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Keywords

australia, china, trade, embodied, emissions, bi, co2, lateral

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Abstract

This paper quantifies the CO₂ emissions embodied in bi-lateral trade between Australia and China using a sectoral input - output model. The results revealed: (1) that China performs lower than Australia in clean technology in the primary, manufacturing, energy sectors due to their overuse of coal and inefficient sectoral production processes, and (2) that China had a 30.94 Mt surplus of bi-lateral CO₂ emissions in 2010 - 11 and (3) overall global emissions were reduced by 20.19 Mt through Australia-China trade in 2010-11. The result indicates that the greater the energy efficient a country among the trading partners the lower will be the overall global CO₂ emissions. Global emissions decreased mainly because China consumed Australian primary products rather than producing them. Australia is an energy efficient producer of primary products relative to China. The bilateral trade compositions and trade volume played an important role in lowering global emissions and therefore one can view proposed China Australia Free trade Agreement positively in reducing global emissions. However, for the sustainable development, China should strengthen clean energy use and both countries should adopt measures to create an emission trading scheme in order to avoid protectionism in the form of future border price adjustments.

Key Words: Carbon leakage, Australia-China bilateral trade, Input-output table

JEL Codes: F18, C67, L51

1.Introduction

China ranks as the biggest trading partner for Australia and Australia remains the eighth largest trade partner for China since 2008. Australia's export of goods and services to China are mainly primary and they have grown rapidly with an average annual growth rate of around 25 per cent, whereas imports from China are mainly manufactured products that have grown around 8 per cent during the 2005 – 2012 period. The primary exports of Australia and the manufactured goods of China are the primary focus of the Australia China bilateral trade agreement that deviates from the USA – China bilateral trade composition. Those assessments of the causes and consequences of the Australia – China bilateral trade focused primarily on the economic and political factors and paid almost no attention on the environmental implications. By rank, China is the 1st top emitter of CO₂, and Australia is around the 14th emitter in the world. Estimating CO₂ embodiments in Australia – China bilateral trade is one of the ways of capturing the environmental implications of international trade that are not addressed and where the research gap prevails. Decreasing domestic CO₂ emissions may not be effective if imports continue to contribute to domestic consumption (Wyckoff and Roop, 1994) because this will result in increased CO₂ embodiments via imports and undermine every effort being made to address global warming.

Both countries are under pressure on climate change negotiations to reduce their greenhouse gas emissions by imposing credible measures. If these calls are to be heeded, appropriate statistical evidence of all aspects, including bilateral sectoral carbon leakage, must first be made available. Despite those facts, only a few recent studies (Tan et.al. 2013) have examined the CO₂ emissions embodied in the Australia-China trade in a bilateral context using Emissions Embodied in Bilateral Trade (EEBT), even though trade between these two countries has been expanding rapidly since 2006 (Figure 1) and a China Australia Free trade

Agreement (ChAFTA) has been signed recently. This study will not only fill this existing research gap on bilateral carbon leakage, it will also take Australia and China bilateral trade as a special case for exploring the nature of CO₂ embodiments for primary and manufactured trade.

Figure 1: Australia's Trade with China: 2005-06 – 2011-12 (billion A\$, 2005 prices)

Source: ABS, 2013b.

1.1 Australia-China bilateral trade

In late 2007, China surpassed Japan as Australia's biggest trading partner. In 2009, China was promoted as Australia's biggest export destination. Being Australia's first biggest trading partner, China might have a significant effect on the Australian economy and environment by any changes to these liberal trade policies. Prior studies of bilateral trade between Australia and China have generally concluded that each country's individual comparative advantages drive the trade (Sheng and Song, 2008). Australia's exports to China are mainly primary products such as mineral, agricultural, and energy related goods, while China's exports to Australia are manufactured goods. Bilateral trade flows have generated a high degree of trade

complementarity between Australia and China, showing that freer trade will tend to increase their mutual trade gains (McDonald *et al.*, 2005). The authors estimated the revealed comparative advantage (RCA)¹ indices and applied global trade and environment model (GTEM) in their analysis.

Australia's export of goods and services to China have grown rapidly from A\$18.14 billion in 2005-06 to A\$64.13 billion in 2011-12, with an average annual growth rate of 25 per cent, while the total imports from China increased from A\$23.20 billion in 2005-06 to A\$36.26 billion in 2011-12, which represents around an 8 per cent annual growth rate (Figure 1). Because of a substantial increase of primary exports to China, especially from 2008-09, net exports from Australia have grown rapidly, mainly due to the increased rate of growth of Australia's exports to China. The majority of exports to China are primary goods such as iron ore, coal, gold, and crude petroleum, while the majority of imports from China are manufactured goods such as metal, non-metallic minerals, machinery and equipment, wood, paper, petroleum, clothing, and furniture. The rapid growth of industries, construction, and transportation in China has driven the energy demand from Australia (Zhao and Wu, 2006). The ChAFTA was signed off in 2015 after a decade long negotiations. If this agreement is fully implemented, then 95 per cent of Australian exports (mainly primary products) will be tariff free in China and allow greater access in China's market for Australian goods and services, increase investment in Australian industry and infrastructure and access for cheaper Chinese manufactured goods in Australia.

