Environmental Accounting from a Producer or a Consumer Principle; an Empirical Examination covering the World

Harry Wilting and Kees Vringer

Draft version; please do not quote!

Abstract:

Countries are usually judged on the use of natural resources and emissions at their territories, i.e. from a producer principle. An alternative environmental accounting principle for countries is the consumer principle that includes environmental load of imports. Several studies compare emissions for both principles for individual countries. This paper presents a more comprehensive overview by comparing both principles for 87 countries/regions covering the world. Greenhouse gas (GHG) emissions and land use per capita are calculated for both principles with a multi-region input-output model including feedback loops. GHG and land-use intensities, calculated for 12 world regions accounting for the origin of imports, are combined with demand in 87 regions. For most developed countries, total GHG emissions and land use are higher for the consumer principle than for the producer principle. Differences in emissions and land use per capita over countries are the result of differences in income, production technologies and consumption patterns. The differences in consumption patterns are analyzed by using intensities based on world average production technology. The multi-regional approach significantly differs from an approach in which imports are treated as they were produced domestically. The latter approach, e.g., underestimates emissions and land use for developed countries.

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

Addresses:

Harry Wilting (corresponding author), Kees Vringer, Netherlands Environmental Assessment Agency (MNP), P.O. Box 303, 3720 AH Bilthoven, The Netherlands.

e-mail: Harry.Wilting@mnp.nl; Kees.Vringer@mnp.nl.

Introduction

With a growing world population and per capita income, the demand for goods and services is increasing all the time. Although technological development makes the production of these goods and services more and more efficient, the demand on energy and materials still grows. Due to this, greenhouse gas emissions and land use remain increasing resulting in climate change and further decrease of biodiversity (MNP, 2007). National environmental policies are traditionally directed at emission reduction and improvement of the environmental quality at the territory of the country, but nowadays there is some interest for environment abroad. Dutch policies on environment and sustainability, e.g., give attention to the effect of national consumption on environmental quality in other countries. The Dutch government states that sustainable economic growth should take place in the Netherlands under the condition that shifts to elsewhere or later are prevented (VROM, 2006). In order to support national environmental policies, appropriate accounting systems are required.

There are two main accounting principles for environmental pressures on a country basis. The first is the most common one and it considers all the pressures at the territory of the country. The producers of emissions are kept responsible in line with the polluter pays principle and national policies and targets are usually based on this approach. The Kyoto protocol directed at the world-wide reduction of greenhouse gas emissions, e.g., starts from such a producer principle. The second accounting principle lays the responsibility of environmental pressure with the consumer. All pressures related to consumption of the inhabitants of a country are assigned to that country. The ecological footprint, e.g., is based on this principle that includes environmental load of imports (Wackernagel and Rees, 1996).

Several studies compare both accounting principles for individual countries. Munksgaard and Pedersen (2001), e.g., investigated CO_2 emissions for both accounting principles for Denmark for the period 1966-1994. Wilting and Ros (2007) compared both approaches for greenhouse gas (GHG) emissions for the Netherlands and the European Union. Studies on the environmental load of trade implicitly make a comparison for both accounting principles. Hoekstra and Janssen (2006) give a broad overview of the literature on environmental responsibility and effects of trade. A world-wide comparison that may be useful in order to identify differences between countries or regions is not available yet. This paper fills in this deficiency by presenting a more comprehensive overview by comparing the outcomes of both principles for 87 countries and regions covering the world. Greenhouse gas emissions and land-use per capita are calculated for both principles. Direct emissions and land use according to the producer principle are obtained from statistics. A multi-regional input-output model including feedback loops between regions is used for calculating the emissions and land use according to the consumer principle. GHG and land-use intensities, calculated for 12 regions accounting for the origin of imports, are combined with demand on consumption in 87 regions.

The final purpose of the paper is the comparison between both principles, but due to differences in elaboration in compiling both accounts, the paper focuses more on the latter principle. Differences in total emissions and land use per capita over countries for the consumer principle are discussed. These differences are the result of differences in income, consumption patterns, trade flows and production technologies. The comparison of consumer related emissions based on world average intensities gives insights in differences in consumption over world regions. The differences in consumption patterns are analyzed by using world average intensities based on world average production technology. In some sense, a comparison of the world average intensities with the region-specific intensities gives an impression of differences in efficiencies over regions.

The consumer-related emissions and land use are calculated with a multi-region input-output table for the world. In early input-output studies in which imports are considered, it was often assumed that imported goods and services are produced with production technologies similar to the domestic technology. Among others, 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 between technologies over countries. This paper demonstrates the need of such a multi-regional input-output model at the region level by comparing the multi-region based intensities with intensities based on the assumption that imports of a region are produced with the technology of that region.

Both accounting principles have their advantages and drawbacks. The paper goes into the differences in calculation and outcomes for both principles. Finally, the usefulness of both approaches for policy is discussed.

Background

Countries are usually judged on the use of natural resources and emissions at their territories, i.e. from a producer principle. E.g. national targets and international agreements, like Kyoto, are based on this principle. Environmental policy aims at domestic producers of emissions through issuing rules, standards, agreements, taxes, and etcetera. Dutch government e.g., fixed sectoral emission targets for domestic emissions in order to realize the Kyoto targets. The producer approach led to substantial lower emissions of several substances in the Netherlands in the past decennia, a period with a growing GDP (MNP, 2006). Environmental policy was successful especially in cases where efficiency improvements could be realized via measures directed at stimulating new technologies. However, there exist some persistent global environmental problems where environmental policy at a national level does not lead to substantial emission reduction yet.

Environmental policies aiming at emission reductions in a country may be suboptimal. By limitation of polluting activities it is possible to reach targets, e.g. by restricting the growth of polluting exports or by increasing imports, e.g. electricity. In both cases, this is a shift of a part of domestic emissions to abroad. In case foreign efficiencies are lower this will result in higher overall emissions (carbon leakage). 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). However, there is no indication that this happens on a large scale in the Netherlands (Wilting *et al.*, 2006). Another disadvantage of national environmental policies directed at emissions inside the territory is the exclusion of emissions of international (sea and air) transport. These emissions are not included in national targets since they take place outside the territorial boundaries of countries. A way to meet this latest disadvantage is to direct environmental policy at all direct emissions of the residents and companies in a country independent of the location of emission. Dutch producers and consumers are then judged on the direct emissions they cause outside the Netherlands.

