Environmental Accounting from a Producer and a Consumer Principle; an Empirical Examination covering the World [1]

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Abstract:
Countries are usually judged on their use of natural resources and production of emissions in their own territories, i.e. from a producer principle. So, policies on reducing environmental pressures generally start from this principle. An alternative environmental accounting principle for countries is the consumer principle, which includes the environmental pressure pertaining to imports. The carbon footprint, e.g., is such an approach in which CO_2 emissions are considered from the consumption perspective. The consumer principle may offer policies other ways to reduce pressures, and therefore it may be interesting to take the consumer principle into account for national environmental policies and international negotiations. In order to gain insights in the differences between the principles, this paper discusses the concepts of both principles, shows the results of an empirically analysis and goes into the applicability in policy.

For each country the differences in environmental pressures accounted for by both principles are different. This paper presents a world-wide overview by comparing the two principles for greenhouse gas (GHG) emissions and land use for 12 world regions. Furthermore, a quantitative comparison is made for GHG emissions for 87 countries and regions covering the world. Consumption-related GHG emissions and land use per capita are calculated with a full multi-region input-output model. The paper shows that, for most developed countries, total GHG emissions and land use are higher for the consumer

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[1] Submitted version of: Harry C. Wilting & Kees Vringer (2009) *Carbon and Land Use Accounting from a Producer's and a Consumer's Perspective - An Empirical Examination covering the World.* ESR, Economic Systems Research, special issue on Carbon Footprints and Input-Output Analysis. **21**, No.3, September 2009.

principle than for the producer principle. For most developing countries it is the other way around. When applying national targets for the consumer principle, e.g. in climate policies, further improvements and standardization of methodology and data are necessary.

Keywords: Environmental accounting, environmental policy, international trade, multi-region input-output analysis, responsibility

1. Introduction

There are two main accounting principles for environmental pressures on a country basis. The first, and the most common, considers all the pressures in a country's territory. The producers of emissions are held responsible in line with the 'polluter pays principle' (and national policies and targets are usually based on this approach). The second accounting principle lays the responsibility of environmental pressure on the consumer. All pressures related to consumption of the inhabitants of a country including the environmental pressures from imports are assigned to that country. Footprint approaches, like the carbon footprint (Wiedmann and Minx, 2008), the ecological footprint (Wackernagel and Rees, 1996) and the water footprint (Hoekstra and Chapagain, 2007) are based on this principle.

Countries are usually judged on the use of natural resources and production of emissions in their territories, i.e. from a producer principle. National targets and international agreements, for example, the Kyoto Protocol directed at the world-wide reduction of greenhouse gas (GHG) emissions, are based on this principle. National environmental policies aim at domestic producers of emissions by issuing rules, standards, agreements, taxes, et cetera. For instance, the Dutch government has fixed sectoral emission targets for domestic emissions in order to realize the Kyoto targets. The producer approach has led to substantially lower emissions of several substances in the Netherlands in the past decennia, a period with a growing GDP (PBL, 2008a). Environmental policy has been successful, especially in cases where efficiency improvements could be realized via measures directed at stimulating new technologies. However, there are some persistent global environmental problems where environmental policy at a national level has not yet led to substantial emission reductions.

Since not all countries participate in international agreements on reducing emissions, environmental policies aiming at emission reductions in a country may be suboptimal. In the case that producers pass on higher production costs through taxes to consumers, consumers can choose products of countries with a lower level of environmental legislation. Further, by limiting polluting activities it is possible to achieve targets, for example, by restricting the growth of polluting exports or by increasing imports, e.g. electricity. In both cases, this represents a shift of some domestic emissions abroad. If foreign efficiencies are lower, this will result in higher overall emissions (in case of GHG emissions and a shift to countries not participating in the Kyoto protocol, this phenomena is called carbon leakage). So, a stringent environmental policy aimed at producers may lead to a shift from domestic production to countries with less strict environmental policies (pollution haven theory, see e.g. Antweiler et al., 2001)[2]. Another disadvantage of (inter)national environmental policies directed at territorial emissions is the exclusion of international (sea and air) transport emissions. These emissions are not included in national targets since they occur outside the territorial boundaries of countries[3]. A way to overcome this latest disadvantage is to apply environmental policy in a country to all direct emissions originating in the population and companies independent of the location of emission. Dutch producers and consumers are then also judged on the direct emissions they cause outside the Netherlands (mostly caused by transport).

The consumer accounting principle is, from a responsibility perspective, proposed to overcome the above-mentioned drawbacks of the producer accounting principle (see, for example, Peters, 2008). Instead of national environmental policies allocating the burden of reducing emissions to the producer of emissions (the polluter pays principle), this burden is allocated to consumers (consumer should pay principle)[4]. The underlying idea is that consumers initiate production processes with their consumption. Environmental policy directed at consumption does not have the disadvantages as mentioned above for national territorial-based policies. There is no carbon leakage or shift to pollution havens in the

[2] However, there is no indication that this is happening on a large scale in the Netherlands (Wilting *et al.*, 2006).
[3] From 2012, European airline companies have to participate in the European Emission Trading Scheme (ETS).
[4] Besides the full producer and consumer responsibilities (as discussed in this paper), mixed forms like shared responsibility exist (Steenge, 1999; Lenzen *et al.*, 2007).

consumer approach, since emissions of imports are considered in the accounting. Furthermore, emissions of international transport can be considered in the consumer approach. So, it may be useful to include the consumer principle in environmental policies.

Although national environmental policies are traditionally directed at emission reduction and improvement of the environmental quality in the territory of the country, there is growing interest in the environment abroad. Dutch policies on environment and sustainability, e.g., pay attention to the effect of national consumption on environmental quality in other countries. The Dutch government recommends that sustainable economic growth takes place in the Netherlands under the condition that shifts in pollution to elsewhere or later are prevented (VROM, 2006). However, in order to fully include the consumer principle in (inter)national policies and negotiations, further steps are required. A first step may be an empirical comparison of both principles for different countries. Such a comparison may support national environmental policies in enhancing their possibilities for reducing environmental pressures in their countries and abroad. This requires policies that focus both on sectors and on life chains.

This paper presents world-wide GHG emissions and land use for 12 world regions calculated according to both principles. Direct emissions and land use according to the producer principle are obtained from statistics directed at nations. For calculating the emissions and land use according to the consumer principle a full multi-region input-output model is used. GHG and land-use intensities accounting for the origin of imports, calculated for 12 regions, are combined with demand on consumption in these regions. Furthermore, for GHG emissions a more detailed analysis is carried out by comparing the outcomes for 87 countries and regions worldwide. In order to facilitate comparability between regions GHG emissions and land use are expressed in units per capita. International comparisons at a world citizen level may give insights in the environmental aspects of consumption patterns between countries from an equity perspective.