¹ RCA is defined as observed trade patterns that show both relative costs and variation of factor intensities. This measure is an indirect measure to resolve the difficulties in measuring comparative advantage.

Since 2014, China's GDP growth began falling to around 7 per cent and recorded its lowest level of growth since the economic reforms were introduced in the early 1980s. As a consequence, one can observe a reducing role of commodity-based infrastructure sectors in the economy and shifting investments on more consumption-based sectors in future. The expectation is that this hinders Australian resource exports to China but not ruling out exports of agriculture, services, tourism and education. In the meantime, if a ChAFTA is implemented successfully and appropriately then there will be a rapid increase in primary exports from Australia and manufacturing imports from China. Such a structural change in bilateral trade composition and trade volumes has implications in bilateral energy use, bilateral emissions and overall global emissions in future.

1.2 Carbon leakage

Greater global integration increases the division between the location of production and consumption and requires sophisticated methods for accounting global emissions in order to reach agreements in reducing CO₂ emissions on global climate change negotiations. These concerns have resulted in a call for the Kyoto protocol. The Kyoto protocol is fundamentally a non-discriminatory global policy to simultaneously and significantly reduce carbon leakage and loss in competitiveness. Any sub-global policies to reduce greenhouse gas emissions are potentially sensitive to both carbon leakage and loss in competitiveness for carbon constrained countries because they discriminate against carbon constrained and non-carbon constrained countries.

Carbon leakage may be defined as the displacement of carbon emissions as a consequence of a shift in their environmental policy by a sector/industry and/or country. In the recent past industry perspective carbon leakage across countries has been linked to competitiveness,

where the competitiveness of an industry reflects its ability to maintain profits and market share. Carbon constraint nations are likely to import from nations with lesser environmental standards and as a result end up uncompetitive in an industry with pollution concentrated products (Antweiler *et al.*, 2001). Thus, non-carbon constrained countries gain the upper hand in pollution intensive industries relative to carbon constrained countries.

If these concerns are to be heeded, appropriate statistics of carbon leakage and loss of competitiveness must first be estimated upon global and bilateral trade by nations. The traditional production based approach in our Australia – China bilateral trade example means that China is made accountable for their emissions despite the fact that some of their production is consumed in Australia. A consumption based approach to account for greenhouse gas permits emissions to be allocated to individual nations in a reliable manner, based on their final consumption (Wiedmann, 2009). This method estimates CO₂ emissions regardless of where they were produced and promotes equity by allocating the reductions appropriately while avoiding carbon leakage, by increasing the option of mitigation (Peters and Hertwich, 2008).

Most empirical studies on a consumption based approach adopted global supply chains using multi-region input-output (MRIO) analysis that only consider final consumption to avoid double counting (Wiedmann, 2009). MRIO analysis is able to capture the entire economic structure across countries within a particular year by considering all the trade linkages with a large bundle of goods (Wiedmann, 2009). Alternatively, the analysis on Emissions Embodied in Bilateral Trade (EEBT) focused more on the domestic supply chain and incorporated the total trade (intermediate and final consumption) among bilateral trading partners. EEBT captures the share of domestic emissions from the exported products of bilateral partners, a

method which is considered to be an advantage over MRIO because the MRIO method only allocates emissions to the country of final consumption (Sinden *et al.*, 2011). Considering bilateral trade, this study incorporates the EEBT method to analyse the total trade flows between Australia and China.

Based on the EEBT approach, China's CO₂ emissions, which were directly attributable to the production of manufactured exports for consumption, were estimated to be between 7 per cent and 14 per cent for USA (Shui and Harris, 2006) and around 4 per cent for UK (Li and Hewitt, 2008) respectively. Chemicals, fabricated metal products, and non-metallic mineral products and machinery were subjected to higher carbon leakage in bilateral China – USA trade (Guo *et al.*, 2010). Estimations also show that bilateral trade could reduce the intensity of CO₂ emissions over time by improving energy efficiency and structural change. For example, the carbon intensity of China was about 11.5 times that of Japan's in 1990, but this was reduced to 4.2 times the level of Japan's economy by 2000 (Liu *et al.*, 2010). For the China – USA trade, the net export of CO₂ emissions increased from 2002 to 2005 but decreased from 2005 to 2007. This decrease was mainly due to a decline in the intensity of CO₂ emissions, a reduction in the exchange rate, and lower imports that embodied CO₂ emissions (Du *et al.*, 2011). However, China's exports consist of products that come from less-polluting labour-intensive sectors in the past. One would expect that currently China is experiencing rapid trade-related increases in emissions as it produces more highly-polluting capital-intensive products. Using a sixteen manufacturing – industry one nation linked input – output model, He and Fu (2014) estimate the EEBT and the Pollution Terms of Trade (PTT) for China's trade with the rest of the world, and concluded that China is a net emissions exporter in absolute and relative terms.

