Using Micro-data for the Assessment of Carbon Emissions in the New Zealand Manufacturing Industry

Paper presented at Markets and Models: Policy Frontiers in the AWH Phillips Tradition,
at Wellington, New Zealand,
9-11 July 2008

Martin Brown-Santirso and Nedra Fu

Statistical Analyst, Geography, Regional and Environment, Statistics New Zealand

P O Box 2922
Wellington, New Zealand
info@stats.govt.nz

www.stats.govt.nz

Abstract

In the years leading to the Kyoto Protocol Commitment Period commencing on 1 Jan 2008, the New Zealand Government has put forward a number of proposals intended to help the country meet its international obligations. This has led to a number of studies being carried out which attempt to determine the overall effect of implementing these proposals to the economy, including flow on effects on consumption and investment patterns.

Using unit record data from the Manufacturing Energy Use Survey (MEUS) carried out by Statistics New Zealand in 2006, this study adds to this body on knowledge by calculating energy related carbon emissions down to the company level for the March 2006 year.

This study also makes use of the Annual Enterprise Survey (AES) unit record data to directly compare the intermediate consumption values for each enterprise against costs of carbon emissions at several carbon price scenarios ($15, $25, $50 and $100 dollars per tonne). Thus, the study generates an estimate of the added cost of production that arises from energy related carbon emissions for each enterprise.

The results are an estimate of the economic burden that a carbon pricing system will place on the manufacturing industry through direct added costs from energy use. The study does not venture into expanding the estimates to indirect costs, costs to the rest of the economy, make any projections, or speculate about how carbon costs will be absorbed or managed by the manufacturing industry.

Introduction

For the better part of the last two decades growing attention was paid to the enhanced greenhouse effect and the threat of climate change. This led to the signing of the Kyoto Protocol in 1997, where signatory nations agreed to reduce their anthropogenic (man-made) greenhouse gas (GHG) emissions, in particular carbon dioxide.

There is an increasing amount of research on the science of climate change, on practical and operational carbon reduction options, and the social and economic impacts of carbon reduction policies. While debate on the science of climate change research continues, there is a rising acceptance of the need to reduce GHG emissions.

Whether or not the science of climate change and GHG emissions is correct, the Kyoto Protocol Commitment Period 1 (CP1) began in January 2008. In order to comply with its obligations, the New Zealand Government has opted for an emissions trading scheme (ETS) to regulate GHG emissions. The New Zealand ETS joins other similar schemes around the world, such as the European Union ETS which has been operating since 2005; and Australia, who ratified the Kyoto protocol in early 2008, has announced an ETS that will probably be in operation by 2010. In the United States, many states in the northwest are also setting up an inter-state ETS for the region which includes the Canadian provinces.

The focus on carbon policy has led to an increasing amount of research on the economic impacts of pricing carbon in an economy. The aim of this paper is to add to this growing body of knowledge, by providing an assessment of energy-related carbon emissions of the manufacturing industry in 2006 based on survey micro-data. The cost of emissions is calculated using a number of price scenarios and compared with financial performance, both at industry and company levels.

This paper has two sections:

Part one assesses the direct energy-related carbon emissions and costs at an industry level based on published information.

Part two uses unit record data from Statistics New Zealand's survey collections to calculate energy-related emissions at a company level and compare them against financial unit record data to assess the burden of a carbon charge.

Statistics New Zealand's standard confidentiality principles were applied to this analysis to ensure the confidentiality of our respondents.

For this paper direct energy-related costs refer to the costs incurred by the final user of the energy and not the generator (ie electricity generators will pass costs to users). While it is understood that there may be a number of indirect costs generated from a carbon pricing policy (such as increased prices on supplies due to carbon costs), this paper does not attempt to assess them.

Relevant studies

At the forefront of the political, scientific and economic debate surrounding the Kyoto Protocol is the issue of the economic costs associated with carbon reduction.

Given the pervasive nature of energy in modern society, a charge on carbon emissions is very complex and will affect all entities within the economy. The Australian Minister for Climate Change, Hon Penny Wong, highlighted this in a recent statement on the Australian ETS: "emissions trading will be one of the most far-reaching and complex reforms in Australian history".[1]

There have been a number of national and international studies that aim to estimate the magnitude of potential effects on the economy and society. Examples include a research paper compiled by researchers from US and Australian universities, and the US Environmental Protection Agency (McKibbin, 1998) – "What to Expect from an International System of Tradable Permits for Carbon Emissions". This paper attempts to forecast the effects of the implementation of an international system of tradable permits on the flow of trade and capitals using a multi-region, multi-sector, inter-temporal general equilibrium model of world economy. In terms of the New Zealand context, the best known example is the report "General Equilibrium Analysis of Options for Meeting New Zealand's International Emissions Obligations" (Stroombergen, 2007) prepared by Infometrics for the Emissions Trading Group in 2007. This report provides estimates of the macroeconomic impacts on New Zealand given different carbon price scenarios and reduction strategies using a general equilibrium model. Another national example includes "The impact of the proposed Emissions Trading Scheme on New Zealand's economy" (NZIER, 2008) which also employs a general equilibrium model to carry out a macroeconomic analysis of the New Zealand economy.

While studies such as those mentioned above provide valuable insights into the possible effects of future development, they are powered by models that are based on many assumptions, and are therefore subject to change and unexpected developments.

In contrast, while this paper does not analyse consequential impacts, it adds to this field of research by providing an estimate of the additional economic burden to the manufacturing industry for their energy-related carbon emission using empirical unit record data. To ensure that confidentiality is protected, aggregated results are presented in this paper. It does not discuss the possible downstream effects to the economy, or how the manufacturing sector might deal with this burden.