2. Background

The difference between the two accounting approaches stems from international trade and studies on the environmental aspects of trade make an implicit comparison between the two accounting principles (Serrano and Dietzenbacher, 2008). The emissions and land use allocated to domestic consumption include a part of the emissions and land use of production processes in other countries. In fact, the environmental pressure related to consumption equals the environmental pressure from production minus the domestic pressure for exports plus the environmental pressure abroad concerning imports for consumption. If there would be no trade, all economies would be closed and environmental pressures following both methods would be the same. However, economies are not closed, but become more open, since trade increases as a result of globalization. So, the difference between the two approaches may increase too.

In early input-output studies, it was often assumed that imported goods and services were produced with production technologies similar to the domestic technologies (single-region input-output analysis). Several studies, for example, Battjes *et al.* (1999), Lenzen *et al.* (2004), and Peters and Hertwich (2006), showed that this assumption is too rough at the country level since there are significant differences in technologies and efficiencies between countries. Since technologies in more developed countries are often more efficient than technologies in less developed countries, the single-region assumption on imports overestimates the emissions in developing countries and underestimates the emissions in developed countries. To tackle this problem, the consumer-related emissions and land use are calculated with a full multi-region input-output model for the world. In the appendix, the usefulness of such a multi-region input-output model is demonstrated by comparing the multi-region based GHG emissions and land use with the single-region-based ones. Furthermore, the appendix goes into the differences with another calculation approach in which all pressures according to the consumer principle are calculated with the same (world-average) sectoral intensities for all regions.

A large amount of studies only concerns consumption-related resource use and environmental pressures with the idea that consumers are responsible for production and distribution of goods and services. Wilting (1996) and Vringer (2005) e.g., investigated the energy requirements of household consumption in the Netherlands. Studies directed on consumption-related environmental pressures are e.g. Nijdam et al. (2005), Peters and Hertwich (2006), and Weber and Matthews (2008).Where responsibility lies with the consumers, environmental policy may aim at consumption too in order to realize further reductions of environmental pressures than could be achieved by only a sectoral approach. Hoekstra and Janssen (2006) present a broad overview of the literature on environmental responsibility.

Some studies have already compared the two accounting principles for individual countries. Munksgaard and Pedersen (2001), for example, investigated CO_2 emissions for both accounting principles for Denmark for the 1966-1994 period. Wilting and Ros (2009) compared the two approaches for GHG emissions for the Netherlands and the European Union. Examples of other countries for which both accounting principles were compared are New Zealand (Andrew and Forgie, 2008) and the UK (Druckman et al., 2008). However, world-wide comparisons that may be useful in order to identify differences between countries or regions are scarce. One example is the study by Peters and Hertwich (2008) that determines CO_2 emissions for both principles for 87 countries. This paper goes further by considering other GHG emissions[5] and land use too.

3. Methodology

A quantitative comparison between GHG emissions and land use by the producer and consumer principle is carried out for 12 world regions. For GHG emissions also an indicative calculation is made for 87 regions throughout the world (based on the countries and regions in the GTAP 6 database). Table 1 gives an overview of the aggregation scheme from 87 regions to 12 world regions. This section describes the methods for determining environmental pressures according to both principles.

[5] CH_4 and N_2O.

Table 1 *World regions based on the GTAP 6 regions*

World region No.	Code	Description	GTAP 6 region No.	Code	Description
1	NAm	North America	21	can	Canada
			22	usa	United States
			24	xna	Rest of North America
2	CSAm	Central and South America	23	mex	Mexico
			25	col	Colombia
			26	per	Peru
			27	ven	Venezuela
			28	xap	Rest of Andean Pact
			29	arg	Argentina
			30	bra	Brazil
			31	chl	Chile
			32	ury	Uruguay
			33	xsm	Rest of South America
			34	xca	Central America
			35	xfa	Rest of FTAA
			36	xcb	Rest of the Caribbean
3	Oc	Oceania	1	aus	Australia
			2	nzl	New Zealand
			3	xoc	Rest of Oceania
4	JNIE	Japan and New Industrializing Economies	5	hkg	Hong Kong
			6	jpn	Japan
			7	kor	Korea
			8	twn	Taiwan
			13	sgp	Singapore
5	SEA	Southeast Asia	10	idn	Indonesia
			11	mys	Malaysia
			12	phl	Philippines
			14	tha	Thailand
			15	vnm	Vietnam
			16	xse	Rest of Southeast Asia
6	EA	East Asia	4	chn	China
			9	xea	Rest of East Asia
7	SA	South Asia	17	bgd	Bangladesh
			18	ind	India
			19	lka	Sri Lanka
			20	xsa	Rest of South Asia
8	ME	Middle East	71	tur	Turkey
			72	xme	Rest of Middle East
9	FSU	Former Soviet Union	69	rus	Russian Federation
			70	xsu	Rest of Former Soviet Union
10	EEU	Eastern Europe	54	xer	Rest of Europe
			55	alb	Albania
			56	bgr	Bulgaria
			57	hrv	Croatia
			58	cyp	Cyprus

			59	cze	Czech Republic
			60	hun	Hungary
			61	mlt	Malta
			62	pol	Poland
			63	rom	Romania
			64	svk	Slovakia
			65	svn	Slovenia
			66	est	Estonia
			67	lva	Latvia
			68	ltu	Lithuania
11	OEU	OECD Europe	37	aut	Austria
			38	bel	Belgium
			39	dnk	Denmark
			40	fin	Finland
			41	fra	France
			42	deu	Germany
			43	gbr	United Kingdom
			44	grc	Greece
			45	irl	Ireland
			46	ita	Italy
			47	lux	Luxembourg
			48	nld	Netherlands
			49	prt	Portugal
			50	esp	Spain
			51	swe	Sweden
			52	che	Switzerland
			53	xef	Rest of EFTA
12	Af	Africa	73	mar	Morocco
			74	tun	Tunisia
			75	xnf	Rest of North Africa
			76	bwa	Botswana
			77	zaf	South Africa
			78	xsc	Rest of South African CU
			79	mwi	Malawi
			80	moz	Mozambique
			81	tza	Tanzania
			82	zmb	Zambia
			83	zwe	Zimbabwe
			84	xsd	Rest of SADC
			85	mdg	Madagascar
			86	uga	Uganda
			87	xss	Rest of Sub-Saharan Africa

3.1 Producer accounting principle

The GHG and land-use accounting by the producer principle is straightforward. Data on emissions and land use are obtained from national or regional statistics, databases or models. GHG emissions data were compiled for 12 and 87 regions, and land use data for 12 world regions. The data apply to total emissions and land use for production and consumption within the regional borders, and international transport related to producers seated in the regions (fishermen, transport companies, etc.)[6]. The collected data serve as a basis for the consumer accounting principle too, in which, in fact, the data are reshuffled over consumers and regions.

