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New Zealand's carbon balance: MRIO applied to a small developed country

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Abstract

Like many small countries, New Zealand is heavily dependent on international imports to provide many commodities that cannot be economically produced domestically, and on exports that generate foreign currency to pay for these imports. In New Zealand's case primary products such as meat, dairy, and wood account for about 40% of exports. We use multi-regional input-output (MRIO) analysis to construct a preliminary emissions balance of trade in 2001 for New Zealand. This shows New Zealand was a significant net exporter of embodied emissions; and that this is true for the group of

Annex I countries that have ratified the Kyoto Protocol, for the USA, and for the group of Annex II countries. As this research is at a very early stage, we focus particularly on data requirements, methodological aspects in the New Zealand context, and directions for future research on this topic.

Keywords: multi-region input-output, emissions trade balance.

1. Introduction

The Kyoto Protocol obliges New Zealand (NZ) to reduce its net territorial greenhouse gas (GHG) emissions to 1990 levels in the first commitment period (2008–2012). New Zealand's GHG emissions profile is very different from other developed nations (see Table 1), with 48% of total emissions in 2006 coming from the agriculture sector (Ministry for the Environment, 2008). In contrast, emissions from agriculture typically account for about 12% of total greenhouse gas emissions in other Annex-1 parties (Ministry for the Environment, 2008). The vast majority of NZ agricultural production is destined for export markets – over 90% of meat and dairy products are exported – generating approximately 40% of New Zealand's export revenues. Additionally, New Zealand's plantation forests are estimated to have sequestered carbon dioxide equivalent to 32% of territorial emissions in 2001 (Ministry for the Environment, 2007).

Table 1

The New Zealand government has introduced a range of measures aimed at reducing New Zealand's GHG emissions. These include an energy efficiency and conservation strategy, renewable energy targets, a biofuels obligation, a Permanent Forest Sinks Initiative, and an Emissions Trading Scheme (Clark, 2007).

It has been argued that consumption-based inventories should be used in a post-Kyoto accounting architecture, better reflecting responsibility for emissions (Ward, 2005; Peters and Hertwich, 2008). With New Zealand's peculiar combination of a high level of development and high dependence on exported primary production, a consumption-based inventory would be expected to be quite different to the existing production-based inventory used by the UNFCCC.

In this paper we apply the GTAP-MRIO model of Peters (2008) to investigate New Zealand's emissions balance of trade and emissions resulting from New Zealand final consumption. The primary objective of this paper is to present methods of analysis and data that can be used for this purpose, and to identify priorities for their future development. Because the validity of the data has not been established, the detailed results presented herein should be treated with caution.

2. Methodology

Multi-regional input-output analysis (MRIO)

The standard IOA framework begins with an accounting balance of monetary flows,

$$x^r = A^r x^r + y^r + e^r - m^r \quad \textbf{(1)}$$

where x is the vector of total output in each sector, y is a vector with each element representing final consumption – households, governments, and capital – in each industry sector (domestic plus imports), e is the vector of total exports, m is the vector of total imports (for both intermediate and final consumption), A is a matrix where the columns represent the input from each industry (domestic plus imports) to produce one unit of output for each domestic industry, Ax is the vector of total intermediate consumption, and r is the region under investigation. This balance equation holds in all regions. The trade components can also be expressed using bilateral trade data

$$e^r = \sum_s e^{rs} \quad \textbf{(2)}$$

for exports from region r to s and by symmetry the total imports are

$$m^r = \sum_s e^{sr} \quad \textbf{(3)}$$

where e^{rs} is the bilateral trade data.

To perform analysis with this model the imports are usually removed from the system:

$$x^r = A^{rr} x^r + y^{rr} + e^r \quad \textbf{(4)}$$

which expresses the same balance using only domestic activities. The domestic final consumption is decomposed as

$$y^r = y^{rr} + \sum_{s \neq r} y^{sr} \tag{5}$$

and the inter-industry requirements are decomposed as

$$A^r = A^{rr} + \sum_s A^{sr} \tag{6}$$

where A^{rr} represents the industry input of domestically produced products and A^{sr} represents the industry input of products from region *s* to region *r*.

The environmental impacts are calculated as

$$f^r = F^r x^r = F^r \left(I - A^{rr} \right)^{-1} \left(y^{rr} + \sum_s e^{rs} \right) \tag{7}$$

where *F* is the GHG emissions per unit industry output (a row vector). These are the emissions that occur domestically to produce both domestic final consumption and total exports.

The MRIO model needs to distinguish between trade that goes to intermediate and final consumption. This can be performed by splitting the bilateral trade data into use by final demand, *y*, and industry, *z*, (details below),

$$e^{rs} = z^{rs} + y^{rs} \tag{8}$$

The exports to industry can be expressed as

$$z^{rs} = A^{rs} x^s \tag{9}$$

where x^s represents the output in region *s*. By substitution of the decomposed exports into (4) the standard MRIO model results,

$$x^r = A^{rr} x^r + y^{rr} + \sum_{s \neq r} A^{rs} x^s + \sum_{s \neq r} y^{rs} \tag{10}$$

