4 Quantifying environmental impacts of consumption: Implications for governance

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1. Introduction

Ultimately, all production is driven by consumption. It is hence final consumption by humanity that drives the environmental impacts of production. In the past, global trade was just a small part of the economic production within a country. At that time, the monitoring of carbon and other emissions and resource extraction at country level was reasonably representative of the environmental pressures caused by consumption in each country. However, in recent decades, growth in international trade has outpaced the growth of global gross domestic product (GDP). It is no longer sufficient to analyse the impacts of production at national level (Peters et al., 2011; Wiedmann et al., 2011). Consumption in one country drives production in value chains spanning many others. This creates a complex, global web of activities impacting the environment in multi-faceted ways (Tukker and Dietzenbacher, 2013). For proper governance of sustainable consumption, it is essential to understand how consumption of specific categories of goods and services in specific countries (and ideally by specific consumer groups) drive environmental impacts in global value chains.

Against this background, this chapter will review how final consumption drives environmental pressures, identify the priority areas, and address crucial consumption drivers. We start by reviewing methods for analysing the impacts of consumption, then look at priority consumption areas and the main drivers. This is followed by proposals for methods to analyse the relation between consumption and the impacts of production can be made more reliable and robust before ending with conclusions and governance implications.

2. Approaches for assessing impacts of consumption

To deal with the assessment of environmental pressures in trade, practitioners use two broad approaches (see Tukker et al., 2016). The first is the *coefficient* approach and has been frequently applied with regard to water and land use (Hoekstra and Chapagain, 2007; Moran et al., 2009). This approach uses the detailed trade statistics of, for example, the UN Comtrade Database (United Nations, 2014–17) and FAOSTAT, the statistical system of the Food and Agricultural Organization of the United Nations (Food and Agricultural Organization of the United Nations, n.d.), the former, for instance, covering over 5000 products traded between countries. This means that water or land use per kilogramme or the monetary value of a product imported from the country of export can be analysed, detailing the water and land use embodied in imports. National statistics give information on national water and land use, and also enable the calculation of the water and land use embodied in exports. The net water and land use of each product can be estimated from the water and land use of national production and of imports and exports.

This example focuses on land and water pressures for a reason: agricultural products are the main drivers for land and water use. These tend to be produced in the country of export and do not have supply chains with major water and land use impacts. This approach, however, neglects water and land use related to other imported products, which, according to Hubacek and Feng (2016), can lead to relevant errors in consumption-based accounts for land, to give one example. A significant drawback of the coefficient approach is that it assumes that an imported product was manufactured solely in the country of export, thus neglecting the current situation where many products are created in value chains that span several countries, each with its own coefficients for emissions and resource use. Figure 4.1 provides a stylized example. The imports of country C from B are 110 units. A coefficient approach would estimate the emissions and resource use per unit production in country B, and allocate this number multiplied by 110 units to country C. In reality, however, of the 110 units that country C imports no less than 100 units of added value are created in country A, and only 10 units in Country B. Thus most of the emissions and resource use in the country C imports take place in country A, even though all country C imports come from country B. Particularly for non-agricultural products, which tend to have complex value chains, the coefficient approach does not give an appropriate answer on how consumption in country C drives carbon and other emissions and resource use elsewhere in the world.