This paper intends to quantitatively examine the sectoral carbon content of the bilateral Australia – China trade, and also assess its impact on domestic and global CO₂ emissions. The rest of this paper is arranged such that the second section discusses the method adapted to measure the intensity of CO₂ emissions, CO₂ emissions embodied in Australia-China Trade, Global CO₂ emissions due to Australia-China Trade, and the sources of data. The third section discusses the results, the fourth section contains the discussions, and the last section is the conclusion and policy implication of this study.

2. Methods

This study uses the sectoral level input – output model. As a tool, the IO model will identify a linear economic accounting model to find the production process and source of emissions, and then decompose the direct and indirect emissions embodied in production. This paves the way for estimating CO₂ emissions embodied in international trade for our purpose. An IO framework has been widely used to assess embodied energy and CO₂ emissions stemming from multi-lateral trade activities (Wyckoff and Roop, 1994; Ferng, 2003; Wiedmann, 2009; Kanemoto *et al.*, 2012) and bilateral trade activities of US – China (Shui and Harris, 2006; Guo *et al.*, 2010). An IO framework has also been used to assess embodied CO₂ emissions for US – China and the driving forces based on the emergy/dollar ratio (Du *et al.*, 2011), but the IO study anticipated in this paper shares similarities with Guo *et al.* (2010). By using the linked Australia – China IO model, it is possible to establish the inter-sectoral links in carbon consumption in both countries.

In the EEBT approach in the literature, our analytical procedure begins by estimating the intensity of CO₂ emissions using the standard International Panel on Climate Change (IPCC) formula, and then follows the input-output approach as an accounting tool to track the

production process to track emissions embodied in production. The analysis considers both direct and indirect emissions. Equation 1 shows such a process,

$$X = Y(I - A)^{-1} \quad (1)$$

where X represents the vector of output; Y represents the vector of final demand that includes household consumption, government consumption, investment, variation in stocks and exports; I is the identity matrix; and A is a matrix of direct requirements. $(I - A)^{-1}$ represents the Leontief inverse matrix which demonstrates the total requirement of inputs (direct and indirect) needed to satisfy the final demand.

2.1 Estimating the intensity of CO₂ emissions

Sectoral level CO₂ emissions can be estimated by using the following International Panel on Climate Change (IPCC) formula:

$$CO_{2i} = \sum_{j=1}^8 CO_{2j} = \sum_j E_{ij} \times f_j \times R_j \quad (2)$$

where CO_{2i} are the total CO₂ emissions of the i^{th} sector and CO_{2j} are the carbon dioxide emissions from energy type j . The CO₂ emissions from the i^{th} sector will thus rest on the consumption of j^{th} energy in the i^{th} sector (E_{ij}) as well as the carbon emission factor of each energy type (f_j) and the heat value of energy (the number of calories generated by burning per unit of energy, R_j).

Eight types of energy that are used to capture energy consumption are: coal, coke, crude oil, petrol, natural gas, diesel, electricity and other refined fuels and they are measured in petajoules (PJ). Thus, the sectoral CO₂ emissions can be calculated by multiplying the

consumption of each energy type (measured in PJ) with its emissions factor (t CO₂/PJ). The CO₂ emissions factor of each type of energy comes from Guo *et al.* (2010).

In this process equation 3 demonstrates the intensity of CO₂ emissions in each sector,

$$S_i = CO_{2i}/X_i \quad (3)$$

where S_i is the CO₂ emissions intensity of sector i , X_i is the industrial output of sector i (in PPP \$), and CO_{2i} is the CO₂ emissions of sector i .

2.2 Estimating CO₂ emissions embodied in Australia-China Trade

CO₂ emissions embodied in Australia's exports (EEX) can be calculated by multiplying Australia's sectoral embodied emissions intensity with sectoral exports:

$$EEX_i = S_i^{AUS}(I - A^{AUS})^{-1}Ex_i \quad (4)$$

where EEX_i is the total CO₂ emissions embodied in Australian's exports of the i^{th} sector, S_i^{AUS} is Australia's direct emission intensity of the i^{th} sector; $(I - A^{AUS})^{-1}$ is Australia's Leontief inverse matrix, and Ex_i is Australia's exports from the i^{th} sector.

CO₂ emissions embodied in Australia's imports (EEI) can be estimated based on China's sectoral embodied emissions intensity and imports from China:

$$EEI_i = S_i^{CHI}(I - A^{CHI})^{-1}Im_i \quad (5)$$

where EEI_i is the total CO₂ emissions embodied in Australia's imports of the i^{th} sector, S_i^{CHI} is China's direct emissions intensity of the i^{th} sector; $(I - A^{CHI})^{-1}$ is China's Leontief inverse matrix, and Im_i is Australia's imports from China's i^{th} sector.

2.3 Estimating Australia-China Trade on Global CO₂ Emissions

We assumed here that producers are accountable for the emissions embodied in international trade (under global policies like the Kyoto protocol) and therefore countries import if their local producers are not energy efficient. For example, China may import goods instead of producing them domestically and show lower national or global CO₂ emissions by consuming Australian products. Guo *et al.* (2010) tested the impact of international trade on domestic CO₂ emissions by establishing the following models,

$$CO_2^* = S_i^{AUS}(I - A^{AUS})^{-1}Im_i \quad (6)$$

$$CO_2^\# = S_i^{CHI}(I - A^{CHI})^{-1}Ex_i \quad (7)$$

where CO_2^* is the reduction of CO₂ emissions in Australia by importing from China, $CO_2^\#$ is the increase/decrease of CO₂ emissions of China through the consumption of Australian goods. The remaining notations are as defined in equations 4 and 5.