By considering the equation in each region the matrix form is obtained,

$$\begin{pmatrix} x^1 \\ x^2 \\ x^3 \\ \vdots \\ x^m \end{pmatrix} = \begin{pmatrix} A^{11} & A^{12} & A^{13} & \dots & A^{1m} \\ A^{21} & A^{22} & A^{23} & \dots & A^{2m} \\ A^{31} & A^{32} & A^{33} & \dots & A^{3m} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ A^{m1} & A^{m2} & A^{m3} & \dots & A^{mm} \end{pmatrix} \begin{pmatrix} x^1 \\ x^2 \\ x^3 \\ \vdots \\ x^m \end{pmatrix} + \begin{pmatrix} \sum_r y^{1r} \\ \sum_r y^{2r} \\ \sum_r y^{3r} \\ \vdots \\ \sum_r y^{mr} \end{pmatrix} \quad \textbf{(11)}$$

where each "block" in the large matrix represents the interactions between different countries; A^{rs} is the trade between industries from region r to region s, and y^{rs} is the trade from industries in region r to final consumers in region s. The final consumption in each region r is given by a vector

$$y^r = \begin{pmatrix} y^{1r} \\ y^{2r} \\ y^{3r} \\ \vdots \\ y^{mr} \end{pmatrix} \quad \textbf{(12)}$$

where y^{rr} is the final demand produced domestically. Given the final consumption, the MRIO model endogenously calculates not only domestic output, but also the output in all other regions resulting from trade. Given the output in each region, the emissions can be calculated as

$$f = F^1 x^1 + F^2 x^2 + \dots + F^m x^m \quad \textbf{(13)}$$

The challenge of the MRIO model is to split e^{rs} into the desired components. This is possible using the IOT for imports, which has the balance

$$m^r = \sum_s e^{sr} = Z^{r,imp} e + y^{r,imp} \quad \textbf{(14)}$$

where Z^{r*} represents the collected (or estimated) industry requirements of imported goods and services, y^{r*} is the imports to final consumption, and e is a summation vector. The bilateral trade data, e^{rs}, can then be distributed according to the use of imports by industry. Each component of the industry requirements of imports then becomes

$$Z_{ij}^{sr} = \frac{Z_{ij}^{r,imp}}{m_i^r} e_i^{sr} \quad \textbf{(15)}$$

where the element Z_{ij} is the use of sector i's outputs by sector j, and Z^{rs} is the import from region r to region s (that is, Z_{ij}^{rs} is the import from sector i in region r to sector j in region s). Thus, in each region r the bilateral trade data, e^{rs}, is distributed across using sectors in the same ratio as in equation (14). Similarly, the same distribution applies to the final demand categories:

$$y_{ij}^{sr} = \frac{y_{ij}^{r,imp}}{m_i^r} e_i^{sr} \tag{16}$$

where j represents different categories of final demand (households, government, etc.). Essentially, the method distributes the bilateral trade data according to the structure in the import IOT. The advantage of this splitting method is that if the bilateral trade data is "pre-balanced" rebalancing of the MRIO table is not required (using the RAS method, for example).

The environmental impacts, f, can be disaggregated in two key ways: (i) the production perspective, and (ii) the consumption perspective. The production perspective disaggregates impacts based on the sources of emissions by diagonalisation of the GHG emissions intensity vector, F:

$$f = \hat{F}(I - A)^{-1} y \tag{17}$$

where y is any demand vector, and A is any inter-industry requirements matrix. Examples of the production perspective are the electricity generation emissions resulting from the purchase of a wide range of commodities by households, or the on-farm agricultural emissions instigated by demand for exports of meat and milk products. Conversely, the consumption perspective disaggregates impacts at the other end of the supply chain, based on the purchases indicated by the demand vector, y. This is achieved by diagonalisation of the demand vector:

$$f = F(I - A)^{-1} \hat{y} \tag{18}$$

Examples of the consumption perspective are the total emissions in the supply chain of automobile production through the purchasing of cars by government, or the total supply chain emissions instigated by demand for food products.

Note that these two perspectives do not imply assignment of responsibility to either consumer or producer; they are merely two different ways of disaggregating the analysis.

Data and preparation

The data requirements for a multi-regional IOA are considerable, but most developed countries and many developing countries collect the necessary data. However, converting the country data to a consistent global data set is a considerable task. The Global Trade Analysis Project (GTAP) has constructed the necessary data for the purposes of CGE modelling and this data set can be applied for multi-regional IOA. The GTAP provides data for 87 countries and 57 industry sectors covering IOA, trade, protection, energy, and CO_2 emissions (Dimaranan, 2006). Version 6 represents the world economy in 2001.

Whilst the GTAP database has impressive coverage, care needs to be taken with its consistency and accuracy. Generally, original data are supplied by the members of the GTAP in return for free subscription. The data are often from reputable sources such as national statistical offices. Unfortunately, due to the voluntary nature of data submissions, the data are not always the most recently available. Further, once the original data have been received "[GTAP] make[s] further *significant* adjustments to ensure that the I-O table matches the external macroeconomic, trade, protection, and energy data" (Dimaranan, 2006). These adjustments (or calibrations) are made for internal consistency in computable general equilibrium modelling and are of unknown magnitude.

The GTAP CO_2 data are based on the IEA energy statistics and the IPCC tier 1 reference approach (Dimaranan, 2006). Comparisons of the GTAP CO_2 data and other national data sources show considerable variation. Consequently, when national specific emissions data was readily available we overwrote the GTAP data. This occurred for Australia, China, Japan, New Zealand, USA, and various EU countries – Austria, Belgium, Bulgaria, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, The Netherlands, Poland, Portugal, Slovenia, Spain, Sweden, Switzerland, United Kingdom, and Norway (which we assumed to be Rest of EFTA in the GTAP data).

These data were constructed using an economic system boundary. By comparing the refinery sector in the GTAP data and the national sources we found that on average the GTAP data overestimated refinery emissions by a factor of 3.4. We used this factor to scale down the refinery sector in the remainder of the GTAP database.