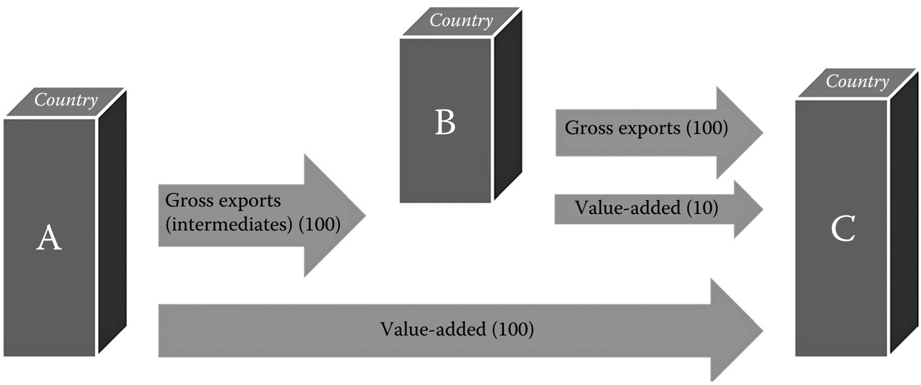

Figure 4.1 Gross exports and trade in value added

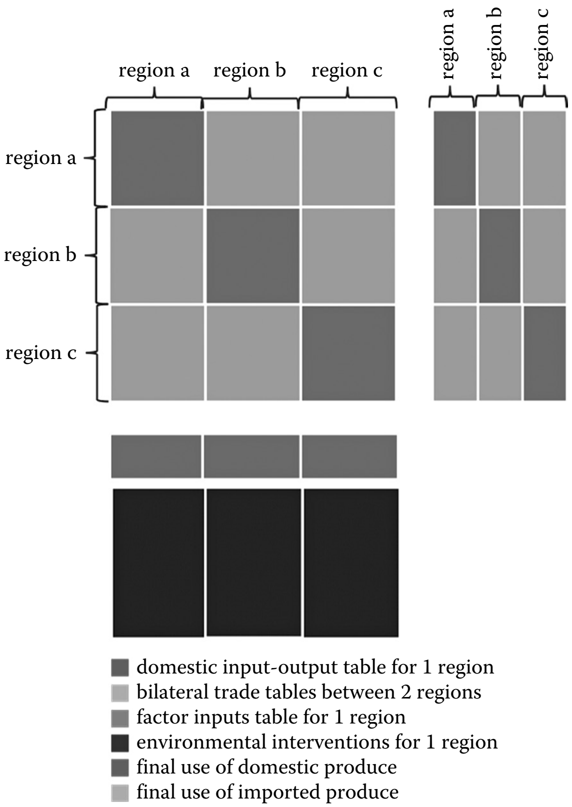

Figure 4.2 Example of MR EE SUT/IOT with three regions

Therefore, practitioners have developed a second method, making use of Multi-Regional Environmentally Extended Supply and Use/Input-Output Tables' (MR EE SUT/IOT, e.g. Tukker et al., 2016).

Figure 4.2 shows a typical MR EE SUT/IOT with a country's total economy where production is divided into a few dozen industry sectors and consumption divided into a few dozen product (and service) groups. Figure 4.2 depicts how much of these specific products (output), for example cars, is produced by each industry sector, expressed in euros. It also shows for each industry sector how many other products are required to achieve this production (input), for example, the amount of steel, glass, plastics, electricity and electronics the car industry in that country needs to produce its output of cars. Furthermore, for each industry, the primary resource use and emissions ('environmental extensions') can be identified, for example, land use by agricultural sector, or CO_2 emissions by electricity production sector. Thus the ways in which the economy is interconnected can be analysed. One example is the final use of cars by consumers; here the production value contributed by the car industry, the steel industry and so on, can be analysed. But

Box 4.1 METHODS FOR ASSESSING POLLUTION AND RESOURCE USE EMBODIED IN TRADE

1. Using emission and resource use coefficients for foreign countries derived with Life Cycle Inventories (LCIs) in combination with trade data on imported products (Schoer et al., 2013).
2. Applying the 'Domestic Technology Assumption' (DTA), that is, assuming that imported products are produced with the same technologies as domestically produced products (Wood and Dey, 2009).
3. Applying the DTA corrected for purchasing power parities, or relative prices of imports compared to European production (Tukker et al., 2013a).
4. Using emission and resource coefficients for foreign countries derived with Environmentally Extended Input Output (EE IO) data for these countries, taking into account bilateral trade only (Lenzen et al., 2004).
5. Using available environmental Global Multi-Regional Input Output (GMRIO) databases at face value, and calculating footprints of a country with such a GMRIO (Tukker et al., 2016).
6. Using official data for a specific country for which environmental footprints need to be calculated, and adjusting and rebalancing an existing GMRIO by implementing the aforementioned country specific data in it. This is also called a 'single-country national accounts consistent (SNAC) footprint' (Edens et al., 2015).
7. Using official data for a specific country for which footprints are calculated, but using the full environmental GMRIO model only to calculate pollution and resources in imports rather than creating a new GMRIO adjusted to this specific country.

since we also know the emissions and primary resource extraction per monetary unit (euros or US dollars) for each industry, we can now estimate the total primary resource extraction and life cycle emissions for the total consumption of cars in that country (see Eurostat, 2008; Miller and Blair, 2009). The example above is for one country only, and as indicated, imports and exports in the current global economy are substantial.