1 http://www.environment.gov.au/minister/wong/2008/pubs/mr20080320.pdf

Methodology

This paper uses the results from the Statistics New Zealand's 2006 Manufacturing Energy Use Survey (MEUS) to derive the energy-related carbon equivalent emissions for the manufacturing industry. MEUS requested enterprises to provide information such as the types and amounts of energy used for the 12 months ending 31 March 2006.[2] Emissions are then calculated at an enterprise level, using the unit record data provided by individual respondents for MEUS.

We applied several carbon price scenarios to the calculated emissions to generate estimates of the total direct cost of energy-related carbon emissions for each price level. This paper assumes that emitters will face the full cost of carbon, and the results would change considerably in case of free emissions allocations.

The Annual Enterprise Survey (AES) 2006 collected a range of financial information from enterprises for the same period.[3]

The study assumes that data collected from these two surveys in 2006 indicated typical energy use pattern and financial performance for the units concerned.

Deriving emissions from energy use data

The method used for the estimation of emissions from energy use data follows that used by the Ministry of Economic Development (MED) to calculate energy emissions in the New Zealand Energy Greenhouse Gas Emissions 1990–2006 (MED, 2007). This method in turn follows the Inter-governmental Panel on Climate Change (IPCC) guidelines.

Energy use figures for each energy source (eg coal or gas) obtained from MEUS have been multiplied by a fuel specific carbon dioxide (CO_2) emission factor. These figures are subsequently multiplied by a fuel specific oxidation factor.[4] The resulting figures for each fuel are aggregated to produce a CO_2 emissions total for each company.

A similar process was followed to calculate methane (CH_4) and nitrous oxide (N_2O) emissions. For these calculations oxidation factors are not needed and are replaced by a Global Warming Potential (GWP) calculation. The GWP is applied to the CH_4 and N_2O figures to produce figures that are compatible with those from CO_2 such that they can be added to produce CO_2 equivalents measures.[5]

Emission factors

The emission factors selected for this process are all published in the MED report cited above, which is available for free from the Ministry's website.[6] While majority of the emission factors selected are the average factor for each fuel type, there were a few cases that required the specific selection of an emissions factor for a fuel. For the specific factors used in this study and their rationale please refer to appendix 1.

2 For more information see: http://www.stats.govt.nz/products-and-services/info-releases/manufacturing-energy-use-survey.htm

3 For more information see: http://www.stats.govt.nz/products-and-services/info-releases/aes-info-releases.htm

4 A small proportion of the carbon content in fuels remains unoxidised due to incomplete combustion. The factors used in this study are those recommended by the IPCC.

5 For more information refer to: http://en.wikipedia.org/wiki/Greenhouse_warming_potential

6 http://www.med.govt.nz/

Although it is understood that average emission factors may detract slightly from the accuracy for some results, there is insufficient information available to apply case specific factors. As such, for this purpose it was decided that the use of average emission factors would simplify the process, reduce potential for errors and increase transparency of procedures and results.

Carbon cost scenarios

Once the derived carbon emissions were calculated, they were then multiplied by four scenarios of carbon price per tonne: NZ$15, $25, $50, $100 to estimate the cost of emissions for each unit and the entire industry.

There has been much discussion on the possible price of carbon, and there is general agreement about the uncertainty of what the price will be in the future (NZIER, 2008). For this reason, a range of prices were selected for this study.

The prices estimated for recent economic simulations or official forecasts range considerably (NZIER,2008. Infometrics, 2008. The Treasury 2006, 2007. Jamieson, 2007). The prices selected for this study represent levels that appear to be of interest in the current debate (Jamieson, 2007):

1. The NZ$15 price was used as it reflects the price used in much of the initial Government analysis on the impacts of the ETS on the New Zealand economy.[7]
2. The NZ$25 price was used to reflect more recent estimates of the price of carbon by Treasury. Also, there is more general interest for analysis using this price of carbon (Jamieson, 2007).
3. The NZ$50 price was selected to provide a perspective of the economic burden if the cost of carbon was twice that of the more accepted general estimate of $25.
4. The NZ$100 price scenario gives an overview of the costs if the price of carbon rises to unexpected highs.

Financial data

For this study it was necessary to source financial performance figures from individual companies that would enable the assessment of the burden of carbon cost as a function of costs or income.

Statistics New Zealand regularly collects financial data from businesses in order to compile New Zealand's macroeconomic statistics such as gross domestic product (GDP) and the balance of payments. A number of sources were probed to determine the suitability of their data to use in this study. Three surveys were identified as potential sources, as they collect financial performance data:

- Quarterly Manufacturing Survey (QMS)
- Business Operations Survey (BOS)
- Annual Enterprise Survey (AES)

Improved Business Understanding via Longitudinal Database Development (IBULDD)[8] – a longitudinal business database currently under development, was used to compare

7 http://www.treasury.govt.nz/government/liabilities/kyoto

8 For more information in this tool please follow the link to the Statistics New Zealand website: http://www.stats.govt.nz/economy/business/longitudinal-business-database.htm

the financial measures for the three surveys. Initially, we assessed the possibility of joining these datasets to maximise the number of respondents in the MEUS represented in the financial data. Joining the datasets, however, added an element of complexity and incompatibility that was not warranted by the small gains in emissions coverage.

In the end, AES was selected because it provided the largest coverage of MEUS sample units – 65 percent. AES data also enabled us to provide estimates of national accounting variables such as gross output and intermediate consumption. Importantly, the units covered in both AES and MEUS included most of the larger emitters, representing over 88 percent of the total emissions for the industry calculated from MEUS.