The CH_4, N_2O, and synthetic gases (non-CO_2) data were obtained from GTAP (Rose and Lee, 2008). The GTAP data did not include non-CO_2 emissions from biomass. We added these using data from the EDGAR database (van Aardenne et al., 2005).

An initial analysis of the methane and nitrous oxide emissions associated with New Zealand in the resulting dataset showed large discrepancies when compared with data available in New Zealand (Statistics New Zealand, 2003; Ministry for the Environment, 2007). The largest errors were in the N_2O assigned to the vegetables, fruits, and nuts; livestock farming; and raw milk sectors (Table 2). This may be the result of incorrect assignment of fertiliser use to crop production, and indicates the need for close examination of these data before use. In particular, the emissions shown in Table 2 represent 19% of New Zealand's total GHG emissions in 2001, and there is therefore significant potential for very large errors in analytical results. The authors therefore replaced CH_4 and N_2O data for NZ with own estimates based on New Zealand's National Inventory Report (Ministry for the Environment, 2007). Smaller errors are also present in the CO_2 and fluorinated gases data, but these will be refined and updated in future work, as will the New Zealand input-output table and bilateral trade data.

Table 2

3. Results and Discussion

New Zealand's emissions trade balance

New Zealand's GHG emissions embodied in bilateral trade (EEBT) are shown in Figure 1. NZ territorial emissions embodied in its exports are over twice the amount of foreign emissions embodied in NZ imports. An emissions trade deficit for CO_2 is more than offset by a large surplus for non-CO_2 gases. This pattern reflects the dominance of agricultural products – and particularly meat and dairy products – in New Zealand's exports, while imports are dominated by manufactured goods.

Figure 1

Table 3 shows in more detail the emissions embodied in bilateral trade (imports, exports, and net) for various countries and world regions. With most of its main trading regions, NZ is a significant net exporter of embodied emissions. With its near neighbour Australia, NZ is a significant net importer of embodied emissions, while emissions embodied in trade with China are approximately balanced. New Zealand's net embodied emissions in trade are 34% of total NZ industry emissions and 30% of total NZ territorial emissions.

Table 3

In the context of negotiations for the Kyoto Protocol post-2012, we show New Zealand's EEBT for Annex-I (industrialised) versus non-Annex-I (developing) countries. We also separate the USA from other Annex-I countries, which have ratified the Protocol. Figure 2 shows that there is a large EEBT surplus with each of these groups. The largest surplus in absolute terms is with Annex-I countries excl. USA, while the largest surplus in relative terms (i.e. ratio of emissions in exports to those in imports) is with the USA. There is also a large surplus with developing countries.

Figure 2

The consumption perspective of emissions reflects the commodities traded with New Zealand (Table 4). Clearly, New Zealand's food production and processing sectors contribute the majority of New Zealand's exported emissions, greatly outweighing imported emissions from the same sectors overseas. However, emissions embodied in imports of oil, metals, chemicals and plastics, minerals, machinery, and clothes are significantly larger than emissions embodied in exports from those same sectors.

Table 4

Table 5 shows the emissions embodied in New Zealand's imports and exports by major commodity groups using the production perspective. The production perspective reveals the extent to which foreign electricity generation emissions contribute to the emissions trade balance, with a net deficit of 3464 kt CO_2-e. The figures for transport should be treated with caution because they include air transport, which has not been verified and is relatively significant in New Zealand (with a large tourism sector and a large share of long-haul flights).

Table 5

EEBT may be broken down by country and sector simultaneously. The only significant bilateral emissions trade deficit in 2001 was with Australia (Table 3). Table 6 shows that the largest single contributions to this deficit from the production perspective were from electricity generation and the metals industry. In contrast to New Zealand's high renewables capacity and use for electricity generation, the majority of Australia's electricity is generated using conventional thermal (coal and gas) stations. The emissions intensity in the GTAP-MRIO dataset for the electricity generation sector in New Zealand is 2.1 kt CO_2-e/\$m compared with 12.3 kt CO_2-e/\$m for Australia. The metals emissions trade balance reflects the importation of aluminium oxide from Australia for smelting into aluminium at New Zealand Aluminium Smelters (NZAS)[1] using predominantly inexpensive, zero-emissions hydroelectricity[2]. About 85% of the aluminium is exported directly, with much of the remainder exported in products. In addition to these specific factors, the EEBT imbalance reflects a significant bilateral trade imbalance for both goods and services in Australia's favour (Statistics New Zealand, 2007).

Table 6

More detail can be obtained by looking at individual EEBT links, as shown in Table 7. While meat and dairy products account for 75% of all NZ emissions embodied in exports, when individual product markets (at the level of disaggregation in our model) are considered, several other products appear. The top three contributions are:

[1] NZAS is majority owned by Rio Tinto Alcan, part of multinational Rio Tinto Group.

non-ferrous metals exported to Japan (likely to be primarily aluminium); bovine meat products to the USA; and air transport to the USA. Air transport to the UK, Germany and Japan also appear in the top thirty contributors. Although these numbers require investigation, as was explained above, they are not unreasonable considering that in 2001, those four countries were among the top six sources of long-haul visitors to New Zealand (accounting for 600 000 arrivals) (Ministry of Tourism, 2008), and that while South Korea had 33% more visitors than Germany, it is somewhat closer. Similarly, while Australia is easily the largest market, with 630 000 arrivals, flights are much shorter.

Table 7

Similarly, a detailed view of emissions embodied in imports highlights the most significant commodity groups, as shown in Table 8. Australia dominates the table, with the top four placings.

Table 8

Comparing emissions under producer and consumer responsibility perspectives

By adding the emissions balance of trade to New Zealand territorial emissions associated with domestic final demands, we obtain New Zealand's overall greenhouse gas emissions balance under a consumer *responsibility* perspective of 45 Mt CO_2-e. This is 33% less than territorial emissions in 2001 (see Table 3).

