International **I**nput-**O**utput **M**eeting
on **M**anaging the **E**nvironment

Seville (SPAIN), July 9 - 11, 2008

CO_2 Emissions from Chinese Imports

By Craig Gaston and Lauren Dong

Environment Accounts and Statistics Division
Statistics Canada

CO_2 Emissions from Chinese Imports

Abstract

Over the last ten years, imports from China have supplanted about 50% of the relative drop in Canada's imports from the United States. Over the same period there has been a substantial shift in the mix of Chinese exports to Canada as textiles and clothing have decreased relative to more energy-intensive products. China's industry is powered mainly by coal, the most pollution-intensive of the fossil fuels. In 2005, coal accounted for 68% of primary energy consumption in China, compared to only 23% in the U.S. and 11% in Canada. The consequence of these shifts is that Canada, like most developed countries, is exporting an increasing amount of its pollution to China. This includes greenhouse gases, which are not restricted to geographical boundaries. This paper will attempt to measure the pollution effects of this shift in imports using a comparative input-output analysis. Emissions of Chinese exports to Canada are calculated first using Chinese IO tables and emission factors and then using Canadian IO tables and emission factors for the same year. Purchasing power parity (PPP) exchange rates are used to harmonize the value of goods in each country. The results are accompanied by a discussion of data quality issues.

Introduction

Statistics Canada has assumed, for want of better information, that in its IO model simulations relating GHG emission factors to various final expenditures, our imports have the same emission characteristics as good purchased from domestic sources. With China increasingly supplanting the U.S. as source of Canadian imports this assumption is no longer realistic. This study will address that problem by estimating the actual emissions that occurred in China resulting from the production of exports to Canada. Another question that arises from this situation is what GHG emissions would result if these Chinese exports were produced in Canada. In other words, how much pollution is Canada exporting to China in exchange for the goods that it purchases from that country? Of course, it is impossible to determine this with any precision. Many of the goods we import are no longer produced to a great extent in Canada and those imports are not necessarily entirely produced in the countries from which we purchase them. Perhaps the most serious problem, however, is the difficulty in equating the value of imports in different countries. In order to compare the emissions related to goods valued in monetary units it is necessary to find a means to preserve the relationship between production (in monetary units) and emissions (in megatons) in both Canada and China. Market exchange rates do not necessarily reflect this relationship since they are subject to influences other than just local market conditions.

Despite all these measurement difficulties there has been considerable work on the subject of trade-related emissions[1]. The most general approach is to use multi-regional input-output models to estimate the balance of emissions from trade. Weber and Matthews describe an ambitious model of U.S. trade in which they represent the economies and trade patterns of their seven largest trading partners. This model estimates that “overall embodied CO_2 in U.S. imports has grown from between 0.5 and 0.8 Gt of CO_2 in 1997 to between 0.8 and 1.8 Gt of CO_2 in 2004”[2]. The large range in the results is due to whether or not one takes account of “through trade” (the use of imports to produce exports) and whether one uses market exchange rates or purchasing power parity (PPP). An earlier study by Shui and Harriss[3] attempted to estimate the CO_2 in trade between the U.S. and China only. Their model is limited by the fact that it did not use a Chinese input-output table; rather, it applied Chinese CO_2 emissions factors to a U.S. table. Both studies

---

[1] For an extensive bibliography, see Embodied Environmental Emissions in U.S. International trade, 1997-2004, Christopher Weber and H. Scott Matthews in *Environment, Science and Technology*, 2007, 4875-4881.

[2] *Ibid*. Weber and Matthews

[3] The role of CO_2 embodied in U.S.-China trade, Bin Shui and Robert C. Harriss, *Energy Policy* 34 (2006), 4063-4068.

mentioned above used PPP adjustment factors, although Weber and Matthews presented emissions for both adjusted and non-adjusted trade data.

This study is more limited than either of the above in that it evaluates only the emissions related to Chinese imports to Canada. We benefit from the recent World Bank PPP data, which provides more detailed estimates by category of final demand.