The difference between EEI and CO_2^* is the rise/fall of world CO₂ emissions by Australia consuming imported goods, while the difference between EEX and $CO_2^\#$ is the rise/fall of world CO₂ emissions is by China consuming imported goods. Thus, the gap in CO₂ emissions caused by import and export is the impact of Australia-China trade on global CO₂ emissions (Guo *et al.*, 2010).

2.4 Data

We have linked IO tables, bilateral trade, and CO₂ emissions from fuel combustion based on Australian New Zealand Standard Industry Classification (ANZSIC). The IO study explained in the methods section necessitates three data series: the IO table of Australia and China; the bilateral trade between Australia and China; and the country – and sector – level energy consumption, output and CO₂ emissions of various types of energies. This paper used the recent 2008/09 IO table of Australia (Australian Bureau of Statistics (ABS), 2013a) and the 2007 IO table of China (China Statistical Yearbook, 2012) over the period 2007/08 to 2010/11 while assuming that the input-output structure remained the same over five years. Given the single year input-output table for both countries, the GDP growth rates were adjusted to project sectoral output growth. The analysis begins by establishing uniform criteria in adjusting the national energy balance from 8 types of energy of both countries on 9 sectors drawn from agriculture, industry, and construction. The CO₂ emissions factor of each type of energy came from Guo *et al.* (2010).

Bilateral exports and imports are based on financial years and came from the ABS (2013b) on request. Imports are in Cost Insurance Freight (CIF) prices. This database delivers a detailed set of bilateral trade data for all sectors attributable to the ANZSIC 2-digit level. In order to maintain consistency with Australian data, China's other estimations were adjusted for the financial year. This study used the purchasing power parity (PPP) exchange rate for conversion but because the re-export data was not available and it was very small, the CO₂ emissions caused by the re-export trade data were ignored. Two components of transport costs are relevant for bilateral carbon leakage: shipping costs between Australia and China and domestic transport costs. Since we used CIF prices, it covers the cost of goods at the

point of exports as well as the associated international insurance and transport costs. We assumed that the customs prices reflected the domestic transport cost as well.

Australia's sectoral energy consumption data are available from ABS (2012) and they are measured in petajoules (PJ). China's sectoral energy consumption data are measured by their physical quantity, and were taken from the China Energy Statistical Yearbook, 2008-2010. Eight types of energy represents energy consumption and they are: coal, coke, crude oil, petrol, natural gas, diesel, electricity and other refined fuels. The conversion factors contained in the China Energy Statistical Yearbook (2010) were used to convert China's energy consumption from physical units to calorific values (PJ)². Thus, the sectoral CO₂ emissions can be calculated by multiplying the consumption of each energy type (measured in PJ) with its factor (t CO₂/PJ). Energy use in the energy-producing sectors show in-plant use of consumption energy, and exclude energy products being processed and therefore there is no issue of double counting.³

3. Calculation results

The analysis begins using 9 sectors from Australia and China drawn from agriculture, industry, and construction. The calculations offered in this paper share similarities with Guo *et al.* (2010) because while we also calculated the emissions embodied in trade and bilateral

² In the China Energy Statistical Yearbook (2010), the consumption of coal, coke, crude oil, petrol, diesel, and other refined fuels are measured in tons, natural gas is measured in cubic meters, and electricity is measured in kilo-Watt hours. The conversion factors are as follows: coal: 1 ton = 0.000020908 PJ, coke: 1 ton = 0.000028435 PJ, crude oil: 1 ton = 0.000041816 PJ, petrol: 1 ton = 0.00004307 PJ, diesel: 1 ton = 0.000042652 PJ, other refined fuels: 1 ton = 0.000042243 PJ, natural gas: 1 million cubic meter = 0.038931 PJ, electricity: 1 million kwh = 0.003596 PJ.

³ Both China Energy Statistical Yearbook and Australian Bureau of Statistics publish industrial final energy consumption by both primary and secondary energy types (for China see Zhang *et al.* 2009). For example, electricity sector figure include only energy used for plant operation, not inputs to power and heat generation, which are distributed among end-use sectors by using the gross heat rate of power generation to convert electricity to standards coal (Fridley *et al.*, 2011).

trade on global emissions, we estimated Australia – China bilateral trade instead of USA – China bilateral trade by Guo *et al.* (2010). In this sense the results of both studies are comparable in order to reach some valuable conclusions on greenhouse gas emission negotiations in world forums.

3.1 Intensity of CO₂ emissions

Table 1 shows the sectoral intensity of CO₂ emissions in Australia and China that were obtained using equations 2 and 3. The CO₂ emissions were higher in China in most sectors such as mining, food and textiles, metal, and other manufacturing, which means that China emits more per unit of output relative to Australia for producing products at the sectoral level. One can see a huge gap in the sectoral energy efficiency in China relative to Australia.