In order to solve the above-mentioned drawbacks of the producer accounting principle, the consumer accounting principle is proposed from a responsibility perspective (see e.g. Peters, 2005). Instead of national environmental policy 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)[1]. The underlying idea is that consumers initiate production processes with their consumption. Several studies directed at the energy requirements of household consumption are based on this idea that the consumer is responsible for production and distribution of goods and services (see e.g. Wilting, 1996; Vringer, 2005). In case of responsibility of consumers, environmental policy may aim at consumption in order to realize a further reduction of environmental load. The consumer accounting principle is also used for international comparisons at the level of world citizens. From an equity perspective, the environmental aspects of consumption patterns over countries are compared.

The emissions and land use allocated to consumption include emissions and land use of production processes in other countries for domestic consumption. In fact, the environmental pressure related to consumption equals the environmental pressure of production minus the domestic pressure for exports plus the environmental pressure abroad for imports for consumption. So, the difference between both accounting approaches stems from international transport of goods and persons. Studies on the environmental aspects of trade therefore concern in some extent the same emissions as the emissions in this paper. In case there is no trade, all economies are closed and emissions following both methods are the same. However, due to globalization trade increases and the difference between both approaches may increase too.

Environmental policy directed at consumption does not have the disadvantages like national policy as mentioned above. There is no carbon leakage in the consumer approach since emissions of imports are considered in the accounting. The same holds for pollution haven. Furthermore, in the consumer approach emissions of international transport can be

[1] Besides the full producer and consumer responsibilities as discussed in this paper there exist mixed forms like shared responsibility too (Steenge, 1999; Lenzen *et al.*, 2007).

considered. On the other hand, the environmental load of consumption cannot be monitored easily like direct emissions of producers and consumers, but it is the result of model calculations with several assumptions. Furthermore, it is questionable in what extent policies may influence the environmental load related with imports, which takes place in other countries.

Methodology

In order to make a comparison between GHG emissions and land use for the producer and consumer principle, emissions and land use for both approaches have to be determined. The comparison for GHG emissions is carried out for 87 regions covering the world; the comparison for land use for 12 world regions due to lack of data at the production level. Consumption related environmental load is calculated by combining environmental load intensities with consumption figures. Although economic input-output data is available for 87 regions, it was too data and labor-intensive to calculate environmental load intensities for all these regions. The calculation of environmental load intensities was limited to 12 world regions covering the 87 regions. Appendix A gives an overview of the aggregation scheme from 87 regions to 12 world regions. For each region, the intensities of the world region the region belongs to were used for calculating environmental load of consumption. The underlying assumption is that differences in intensities in world regions are lower than differences in intensities between world regions.

Producer accounting principle

The GHG and land-use accounting from the producer principle is straight-forward. Data on emissions and land use are obtained from national or regional statistics, databases or models. For GHG emissions, data were compiled for 87 regions; for land use for 12 world regions. The data concern total emissions and land use for production and consumption inside the borders of the regions. These data also serve as a basis for the consumer accounting principle, which is in fact a reshuffling of the data over consumers and regions.

Consumer accounting principle

For a single-region economy the following relationship between production **x** and final demand **y** exists:

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

where **A** is the matrix of domestic input-coefficients, sometimes referred to as the technological matrix, which defines the intermediate input requirements per unit output for each sector. By solving this equation for **x**, the standard input-output model for calculating sectoral output **x** for a certain final demand **y**, e.g. consumption, is derived:

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

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

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

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

where **d** is the row vector of direct environmental load intensities depicting the environmental load of one unit of production for all sectors.

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

$$\mathbf{E} = \mathbf{e}\,\mathbf{y} + \mathbf{D} \qquad (4)$$

where **D** is the direct environmental load of final demand.

In case of imports, matrix **A** concerns all intermediate inputs, both domestic and imported, of the sectors in order to include total environmental load over the whole life-chain of products. In a single region model it is assumed that production technology abroad is similar to domestic production technology. The cost structures for domestic and foreign production are the same. The assumption that imports are produced with the same technology is discussed more and more in literature (see introduction), but there exist differences between countries in efficiencies. Technology in more developed countries is more efficient than technology in less developed countries. So, the assumption on imports overestimates the emissions in developing countries and underestimates the emissions in developed countries.

For these reasons, a multi-region model is used for the calculation of the environmental load intensities of the world regions. The multi-region model corresponding with formula 1 is:

$$\begin{bmatrix} \mathbf{x}_1 \\ \vdots \\ \mathbf{x}_n \end{bmatrix} = \begin{bmatrix} \mathbf{A}_{11} & \cdots & \mathbf{A}_{1n} \\ \vdots & \ddots & \vdots \\ \mathbf{A}_{n1} & \cdots & \mathbf{A}_{nn} \end{bmatrix} \begin{bmatrix} \mathbf{x}_1 \\ \vdots \\ \mathbf{x}_n \end{bmatrix} + \begin{bmatrix} \mathbf{y}_1 + \sum_{i \neq 1} \mathbf{y}_{1i} \\ \vdots \\ \mathbf{y}_n + \sum_{i \neq n} \mathbf{y}_{ni} \end{bmatrix} \tag{5}$$

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 sector j importing from sector i

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

$\mathbf{y}_{ij,\ i\neq j}$ vector of imported final demand of sector j importing from sector i

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

$$\mathbf{x}^* = \begin{bmatrix} \mathbf{x}_1 \\ \vdots \\ \mathbf{x}_n \end{bmatrix},\ \mathbf{A}^* = \begin{bmatrix} \mathbf{A}_{11} & \cdots & \mathbf{A}_{1n} \\ \vdots & \ddots & \vdots \\ \mathbf{A}_{n1} & \cdots & \mathbf{A}_{nn} \end{bmatrix},\ \mathbf{y}^* = \begin{bmatrix} \mathbf{y}_1 + \sum_{i \neq 1} \mathbf{y}_{1i} \\ \vdots \\ \mathbf{y}_n + \sum_{i \neq n} \mathbf{y}_{ni} \end{bmatrix},$$

the multi-regional input-output model is:

$$\mathbf{x^* = A^* x^* + y^*} \quad (6)$$

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

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

with $\mathbf{d^*} = [\mathbf{d_1} \;\; \cdots \;\; \mathbf{d_n}]$, where $\mathbf{d_i}$ is a row vector of direct intensities of environmental load of region *i*, and $\mathbf{e^*} = [\mathbf{e_1} \;\; \cdots \;\; \mathbf{e_n}]$, where $\mathbf{e_i}$ is a row vector of total intensities of environmental load of region *i*.

