POLICY-RELEVANT APPLICATIONS OF ENVIRONMENTALLY EXTENDED MRIO DATABASES – EXPERIENCES FROM THE UK

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POLICY-RELEVANT APPLICATIONS OF ENVIRONMENTALLY EXTENDED MRIO DATABASES – EXPERIENCES FROM THE UK

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The impressive development in global multi-region input–output (IO) databases is accompanied by an increase in applications published in the scientific literature. However, it is not obvious whether the insights gained from these studies have indeed been used in political decision-making. We ask whether and to what extent there is policy uptake of results from environmentally extended multi-region IO (EE-MRIO) models and how it may be improved. We identify unique characteristics of such models not inherent to other approaches. We then present evidence from the UK showing that a policy process around consumption-based accounting for greenhouse gas emissions and resource use has evolved that is based on results from EE-MRIO modelling. This suggests that specific, policy-relevant information that would be impossible to obtain otherwise can be generated with the help of EE-MRIO models. Our analysis is limited to environmental applications of global MRIO models and to government policies in the UK.

Keywords: Multi-region input–output models; Environmental extensions; Policy relevance; Applications; UK

1. INTRODUCTION

Recent years have seen the development of several environmentally extended multi-region input–output (EE-MRIO) databases with global coverage, linking national, monetary IO tables with international trade statistics and information on the use of natural resources and emissions of greenhouse gases (GHGs) and other pollutants (Peters et al., 2011a; Wiedmann et al., 2011a). As outlined in the editorial (Tukker and Dietzenbacher, 2013), this special issue of \textit{Economic Systems Research} introduces the EE-MRIO initiatives and provides the technical details of their compilation. Many EE-MRIO applications have already been described in the scientific literature (Wiedmann et al., 2007; Wiedmann, 2009; Minx et al., 2009b) but it is not obvious whether the insights gained from these studies have indeed been used in political decision-making.

Other environmental-economic projection and simulation models, such as computable general equilibrium (CGE) or econometric models with energy and/or environmental extensions, have been used by governments to evaluate the effects of specific policies or scenarios on resource use (energy, land, water, food), emissions or economic growth (for recent

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EE-MRIO modelling does not seem to have a comparable uptake in mainstream policy analyses; however, several reports and papers exist that indicate that EE-MRIO is the appropriate tool for research related to consumption-based accounting and trade analysis of GHG emissions and resource use and that specific applications are emerging (Peters, 2008; Hertwich and Peters, 2009; Peters and Hertwich, 2009; Davis and Caldeira, 2010; Peters et al., 2011b; Ewing et al., 2012; Kanemoto et al., 2012). In this article, we ask what kind of unique information can be produced by EE-MRIO models that cannot be generated by other approaches and whether there is evidence that this information has been used outside of the academic realm. In particular, we pose the question whether EE-MRIO analysis has been used to inform government policies. To keep the scope defined and limited, we only included environmental extensions and applications of global MRIO frameworks in our analysis.

We demonstrate that EE-MRIO-based analyses can indeed deliver relevant information for the design of environmental policies that cannot be obtained from other models. To our knowledge, an account of the extent to which policy-makers are aware of this, and whether EE-MRIO studies actually contributed to political decision-making and policy formulation has not been presented yet. Our review is also relevant with respect to the increasing need for researchers to make applications of their research visible in order to justify or secure government funding.

Our exposé on policy applications is limited to examples from the UK. It is inherently difficult to establish a cause and effect relationship between an individual analysis based on a particular research methodology and a specific policy. This is due to the nature of the policy formation process which involves the four main steps of problem-framing, policy-framing, policy implementation, and policy monitoring and evaluation. This process is informed by many inputs and extends over a time period of years or even decades. Through our personal involvement in consumption-based GHG accounting in the UK, however, we believe we have picked up some of the relationships between the generation of evidence and the policy discussions that have evolved from that. This involvement included research (Minx et al., 2009a; Lenzen et al., 2010; Wiedmann et al., 2010; Wiedmann and Barrett, 2011; Barrett et al., 2011b; Barrett and Scott, 2012) as well as participating in stakeholder consultations (e.g. Barrett et al., 2011a). We acknowledge that there is a focus on consumption-based accounting and that policy responses may be guided by the level of acceptance by governments, statistical offices and other agencies of carbon and environmental footprints as being important indicators. Our review, therefore, is not aimed at providing an exhaustive overview of the impact of EE-MRIO modelling on policy but rather at the exposition of limited, but traceable, evidence of such impact.

