Greenhouse Gas Emissions Embodied in New Zealand's Trade: Methodology

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Abstract

Domestic and international policies for greenhouse gas (GHG) mitigation have focussed on reducing emissions within territorial boundaries, following the 'polluter-pays principle', which underpins many modern environmental policies. However, international trade in goods and services partially decouples activities of production and consumption, which may occur in different countries.

We report on work in progress from a project using multi-regional input-output (IO) analysis to quantify the GHG balance of trade for New Zealand. We start with the readily available GTAP database, produce a new IO table and imports matrix for New Zealand, introduce a new global database for non-CO_2 emissions, calculate international maritime emissions and air passenger transport emissions using a detailed bottom-up model specific to New Zealand, and project these emissions over 2001–2009.

Estimating the GHGs embodied in New Zealand's imports, exports and final consumption will provide important information that complements that currently available in the Government's National Greenhouse Gas Inventory Report. The methods used to generate historical estimates of these embodied emissions can also be applied to analyse the impacts of different scenarios for future global demand and trade patterns. These estimates will allow the Government to assess the implications of New Zealand's international trade for emissions targets and general and sector-specific accounting rules that may be negotiated for a post-Kyoto regime.

This paper describes the methodology used in the project, with results remaining confidential to the client at time of writing.

Introduction

Domestic and international policies for GHG mitigation have focussed on reducing emissions within territorial boundaries. This follows the 'polluter-pays principle' (OECD, 1972), which underpins many modern environmental policies. However, international trade in goods and services partially decouples activities of production and consumption, which may occur in different countries. A 'consumer responsibility' perspective is relevant if governments seek to directly influence consumption decisions. It is also relevant to individual consumers and community organisations seeking to voluntarily change patterns of household consumption. This principle is also attracting attention in the context of international negotiations on climate change (Peters and Hertwich, 2008), as some countries may be able to reduce their emissions.

This paper presents the methodology developed for estimating New Zealand's (NZ's) emissions embodied in trade, being a significant update of an earlier, preliminary study performed for NZ (Andrew et al., 2008).

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Methodology

Choice of Multi-Region Input-Output Approach

Peters (2008) distinguishes two accounting approaches for constructing consumption-based national emission inventories. Both approaches are based on IO analysis but differ in the allocation of intermediate consumption of imported products. One considers the emissions embodied in total bilateral trade between regions (EEBT), the other uses full MRIO modelling and considers embodied emissions in trade to final consumption (EEC) of a nation. The EEBT method determines all embodied emissions in one region associated with the total bilateral trade flows from this region. The method does not split the bilateral trade flow into components to intermediate and final consumption. It therefore cannot determine the total emissions to produce a given product since some regions require imports to produce exports.

On the other hand, total embodied emissions in consumption (EEC) – and thus of final products – can be calculated by using an MRIO model (see Annex III in WWF, 2008). This type of analysis endogenously determines trade to intermediate consumption and is analogous to the upstream (cradle-to-shelf) part of Life Cycle Assessment (LCA). Peters (2008) explains that "Overall, the MRIO [EEC] model is better for the analysis of final consumption, while the EEBT model is arguably better for analysis of trade and climate policy where transparency is important."

We have chosen the EEBT approach in this project because of its policy focus. Implementation of EEBT is straightforward: embodied emission factors are calculated for each export commodity, and these factors are then multiplied by exports, generally disaggregated by destination.

The GTAP Database

As discussed by Wiedmann (2007; 2009), the GTAP[4] database has been used by a number of authors for MRIO analysis since Peters first showed a method for constructing an MRIO table from the IO tables and trade data provided by GTAP (Peters, 2007).

The GTAP database is a fully documented, global database that contains input-output tables, bilateral trade data, energy data, and other key economic and protection data. The GTAP database hasn't been widely used in the IO community, and this may be because the GTAP database is designed for use in Computable General Equilibrium (CGE) modelling. Thus, the publicly available version of the GTAP database has already been balanced for CGE purposes and the GTAP data differ from the originally submitted datasets (Peters, 2007). Despite its possible shortcomings, the GTAP database is the most detailed and comprehensive dataset available for environmental MRIO analysis. A detailed dataset focussing on the European Union with a base year of 2000 is due for release in 2010 (Tukker et al., 2009), while the OECD publish a set of tables that include all 30 OECD countries and 12 other countries with a base year of 2005 (OECD, 2010).