Methodology

Chinese model

The estimation of emissions in China was made with standard Leontieff model based upon the 2002 Chinese symmetric input-output table, which is defined by a 47-category commodity classification in both dimensions[4]. This is the most recent "benchmark" table produced by China's National Bureau of Statistics (NBS). The benchmark tables benefit from large-scale input-output surveys. This commodity-by-commodity table is more complete than the symmetric industry table because of the nature of Chinese business surveys, which use the enterprise, rather than the establishment, as the basic survey unit[5]. Although an input-output table exists at the level of 122 commodities, we were unable to find emission intensities at that level of detail. The following equation defines total emissions of CO_2 (E^{Ch}) as a function of Canadian imports from China, in Renminbi (m^*), the intermediate input coefficients without import leakages (A^T), and Chinese emission intensities (λ^{Ch}).

$$(1) \qquad E^{Ch} = \lambda^{Ch}(I - A^T)^{-1}m^*$$

Emission intensities for China were taken from work done by Peters, Weber and Liu[6]. The authors note that the official coal use statistics used in their tables could be understated since the reported deviation from the trend between 1997 and 2003 is not consistent with other indicators.

Imports by Canada from China were converted to Renminbi using market exchange rates. The corresponding Chinese statistics on exports to Canada are considerably understated, mainly because of indirect trade through Hong Kong and the U.S.[7, 8]

Canadian model

Canada's merchandise trade statistics on imports from China are expressed in Canadian dollars. However, official exchange rates do not, in most cases, reflect the same physical amount of goods in both countries. Purchasing Power Parity (PPP) is one way to help compensate for this discrepancy since it represents the relationship between domestic value of money in two countries, unaffected by other factors such as financial flows and currency speculation. This adjustment is not perfect, of course. Residents of China may not pay the same price as foreign buyers with considerable purchasing power. Furthermore, some goods, like machinery and equipment, are largely imported by China so the PPP values in this case tend to reflect market exchange rates. Some previous studies have used total GDP-weighted PPPs, which would considerably overestimate the adjustment required since they reflect food and services, which are

---

[4] The tables can be obtained from the OECD at …. The next benchmark table is scheduled for 2007.

[5] See: New Features of China's National Accounts, OECD, STD/CSTAT (2006) 5, 30 May 2006.

[6] Norwegian University of Science and Technology (NTNU), "Construction of Chinese Energy and Emissions Inventory", Glen Peters, Christopher Weber, Jingru Liu, Program for industriell økologi Rapport nr: 4/2006. The data are available online at www.indecol.ntnu.no/indecolwebnew/publications/reports/reports06.htm (Excel China energy 2002)

[7] *Merchandise Trade Reconciliation Study: Canada-China, 2002 and 2003*, Sandra Bohatyretz and Bruna Santarossa, Statistics Canada, Catalogue no. 65-507-MIE - No. 003, August 2005.

[8] Since we did not have precise definitions for several of the 47 commodities in the 2002 table, we had to make some allocation assumptions for categories 16 -19 pertaining to machinery and equipment.

not represented to any significant degree in trade (especially services, which are not considered in this study).

The most recent World Bank report, *2005 The International Comparison Program* (ICP)[9], provides PPPs for a number of final demand categories. The categories selected for this study can be seen in Table 1. The ICP data are all denominated in US dollars so to obtain the China-Canada values it is necessary to calculate:

$$(2) \qquad PPP^{CH\text{-}CAN} = PPP^{CH\text{-}US} / PPP^{CAN\text{-}US}$$

The next step is to convert the Chinese imports into purchasing power parity values as follows:

$$(3) \qquad m^P = m * r^{ch\text{-}can} / PPP^{ch\text{-}can}$$

where $r^{ch\text{-}can}$ is the market exchange rate (MER) for Renminbi per Canadian dollar in 2005.

Table 1 PPP Adjustment Factors

		Total GDP	Food & beverages	Clothing & footwear	Furnishings & hhld eqp.	Misc. goods and services	Machinery & equipment
1	PPP Canada-US	1.21	1.49	1.5	1.46	1.2	1.28
2	PPP China-US	3.45	5.52	6.86	5.27	4.13	8.79
3	PPP China-Canada (2/1)	2.85	3.70	4.57	3.61	3.44	6.87
4	Market exhange rate: $r^{ch\text{-}can}$	6.77					
5	PPP Adjustment factors: (4/3)	**2.37**	**1.83**	**1.48**	**1.88**	**1.97**	**0.99**

Sources:
2005 International Comparison Program: Tables of Final Results , World Bank, February 2008, pp 12-15

Equation 3 can be understood as first converting Canada's imports from China imports back into Renminbi using market exchange rates and then dividing this result by the appropriate 2005 PPP[10]. A further adjustment could be made in order to align the values with the base year (2002) of the Canadian IO model since the CO_2 intensities are related to production in that year. To do this, we would further multiply M^P by the relative price changes between Canada and China from 2002 to 2005. However, the price changes recorded in China and Canada over this period are well within the bounds of uncertainty regarding the preceding calculations, rendering this adjustment superfluous.

