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Quantitative evaluation of time-series GHG emissions by sector and region using consumption-based accounting

Takashi Homma [a,*], Keigo Akimoto [a,b], Toshimasa Tomoda [a]

[a] Systems Analysis Group, Research Institute of Innovative Technology for the Earth (RITE), 9-2 Kizugawadai, Kizugawa-shi, Kyoto 619-0292, Japan
[b] Graduate School of Art and Science, The University of Tokyo, 3-8-1, Komaba, Meguro-ku, Tokyo 153-8902, Japan

HIGHLIGHTS

- We evaluate global time-series production-based and consumption-based GHG emissions.
- We focus on both CO_2 and non-CO_2 GHG emissions, broken down by region and by sector.
- Including non-CO_2 GHG emissions is important in agricultural sector.
- In agriculture, differences in accountings are dependent on production structures.
- In manufacturing sector, differences in accountings are determined by economic level.

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ABSTRACT

This study estimates global time-series consumption-based GHG emissions by region from 1990 to 2005, including both CO_2 and non-CO_2 GHG emissions. Estimations are conducted for the whole economy and for two specific sectors: manufacturing and agriculture. Especially in the agricultural sector, it is important to include non-CO_2 GHG emissions because these are the major emissions present. In most of the regions examined, the improvements in GHG intensities achieved in the manufacturing sector are larger than those in the agricultural sector. Compared with developing regions, most developed regions have consistently larger per-capita consumption-based GHG emissions over the whole economy, as well as higher production-based emissions. In the manufacturing sector, differences calculated by subtracting production-based emissions from consumption-based GHG emissions are determined by the regional economic level while, in the agricultural sector, they are dependent on regional production structures that are determined by international trade competitiveness. In the manufacturing sector, these differences are consistently and increasingly positive for the U.S., EU15 and Japan but negative for developing regions. In the agricultural sector, the differences calculated for the major agricultural importers like Japan and the EU15 are consistently positive while those of exporters like the U.S., Australia and New Zealand are consistently negative.

1. Introduction

In order to alleviate global warming, worldwide reductions in GHG emissions are needed, based on the principle of "common but differentiated responsibilities" as stipulated in Article 4 of the UN Framework Convention on Climate Change (UNFCCC). The most widely used methodology for measuring GHG emissions in the IEA (2010a) and UNFCCC (2010) involves their expression on a territorial basis in which all the GHGs emitted within a particular nation are measured. The IPCC methodology counts all the GHG emissions emitted from domestic activities, including both production and consumption. However, a country's standard of living is primarily achieved through consumption activities, and GHG emissions expressed on a territorial basis do not always adequately reflect fairness issues. According to Sato (2012), measurements of consumption-based emissions can help assessments of fairness in the allocation of responsibility between producers and consumers. Some studies support the full attribution of responsibility to the consumer while others support shared responsibility because of benefits obtained by both producers as value-added and job, and consumers as utility. According to Wiedmann et al. (2009), a comparison of consumption-based emissions between regions takes into account the differences in the levels of welfare and consumption between individual countries.

* Corresponding author. Tel.: +81 774 75 2304; fax: +81 774 75 2317.
E-mail address: homma@rite.or.jp (T. Homma).

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In order to evaluate the relationships between GHG emissions and consumptions, several recent studies have adopted an alternative methodology in which emissions are expressed on a consumption basis, including the emissions generated exclusively for domestic consumption. This is similar to the "carbon footprint labels" introduced on goods to help customers with their shopping in the UK in 2007. These labels indicate the amount of GHG emitted during all the processes associated with the goods, from the material preparation stage through to manufacturing, transport, use and final disposal.

Sato (2012) summarizes previous studies on the variety of approaches which quantify emissions embodied in trade as consumption-based emissions. Most quantitative studies on consumption-based emissions have, up till now, focused only on CO_2 emissions and some have only estimated consumption-based CO_2 emissions for selected countries. Taylor (2007) and Machado and Shaeffer (2002) revealed that, as a result of the globalization of industries, developing regions often produce "dirty" (pollution-intensive) goods such as CO_2-intensive products, while developed regions produce "clean" goods. Bosi and Riey (2002) have investigated consumption-based CO_2 emissions for the energy sector in the IEA countries. Ahamad and Wyckoff (2003) estimated emissions for manufactured goods in Annex I countries and selected Annex II countries. Hoshino et al. (2010) evaluated consumption-based emissions in some developed countries and in China, using regional CO_2 intensities and trade matrices.