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

$$\mathbf{E_i = e^* y_i^* + D_i} \quad (8)$$

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

The calculation process of the environmental load intensities accounts for capital goods. Capital investments in the past contribute to total resource use and emissions of production for final demand, but do not belong to production in the current year. In order to account for these investments, replacement investments are included in the intermediate matrix.

Data: sources and processing

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 the imports of the world regions. These imports include then the trade flows between regions in the aggregated world region. So, the intra-regional trade flows in a world region are 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. The same was done for final demand.

For each world region, the aggregated intermediate and final demand imports have no segmentation in region of origin. Therefore, 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 over regions of origin.

The technological 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 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 sectors as extra deliveries from these sectors. Data in f.o.b. were used in compiling the import matrices.

As said above, the calculation of intensities includes replacement investments, which can be seen as an approximation of capital goods included in production processes. The GTAP database does not distinguish replacement and extension investments. Therefore we assumed for all countries that 75% of total investments concern replacement investments. It may be possible that fast growing world regions have a higher share of extension investments, but it is beyond the scope of this paper to distinguish figures per region. For each sector the deliveries to the replacement investments were assigned to the inputs in the intermediate matrices (domestic and imports) on the basis of depreciation per sector.

GHG emission data

Data on greenhouse gas 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 is 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, e.g., only contains fossil-fuel related CO_2 emissions and no process emissions, e.g. at the production of concrete, or emissions related to biomass burning.

The data used in the calculations concern the year 2000. Starting point for the data compilation was the EDGAR dataset, since it is more consistent with other modeling in our institute. 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 does 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 of these fires have an anthropogenic cause or that they are the result of thunderbolt. Similarly, CH_4 and N_2O emissions of forests, savannah, shrubs and grassland fires were excluded.

The emissions in the EGAR database are not at the detailed level of the 57 GTAP sectors. The further subdivision of the EDGAR emission data to 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. Emissions related to waste processing, e.g. landfills, were also allocated to direct emissions. For convenience, they were not allocated 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 are a measure for the contribution of separate GHG to climate change.

Land use data

Just as with emission data, land use data were obtained from several sources. The main data source is the IMAGE model (MNP, 2006b) that consists of land use data for 24 world regions. Most data in the IMAGE model is based on FAO databases (FAO, 2006). For the compilation of crop land use for the multi-region model, data on crop area from the IMAGE model was 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. All data were compiled at the level of 12 world regions. The IMAGE model also provided data on crop areas for biofuel production. These figures were assigned to the refinery sector.

Land use for pasture was directly obtained from IMAGE and assigned to two pasture sectors in GTAP: cattle and milk. The breakdown by cattle and milk was based on several factors like animal feed (Eickhout, 2007). All land use data are in physical areas and no correction was made for extensive or intensive use of the land. Especially for pasture land, there are huge differences over 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 for the calculation of the land-use intensities, but it was directly assigned to final demand.

GHG emissions and land use from the consumer principle

First, this section shows the results for the consumer approach. The next section presents the result of the comparison between both principles. Figure 1 shows GHG emissions and land use per capita plotted against world population (cumulative on the x-axis). The left side of the figure show that about one billion people have GHG emissions related to consumption that are higher than 10 ton CO_2-eq. per capita. These people live in the developed regions of the world. This part of the world population (16%) cause about 55% of total GHG emissions. The other part of the world population (well over 5 billion people) causes for only 45% of world GHG emissions.

<Figure 1>

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 1). The total land use for this group is almost 70% of total land use for production and consumption.

The figures presented may not be surprising, since income and GDP are not equally distributed over world population. Figure 2 shows GDP per capita per region over the world population. These differences in income and therefore in consumption explain differences in GHG emissions and land use to a large extent.

<Figure 2>

Differences in consumption per region can also be illustrated by using average world intensities. These world average intensities were calculated with equation 3. Figure 3 shows GHG emissions and land use per capita from the consumer principle calculated with the same world average intensities for all regions. Consumption per capita has highest level in North America, OECD Europe, Japan and New Industrializing Economies (JNIE) and Oceania.

<Figure 3>

Figure 3 also shows differences in production efficiencies over regions. Comparing world average intensities with region specific intensities gives better insights in efficiencies. Efficiencies in North America, JNIE and OECD Europe are higher than world average efficiencies in the production of consumption in these regions. For land use, efficiency in Eastern Europe is also higher than world average. The land use in Oceania is very inefficient due to the use of large areas extensive pasture land. The comparison of world-average intensities with region-specific intensities shows that efficiencies in developed regions are higher than in developing countries. However, the huge differences in income and wealth exceed the differences in efficiencies as explaining factors for differences in environmental load for consumption per region.

GHG emissions and land use for two principles

Figure 4 shows the outcome of the comparison of GHG emissions and land use for two principles in 12 world regions. GHG emissions according to the consumer principle are higher in three world regions: North America, the JNIE region and OECD Europe. These are all well-developed regions with high consumption levels. Figure 4 also shows the differences for both approaches for 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, which has low area of fertile land, shows higher land use for the consumer principle.