One might argue that the very fact that imports from China are the main driver of the changes in Canadian prices of consumer we are examining in this study ensures that their price movements will be similar in both countries. However, it is the producer prices that interest us here since the point is to compare the relationship between *production* and emissions in each country. This point highlights an inevitable limit of the methodology: The domestic production of the types of goods that we import from China is quite limited and may not correspond to them closely. At best, they will be products made in the same industry and all products produced by an industry are assumed to have the same emission intensities, rightly or wrongly. Furthermore, the PPPs themselves are based upon consumption prices rather than production prices.

The Canadian model uses the rectangular tables in which there are more commodities than industries. In general the DB (market-share, D, times industry-technology B) inner product is equivalent to the Leontieff inter-industry A matrix, except that in this case the Chinese A matrix in equation 1 is defined by commodities in both dimensions, another concession to data availability.

$$(4) \qquad E^{Can} = \lambda^{Can}(I\text{-}DB)^{-1}m^p$$

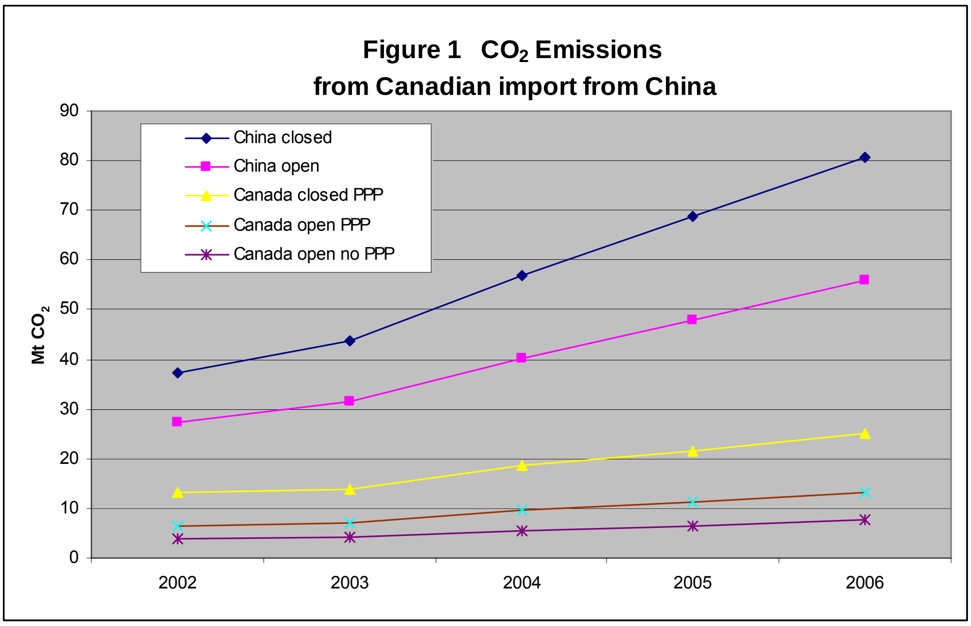
[9] 2005 International Comparison Program: Table of Final Results, World Bank, Washington, February 2008.

[10] In order to simplify the presentation, I omitted subscripts reflecting the different categories of PPP.

The problem with a simple comparison of E^{Can} to E^{Ch} is that we know that both Canada and China are large importers. This means that we should not attribute emissions to these countries for goods that they must import in the production of the goods we are examining. A more sophisticated approach would be to model the emissions from the production of goods by all important trading partners, as well as those produced in Canada and China, but this is beyond the scope of this study.

Model results

In the following simulations we show a possible range of emissions using a “closed” model (all goods are assumed to be produced with domestic inputs) and an “open” model (only the emissions related to inputs produced domestically are counted).