Figure 3

Figure 4 compares the use of the production (territorial emissions accounting) and consumption (add imports, subtract exports) responsibility perspectives when calculating New Zealand's per-capita emissions. When only CO_2 is accounted the consumption responsibility perspective gives a very similar result to the production responsibility perspective, reflecting that total levels of CO_2 emissions embodied in imports are similar to those embodied in exports. However, when all GHGs are

[2] Meridian Energy announced on 1 Oct 2007 that it has signed an agreement with New Zealand Aluminium Smelters Ltd, to supply 572MW of baseload power from 2013 to 2030.

combined, the consumption responsibility perspective gives a markedly lower per-capita emission rate, reflecting the high non-CO_2 emissions intensity of New Zealand's exported commodities compared with imports.

Figure 4

Where do New Zealand's territorial emissions end up?

Using MRIO we can estimate the ultimate destination of NZ territorial emissions embodied in goods and services. As shown in Figure 5, 38% of emissions from New Zealand industry were associated with New Zealand final consumption (using full MRIO). A further 16% were ultimately embodied in final consumption in Europe; 15% in North America; and 12% in the S, SE, and Rest of E Asia. From a consumer-responsibility perspective this means that 62% of New Zealand's industry emissions were 'exported' with exported commodities.

Figure 5

Emissions resulting from New Zealand household demand

The industry emissions resulting from New Zealand's final consumption are shown in Tables 9 and 10. New Zealand households' emissions footprint was 23805 kt CO_2-e in 2001, of which 14931 kt CO_2-e were New Zealand territorial emissions. Carbon dioxide is the main contributing GHG to both these totals. Note the large methane footprint allocated to NZ Government, which is mostly landfill emissions.

Table 9

Table 10

After direct emissions from private transportation of 6453 kt CO_2-e, by far the largest source of emissions resulting from NZ household expenditure was in NZ Livestock Farming, with 5076.6 kt CO_2-e (Table 11). This was followed by NZ Electricity Generation (2438.7 kt), NZ Dairy Farming (2135.5 kt), and NZ Road Transport (1204.2 kt). The NZ Trade sectors are in seventh place (539.3 kt), showing the effect of distribution. Australian Electricity Generation appears in sixth place with 684.9 kt, and Chinese Electricity Generation was eighth with 439.2 kt.

Table 11

When these sectoral emissions are aggregated by region, industry emissions in New Zealand make the largest contribution (14931 kt CO_2-e) to the total (Table 12). Emissions in Australia contributed a further 2093 kt, and those in China contributed 1395. Total emissions contribution from overseas was 8874 kt CO_2-e (37% of the total).

Using the one-tier MRIO (i.e. restricting supply chains to allow only one international link), only 92% of New Zealand households' greenhouse gas footprint is captured (Table 12). However, only 79% of foreign emissions are captured with this approach, highlighting the importance of using a full MRIO model to determine household footprints.

Table 12

Aggregating by sector shows that Household transport (21%), Meat (20%), and Electricity (16%) were the largest contributors to New Zealand households' greenhouse gas footprint (see Table 13 and Figure 6). These electricity emissions include those resulting from household electricity demand, as well as emissions resulting from electricity generated for the production chain of commodities purchased by New Zealand households. For example, electricity generation emissions in Australia contributed 3% (685 kt CO_2-e) via a large number of production pathways to New Zealand households' GHG footprint, even though a structural path analysis (SPA) shows that the largest single pathway including Australian electricity generation was ranked 67th with 21.7 kt CO_2-e (SPA results not shown here).

Table 13

Referring again to Table 13, the majority of emissions associated with meat and dairy products occurred in New Zealand (87% and 97%, respectively), whereas about half of electricity emissions occurred abroad, and more than half of fossil fuel (excluding combustion) and metal production emissions occurred overseas (85% and 63%, respectively). Note that emissions from electricity generation in New Zealand form a smaller proportion of the total than might be expected, but this is because of New Zealand electricity's high renewable energy content. Overall, 77% of emissions contributing to New Zealand households' GHG footprint were embodied in goods and services purchased, and 37% of these embodied emissions occurred outside of New Zealand.

Most household direct emissions resulted from household transport, with a small amount for household heating. Household heating in New Zealand is mostly provided by purchased electricity and (carbon-neutral) wood burners.

Figure 6

4. Conclusions and Future Work

This work represents an initial analysis applying the GTAP-MRIO model of Peters (2008) to New Zealand. As such, little work has been done on improving data, more on proving the concept and providing a platform for future work. Because of this, results presented here must be treated with caution. They are intended to show the sort of work that can be done and to highlight areas that need improvement in future.

The value of the GTAP datasets are that they are comprehensive and harmonised, allowing world models to be created. However, these datasets should be seen as a first-cut, and individual countries' data should be refined where possible. Significant work is therefore required to verify the robustness of the top-down estimates presented in this article of emissions embodied in New Zealand's bilateral trade and households' consumption. Significant effort is required to further improve the emissions data for New Zealand, in particular the CO_2 emissions and air transport data. Import and export data will also require special attention to ensure correct classification.

Version 7 of the GTAP dataset is due to be released mid-2008, with all data updated to 2004 and with the inclusion of more country-specific data. The analysis presented here will need to be updated to use this more up-to-date dataset when it becomes available.