Table 1: Sectoral CO₂ Emission Intensities of Australia and China: 2008-09 – 2010-11

ANZSIC code	Australia			China		
	2008-09	2009-10	2010-11	2008-09	2009-10	2010-11
01-05	0.1913	0.1906	0.1944	0.1051	0.1006	0.0960
06-09	0.3123	0.3128	0.3455	0.7467	0.7312	0.7378
11-13	0.1177	0.1170	0.1146	0.1298	0.1195	0.1168
18	0.5483	0.5142	0.4275	0.4629	0.4241	0.3950
21-22	0.6827	0.6695	0.6858	0.8687	0.8499	0.8679
14-17, 19-20, 23-25	0.1117	0.1106	0.1069	0.4271	0.4147	0.4174
26-29	0.7777	0.7454	0.7105	3.4570	3.3570	3.2100
30-32	0.0502	0.0496	0.0602	0.0350	0.0354	0.0374
33-96	0.1047	0.1025	0.1044	0.1635	0.1596	0.1597

Note: CO₂ intensity = CO₂ emissions/output (kg/PPP\$2008)

ANZSIC codes: 01-05: agriculture, forestry and fishing; 06-09: mining; 11-13: food and textile manufacturing, 18: chemical products manufacturing; 21-22: metal product manufacturing; 14-17, 19-20 and 23-25: other manufacturing sectors including wood, paper, printing, petroleum, polymer non-metallic mineral, machinery and equipment, furniture; 26-29: electricity, gas, water and waste services; 30-32: construction; 33-96: service sectors.

Source: Authors' calculation.

This indicates that China performs lower than Australia in clean technology, especially in mining (06 – 09), manufacturing (14 – 17, 19 – 20, 21 – 22 and 23 – 25), and energy sectors (26 – 29). This may be due to China's overuse of coal and its inefficient sectoral production processes relative to Australia. In other words, the world would be slightly better off if those mining and manufacturing products were produced in Australia instead of China because those sectors are highly energy intensive and energy saving technology is vital in order to reduce emissions in China.

3.2 CO₂ emissions embodied in Australia-China Trade

Table 2 reports the results of total CO₂ emissions embodied in Australia-China trade by sectors from 2008 – 09 to 2010 – 11. The EEX from Australia to China were 11.70 Mt of CO₂ in 2008 – 09 and 21.55 Mt of in 2010 – 11. The EEI from China to Australia were 49.49 Mt of CO₂ in 2008 – 09 and 52.49 Mt in 2010 – 11. The EEI from China to Australia were much higher than the reverse flow of emissions. This resulted in a net import of CO₂ emissions that were negative from an Australian perspective and were reflected in a negative balance of emissions embodied in trade (BEET). In other words, China has a surplus of CO₂ emissions from the Australia-China trade of around 37.79 Mt in 2008 – 09 and 30.94 Mt in 2010 – 11.

Table 2: Sectoral Trade Data and Total CO₂ Emissions Embodied in Australia-China Trade by Sectors: 2008-09 and 2010-11

ANZSIC code	2008-09								
	Exports (million PPP \$)	% of Total	Imports (million PPP \$)	% of Total	EEX (Mt CO ₂)	% of Total	EEI (Mt CO ₂)	% of Total	BEET (Mt CO ₂)
01-05	346.19	1.36	60.48	0.24	0.11	0.94	0.04	0.08	0.07
06-09	19300.50	76.00	61.52	0.25	9.17	78.38	0.13	0.26	9.03
11-13	938.78	3.70	5125.22	20.66	0.29	2.48	5.42	10.95	-5.13
18	284.61	1.12	1013.27	4.08	0.06	0.51	2.33	4.71	-2.26
21-22	1637.37	6.45	2263.97	9.12	1.73	14.79	6.91	13.96	-5.18
14-17, 19-20 and 23-25	786.43	3.10	15686.06	63.22	0.34	2.91	34.66	70.03	-34.32
54 and 98	2110.51	8.31	601.02	2.42	--	--	--	--	--
Total	25404.40	100.00	24811.54	100.00	11.70	100.00	49.49	100.00	-37.79
ANZSIC code	2010-11								
	Exports (million PPP \$)	% of Total	Imports (million PPP \$)	% of Total	EEX (Mt CO ₂)	% of Total	EEI (Mt CO ₂)	% of Total	BEET (Mt CO ₂)
01-05	2186.85	5.12	72.85	0.27	0.73	3.39	0.04	0.08	0.68
06-09	33683.20	78.84	99.66	0.37	17.64	81.86	0.21	0.40	17.43
11-13	1121.20	2.62	5053.56	18.66	0.36	1.67	4.97	9.47	-4.61
18	481.86	1.13	1090.93	4.03	0.25	1.16	2.30	4.38	-2.05
21-22	1988.76	4.65	2243.00	8.28	2.14	9.93	6.66	12.69	-4.52
14-17, 19-20 and 23-25	893.23	2.09	18033.60	66.59	0.43	2.00	38.31	72.99	-37.88
54 and 98	2368.93	5.54	487.19	1.80	--	--	--	--	--
Total	42724.45	100.00	27080.79	100.00	21.55	100.00	52.49	100.00	-30.94

Note: 01-05: agriculture, forestry and fishing; 06-09: mining; 11-13: food and textile manufacturing; 18: chemical products manufacturing; 21-22: metal product manufacturing; 14-17, 19-20 and 23-25: other manufacturing sectors including wood, paper, printing, petroleum, polymer non-metallic mineral, machinery and equipment, furniture; 54: publishing; 98: items not readily classified and those which are confidential and cannot be more specifically classified.

