CARBON EMISSIONS IN GVC AND POLLUTION HAVEN HYPOTHESIS

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Introduction

China's flourishing economic growth, increasing energy consumption and carbon emission has been extraordinary regional differentiation problem for structure of a nation's economy, physical geography, resource endowments, and other factors. The fragmentation of production across national and regional boundaries is a defining feature of the modern interregional economy. This calls for new measures to analyse trade patterns and embodied CO2 emissions in trade. As the McKerlie et al. (2006) suggest that all parties with a role in designing, selling or using a product are responsible for minimizing the environmental impact of the product over its life. A significant amount of emissions originates and flows between regions in the goods that are traded between provinces, the embodied emissions in trade. Embodied emissions is a kind of concept used to examine the extent to which emissions are embodied in the interregional trade of goods and services (Wiedmann, 2008). If a country has to import a large amount of intermediate inputs to assemble its export products, the value added is much less than the gross exports value. In the end, it is the domestic emissions content in trade. In a hypothetical case, If cars are produced in two regions Guangdong and Shanghai. Guangdong sells cars to consumers in itself and in Yunnan. Shanghai's car industry sells on its domestic market and to export. Steel was produced in Yunnan then the emissions that went into producing that steel is typically attributed Yunnan. Perhaps a better way of accounting for the emissions is to attribute it to the province in which the car itself is consumed, at the source of demand, rather than that of supply. Therefore, how to estimate the embodied emissions in interregional trade is vertical to measure the domestic value chains and trade patterns.

Early studies on global value chain (GVC) focus on the value chain of a single firm or industry, and on technology intensive products. Dedrick et al. (2010) found that the value-added of HP and Lenovo laptops created in China only amounted to 3% of the ex-factory price. Related research was also conducted for the global production of iPod® (Linden et al., 2009), Boeing aircraft (Humphrey &Memedovic, 2003), motor industry (Lall et al., 2004), electronic industry (Lall et al., 2004), and furniture industry (Ivarsson et al., 2011). Although the case studies on products shed some light on a country's position in GVC, they do not describe the entire pattern of the whole world. Moreover, there is interdependency among different products and industries (e.g., a single product requires many other products as intermediate inputs). It is difficult to give an overall description of GVC based only on a single product or industry.

In the last ten years, the focus shifted from single products to the entire production chain (Koopman et al.,2012,2014; Davis et al., 2011; Peters et al.,2011; Jiang and Liu,2015; Liou et al.,2016). Koopman et al. (2012) estimated the value added in exports and decomposed this value into three components. Davis et al. (2011) found that the 37% of global emissions are from fossil fuels traded internationally and additional 23% of global emissions are embodied in traded goods. Wu et al. (2015) shown that China was a net exporter of embodied CO2 emissions between China and Japan in bilateral trade approach. Peters et al.(2011) estimated that total CO2 emissions embodied in global international trade have increased from 4.3 Gt CO_2 in 1990 to 7.8 Gt IN 2008. Bart Los et. al. (2012) distinguished two perspectives (direct trade flow and perspective) on the value added content of international trade. They supposed that the former should be interpreted to analyse the domestic value added content of exports, and the latter is useful for analysing the foreign demand for income generation in domestic economy. Jiang and Liu (2015) sliced up the value chain and the accompanied carbon dioxide emissions linked to the international trade of global information and communication technology (ICT) manufacturing sector.

In this paper, we outline two perspectives on the CO_2 emissions content of interregional trade. We distinguish two perspectives: the bilateral trade perspective (BT) or direct trade flow (DTF) perspective, and the multi-lateral trade perspective (MT) or global value chain (GVC) perspective. We found that the BT perspective is useful to analyse the domestic embodied emissions content of exports or outflows. The MT perspective is useful for tracing the carbon footprints and the development of global value chains.

Methodology

As mentioned before, the value added and emissions responsibility of each participant gained from the global value chain is the key for global value chain studies, irrespective of the value chain of a single firm/industry, or of multi-industry/multi-country is concerned. Therefore, trade in value added or embodied emissions in trade has become a hot research topic of international academicians and institutions in the recent decade. If the CO_2 emissions gained from the international and domestic trade is focused on, the world and domestic trade pattern would change substantially.