Accounting for carbon sequestered in standing timber and harvested wood products (HWP) is an important issue for New Zealand. This requires further investigation and methodological development before we can incorporate this into the

MRIO framework for embodied GHGs. Under the default accounting system of the Kyoto Protocol, carbon is assumed to return to the atmosphere when timber is harvested. Of course, this is not the case, and substantial quantities of carbon are sequestered for many years or even decades in HWPs. The situation becomes especially complex when HWP products at various stages of manufacture are traded internationally.

The production and consumption responsibility perspectives presented in this article form but two ends of a continuum of responsibility paradigms, and application of shared responsibility (see, for example, Lenzen et al., 2007; Andrew and Forgie, 2008; Peters, 2008) should be investigated. The shared responsibility perspective allocates responsibility to agents in the supply chain according to some measure of benefit obtained by the agent from the part in the supply chain.

5. Acknowledgements

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7. Appendix: Regional Aggregation

Table 14

8. Tables and Figures

Table 1

Gas	Emissions (Mt CO_2-e)		
	1990	2001	2006
CO_2	25.5	33.0	36.4
CH_4	25.5	27.0	27.5
N_2O	10.4	12.5	13.3
Fluorinated	0.5	0.5	0.7
Total	61.9	73.1	77.9

New Zealand territorial greenhouse gas emissions (excluding Land-use, Land-use Change and Forestry), 1990, 2001, and 2006

Table 2

Sector number	Sector code	Sector name	GTAP N_2O (kt CO_2-e)	Corrected N_2O (kt CO_2-e)
4	v_f	Vegetables, fruit, nuts	4488	159
9	ctl	Cattle, sheep, goats, horses	4769	6709
10	oap	Animal products nec	46	636
11	rmk	Raw milk	2537	4205

Most significant changes to the GTAP emissions dataset in this study

Table 3

Region	kt CO_2-e			
	NZ	Imports	Exports	Net
New Zealand households	6939			
New Zealand industry	60485			
Total territorial emissions	67424			67424
Australia		5612	-2321	3291
China		2263	-2126	137
Japan		584	-3372	-2788
S, SE, and Rest of E Asia		2217	-7836	-5620
North America		2018	-7982	-5963
Central and South America		323	-2582	-2259
Europe		1777	-9523	-7746
Russia and Rest of Former USSR		309	-157	152
Middle East		1522	-1153	370
Africa		397	-767	-370
EEBT Total		17022	-37819	46628
Emissions net of EEBT				**46627**

Components of New Zealand's overall greenhouse gas balance in 2001

Table 4

Sector	kt CO_2-e Exports	Imports	Net
Meat	17339	785	-16555
Dairy	10393	76	-10317
Other food	1662	1225	-437
Oil (crude and refined)	45	1558	1512
Metals	1625	2012	387
Chemicals and Plastics	595	2203	1608
Minerals	86	1044	959
Machinery	473	2853	2380
Clothes	663	1204	541
Transport	1995	1973	-22
Others	2942	2089	-853
Total	37818	17022	-20796

Consumption perspective of New Zealand's imported and exported emissions, 2001

Table 5

Sector	kt CO_2-e Exports	Imports	Net
Meat	18129	1283	-16845
Dairy	10250	88	-10161
Other food	765	928	163
Oil (crude and refined)	87	1548	1462
Metals	1332	1640	308
Electricity	1569	5033	3464
Transport	3496	2343	-1154
Others	2190	4159	1968
Total	37818	17022	-20796

Production perspective of New Zealand's imported and exported emissions, 2001

Table 6

Sector	kt CO_2-e Exports	Imports	Net
Meat	616	772	156
Dairy	435	47	-388
Other food	73	263	189
Oil (crude and refined)	20	349	329
Metals	347	1010	663
Electricity	282	2068	1786
Transport	230	213	-17
Others	317	890	573
Total	2321	5612	3291

Production perspective of sectoral emissions embodied in trade (EEBT) between Australia and New Zealand

Table 7

Rank	kt CO_2-e	Destination country and exporting sector
1	344	Japan – NZ Metals nec
2	291	United States – NZ Bovine meat products
3	244	United States – NZ Air transport
4	175	Australia – NZ Ferrous metals
5	160	United States – NZ Transport nec
6	154	Australia – NZ Metals nec
7	137	Japan – NZ Food products nec
8	126	United Kingdom – NZ Air transport
9	122	Japan – NZ Wood products
10	119	Rest of Oceania – NZ Ferrous metals
11	117	Australia – NZ Food products nec
12	116	Australia – NZ Paper products, publishing
13	111	United Kingdom – NZ Bovine meat products
14	101	United States – NZ Wood products
15	96	Germany – NZ Air transport
16	95	Australia – NZ Machinery and equipment nec
17	94	Korea – NZ Forestry
18	89	Korea – NZ Metals nec
19	86	Japan – NZ Dairy products
20	84	Australia – NZ Wood products
21	83	United States – NZ Food products nec
22	82	Japan – NZ Air transport
23	78	United States – NZ Ferrous metals
24	76	Mexico – NZ Dairy products
25	76	United States – NZ Dairy products
26	76	Malaysia – NZ Dairy products
27	75	Indonesia – NZ Dairy products
28	74	Philippines – NZ Dairy products
29	72	Germany – NZ Bovine meat products
30	72	United States – NZ Chemical, rubber, plastic products

Top 30 export emissions from New Zealand by destination country and exporting sector, full disaggregation, 2001

