by the National Institutes of Health [grant numbers xxxx, yyyy]; the Bill & Melinda Gates Foundation, Seattle, WA [grant number zzzz]; and the United States Institutes of Peace [grant number aaaa]. It is not necessary to include detailed descriptions on the program or type of grants and awards. When funding is from a block grant or other resources available to a university, college, or other research institution, submit the name of the institute or organization that provided the funding. If no funding has been provided for the research, please include the following sentence:

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Figure captions

Ensure that each illustration has a caption. A caption should comprise a brief title (not on the figure itself) and a description of the illustration. Keep text in the illustrations themselves to a minimum but explain all symbols and abbreviations used.

Tables

1. Number tables consecutively in accordance with their appearance in the text. Place footnotes to tables below the table body and indicate them with superscript lowercase letters. Avoid vertical rules.
2. Be sparing in the use of tables and ensure that the data presented in tables do not duplicate results described elsewhere in the article. Large tables should be avoided. Reversing columns and rows will often reduce the dimensions of a table.
3. If many data are to be presented, an attempt should be made to divide them over two or more tables.
4. Each table should be typewritten on a separate page of the manuscript. Tables should never be included in the text.
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6. Column headings should be brief, but sufficiently explanatory. Standard abbreviations of units of measurement should be added between parentheses.

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**Text: All citations in the text should refer to:**

1. Single author: the author's name (without initials, unless there is ambiguity) and the year of publication;
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Citations may be made directly (or parenthetically). Groups of references should be listed first alphabetically, then chronologically.

Examples: 'as demonstrated (Allan, 2000a, 2000b, 1999; Allan and Jones, 1999). Kramer et al.

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Reference to a journal publication: Van der Geer, J., Hanraads, J.A.J., Lupton, R.A., 2010. The art of writing a scientific article. J. Sci. Commun. 163, 51–59.

Reference to a book: Strunk Jr., W., White, E.B., 2000. The Elements of Style, fourth ed. Longman, New York.

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Cancer Research UK, 1975. Cancer statistics reports for the UK. <http://www.cancerresearchuk.org/> aboutcancer/statistics/cancerstatsreport/ (accessed 13.03.03).

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1. © 2016 Global Footprint Network. National Footprint Accounts, 2016 Edition. Please contact Global Footprint Network at data@footprintnetwork.org for more information. [↑](#footnote-ref-2)
2. LCA data is been used for disaggregation on original SUTs [↑](#footnote-ref-3)
3. Production based emissions includes emissions from industries and direct emissions from households, and government sectors. [↑](#footnote-ref-4)
4. Including emissions from processes [↑](#footnote-ref-5)
5. Excluding emissions from processes [↑](#footnote-ref-6)
6. SCB(1) includes emissions from processes and SCB(2) excludes emissions from processes [↑](#footnote-ref-7)
7. SCB(1) includes emissions from processes and SCB(2) excludes emissions from processes [↑](#footnote-ref-8)
8. SCB(1) includes emissions from processes and SCB(2) excludes emissions from processes [↑](#footnote-ref-9)
9. As noted above, ‘rest of world’ includes all those countries in the MRIO models that are not part of the 40 reported at this level of aggregation (see section 2.6). [↑](#footnote-ref-10)
10. (1) the way that imports in the supply table are allocated to the different demand components (intermediate, investments and final demand) and (2) how margins are dealt with for conversion between purchasers and basic prices [↑](#footnote-ref-11)
11. <http://www.oneplaneteconomynetwork.org/> [↑](#footnote-ref-12)
12. Angel, A., Narayanan, B.,McDougall, R.. 2016 [↑](#footnote-ref-13)
13. Lenzen, M., Moran, D., Kanemoto, K., Geschke, A., 2013) [↑](#footnote-ref-14)
14. Tukker, A., de Koning, A., Wood, R., Hawkins, T., Lutter, S., Acosta, J., Rueda Cantuche, J.M., Bouwmeester, M., Oosterhaven, J., Drosdowski, T., Kuenen, J., 2013 [↑](#footnote-ref-15)
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