There are a number of financial variables either directly available or estimated from AES that could be used for this paper including: intermediate consumption (IC), gross output (GO), value added, gross operating surplus and more. The main criteria for the selection of financial variables were:

- The stability of the series, where the figures are a good indication of financial activity and are not heavily affected by single events or accounting artefacts.
- The perception of what the costs of carbon will be measured against in the industry's bottom lines.
- Comparability across the industries.

After consultation with internal experts of this information, it was decided that the most appropriate variables for the purpose of this study would be:

- Intermediate consumption (IC) – consists of the value of all goods and services consumed as inputs by a process of production.
- Gross output (GO) – the value of goods and services produced during a time period.

These two variables are considered to be very stable and are less prone to be affected by accounting artefacts. The selection of IC is also based upon the idea that the cost of carbon represents an added cost of production. GO was selected as a measure of total production, to enable estimates of energy intensity measures, that is the amount of energy required for the production of x amount of output (in this case $1,000 of GO).

For more information on IC and GO please refer to appendix 2.

Industrial process emissions

Some industries produce non-energy-related carbon dioxide emissions as part of their manufacturing activities. Industrial process emissions are not included for the most part of this study as they do not form part of our statistical collections. However, a small section was included in the first part of this paper (page 9) that incorporates these emissions as reported by the MED (2007) to portray a more complete analysis at the industry level. This inclusion only occurs at an aggregated industry level as MED does not report these on an enterprise basis. The industrial process emissions were directly added to the industry that gave rise to them.

Exceptions

There were a number of small exceptions in the calculations in keeping with accounting frameworks or due to lack of reliable data. These include

1. Biomass – burning biomass (wood, wood waste and black liquor) for energy is theoretically carbon neutral so they were excluded from our

CO_2 calculations. However they were included for the calculation of CH_4 and N_2O in accordance with IPCC standards.

2. Steam – for those who purchased steam from third parties, the manner in which the steam was generated was not known, so it was not possible to calculate these emissions. For geothermal steam users, the field from which the steam was sourced is unknown, so specific emissions cannot be calculated, but they are believed to be small.
3. Exothermic reactions – for those operations designed to capture residual heat from an industrial/chemical process there was little information, and again it is not possible to calculate an emission. Note that these operations do not use added process energy, so there should be no related emissions.
4. Petroleum refining derives much of its process energy from the use of refining by-products as fuel.[9] The MEUS did not capture this flow of energy, as it is a specialised use. To cover this gap we used data provided by MED, which was added in the appropriate space.

Energy-related emissions and costs in the manufacturing industry

Using the methods described above, the estimated energy-related emissions for the New Zealand manufacturing industry were nearly 8.3 million tonnes of CO_2e for the year ended March 2006. Of these, 41 percent are from electricity, followed by coal and natural gas accounting for 20 and 18 percent, respectively. The remainder includes petroleum products and other small energy uses.

The industry that registered the largest CO_2e energy-related emissions for the March 2006 year was the food, beverages and tobacco manufacturing industry (ANZSIC C21) accounting for 29 percent of the manufacturing industry total. The metal products industry (ANZSIC C27) was the second largest emitter with 23 percent; wood and paper product manufacturing (ANZSIC C23) and the petroleum, coal, chemical and associated product manufacturing (ANZSIC C25) industries each accounted for 18 percent of the total emissions by the manufacturing industry.

In terms of costs, the total cost of these emissions to the manufacturing industry start from $124 million for the $15 per tonne scenario, moving through $207 million and $415 million for the $25 and $50 per tonne, and reaching $829 million for the $100 per tonne scenario. See table 1 for more details.

9 For more detail se: http://www.eia.doe.gov/emeu/mecs/iab/petroleum/page2a.html

Table 1

Energy use, Emissions and Carbon Costs by Industry
Year ended March 2006

Industry Group	Energy (PJ)	Emissions (KtCO2e)	Cost Scenarios ($NZ million)			
			$15	$25	$50	$100
Food, beverage and tobacco	36.47	2,384	35.8	59.6	119.2	238.4
Textile, clothing, footwear and leather	2.46	166	2.5	4.2	8.3	16.6
Wood and paper product	57.83	1,489	22.3	37.2	74.4	148.9
Printing, publishing and recorded media	0.81	52	0.8	1.3	2.6	5.2
Petroleum, coal, and chemical	12.70	1,473	22.1	36.8	73.7	147.3
Non-metallic mineral product	8.75	647	9.7	16.2	32.4	64.7
Metal product	30.61	1,926	28.9	48.1	96.3	192.6
Machinery and equipment	1.90	124	1.9	3.1	6.2	12.4
Other manufacturing	0.45	29	0.4	0.7	1.4	2.9
Total	**152**	**8,290**	**124.4**	**207.3**	**414.5**	**829.0**

Source: Manufacturing Energy Use Survey

Note: Energy use in petajoule (PJ) is not directly proportional to emissions in kilotonnes of CO_2e due to different compositions of energy types used by different industries.

In financial terms, the manufacturing industry produced a gross output (GO) of $69.9 billion for year to March 2006 (see table 2). It also consumed goods and services to the value of $46.9 billion in the same period. The largest contributor during this period was the food manufacturing industry which contributed 41 percent to GO and 45 percent to intermediate consumption (IC). The second largest contribution was by the machinery and equipment industry (ANZSIC C28) followed by the petroleum, coal, chemical and associated product industry (ANZSIC C25) which contributed 12 and 11 percent, respectively, to GO and 11 and 9 percent, respectively, to IC.