In Section 2, we briefly summarise the most recent progress in EE-MRIO model development, including recent work on environmental extensions and topics of recent publications.

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1 One example of many is the modelling of a carbon pricing policy by the Australian Treasury (The Treasury, 2011).
3 Corporate decision-making was excluded from the analysis here. There seems to be an increasing demand for carbon footprint consulting, including global supply chains, and at least one company, engineering firm Arup, is using an EE-MRIO model for this purpose (based on GTAP 7, see http://www.arup.com/Services/Carbon_management.aspx).
With potential relevance for policy. In Section 3, we first summarise the unique characteristics of EE-MRIO results and then examine policy-making processes in the UK that make use of EE-MRIO results. Section 4 concludes.

2. RECENT ADVANCES IN ENVIRONMENTALLY EXTENDED MRIO MODELLING

2.1. Recent Work on Environmental Extensions to MRIO Models

In the last few years, the development of EE-MRIO data sets with global coverage has come a long way (Wiedmann, 2009; Minx et al., 2009b; Peters et al., 2011a; Wiedmann et al., 2011a). Since this special issue provides an extensive overview of current global MRIO databases, we restrict this section to a short summary of the environmental extensions featured in the various models. Table 1 complements the table in the editorial (Tukker and Dietzenbacher, 2013) by listing details of these extensions.

Note that Table 1 excludes the Asian International Input–Output Tables presented in this special issue (Meng et al., 2013) as this database does not currently hold environmental extensions. Furthermore, we have not listed models that only consist of one national IO table linked to bilateral trade data, as done, for example, for Japan (Nansai et al., 2009; 2012a; 2012b), Germany (Mayer and Flachmann, 2011) or Estonia (Gavrilova and Vilu, 2012). Nor have we included sub-national MRIOs for individual countries.

TABLE 1. Environmental satellite accounts of global MRIO databases.

<table>
<thead>
<tr>
<th>Name of EE-MRIO data set</th>
<th>Environmental extensions</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eora</td>
<td>Energy use, GHG emissions, air pollution, water use, material flows, ecological footprint, Human Appropriation of Net Primary Productivity, threatened species</td>
<td>Lenzen et al. (2012a, 2012b, 2012c), <a href="http://www.worldmrio.com">http://www.worldmrio.com</a></td>
</tr>
<tr>
<td>WIOD</td>
<td>Gross and emission-relevant energy use, CO\textsubscript{2} emissions from combustion, other GHG and pollutant emissions, material flows, land use, water use</td>
<td>University of Groningen (2010), Dietzenbacher et al. (2013), <a href="http://www.wiod.org">http://www.wiod.org</a></td>
</tr>
<tr>
<td>GRAM</td>
<td>GHG emissions, material flows</td>
<td>Giljum et al. (2008, 2009), Bruckner et al. (2012), Wiebe et al. (2012a, 2012c)</td>
</tr>
</tbody>
</table>
GHG emissions have been part of every global MRIO model from the beginning (Wiedmann et al., 2007; Wiedmann, 2009) and data on the use of natural resources (land, water, energy) are also relatively well represented in the models. More recently, data on material flows and pollutant emissions have been added. The Eora and EXIOBASE initiatives invested extra effort to introduce novel extensions such as threatened species or external cost values.

2.2. Topics from Recent Publications with Potential Policy Relevance

In the last few years, a number of journal publications and reports, some of them high-profile, have presented results from EE-MRIO analyses and their implications for policy. While there is no explicit description of a policy that would have been directly based on EE-MRIO results, the list of topics addressed by these publications clearly shows that there is a significant potential relevance for policy formulation and decision-making. Themes include:

- The contribution of international trade to changes in GHG emissions, analysed by enumerating emissions embodied in multi-country supply chains, intermediate and final products, sectors or final demand (Hertwich and Peters, 2009; Davis and Caldeira, 2010; Carbon Trust, 2011; Davis et al., 2011; Sinden et al., 2011; Skelton et al., 2011; Peters et al., 2011b; Nansai et al., 2012a).
- Trade in virtual water and national water footprint accounts (Yu et al., 2010; Daniels et al., 2011; Duarte and Yang, 2011; López-Morales and Duchin, 2011; Feng et al., 2011a, 2011b; Zhang et al., 2011; Feng et al., 2012). Daniels et al. (2011, pp. 363–367) list potential uses of water footprint MRIO analysis in water management policy structured by decision entity (government, private sector, science community) and policy area.
- Evaluation of European (and international) policy objectives and outcomes with a combined set of carbon, water and ecological footprint indicators in a global EE-MRIO framework (Galli et al., 2012).4
- Food security in Europe (informed by land and water footprint calculations).5
- Exploration of future production and consumption-based national GHG accounts and associated costs (through a combination of global MRIO and dynamic econometric-statistical analysis).6
- The links between international trade and global threats to biodiversity (Lenzen et al., 2012b).
- Quantification of raw material equivalents of trade and consumption by attributing the amount of raw materials extracted or produced in one country to the final demand of other countries (Muñoz et al., 2009; Weinzettel and Kovanda, 2009; 2011; Arto et al., 2012; Bruckner et al., 2012; Schoer et al., 2012; Wiebe et al., 2012b).
- The uncertainty (and therefore reliability) of the EE-MRIO model construction (Peters et al., 2012).7

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5 See Note 4 above.
6 See Note 4 above.
7 See Note 4 above.
These topics are of direct relevance to national and international environmental policy and demonstrate the increasingly important role that EE-MRIO models can play in informing political decision-making. We have found no comprehensive evaluations in the scientific literature to what extent and how results from these studies have been used by policy-makers. We, therefore, evaluate in Section 3.2 the uptake by policy on the basis of projects for which we have personal experience, and which are restricted to the UK.

3. POLICY RELEVANCE OF EE-MRIO MODELLING

3.1. Unique Information from EE-MRIO Analysis

In this section, we briefly summarise the specific characteristics of EE-MRIO analysis that provide unique information not otherwise obtainable. This leads on to an account of actual use of EE-MRIO information in policy processes in Section 3.2.

Because of its full representation of trade flows (Kanemoto and Murray, 2013; Tukker and Dietzenbacher, 2013), an MRIO table is the only approach that can provide a detailed and comprehensive picture of an economic sector and its interrelationship with other sectors. In the case of global MRIO databases, these interrelationships span across countries, thus capturing the whole (cradle-to-shelf) life cycle of products and services across international production and supply chains. Extending this multi-national framework with environmental (or social or economic) information about production allows for a traceable link to be made between the location of environmental (or other) impact and the processes that led to the impact instigated by demand for goods and services elsewhere in the world. Concepts and models that rely on bilateral trade data alone to establish this link – even though these data might be extremely detailed – fail to represent the complex web of cross-country intermediate production and supply steps.

This feature of multi-national linkage is unique to MRIO and has considerable application potential. In the following example, we focus again on environmental applications with potential policy relevance, acknowledging that there are many other potential uses, especially in the domain of economic research (e.g. trade analyses).

A key area is the establishment of consumption-based national carbon accounts (carbon footprints), where EE-MRIO has been recognised as the most suitable method to generate trade-adjusted GHG emissions accounts of countries (Wiedmann et al., 2011a). Consumption-based GHG accounting is likely to stay on the political agenda of the global climate policy due to the announcement following the Conference of the Parties meeting in Durban in 2011. As there will be no global comprehensive agreement until 2020, the issue of weak carbon leakage, i.e. not accounting for emissions that are embodied in imported products, will remain relevant to the global climate policy.

Global value chain, or ‘scope 3’, GHG accounting, as defined by the GHG Protocol (WRI and WBCSD, 2011), is another key application area. The identification of those countries and economic sectors that contribute most to the carbon load of international trade is potentially relevant to the design of trade policies aimed at mitigating climate change. EE-MRIO frameworks with a high degree of disaggregation of countries and sectors have the advantage of providing more detail in this area (Wiedmann et al., 2011a). Such detail is also beneficial for environmental pressure or impacts which are locally specific, such as water withdrawals or habitat destruction (which varies widely across
countries and regions) and for special trades, e.g. uranium exports. These topics are highly relevant to international and national environmental policy, demonstrating the increasing importance of EE-MRIO models in informing political decision-making. A key area includes priority-setting and *ex post* assessment where EE-MRIO models can provide important information on ‘hotspots’ of environmental impacts through the global supply chain. Additionally, where time series are available EE-MRIO can offer insights into the drivers of environmental impacts through the use of decomposition analysis understanding the contribution to emissions of final consumption, structural and efficiency changes.