Practitioners have sought various solutions to this problem (for an overview, see Tukker et al. 2018a), summarized in Box 4.1.

The simplest approach is using a national input–output table and assuming that the pollution and resource use of imported products is identical to that of nationally produced products (DTA). A slightly more sophisticated approach is to correct for relative prices of domestically produced and imported products (price-corrected domestic technology assumption). However, these two approaches do not account for country-specific intensities for emissions and resource use by production sector. To address this, a multi-regional input–output approach must be used. It is necessary to create EE SUT/IOT data for the most important world economies and to identify the trade flows between the specific sectors of all these countries (Peters et al., 2012; Tukker et al., 2013b). The result is the aforementioned MR EE SUT/IOT, which gives a detailed picture of all linkages between production and consumption in the global economy. Figure 4.2 provides an example with three regions.

Table 4.1 Characteristics of existing GMRIOs

No.	Name	Characteristics and references
1	Eora	Sector detail varying from 25 to 500; about 180 countries (Lenzen et al., 2012a; 2012b; 2013)
2	EXIOBASE	200 products, 160 industries, 48 countries/regions (Tukker et al., 2009; 2013b; Wood et al., 2014; 2015; Stadler et al., 2017)
3	WIOD	35 sectors, 40 countries plus 1 Rest of World (Dietzenbacher et al., 2013)
4	GTAP-MRIO	57 sectors, 140 countries/regions (Peters et al., 2011)
5	ICIO (Inter-country Input-Output table)	34 sectors, 64 countries/regions (OECD, 2015). Researchers used OECD IO data to build an early GMRIO called GRAM: 48 sectors, 53 countries/region (Wiebe et al., 2012a, 2012b; Bruckner et al., 2015)

Source: Tukker and Dietzenbacher, 2013; Tukker et al., 2018a; 2018b.

Creating MR EE IO databases is, however, labour intensive, even if this is done via automation (Wood et al., 2015) or virtual laboratory environments (Lenzen et al., 2014). Only a handful of such databases have been constructed (Table 4.1). While MR EE IO databases have drawbacks like an aggregated sector classification, and assume that economic flows are a reasonable representation of physical flows (Weisz and Duchin, 2006), their strength is their inherent consistency at global level. All direct emissions of greenhouse gases (GHG) and primary extraction/use of water, land and materials, as well as the number of jobs and added value created by industries are, by definition, directly related to the final consumption of products – these cannot be 'lost' in the calculations. The MR EE IO approach is now the method of choice to assess how final consumption, via value chains, drives emissions and resource use per economic sector per country.

3. Drivers and priorities of environmental impacts of household consumption

3.1 Introduction

We now turn to the assessment of the impacts of consumption and related priority areas. One of the first reviews of such analyses was done in the context of the environmental impacts of products (EIPRO) project funded by the EU and published as a special issue of the *Journal of Industrial Ecology* (Tukker, 2006). This review will be expanded below with more recent work.[1] Most studies focus on energy use, CO_2 emissions or GHG emissions. We first review these results as well as other indicators that not all studies reviewed have covered (such as land use, water use, etc.).

3.2 Priority consumption categories[2]

Table 4.2 shows results of energy-related indicators (expanded from Tukker and Jansen (2006). Final consumption categories have been reclassified and aggregated to over ten COICOP (Classification of Individual Consumption According to Purpose) categories. It should be noted that most studies focused on total final consumption, that is, combining household consumption, government consumption and sometimes also exports.[3]

Table 4.2 shows a clear pattern (Hertwich, 2005). Food, housing (including electrical appliances) and individual transport dominate the use of energy, CO_2 emissions and GHG emissions. In all studies each of these categories tends to contribute between 15% and 30% of the total impacts, and add up to 70% or more of the total. Deviations from this pattern are due to methodological issues. Nemry et al. (2002) and Labouze et al. (2003), for example, have low contributions of food due to the fact that food was either not included or since methane emissions, particularly relevant in the production of rice and animal husbandry, were neglected. Consequently, the relative contribution of housing and transport in their work may have been overestimated. We further see that in the study of Palm et al. (2006). Here, transport is relatively low since this is a specific sector for all household-related energy use. Finally, Peters and Hertwich's study (2006) gives a relatively high contribution of transport to the overall CO_2 emissions of household consumption, while overall emissions per capita in Norway are relatively low, largely thanks to abundant hydroelectric power. Furthermore, Nijdam and Wilting (2003) have a relatively high contribution from recreation, largely because this category includes package holidays, which in other studies would be classified under transport.