3.2 Consumer accounting principle

The GHG emissions and land use by the consumer principle are calculated with environmental input-output analysis (see e.g. Suh, 2009). Standard input-output analysis gives the following relationship between production $\mathbf{x}$ and final demand $\mathbf{y}$ for a single-region economy:

$$\mathbf{x} = \mathbf{A}\,\mathbf{x} + \mathbf{y} \qquad (1)$$

where $\mathbf{A}$ is the matrix of input-coefficients, which defines the intermediate input requirements per unit output for each sector. The standard input-output model for calculating sectoral output $\mathbf{x}$ for a certain final demand $\mathbf{y}$, e.g. consumption, is derived by solving equation 1 for $\mathbf{x}$:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\,\mathbf{y} \qquad (2)$$

where $(\mathbf{I} - \mathbf{A})^{-1}$ is the Leontief inverse matrix. Matrix $\mathbf{I}$ is the identity matrix.

The input-output model for calculating cumulative intensities of resource use or environmental pressure in the single region is now:

$$\mathbf{e} = \mathbf{d}\,(\mathbf{I} - \mathbf{A})^{-1} \qquad (3)$$

[6] So, there is a distinction between territorial emissions and emissions by the producer principle.

where **d** is the row vector of direct environmental pressure intensities depicting the environmental pressure from one unit of production for all sectors. Vector **e** of cumulative intensities depicts all environmental pressure along the whole upstream supply chain per unit of production.

Assuming that the row vector of environmental pressure intensities **e** defines the environmental pressure per unit of output for all industries, the input-output model for calculating the environmental pressure **E** related to final demand is:

$$\mathbf{E} = \mathbf{e}\,\mathbf{y} + \mathbf{D} \tag{4}$$

where **D** is the direct environmental pressure from final demand, e.g. residential emissions of heating or car use.

In order to take into account imports, and region-specific production technologies and efficiencies, a multi-region model is used for the calculation of the environmental pressure intensities of the world regions (as discussed in the background). The multi-region model corresponding to equation 1 is:

$$\begin{bmatrix} \mathbf{x_1} \\ \vdots \\ \mathbf{x_n} \end{bmatrix} = \begin{bmatrix} \mathbf{A_{11}} & \cdots & \mathbf{A_{1n}} \\ \vdots & \ddots & \vdots \\ \mathbf{A_{n1}} & \cdots & \mathbf{A_{nn}} \end{bmatrix} \begin{bmatrix} \mathbf{x_1} \\ \vdots \\ \mathbf{x_n} \end{bmatrix} + \begin{bmatrix} \mathbf{y_1} + \sum_{\mathbf{i \neq 1}} \mathbf{y_{1i}} \\ \vdots \\ \mathbf{y_n} + \sum_{\mathbf{i \neq n}} \mathbf{y_{ni}} \end{bmatrix} \tag{5}$$

with:

$\mathbf{x_i}$ vector of production in region i

$\mathbf{A_{ii}}$ matrix of domestic input coefficients of region i

$\mathbf{A_{ij,\ i \neq j}}$ matrix of import coefficients of region j importing from region i

$\mathbf{y_i}$ vector of domestic final demand of region i

$\mathbf{y_{ij,\ i \neq j}}$ vector of imported final demand of region j importing from region i

This is a full multi-region model with feedback loops (according to the terminology in Wiedmann *et al.*, 2007). Setting

$$\mathbf{x^*} = \begin{bmatrix} \mathbf{x_1} \\ \vdots \\ \mathbf{x_n} \end{bmatrix}, \ \mathbf{A^*} = \begin{bmatrix} \mathbf{A_{11}} & \cdots & \mathbf{A_{1n}} \\ \vdots & \ddots & \vdots \\ \mathbf{A_{n1}} & \cdots & \mathbf{A_{nn}} \end{bmatrix}, \ \mathbf{y^*} = \begin{bmatrix} \mathbf{y_1} + \sum_{\mathbf{i} \neq \mathbf{1}} \mathbf{y_{1i}} \\ \vdots \\ \mathbf{y_n} + \sum_{\mathbf{i} \neq \mathbf{n}} \mathbf{y_{ni}} \end{bmatrix},$$

the multi-region input-output model is:

$$\mathbf{x^* = A^* \, x^* + y^*} \tag{6}$$

Similar to equation 3, the intensities for total environmental pressure are:

$$\mathbf{e^* = d^* \, (I - A^*)^{-1}} \tag{7}$$

with $\mathbf{d^*} = \begin{bmatrix} \mathbf{d_1} & \cdots & \mathbf{d_n} \end{bmatrix}$, where $\mathbf{d_i}$ is a row vector of direct intensities of environmental pressure in region *i*, and $\mathbf{e^*} = \begin{bmatrix} \mathbf{e_1} & \cdots & \mathbf{e_n} \end{bmatrix}$, where $\mathbf{e_i}$ is a row vector of total intensities of environmental pressure in region *i*.

Total environmental pressure related to domestic final demand in region *i*, $\mathbf{E_i}$**,** is

$$\mathbf{E_i = e^* \, y_i^* + D_i} \tag{8}$$

with $\mathbf{y_i^*} = \begin{bmatrix} \mathbf{y_{1i}} \\ \vdots \\ \mathbf{y_{ni}} \end{bmatrix}$, and $\mathbf{D_i}$ is the direct environmental pressure from final demand of region *i*.

Consumption-related environmental pressure is calculated by combining total intensities of environmental pressure with consumption figures. The calculation of environmental pressure intensities was limited to 12 world regions covering the 87 GTAP regions. Although economic input-output data is available for 87 regions, it was too data and labour-intensive to calculate environmental pressure intensities for all these regions. For the indicative calculation of GHG emissions for the 87 countries, the intensities of the 12 world regions were used. The intensities of the world region to which the region belongs to were used for calculating environmental pressure from consumption per region. The underlying assumption is that differences in intensities in world regions are lower than differences in intensities between world regions.

4. Data: sources and processing

4.1 Economic data

Economic data were derived from the GTAP database, version 6, which consists of input-output data of 87 regions and 57 sectors (Dimaranan, 2006). Version 6 concerns the global economy in 2001. The aggregation of the GTAP data from 87 regions to 12 world regions was carried out by the GTAP aggregation tool GTAPAgg (Horridge, 2006). In the aggregation process, all imports of regions are summed up to give the imports of the world regions. These imports then include the intra-trade flows between regions in the aggregated world region. In this way, the intra-regional trade flows in a world region are unintentionally seen as imports of that world region. To tackle this problem, these intra-regional 'imports' were added to the domestic intermediate flows of the world region. Similarly, the intra-regional final demand was added to the 'domestic' final demand of world regions in aggregating final demand.