Source: Authors' calculation.

Australia's export of goods and services to China have grown quickly from an average annual growth rate of 24.5 per cent, while the imports from China increased by only around 7.6% of annual growth rate. This reflects the reduction in the surplus of BEET in China over time. China's demand for a significant amount of agricultural, minerals, and energy products has driven the Australian economy during the global financial crisis of 2008 – 11. Table 2 shows that the mining sector (06 – 09) contributed around 76 per cent of Australian exports (19,300/25,404) and around 78 per cent of EEX (9.17/11.7) in 2008 – 09. The exports and EEX increased to 78 per cent and 82 per cent (17.64/21.55), respectively in 2010 – 11.

Australia's major imports from China were mainly manufactures, with the major categories being metal, wood, paper, printing, petroleum, polymer non-metallic minerals, machinery and equipment, and furniture (21 – 22, 14 -17, 19 – 20, 23 – 25), all of which contributed around 75 per cent of imports and 86 per cent of EEI in 2010 – 11. These were stable and consistent estimates over time and reflect the extraordinary build-up of carbon by China for which Australian consumers are responsible.

All six sectors can be divided into two groups on the basis of BEET. The agriculture (01 – 05) and mining (06 – 09) sectors are in the first group with net-exported emissions (positive BEET), which increased Australia's CO₂ emissions as a result of providing goods for Chinese consumption. The remaining sectors are in the second group (negative BEET), which indicates that in Australia, these sectors avoided emitting domestically. This reflects Australia's comparative advantage in agriculture and mining due to the availability of land, and China's comparative advantage in manufacturing due to lower labour costs.

3.3 Australia-China Trade on Global CO₂ Emissions

Note that the intensity of CO₂ emissions from primary products (06 – 09) in Australia were lower than in China (Table 1), even though they increased Australia's CO₂ emissions (Table 2) due to exporting for Chinese consumption, and they were produced in relatively efficient locations and otherwise reduced emissions. On the other hand, the intensity of CO₂ emissions in China from manufacturing products (14 – 25) was higher than Australia. These products were produced in relatively inefficient locations to satisfy Australian consumers and they ultimately harm the world as a whole. On this basis a complete and deeper

understanding of the role of foreign trade and CO₂ emissions from the perspective of Australia and the world could be sought.

The impact of Australia – China trade on both national and global CO₂ emissions can be estimated using equations 6 and 7. In 2010-11, due to importing goods from China, Australia reduced 13.36 Mt of its domestic CO₂ emissions, which accounted for 4.2 per cent of total Australian national emissions. Figure 2 shows the reduction of sectoral CO₂ emissions in detail, such that the ANZSIC sectoral codes 14 – 17, 19 – 20, 23 – 25 in Australia were reduced by 8.67 Mt, while ANZSIC 21 – 22 and 11 – 13 were reduced by 2.41 Mt and 1.64 Mt respectively. Note that these sectors had relatively high emissions in China relative to Australia (Table 2), while imports from China reduced the total Australian national emissions by around 4.2 per cent.

Figure 2: Impact of Australia Imported Goods from China on Australia and Global CO₂ Emissions in 2010-11 (Mt CO₂)

Note: 01-05: agriculture, forestry and fishing; 06-09: mining; 11-13: food and textile manufacturing; 18: chemical products manufacturing; 21-22: metal product manufacturing; 14-17, 19-20 and 23-25: other manufacturing sectors including wood, paper, printing, petroleum, polymer non-metallic mineral, machinery and equipment, furniture.

Source: Authors' calculation.

Australian imports of goods from China increased global CO₂ emissions by 39.13 Mt by reducing domestic emissions, which accounted for 12.43 per cent of total Australian national emissions in 2010-11 (Figure 2). From a global perspective, although Australia reduced emissions by importing Chinese goods (13.36 Mt), this was not enough to offset the rise of CO₂ emissions while these products were made in China (EEI=52.49 Mt).⁴ The ANZSIC sectors 14 – 17, 19 – 20 and 23 – 25 are competitive in China relative to Australia and they have a large impact on GHE.

In 2010 - 11, China reduced its domestic CO₂ emissions by 80.87 Mt due to importing Australian goods, which accounted for 0.65 per cent of their total national emissions (Figure 3). China avoided producing those goods by importing from Australia. The reductions mainly come from ANZSIC 06 – 09 which contributed 69.62 Mt.