The conclusion that food, housing and transport drive some 70% of the impacts of final consumption has consistently been confirmed by later studies including a 2010 review of the International Resources Panel (Weber and Matthews, 2008b; Kerkhof et al., 2009; Hertwich et al., 2010; Huysman et al., 2016; Tukker et al., 2016; Ivanova et al., 2017). Tukker and Jansen (2006) also analysed which subgroups within the areas of food, mobility and housing were relevant. In the case of food, this was meat and meat products (including poultry); milk, cheese, and related products; other non-animal food products; and expenditures in restaurants. For housing, this concerned heating equipment, cooking equipment, and hot water generation equipment (particularly due to their energy use); (electrical) energy-using products; and housing construction. Finally, for transport, relevant subcategories are private car travel (highly dominant); air travel services; train travel services; and travel related to package holidays.

Tukker and Jansen (2006) also looked at other impact indicators, such as resource extraction and water use and land use. Again, the same categories of food, housing and transport were responsible for over 70% of the impacts driven by final consumption. The relative importance differs however by final consumption category. Water use and particularly land use are mainly driven by food consumption. For resource use, housing, transport and food have more equal contributions.

Table 4.2 Contribution per COICOP category to energy-related impact indicators in different studies

			1	2	4	5	6	7	8	9	10	
COICOP	Study	% of total expenditure in EU25 Tukker and Jansen (2006)	Collins et al. (2006)	Dall et al. (2002)	Labouze et al. (2003)	Moll and Acosta (2006)	Jansen and Thollier (2006)	de Vries and te Riele (2006), Nijdam and Wilting (2003)	Palm et al. (2006)	Peters and Hertwich (2006)	Huppes et al. (2006)	Druckman and Jackson, 2008
	Geographical focus	EU25	Cardiff	Denmark	EU15	Germany	Belgium	Netherlands	Sweden	Norway	EU25	UK
	Indicator		Footprint	Energy	GWP	Energy	GWP	GWP	CO2	CO2	GWP	CO2
	Main approach		Top-down/ hybrid	Bottom-up	Bottom-up	Top-down	Bottom-up	Top-down	Top-down	Top-down	Top-down	Top-down
CP01–02	Food	19.3%	20.6%	26.2%	7.0%**	13.0%	3.6%**	22.1%	7.7%	12.2%	31.0%	15%
CP03	Clothing	3.1%	0.8%	1.3%	3.3%	2.2%	1.3%	6.5%	0.7%	10.3%	2.4%	11%
CP04–05	Housing	25.1%	30.2%	40.8%	58.8%	54.3%	53.5%	33.4%	29.1%	23.0%	23.6%	27%
CP06	Health	3.9%	0.3%	n/a***	n/a	1.8%	0.3%	0.3%	1.0%	1.1%	1.6%	8%
CP07	Transport	14.1%	21.9%	19.5%	29.6%	18.3%	32.9%	17.3%	15.5%	35.9%	18.5%	9%
CP08	Communication	4.0%	0.5%	n/a	0.0%	n/a	2.9%	0.0%	1.7%	2.1%	2.1%	1%
CP09	Recreation	9.1%	10.2%	7.2%	0.0%	8.1%	n/a	15.1%	0.5%	0.5%	6.0%	26%
CP10	Education	1.4%	0.4%	n/a	n/a	1.8%	n/a	0.7%	0.3%	0.1%	0.5%	2%
CP11	Restaurants	9.6%	10.8%	n/a	n/a	n/a	n/a	2.8%	1.8%	1.3%	9.1%	See CP09
CP12	Miscellaneous	10.3%	4.4%	5.1%	1.3%	0.4%	5.4%	1.8%	6.6%	13.1%	5.2%	–
Other	Refined petroleum products / Direct household energy*								35.0%			–
	TOTAL	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	

Notes:

* Palm et al (2006) reported energy use by households as a separate category. To be distributed over housing and transport.