We use the GTAP database for estimation of emissions embodied in imports and for emissions embodied in exports of services. For emissions embodied in exports, we use a NZ IO table constructed specifically for this project.

New Zealand Input-Output Table Construction

Existing tables

The New Zealand IO table provided in the GTAP7 database ostensibly represents the year ended December (YED) 2004. However, the provenance of this table is convoluted, being originally based on a table released by Statistics New Zealand in 2001 representing the year ended March (YEM)

[4] Global Trade Analysis Project, hosted by Purdue University.

1996 (Statistics New Zealand, 2001). Malcolm and Rae (2006) modified this table for submission to GTAP for the GTAP6 database. However, the authors do not indicate whether they updated the table to YED 2001, and it is likely that this update was left to GTAP in their updating and balancing procedure, which uses macroeconomic data (GDP, trade data, etc.) to fit regional IO tables into the global database (McDougall, 2006). For the GTAP7 database, there was no new submission of a New Zealand IO table, so the table from GTAP6 was re-updated using this same procedure. As a consequence of this tortuous provenance, the NZ IO table in GTAP7 is likely to be a poor representation of the NZ economy in the 2004 calendar year.

In October 2007 Statistics NZ produced supply and use tables for YEM 2003 in producer prices (Johan Erasmus, pers. comm., 16/10/07). Shortly afterward basic-price versions of these tables were produced and released to the public (Johan Erasmus, pers. comm., 31/1/08). These tables represented the NZ economy with a 53-industry and 60-commodity classification. However, both these sets of tables were still based on the technical coefficients used in the 1996 tables. As part of this project Statistics NZ was commissioned to disaggregate these tables further, and these were released in April 2009 (Johan Erasmus, pers. comm., 8/4/09) with the same commodity classification but with 85 industries, and in basic prices only. Statistics NZ has subsequently collected new data that permit updating the technical coefficients, but new tables based on these may not be available before the end of 2011 (Johan Erasmus, pers. comm., 23/4/10).

Several significant issues remained with the 60×85 supply and use tables before they were of use in our analysis: (i) The use table was total use, not separated between use of domestic production and imports, (ii) The meat and dairy processing industries (and meat and dairy products commodities) were aggregated, and these two industries have some of the largest emissions embodied in exports from New Zealand (Andrew et al., 2008), and (iii) GTAP7 represents YED 2004, and the tables supplied by Statistics NZ represented YEM 2003.

Because national accounts data in NZ are calculated annually for years ended March, we chose to update the supply and use tables to YEM 2005, thereby ensuring balance with the national accounts data, and to assume that the technical coefficients derived from this table were a very good approximation of YED 2004.

Domestic and Imported Use Tables

To address the issue of separating the use table between domestic and imported production, Statistics NZ was commissioned to produce imports matrices by matching the tax department numbers of goods importers and exports to the Business Frame, which matches companies to the ANZSIC industry classification (Scott Davis, pers. comm., 19/1/09). As well as a table for YEM 2005, tables for previous and subsequent years were produced, providing additional information where cells were confidential in YEM 2005. Confidential cells in the YEM 2005 goods table were then replaced by estimated values using a quadratic programming solver with constraints including row and column sums as well as estimates from other years. A YEM 2005 services imports table was produced starting from the detailed 1996 imports table in combination with data from published national accounts and data provided directly by Statistics NZ. These two tables were then combined into a single imports table for YEM 2005.

Importantly, this resulting imports table indicates the importation of commodities by each industry, but not their use of imported goods: several industries import significantly more than they use themselves, particularly of goods, on-selling the surplus to other industries. We have assumed that industries with imports surplus to their use requirements on-sell that entire surplus to other industries. For these other industries, and for final demand sectors, shortfall in use is met through a mix of redistributed imports and domestic supply, and that mix is commodity-specific but the same across all industries.

This redistributed imports matrix is then subtracted from the use matrix to derive a domestic use matrix.

Disaggregating Meat and Dairy Industries and Commodities

The 1996 supply and use tables include the meat and dairy industries separately because they were produced before actual industry consolidation substantially reduced the number of companies. The reduction in numbers of companies, and the market dominance of certain companies, meant that Statistics NZ was forced by legislation to aggregate the industries in all data releases to protect commercial sensitivity. While the 1996 tables provide some useful information for disaggregating the industries for 2005, the nine-year interval was marked by significant changes in the industry, including efficiency gains. However, we have combined the 1996 disaggregation data with 2005 data for commodity prices, export data (95% of meat and dairy products are exported), and disaggregated data in the 2003 tables for meat and wool farming operations versus dairy cattle farming to substantially improve the robustness of the estimates.