<Figure 4>

Since GHG emissions are available for the producer principle at the level of 87 regions, it is possible to make a comparison between both approaches at this more detailed level. Figure 5 shows for GHG emissions the difference between the consumer and producer approach for 87 regions. For 40 regions, consumer related emissions are higher and for 26 regions, the difference between consumption and production related emissions is more than 20%. On the other hand, for 31 (out of 87) regions, producer related emissions are more than 20% higher than consumer related emissions. These regions are especially in Oceania, Asia, South-America and Africa.

<Figure 5>

Differences between both approaches for GHG emissions are lower at the level of 12 world regions than at the more detailed level of 87 regions. Where the maximum difference at the world region level is about 30% (for East Asia, Oceania and the former Soviet Union), 6 regions show a difference above 100%. These are relatively small regions with specific production structures: Malta, Slovenia, Switzerland, Sri Lanka, Hong Kong and the region rest of North America. For larger regions, the import and export flows are relatively lower related to total economy. After all, all intra-regional flows in the aggregated world regions are considered as 'domestic'. Although the comparison between the world region level and the more detailed level is not available for land use, huge differences can be expected too. Especially, small regions with high population densities will require high amounts of land use outside the borders.

Discussion

The calculations of the emissions and land use for the consumer principle were carried out with a multi-region model with imports specified per region and feedback loops. Some studies assume 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. Figure 6 shows the outcomes of consumption per capita calculated with both methods.

<Figure 6>

The use of domestic intensities instead of multi-region intensities would lead to an underestimation of consumer related GHG emissions for North America and OECD Europe. Domestic GHG-efficiencies are higher in these world regions than in the regions imports come from. On the other hand, GHG emissions in Eastern Europe and South East

Asia would be more than 20% higher as a fact that these regions import for a large extent from regions with more eco-efficient production technologies.

The land use figure shows similar effects. An approach in which imports are treated as domestically produced would lead to a huge underestimation of consumer related land use in North America, JNIE and OECD Europe. 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 lower than that of the regions imported from. East Asia and the former Soviet Union have in terms of percentage the highest difference between both approaches.

So, in case this study was based on calculations under the assumption that imports are produced with domestic technologies, this would lead to other outcomes in the comparison between consumer and producer related GHG emissions and land use.

The calculation of GHG emissions and land use for the consumer principle was based on intensities of 12 world regions. At the detailed level (of 87 regions), consumer related GHG emissions, which were calculated with world region intensities, were compared with domestic emissions, which were specified for 87 regions. The underlying assumption is that efficiencies of countries in the same world region are the same or at least less different than efficiencies of different world regions. In case there is 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. 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 load of consumer goods directly imported from other world regions. It was assumed for all world regions that the distribution of imports over world regions (as place of origin) for each region per world region is the same. However, there are e.g. differences in the origin of imports of the Netherlands and those of whole OECD-Europe.

Another methodological source of difference between the environmental loads for both principles is the treatment of extension investments. Environmental load of these investments is included in the producer approach, but excluded from the consumer approach. Since environmental load related to the production of extension investments is only a few percents of total environmental load for production, these effects are expected to be small.

The non-methodological differences in the outcomes for both approaches per region are the result of trade, i.e. differences in structure of imports and exports, and differences in efficiencies over regions. In case environmental load following the producer principle is higher than that of 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 higher environmental load for the producer principle is less efficient production in the region under consideration and relatively more efficient production of the imports. E.g. the former Soviet Union and Oceania have lower efficiencies. On the other hand, when environmental load 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.

Environmental policies are mainly based on the producer accounting principle. In case producers pass-on higher production costs due to taxes to consumers, consumers can choose for products of countries with lower environmental legislation. However, it is more difficult to pursue policies based on the consumer principle. Where national policies have targets for direct emissions of producers, targets directed at environmental load of consumption would concern production chains over countries. Measures aimed at reaching these targets are not easily implemented and maintained. Countries have few possibilities to restrict imports on environmental criteria because of international trade agreements under the terms of WTO. In the Netherlands, environmental policy directed at consumers does not have any targets yet. This type of policy is based on information supply and voluntary changes in behavior.

International environmental policy may meet to the objections concerning shifts to abroad by producers or 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. This is an argument for further expansion of environmental policy over world regions.

Conclusions

This paper presented the outcome of a comparison of two environmental accounting principles. The producer principle is based on monitoring of direct pressures; the consumer principle is based on a life-cycle approach of pressures related to consumption. The consumer principle figures are the result of model calculations which reshuffle the data according to the producer principle. In view of the attention for both principles in this paper, it may be clear that accounting for the consumer principle is more laborious and an extra step above the producer principle accounting. Differences in the outcomes of both principles for world regions result from differences in production structures, efficiencies and trade. Environmental load 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.

Environmental policies based on the producer principle may lead to a shift of environmental load to regions with lower efficiencies due to less strict policy. It is more difficult to pursue policies based on the consumer principles. In the Netherlands, policies directed on consumers are based on supply of information and voluntary adaptation of behavior. Countries have few possibilities to restrict imports on environmental criteria because of international trade agreements under the terms of WTO. International agreements on reducing environmental load may relieve, but it is of importance then that all countries participate.

References

Battjes, J.J., K.J. Noorman and W. Biesiot (1998) Assessing the energy intensities of imports, *Energy Economics*, 20, pp. 76-83.

Dimaranan, Betina V., editor (2006) *Global Trade, Assistance, and Production: The GTAP 6 Data Base*, Center for Global Trade Analysis, Purdue University.

Eickhout, B. (2007) *Personal communication*, Netherlands Environmental Assessment Agency (MNP), Bilthoven.

FAO (2006) *FAOSTAT database collections*, Food and Agriculture Organization of the United Nations, Rome (www.apps.fao.org).

Hoekstra, R. and M.A. Janssen (2006) Environmental Responsibility and Policy in a Two-country Dynamic Input-Output Model, *Economic Systems Research*, 18, pp. 61-84.

Horridge, M. (2006) *GTAPAgg Data Aggregation Program*, Chapter 9.B in GTAP V6 database documentation, GTAP Resource #1798, Center for Global Trade Analysis, Purdue University.