Figure 3: Impact of Australia Exported Goods to China on China and Global CO₂ Emissions in 2010-11 (Mt CO₂)

Note: 01-05: agriculture, forestry and fishing; 06-09: mining; 11-13: food and textile manufacturing; 18: chemical products manufacturing; 21-22: metal product manufacturing; 14-17, 19-20 and 23-25: other manufacturing sectors including wood, paper, printing, petroleum, polymer non-metallic mineral, machinery and equipment, furniture.

Source: Authors' calculation.

⁴ In 2008 – 09, Australia reduced emissions due to importing Chinese goods (11.09 Mt), this was not adequate to offset the rise of CO₂ emissions while these products were made in China (EEI=49.49 Mt).

Figure 3 also shows that due to the consumption of Australian goods, global CO₂ emissions were reduced by 59.33 Mt, which accounted for 0.47 per cent of China's total national emissions. From a global perspective, China importing Australian goods reduced 80.87 Mt of CO₂ emissions domestically, which was more than 21.55 Mt caused by Australian production (EEX).⁵

If Australia produced and consumed its own goods and services instead of importing from China, it would have generated 13.36 Mt CO₂, which was lower than the amount of CO₂ China generated by producing the same goods and services (52.49 Mt CO₂). Therefore, Australia's consumption of Chinese goods increased global CO₂ emissions by 39.13 Mt (52.49 – 13.36). Meantime if China did not import goods from Australia it would produce 80.87 Mt of CO₂ emissions by producing the same goods, which would be much higher than the amount of CO₂ Australia generated (21.55 Mt). So China's consumption of Australian goods reduced emissions by 59.32 Mt (21.55 – 80.87), while overall global emissions were reduced by 20.19 Mt (39.16 – 59.32) through Australia-China trade in 2010-11 (Figure 4).

⁵ In 2008 – 09, China reduced emissions by importing Australian primary goods (50.05 Mt) which was more than 11.7 Mt caused by Australian production.

Figure 4: Impact of the Australia-China Trade on Global CO₂ Emissions in 2010-11 (Mt CO₂)

Note: 01-05: agriculture, forestry and fishing; 06-09: mining; 11-13: food and textile manufacturing, 18: chemical products manufacturing; 21-22: metal product manufacturing; 14-17, 19-20 and 23-25: other manufacturing sectors including wood, paper, printing, petroleum, polymer non-metallic mineral, machinery and equipment, furniture.

Source: Authors' calculation.

4. Discussion

China's continuing economic growth and increased Australia-China bilateral trade have implications for bilateral carbon leakage. Most studies have concluded that China as a net exporter of emissions and as a result China has experienced carbon efficiency gains. For example, China's carbon emission intensity per unit of GDP is still 10 times higher than France and Japan, 3.9 times higher than the US, and 5 times higher than Canada (He and Fu, 2014). Australia's imports partly promote the metals, machinery, and equipment sectors in China, which are very emissions intensive (Sinden *et al.*, 2011). In the mid-1990s Ahmad and Wyckoff (2003) concluded that Australia is also a net exporter of CO₂ emissions, while from 1993 to 1997, Australian emissions embodied in exports (EEX) increased by 13% and emissions embodied in imports (EEI) grew by over 40%. Indeed, one third of the increases in EEI reflected increased imports from China. There is no doubt that emissions embodied in

bilateral trade are growing as the level of trade between Australia and China has increased rapidly over the past decade. Our research interest lies on what impact this rapidly increasing bilateral trade would make in overall global emissions? Prior studies on USA – China bilateral trade have indicated that bilateral and overall global emissions are on the rise (Guo *et al.*, 2010).

The factors influencing bilateral global emissions are carbon intensities, trade compositions, and trade volumes. If trade composition consists of products that use lower energy relative to the partner country then international trade does not necessarily increase global CO₂ emissions, but if we assume that few trading partners have relatively energy efficient technology in their production system (higher levels of competitiveness with regard to energy efficient production) then their EEX becomes low. This leads to overall global emissions being low by offsetting emission flows between the countries. For example, Australia is a relatively carbon efficient exporter of primary products relative to China, but if China replaces the imports by producing on their own then global emissions increase, so by not producing primary products China contributes lower global emissions to the world as a whole. In other words, if China produces all of its primary imports locally, then overall global emissions would have been even higher. If ChAFTA is fully implemented then this will ensure greater access of Australian primary products and technology in China's market and also ensure lower emissions.

In the absence of global policies like the Kyoto protocol, both Australia and China are under global pressure to enforce an emissions trading scheme (ETS) or some other measures to reduce greenhouse gas emissions. The Australian Federal Government introduced a carbon tax which involves implementing a fixed price of around \$24 a tonne from mid – 2012 and

extending it to a standard ETS by 2015. However, Australia backed off from implementing this under the new government formed in 2014. China launched an ETS system in Shenzhen with the intention of quickly expanding it to another four major cities. In this context the greater the divergence of an ETS between Australia and China, the greater will be their bilateral carbon leakage. At this stage both countries are not fully committed to their ETS plan, which will lead to higher levels of carbon leakage. If both countries adopt ETS then both countries end up with energy saving technologies and reduce the bilateral carbon leakage. ETS would increase government revenue and the capability of spending on low-emissions technology.