** Nemry et al (2002) did not include food in their study; this value is related to packaging for food. Labouze et al. (2003) under-estimated the impacts of food for a variety of reasons in their work; see Tukker and Jansen (2006).

*** n/a: not visible as a specific category in the underlying study.

3.3 Determining variables

Various authors have analysed the determining variables that explain high or low environmental footprints of household consumption (e.g. Lenzen et al., 2006; Tukker et al., 2010; Ivanova et al, 2015; 2017). Literature tends to agree on such determining variables. These are listed here, largely following the earlier text of Tukker et al. (2010), expanded with factors mentioned by Ivanova et al. (2017), who compared the per capita carbon emissions of consumption at detailed regional level in Europe, and carried out a quantitative correlation analysis between such factors and carbon emissions.

- *Income*: Environmental impacts rise with household income since increasing affluence enables consumers to use more energy and to acquire larger volumes of material goods. In general, luxury goods generate smaller additional impacts per monetary unit compared to goods designed to meet basic needs (Druckman and Jackson, 2008; Weber and Matthews, 2008b; Kerkhof et al., 2009). Some literature suggests that consumption-based impacts may rise proportionally more than with income (Baiocchi et al., 2010).
- *Household size*: Per capita environmental impacts vary inversely with household size. People living under the same roof share energy-using appliances and cohabitants tend to require less individual living space (and related heating and cooling demands) than single household occupants (Weber and Matthews, 2008b). A generally positive correlation exists between household size and emissions in absolute terms, however. These analyses lead to two important observations – growing populations and decreasing household sizes both lead to increases in emissions (Liu et al., 2003; Wilson and Boehland, 2005).
- *Location*: Urban residents are typically responsible for fewer overall environmental impacts than people living in suburbs or rural communities. First, urban dwellings are generally smaller and, due to higher building densities, have less exposed surface area than suburban homes. Second, suburbanites and rural residents usually have high automobile dependency (Ewing and Cervero, 2001; Sanne, 2002; Jackson, 2003).
- *Automobile ownership:* Given that mobility is responsible for a substantial proportion of the environmental impacts that emanate from household consumption, people who use public transport on a regular basis generally have smaller footprints. An important caveat, however, is that public transport tends to be less expensive than automobile ownership. Spending this saved income can lead to significant rebound effects (Ornetzeder et al., 2008). Ivanova et al. (2015) mention that access to forests and semi-natural areas may help foster low-carbon leisure activities (walking, skiing, etc.) but could also lead to higher use of natural resources.
- *Food consumption patterns*: Vegetarians and consumers who eat locally harvested, seasonal, or organic food generally have lower per capita environmental impacts than individuals who rely on more customary diets (Garnett, 2008; Weber and Matthews, 2008a; Tukker et al., 2011). The assessment becomes

more complicated when local fruit and vegetables produced in energy-intensive greenhouses are compared with the 'food miles' accrued by field-grown alternatives from distant locations (Blanke and Burdick, 2005; Pretty et al., 2005).

- *Social and cultural differences*: Going back at least as far as the work of Erickson (1997), researchers have recognized the variation that exists in energy consumption across countries of similar incomes. Although some of this variability can be attributed to population density, infrastructure, and so forth, it is also important to recognize how different social and cultural predispositions temper prevalent understandings pertaining to the use of energy and materials (Marechal, 2009).
- *Geographic location and housing type*: Residents of climatically extreme regions who have low-quality, poorly insulated homes tend to have comparatively high environmental impacts. The situation is more complicated than a simple case of relatively warmer or cooler climates, however. One also needs to account for the vastly different policy circumstances created by housing stock that is predominantly owner-occupied versus renter-occupied as well as factors related to how different information technologies (feedback) and energy-control devices (e.g. thermostats) can differently affect household energy consumption without changes in price or other policy parameters (Wood and Newborough, 2007; Burgess and Nye, 2008).
- *Tertiary education*: According to Chancel and Piketty (2015), education and social status could lead to individual preferences, both of which can result in more or less emission intensive lifestyles.
- *Electricity mix*: Households usually have limited influence on the average electricity mix that is offered in a country. Countries such as Sweden and Norway that rely heavily on hydroelectric power (also nuclear in Sweden) tend to have lower carbon emissions per capita than other developed nations.