The standard Leontief quantity Input Output model will be denoted here with i intermediate industries, k final demands categories and p value added categories. We will use the following standard symbols:

$x =$ i- vector of total output or input

$Z = i \times i$-matrix of intermediate demand

$F = i \times k$-matrix of final demand (the most common final demand categories are household consumption, investment and foreign exports)

$f =$ the total i-vector of final demand

$v = p \times i$-matrix of primary inputs or value added (the most common value added categories are imports, wages , capital depreciation, operating surplus)

$I = i \times i$-diagonal matrix with ones

$\mu =$a summation vector

If the cells of Z are divided by their column totals from X, we get the $i \times i$ matrix fo input coefficients $A, a_{ij} = z_{ij}/x_j$.

With the final economic assumption that supply follows demand, the accounting identities give the definition of total output across the rows of the IO table:

$$X = Z\mu + F\mu = AX + f = (I - A)^{-1}f = Lf$$

The $i \times i$ matrix L is the so-called Leontief inverse, which equals: $I + A^1 + A^2 + A^3 + \cdots$. The expansion of L indicates the direct effect I, and the first and higher order indirect effects $A^1 + A^2 + A^3 + \cdots$ of a change in exogenous final demand.

For a given region r, our analysis follows trends in territorial-based energy consumption (that is production-based, PE) and consumption-based energy consumption, CE. We define the difference between the territorial- and consumption-based energy consumption a “net energy transfer” (or embodied energy consumption) are not a physical part of the exports but, rather, are consumed in the production of the exports. If the net value is negative then r is a net importer of embodied energy consumption, and if positive then r is a net exporter.

We use two different methods to construct the consumption-based energy consumption inventories, for energy consumption by adjusting established territorial consumption inventories with estimates of energy consumption transfers via interregional trade. All two contribution methods include the energy consumption that occur in the supply chain to produce consumed goods and services (eg. products produced in Hebei, but consumed in Zhejiang). The first method, embodied energy consumption in bilateral trades (or direct trade, EEBT), enumerates the intra-regional supply chain and considers total bilateral exports. The second method, MRIO analysis (or domestic production chain), further disaggregates the EEBT method into domestic supply chains by treating final demands as exogenous and interregional trade for intermediate consumption as endogenous. The MRIO and EEBT methods give the same domestic energy consumption, but distinct regional energy consumption because of the different allocation of intermediate consumption. We present the results from both approaches as they provide different perspectives of how to allocate the energy consumption from interregional trade to countries. We argue that both have their particular interpretations. The choice for one specific perspective should depend on the particular policy question at hand.

Conceptualising EEBT and MRIO perspective

The embodied energy consumption in region's gross exports (EEBT perspective), allocating the interregional trade for intermediate consumption and final demands as exogenous, refers to energy consumption from the production of the region's gross exports. Because this method focuses on where the energy consumption comes from but not where it is consumed, it does not exclude the part of energy consumption that generated by producing intermediate consumption for other regions but eventually returns home via imports to satisfy intra-regional final demands. The perspective focuses on the embodied energy consumption content of particular trade flows originating from a region.

In contrast, the MRIO perspective takes final demand of goods in a country as a starting point and traces the energy consumption that has been added by different regions in the various production stages. In this perspective, the exports of energy consumption is defined as the amount of energy consumption produced in a given source region that is ultimately embodied in final products consumed abroad. That means, although there are no products physically crossing the "border" between two regions, one of them still exports energy to another one, according to this concept. The method is useful when you want to study how much various regions contribute to the energy consumption of a particular product, say a mobile phone produced in Tianjin as it allows one to trace the energy consumption in all stages of domestic production.

For simplicity's sake we will only discuss two regions r and s that represent all regions.

Fig. 1. Layout of China's MRIO table with import being split-up

	Intermediate demand		Final demand		Export		TO
	in region *r*	in region *s*	in *r*	in *s*			
r	Z^{rr}	Z^{rs}	F^{rr}	F^{rs}	e^{r}	f^{r}	x^{r}
s	Z^{sr}	Z^{ss}	F^{sr}	F^{ss}	e^{s}	f^{s}	x^{s}

IM	M^{Zr}	M^{Zs}	M^{Fr}	M^{Fs}	m
VA	$(v^r)'$	$(v^s)'$			
TI	$(x^r)'$	$(x^s)'$			

Note: TO = total output; IM = import; VA = value added; TI = total input. A hat indicates diagonalization.