In the absence of a single climate policy like the Kyoto protocol, policy makers are compelled to juggle between industrial competitiveness and carbon leakage if they adopt ETS. If only one country among bilateral partners adopts ETS then there are three short-term measures which can reduce the adverse effect of sectoral competitiveness in the presence of ETS (van Asselt and Brewer, 2010): (1) the free allocation of tradable emission allowances, or offering state aid in order to offset the ETS, (2) border price adjustments which is an adjustment of imports and exports for offsetting carbon price differences⁶, or (3) negotiating international agreements that create a similar carbon price such as the Kyoto protocol. The first and second options require state intervention in international trade and that harms energy efficiency and industrial competitiveness.

⁶ It is possible to quantify and compare boarder adjustment measures (BAM) in a subset of emitting countries by taking into account changes in trade flows, exchange rates, rate of carbon leakage and employment. By doing this exercise, one can estimate the likely magnitude of leakage, and the magnitude of BAM required offsetting the leakage.

5. Conclusion and Policy Implications

This paper fills a gap in the literature on CO₂ emissions embodied in bilateral Australia-China trade. China is Australia's largest two-way trading partner and contributes one fifth of the overall trade of Australia. Australia's exports to China are primary goods and the imports consist of manufactured goods. Our analysis shows that China performs lower than Australia in clean technology, especially in the mining (06 – 09), manufacturing (14 – 17, 19 – 20, 21 – 22 and 23 – 25), and energy (26 – 29) sectors. This may be due to China's overuse of coal and inefficient sectoral production processes that are likely to adversely affect greenhouse gas emissions, but Australian consumers are also partly responsible due to their increasing demand for these products. In this regards an increase in carbon leakage is attracting concern because China had a surplus of 30.94 Mt of bilateral CO₂ emissions in 2010 – 11, and this showed that the rate of increase in the scale of production for the Australian market was faster than China's own consumption. Australia's consumption of Chinese goods increased global CO₂ emissions by 39.13 Mt, while in 2010-11, China's consumption of Australia's goods decreased world emissions by 20.19 Mt.

This shows that Australia is a relatively carbon efficient producer of primary products and therefore their exports to China contribute to lower global emissions as a whole, but if China produces all of its imports locally then overall global emissions would have been even higher. These results clearly show that international trade does not necessarily always increase the global CO₂ emissions. Australia – China bilateral trade compositions and trade volume played an important role in influencing global emissions. The greater the carbon efficiency that a country has among its trading partners the lower will be the global CO₂ emissions however, to maintain a sustainable economic relationship both countries must adopt a sustainable energy and environmental policy.

Locations with lower energy intensity may be the level playing field of the future because to remain competitive China should strengthen its energy-saving technology and transfer it to the highly emitting processing and manufacturing sectors as a priority. Those sectors of China with high emissions embodied are as follows: 42 per cent of China's overall EEX are from the manufacture of machinery and equipment sector, and 35 per cent of overall EEX are from textiles, wearing apparel and leather industries, chemical industry and metals industry (Liu *et al.*, 2013). These high energy intensive sectors need to focus on substantially reducing their overall carbon leakage, while the industries concerned have the potential to reduce emissions by promoting learning and adopting energy saving technology from elsewhere. This recommendation is similar to Guo *et al.* (2010: p.1396) for bilateral USA-China's global emissions. Authors say that 'China should pay more attention to the responsibility of reducing emissions rather than focusing on the accounting of emissions when participating in the international climate change negotiations in the future'. China's policies on other areas, for example the exchange rate policy, are also matters that determine competitiveness.

The expectation of the recent ChAFTA agreement is to promote more primary exports from Australia and therefore this will enhance the sustainability of trade between the two countries. For a sustainable trade relationship both countries must adopt a sustainable energy policy. By adopting ETS or a similar policy, both countries can achieve competitiveness in the light of their own changing comparative advantage, while generally reducing greenhouse gas emissions and carbon leakage. Failing this, protectionism in the form of border protection may be the only option available to address country-based competitiveness, but this option will increase regulations in the industry/sector and tend to reduce bilateral trade and competitiveness.

This paper has certain limitations which will be addressed by upcoming works. First, a comprehensive approach to the impact of trade on greenhouse gas emissions means that the MRIO model must be incorporated. The combined EEBT and MRIO methods gave more insight where the EEBT analysed total trade flows and MRIO analysed final consumption (Sinden *et al.* 2011). Second, the role of processing trade and imports from other countries and from other regions were not completely accounted for because in this globalised world two countries are not isolated in their economic activities and their interactions with all their other trading partners were not captured. Third, in order to match last available Australian IO table (2008/09), we used China IO table (2007). Updated annual IO tables for Australia and China will be used in future studies. Fourth, Sectoral classification was limited to 9 sectors mainly because the matching detailed sectors for both countries were not available. More in-depth industry/sector analysis may help to identify the opportunities of CO₂ emissions by industry/sector for making policy suggestions for both nations.

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