Table 8

Rank	kt CO_2-e	Country/region of origin and exporting sector
1	1068	Australia – Metals nec
2	455	Australia – Ferrous metals
3	452	Australia – Chemical, rubber, plastic products
4	436	Australia – Machinery and equipment nec
5	354	Rest of Middle East – Oil
6	262	United States – Chemical, rubber, plastic products
7	251	United States – Transport equipment nec
8	251	Australia – Petroleum, coal products
9	241	China – Chemical, rubber, plastic products
10	238	China – Machinery and equipment nec
11	219	Australia – Motor vehicles and parts
12	219	Australia – Mineral products nec
13	207	Australia – Paper products, publishing
14	199	Rest of Middle East – Chemical, rubber, plastic products
15	197	Japan – Motor vehicles and parts
16	186	China – Wearing apparel
17	180	Australia – Food products nec
18	173	Rest of Middle East – Petroleum, coal products
19	171	United States – Air transport
20	148	China – Textiles
21	138	United States – Machinery and equipment nec
22	130	Rest of Middle East – Mineral products nec
23	125	China – Mineral products nec
24	111	China – Electronic equipment
25	111	United States – Transport nec
26	110	Australia – Metal products
27	102	China – Metal products
28	99	China – Manufactures nec
29	99	Japan – Machinery and equipment nec
30	92	Australia – Electronic equipment

Top 30 emissions in imports to New Zealand from source country and exporting sector, full disaggregation, 2001

Table 9

Gas	Households	Government	Capital formation	International transport
CO_2	13351	2654	5984	1387
CH_4	6859	2182	884	146
N_2O	3268	296	392	37
FGAS	327	49	290	4
CO_2-e	23805	5181	7549	1574

Total footprints for NZ final purchases, full MRIO

Table 10

Gas	Households	Government	Capital formation	International transport
CO_2	6825	1436	2026	1053
CH_4	5468	1993	561	79
N_2O	2503	230	243	26
FGAS	135	20	96	1
CO_2-e	14931	3679	2926	1158

Total footprints for NZ final purchases, only including NZ territorial emissions

Table 11

Rank	Value	Country/Region and Sector
1	5076.6	New Zealand – Bovine cattle, sheep and goats, horses
2	2438.7	New Zealand – Electricity
3	2135.5	New Zealand – Raw milk
4	1204.2	New Zealand – Transport nec
5	979.2	New Zealand – Air transport
6	684.9	Australia – Electricity
7	539.3	New Zealand – Trade
8	439.2	China – Electricity
9	428.6	New Zealand – Public Administration, Defence, Education, Health
10	367.1	Australia – Bovine cattle, sheep and goats, horses
11	331.4	United States – Electricity
12	277.3	Rest of Middle East – Oil
13	270.0	New Zealand – Ferrous metals
14	190.7	New Zealand – Water transport
15	182.8	China – Bovine cattle, sheep and goats, horses
16	168.0	New Zealand – Paper products, publishing
17	146.0	Australia – Ferrous metals
18	130.1	New Zealand – Dairy products
19	128.3	New Zealand – Animal products nec
20	125.8	New Zealand – Vegetables, fruit, nuts
21	119.0	United States – Air transport
22	115.2	China – Chemical, rubber, plastic products
23	109.5	New Zealand – Mineral products nec
24	101.2	New Zealand – Fishing
25	95.9	Australia – Metals nec
26	88.4	Rest of Middle East – Petroleum, coal products
27	85.6	New Zealand – Chemical, rubber, plastic products
28	82.7	China – Ferrous metals
29	81.3	United States – Chemical, rubber, plastic products
30	81.0	Rest of Middle East – Electricity

Top 30 emissions resulting from New Zealand household expenditure, production perspective, 2001

Table 12

Region	kt CO_2-e contribution n1-MRIO	MRIO	%
New Zealand	14914	14931	99.9%
Australia	2033	2094	97.1%
China	1116	1395	80.0%
Japan	188	256	73.5%
S, SE, and Rest of E Asia	964	1268	76.0%
North America	877	1112	78.9%
Central and South America	156	261	59.7%
Europe	736	1068	68.9%
Russia and Rest of Former USSR	138	316	43.9%
Middle East	639	839	76.2%
Africa	166	265	62.6%
Total	21928	23805	92.1%
International totals	7014	8874	79.0%

Comparison of regional industry contributions to New Zealand households' GHG footprint using only one international trade link (n1-MRIO) versus full MRIO

Table 13

Sector	kt CO_2-e New Zealand	Rest of World	Total	%
Household transport	6453	-	6453	21%
Household heating	486	-	486	2%
Meat	5277	787	6064	20%
Dairy products	2266	66	2332	8%
Other food	277	737	1014	3%
Electricity	2439	2409	4847	16%
Road transport	1204	546	1750	6%
Air transport	979	608	1587	5%
Fossil fuels	201	1103	1304	4%
Metals	338	574	913	3%
Others	1951	2044	3995	13%
Total	21870	8874	30744	100%

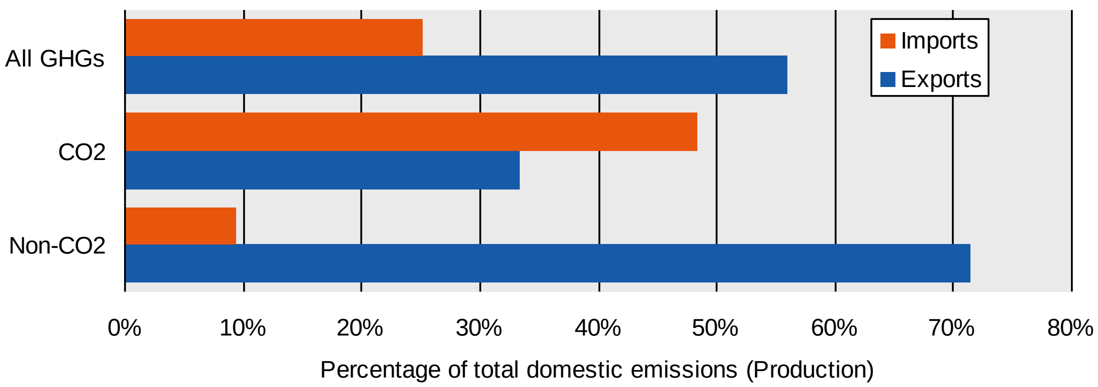
Aggregated production perspective sectoral emissions resulting from New Zealand household expenditure, showing where emissions occurred

