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Analysis

Production-based and consumption-based national greenhouse gas inventories: An implication for Estonia

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ABSTRACT

Two national greenhouse gas (GHG) inventories were prepared for Estonia: (1) an inventory that includes GHG emissions from the production of goods and services (i.e., commodities) within its national territory and (2) an inventory of GHG emissions occurring within and outside its national boundaries due to Estonia's consumption of commodities, whether produced domestically or traded bilaterally. The inventories included estimates of energy-related and non-energy-related carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions (converted to CO_2-equivalent, CO_2eq) associated with the production and consumption of commodities, grouped in three main sectors: energy, industrial processes and agriculture. Input–output (IO) analysis, emissions embodied in bilateral trade (EEBT) approaches and the basic methods of the 2006 IPCC Guidelines were used to perform the estimates. The results of the study illustrated that the total CO_2eq emissions associated with consumption in Estonia in 2005 were 18% higher than those associated with production, primarily due to the net import of CO_2eq emissions from countries outside of the European Union.

1. Introduction

Two types of national greenhouse gas (GHG) inventories have been developed intensively during recent years. The first type of national GHG inventory, referred to as production-based (Peters, 2008), was established under the United Nations Framework Convention on Climate Change (UNFCCC (1992)) to (1) analyse the magnitude of each country's influence on climate as a result of its annual GHG emissions (i.e., direct GHGs, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), the halocarbons (HFCs), the perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6), and ozone precursors,[1] including carbon monoxide (CO), oxides of nitrogen (NO_x), non-methane volatile organic compounds (NMVOCs) and sulphur dioxide (SO_2)); (2) develop GHG emission-reduction targets (i.e., under the Kyoto Protocol (UN, 1998) and the Copenhagen Accord (UNFCCC, 2010a)); and (3) monitor progress towards achieving the targets that have been set up to mitigate human influence on the climate system. This type of inventory focuses and defines GHG emissions and removals occurring within the territory of a country due to production activities, which are aggregated into the following six sectors: energy, solvents and other product uses, industrial processes, agriculture, land use and land use change (LULUCF) and waste (IPCC, 1997).

The second type of national GHG inventory, which is consumption-based (Peters, 2008), has its roots in the academic community and is becoming an increasingly important alternative accounting method for GHG emissions in the context of globalisation. Globalisation 'breaks down' the national boundaries of countries by integrating their economies and societies through the liberalisation of trade and the emergence of a worldwide production market. The latter promotes access to a wide range of goods and services for consumers in different parts of the world due to exports and imports between countries (i.e., international trade). International trade, in its turn, obliterates 'GHG emission boundaries'. In other words, GHG emissions caused by the production of commodities for export in one country (i.e., country–producer) are accounted for as GHG emissions associated with a country–producer, and this country should attempt to reduce the emissions. However, the exported commodities are consumed in another country (i.e., country–consumer) that does not account for the GHG emissions associated with their production and uses the commodities without any 'responsibility for climate change'. Therefore, considering GHG emissions associated only with production of commodities and omitting GHG emissions embodied in traded commodities leads to an incomplete understanding of the overall GHG emissions associated with each country on the global scale.

The consumption-based inventory explicitly includes GHG emissions embodied in imported commodities and excludes GHG emissions associated with exported commodities. The results obtained by estimating GHG emissions using a consumption-based inventory

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[1] Because these gases are not GHGs, they are not included in global warming potential; however, they contribute indirectly to the greenhouse effect. Emissions of ozone precursors were included among the items to be reported under the national GHG inventory (IPCC, 2006). However, they were not included in the Kyoto Protocol targets for reducing GHG emissions. For convenience, all gases discussed are referred to as 'GHGs'.

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reflect a more full and adjusted picture of the overall GHG emissions in relation to the actual living standards (i.e., consumption level) of a country.

To date, numerous global-scale and individual case studies analysed GHG emissions estimated by production-based and consumption-based inventories. A brief overview of such studies was summarised in Wiedmann, 2009; Wiedmann et al., 2007; a short list of the latest studies includes Chen and Chen, 2011; Davis and Caldeira, 2010; Edens et al., 2011; Lin and Sun, 2010; Muñoz and Steininger, 2010; Peters et al., 2011a,b; Rodrigues et al., 2010; Su and Ang, 2010; Su et al., 2010. On the whole, GHG emissions associated with production and consumption of commodities were evaluated and recorded for more than 110 countries. The results obtained in the framework of the global-scale studies make possible the quantification of economic and 'GHG emissions' linkages between countries and the identification of the main importer-countries and exporter-countries of GHG emissions embodied in international trade. The individual case studies evaluated for several countries, primarily the members of the Organisation for Economic Co-operation and Development (OECD) (including the 15 old member states[2] of the European Union (EU27)), provide a basis for detailed analysis of the differences between GHG emissions that occur due to production and those that are associated with the consumption of commodities at the sectoral or the product level in these countries and provide a broader understanding of the factors (e.g., trade structure, volume, trade partners) that result in differences in the levels of the emissions. Hence, the global-scale and individual case studies reinforce and benefit each other and can be considered to provide a solid basis for the development of further climate policy.