In terms of scenario development, EE-MRIO provides an accounting system where the modeller changes the model variables explicitly, not implicitly by a set of pre-defined rules (i.e. the model is not dynamic), unlike econometric and CGE models (Scott et al., 2012). The demand-driven nature of the IO model makes it easy to make explicit changes to the level and pattern of household and government consumption expenditure. Examples of this have been provided in several studies (Hubacek and Sun, 2001; Takase et al., 2005; Kagawa et al., 2006; 2008; Kronenberg, 2009) where alternative consumption patterns are analysed and changes in carbon savings calculated.

Another key advantage of the EE-MRIO approach is its ability to be combined with other modelling approaches. This is partly due to standardised methods of accounting allowing integration of modelling approaches. Many of the policy examples in this paper used EE-MRIO in combination with other methods. To name a few, Barrett and Scott (2012) combined EE-MRIO with econometric forecasting models and Wiedmann et al. (2011b) combined process-based life cycle assessment (LCA) with EE-MRIO in the assessment of wind power.

3.2. Use of EE-MRIO Results in Policy-Making Processes – Experiences from the UK

Certainly, there have been impressive developments in EE-MRIO database compilation and research publications, but have results from EE-MRIO analysis actually been used to inform government policies? Through personal involvement and experience, we feel confident to provide evidence indicating that outcomes from EE-MRIO research have found their way into the policy-making process in the UK.

Most of our examples relate to the UK Department for Environment, Food and Rural Affairs (Defra). Defra makes policy and legislation in a range of environmentally relevant areas, including sustainable development and green economy. Defra has committed to reporting the consumption-based accounts of GHG emissions by the UK for the next five years. In contrast to results from accounting for territorial GHG emissions under the Kyoto Protocol, consumption-based accounting has shown that emissions attributable to the UK have increased during the last two decades (Druckman and Jackson, 2009; Baiocchi and Minx, 2010; Defra, 2010, (p. 15); Wiedmann et al., 2010; Barrett et al., 2011b, p. 15; Peters et al., 2011b). Defra’s commitment means that consumption-based accounts now form part of the UK’s headline indicators for sustainability (Defra, 2010, p. 15). The UK Government has previously commissioned the calculation of a complete time series of the UK’s carbon footprint between 1990 and 2009.

In September 2011, the UK Energy and Climate Change Committee launched an inquiry to investigate the case for consumption-based GHG emissions accounting in the UK. The Committee examined the case for adopting consumption-based reporting in the UK, whether it would be feasible to do this in practice, whether emissions reduction targets might be adopted on a consumption basis, and what the implications for international negotiations on climate change might be if the UK and others took this approach. Answers to these and a range of other questions were invited in writing and were heard at the first evidence session on 29 November 2011. Written evidence provided by 30 organisations was published on 3 December 2011.

In its response (Barrett et al., 2011a), the UK Energy Research Centre (UKERC) confirmed that it is possible to develop a robust methodology for accounting for GHG emissions on a consumption basis and that EE-MRIO analysis is the method of choice. This had been demonstrated in recent years by several EE-MRIO studies focused on the UK national carbon footprint emissions (Baiocchi and Minx, 2010; Lenzen et al., 2010; Wiedmann et al., 2010; Wiedmann and Barrett, 2011; Barrett et al., 2011b), and headline results had been published by the UK Government as part of its Sustainable Development Indicators programme (Defra, 2010, p. 15). UKERC further proposed that the “UK Government, in conjunction with UNFCCC and Eurostat, could establish standards for the harmonisation of consumption-based emission reporting methods to ensure robustness and consistency between country estimates” (Barrett et al., 2011a, p. 17). If such standards were to be implemented in the future, it is likely that EE-MRIO would play a prominent role as the underlying calculation methodology.

As well as EE-MRIO models being applied to the generation of headline indicators, there is an increasing number of examples of applications related to policy formulation and appraisal. Before discussing examples relevant to the UK, it is important to consider the attribution of policy-orientated research directly to policy impact. It is very rare that an individual report or research output directly links to a measurable and isolated change in policy. Policy formulation is a complex process of negotiation with affected stakeholders, political persuasion, scientific evidence and other unmeasurable forces. To suggest that one report directly changed policy would be naive. Additionally, the change could occur years after the study.

This was very much the situation in the UK. In 2006, results were ready for publication, reporting UK’s consumption-based GHG accounts. It was not until 2011 that the UK Government adopted consumption-based accounts as a headline indicator and committed to this for the following five years. However, this progress would not have happened were it not for the original study. Two specific applications are shown below, one more concrete and the other more speculative.