Table 14

S, SE, and Rest of E Asia	**Europe**	**Central and South America**
Rest of Oceania	Austria	Mexico
Hong Kong	Belgium	Colombia
Korea	Denmark	Peru
Taiwan	Finland	Venezuela
Rest of East Asia	France	Rest of Andean Pact
Indonesia	Germany	Argentina
Malaysia	United Kingdom	Brazil
Philippines	Greece	Chile
Singapore	Ireland	Uruguay
Thailand	Italy	Rest of South America
Vietnam	Luxembourg	Central America
Rest of Southeast Asia	Netherlands	Rest of FTAA
Bangladesh	Portugal	Rest of the Caribbean
India	Spain	
Sri Lanka	Sweden	**Africa**
Rest of South Asia	Switzerland	Morocco
	Rest of EFTA	Tunisia
North America	Rest of Europe	Rest of North Africa
Canada	Albania	Botswana
United States	Bulgaria	South Africa
Rest of North America	Croatia	Rest of South African CU
	Cyprus	Malawi
Russia and Rest of Former USSR	Czech Republic	Mozambique
Russian Federation	Hungary	Tanzania
Rest of Former Soviet Union	Malta	Zambia
	Poland	Zimbabwe
Middle East	Romania	Rest of SADC
Turkey	Slovakia	Madagascar
Rest of Middle East	Slovenia	Uganda
	Estonia	Rest of Sub-Saharan Africa
	Latvia	
	Lithuania	

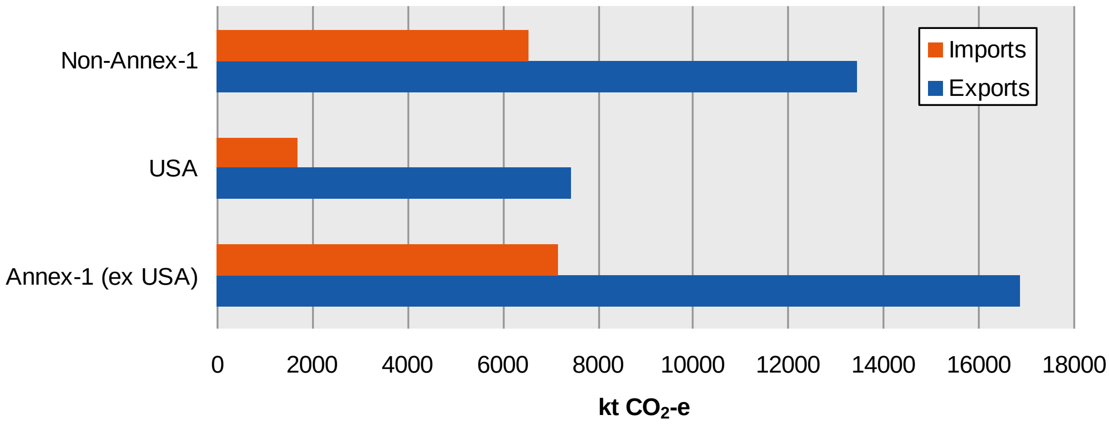
Regional aggregation of GTAP v6 regions used in this study

Figure 1



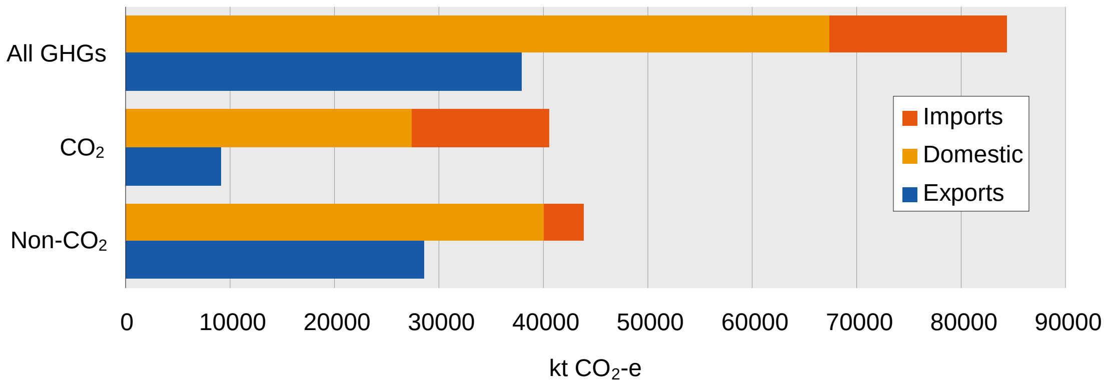
Total New Zealand GHG emissions imports and exports by GHG grouping

Figure 2



New Zealand's greenhouse gas international trade balance by Kyoto Protocol participation category[3]