Since the aggregated intermediate and final demand imports for each world region have no segmentation in region of origin, these imports were split up by using GTAP trade data concerning trade flows at the level of 57 sectors and 87 regions. It was assumed that both intermediate demand for imports (per sector) and final demand imports have the same division across regions of origin.

The domestic and import matrices for all world regions were based on the cost structure of firms; final demand was based on the cost structures of private household consumption and government consumption. All cost structures distinguish domestic and imported purchases and are expressed in basic prices (market prices in GTAP). Import taxes and subsidies were removed from imports in basic prices resulting in c.i.f. (cost, insurance, freight) prices (world prices in GTAP). Valuation in c.i.f. prices is based on f.o.b. (free on board) prices and transport costs (concerning costs of transport and insurance abroad). Transport costs were removed from c.i.f. prices and assigned to the transport sector rows as extra deliveries from these sectors. Data in f.o.b. were used in compiling the import matrices.

Investments, which are usually part of final demand, were included in the intermediate matrices. In this sense, the calculation process of the environmental pressure intensities accounts for capital goods. Capital investments in the past contribute to total resource use and emissions related to production for final demand, but do not belong to production in the current year. The deliveries to the investments were, for each sector, assigned to the inputs in the intermediate matrices (domestic and imports) on the basis of depreciation per sector. Since both replacement and extension investments were included in the intermediate matrices, the calculated environmental pressures related to consumption and exports may be overestimated. On the other hand, this approach guarantees that global pressures according to both accounting approaches should be the same.

4.2 GHG emission data

Data on GHG emissions (CO_2, CH_4 en N_2O) were derived from two main databases: the EDGAR 3.2 Fast Track 2000 dataset (Van Aardenne *et al*., 2005) and the GTAP/EPA database (Lee, 2002, 2003). The GTAP/EPA database is more detailed at the sectoral level and is, for CO_2 emissions, compatible with the 87 GTAP 6 regions. CH_4 and N_2O emissions are available for 66 countries and regions according to the GTAP 5 database. The EDGAR 3.2FT dataset represents a fast update of the EDGAR database, which is a set of global anthropogenic emission inventories of various trace gases for 234 countries. This database contains more emissions sources than the GTAP/EPA database. The GTAP/EPA database contains, for example, only fossil-fuel related CO_2 emissions and no process emissions such as seen in the production of concrete or emissions related to biomass burning.

The data used in the calculations apply to the year 2000. Starting point for the data compilation was the EDGAR dataset. Since the calculations focus on fossil fuel use and agricultural emissions, some sources of emissions in the EDGAR database were not included in the data. The CO_2 data used do not include the emissions allocated to non-energy use and chemical feedstock, which are not actually emitted, and the emissions caused by tropical forest fires for deforestation. It is not always clear if these fires have an anthropogenic cause or if they are the result of thunderbolt. Similarly CH_4 and N_2O

emissions from forests, savannah, shrubs and grassland fires were excluded from the calculations.

The emissions in the EDGAR database are not at the detailed level of the 57 GTAP sectors. The further subdivision of the EDGAR emission data into these 57 sectors was carried out on the basis of the emission data collected in the GTAP/EPA project. All emission data were compiled at the level of 87 regions and at the aggregated level of 12 world regions. Residential emissions including private transport were allocated as direct emissions of final demand. For convenience, emissions related to waste processing, e.g. landfills were also allocated to direct emissions instead of allocating them to industrial sectors or the waste-processing sector. Finally, the emissions of N_2O and CH_4 were expressed in CO_2–equivalents by using Global Warming Potential (GWP) values (21 for CH_4 and 310 for N_2O). These GWP values represent a measure of the contribution of individual GHG to climate change.

4.3 Land-use data

Just as for emission data, land-use data were obtained from several sources. The main data source was the IMAGE model (MNP, 2006) consisting of land-use data for 24 world regions. Most data in the IMAGE model are based on FAO databases (FAO, 2006). For the compilation of crop land data used in the multi-region model, data on crop area from the IMAGE model were combined with data on harvested area from the GTAP land-use database (Lee *et al*., 2005). The latter database consists of land use for crop production for 19 crops in 226 countries. These data were used to split up the aggregated land use from the IMAGE model further to the sectoral level of GTAP. All data were compiled at the level of 12 world regions.

Land use for pasture was directly obtained from IMAGE and assigned to two pasture sectors in GTAP: cattle and milk. The breakdown according to cattle and milk was based on several factors, e.g. animal feed (Eickhout, 2007). All land-use data apply to physical areas and no correction was made for extensive or intensive use of the land. Especially for pasture land, there are huge differences in the areas per animal between countries. Land use for forestry products was obtained from the IMAGE model too (Van Oorschot, 2007). Finally, data on built-up land was derived from UN and HYDE databases

(UN, 2004; Klein Goldewijk, 2006). Built-up land concerns urban land and land for infrastructure. Built-up land was not used in the calculation of the land-use intensities, but was directly assigned to final demand.

5. GHG emissions and land use by the two principles

5.1 The two principles applied for 12 world regions

Figure 1 shows GHG emissions and land use accounted according to the two principles in 12 world regions. The absolute levels of GHG emissions per capita depict the differences in welfare between world regions in some sense. The consumer-related emissions of an inhabitant of North America (Nam) are about 13-15 times higher than those of inhabitants of Southeast Asia (SEA), South Asia (SA) and Africa (Af)[7]. GHG emissions according to the consumer principle are higher than those according to the producer principle in three world regions: North America, the JNIE region and OECD Europe. These are all well-developed regions with high consumption levels importing from regions which may have lower efficiencies. Figure 1 also shows the differences for both approaches in land use. The same regions as identified for GHG emissions show higher land use for the consumer principle than for the producer principle. Furthermore, the Middle East (ME), which has low levels of fertile land, shows higher land use for the consumer principle. On the other hand, land use in Oceania is very high due to the very extensive use of land in sheep breeding, which produces for exports mainly.

The differences in the outcomes for both approaches per region are the result of trade, i.e. differences in structures of imports and exports, and in efficiencies between regions. If environmental pressure according to the producer principle is higher than that to the consumer principle, a region may have a high polluting production structure (although the polluting industries may be efficient compared to the same industries in other countries).

Another reason for a higher environmental pressure for the producer principle is less efficient production in the region under consideration and relatively more efficient

[7] In fact, the differences in welfare are even higher, since the figures in figure 1 are based on different efficiencies per region. The appendix shows emissions according to the consumer principle calculated with average world intensities depicting differences between regions as the result of differences in consumption volume and patterns only.

production of the imports. The Former Soviet Union and Oceania, for example, have lower efficiencies for land use than other regions (see appendix). When environmental pressure for the consumer principle is higher than for the producer principle, which is the case for GHG emissions and land use for most developed countries, then imports are less efficiently produced or the structure of exports is less polluting than the structure of imports for consumption.