Estonia is one of the less studied countries. The GHG emissions associated with the production and consumption of commodities in Estonia were recorded only in the framework of global-scale studies (Bang et al., 2008; Davis and Caldeira, 2010; Peters et al., 2011a,b; Rodrigues et al., 2010). No detailed estimated data on GHG emissions embodied in commodities imported and exported and no analysis of differences in GHG emissions on sector level between the production-based and consumption-based inventories were performed. However, Estonia, as a full member of the EU, ratified the Kyoto Protocol; the EU is taking the lead in establishing global agreement to minimise adverse effects of countries' activities on the climate and to implement domestic actions to achieve reductions in GHG emissions by each member country (EC, 2009). It is reasonable to assume that further rational climate policy should be developed based on sound knowledge and understanding of the objective situation.

In the present study, we compiled national production-based and consumption-based inventories of three main gas emissions, CO_2, CH_4 and N_2O for three main inventory sectors (energy, industrial processes and agriculture) of Estonia for 2005. For CH_4 and N_2O, emissions were converted to CO_2-equivalent (CO_2eq) emissions using the corresponding global warming potential of the 100-year time horizon provided by (IPCC, 1995) and established to be used under the Kyoto Protocol (UN, 1998). Specifically, we investigated energy-related CO_2eq emissions caused by the combustion of energy sources (i.e., the energy sector) associated with the production, bilateral trade and consumption of commodities as well as those that occurred in the process of primary fuel extraction (i.e., fugitive emissions; energy sector) and those associated with the production and consumption of the primary fuels. In addition, we examined non-energy-related CO_2eq emissions resulting from manufacturing processes and agricultural activities (i.e., industrial processes and the agriculture sector of national inventories) in the production of goods consumed in Estonia or exported abroad and emissions associated with the importation of these goods.

The main principles of input–output (IO) analysis (Eurostat, 2008), the basic methods reported in the 2006 IPCC Guidelines (IPCC, 2006) and the main rules of the emissions embodied in bilateral trade (EEBT) approach (Peters, 2008) were employed in completing the inventories. The potential uncertainties and challenges associated with completing a detailed and accurate consumption-based GHG inventory of Estonia are also discussed in the present study.

2. Methodology and data

The fundamental methodological difference in estimating CO_2eq emissions using production-based and consumption-based inventories is that the latter also accounts for CO_2eq emissions embodied in commodities imported and exported between countries (Ahmad and Wyckoff, 2003), as shown in the following:

$$E_{DCd} = E_{DPd} - E_{EXdj} + E_{IMjd}, \quad (1)$$

where E_{DPd} represents the total CO_2eq emissions associated with the production of commodities within the boundaries of country *d*, E_{DCd} represents the total CO_2eq emissions associated with the consumption of commodities in country *d*, E_{EXdj} is the total CO_2eq emissions embodied in the commodities produced in country *d* and exported to countries 1…*j* and E_{IMjd} represents the total CO_2eq emissions embodied in the commodities produced in countries 1…*j* and imported to country *d*.

The total CO_2eq emissions associated with the production and consumption of commodities in Estonia in 2005 were determined as the sum of energy-related (i.e., due to energy source combustion and primary energy extraction) and non-energy-related (i.e., resulting from manufacturing and agricultural activities) CO_2, CH_4 and N_2O emissions (converted to CO_2eq emissions (IPCC, 1995)).

The standard monetary IO tables developed by the OECD (OECD, 2010) and the Statistical Office of European Communities (Eurostat, 2010a) and data on primary and secondary energy fuels combusted (Eurostat, 2010c; IEA, 2003a,b, 2005a,b) were used in the context of the EEBT approach to estimate the energy-related CO_2eq emissions embodied in each of 42 commodities produced in Estonia and in the countries-trade-partners of Estonia. The latter, together with data on the bilateral trade of Estonia (measured in monetary terms; Eurostat, 2010b,d), were used to estimate the energy-related CO_2eq emissions embodied in the import and export of Estonia. The EEBT approach was employed because, first of all, this approach is considered to be the most transparent (Peters and Hertwich, 2008) and more appropriate for the analysis of GHG emissions associated with bilateral trade relationships (Peters et al., 2011a; Su and Ang, 2011), than another calculation approach, multiregional input–output (MRIO). The latter is also widely employed in the framework of consumption-based GHG inventory and reputed to be more complex in use and in more data-demanding. The approaches differ in how they treat imported commodities and, consequently, in the sources of GHG emissions embodied in them. The EEBT does not distinguish between different uses of imported commodities, i.e., whether they are used for final consumption or for intermediate consumption to produce commodities that could be domestically consumed or exported. In other words, the EEBT approach assumes that GHG emissions embodied in commodities imported to a country remain within the boundaries of the country and are not '(re)exported' with commodities in the production process of which imported commodities were used, i.e., the overall GHG emissions 'imported' to a country are considered 'consumed in the country'. Nevertheless, the MRIO approach splits GHG emissions embodied in commodities imported to a country into two parts—for final consumption and for intermediate

[2] The older member countries are Austria (AT), Belgium (BE), Germany (DE), Denmark (DK), Spain (ES), Finland (FI), France (FR), Greece (GR), Ireland (IE), Italy (IT), Luxembourg (LU), the Netherlands (NL), Portugal (PT), Sweden (SE) and United Kingdom (UK). The new member countries are Bulgaria (BG), Cyprus (CY), the Czech Republic (CZ), Estonia (EE), Hungary (HU), Lithuania (LT), Latvia (LV), Malta (MT), Poland (PL), Romania (RO), Slovenia (SI), and Slovakia (SK).