Updating the Supply and Use Tables to YEM05

The YEM 2003 supply and use tables were updated to YEM 2005 using a quadratic programming solver with a wide range of constraints mostly taken from Statistics NZ's National Accounts 2009 edition (Statistics NZ, 2009), but supplemented with electricity purchase data by industry (MED, 2006), and trade data. There are boundary differences between system of national accounts (SNA) and Customs with respect to trade data concerning whether goods importation constitutes actual transfer of ownership: Customs report all goods crossing the border, regardless of ownership, whereas SNA requires imports and exports to reflect monetary transfers. Examples that fall in this space are leased aircraft, stocks of oil purchased but not yet physically imported, and trial periods of use for significant equipment including defence vehicles. Statistics NZ make adjustments for these when calculating national accounts, but these adjustments could not be released for use in this project. We have therefore applied the adjustments made in YEM 2003 proportionally to the YEM 2005 trade data. While this is unfortunate, the adjustments in YEM 2003 were only approximately 2% of total trade.

Producing the Input-Output Table

To avoid the issues of negative multipliers surrounding the construction of commodity-by-commodity input-output tables, and because our emissions data are based on industries, we have constructed an industry-by-industry input-output table using the fixed-product sales structure assumption (FPSSA), the industry-by-industry equivalent of the industry technology assumption (Eurostat, 2008).

GHG Database

The starting point for compilation of the GHG database for this work is the GTAP7 CO_2 emissions database, which provides fuel combustion CO_2 emissions for all 113 regions of the GTAP dataset derived from GTAP7 energy data (Lee, 2008). This was recently supplemented with a preliminary non-CO_2 emissions database produced by applying projected, annualised growth factors from US Environmental Protection Agency projections (USEPA, 2006; Rose et al., 2010).

Because the GTAP CO_2 emissions database represents only emissions from combustion activities it excludes significant emissions from cement manufacturing and gas flaring. We have added the latter emissions from the CDIAC emissions database (Marland et al., 2009). We have also overwritten Annex-I countries' agricultural emissions in the GTAP non-CO_2 database using data extracted from those countries' national submissions to the UNFCCC (UNFCCC, 2008; Andrew, 2010).

Emissions for NZ were produced from New Zealand's submissions to the UNFCCC, including the detailed background tables (MfE, 2009), in combination with data from the NZ Energy End-Use Database (EECA, 2009).

Australian emissions were provided by the University of Sydney in the same classification as the input-output table produced by the Australian Bureau of Statistics (Manfred Lenzen, pers. comm., 23/10/09).

International Transport emissions

Allocation based on economic value – the method of monetary input-output analysis – is a poor means of calculating transportation emissions of freight and passengers because of the weak correlation between emissions and value. Additionally, international transportation data are extremely poor in GTAP[5]. We have therefore used a bottom-up approach to estimate emissions associated with transportation of goods and passengers to and from NZ rather than relying on input-output analysis.

Freight Transportation

Merchandise trade data are collected by NZ Customs from importing and exporting companies. Statistics NZ manage these data for public release, and we have obtained data at the most disaggregated Harmonised System (HS) 10-digit level for 2001–2009 (both YEM and YED), with NZ port and country of origin/destination, and with gross weight (including packaging, given for almost all records), net quantities in commodity-specific units, and values (FOB, VFD, and CIF). These data are also submitted to the UN COMTRADE database (UNSD, 2010), but at a much more aggregated level (HS 4 digit), and excluding re-exports information and NZ port. Importantly, the port indicates whether the goods were transported by air or by sea.

Some goods trade data are suppressed by Statistics NZ for reasons of commercial sensitivity, but the dataset retains information about the origin and destination of confidential items as well as the port, weight, and value. Using this information, additional information on which goods may be suppressed, and data from COMTRADE reported by trade partners for whom the same goods are not suppressed, some of the confidential data can be estimated.

We have constructed a database of marine transportation inter-port distances for New Zealand based on freely available online databases (Dataloy Systems AS, no date; World News Network, no date). By combining the gross weight and origin/destination data from the trade dataset with the marine inter-port distances we obtain tonne-km estimates for each record in the trade dataset. We then assign expected vessel types to HS categories at 4-digit level and use vessel-specific, per-tonne-km emission factors from Lipasto (VTT, 2009), which are a comprehensive set of emission factors and also include non-GHG emissions, which may be useful to extend the current study[6].