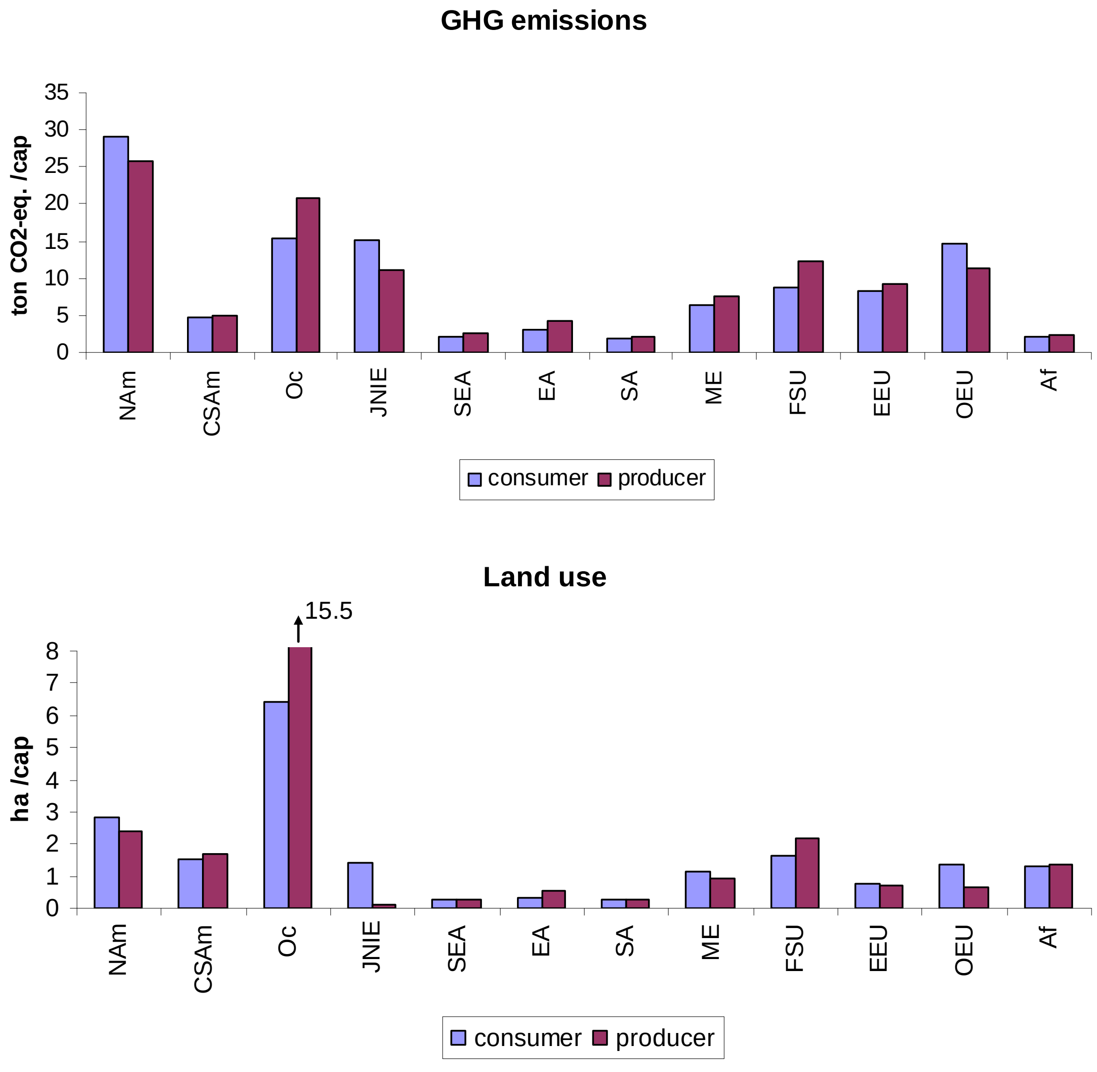

Figure 1 *GHG emissions and land use per capita for the two principles for 12 world regions (2001).*

5.2 The consumer principle applied for 87 countries/regions

GHG emissions and land use were also calculated for the consumer principle at a more detailed level of 87 countries and regions by combining consumption patterns of these regions (based on GTAP data) with the intensities of the 12 world regions. Figure 2 shows GHG emissions and land use per capita plotted against world population (cumulative on the x-axis). The left side of the figure shows that about 1 billion people – living in developed world regions - have GHG emissions related to consumption that are higher than 10 ton CO_2-eq. per capita. This part of the world population (1 billion or 16%) causes about 55% of total GHG emissions. The other part of the world population (well over 5 billion people) causes only 45% of world GHG emissions.

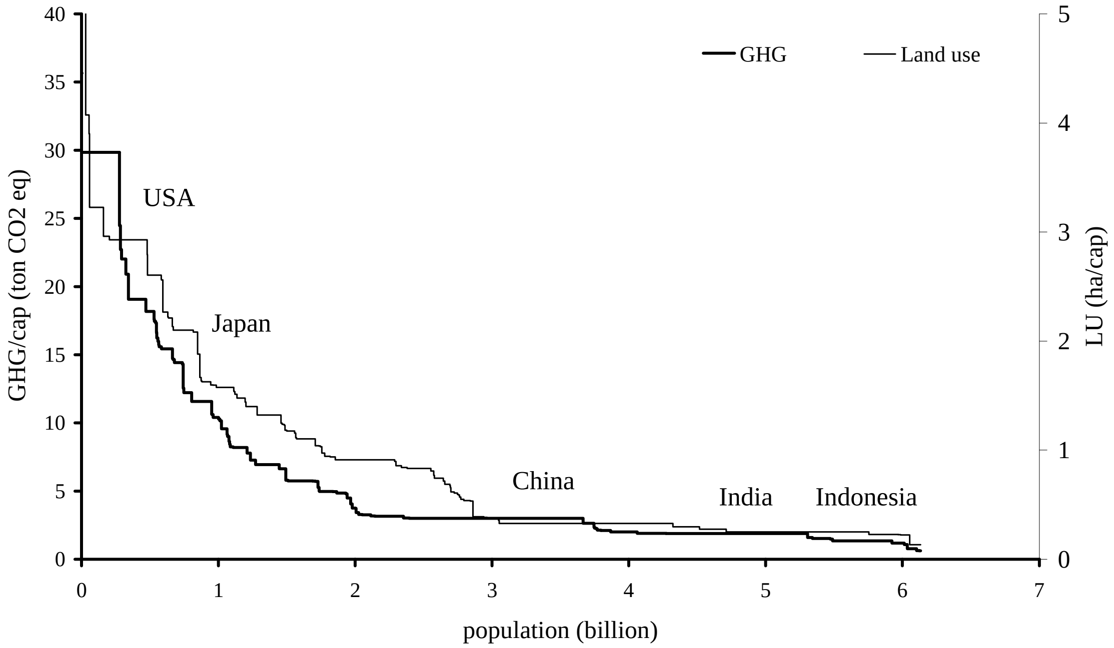

Figure 2 *GHG emissions and land use for the consumer principle across regions (2001).*