IMF (2006) *World Economic Outlook Database, September 2006*; International Monetary Fund, Washington D.C.

Klein Goldewijk, K. and G. van Drecht (2006) HYDE 3: Current and historical population and land cover, in: Bouwman, A.F., T. Kram and K. Klein Goldewijk (eds)**,** *Integrated modelling of global environmental change; An overview of IMAGE 2.4*, Netherlands Environmental Assessment Agency (MNP), Bilthoven.

Lee, H.-L. (2002) *An Emissions Data Base for Integrated Assessment of Climate Change Policy Using GTAP*, Center for Global Trade Analysis, Purdue University.

Lee, H.-L. (2003) *The GTAP Non-CO_2 Emissions Data Base*, GTAP Resource #1186, Center for Global Trade Analysis, Purdue University.

Lee, H.-L., T. Hertel, B. Sohngen and N. Ramankutty (2005) *Towards An Integrated Land Use Database for Assessing the Potential for Greenhouse Gas Mitigation*, GTAP Technical paper no. 25, Resource #1900, Center for Global Trade Analysis, Purdue University.

Lenzen, M., L.-L. Pade, J. Munksgaard (2004) CO_2 multipliers in Multi-region input-output models, *Economic Systems Research*, 16, pp. 391-412.

Lenzen, M., J. Murray, F. Sack and T. Wiedmann (2007), Shared producer and consumer responsibility – Theory and practice, *Ecological Economics*, 61, pp. 27-42.

MNP (2006a) *Milieubalans 2006*, Netherlands Environmental Assessment Agency (MNP), Bilthoven.

MNP (2006b) (Edited by A.F. Bouwman, T. Kram and K. Klein Goldewijk) *Integrated modelling of global environmental change; An overview of IMAGE 2.4*, Netherlands Environmental Assessment Agency (MNP), Bilthoven.

MNP (2007) *Duurzaamheidsverkenning 2; Part 1 Nederland in relatie tot de wereld*, Netherlands Environmental Assessment Agency (MNP), Bilthoven.

Munksgaard, J. and K.A. Pedersen (2001) CO_2 accounts for open economies: producer or consumer responsibility?, *Energy Policy*, 29, pp. 327-334.

Peters, G.P. (2005) Should consumers or producers be held responsible for climate change?, *Cicerone*, 5, Center for International Climate and Environmental Research, Oslo.

Peters, G.P. and E.G. Hertwich (2006) The Importance of Imports for Household Environmental Impacts, *Journal of Industrial Ecology*, 10, pp. 89-109.

Steenge, A.E. (1999) Input-output theory and institutional aspects of environmental policy, *Structural Change and Economic Dynamics*, 10, pp. 161-176.

UN (2004) *United Nations World Population Prospects; The 2004 Revision*, United Nations Publications, New York.

van Aardenne, J.A., F.D. Dentener, J.G.J. Olivier, J.A.H.W. Peters and L.N. Ganzeveld (2005) *The EDGAR 3.2 Fast Track 2000 dataset (32FT2000)*, Downloaded from http://www.mnp.nl/edgar/model/v32ft2000edgar.

van Oorschot, M.M.P. (2007) *Personal communication*, Netherlands Environmental Assessment Agency (MNP), Bilthoven.

Vringer, K. (2005) *Analysis of the energy requirement for household consumption*, Milieu en Natuur Planbureau (MNP), Bilthoven.

VROM (2006) *Toekomstagenda Milieu: schoon, slim, sterk*, Ministry of Housing, Spatial Planning and the Environment (VROM), Den Haag.

Wackernagel, M. and W.E. Rees (1996) *Our Ecological Footprint: Reducing Human Impact on the Earth*, New Society Publishers, Gabriola Island, B.C.

Wiedmann, T., M. Lenzen, K. Turner and J. Barrett (2007) Examining the global environmental impact of regional consumption activities — Part 2: Review of input–output models for the assessment of environmental impacts embodied in trade, *Ecological Economics*, 61, pp. 15-26.

Wilting, H.C. (1996) *An Energy Perspective on Economic Activities*, Groningen University, Groningen.

Wilting, H.C., R. Hoekstra, S. Schenau (2006) *Emissions and Trade; a Structural Decomposition Analysis for the Netherlands*, paper presented at the Intermediate Input-Output Meeting on Sustainability, Trade & Productivity, 26-28 July, Sendai, Japan.

Wilting, H.C. and J.P.M. Ros (2007) Comparing the Environmental Effects of Production and Consumption in a Region; a Tool for Policy, in: S. Suh (ed), *Handbook on Input-Output Economics for Industrial Ecology (Eco-Efficiency in Industry and Science)*, Springer-Verlag.

Appendix A World regions based on 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