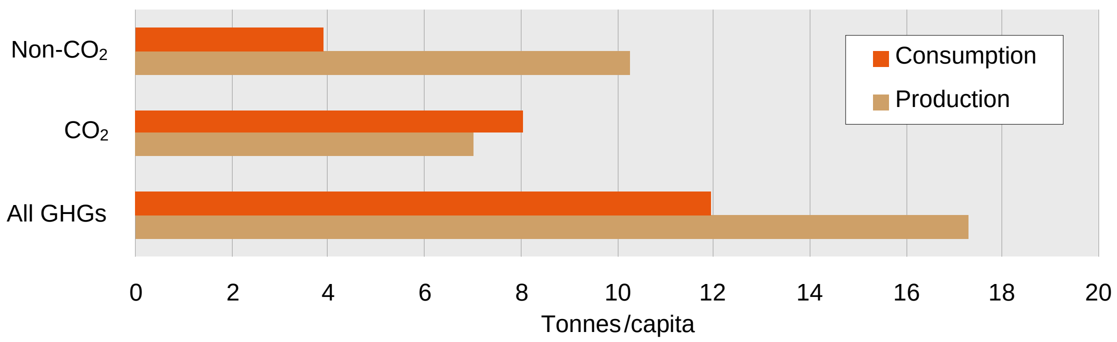
Figure 3



New Zealand's overall GHG emissions balance by gas group

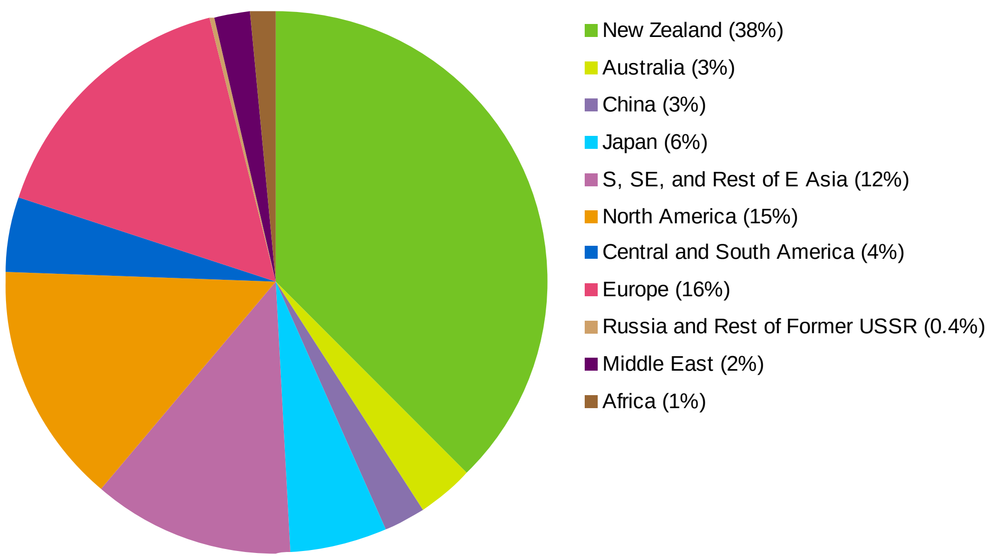
[3] USA is a member of the Annex 1 group of nations but had not ratified the protocol at the time of writing

Figure 4



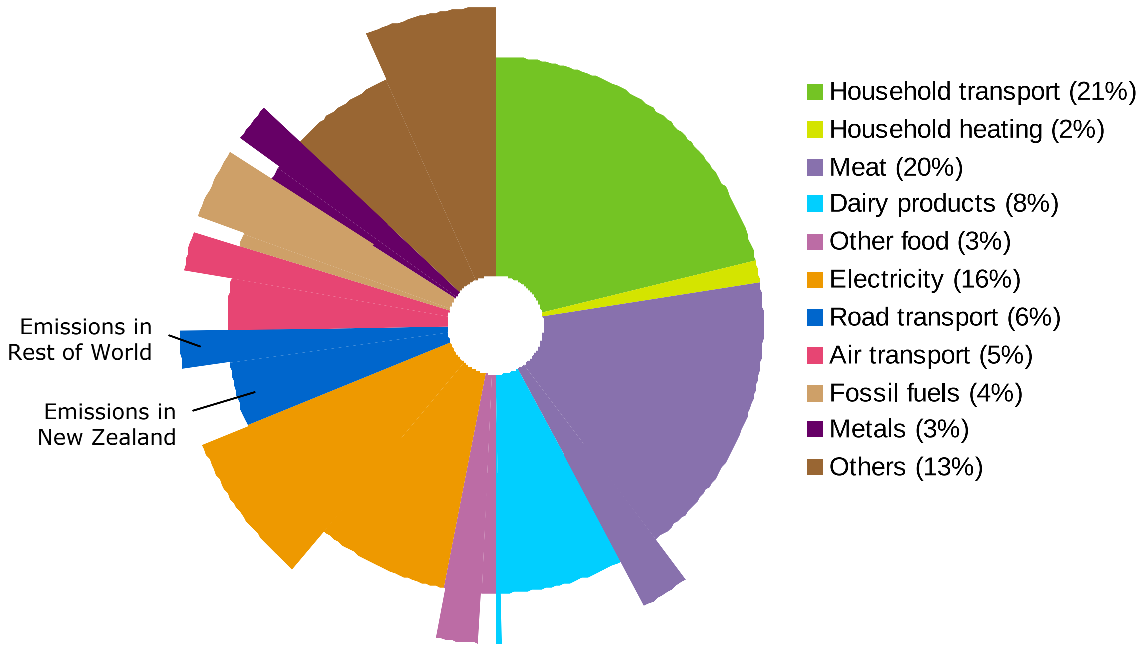
New Zealand per-capita emissions of CO_2 and all GHGs using production and consumption responsibility perspectives, 2001

Figure 5



Final demand regions for New Zealand's territorial greenhouse gas emissions

Figure 6



Production perspective emissions resulting from New Zealand household direct activities and expenditure, with imported components shown as protrusions