Land use shows a similar pattern as GHG emissions. About 2 billion people (32% of world population) require more than 1 ha/cap (right y-axis in Figure 2). The total land use for this group is almost 70% of the total land use for production and consumption. The figures presented may not be surprising, since Gross Domestic Product (GDP) per capita and the connected private income are not equally distributed over the world population. Figure 3 shows the GDP per capita per region for the world population. The differences in income, and therefore in consumption volume, explain the differences in GHG emissions and land use to a large extent. Further sources for differences are consumption patterns, trade flows and production technologies. With a growing world population and per capita income, the demand for goods and services will further increase in the future. PBL (2008b) shows in a study concerning the year 2040, that although technological development makes the production of these goods and services more and more efficient, the demand on energy and materials will still grow. As a result, GHG emissions and land use remain on the increase, leading to climate change and further decrease of biodiversity.

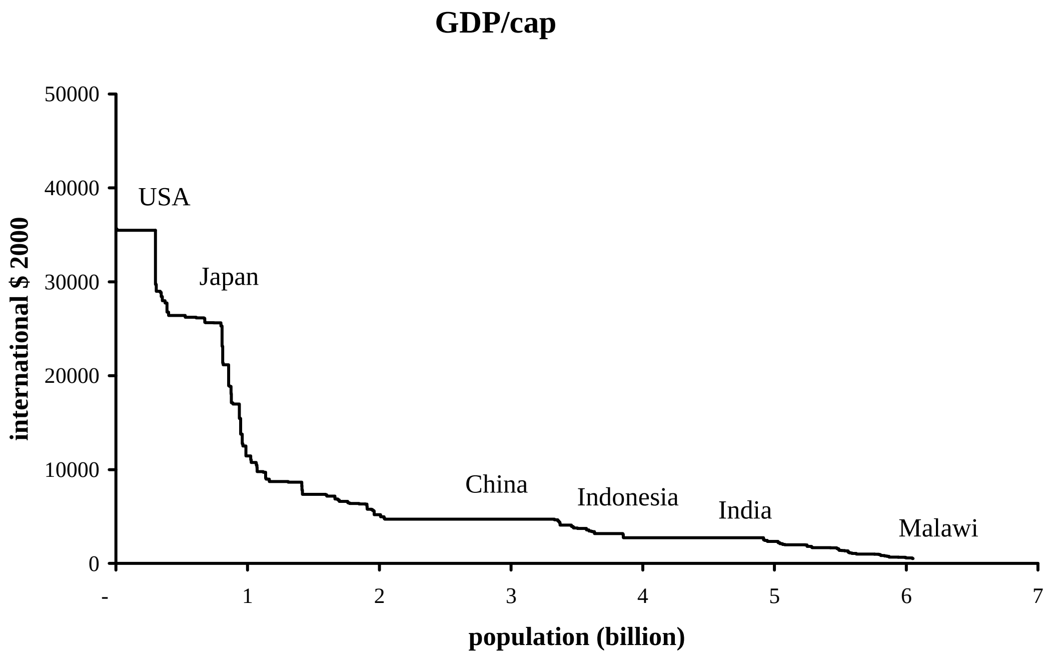

Figure 3 *GDP per capita across regions, 2003 (IMF, 2006).*

5.3 The two principles applied for 87 countries/regions

GHG emissions accounted according to the producer principle are also available at the level of 87 regions. Figure 4 shows a comparison between the consumer and producer approach for GHG emissions at this more detailed level. For 27 regions, emissions accounted according the consumer principle are more than 20% higher than those accounted according the producer principle. On the other hand, for 28 (out of 87) regions, producer-related emissions are more than 20% higher than consumer-related emissions. These regions are found especially in Oceania, Asia, South America and Africa which is in line with figure 1.

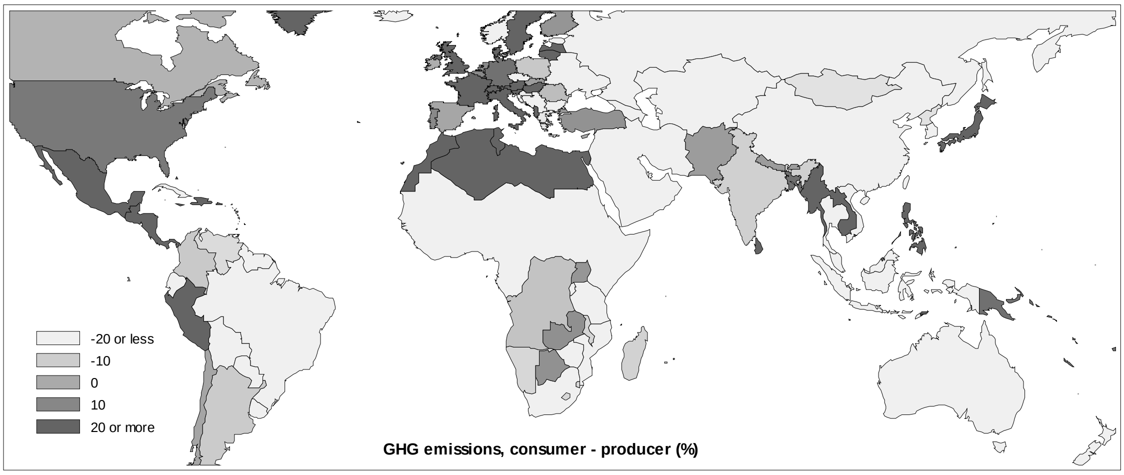

Figure 4 *Difference in GHG emissions for consumption and production for 87 regions (as percentage).*

For several countries the differences between both approaches for GHG emissions are far higher than for the 12 regions (figure 1). While the maximum difference at the world region level is less than 40% (JNIE), six regions show a difference above 100%. These are relatively small regions with specific trade and production structures: Malta, Slovenia, Switzerland, Sri Lanka, Hong Kong and the rest of North America. It is evident that some of the individual regions in the same world region show larger deviations, since the outcome of the world regions is a weighted average of the outcomes of the detailed countries in that region. The differences between pressures accounted by both principles may be lower for larger regions, since their import and export flows are relatively lower in relation to the total economy than for smaller countries. Furthermore, differences for countries in the same world region may be the artefact of the methodology in which the consumer-related pressures were calculated with the average intensities of the world region concerned (see discussion). Therefore, the outcomes at the level of 87 countries must be seen as indicative. Further data collection and analysis is required to draw more robust conclusions about any patterns in the differences between both principles and if there are correlations with e.g. welfare, population density, and presence of raw materials or land.