Combining financial information and resource use data, we calculated a number of measures to assess the burden of a carbon charge on energy related emissions. These include measures such as:

- percentage increase in IC due to energy related carbon emission costs
- carbon intensity for the industry
- energy intensity for the industry.

For the $15 per tonne scenario the manufacturing industry would see a 0.3 percent increase to its costs of production, or an extra $3 per $1,000 of IC. The increase in costs rises to just over 0.4 and 0.9 percent for the $25 and $50 per tonne scenarios, respectively. The increase in costs escalates to 1.8 percent or an extra $18 per $1,000 of IC for the $100 per tonne carbon price scenario.

Energy and carbon intensity

GO was selected as a measure of production for each industry, to enable estimates of the energy requirements and related emissions as a function of production. Energy and intensities in this paper are expressed in terms of gigajoules[10] (GJ) of energy per $1,000 of GO, while emissions intensities are expressed in kilograms (kg) of CO_2e per $1,000 of GO.

10 A gigajoule is roughly equivalent to 29 litres of petrol, a drive from Wellington to Palmerston North and back in an average car, or running a 2 kw heater for six straight days.

The manufacturing industry had an overall intensity of 2.2 GJ per $1,000 of production and 119kg of CO_2e of associated emissions. This equates to under $2 worth of emissions per $1,000 of GO for the $15 per tonne scenario, and increasing to almost $12 dollars for the $100 per tonne scenario (see table 2).

Table 2

Financial Performance, Energy and Carbon Intensities by Industry

Year ended March 2006

Industry Group	Gross Output	Intermediate Consumption	Energy intensity	Emissions intensity
	$NZ million		GJ/$1000 GO	KgCO2e/$1000 GO
Food, beverage and tobacco	28,851	21,267	1.26	83
Textile, clothing, footwear and leather	2,227	1,431	1.10	75
Wood and paper product	7,143	5,128	8.10	208
Printing, publishing and recorded media	3,826	2,135	0.21	14
Petroleum, coal, and chemical	7,594	4,251	1.67	194
Non-metallic mineral product	2,328	1,437	3.76	278
Metal product	7,236	4,656	4.23	266
Machinery and equipment	8,684	5,332	0.22	14
Other manufacturing	2,008	1,251	0.22	14
Grand Total	**69,897**	**46,888**	**2.17**	**119**

Source: Manufacturing Energy Use Survey and Annual Enterprise Survey 2006

Table 2 shows the financial data and the calculated energy and emission intensities at a sub-industry level (ANZSIC 2 digit). The industry with the largest energy intensity is wood and paper product manufacturing with over 8 GJ/$1,000 of GO, nearly double the intensity of metal product manufacturing (in second place).

At the other end of the scale the printing, publishing and recorded media has the lowest intensity at 0.2 GJ/$1,000 followed closely by machinery and equipment, and other manufacturing. This indicates that the outputs of these industries are of high value compared with the energy inputs required.

In terms of emissions intensity, the non-metallic mineral industry is the most emissions-intensive industry with 278 KgCO2e/$1,000 of GO. It is followed closely by metal product manufacturing with 266 KgCO2e/$1,000 of GO. The main reasons for this are the high energy inputs required for production and the mix of energy products used in each industry. For example, coal emits more carbon per unit of energy than natural gas. The intensities for the non-metallic minerals and metal product industries translate to around $4 per $1,000 of GO for the $15 per tonne, rising to $27 per $1,000 of GO for the $100 per tonne.

Carbon emissions and costs including industrial process emissions

Emissions from industrial processes were not included in the rest of this study as Statistics New Zealand does not collect information that enables their direct estimation. This section adds industrial process emissions to the previous results to provide a more comprehensive view of carbon emissions in the manufacturing industry.

Industrial emissions figures were obtained from MED's greenhouse gas emissions publication (MED, 2007) and assigned to an industry based on the ANZSIC96 classification. Figures for industrial emissions are published for six categories: urea, lime, cement, hydrogen, aluminium, and iron and steel. Based on these categories, the figures for aluminium and iron and steel were assigned to metal product manufacturing; hydrogen and urea to petroleum, coal and chemical manufacturing; and cement and lime to non-metallic minerals. After this allocation the treatment for each industry is repeated as in the analysis above (see table 3).

Table 3

Total emissions, costs and intensity including industrial emissions

Year ended March 2006

Industry Group	Emissions (KtCO2e)	Cost Scenarios ($NZ)				Emissions intensity
		$15	$25	$50	$100	KgCO2e/$1000 GO
Food, beverage and tobacco	2,384	35,761	59,601	119,203	238,406	83
Textile, clothing, footwear and leather	166	2,493	4,155	8,311	16,622	75
Wood and paper product	1,489	22,334	37,223	74,446	148,891	208
Printing, publishing and recorded media	52	785	1,308	2,616	5,232	14
Petroleum, coal, and chemical	2,032	30,485	50,809	101,618	203,235	268
Non-metallic mineral product	1,345	20,182	33,636	67,272	134,544	578
Metal product	4,157	62,348	103,914	207,828	415,655	574
Machinery and equipment	124	1,860	3,100	6,201	12,402	14
Other manufacturing	29	428	714	1,427	2,854	14
Total	**11,778**	**176,676**	**294,460**	**588,921**	**1,177,841**	**169**

Source: Manufacturing Energy Use Survey and Annual Enterprise Survey 2006

The inclusion of industrial emission figures cause the cost of an emissions charge on the manufacturing industry to rise to $177 million (from $124 million) for the $15 per tonne scenario increasing to nearly $1.2 billion for the $100 per tonne.