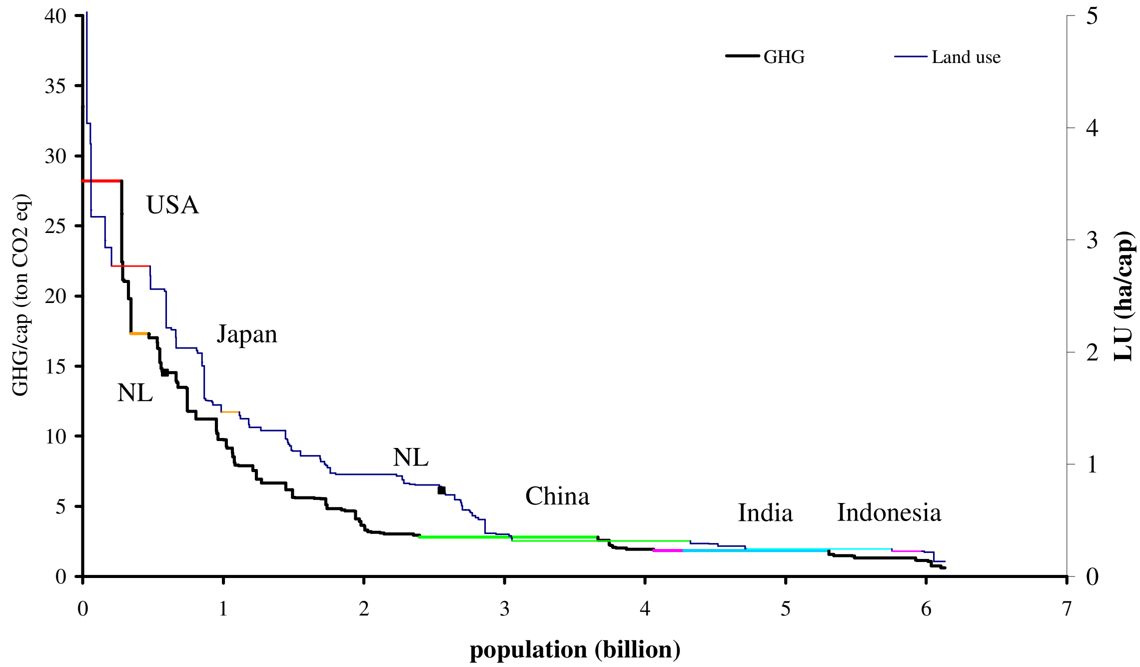


Figure 1 GHG emissions and land use for the consumer principle over regions (2001).

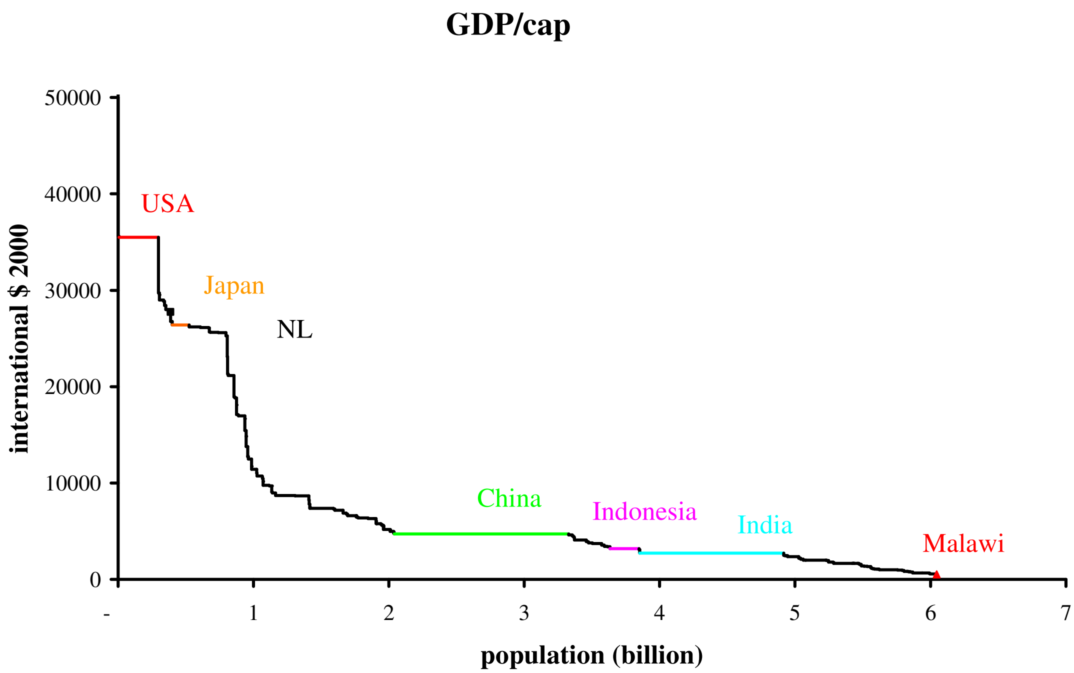


Figure 2 GDP per capita over regions, 2003 (IMF, 2006).