Passenger Transportation

Because of NZ's distance from other countries, international passenger travel by ship is negligible compared with travel by aeroplane, so we ignore ship travel here.

Our estimates are made using simple bottom-up methods based on per-passenger emission factors for different flight routes and actual or estimated passenger numbers on these routes.

Key data sources are:

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[5] For example, according to the GTAP database, approximately one third of NZ's imports arrive by land. This is unlikely given NZ's oceanic isolation.

[6] These emission factors are specific to Finland, but they ought to be suitable for general use; NZ-specific emission factors were not available. Note that these emission factors include assumptions about load factors.

- Inbound and outbound tourism statistics for New Zealand (Statistics New Zealand)
- Passenger statistics to and from New Zealand by airport of origin and destination (International Civil Aviation Organization)
- Per-passenger (economy class) emission factors by airport pair (International Civil Aviation Organization)

Available data on passenger movements do not distinguish countries of residence. We have therefore assumed likely routings for tourists based on their country of residence (inbound) or their stated main destination (outbound). Where relevant, we assume travel via one or more likely transit airports. For example, we assume that New Zealanders travel to the United Kingdom from Auckland to London Heathrow via Hong Kong.

Trade Data

Quality trade data are clearly a key requirement of robust estimates of emissions embodied in trade. GTAP7's trade data are sourced from the UN COMTRADE database (UNSD, 2010), albeit with significant modifications. These modifications are required because of deficiencies in the COMTRADE dataset (under-reporting, over-reporting, non-reporting, confidentiality, black-market trading, classification errors, etc.); to ensure that the trade data fit in the overall macroeconomic balance of the GTAP database; and to account for re-exports of the two most significant re-exporting nations, Hong Kong and the Netherlands (Gehlhar, 2005b, a). While these modifications result in a balanced and harmonised dataset, they cause significant changes in some individual values, and these are used in place of trade data submitted with IO tables by contributors.

Harvested Wood Products

The default IPCC assumption for assessing emissions from forestry is that all carbon is emitted to the atmosphere when timber is harvested. Net emissions (removals) from forestry are reported on this basis in New Zealand's national inventory. In reality though, a large fraction of the carbon is stored in harvested wood products (HWPs) for years or decades during their use phase. Carbon is also stored for many years when HWPs are disposed of in landfills.

We extend the accounting of embodied emissions by accounting for temporary carbon storage following the 'tonne-year' approach. The approach is based on the principle that removing one tonne of CO_2 from the atmosphere and storing it for 55 years counteracts the radiative forcing effect, integrated over a 100-year time horizon, of a pulse emission of one tonne of CO_2 (Costa & Wilson 2000). Under the consumer responsibility perspective, the purchasing country is seen as responsible for the temporary sequestration associated with production of the products imported, just as they are seen as responsible for the associated emissions.

Based on the typical growth of plantation forest trees in New Zealand over an average rotation length of 28 years, we have estimated the tonne-years of storage in New Zealand's forests associated with exported HWPs.

In principle, tonne-year accounts by sector could be integrated within the MRIO framework. However, given very limited data on intermediate uses of HWPs and the relative dominance of final uses in the domestic economy (e.g. structural timber in new buildings), we have chosen to account only for carbon storage in traded HWPs (e.g. logs, plywood) and not for any indirect carbon storage in other traded goods and services.

Time Series Projections

Because of price and commodity group composition changes, the emission factors estimated in kg/NZD for YED 2004 are not directly transferable to other years. Emissions by weight are much more likely to be stable over a short period, ignoring efficiency changes, and ignoring changes within the aggregated commodity grouping. We therefore calculate average export/import prices in NZD/kg (gross weight) at HS 6-digit level, convert the emission factors from per NZD to per kg, and apply these new factors to the gross weights given in the trade data time series.

However, not all records in the trade database have correct gross weights. In particular, many large-value aircraft and ships (HS chapters 88 and 89, respectively) have gross weight equal to the number of units. For these two chapters, we have used the per-dollar emission factors instead of per-kilogram, and adjusted the emission factors using annual-average exchange rates.

Conclusions

In this paper we have presented the methodology developed for producing robust estimates of the emissions embodied in New Zealand's trade. This is a complex project, bringing together many data from a range of sources, and a variety of methods are required to build a complete picture of these emissions. We have not presented results here because of a client request for confidentiality.

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