At the ANZSIC 2 digit level, the metal product industry is now the largest emitter by a fair margin accounting for over 35 percent of emissions, and costs that range from $62 million to $415 million depending on the price of carbon.

In terms of intensity, the non-metallic mineral product industry is still the most intensive industry followed very closely by the metal product industry with intensities of 578 and 574 kgCO_2e/$1,000 of GO, respectively. This translates to emissions-related costs of around $9 per $1,000 of GO for the $15 per tonne scenario and up to $58 for the $100 per tonne.

Energy-related emissions and costs at enterprise level

The topic of pricing carbon emissions and the potential effect that it will have on individual companies has been a source of keen debate in the media.[11] This study uses financial data at an enterprise level to compare the costs of carbon against estimates of manufacturing companies' IC and GO. This comparison provides an overview of the burden generated from energy related carbon costs similar to the previous section but focuses on individual companies. Estimates of energy and emissions intensity are also provided in this section. This section does not include industrial process emissions.

Of the 1,029 enterprises surveyed in MEUS (ie there is energy use data available), 675 were also included in AES. A small number of units in this group were subsidiaries of larger companies, and their financial information was consolidated to their group's top

11 See these examples for more details: http://www.scoop.co.nz/stories/PA0804/S00484.htm, http://www.stuff.co.nz/sundaystartimes/4269029a23615.html

enterprises. Therefore, the following work involves 668 enterprises (called 'the sample' henceforth). This translates to:

- 65 percent coverage in terms of units in the MEUS sample
- over 88 percent of energy-related GHG emissions for the manufacturing industry
- Over 61 percent of GO for the manufacturing industry
- Over 64 percent of IC for the manufacturing industry.

The above figures indicate that companies that produced the remaining 12 percent of emissions (995 ktCO_2e) accounted for an estimated 36 percent of IC ($16.9 billion) and 39 percent of GO ($27.3 billion) for the manufacturing industry in the year to March 2006. This suggests a relatively low emissions intensity (average of 36kg/$1000 of GO) for the remainder of the manufacturing industry.

Intermediate consumption and carbon cost

This paper assumes that the energy-related carbon cost incurred by businesses will be treated as a new cost of production, thus included towards IC. As such, it would be useful to assess the cost of carbon as a percentage of an enterprise's IC. This percentage is, in effect, the estimated direct increase in costs of production due to energy related carbon emissions. Carbon cost as a percentage of intermediate consumption (IC) was calculated as follows:

$$\frac{Carbon\ Emission(tonnes) \times Carbon\,\$}{Intermediate\ Consumption(\$million)} \times 100\%$$

Once the carbon cost was calculated as a percentage of IC for individual enterprises, we carried out counts of companies based on the percentage level. Based on the results, we intuitively selected seven different categories for each carbon price scenario to portray the results of the analysis. The categories are:

Carbon cost = 35 percent to 65 percent of Intermediate consumption

Carbon cost = 20 percent to 35 percent of intermediate consumption

Carbon cost = 10 percent to 20 percent of intermediate consumption

Carbon cost = 5 percent to 10 percent of intermediate consumption

Carbon cost = 1 percent to 5 percent of intermediate consumption

Carbon cost = 0.5 percent to 1 percent of intermediate consumption

Carbon cost = less than 0.5 percent of intermediate consumption

A summary of the results from this analysis is presented in table 4 indicating the proportion of companies in the sample that fall within each category of increased costs for the different price scenarios.

Table 4

Distribution of Enterprises by Carbon Cost to Intermediate Consumption Ratio

Carbon cost as a percentage of IC	Proportion of companies by carbon price scenario			
	$15 per tonne	$25 per tonne	$50 per tonne	$100 per tonne
35% to 65%	-	-	-	0.6%
20% to 35%	-	-	0.3%	0.4%
10% to 20%	-	0.3%	0.7%	1.6%
5% to 10%	0.6%	0.7%	1.6%	2.2%
1% to 5%	3.3%	5.4%	11.5%	20.1%
0.5% to 1%	3.3%	7.8%	10.8%	20.2%
less than 0.5%	92.8%	85.8%	75.0%	54.8%

Source: Manufacturing Energy Use Survey and Annual Enterprise Survey 2006

The results in table 4 indicate that for the $15 per tonne scenario, none of the 668 enterprises would experience an increase in their IC greater than10 percent of their 2006 level as a result of their energy related carbon emissions. About 0.6 percent of the units' IC would increase between 5 and 10 percent, while the vast majority of the enterprises would experience less than a 0.5 percent increase on their IC from carbon emissions.

For the $25 per tonne scenario, the proportion of businesses in the 5 to10 percent bracket of IC increases to 0.7 percent, while 0.3 percent of enterprises reached the 10 to 20 percent bracket of IC. However, the proportion of enterprises in the less than 0.5 percent increase of IC from energy related carbon emissions remains the largest group at 85.8 percent of the population.

At $50 per tonne of CO_2e emissions, around 1 percent of enterprises would experience a 10 percent or more increase in IC. Around 13.1 percent of the enterprises fall into the bracket of 1 to10 percent increase in IC, while 85.8 percent of enterprises would experience less than 1 percent increases to their IC due to energy related carbon emissions.

If the price of carbon increases to $100 per tonne, then around 2.6 percent of the enterprises would experience a 10 percent or more increase of their IC, including small proportion of companies in the 35 to 65 percent bracket. However, even at this price, the majority of enterprises (54.8 percent) would still be in the 0.5 percent or less bracket.