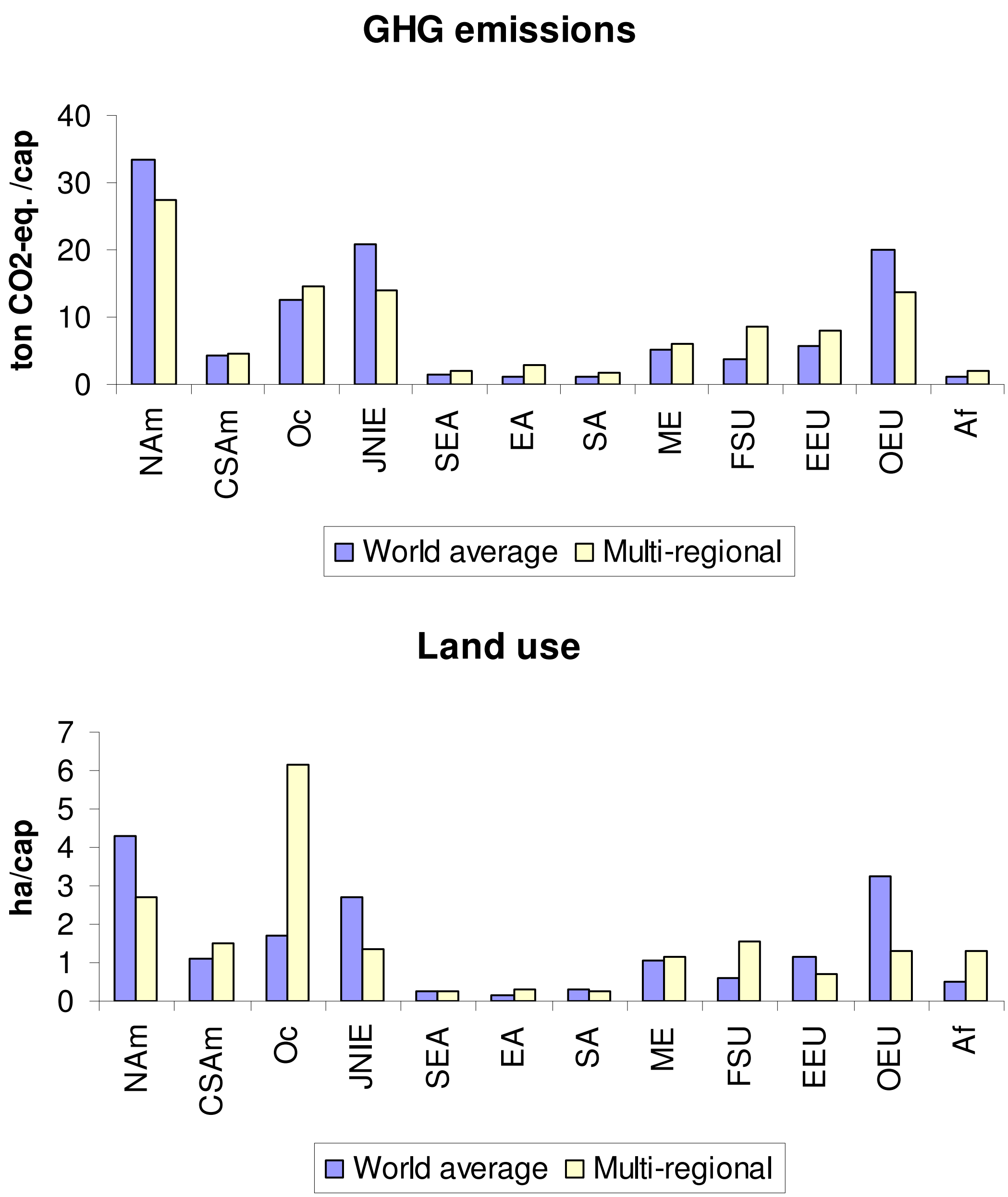


Figure 3 Consumer related GHG emissions and land use per capita calculated with world average intensities (left bars) and multi-regional intensities (right bars) for 12 world regions.

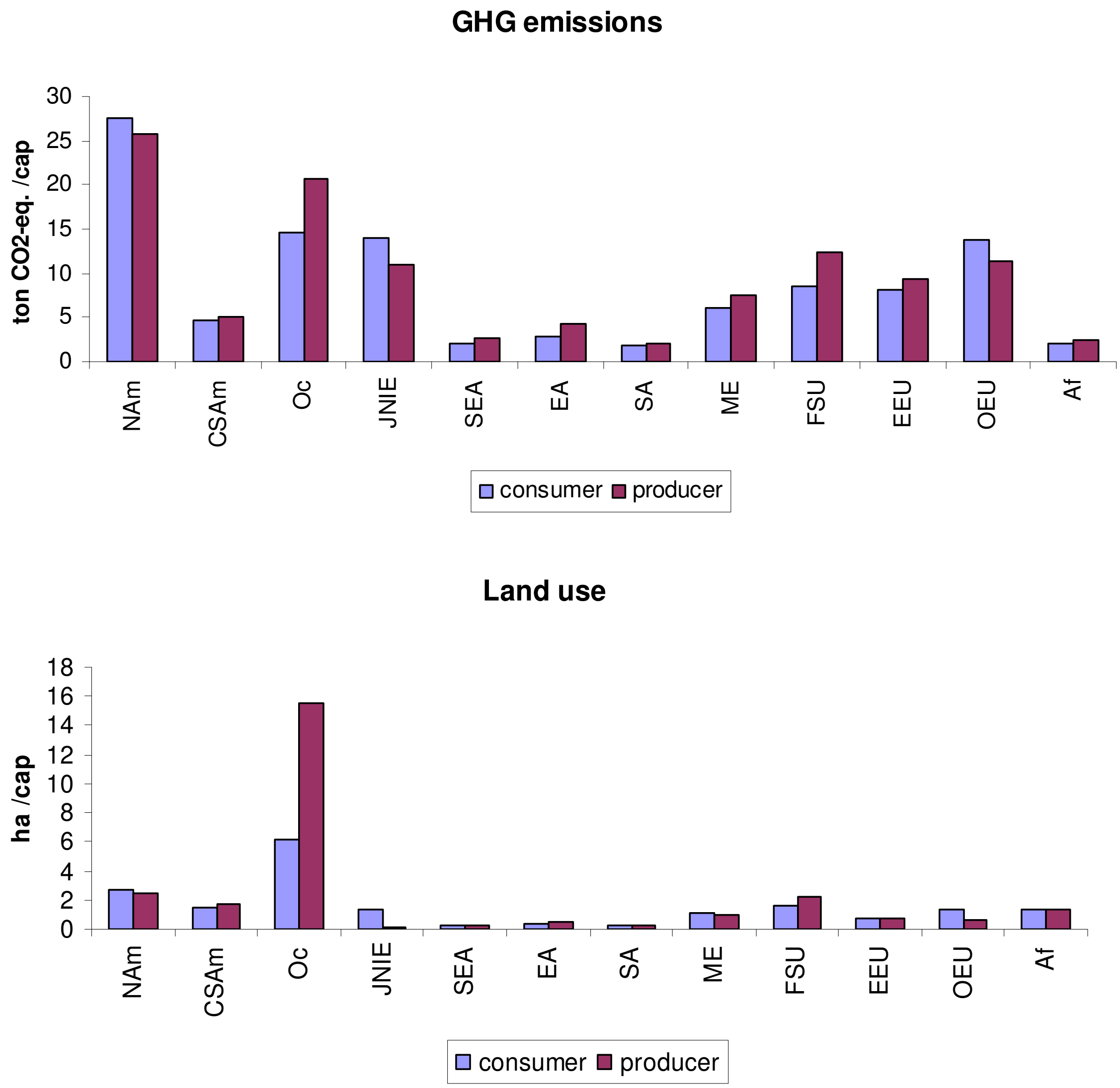


Figure 4 GHG emissions and land use for two principles for 12 world regions (2001).