Whether or not we adjust the imports from China using the PPP exchange rate, there is a large difference between the results using the Canadian and the Chinese models (Figure 1). The Chinese closed-model simulation results in about three times the emissions as the Canadian closed model (PPP adjusted). If we compare open-model emissions between the two countries, the ratio of is about four. Neither the open or closed models is perfectly comparable, however. Since each country has its unique degree of dependence on imports, the open model does not necessarily measure the same degree of processing. Furthermore, the closed models do not represent the real embodied emissions in either country.

A good example of this difference is computer equipment, for which the Chinese share of Canadian imports increased considerably over the time period examined in this study, reaching over 14% in 2006[11].The Computer and Peripheral Equipment Manufacturers industry in Canada is one of the least energy-intensive industries in the economy, suggesting that it mainly assembles highly-processed components. Conversely, although China had a relatively limited capacity to produce semi-conductors in 2002 (the base year for the model), it did relatively more processing than Canada[12].

---

[11] Based on 2006 dollar shares; this is reduced to 11% when adjusted to 2002 dollars.

[12] By 2006, China was an important producer of semi-conductors but the model simulations assume 2002 technology and emission intensities.

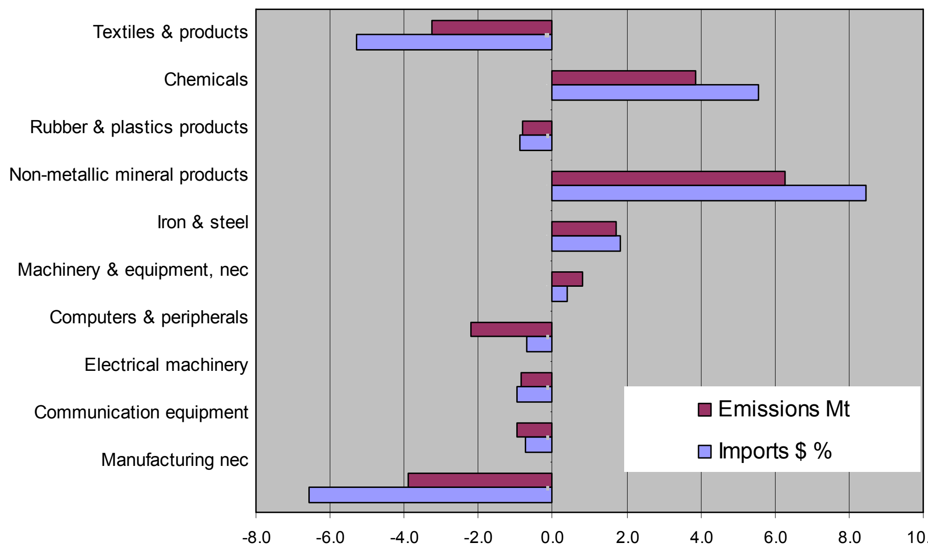
One can conclude from the above, therefore, that the differences between the Chinese and Canadian open-model results reflect both the differences in the depth of the production chain in each country and the differences in energy mix and CO_2 emissions related to the production.

Closing the model (i.e. simulating the assumption that all industrial inputs will be produced domestically in each country) will still not compensate for the fact that the Canadian manufacturing sector does not include some of the highly energy-intensive processes that have increasingly migrated to countries with lower labour costs. In the example of the computer industry, closing the model for imports will incorrectly apply the very low energy and emission intensities related to the final-stage Canadian assembly to products that require a very large amount of energy to produce.

Consequently, the best measure of emissions related to our imports from China, albeit partial, is the Chinese open-model simulation. This shows that there would be approximately four times the CO_2 emissions than what would be calculated using the Canadian IO model. Since the Canadian IO model is used to calculate embodied emissions in goods consumed by Canadians, this is an important result as these goods increasingly come from China.

Analysing the growth in imports from China between 2002 and 2006 also reveals that almost all of the increase in emissions was due to the increase in the level of imports rather than the change in their composition. At first glance this may be surprising because there was relative shift away from low emission-intensity goods (clothing, textiles and miscellaneous manufactured goods) to higher-intensity products (machinery and electronic goods). This should have increased the emissions but this shift was offset by a relative decline in chemicals and non-metallic mineral products imported from China. The latter were not large in terms of value but they have high emission intensities (See Figure 2). Simulating the 2002 pattern with 2006 levels of imports gives the same overall emissions as simulating the 2006 imports.