Overall, the results indicate that a large proportion of enterprises in the manufacturing sector are engaged in relatively low-intensity activities. As the resulting impacts in costs of production are causally related to intensity, the direct costs increases are relatively low.

Gross output and carbon cost

The gross output variable is similar to a business's total revenue so carbon cost as a proportion of GO is a useful measure to assess the impact of carbon cost in relation to an enterprise's revenue. This measure also provides a good indication of the carbon intensity of the production by each company and industry. Carbon cost as a proportion to gross output (GO) is calculated as follows:

$$\frac{Carbon\ Emission\,(tonne)\times Carbon\,\$}{GrossOutput}\times 100\%$$

Given that GO is almost always higher than IC, the carbon cost as a proportion of GO levels were generally lower than that of IC across the different carbon price scenarios. The lower levels were translated into small change in the categories selected for the analysis (the 35 to 65 percent category was not needed). Table 5 shows a summary of the results.

In this analysis we also included an estimate of the proportion of the total GO of the manufacturing industry that is represented by each of the categories. For example, this indicates that at $15 per tonne about 4.6 percent of GO was subject to intensities representing 1 to 5 percent of the output of the company.

Table 5

Distribution of Enterprises by Carbon Cost to Gross Output Ratio

Carbon cost as a percentage of GO	Proportion of companies by carbon price scenario							
	$15 per tonne		$25 per tonne		$50 per tonne		$100 per tonne	
	% of enterprises in the sample	GO as a % of industry total	% of enterprises in the sample	GO as a % of industry total	% of enterprises in the sample	GO as a % of industry total	% of enterprises in the sample	GO as a % of industry total
20% to 35% of GO	-	-	-	-	-	-	0.6%	1.0%
10% to 20% of GO	-	-	-	-	0.6%	1.0%	0.3%	0.5%
5% to 10% of GO	-	-	0.6%	1.0%	0.3%	0.5%	2.1%	3.7%
1% to 5% of GO	2.1%	4.6%	3.0%	4.3%	7.2%	8.7%	12.7%	20.9%
0.5% to 1% of GO	2.4%	2.1%	4.5%	4.8%	7.6%	15.9%	12.1%	10.2%
less than 0.5% of GO	95.5%	54.4%	91.9%	51.0%	84.3%	35.1%	72.2%	24.8%

Source: Manufacturing Energy Use Survey and Annual Enterprise Survey 2006

Note: The figures in the columns titled 'GO as a % of industry total' do not add up to 100 percent as the enterprises in this sample contribute to approximately 61.1 percent of gross output for the manufacturing industry.

For the $15 per tonne scenario, 95.5 percent of the enterprises would have to pay an equivalent of 0.5 percent or less of their GO for carbon emissions. This group of enterprises contributed to 54.4 percent of the industry's total GO. For the remaining 4.5 percent of enterprises, their carbon cost would be between 0.5 and 5 percent of their GO. In other words, at $15 per tonne, none of the enterprises in this sample would pay more than $5 of energy related carbon costs for every $1,000 of production.

At $25 per tonne, the vast majority of enterprises (91.9 percent) are still in the 0.5 percent or less bracket, accounting for 51.0 percent of the industry's total GO. While 0.6 percent of enterprises in the sample would now have to pay an equivalent of 5 to 10 percent of GO on energy related carbon emissions. The enterprises in this top bracket contribute to 1.0 percent of the manufacturing industry's total GO.

At $50 per tonne, around 1 percent of the enterprises in our sample will spend an equivalent of 5 to 20 percent of their GO on carbon costs. However, the vast majority of enterprises in the sample (84.3 percent) are still paying the equivalent of less than 0.5 percent of their GO on carbon costs. Collectively, enterprises in this category contribute to 35.1 percent of the industry's total GO.

For the $100 per tonne scenario, 0.6 percent of enterprises would spend an equivalent of 20 to 35 percent on carbon emissions. Even at this carbon price, the majority of enterprises (72.2 percent) would have to spend less than 0.5 percent of their GO equivalent on energy related carbon emissions.

In terms of economic significance however, the enterprises in this category of lowest carbon cost to GO ratio make up for 24.8 percent of the industry's total GO. At this price scenario, 3 percent of the enterprises in this sample would have to spend an equivalent of 5 to 35 percent of their GO on energy related carbon costs. Collectively, enterprises in these top categories of carbon cost to GO ratio contribute to 5.2 percent of the industry's total GO.

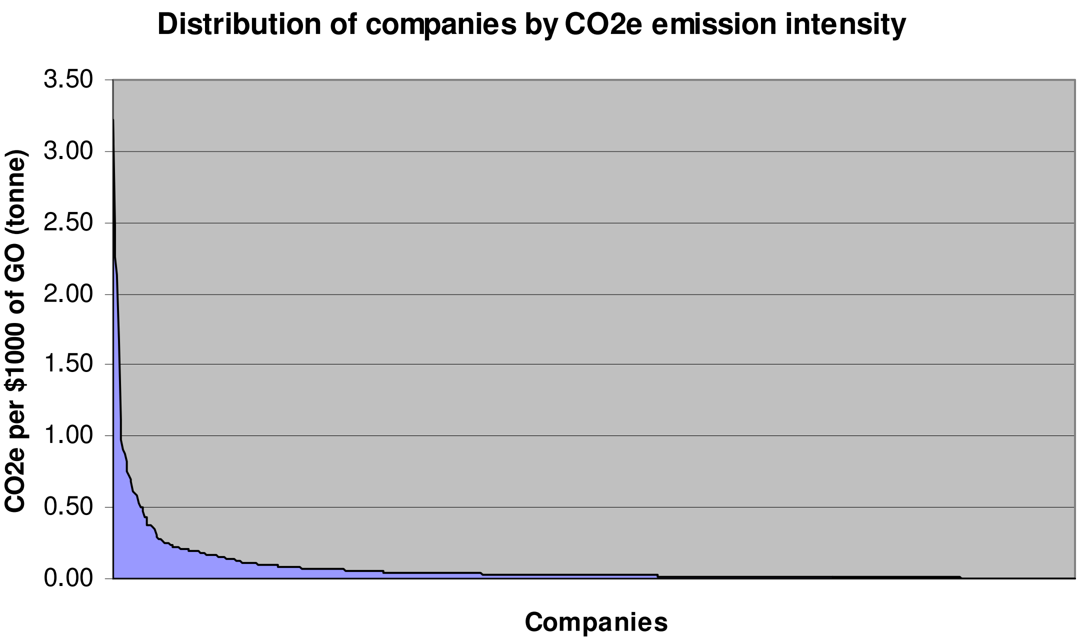
Energy-related carbon emissions intensities