Income appears to have the highest explanatory factor, explaining 29% of household emissions. As well as the electricity mix, heating degree days are another important factor. Impacts related to expenditure on clothing, mobility and manufactured products appear to be rather income inelastic. Higher members per household reduces impact; additional rooms per household increases impact; higher education levels increases impact, particularly due to food consumption (higher animal protein consumption). The differentiation between urban and rural regions appears to be insignificant except for mobility.

4. Discussion: improved monitoring of how consumption drives environmental impacts

The sections above demonstrate a clear consensus about the most important consumption categories that drive the impact of household consumption, as well as their determining variables. Virtually all studies single out food (meat, dairy, followed by the rest), housing (heating, cooling, electrical equipment and construction) and transport (private car driving, followed by public transport and air travel) as the priorities. There is robust agreement that factors such as income, the numbers of dwellers per household, house size, and the electricity mix are among the most important explanatory variables of the impacts of household consumption. Such top-level insights provide a good basis for a governance agenda in support of sustainable consumption. Some suggestions will be made in the conclusions.

Having said this, a sustainable consumption governance agenda is also supported by the availability of sound monitoring mechanisms. These enable the analysis of the effectiveness of governance interventions and how behavioural change, via changes in expenditure patterns, may lead to lower impacts along global value chains. In principle, time series of the (global) MRIO models discussed in this chapter allow such monitoring. If we have knowledge of expenditure patterns by income group or consumer type, in particular, it would be possible to see how changes in impacts of consumption relate to changes in expenditure patterns, income level, efficiency gains in production processes, structural economic change, or change in source country of imported products. This, however, relies on the availability of more detailed consumption expenditure data by income group globally (see Ivanova et al., 2017), and creating more robust GMRIO databases while ensuring these are updated annually. Currently, environmental footprints of consumption calculated with different MRIO databases still vary significantly. Interestingly, differences in the emission and resource extraction data per country appear to be a dominant factor in calculated differences in footprints. The solution for this problem is obvious: the harmonization of databases used to compile extensions like CO2 and other emissions, resource extractions, water and land use. The next important factor contributing to uncertainty is the estimation of a country's GDP as a percentage of global GDP, in addition to the structure of the MRIO of a specific country as captured in a specific GMRIO. The least important factor, surprisingly, appears to be the estimation of global trade relations (see Owen, 2017; Tukker et al., 2018b). This leads to the following suggestions for improved monitoring of how consumption drives (global) environmental impacts:

1. Harmonize the most important factors contributing to uncertainty in GMRIO databases as listed above.
2. Create an institutional context in which GMRIO databases are regularly updated, instead of those being currently developed by short-term academic projects without permanent funding.
3. Ensure that GMRIO databases have sufficient detail for monitoring the shift towards sustainable consumption. First, product and sector detail is relevant for calculating sound water, material, and land footprints. Consumption items like beef with high footprints and beans with low footprints should be visible, for example, and illustrating the impact of diet change is also important (Lenzen, 2011; de Koning et al., 2015; Tukker et al., 2018b). Second, consumption expenditure patterns by income category and consumer type should ideally be available to monitor the influence of income and life-style changes.

Tukker et al. (2018b) suggest the following roadmap for such improvements.[4] In the short term, basic harmonization of existing GMRIO databases constructed by scientists could be realized as follows. First, harmonized databases for extensions should be developed or used, such as the resource extraction database recently developed by the UN International Resources Panel (IRP). Here, particularly work on water, land and emission extensions remains to be done. It is likely that such simple measures could reduce the differences in calculations of footprints of nations with different databases by over 50%.

A further step towards a higher level of credibility of GMRIO databases could be made as follows: the Organisation for Economic Co-operation and Development (OECD) produces currently the ICIO GMRIO, which has a (too) high level of aggregation of 30 sectors, with the aim of performing footprint analyses. Using procedures developed for EXIOBASE and Eora, ICIO GMRIO could be detailed to an appropriate level for footprint analyses, and combined with the common environmental extension databases.[5] This would lead to a GMRIO database with an appropriate level of detail, but in which important elements (the structure at the level of 30 sectors globally and extensions) are harmonized and endorsed by important organizations such as the OECD and UN IRP.