Figure 2 Analysis of Change in Composition of Imports 2002-2006



Data quality issues

There are many data problems in this study, some of which were discussed above, that limit the accuracy of these results. First, it appears that China's coal consumption could be underestimated by as much as 20% in 2002, based upon interpolating the trend between 1997 and 2003[13]. The reported drop in coal consumption between these years is not supported by information obtained from satellites. However, it is likely that Chinese companies that export are more efficient in their energy use than average, so these two problems would tend to compensate for each other. It is impossible to know to what extent, however.

The quality of the Chinese input-output tables has been criticised but considerable effort has been made to improve them in recent years as survey coverage[14]. The benchmark IO tables (years ending in 2 or 7) are better than the updated tables (years ending in 5 and 0) because they are constructed from more extensive survey data, which means that 2002 is a good choice for a base year. In this study we have chosen the commodity by commodity tables because they are more complete and it is impossible to know how well they conform to the emissions data, which are reported by industry. Given that the basic survey unit is the enterprise, there will inevitably be distortion whether industries or commodities are used to define the tables. However, the proportion of large government-owned multi-product enterprises is diminishing over time as the market economy expands and it should become easier to survey establishments.

Aggregation is another source of error in the both countries' IO tables. It would have been preferable to use the Chinese 122-commodity symmetric tables but we did not find fuel use at this level of detail. The Canadian model, by comparison, is based on 300 industries by 700 commodities. However, a larger IO table may not provide any more precision to our results if the increased detail is not for emission-intensive industries or commodities. A distinction should be made, for example, between assembly and fabrication, as explained above with regard to semi-conductors and other computer components. If this were clarified in the Canadian classification, it would be obvious that semi-conductors are a non-competing import for Canada. In general, except for transportation, there is very little advantage for emissions simulations in providing more detail in the services sector.

We have addressed the problems related to PPP adjustments above but it is important to note that the adjustment factors vary considerably by type of good. The average PPP adjustment based on all final demand categories is much larger than the factor related only to the goods that Canada imports from China. This average takes into account the prices of services and food which are almost not traded with Canada. If we had used the average GDP-weighted PPP, it would have increased the value of Canadian imports by 137% (and CO_2 emissions proportionally) whereas the PPP adjustment related to the imports from China yields an overall increase of only 60%[15]. About 40% of imports from China in 2006 were machinery and equipment for which the PPP exchange rate approaches the market exchange rate (i.e. there is no adjustment required).

Finally, Chinese emissions are understated because of the need to ship the goods from China to Canada. Information on this is rare, but using parameters from one source[16] allowed us to estimate marine-shipping emissions related to imports from China at .5 million tonnes of CO_2 in 2002, increasing to about 1 mt in 2006.

Despite the data problems in this study, the difference in emissions between Canada and China are supported by the data in Table 2. The rows in this table are sorted by descending order of carbon content. Of Canada's total energy consumption, high-carbon sources account for 53% compared to 88% for China. Of course, fuel mix is only one of the factors explaining the difference between Chinese and Canadian emissions, industrial efficiency being another important one (which is accounted for in the input-output matrices).

---

[13] Peters, Weber and Liu, p. 6.

[14] Discussion with Zhao Hong of China's National Bureau of Statistics.

[15] This percentage is not shown in Table 2

[16] http://www.marisec.org/shippingfacts/environmental/atmospheric-pollution.php; Transport Canada says that it is difficult to confirm the validity of this estimate and especially the application of it to Canada's trade with China.

Table 2 Source of Primary Net Energy 2005-6

Energy source	US	China	Canada
	% based on energy content		
Coal	23%	68%	11%
Petroleum	43%	20%	42%
Natural Gas	22%	3%	30%
Electricity (nuclear and hydro)	13%	10%	16%
	100%	**100%**	**100%**

Source- US department of Energy

Conclusion

This study provides an approximate comparison of China's and Canada's emissions related to Canadian imports from China. It also shows the weakness of the traditional assumption made in Canadian IO model simulations – that imported goods are made using the same technology and have the same emission intensities as domestic goods. There is a difference of a factor of about four between the two models in the case of Chinese imports. This difference amounted to about 43 mt of CO_2 in 2006, or 6% of Canada's emissions. A more accurate simulation of embodied energy and emissions in trade must take account of the trade patterns between Canada's major trade partners and the input-output relationship parameters specific to each of them.