Another useful measure in this context is to examine the amount of CO_2e emitted for every $1,000 of GO. This measure allows us to assess the emissions intensity of individual enterprises within the manufacturing industry. This emissions intensity measure is calculated as follows:

$$\frac{Total\ \mathrm{CO_2e\ Emission}(tonne)}{Gross\ Output(\text{'000})}$$

Figure 1 provides a breakdown of enterprises by their CO_2e emission for every $1,000 of gross output.

Figure 1



Source: Manufacturing Energy Use Survey and Annual Enterprise Survey 2006

Figure 1 provides an overview of the enterprises in the sample in terms of the emission-intensity of their operations. It depicts a distribution where a small number of enterprises have high levels of emissions intensity of over 1 tonne of CO_2e per $1,000 of GO, while the majority of enterprises emit less than 0.25 tonne of CO_2e for the same amount of GO.

Table 6 is very similar to table 5 but it presents this information in monetary terms by applying the four different carbon price scenarios. The purpose of this is to provide a dollar value to the percentage categories. This was calculated as follows:

$$\frac{\textit{Total}\ \mathrm{CO_2e\ Emission}\ (\textit{tonne})}{\textit{Gross Output}\ ('000)} \times \textit{Carbon}\$$$

Table 6

Distribution of Enterprises by Carbon Cost per $1000 of Gross Output

Carbon cost per $1000 of GO	Proportion of companies by carbon price scenario							
	$15 per tonne		$25 per tonne		$50 per tonne		$100 per tonne	
	% of enterprises in the sample	GO as a % of industry total	% of enterprises in the sample	GO as a % of industry total	% of enterprises in the sample	GO as a % of industry total	% of enterprises in the sample	GO as a % of industry total
$100 or more	-	-	-	-	0.6%	1.0%	0.9%	1.4%
$75 to $100	-	-	0.1%	0.1%	0.1%	0.2%	0.7%	0.2%
$50 to $75	-	-	0.4%	0.9%	0.1%	0.3%	1.3%	3.4%
$30 to $50	0.6%	1.0%	0.1%	0.2%	1.3%	3.3%	1.6%	2.6%
$20 to $30	0.1%	0.2%	0.7%	0.5%	1.3%	0.5%	3.4%	2.4%
$10 to $20	1.3%	3.5%	2.1%	3.7%	4.5%	4.8%	7.6%	15.9%
$5 to $10	2.4%	2.1%	4.5%	4.8%	7.6%	15.9%	12.1%	10.2%
less than $5	95.5%	54.4%	91.9%	51.0%	84.3%	35.1%	72.2%	24.8%

Source: Manufacturing Energy Use Survey and Annual Enterprise Survey 2006

At $15 per tonne, the vast majority of enterprises in this sample (95.5 percent) would spend less than $5 on carbon emissions for every $1,000 of GO, while 0.6 percent of enterprises would have to spend between $30 and $50. These two groups at the two extremes represent 54.4 percent and 1.0 percent of the industry's total GO, respectively.

For the $25 per tonne scenario, 4.5 percent of enterprises in the sample would spend $5 to $10 on carbon emissions per $1,000 of GO, while 91.9 percent would spend less than $5 on energy related carbon costs. At this price scenario, the enterprise with the highest emissions intensities would pay between $75 and $100 per $1,000 of GO.

At $50 per tonne, 4.5 percent of enterprises would spend $10 to $20 on energy related carbon costs per $1,000 of GO while 84.3 percent of enterprises would spend less than $5. At this price scenario, a small group of enterprises would have to pay over $100 on carbon emissions per $1,000 of GO. This group of enterprises constitutes about 1.0 percent of the industry's total GO.

For the $100 per tonne scenario, 0.9 percent of the enterprises in this sample would spend $100 or more on carbon emissions per $1,000 of GO. Enterprises that spend less than $5 on carbon credits remain the largest group, making up 72.2 percent of the enterprises, however, they account for 24.8 percent of the industry's total GO.

Conclusion

Energy intensities and emissions intensities vary widely across the activities within the manufacturing industries. This is due to the different natures of work and the varying mix of energy products used. As such, carbon costs for energy related GHG emissions would have similarly varying effects on manufacturing businesses. For example, at the top end of the spectrum, the non-metallic mineral product manufacturing industry (ANZSIC C27) emitted an average 278 kg of CO_2e for every $1,000 of GO while printing, publishing and recorded media (ANZSIC C24) and machinery and equipment manufacturing (ANZSIC C28) emitted an average of 14 kg of CO_2e for every $1,000 of GO.