Finally, the problem that even such a GMRIO database overrides national accounts data can be overcome by applying the SNAC or 'simplified SNAC' procedure described in Box 4.1. This simplified SNAC procedure can be applied for all countries that have limited 'feedback emissions' (i.e. emissions and resource use in their exports that also appear in their imports via global value chains). This is the case for almost all countries except China and the USA. If a semi-standardized GMRIO were available and combined with available national accounts data, the calculation of country footprints would be a rather straightforward exercise.

In the long term, bodies such as the UN Statistical Division, World Bank, OECD, Eurostat and National Statistical Institutes (NSIs) should be provided with the resources to make national accounts, and particularly the importing and exporting of data, consistent at the global level at regular time intervals, ideally yearly. The World Bank already has set up a detailed consumption expenditure database by income group for some 160 low- and medium-income countries. Ideally this database would be expanded to all countries globally and annually updated (World Bank, 2017). Unlike researchers, such official organizations (particularly NSIs) have access to data of unprecedented quality and detail and, in principle, are in the best position to provide high-quality statistics that at the same time are consistent at global level. From the experience of compiling the existing GMRIO databases, they could identify the most pressing inconsistencies at international level as input to the continuous improvement processes already applied in their regular data inventory and reconciliation work.

5. Conclusions

This chapter has reviewed the findings of studies in the last 10 to 15 years that have analysed how final consumption drives environmental impacts along global value chains. Since trade – and with this, embodied emissions and resource use – has exploded in recent decades, monitoring environmental impacts of consumption at national level is insufficient. Impacts of consumption of product category x in country y can take place largely abroad. Global Multi-Regional Input Output Tables (GMRIO) have become the method of choice for monitoring the relation between final consumption by country and product and environmental impacts along global value chains.

Work thus far shows convincingly that housing (cooling and heating), food consumption (meat and dairy followed by the rest), mobility (car and air transport) and the use of electrical appliances dominate impacts of consumption. Income and household size are among the most important indirect drivers of impacts of consumption. This provides a number of obvious leverage points for the reduction of the impacts of consumption: stimulate carbon neutral housing, discourage low-density use of houses, make the energy system carbon neutral, stimulate low-meat and low-dairy diets, make cities compact and provide alternative mobility options for car ownership (e.g. public transport, e-bikes), minimize energy use of appliances via product policy and stimulate low-impact expenditures in general while potentially stimulating a good quality of life without significant growth in future income. For policymakers, the main message of this chapter is hence that governance approaches stimulating sustainable consumption could be focused on such solutions.

GMRIO databases with appropriate detail are an excellent tool to monitor the effectiveness of governance approaches that stimulate sustainable consumption and lifestyles. For this purpose, existing GMRIO databases should be harmonized, particularly with regard to environmental extensions, to reduce uncertainty in current footprint assessments. Furthermore, GMRIO databases should be regularly updated, ideally by providing resources to international organizations or collaborative NSIs. Finally, monitoring of expenditures on specific products and services by country ideally is differentiated by income category or consumer type, following the example of the World Bank consumption database (World Bank, 2017). Such an infrastructure would make it possible to assess changes in the impact of consumption by income category by country as well as the factors that drive such changes such as changes in consumption patterns, changes in income, efficiency improvements in production, or structural changes in the economy including trade patterns. For scientists and statistical professionals, the main message is hence to embark on further work on the monitoring system outlined here, while policymakers taking sustainable consumption governance seriously need to acknowledge that resources must be made available to enable such an effort.

NOTES

1 The choice of adding additional studies is only arbitrary. The field of environmental footprint analyses has exploded and a great number of papers are now available (e.g. Hoekstra, 2010). It is not the purpose of this chapter to provide a complete review, but merely to provide main indications of the priority areas.

2 This section summarizes and expands upon Tukker and Jansen (2006)

3 The data of Collins et al. (2006) deal only with household expenditure. Palm et al. (2006) concentrate all energy-related household emissions in a specific energy-related emissions sector in their IO table.

4 The text below largely follows the concluding section of Tukker et al. (2018a)

5 In this, we assume the ICIO database is using also harmonized data that ensure the GDP or final demand in a country is a sound representation of the percentage of global GDP, another factor that can influence footprint calculations significantly.

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