6. Discussion

The previous section showed that calculating environmental pressures for regions and countries according to two accounting principles resulted in different sets of pressures. These differences should not be used to give value judgements about countries, but can be used to direct policies on both sets of pressures which may lead to more efficient environmental policies. This pleads to policies with targets for both sets of pressures enhancing the reduction possibilities and meeting the problem of carbon leakage in the case of the territorial approach only (on which present environmental policies often are based).

For most developed countries and regions pressures according the consumer principle are higher than those for the producer principle. It is especially useful for these countries to direct policy also on these pressures, since a substantially higher set of pressures (which are partly not covered by targets) is addressed then. Countries with higher producer-related pressures than consumer-related pressures, which are mostly in developing regions, have a relatively higher overlap in pressures. For these countries it may be useful directing policies on domestic pressures in the first place.

However, it is more difficult to pursue policies based on the consumer principle. Whereas national policies have (sectoral) targets for direct emissions of producers in the country, targets directed at the environmental pressures from consumption concern production chains across country borders (and they are partly beyond the direct sphere of influence of national governments). Measures aimed at reaching these targets are less easily implemented and maintained, but policy has some options to influence environmental pressures abroad. E.g. Joint Implementation (JI) and Clean Development Mechanism

(CDM), which are the flexible mechanisms under the Kyoto protocol, enable countries to meet their GHG emissions reduction obligations by supporting projects in other industrialized countries and developing countries, respectively. Countries are allowed to add emissions reductions achieved through investments in new technologies abroad to territorial emission reductions. Furthermore, policies can be directed on stimulating consumers purchasing more sustainable goods and services. Until now, this type of policy is often based on information supply, e.g. by certification or labelling of products, and voluntary adaptation of behaviour, but consumers on their turn are able to incite companies to change their purchase policies in more sustainable directions[8]. Countries have few possibilities to restrict imports based on environmental criteria because of international trade agreements under the WTO. It is unclear if the WTO permits border tax adjustments on the basis of carbon footprint of products. Furthermore, the effects of border measures are limited in case of full CDM (Manders & Veenendaal, 2008).

International environmental policy and agreements may meet the objections concerning shifts to abroad by producers and consumers. When all individual countries in a world region experience the same environmental legislation, this may lead to similar efficiencies in these countries. Then a shift from environmental pressure to other countries in the same world region is no problem, but the risk of a shift of pollution to outside the world region remains, providing an argument for further expansion of environmental policy across world regions. In the ideal situation all countries will participate in international agreements on reducing pressures and the producer and consumer-related pressures under these agreements are the same. In this situation it may still be useful to distinguish accounting according to both principles, since each principle has its own starting-points for policy.

In case of national targets based on consumption-related pressures, these pressures have to be determined with certain accuracy (just as is done in case of territorial emissions). However, the environmental pressures from consumption cannot be monitored as easily as the direct emissions of producers and consumers, but are the result of model calculations with several assumptions. E.g. in the calculations in this paper concerning GHG emissions

[8] When companies purchase more sustainable materials and resources, this also effects the environmental pressures related to imports for producing exports that do not belong to one of the principles.

and land use for the consumer principle at the level of 87 regions/countries, some assumptions were made that certainly have influenced the outcomes. These calculations were based on intensities of 12 world regions with the underlying assumption that efficiencies of countries in the same world region are the same or at least less different than efficiencies in different world regions[9]. In the case of a common environmental policy in a world region, e.g. in the European Union, differences between efficiencies may be small. However, since not all world regions have common environmental goals, this may not be the case for all world regions. E.g. the countries in North Africa show quite different outcomes than those in South Africa. The pressures are calculated with the same intensities, although there may still exist differences in efficiencies or production structures. South Africa, e.g. has a relatively energy-intensive production structure. Another assumption that may have effect on the outcomes is on the origin of imports. The place of origin plays a role in the calculation of the total intensities per world region and in the calculation of the environmental pressure from consumer goods directly imported from other world regions. For all world regions it was assumed that for each detailed region the distribution of imports across world regions (as place of origin) per world region is the same. However, there are, for example, differences in the origin of imports in the Netherlands and those for the whole of OECD-Europe.

Since the effects of the assumptions described on the results are not clear, the results should be seen as indicative. For application of consumer-related pressures in environmental policies, further improvements of methodology and data are necessary. The European Commission started several initiatives in this direction by means of financing research projects. The EIPOT project, e.g., assessed all types of life-cycle methodologies on their appropriateness for determining the environmental impacts of trade flows (Wiedmann et al., 2009). Furthermore, the EXIOPOL project directs at compiling an environmentally-extended input-output database consisting of all EU member countries and their main trading partners (Tukker et al., 2009).

[9] In fact, this is a similar approach at the level of world regions as applying global average intensities for all countries in the world as elaborated in the appendix.

7. Conclusions

This paper shows that it is possible to calculate the worldwide environmental pressure due to consumption and to compare it with environmental pressure due to production at the level of aggregated and more detailed regions. Where the producer principle is based on ‘simply’ monitoring of direct pressures, the consumer principle accounting mechanism requires an extra model-calculation step in which the data from the producer principle are reshuffled on the basis of a life-cycle approach. Accounting according the consumer principle is therefore more laborious and far beyond the producer principle accounting. For application of the outcomes of the consumer approach in policies, further standardisation of methodology and data is necessary.

The consumer and producer principles lead to significant different environmental pressures per capita per (world) region. These differences result from different production structures, efficiencies and trade relations. Environmental pressure for the consumer principle is higher than for the producer principle for most developed countries, which, in general, have more service-oriented production structures and higher efficiencies. If the world is divided into 12 regions, OECD Europe, and Japan and the New Industrializing Economies show deviations of more than 20% for the consumer-related GHG emissions in relation to emissions from production. For the Chinese region and the former Soviet Union producer-related GHG emissions are more than 20% higher than the consumer-related emissions in these regions.