The two subscript r and s subsequently indicate the region of origin and the region of destination. The $i \times i$ matrix Z^{rr} represents the intermediate flows between industries within region r, and Z^{rs} represents the intermediate exports from industries in region r to industries in region s ($r \neq s$). x^r is the i-vector of production in region r. M^{Zr} is the i-vector of intermediate imports in region r and M^{Fr} is the i-vector of imports of final demand in region r. F^{rr} denotes the domestic final demand produced and consumed in region r, F^{rs} is the final demand produced in region r consumed in region s. e^r denotes the final demands produced in region r, which do not have region r or s as their destination but go somewhere else, i.e. foreign exports. The total final demand f^r for products from industries in region r equals the combined row sum of F^{rr}, F^{rs} and e^r. In compact form,

$$A = \begin{bmatrix} A^{rr} & A^{rs} \\ A^{sr} & A^{ss} \end{bmatrix},\ X = \begin{bmatrix} x^r \\ x^s \end{bmatrix},\ f = \begin{bmatrix} F^{rr} + F^{rs} \\ F^{sr} + F^{ss} \end{bmatrix} \mu + \begin{bmatrix} e^r \\ e^s \end{bmatrix}$$

In formulas:

$$X^r = Z^{rr}\mu + Z^{rs}\mu + f^r = A^{rr}X^r + A^{rs}X^s + f^r$$
$$X^s = Z^{sr}\mu + Z^{ss}\mu + f^s = A^{sr}X^r + A^{ss}X^s + f^s$$

We assume i- vector of direct CO2 emissions coefficients' matrix C for environmental implementations.

$$C = [c^r \quad c^s]$$

In a single-region model, Z^{rs}, Z^{sr}, f^r, and f^s would be exogenous.

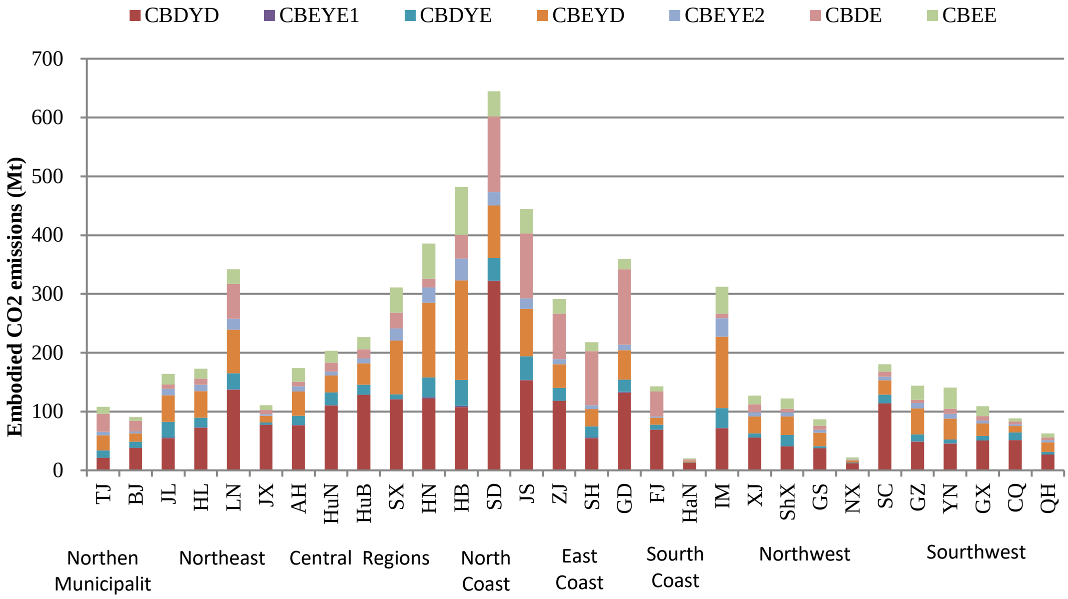
$$C^r = c^r X^r = c^r(I - A^{rr})^{-1}(Z^{rs}\mu + f^r) = c^r(I - A^{rr})^{-1}y^r$$
$$C^s = c^s X^s = c^s(I - A^{ss})^{-1}(Z^{sr}\mu + f^s) = c^s(I - A^{ss})^{-1}y^s$$