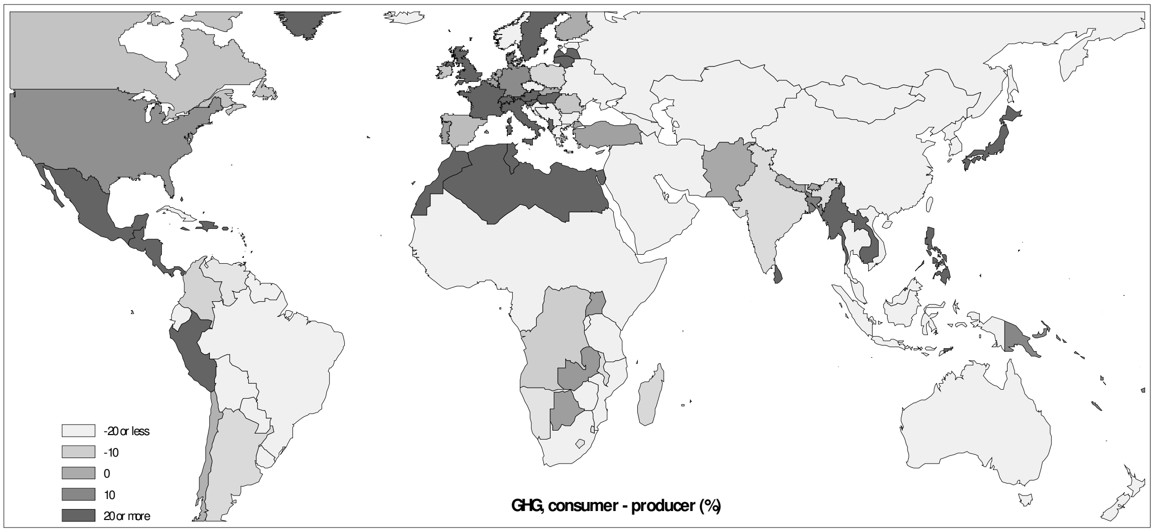
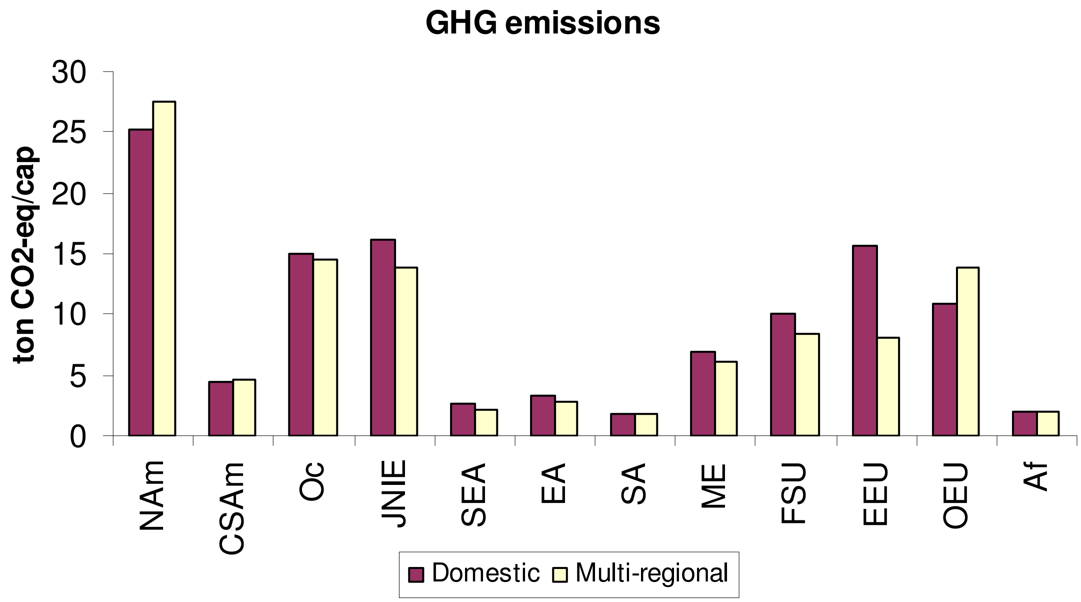


Figure 5 Difference of GHG emissions for consumption and for production for 87 regions (in percentages).



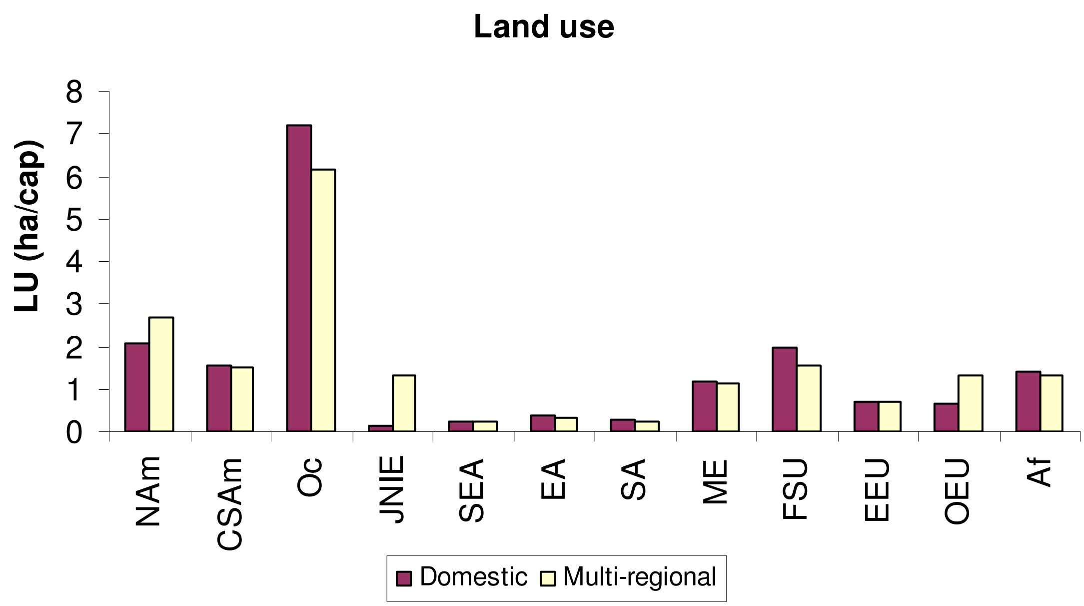


Figure 6 Consumer related emissions and land use per capita calculated with domestic intensities (left bars) and multi-regional intensities (right bars) for 12 world regions.