The price of carbon plays an essential role in determining the final impact of a carbon charge policy; this is highlighted in table 4. Under a $15 per tonne price scenario, the cost of production increase would be less than 1 percent for more than 95 percent of the companies in our sample. For the $100 per tonne scenario this figure decreases to 55 percent.

Despite the limitations, this study demonstrates the value of using good quality unit record data to carry out studies that enable a closer look at economic impacts of policy on individual enterprises. While this study is limited to enterprises in the manufacturing industry, the relationship between carbon intensities and costs can be applied elsewhere. As such, Statistics New Zealand is working on a project in collaboration with MED and EECA aimed at expanding the collection of energy use data across the New Zealand economy to provide quality micro-data for future studies.

Appendix 1: Emission factors

The emission factors used for the calculations of emissions from the unit record data were taken from MED's energy greenhouse gas emissions publication of 2007. The table below summarises the emission factors used followed by a description of the choices.

CO2 Emission Factors

Fuels	Emissions (grams/MJ)
Nat Gas	52.3
Coal	91.2
Electricity	64.16
Petrol	66.2
Diesel	69.5
LPG	60.4
Fuel Oil	72.75

Natural gas

The 52.3g/MJ was selected as it is the average for the treated gas that enters the reticulated networks. While it is known that some companies use raw natural gas, which has larger emission factors, the information as to who and how much is not known to Statistics New Zealand.

Coal

The 91.2g/MJ represents the average emission factor for sub-bituminous coal. While we know that there is some use of bituminous coal (88.8g/MJ) and lignite (95.2g/MJ), the MEUS did not capture the rank of the coal being used. In consultation with MED and using the proportions of each of the ranks of coal supplied to the energy markets, it is believed that the potential over- and underestimations from using the 91.2g/MJ factor would cancel each other out.

Electricity

The emission factor of 64.14g/MJ used for electricity was derived by dividing the total emissions from the generation of electricity in the country by the total electricity generated by the electricity companies. Given the structure of the electricity market it is not possible to differentiate who is using what electricity, thus every user is allocated an average.

In certain cases some studies use larger emission factors to test the cost of carbon incurred when the extra demand for electricity forces thermal generation to come online. We have not done this in this paper as it requires a number of assumptions such as the type of generation or the time of day (eg peak load)

Petroleum products

The emissions factors for petroleum products were simpler as they have a number of strict quality measures they adhere to making them more homogeneous. For petrol, we selected the emission factor for regular petrol (rather than premium) as it dominates the market. The fuel oil factor was a direct average of the light and heavy fuel oil factors and their presence in energy markets is roughly the same. LPG has only one average emissions factor available. Diesel has only one emission factor available.

Appendix 2: Explanatory notes

Intermediate consumption (IC)

This consists of the value of all goods and services consumed as inputs by a process of production. It includes raw materials used up directly in the production of goods or services, as well as general operating costs such as rent, electricity, accounting and legal fees, and the like. Excluded are transactions not directly associated with current production of goods and services such as interest paid, bad debts, donations and losses on the sale of assets.

Goods and services purchased for use in production

- Raw material inventory change

= **Intermediate consumption**

Gross output (GO)

This is the value of goods and services produced during a time period, irrespective of whether they are produced for sale on the market or for own use. Any changes in inventories (stocks) also need to be taken into account.

Value of goods and services sold

+ Value of goods and services for own use

+ Changes in inventories

= **Gross output**

While IC and GO are terms used in the National Accounts unit of Statistics New Zealand, the estimates for individual enterprises used in this paper are based on AES 2006 data.

References

Fischer C and Morgenstern R (2003). "Carbon Abatement Costs: Why the Wide Range of Estimates?". http://www.rff.org/Documents/RFF-DP-03-42.pdf [17March 2007].

Glomsrod, Solveig, Haakon Vennemo, Torgeir Johnsen (1992). "Stabilization of Emissions of CO2: A Computable General Equilibrium Assessment", *The Scandinavian Journal of Economics*, 94:1 (March 1992), 53–69.

Stroombergen, Adolph (2007). "General Equilibrium Analysis of Options for Meeting New Zealand's International Emissions Obligations", Infometrics, Wellington, http://www.mfe.govt.nz/publications/climate/general-equilibrium-analysis-oct07/general-equilibrium-analysis.pdf [17 March 2008].

Jamieson T (2007). "Carbon abatement effects of electricity demand reductions", Ministry for the Environment, Wellington.

McKibbin W, Shackleton R and Wilcoxen P (1998). "What to Expect from an International System of Tradable Permits for Carbon Emissions", http://www.brookings.edu/views/papers/mckibbin/143.pdf [17 March 2008]

Ministry of Economic Development (2007). "New Zealand Energy Greenhouse Gas Emissions 1990-2006", Ministry of Economic Development, Wellington.

Ministry of Economic Development (2007). "New Zealand Energy Data File", Ministry of Economic Development" June 2007, Wellington.

Ministry for the Environment (2008). "New Zealand's Greenhouse Gas Inventory 1990 – 2006", Ministry for the Environment, Wellington.

New Zealand Institute of Economic Research (2008). "The impacts of the proposed Emissions Trading Scheme on New Zealand's economy", NZEIR working paper 2008/02, Wellington.

Sims, Ralph E. H., Hans-Holger Rogner and Ken Gregory (2003). "Carbon emission and mitigation cost comparisons between fossil fuel, nuclear and renewable energy resources for electricity generation ", *Energy Policy*, 31:13, 1315–1326.