In a multi-region model, the intermediate exports Z^{rs} and Z^{sr} become endogenous by making them dependent on the output X^r and X^s of the industries in the destination region, respectively, whereas the rest of final demand f^r and f^s remain exogenous. Solving the original formulas step-by-step gives the following disaggregated version,

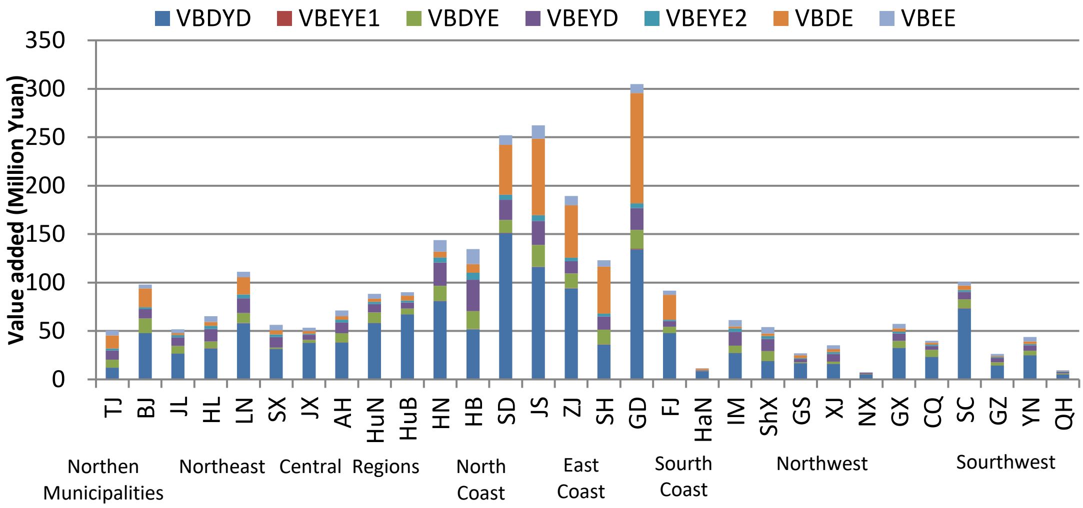
$$C^r = c^r(I - A^{rr})^{-1}(A^{rs}X^s + f^r)$$
$$C^s = c^s(I - A^{ss})^{-1}(A^{sr}X^r + f^s)$$

Results

First, there are three key trading blocks. The Central Region is the main embodied emissions exporter, with significant flows to the East and North Coasts, while the Southwest Region is the main supplier of embodied emissions to the South Coast provinces. A smaller trading bock exists in the north between the interior Northwest Region and the Northern Municipalities and Northeast. These distinct groupings reflect the regional characterization of internal trade within China, due to the limited transport infrastructure linking the country, combined with the distances involved.



Second, the bialateral perspectives require a split of the exports by region of destination but still do not require a multi-regional input-output table. To analyze the new trade patterns, we decompose emissions into tree components, a multi-regional input-output table is needed and some double-accounting pitfalls should be avoided.



Conclusions

We highlighted two perspectives on the CO2 emissions content of trade. Since both perspectives as generated in a region to trading partners and to itself, it is vertical that the input output data used to calculate the BT and MT contents accurately reflect domestic embodied emissions and their division over industries and regions. The MT perspective is useful when you want to know how much various regions contribute to the emissions of a particular product, like a car produced in China as it allows tracing the embodied emissions in all stages of production.

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Appendix Table A.1 Eight regions in 30 provinces in China

Regions	Provinces
Northeast	Heilongjaing(HL), Jilin(JL), Liaoning(LN)
Northern Municipalities	Beijing(BJ), Tianjin(TJ)
North Coast	Hebei(HB), Shandong(SD)
East Coast	Shanghai(SH), Jiangsu(JS), Zhejiang(ZJ)
South Coast	Guangdong(GD), Fujian(FJ), Hainan(HaN)
Central Regions	Shanxi(SX), Henan(HN), Hubei(HuB), Hunan(HuN), Anhui(AH), Jiangxi(JX)
Northwest	Innermonglia(IM), Shannxi(ShX), Ningxia(NX), Gansu(GS), Xinjiang(XJ)
Southwest	Sichuan(SC), Chongqing(CQ), Yunnan(YN), Guizhou(GZ), Guangxi(GX),Qinghai(QH)