Environmental policies based on the producer principle alone may lead to shifts in environmental pressures to regions with lower efficiencies due to a less strict policy. In order to avoid such leakages, policies based on the consumer principle may offer a solution, although it is more difficult to pursue such policies. Production abroad is not in the sphere of influence of a country’s legislation and countries have few possibilities to restrict imports on environmental criteria because of international trade agreements under the terms of WTO. However, via the Joint Implementation and Clean Development Mechanisms it is still possible to reduce environmental pressures in other countries. Furthermore, producers and consumers can be stimulated to purchase more sustainable products by pointing out their responsibilities for production chains. Targets for pressures based on consumption may frame and facilitate these policies

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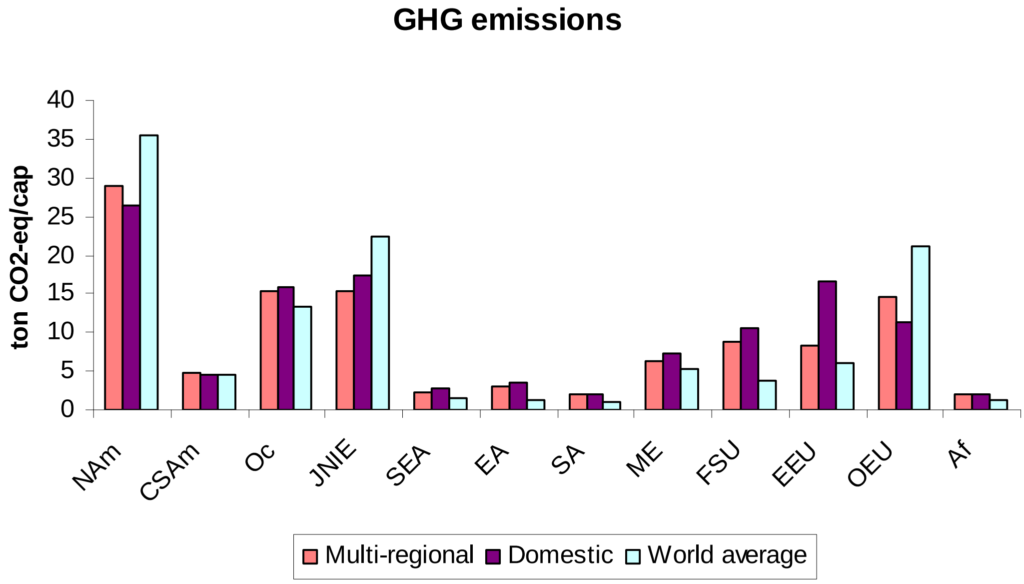
Appendix: The effect of using different intensities

The GHG emissions and land use for the consumer principle were calculated with a full multi-region model with imports specified per region and feedback loops. Several studies start from a single-region input-output analysis assuming that production technologies and efficiencies of imports are the same as domestically produced goods and services. In order to estimate the effects of using a multi-region model instead of a model in which imports are treated as domestically produced, outcomes of both models were compared in order to underpin the choice for a multi-regional approach. Domestic intensities were calculated for each region on the basis of equation 3 in which **A** represents the input-output coefficients (both domestic and imports). Figure 5 shows the outcomes of GHG emissions and land-use from consumption per capita calculated with the two methods (left-hand and middle bars).

The use of domestic intensities instead of multi-region intensities leads to an underestimation of consumer-related GHG emissions for NAm and OEU. Domestic GHG efficiencies are higher in these world regions than the average efficiencies in the regions where imports originate. On the other hand, GHG emissions in EEU and SEA are more than 20% higher since these regions import, to a large extent, from regions with more GHG-efficient production technologies. For land use, the figures are quite similar as for GHG emissions. An approach in which imports are treated as domestically produced would lead to a huge underestimation of consumer related land use in NAm, JNIE and OEU. Land use in these world regions is on average far more efficient than in the regions from which imports come. In other regions, domestic land-use efficiency is more extensive than that in the regions imported from. EA and FSU show percentage-wise the greatest difference between the two approaches. Another approach is the calculation of GHG emissions and land use per capita with the same intensities for all regions. In order to gain insights in such an approach GHG emissions and land use per capita were calculated with the (same) world average intensities per sector applied to all regions. These world average intensities based on world average production technology were calculated with equation 3 applied to data for the whole world.



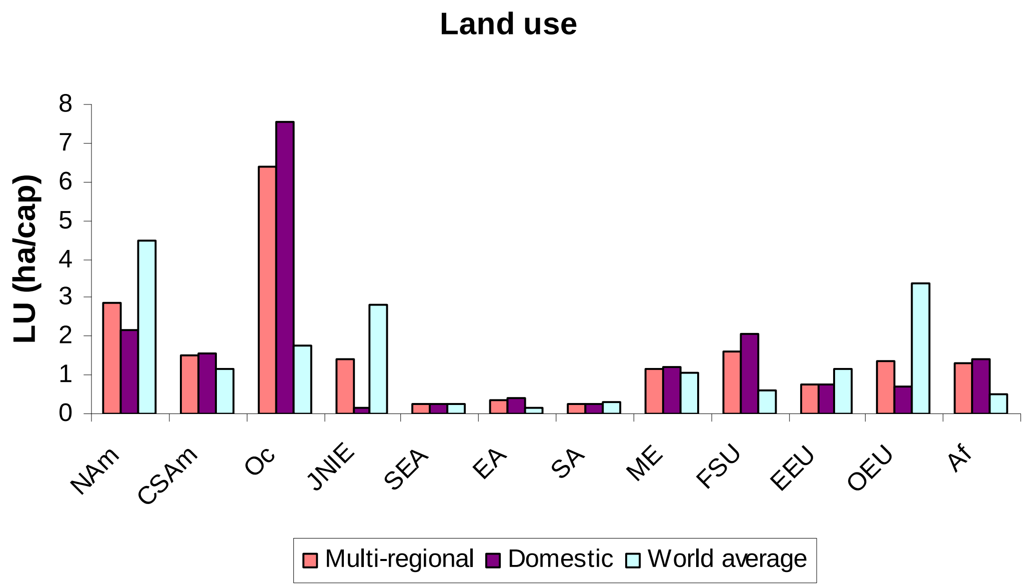


Figure 5 *Consumer-related emissions and land use per capita for 12 world regions calculated with multi-regional intensities (left-hand bars), domestic intensities (middle bars) and world-average intensities (right-hand bars).*

Figure 5 shows GHG emissions and land use per capita from the consumer principle calculated with the same world average intensities for all regions (right-hand bars). By using world average intensities differences in trade and technology are excluded. The comparison of consumer-related environmental pressures based on world average intensities between world regions gives insights into differences in consumption (volumes and patterns) between these regions. In case efficiencies and technologies were the same world-wide, GHG emissions from consumption per capita would have the highest levels in NAm, OEU, JNIE, and Oc.

Comparing the environmental pressures based on average world intensities with those based on single-regional intensities gives insights in technologies and production efficiencies between regions. So, it can be concluded from figure 5 that GHG efficiencies in NAm, JNIE and OEU are higher than world average efficiencies in the production for consumption in these regions. For land use, efficiency in Eastern Europe (EEU) is also higher than the world average. The land use in Oc is very inefficient due to the use of large areas of extensive pasture land. The comparison of environmental pressures based on world-average intensities with pressures based on multi-region intensities is more difficult since in the latter case different technologies are considered for the ‘domestic’ part and the import part. Considering these parts individually should give further insights in differences in technologies between regions.

This appendix shows that the consumer-related environmental pressures are highly determined by the assumptions in the calculation of the intensities. This will also effect the conclusions obtained from comparisons between environmental pressures accounted with the producer and consumer principles.