The first example relates to the consideration of resource efficiency strategies within climate change mitigation policy (Barrett and Scott, 2012). The study was commissioned...
by the Waste Resource Action Programme (WRAP). WRAP is an agency established by
the UK Government that supports businesses and households to reduce waste, develop
sustainable products and use resources in an efficient way. Historically, WRAP had focused
primarily on increasing recycling rates in industry and households in the UK. In the past, the
UK was considerably behind the rest of Europe in terms of recycling rates and WRAP has
been effective in increasing these rates and ensuring that there are markets for recyclable
products. While focusing on recycling, WRAP was always aware that the underlying issue
related to the consumption of resources but felt that there was a lack of evidence on the
potential benefits of resource efficiency. To overcome this, WRAP commissioned a com-
prehensive study to assess the effectiveness of resource efficiency strategies to deliver GHG
emission reductions.

The project, led by the Stockholm Environment Institute, employed a number of methods
of which the most prominent was based on EE-MRIO (in the form of an environmentally
extended two-region model comprising the UK and the rest of the world). This was com-
bined with econometric forecasting models to provide an understanding of the changing
production structure of the UK economy and to assess the role of material efficiency mea-
sures in reducing UK GHG emissions by 2050. The approach includes both production
systems and consumption patterns and has the ability through scenarios to analyse the
(GHG) effectiveness of a wide range of material efficiency options.

The study provided robust evidence on the role of resource efficiency strategies and
the contribution they could make to climate change targets. The study demonstrated that
structural change would occur but strategies such as extending the lifetime of products, lean
design techniques, reducing food waste and increasing product durability could all boost
the service-based economy in the UK and reduce weak carbon leakage (Barrett and Scott,
2012).

WRAP have since used the study extensively to help reshape their agenda, now increas-
ingly concentrating on many of the resource efficiency measures included in the study.
Additionally, the study has been circulated widely across UK Government departments,
presented at cross-departmental committees and used as evidence in Parliamentary Select
Committees. The study has also been used within Defra to help shape their sustainable
products policy, clarifying what different resource efficiency strategies could be delivered
in terms of emission reductions. Finally, the study has also ensured that further evidence
on specific resource efficiency measures is being investigated, in particular the shift from
ownership of goods to services.

The second example relates to research undertaken through the UKERC. UKERC cal-
culated the upstream GHG emissions associated with emerging energy technologies. The
research was designed to consider that every energy technology at some stage through
its production, life and disposal will directly or indirectly produce GHG emissions and
that upstream emissions can vary widely across different energy technologies. Prominent
traditional energy systems models, for example MARKAL in the UK (Fishbone and Abilock,
1981), do not consider upstream emissions associated with energy technologies.

The research resulted in the development of innovative hybrid LCA methods that com-
bined EE-MRIO with traditional process LCA databases (in this case, ecoinvent, see
Wiedmann et al., 2011b). The findings of the research will be fed directly into MARKAL, a

13 For more information on WRAP, see http://www.wrap.org.uk.
partial equilibrium energy systems model. This will ensure that when the model optimises for price, each energy technology will have a more realistic estimate of the GHG emissions associated with that technology. Potentially, this could mean that a particular technology that was favoured historically could be less advantageous. As the MARKAL model is used widely by the UK Department of Energy and Climate Change (DECC) and the Committee on Climate Change, this could have considerable impact on renewable energy policy.

More precisely, and as an example, DECC is concerned that the upstream emissions associated with the construction of photovoltaic power generation could be significant and counteract some of the benefits in terms of emission reduction. In the UK, ‘Feed-In Tariffs’ (FITs) have been introduced for small-scale renewable installations. This has resulted in considerable growth in the small-scale solar market. Using a hybrid LCA approach, including EE-MRIO, research is currently being undertaken to provide the necessary information. Potentially this could result in a direct policy adjustment to the FITs to account for upstream emissions. The introduction of hybrid LCA models provides a more comprehensive assessment of photovoltaics as it removes the truncation errors associated with bottom-up, process-based LCA, and multi-region IO analysis allows for the distinction of imported and domestically produced products.