Static estimations of consumption-based CO_2 emissions have also been conducted, worldwide. Davis and Calderia (2010) estimated consumption-based CO_2 emissions, by country, in 2004 using the Global Trade Analysis Project (GTAP) and Carbon Dioxide Information Analysis Center (CDIAC) emissions databases. Other studies have focused on time-series estimations of consumption-based CO_2 emissions, but the databases used have not always been consistent. Nakano et al. (2009) evaluated consumption-based CO_2 emissions on a country by country basis using OECD data sources, although the world CO_2 emissions expressed on a consumption basis were not equal to those expressed on a production basis (contrary to common belief) because of inconsistencies in the trade data at the global level caused by the different base years used in input–output tables by different countries.

Time-series estimations of consumption-based CO_2 emissions have been conducted for all regions of the world by Peters et al. (2011). They evaluated time-series consumption-based CO_2 emissions on a country by country basis from 1990 to 2008 using the GTAP and CDIAC emissions databases. These studies indicated that, to some degree, most Annex I countries import CO_2-intensive commodities instead of producing them domestically, even though imported commodities usually have larger carbon intensities than domestic equivalents. These studies have indicated that differences between the accounting methodologies used for CO_2 emissions can exert a substantial impact on the implementation of countries' coherent emission reduction policies.

Some previous studies have focused on consumption-based GHG emissions, including CO_2 and other non-CO_2 emissions, but only for a limited number of countries. Helm et al. (2007) evaluated the UK's time-series GHG emissions using a consumption-based measurement technique in a single-country analysis. The results showed that the UK had, since 1990, imported GHG-intensive goods from abroad even though production-based GHG emissions in the UK had steadily decreased. However, for simplicity, they treated the whole economy as a single economic sector and used the macro-trade balance for data. Because they did not consider the differences between sectoral CO_2 intensities within a region, they evaluated only the sector averages of consumption-based GHG emissions. Hoshino and Sugiyama (2010) focused on consumption-based GHG emissions for agriculture and land use, land-use change and forestry sectors in some developed regions. They found that consumption-based GHG emissions for land-use change in the U.S. and EU were larger than production-based emissions, and that Japan had increased consumption-based GHG emissions from the agricultural sector since 1990.

Relatively few comprehensive studies have been carried out on consumption-based GHG emissions using a globally consistent database. Therefore, the purpose of this study is to evaluate time-series consumption-based GHG emissions, including both energy-related and energy-unrelated CO_2 emissions plus the five kinds of non-CO_2 GHG emission specified in the Kyoto protocols, broken down by region and by sector using globally consistent sets of economic and emission databases as well as the latest available data on GHG inventories derived from UNFCCC, IEA, GTAP, World bank and IEA statistics. Especially in the agricultural sector, it is important to cover not just CO_2 but all GHG emissions, as described in detail below. We use individual GHG emissions intensities, broken down by sector and by region, and a consistent trade database covering the agriculture and manufacturing sectors. In addition, we assume that the two types of emission found in the transport, residential, commercial and other sectors are essentially the same. This assumption is not expected to cause problems for the evaluation of consumption-based GHG emissions because of their smaller international trade volume and smaller GHG intensities compared to those of agriculture and manufacturing. Another reason for this assumption is the lack of suitable import and export databases for these sectors.

The paper is structured as follows. Section 2 outlines the methodology used for evaluating time-series consumption-based GHG emissions. Section 3 describes the results of time-series consumption-based GHG emissions, evaluated by sector and by region, and compares them with production-based results. Finally, Section 4 presents the conclusions and suggestions for future research.

2. Methodology

We define production-based GHG emissions (hereinafter referred to as [PE]) as the emissions generated inside a country, and consumption-based GHG emissions (hereinafter referred to as [CE]) as the emissions generated from domestic consumption, in accordance with the definitions used by Peters et al. (2011). In this study, we generally make use of the differences (hereinafter referred to as [CE − PE]) calculated by subtracting [PE] from [CE]. Positive [CE − PE] values within a region indicate that the GHG emissions from the consumption of imported goods are larger than those from the production of exported goods, whereas negative values mean the opposite. The amounts of GHG emissions embodied in exported or imported goods are determined by the amounts of goods exported or imported and their emission intensities in the respective countries of origin.

The absolute value of [CE − PE] corresponds to "emission transfer", as defined by Peters et al. (2011), and the "balance of emissions embodied in trade", as defined by Muradian et al. (2002). In addition, negative and positive [CE − PE] values correspond to the "net exports and imports of embodied emissions", as defined by Peters et al. (2011).

In this study, the [CE − PE] of the whole economy within a region is considered to be equivalent to that of the agriculture and manufacturing sectors since, as mentioned in the previous sections, the levels of international trade for all other sectors are negligibly small by comparison.

This study divides the world into 24 regions and the whole economy is broken down into 11 sectors. Tables 1 and 2 show the types of sectoral and regional disaggregation used in this study. We define the large economies as consisting of three regions, the U.S., EU15 and Japan (with 29%, 27% and 17% of the global GDP in