In 2011, Barrett et al. (2011b) provided an analysis of the UK, using GTAP data that was developed into an EE-MRIO by Peters et al. (2011a). The analysis provided the origin and destination of GHGs for the UK by 113 world regions and 57 sectors. For each product, a matrix was constructed to show where emissions occurred and in which sector. The report was commissioned by Defra to provide insights into the origin of UK consumer emissions. There was not a specific policy question in mind when the study was commissioned but it was believed that the information would be useful to a number of issues in some of the government departments. It was felt within Defra and its Sustainable Consumption and Production (SCP) Programme that there was a pressing need for accurate and detailed CO2 emissions data showing not only the sectors which emit the highest levels of carbon dioxide globally as a result of demand from the UK but also the specific countries where these emissions occur. Clearly, a truly multi-regional (multi-national) IO approach was needed to answer these questions.

It was envisaged that the data would allow the SCP Programme inside Defra to target its activities towards those sectors that emit the highest levels of carbon globally due to UK consumption, strengthen and focus dialogue with those countries where these emissions occur, and provide evidential input into initiatives in other departments. An example of this would be the green economy initiative being undertaken by the UK Department for Business, Innovation and Skills. It was hoped that the information could be used to establish priority sectors and focus their work on informing sustainable procurement strategies in their key publication *Enabling the Transition to a Green Economy* (HM Government, 2011). The publication explored the international action available to UK firms in achieving resource efficiency and further promotion of the green economy.

While it is difficult to pinpoint a precise change that the Barrett et al. (2011b) study made, Defra have had many requests for information from the data set from inside the government. Information from the report features in government publications such as the Energy Intensive Industries Strategy produced by DECC. The study clearly acknowledged

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that while some sectors can be captured by domestic or European policies, such as the EU Emissions Trading Scheme, other sectors may require a more internationally collaborative approach. For example, in the textiles sector, over 80% of the GHG emissions associated with UK consumption occur outside the UK. Additionally the study confirmed to Defra which products it should be focusing on in terms of developing ‘Product Roadmaps’ for the UK.

4. CONCLUSION

Every model is a simplification of reality and, therefore, is limited in its ability to understand historical trends and future outcomes. Policy questions generally require flexible and versatile models and tools that adopt a comprehensive and holistic perspective while at the same time providing sufficient detail to allow for the evaluation of specific policies. We outline what is unique about results from global EE-MRIO models and provide a rather personal and limited account of policy initiatives in the UK that can be linked back to evidence generated by EE-MRIO models.

Two key findings can be condensed from our review. Firstly, EE-MRIO analysis has unique features in comparison with other methods and offers additional, policy-relevant insights into clearly identified areas. These include an evaluation of the contribution of international supply chains to overall environmental pressures and impacts as well as the possibility of compiling national footprint accounts. Secondly, we pointed out the value of EE-MRIO when combined with modelling approaches, in particular econometric forecasting models for scenario construction or engineering-specific information related to resource efficiency strategies. It is difficult to see how other modelling conventions could have achieved the same outcome in terms of a comprehensive coverage of a country’s emissions, the ability to adjust individual sector efficiency within this framework and link such a detailed model to econometric forecasting approaches.

While the UK seems to be the only country that has adopted consumption-based GHG emissions accounting as an official statistic, there are signs that other countries might also implement or at least support such an approach. In a speech in Washington on 6 March 2009, Li Gao, China’s then top climate policy negotiator, reinforced the consumer responsibility viewpoint by calling on importers to shoulder the responsibility of emissions caused by China’s exports. “We produce products and these products are consumed by other countries […] This share of emissions should be taken by the consumers but not the producers.”15 This statement is also a reflection of the fact that negotiations on global emissions reductions have become difficult and complex because of the increasing scale of GHG emissions embodied in trade (Peters et al., 2011b). Global EE-MRIO models have specifically been designed to address this complexity analytically.

As mentioned previously (Wiedmann et al., 2011a), for the further development of EE-MRIO, a long-term strategy and commitment is needed from researchers, statistical offices and other stakeholders interested in decision-relevant outcomes. An important aspect of policy-relevant applications is the reliability and robustness of data sets. In the case of

consumption-based GHG reporting, the establishment, in conjunction with the United Nations’ Framework Convention on Climate Change and Eurostat, of new standards to harmonise reporting is recommended. Nansai et al. (2012a) go a step further and state (p. 161): “If the consumption-based emissions of each country were to be defined using conventional MRIO, a universally approved MRIO table would need to be developed.” Or at least a universally accepted compiling and accounting approach. It is, therefore, encouraging to see a number of EE-MRIO data sets being developed independently. Each has a different setup and focus, making comparisons across model outputs (as, for example, presented by Peters et al., 2012) a valuable source of information on uncertainty.

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